Arizona Riparian Inventory and Mapping Project

December 1, 1993

Arizona Game and Fish Department
2221 West Greenway Rd.
Phoenix, Arizona 85023-4312

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Arizona Riparian Inventory and Mapping Project

A report to the Governor, President of the
Senate and Speaker of the House

Arizona Game and Fish Department

Director
Duane L. Shroufe

Commissioners
Larry Taylor, Chairman
Beth T. Woodin, Vice Chairman
Arthur Porter
Nonie Johnson
Michael M. Golightly

December 1, 1993

ARIZONA GAME AND FISH DEPARTMENT
ARIZONA RIPARIAN INVENTORY AND MAPPING PROJECT

AUTHORS

Ruth A. Valencia, Project Leader	Ecosystems Program Manager, Nongame Branch
Jennifer A. Wennerlund	Senior GIS Specialist, Research Branch
Richard A. Winstead	Ecosystems Field Project Coordinator, Nongame Branch
Scott Woods	GIS Specialist, Research Branch
Larry Riley	Environmental Compliance Supervisor, Habitat Branch
Eric Swanson	Aquatic Habitat Coordinator, Habitat Branch
Susan Olson	GIS Specialist, Research Branch

TECHNICAL OVERSIGHT COMMITTEE

Bruce D. Taubert, Chair	Assistant Director, Wildlife Management Division
Susan Miller	Executive Staff Assistant, Wildlife Management Division
Terry B. Johnson	Chief, Nongame Branch
Dennis Kubly	Section Supervisor, Nongame Branch
Jim deVos	Chief, Research Branch
Denny Haywood	Research Program Supervisor, Research Branch
Jim Burton	Chief, Habitat Branch
Larry Riley	Environmental Compliance Supervisor, Habitat Branch

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EXECUTIVE SUMMARY

This report is submitted to the Governor, the President of the Senate, the Speaker of the House of Representatives and the Riparian Area Advisory Committee in response to the requirements of the Waters - Riparian Protection Program signed into law in 1992, amending ARS 45-101. The act directs the Arizona Game and Fish Department (AGFD) to conduct investigations relating to Arizona's riparian areas and to report on its findings by December 1, 1993. Specifically, it mandates the following:

(1) development of a system for classifying riparian areas including physical and ecological criteria to be used to develop riparian designations consistent with the definition prescribed in this statute. A hierarchical designation system is to be developed according to relative functions and values;

(2) identification, classification and mapping of riparian areas in the state, giving priority to those riparian areas associated with perennial waters;

(3) identification and mapping of land ownership of identified riparian areas according to the general categories of Indian, federal, state and private lands and mapping of current land uses of those areas, and;

(4) identification of existing options for protecting riparian areas in each ownership category that may be available under existing state and federal laws (Section 5, Chapter 298, Laws 1992).

Our choice of classification system was based on the desire to identify geographic areas that represent ecological units. The classification system applied to this project was devised by Brown, Lowe and Pase (1979). This system provides an ecological basis for the location of plant and animal communities in the American Southwest and arranges them within a hierarchical structure.

Our primary charge was to identify, classify and map riparian areas which are defined by "the presence of deep-rooted plant species that depend on having roots in the water table or its capillary zone" (ARS 45-101.6). AGFD contracted with Dr. Lee Graham through the Arizona Cooperative Fish and Wildlife Research Unit at the University of Arizona to formulate a methodology to identify and map riparian vegetation. Graham devised an innovative remote sensing technique combining satellite imagery and aerial videography. The resulting maps show the extent of riparian vegetation along perennial stream corridors in Arizona. The methodology chosen was determined to be the best technology available to map riparian vegetation on a statewide basis given the time requirements of the project.

Products of this riparian inventory include riparian vegetation maps, numerous Geographic Information System (GIS) databases and aerial videotapes. Examples of some of the maps are presented in this report, along with a summary of findings. These examples are intended to give the reader an idea of (1) the types of maps that can be produced, and (2) the types of data contained within these GIS databases.

The identification, classification and mapping of riparian vegetation is being completed in a phased approach. In this first year, priority was given to mapping riparian areas associated with perennial waters. We will begin to map riparian areas associated with intermittent waters in the state once we have met the accuracy standards set for maps associated with perennial waters.

We devised a method to assess the accuracy of the riparian vegetation maps through ground verification. Stream corridors in the southeastern portion of the state were investigated during this first year of the project. Results of that effort are presented. Although maps are not yet at a level of accuracy we would like, we will continue to verify and modify maps until our accuracy expectations are met. This should be completed by June 1994.

Riparian vegetation maps are the result of a broadly applied remote sensing process. However, precision of data can often be a problem. Therefore, data should always be field verified. That means the site represented on a map should be visited to ensure the information is correctly represented. The maps are a representation of the general location and type of riparian vegetation that existed in an area at the time the satellite images were created. The process was not intended to create maps that delineate each tree and shrub in the riparian corridor. In fact, any attempt to create statewide maps on this scale would be futile. Riparian vegetation is subject to many disturbances, primarily flood events. By the time one portion of the state is completed, other riparian areas in the state may have been severely altered. Therefore, it is important to realize that these maps are best used (1) for collecting general data on the amount of riparian vegetation existing at a given time in the state, (2) for determining the general location and percentage of various riparian vegetation community types, and (3) for change analysis studies (comparing general trends or changes between years). The suitability of these maps for regulation can only be evaluated at a later date.

The inventory covered 4,628.95 miles of streams and mapped 266,786.39 acres of riparian vegetation. Portions of the Colorado River and its tributaries that are within Grand Canyon National Park have not yet been inventoried because of flight restrictions. This portion represents an additional 393.52 miles of regulated river.

Total miles of perennial streams inventoried	**4,628.95 miles**
Total miles of perennial streams identified	5,022.47 miles
Flow unregulated	3,961.26
Flow regulated	972.95
Effluent dominated	88.26

Based on the methods as described in this document, riparian vegetation associated with perennial streams comprises approximately 0.4% of the total land area of the state. Vegetation associated with most lakes and wetlands (marshes, cienegas) and with the excluded portions of the Colorado River are not represented in these numbers. **It should be noted that not all riparian vegetation, as defined by legislation was mapped during this first phase of the inventory.** A great deal of riparian vegetation is supported by intermittent waters in Arizona, but, these areas have not yet been inventoried.

Miles of perennial waters by land ownership category*

	Miles	Percent of Total Mapped
Total Federal	2,510.79	49.99
National Forests	1,573.50	31.33
National Parks	611.90	12.18
BLM	289.07	5.76
Wildlife Refuges	28.26	0.56
Military	8.06	0.16
Total State & Municipal	254.58	5.07
State trust/state sovereign	156.06	3.11
State & municipal parks	82.40	1.64
AGFD lands	16.12	0.32
Total Private	856.67	17.06
Total Tribal	1,408.80	28.05

**NOTE: These figures exceed 100% of the total miles of perennial streams because there are instances where landownership is different on each bank of a given length of stream. In those cases, stream mileage is included in both landownership categories.*

This inventory revealed seventeen (17) riparian vegetation community types (series level), and approximately 85 vegetation associations in Arizona. Accuracy on vegetation data is still being verified and should be completed by June 1994. Conversion of vegetation classes to the Brown, Lowe and Pase (1979) system is currently underway. The following table shows riparian vegetation community types as a percentage of the total amount of riparian vegetation mapped during this phase of the inventory. Although the inventory is not complete, these percentages begin to give a picture of the relative amounts of the various riparian vegetation community types found in Arizona. More detailed data on vegetation classifications will be available from AGFD when all components have been verified.

Relative amounts of riparian vegetation communities associated with perennial waters in Arizona.

Total acres of riparian vegetation associated with perennial waters as inventoried by AGFD in 1992-1993: 266,786.39 acres

Vegetation Community	Percent	Vegetation Community	Percent
Tamarisk	20.3	Russian olive	<1.0
Mesquite	17.5	Reed	<1.0
Arrowweed	14.8	Sacaton grass	<1.0
Conifer	11.2	Mixed canyon scrub	<0.5
Mountain meadow	6.3	Acacia	<0.5
Oak	4.4	Desert willow	<0.5
Cottonwood-willow	4.2	Mexican elder	<0.5
Mixed scrub	3.0		
Cattail	2.1	Flood scoured*	7.4
Sycamore	1.2	Unlabelled**	5.4

* *Vegetated according to satellite data, but scoured by winter flooding before classification with videography.*

** *Not classified due to lack of videography coverage.*

General land ownership and land use maps for Arizona are also presented in this report. As directed by the legislation, the land ownership map displays federal, state, private and tribal lands. Although the legislation did not specify land uses to be mapped, AGFD attempted to locate data sources for mapping the land use activities listed in the Waters - Riparian Protection Program law (Section 6, chapter 298, Laws 1992). In some cases, limitations on data availability restricted our ability to map land uses. In other instances, such as for recreational activities, it was difficult to delineate specific geographic areas where an activity was taking place. That is, some activities can realistically occur almost anywhere.

Accompanying each land use map is a brief description of what is depicted. Data sources, methods of verification, and limitations on use of the maps are discussed. Summary statistics calculated from land use and land ownership databases are presented.

Land use maps presented in this report include:

(1) Commercial Grazing Activities
(2) Commercial Wood Harvesting Activities
(3) Urban, Industrial and Agricultural Lands
(4) Public Recreation
(5) Current and Historical Mining Locations
(6) Active Mining Locations
(7) Sand and Gravel Mine Locations
(8) Mineral Potential

The purpose of compiling land ownership and land use data was to identify activities occurring in and adjacent to riparian areas across the state. Several examples are presented in this report to illustrate the application of these data to evaluate land use influences on a riparian area.

Factors that affect landform, and vegetative and wildlife diversity are discussed in the report. These factors consequently influence the diversity of functions occurring within a riparian area and are the key to functional assessment of riparian areas. Because of the Arizona Game and Fish Commission's legislated authority and the Department's mission, our efforts this past year were focused on evaluating methods to assess biological life support functions and wildlife values provided by riparian habitats for vertebrate wildlife (fishes, amphibians, reptiles, birds and mammals).

An approach that was specifically developed for assessment of riparian wildlife habitats in Arizona, and that can be evaluated rapidly in the field was conceived by Anderson and Ohmart (1984) for the Bureau of Reclamation (USBR). Ohmart and Anderson subsequently reviewed alternate methodologies for AGFD and attempted to further develop their own technique to provide a single index value that would allow comparison among riparian habitat types. The methodology they developed was specific to riparian forest and riparian scrub habitats.

The utility of a simple index of wildlife value for riparian areas is multifold. It could be used to provide a range of potential wildlife values based on identified vegetative community type (Brown, Lowe and Pase series level). Remotely sensed data combined with ground-truthing can provide additional information to decision-makers. AGFD will continue to evaluate the utility of a simple index of wildlife value. Anderson and Ohmart's report to AGFD is still being finalized and must undergo final internal review.

The AGFD was instructed to incorporate a hierarchical designation system based on relative functions and values into the development of a classification system for riparian areas (Chapter 298, Laws 1992). Based on direction from the legislation, the approach to a riparian designation system must take into account an assessment of functionality. The overall functional condition of a riparian area should be the focal point of a designation system.

There have been few attempts at formulating a method to rapidly assess the functionality of riparian areas. Previously, national approaches created for application to wetlands were applied to arid and semi-arid riparian areas with limited success. Two recent federal reports describing approaches to assessing functions of riparian and wetland areas are of particular interest. They are BLM's "Process for Assessing Proper Functioning Condition" and COE's "A Hydrogeomorphic Classification for Wetlands" (Brinson 1992). A brief discussion of each is presented. Components of these two approaches serve as the basis for the proposed hierarchical designation system.

The development of a hierarchical designation system based on riparian functions and values should take into account a number of items.

1) New information on riparian functions is almost constantly being presented as research continues on this subject. Therefore, the approach should be flexible enough to allow for the incorporation of new information.

2) According to the legislation, the approach must incorporate functions and values of these resource areas. Use of indicators and rapid assessment methods has been discussed.

3) Because there is so much federal land in the state, the approach should be compatible with federal activities, or should be able to incorporate the data and information collected by federal agencies into the approach. At this time, data collection techniques appear to be inconsistent and incompatible.

4) Completion of the three project areas under this legislation (AGFD, ADWR, ADEQ) adds a great deal of information to our knowledge base. Riparian vegetation, land ownership and land use maps are contained in a digitized format. GIS maps and databases provide us with a powerful tool to apply to riparian assessment.

5) Recent controversial proposals included in the Clean Water Act reauthorization have attempted to classify or rank wetlands according to their functions and values, and then regulate these categories differently. The primary question is whether all wetlands should be treated the same or not. If all wetlands have some functions and values, do some have more than others, and consequently should those with lesser values be accorded less stringent regulatory protection? This controversy raises issues directly applicable to riparian area protection strategy development for Arizona.

6) The designation system chosen should address a number of other considerations.

    (a) A consistent geographic unit of evaluation should be identified.
    (b) The evaluation system should have a systems perspective and should be able to take into account the effect of upstream and downstream activities of an assessment area.
    (c) It should be capable of dealing with potential functions since systems are often degraded.
    (d) Temporal variability of the system needs to be considered because the system is dynamic.

7) Several federal agencies are in the process of formulating functional assessment methods for application to riparian areas. These methods have been devised by interdisciplinary teams of scientists and land managers and are currently undergoing public review. However, these approaches represent the best available methods for assessing functionality within riparian and wetland systems at this time.

8) Information needs should be balanced with the development of action strategies. "Enough information needs to be amassed to allow for sound policy choices, but collecting too much information can stall action. It's important to remember that decisions can be made and actions taken before all the needed information has been gathered. Gathering information can take a lot of time and resources, delaying strategy development for years. To the extent possible, a state should draw on existing data and the professional judgement of people familiar with the state's wetlands. As gaps in data are identified, objectives can be set for collecting and analyzing any missing data and information" (World Wildlife Fund 1992).

Based on these considerations, AGFD proposes a preliminary outline as a first step in the development of a hierarchical designation system for riparian assessment based on functions and values. The preliminary approach is outlined in the document and illustrated by a flowchart.

Step 1. Assess the functional condition of a given unit of riparian area (stream and terrestrial land area).

Step 2. Categorize areas based on their general functional condition (BLM approach).

Step 3. Each of these categories has implications as to protection and management actions.

Step 4. Within each category, assess whether high, medium or low values exist.

Step 5. Prioritize areas for protection or management action based on assessment of values and functional category.

The completion of this report does not signal the end of AGFD's work on inventorying and assessing riparian areas in Arizona. In fact, in the next year, AGFD staff will be working on bridging information gaps that will help us achieve an implementable hierarchical designation system. The following is a list of action items that are either in process or are proposed for next year:

1) AGFD will continue to refine the perennial database and map riparian areas in Arizona, including areas associated with intermittent waters. AGFD will continue to assess the full capability of the remote sensing technology and accompanying databases and videotapes.

2) To assist with our understanding of riparian functions, AGFD applied for and was awarded a grant from the EPA under the Clean Water Act, 104(b)(3) Wetlands Grant Fund. The grant will allow us to develop a functional assessment methodology and a methodology to determine status and trends of riparian areas statewide.

The final section of this report identifies existing options for protecting riparian areas in the state. While the listing of regulatory and nonregulatory riparian programs in Arizona appears extensive, it is important to recognize that there are no regulatory programs (at any level of government) specifically developed or implemented for the protection of riparian areas. Existing programs have only limited applicability to the protection of important riparian area functions by focusing only on the management and planning of water, soil and/or landscape--typically within a small geographic area. Furthermore, even though most of the listed programs have been in place for some time, it is widely recognized that some greater degree of riparian area protection is needed to preserve and maintain the health and integrity of our existing riparian resources in Arizona.

ACKNOWLEDGEMENTS

This project could not have been completed without the involvement of a great many people. The Arizona Game and Fish Department would like to thank all those who took the time to assist us in this effort. Special thanks is extended to Susie MacVean, who spent seven months as Ecosystems Field Project Coordinator and was instrumental in formulating many of the field methods. We would also like to acknowledge Steve Rosenstock, Sherry Ruther, Bill Werner Peter Warren, and Bob Vahle for their technical assistance on the project; Vicky Meretsky, Dana Slaymaker, and Dr. Charles Curtis (pilot) for their major contributions regarding the mapping and videography; Jana Fry and Cindy Zisner for assisting with research; Karen Reichhardt, Greg Imdorf and Kathleen Rice for assisting us with plant identification training; and Dr. Julie Stromberg and the Arizona Riparian Council for their technical review and comments during the process. Also, we would like to express our gratitude to all those individuals at the Arizona Department of Environmental Quality, Arizona Department of Water Resources, Arizona State Land Department, Arizona State Parks, U.S. Bureau of Land Management, U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Geological Survey, and the U.S. Air Force who took the time to assist us with our data and information needs. Very special thanks to Brian Czech of the San Carlos Apache Wildlife Department and all the private landowners who so generously allowed us access to their property and were so supportive of our efforts. We would also like to give special acknowledgement to our contractors and field biologists on this project.

Field Biologists

Mark Brennan, Field Team Leader
Jeff Sorenson, Field Team Leader
Vir McCoy
Gary Benoit

Laurel Schulze, Field Team Leader
Mary Franks
Vince Fitzpatrick
Jennifer Hodge

Riparian Vegetation Mapping

O. Eugene Maughan, Unit Leader
Arizona Cooperative Fish and Wildlife Research Unit
210 Biological Sciences East
University of Arizona
Tucson, Arizona

Lee A. Graham, Ph.D., Assistant Professor
Wildlife and Fisheries Sciences
School of Renewable Natural Resources and Advanced Resource Technology
University of Arizona
Tucson, Arizona

Riparian Habitat Evaluation Model

Robert Ohmart, Ph.D.
Professor of Research
Center for Environmental Studies
Arizona State University
Tempe, Arizona

Bertin Anderson, Ph.D.
President
Revegetation & Wildlife Management Center
201 S. Palm
Blythe, California

ARIZONA RIPARIAN INVENTORY AND MAPPING PROJECT

Project Overview

This report is submitted to the Governor, the President of the Senate, the Speaker of the House of Representatives and the Riparian Area Advisory Committee in response to the requirements of the Waters - Riparian Protection Program signed into law in 1992, amending ARS 45-101. The act directs the Arizona Game and Fish Department (AGFD) to conduct investigations relating to Arizona's riparian areas and to report on its findings by December 1, 1993. Specifically, it mandates the following:

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(2) identification, classification and mapping of riparian areas in the state, giving priority to those riparian areas associated with perennial waters;

(3) identification and mapping of land ownership of identified riparian areas according to the general categories of Indian, federal, state and private lands and mapping of current land uses of those areas, and;

(4) identification of existing options for protecting riparian areas in each ownership category that may be available under existing state and federal laws (Section 5, Chapter 298, Laws 1992).

The format for this report reflects, to some degree, the sequence of steps taken to satisfy the requirements of the legislation, as opposed to the sequence of tasks listed above. This sequence is primarily because the methods chosen to identify, describe and map riparian areas influenced the decisions regarding classification and designation systems. The mapping method combines remote sensing techniques and a Geographic Information System (GIS) to create a computerized framework for data storage, display and analysis of spatial data. This method represents an innovative and experimental approach in statewide ecological mapping of riparian areas.

Because of its exploratory nature, decisions regarding the general approach to mapping needed to be made early in the process to allow time for development of the methods and to ensure that the mapping was completed in the given timeframe. Several issues inherent to those decisions had to be evaluated early in the planning stages. First, the success of a remote sensing technique hinged on whether ecologically important units of riparian vegetation were discernible from an aerial view. Second, the question had to be addressed as to whether there was a way to accurately delineate and classify these units once they were identified. Assuming both of these issues could be accomplished, the choice of a classification system was somewhat limited to systems based on features and characteristics that could be determined from these remote sensing techniques.

Our ability to evaluate and analyze data associated with riparian areas is enhanced by the flexibility of a GIS format. GIS allows us to make spatial calculations and to visually analyze spatial interrelationships. Integration of other GIS databases containing natural resource and wildlife data expands our analytical abilities. The full potential of the system has not entirely been explored in this first year of data collection.

Discussion of a hierarchical designation system based on functions and values takes into account the future potential of this system. By combining or "overlaying" GIS databases containing data on hydrology, water quality, vegetation, land use, land ownership, etc., our ability to categorize riparian areas is enhanced as is our ability to identify landscape level processes that affect riparian vegetation.

It should be noted that the definition of riparian area provided in the legislation is inclusive of riparian vegetation occurring "within or adjacent to natural perennial or intermittent stream channel(s) or within or adjacent to a lake, pond or marsh bed maintained primarily by natural water sources." In this first year of the riparian inventory and mapping project, AGFD focused efforts on riparian vegetation associated with perennial streams. Perennial waters associated with lakes, ponds and marshes or cienegas were, for the most part, excluded from this first stage of mapping. Some marshes or cienegas that occur adjacent to a perennial stream have been mapped. However, completion of mapping riparian vegetation associated with intermittent waters, marshes and other types of wetlands is important for comprehensive management of these precious resources.

This report is divided into six sections. The first section presents the classification system applied to riparian vegetation mapping and discusses the reasons for choosing that particular classification system. The next section contains the general approach to the identification, classification and mapping of riparian areas as well as the method for compiling a perennial waters map of Arizona. A general description of the mapping methodology is provided with emphasis on (1) the use of satellite imagery to delineate the extent of the riparian zone and to establish boundaries for vegetation classes, and (2) the use of aerial videography to identify and classify vegetation. Since this process was experimental, the Department devised a ground-truthing method to evaluate accuracy of maps. Results of this verification process are presented along with a discussion of limitations on the application of these maps.

Although it was impossible to present all the riparian vegetation maps in this report, examples of maps are included at two different scales. A statewide map shows areas of riparian vegetation mapped during the past year. Portions of riparian vegetation maps from Cave Creek in the Chiricahua Mountains, the San Pedro River and the Colorado River are depicted at a large scale to show the degree of mapping detail. Summary statistics calculated from the statewide databases are also presented.

Land use and land ownership maps with associated statistics are presented in the third section. A brief description of each map, along with data sources, and a summary of pertinent data and assumptions are provided. These maps were digitized into a GIS and can be printed at various sizes and scales.

The fourth section contains an overview of riparian functions and values with emphasis on wildlife and fish habitats. Indicators or measurements necessary to evaluate functionality and quality of a riparian area are discussed. A method to rapidly assess the relative values of riparian areas for wildlife is presented. The method is based on description of vegetation species composition, foliage density and vertical height diversity. The method was tested on low elevation riparian areas and needs further evaluation before it can be applied statewide.

Section five outlines a preliminary approach to a hierarchical designation system based on functions and values. This approach is based on methods currently being evaluated for application by the federal government. The application and analysis of GIS databases compiled by state and federal agencies has a great deal of utility in this arena. The riparian vegetation classification system and wildlife habitat evaluation methodology are two components that expand our ability to evaluate the functionality of a riparian area.

The final section lists existing options used for riparian area protection in Arizona under existing state and federal laws. Included under riparian protection mechanisms are regulatory and nonregulatory programs that have some degree of applicability in protecting resources that support and sustain riparian areas. A discussion is offered on how this information might be used to improve riparian area protection is offered.

Section I

Classification System

All classifications have as their objective the orderly arrangement of objects into groups or sets on the basis of similarities or relationships (Daubenmire 1968, Platts 1980). For purposes of this study, the term "classification" describes systems that are almost purely descriptive and that do not impose a value based on ranking or position in the classification system. In the case of riparian areas, classification groupings might be based on any number of characteristics, such as vegetation type, stream channel geometry, hydrology or elevation. Or, the groups might be comprised of areas that function in a similar manner. The many attributes on which one can group or classify riparian areas is a reflection of their complexity. The complexity of these areas makes the task of classification a challenging endeavor.

State and federal agencies have developed numerous riparian and wetland classification systems for a variety of purposes (Gebhardt et al. 1990, World Wildlife Fund 1992). Some systems deal solely with wetlands such as bogs, fens, marshes and swamps (Windell et al. 1986, National Wetlands Working Group 1987), while others take into account the special features of both riparian and wetland ecosystems (Brown et al. 1979, Cowardin et al. 1979, Youngblood et al. 1985, Hann and Jensen 1987, Kovalchik 1987, S. Swanson et al. 1988, Hansen et al. 1990). Some are regional in scope and have limited applicability, while others attempt to classify areas on a national level. The stated objectives of these systems are fairly similar, but the individual categories of measurement are quite varied. Most systems categorize at least on the basis of stream/wetland attributes and vegetation or biotic community type. However, in some cases, categories are based on highly detailed criteria, taking into account features such as soil type, stream channel morphology, species composition, substrate, climate, vegetation structure and seral stage. (See glossary and page 94 for description of seral stage.)

Our choice of classification system was based on the desire to identify geographic areas that represent ecological units having similar properties. An ecological unit contains species that share a common evolutionary history; there is a shared flora and fauna between areas of the same name. In addition, our charge was to identify, classify and map riparian areas which are defined by "the presence of deep-rooted plant species that depend on having roots in the water table or its capillary zone" (ARS 45-101.6). Another factor considered was the need for uniform identification of the different types of riparian areas, thus providing a means to more accurately assess distribution and relative amounts. This method should result in a categorization of riparian areas that provides a management tool for land and resource professionals. Finally, this project required the selection of a classification system that could be easily applied to the mapping methodology.

The classification system applied to this project was devised by Brown, Lowe and Pase (1979). This system provides an ecological basis for the location of plant and animal communities in the American Southwest and arranges them within a hierarchical structure. A systematic hierarchy has the great advantage of having data ordered from the general to the specific, so that it can be used at different levels of organization - national, regional or local. The hierarchy is open-ended, in that it provides for expansion at all levels as more information is known about an area. Table 1 summarizes the categories and units of classification used in the Brown, Lowe and Pase hierarchical vegetation classification system.

The Brown, Lowe and Pase classification system is based on natural groupings of biotic communities that occur across the landscape. Biotic communities represent complex aggregations of plants and animals that are the result of responses to integrated physical and biological factors, more or less regional in scope. These factors include common evolutionary history, climate, and moisture available to plants (Brown et al. 1979). In this system, biotic communities are primarily delineated by the composition and form of vegetation.

Vegetation tends to be naturally grouped in different combinations forming communities. In other words, the plant species are not scattered at random, but are distributed in a pattern over the landscape. The concept of a community presumes a degree of biologic homogeneity in structure and species composition that is associated within a defined area (Daubenmire 1968). Similar vegetative communities tend to appear wherever equivalent environmental conditions occur. Since vegetation is more readily identified, inventoried and mapped than the animal component of a community, vegetation communities provide a convenient unit of classification. Although animal constituents are an important factor in the determination and classification of biotic communities, it is the vegetative form, structure and components that provide the readily observable and, therefore, measurable manifestation of these natural communities (Brown et al. 1979).

Any large unit of vegetation is a mosaic of plant communities creating a corresponding mosaic of habitats for wildlife. Vegetation serves as a valuable criterion of degrees of similarity and difference among habitats. One obvious advantage of classifying and mapping natural vegetation is to enable wildlife, forest and range managers to efficiently stratify and sample populations in any given land area (Leopold 1933). Statistically valid surveys then can be used to measure and predict an area's wildlife density, timber potential or range capability (Brown et al. 1979).

Under this system, the hierarchy is organized into a digital, numerical array that makes the system computer-compatible. Thus the classification system has been applied as the basis of several habitat and wildlife databases in the Southwest, such as RUNWILD (Patton 1978) and the AGFD Native Fish Database. It has been incorporated into the Arizona Land Resources Inventory System (ALRIS) at the Arizona State Land Department (ASLD) and has been used extensively as a means of describing and identifying habitat types in AGFD wildlife studies.

The hierarchical sequencing of this classification system permits mapping at any scale and maintains the needed flexibility for mapping complex communities where more intensive systems are impractical or needlessly time consuming (Brown et al. 1979). This flexibility is especially pertinent when attempting to conduct a statewide classification and mapping of riparian areas. The inventory covers thousands of stream miles across the state thus requiring a small-scale approach. By applying a small scale, we are able to evaluate the entire state at once to analyze extent of riparian areas as compared to upland areas, for instance. However, the utility of differentiating riparian vegetative communities on small-scale ecological maps is limited because these ecosystems tend to cover small areas relative to other upland communities. In fact, on a small-scale map of the state, riparian areas are almost indiscernible.

The flexibility provided by the Brown, Lowe and Pase system coupled with the use of remote sensing techniques allowed us to classify riparian areas at a large-scale while maintaining the capability to produce maps at a local, regional or statewide level. For the most part, riparian vegetation was classified to the series level (also called community type). In some cases, riparian areas were classified according to the vegetation associations occurring there. These classes are represented by the fifth and sixth levels in the Brown, Lowe and Pase system (See Table 1 and Figure 1).

Vegetation communities within riparian areas do not often occur as distinct, easily discernible units. Various classifications of riparian vegetation tend to intergrade over a considerable area, forming broad transitional zones called ecotones. At the outer extent of the riparian zone, vegetation transitions into upland communities; sometimes gradually, sometimes abruptly. In some vegetation communities, such as mesquite or sacaton grass communities, the same plant will characterize both the riparian and the upland community, growing more vigorously in the riparian area where soil moisture is more readily available. It is important to understand this natural phenomenon when viewing maps of riparian vegetation because lines drawn to delineate vegetation communities may mislead one into thinking these are distinct and separate units on the ground.

Table 1. **Brown, Lowe and Pase Hierarchical Classification System (1979)**

	Where:
DIGIT PRECEDING COMMA	1,000 = Biogeographic Realm
FIRST LEVEL	1,100 = Vegetation
SECOND LEVEL	1,110 = Formation type
THIRD LEVEL	1,111 = Climatic (Thermal) Zone
FOURTH LEVEL	1,111.1 = Regional Formation (Biome)
FIFTH LEVEL	1,111.11 = Series (Community of generic dominants)
SIXTH LEVEL	1,111.111 = Association(Community of specific dominants)
SEVENTH LEVEL	1,111.1111 = Composition - structure - phase

Digit preceding the comma: This identifies the world's biogeographic realm. Since all of our classification will take place in Continental North America, the biogeographic realm will be identified as Neartic and will be designated with a "1."

First Level: The first digit after the comma refers to vegetation. All existing and potential natural vegetation is classified as belonging to uplands (1,100) or wetlands (1,200). In this system, wetlands include those periodically, seasonally or continually submerged ecosystems populated by species and/or life forms different from the immediately adjacent (upland) climax vegetation, and which are dependent on conditions more mesic than provided by the immediate precipitation. Riparian ecosystems are treated as wetlands under this classification.

Second Level: The second digit after the comma refers to one of the following recognized ecological formations, or formation-types. On continents, these are referred to as formations, which are vegetative responses (functions) to integrated environmental factors most importantly plant-available moisture. Wetland formations are divided into the following categories:

1,210	Wet Tundra	Temperatures are so low that available moisture is unavailable during most of the year. Area is characterized by an absence of trees with establishment of low herbaceous plant structure in a hydric matrix.
1,220	Swamp-Forest /Riparian-Forest	Overstory of trees potentially over 10 meters (31 ft) in height, and frequently characterized by closed and/or multilayered canopies.
1,230	Swamp-scrub /Riparian-scrub	Dominated by short trees and/or woody shrubs, generally under 10 meters (31 ft) in height and often presenting a closed physiognomy.
1,240	Marshland	Principal plant components are herbaceous emergents which normally have their basal portions annually, periodically, or continually submerged.
1,250	Strandland	Beach and river channel communities subject to infrequent but periodic submersion, wind driven waves and/or spray. Plants are separated by significant areas devoid of perennial vegetation.
1,260	Submergent Aquatic	Comprised of plants that are mostly submerged or are lacking emergent structures.
1,270	Non-vegetated	Essentially without vegetation or sparingly populated by simple organisms (e.g. playas, sinks, etc.)

Table 1 (cont'd.)

Third Level: The third digit beyond the comma refers to one of four world climatic zones in which minimum temperature remains a major evolutionary control of and within the zonation and the formation-type. All four of these broad climatic zones are found in the Southwest. They are:

1,211-1,261	Arctic-Boreal	Lengthy periods of freezing temperatures, short growing season (60-150 days), occasionally interrupted by nights of below freezing temperatures.
1,222-1,262	Cold Temperate	Freezing temperatures of short duration although of frequent occurrence during winter months. Potential growing season generally 100-200 days and confined to spring and summer when freezing temperatures are infrequent or absent.
1,223-1,263	Warm Temperate	Freezing temperatures of short duration but generally occurring every year during winter months. Potential growing season over 200 days with an average of less than 125-150 days being subject to temperatures lower than 0 degrees C or to chilling fogs.
1.224-1,264	Tropical-Subtropical	Infrequent or no 24-hour periods of freezing temperatures, chilling fogs or wind.

Fourth Level: The fourth digit beyond the comma refers to a subcontinental unit that is a major biotic community (biome). Biotic communities are natural communities characterized by a distinctive vegetation physiognomy within a formation.

Examples of Biotic Communities:

1,223.2	Interior Southwestern Riparian Deciduous Forest and Woodland
1,224.5	Sonoran Riparian and Oasis Forests
1,244.7	Sonoran Interior Marshland
1,244.8	Sonoran Maritime Marshland

Fifth Level: The fifth digit beyond the comma refers to the principal plant-animal communities within the biomes distinguished primarily on taxa that are distinctive climax plant dominants. These are referred to as "Series" or "vegetation types" and are composed of one or more biotic associations characterized by shared climax dominants within the same formation, zone, and biome.

Examples of Series Level:

1,223.21	Cottonwood-willow Series
1,223.22	Mixed Broadleaf Deciduous Series
1,244.71	Cattail Series
1,244.81	Saltgrass Series

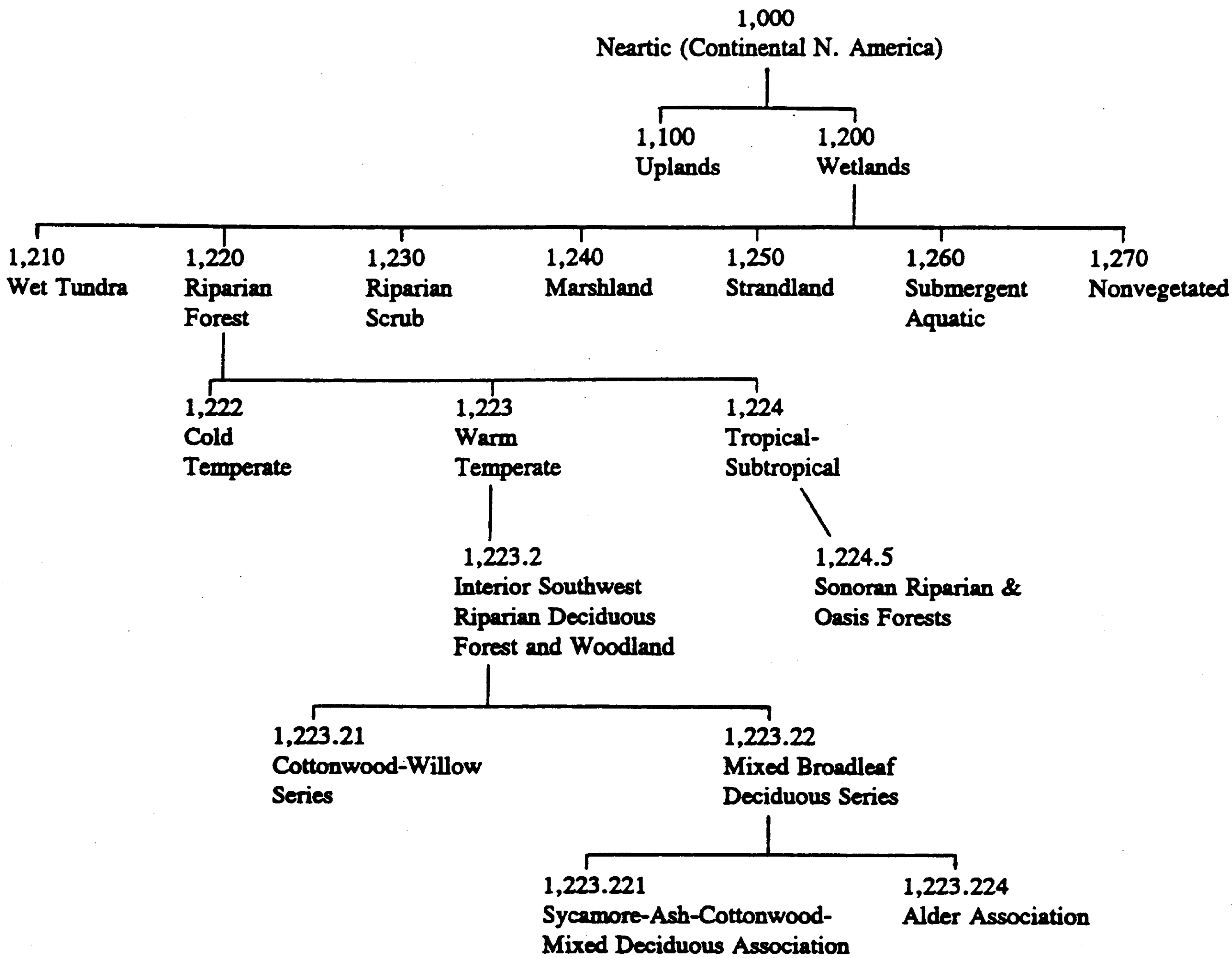
Sixth Level: The sixth digit beyond the comma refers to distinctive plant associations based on the occurrence of particular dominant species more or less local or regional in distribution and generally equivalent to habitat-types as outlined by Daubenmire (1968), Layser (1974), Pfister et al (1977) and others.

Examples of Association Level:

1,223.221	*Platanus wrightii-Alnus oblongifolia-Populus fremontii*-Mixed Deciduous Association (Sycamore-Alder-Cottonwood-Mixed Deciduous)
1,223.224	*Alnus oblongifolia* Association (Arizona Ash)
1,244.711	*Typha domingensis* Association

Seventh Level: The seventh digit beyond the comma accommodates detailed measurement and assessment of quantitative structure, composition, density and other attributes for dominants, understories, and other associated species. This level and additional ones in the system provide the flexibility required for encompassing data for ecological parameters measured in intensive studies on limited areas.

Figure 1. Flowchart of Brown, Lowe and Pase Hierarchical Classification System (1979). The example shown is for Interior Southwest riparian deciduous forest, mixed broadleaf series, sycamore-ash-cottonwood-mixed broadleaf deciduous association, and alder association.



Section II

Riparian Mapping Methodology

A. Introduction

The primary objective for this mapping methodology was to quantify the extent, distribution and representation of major riparian vegetation communities in the state. The methodology also needed to accommodate the Brown, Lowe and Pase (1979) vegetation classification system, as described in the previous section. The methodology chosen was determined to be the best technology available to map riparian areas on a statewide basis given the time requirements of this project.

AGFD contracted with Dr. Lee Graham through the Arizona Cooperative Fish and Wildlife Research Unit at the University of Arizona to formulate the methodology to identify and map riparian areas. Graham was successful in mapping statewide vegetation under the Arizona GAP Analysis Project by applying an innovative remote sensing technique combining satellite imagery and aerial videography (Graham in prep.). Graham modified this approach for mapping riparian areas across the state. Because riparian vegetation tends to occur in narrow linear corridors, the mapping methodology needed to be adapted to a much larger scale than was used on the GAP Analysis project. The vegetation mapping was conducted at the University of Arizona Advanced Resource Technology Laboratory (UA-ART).

It is important for the map user to understand what is being represented on the riparian vegetation maps. The maps were created using two major sources of imagery - Landsat Thematic Mapper (TM) digital satellite data and Multiple Resolution Aerial Videography (MRAV). The satellite imagery was used as the base map for this study and for determining the extent of riparian vegetation along stream corridors. The system that records MRAV was devised by Graham as a cost-effective means of acquiring geographically referenced, high resolution data. Aerial videography flights were initiated in October 1992 and continued periodically throughout the year ending in September 1993. Application of Landsat TM data and MRAV is described in more detail in sections C and D.

The resulting maps show the extent of riparian vegetation along perennial stream corridors in Arizona. Identification of the lateral extent of the riparian zone was accomplished through the manipulation of satellite data. Within the riparian zone, natural groupings of vegetation were identified, again by using the satellite imagery. The videography was used to provide finer resolution imagery suitable for determining the type of vegetation within those groupings. These groupings represented vegetation communities and were then classified according to dominant vegetation types using the Brown, Lowe and Pase system.

The identification, classification and mapping of riparian vegetation is being completed in a phased approach. In this first year, priority was given to mapping riparian areas associated with perennial waters. Several areas appearing on the perennial waters map were not mapped this past year because of flight restrictions. These areas include the Colorado River and its tributaries which occur within or adjacent to Grand Canyon National Park. In addition, several lakes and wetlands were not mapped because of time constraints. AGFD will begin to map riparian areas associated with intermittent waters in the state once maps of perennial waters have been completed.

AGFD devised a method to assess the accuracy of the riparian vegetation maps through ground verification. Stream corridors in the southeastern portion of the state were investigated during this first year of the project. Results of that effort are presented. However, AGFD is continuing to verify maps across the state. Modifications will be made to the riparian maps as errors are found. This process will continue until all maps are found to be at least 80% accurate.

Riparian vegetation maps are the result of a broadly applied remote sensing process. However, precision of data can often be a problem. Therefore, data should always be field verified. That means the site represented on a map should be visited to ensure the information is correctly represented. The maps are a representation of the general location and type of riparian vegetation that existed in an area at the time the satellite images were created. The process was not intended to create maps that delineate each tree and shrub in the riparian corridor. In fact, any attempt to create statewide maps on this scale would be futile. Riparian vegetation is subject to many disturbances, primarily flood events. By the time one portion of the state is completed, other riparian areas in the state may have been severely altered. Therefore, it is important to realize that these maps are best used (1) for collecting general data on the amount of riparian vegetation existing at a given time in the state, (2) for determining the general location and percentage of various riparian vegetation community types, and (3) for change analysis studies (comparing general trends or changes between years). The suitability of these maps for regulation can only be evalulated at a later date.

The extensive flooding that occurred this past year drove home the point that riparian areas are, indeed, dynamic systems. Any attempt at mapping riparian areas is limited by the fact that it simply represents a "point in time" condition. The representation may cease to exist before the map is even complete. In other words, riparian vegetation identified from the satellite imagery may no longer exist in the same form or condition due to the massive flood events of 1993. Such flood events have occurred periodically over recorded history. The method of dealing with this type of problem on this project is discussed later in this section.

B. Determination of Perennial Waters

Before the identification, classification and mapping process could begin, perennial stream segments in the state had to be identified and a GIS database representing these stream segments had to be created. The identification of perennial stream segments was a complex process for a number of reasons. First, there is no comprehensive and definitive streamflow map for the state (i.e., a map that shows which streams are considered perennial, intermittent or ephemeral). Streamflow determinations are typically made from data collected at U.S. Geological Survey (USGS) stream gages. However, there are only about 250 stream gaging stations in the state. Secondly, the complex hydrology of arid and semi-arid stream systems results in a great deal of disparity in streamflow determinations. A third factor that added to the complexity of this task was the historical disturbances to Arizona's stream systems (Minckley and Brown 1982). In some cases, streams that were historically perennial have been altered by increased pumping of groundwater from alluvial and regional aquifers, diversions of surface water, modifications of streamflow by upstream dams, and watershed land use practices that alter water flow patterns or water retention capacity of the floodplain (Arizona Department of Water Resources 1993).

There were two previous efforts conducted by AGFD to identify perennial streams in Arizona. The objective of these efforts was to provide a working tool for fisheries and wildlife biologists for use in categorizing and cataloging data on fisheries resources and wildlife habitats. The first study (Brown et al. 1981) was a joint effort with the USGS. Results were published as a statewide map in 1977 and updated in 1978 and 1981. These maps displayed perennial streams and important wetlands at a scale of 1:1,000,000. Perennial streams were differentiated on the maps according to the following characteristics:

(1) streamflow is regulated or unregulated;
(2) base flow is mainly or entirely municipal, industrial or agricultural wastewater, and;
(3) flow was perennial prior to diversion, impoundment or decline of groundwater levels.

Wetlands were differentiated by whether they had a regulated or unregulated water supply, and whether they were mainly or entirely supplied by wastewater. Within each category, wetlands were differentiated into two size categories, less than 500 acres or greater than 500 acres. Some former wetlands were also identified.

The second effort (Silvey et al. 1984) was conducted in cooperation with the U.S. Forest Service (USFS), Rocky Mountain Forest and Range Experiment Station. The purpose was to create a listing of all naturally occurring perennial waters in Arizona. This listing was coded so that the streams could be easily referenced in a computer database. The approach was based on evaluation of each drainage system in the state. Perennial stream segments were identified using a variety of data gleaned from such sources as scientific publications and reports, fish collection data, and field experience. Ground-truthing was conducted over a period of years in the late 1970s (a drier period than the current decade). Stream segment locations were referenced using the latitude and longitude readings from USGS topographic maps for the upstream point of the segment followed by the number of miles in the stream segment. The resulting list was reviewed and revised by fisheries biologists and others over a period of six years. Today, this system serves as the basis of the AGFD Native Fish Database. The current list contains approximately 545 stream segments and assigns a hierarchical code number to each segment. Although this list serves as an excellent source of information on perennial waters in Arizona, the stream segments were not georeferenced to a computer based map. Therefore, each stream segment listed must be located manually on a map.

Results of these efforts serve as reliable sources of information on perennial waters in Arizona. However, we were not able to directly convert these data into a digital form. We were unable to digitize directly from the Brown et al. (1981) map because it was printed at a scale of 1:1,000,000, and digitizing from this scale could result in large inaccuracies. The Silvey et al. (1984) database could not be converted to GIS without a great deal of data collection, because it did not contain latitude and longitude for both the beginning and ending points of the stream segments.

Because a georeferenced database was required to create the base map of perennial streams, the information in the USGS Digital Line Graph (DLG) database was analyzed. This database represents all line map information that appears on USGS topographic maps (USGS 1991). As part of this database, USGS digitized hydrographic features represented on 1:100,000 scale maps. In the arid and semi-arid areas of the western United States, all stream channels, lakes, reservoirs, ponds, springs, industrial impoundments, playas, marshes, stocktanks, reservoirs and "dry-wash" or ephemeral channels have been mapped (USGS 1971).

According to USGS mapping principles, natural or manmade water features (streams, ponds, etc.) are classified by the periodicity of surface water. In other words, the feature is coded as to whether it is perennial, intermittent or ephemeral according to the USGS definition of these terms (Table 2). However, the perennial code is only applied when the streamflow can be reliably and accurately determined to be perennial. A water feature not definitely known to be perennial is classified as intermittent (USGS 1971).

None of the water-related features that are represented in the USGS DLGs for Arizona have been identified as perennial. Apparently there was enough uncertainty about the periodicity of flow on hydrographic features in Arizona that the perennial coding was never applied. However, because this database contains comprehensive, statewide hydrologic information in a GIS format, the decision was made to use the USGS DLGs as a basis for a perennial waters map. Perennial stream segments were then identified through a process of elimination using the previously mentioned sources and best available knowledge as guides.

The process of identifying perennial waters began by creating a subset of the USGS DLGs roughly representing the Brown et al. (1981) map. This subset served as an evaluation tool to which modifications would be made throughout the process. The subset was evaluated by a variety of reviewers and against a variety of sources.

Table 2. USGS Streamflow Definitions

Perennial waters are those "containing water throughout the year (except for infrequent periods of severe drought)."

Intermittent waters are those "containing water only part of the year."

Ephemeral waters are those containing water only as a direct result of local storms.

Source: USGS 1971

The most difficult part of this process was communicating to reviewers the criteria for determination of perennial waters. The arid Southwest has many unique hydrologic features that make the determination of perennial waters open to a variety of interpretations. For instance, many streams and rivers have perennial reaches or segments that are interspersed among intermittent stretches. Depending on the hydrology and geology of a stream corridor, this phenomenon is sometimes referred to as an interrupted stream (Meinzer 1923). Under these circumstances, perennial segments sometimes surface at different locations in the stream, depending on the local influences (substrate, geology, etc.). This type of situation increases the difficulty of geographically locating perennial waters for mapping purposes. Another question encountered was whether to include perennial stream segments that were historically perennial but are now dominated by effluent. These areas are included on the map, but have been differentiated with unique identifiers in the database. On the map, they are indicated by a black dashed line. Some examples of this type of situation are found along portions of the Santa Cruz River and the Salt River.

To address these ambiguities, a set of streamflow definitions was drafted with the hope that this would provide reviewers with some standard for determination of streamflow. The definitions were reviewed by Arizona Department of Water Resources (ADWR), Arizona Department of Environmental Quality (ADEQ) and AGFD staff, and were modified accordingly. The resulting definitions appear in Table 3. Reviewers were instructed to review the existing map and make changes, as necessary. AGFD made an arbitrary decision that perennial stream segments had to be at least one-half mile in length to be included on the map. With this in mind, reviewers were asked to:

(1) delete stream segments that were not perennial;
(2) identify and add perennial stream segments not appearing on the map;
(3) denote effluent-dominated, perennial stream segments, and;
(4) denote perennial stream segments whose flows are regulated by dam structures.

Table 3. AGFD Streamflow Definitions

Perennial Stream	A stream or part of a stream with surface flow throughout the year, drying only during periods of drought.
Intermittent Stream	A stream or part of a stream that flows only at certain times of the year when it receives water from springs, snowmelt, surface run-off or other sources (Meinzer 1923).
Ephemeral Stream	A stream or part of a stream that flows only in direct response to precipitation. It receives no water from springs and no long-continued supply from melting snow or other surface source (Meinzer 1923).
Wetland	Those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, cienegas, tinajas and similar areas (ADEQ).
Cienega	Most often applied to a mid-elevation marshland community (1,000 - 2,000 m) in Semidesert Grassland and more seldom in Madrean Evergreen Woodland, associated with perennial springs and headwater streams. Cienegas are perpetuated by permanent, scarcely-fluctuating sources of water, and are controlled by permanently saturated, highly organic reducing soils (Hendrickson and Minckley 1984).

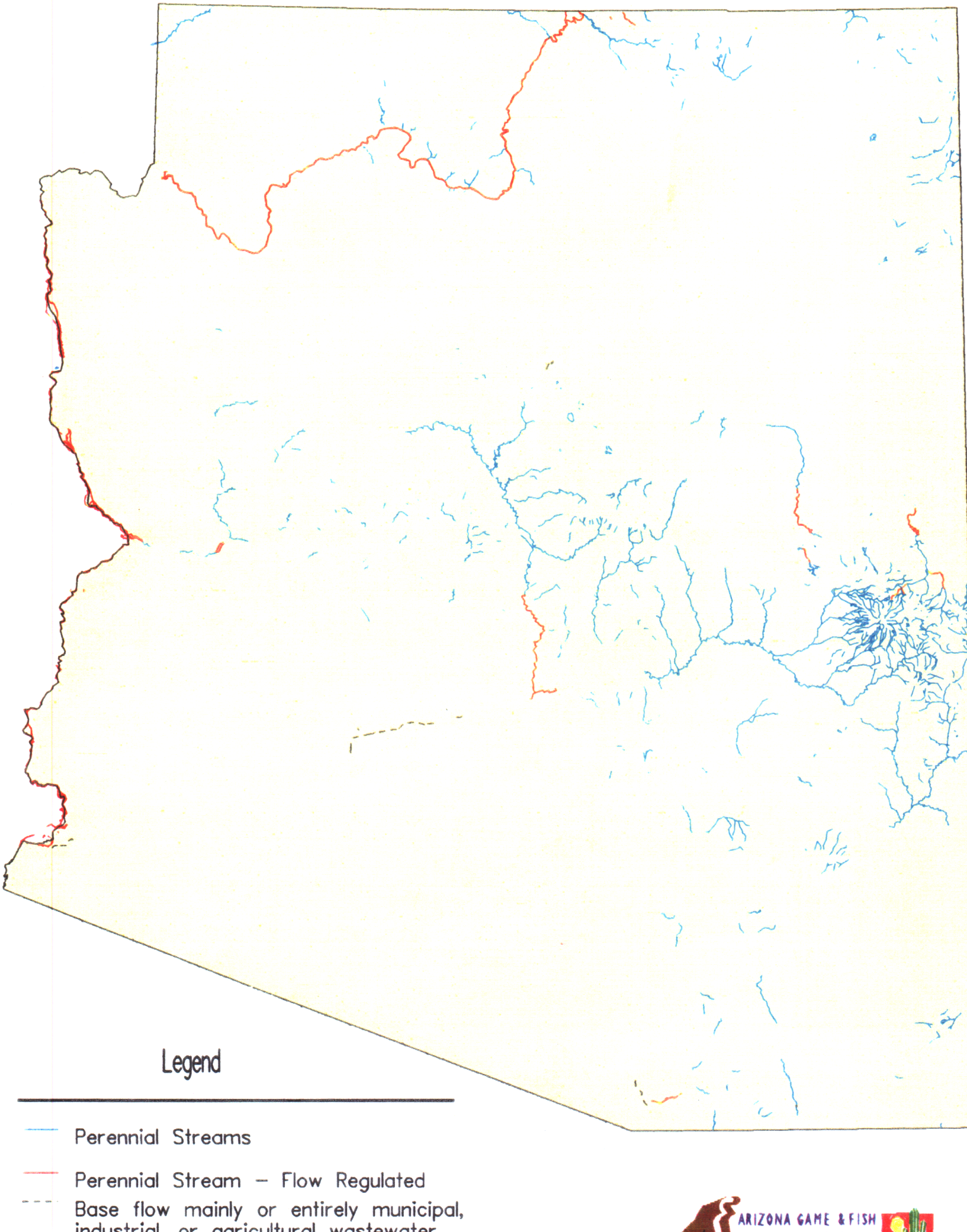
Maps of the DLG subset were initially sent to AGFD Regional Offices and to the Hydrology and Engineering Divisions at ADWR for review and comment. The changes received were then checked with other sources for verification before any corrections were made to the database. USFS and Bureau of Land Management (BLM) personnel were consulted in specific areas, as were private sector hydrologists, academicians, and various state agency personnel. Information contained in the Arizona State Parks Rivers Assessment database was utilized and, in some cases, sources named in the database were contacted for verification. For some stream segments, we received conflicting information. When this occurred, we checked as many sources as possible within our timeframe before making a decision about the flow type.

The resulting map was compared again to the Brown et al. (1981) map. This map was used as our basis for mapping riparian vegetation associated with perennial waters. Over the course of the year, this map was compared to the hand-drawn maps created during the compilation of data that appears in Silvey et al. (1984). Stream segments that appear only on the digitized map are not assumed to be in error unless an additional reliable source can be found to concur. This criterion is due to the fact that Silvey's work may have missed some streams (B. Silvey pers. comm.). There may be a margin of error in assuming that all streams appearing on Silvey's map are indeed perennial. In some instances during a series of wet years, intermittent streams may actually support fish populations but not be considered perennial by our definition. In addition, because our minimum mapping unit for stream segments is one-half mile, some areas may be too small to be represented on the current map.

The legislative definition of a riparian area excluded "artificially created stockponds, man-made storage reservoirs constructed primarily for conservation or regulatory storage, municipal and industrial ponds or man-made water transportation, distribution, off-stream storage and collection system." Every effort was made to exclude these areas from the map. However, our method of differentiating between natural and artificial ponds using remote sensing techniques alone is not highly accurate. Use of aerial videography, when available, increased our ability to determine the nature of the pond. To determine whether a man-made reservoir should be excluded, the sources that identified the purpose for which the reservoir was constructed had to be consulted. In cases where we were able to verify that a reservoir was constructed for purposes listed as exclusions, the reservoir was removed from the map.

The resulting map (Figure 2) represents our best attempt to identify perennial waters in Arizona. Perennial stream segments are identified according to three criteria. Those stream segments that are somehow regulated by a dam structure are identified in red. Stream segments whose base flow is mainly or entirely municipal, industrial or agricultural wastewater are identified by a black dashed line. All other stream segments are identified in blue. Because the map is based primarily on reviewers' knowledge and not on quantitative stream gage data, caution should be exercised in the application of the map beyond this study.

Statewide Riparian Inventory & Mapping Project
Perennial Waters



ARIZONA GAME & FISH HERITAGE FUND

Figure 2.

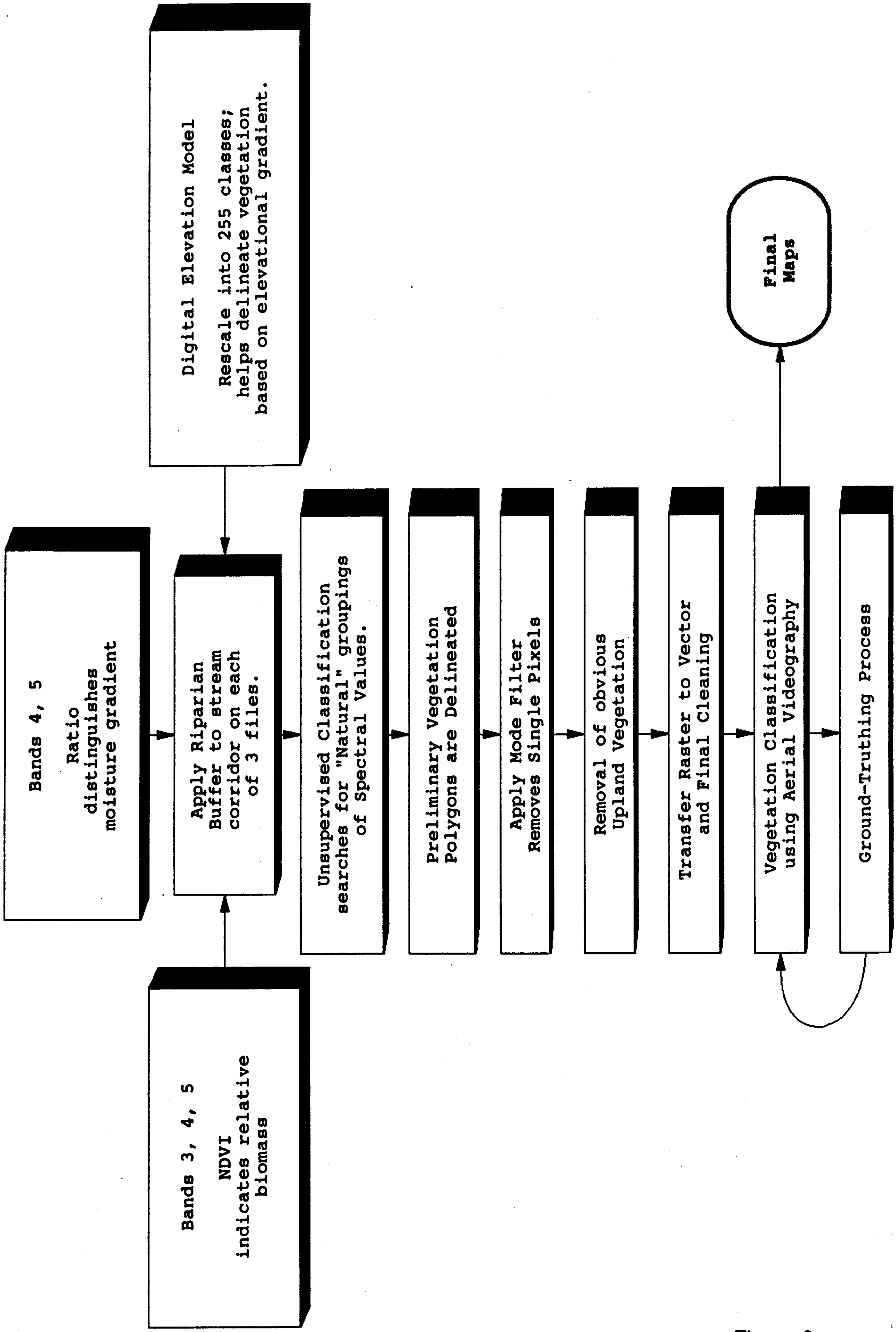
C. Satellite Imagery - Method of Analysis

One of the most critical parts of mapping riparian areas was correctly representing the extent of the riparian area and the various vegetation types that occur within that area. This task was accomplished through the analysis of satellite imagery. The satellite imagery used in this project was obtained from the Earth Observation Company, Landsat satellites 4 and 5, Thematic Mapper (TM) data. Satellite images are collected in scenes, which are areas depicting a specific geographic extent. Approximately 19 scenes are needed to cover the entire state. Each scene is comprised of rows and columns which make up picture elements, or "pixels." Each pixel represents a square cell covering approximately 984 square yards and is 31.4 yards along each side. The Landsat satellite imagery that was used as the base map for this project represents riparian vegetation as it existed in April, May and September of 1991 and 1992. The reason images from multiple months and years were used is that scenes are sometimes obscured by clouds. Graham attempted to use satellite information taken in the spring months because riparian vegetation was more distinct from adjacent vegetation before the summer rains. Scenes from April and May of 1991 and 1992 were used to avoid cloud covered images. In a few cases where cloud cover obscured all spring scenes for an area, September scenes were applied.

The Landsat TM sensor system collects seven bands of reflected and emitted energy in the visible, reflective-infrared, middle-infrared, and thermal-infrared regions of the electromagnetic spectrum (Jensen 1986). To determine the extent of riparian vegetation along a stream corridor, three of the seven bands are used. Bands 3, 4 and 5 are analyzed based on their spectral characteristics. Band 3 is the red chlorophyll absorption band of healthy, green vegetation. It represents one of the most important bands for vegetation discrimination. Band 4 is especially responsive to the amount of vegetation biomass present in a scene. It is useful for crop identification and emphasizes soil-crop and land-water contrasts. Band 5 is sensitive to the amount of water in plants, or turgidity. This information is useful in plant vigor investigations.

To evaluate reflectance, a process of combining bands, via band ratios, was applied to the imagery. These ratios modify the images in a number of ways. First, they reduce the effects of environmental conditions such as seasonal changes in the illumination angle and intensity of sunlight. Secondly, they provide unique information not available from a single band.

Before analysis of a satellite scene, certain areas were removed or "masked" to improve the quality of satellite classification results. These areas were human use areas, such as agricultural or developed lands. They were masked because it was virtually impossible to have an image classification procedure consistently separate out actively growing agriculture from adjacent areas of actively growing riparian vegetation. It was also difficult to separate sand and gravel bars from abandoned agriculture. The human use mask was developed by Graham during the Arizona GAP Analysis Project and represents areas of agriculture, urban, industrial and mixed land uses (Graham in prep.).



Digital Elevation Model
Rescale into 255 classes; helps delineate vegetation based on elevational gradient.
Bands 4, 5
Ratio distinguishes moisture gradient
Bands 3, 4, 5
NDVI indicates relative biomass
Apply Riparian Buffer to stream corridor on each of 3 files.
Unsupervised Classification searches for "Natural" groupings of Spectral Values.
Preliminary Vegetation Polygons are Delineated
Apply Mode Filter Removes Single Pixels
Removal of obvious Upland Vegetation
Transfer Raster to Vector and Final Cleaning
Vegetation Classification using Aerial Videography
Ground-Truthing Process
Final Maps

Figure 3.

The process used to identify the extent of riparian vegetation and to differentiate the types of vegetation is represented in the flowchart in Figure 3. The process was applied to each satellite scene using two different band ratios and elevation data. Examples of images that result from each stage of the process are shown in Figure 4. The first ratio created a normalized difference vegetation index (NDVI), the output of which indicated relative vegetation biomass. The second ratio between bands 4 and 5 distinguished moisture gradients within the scene. The third step applied elevation ranges for the geographic area represented within the scene. The data set used is referred to as a Digital Elevation Model. The elevation data assisted in segmenting the data into regions that were physically and spectrally more homogeneous. It indirectly distinguished topographic changes in the landscape by accounting for illumination effects and stratified a satellite scene into ecological zones (Scott et al. 1993). These three processing steps resulted in three separate computer files.

The next step of the analysis required use of the digital perennial waters map. The map was overlaid on the satellite image contained in each file. Using Arc/Info software, a buffer was created around the stream bed to include all potential riparian vegetation. Buffering is a process that calculates an equal area around a given location. Buffer distance was determined by the application of Arc/Info software. Because the satellite image displays a bright red color where high amounts of vegetation biomass were present, the buffer distance was determined at the furthest red area from the stream bed. The resulting corridor of vegetation was extracted from the satellite scene to be further refined.

Once the riparian corridors were extracted, the three files were combined and analyzed together. An image classification procedure was conducted using cluster analysis. This procedure is referred to as unsupervised classification. It involves clustering of individual units, or "pixels," into classes based on measured reflectance values. More simply, it grouped together those areas that show similarities on the basis of biomass, moisture gradient, topography and elevation.

The result of this image classification is pictured in Figure 4(i). Polygons (contoured areas) outlined on this map represent areas of similar vegetation as identified by cluster analysis. However, at this point, the map was still in a preliminary stage and had to undergo continued refinement. First, areas of upland vegetation that were inadvertently included in the buffering process were identified and removed. Next, a mode filter was applied, which removed or integrated areas that fell below the minimum mapping unit (MMU). The MMU was 0.4 acre (0.4 acre = 2 pixels). However, it increased to 4 acres (4 acres = 20 pixels) in large river corridors (San Pedro, Verde, Colorado, Santa Cruz, Gila and Virgin rivers).

Two units of scale have been presented in this section: pixel size and MMU. Pixel size represents the resolution of satellite imagery. MMU refers to the size of the smallest area depicted on a map. By establishing a MMU of 2 pixels (0.4 acres) for the majority of areas and applying a mode filter during the mapping process, a 2 pixel area becomes the smallest area depicted on the maps. For the large river corridors listed, the MMU is 20 pixels (4 acres).

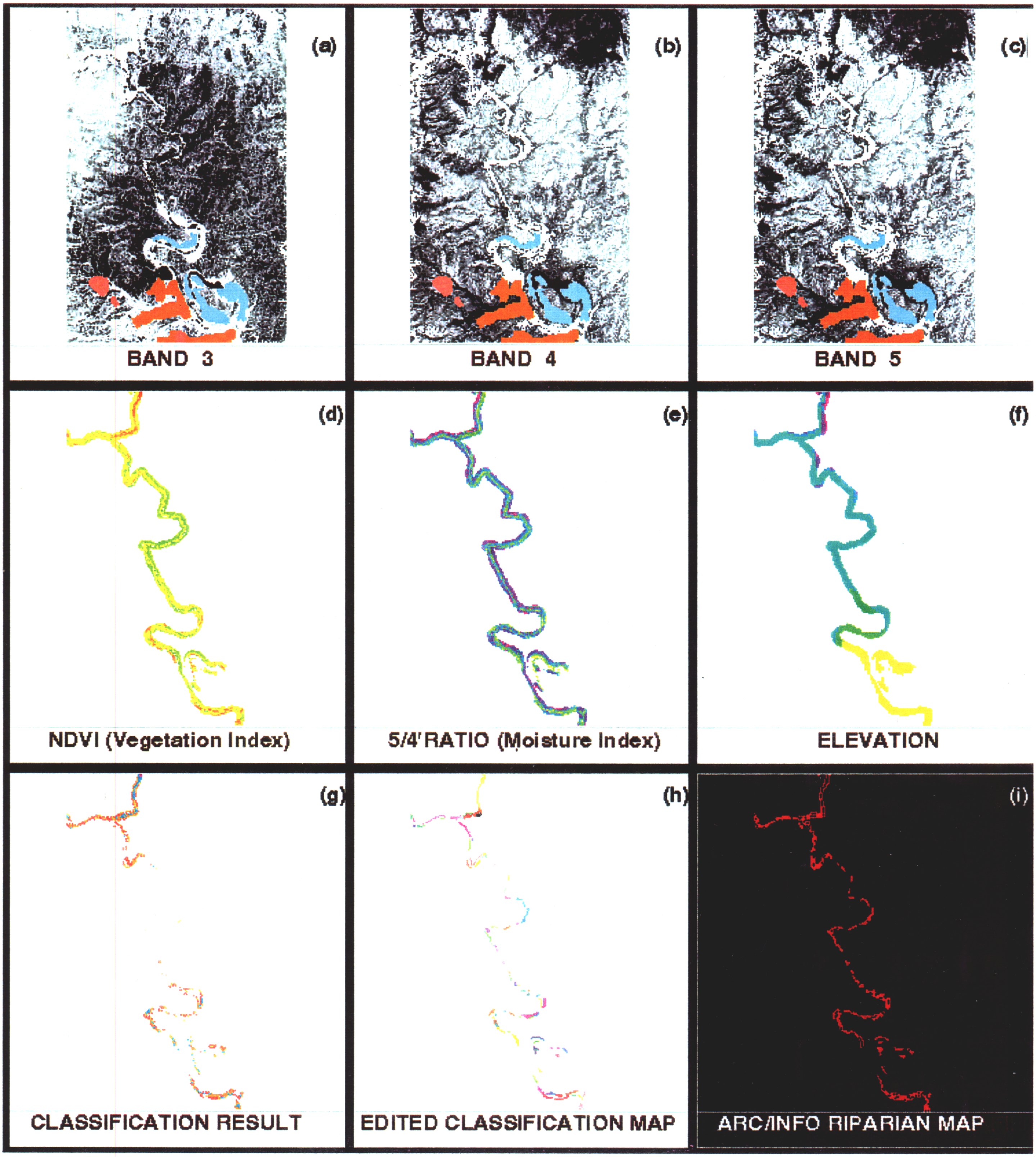
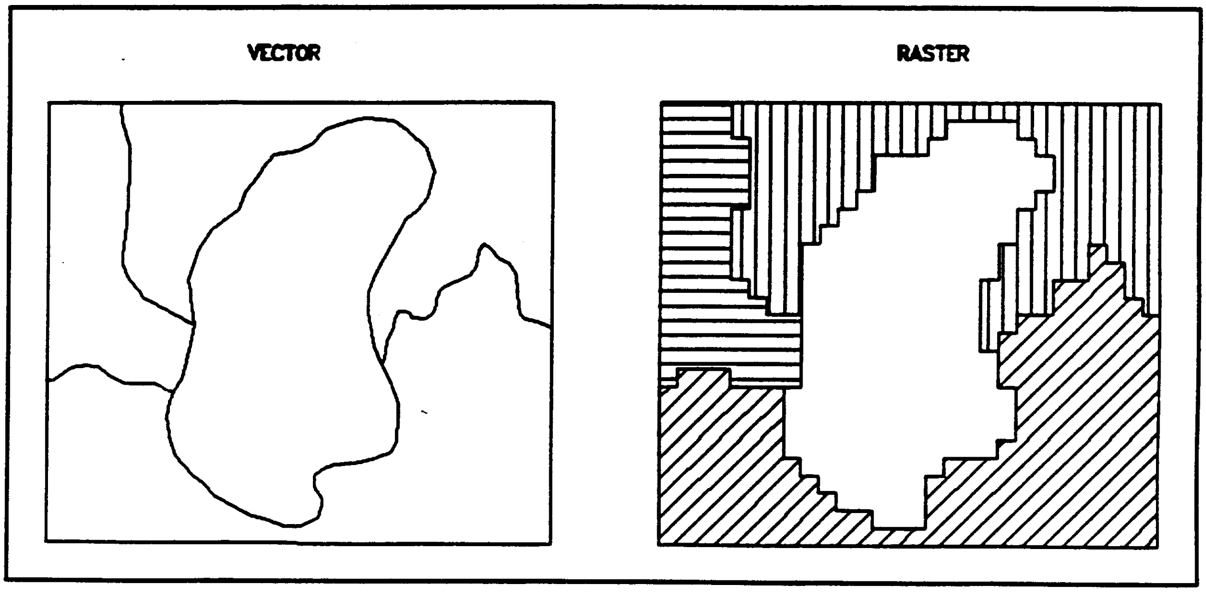

(a)
BAND 3
(b)
BAND 4
(c)
BAND 5
(d)
NDVI (Vegetation Index)
(e)
5/4'RATIO (Moisture Index)
(f)
ELEVATION
(g)
CLASSIFICATION RESULT
(h)
EDITED CLASSIFICATION MAP
(i)
ARC/INFO RIPARIAN MAP

Figure 4.

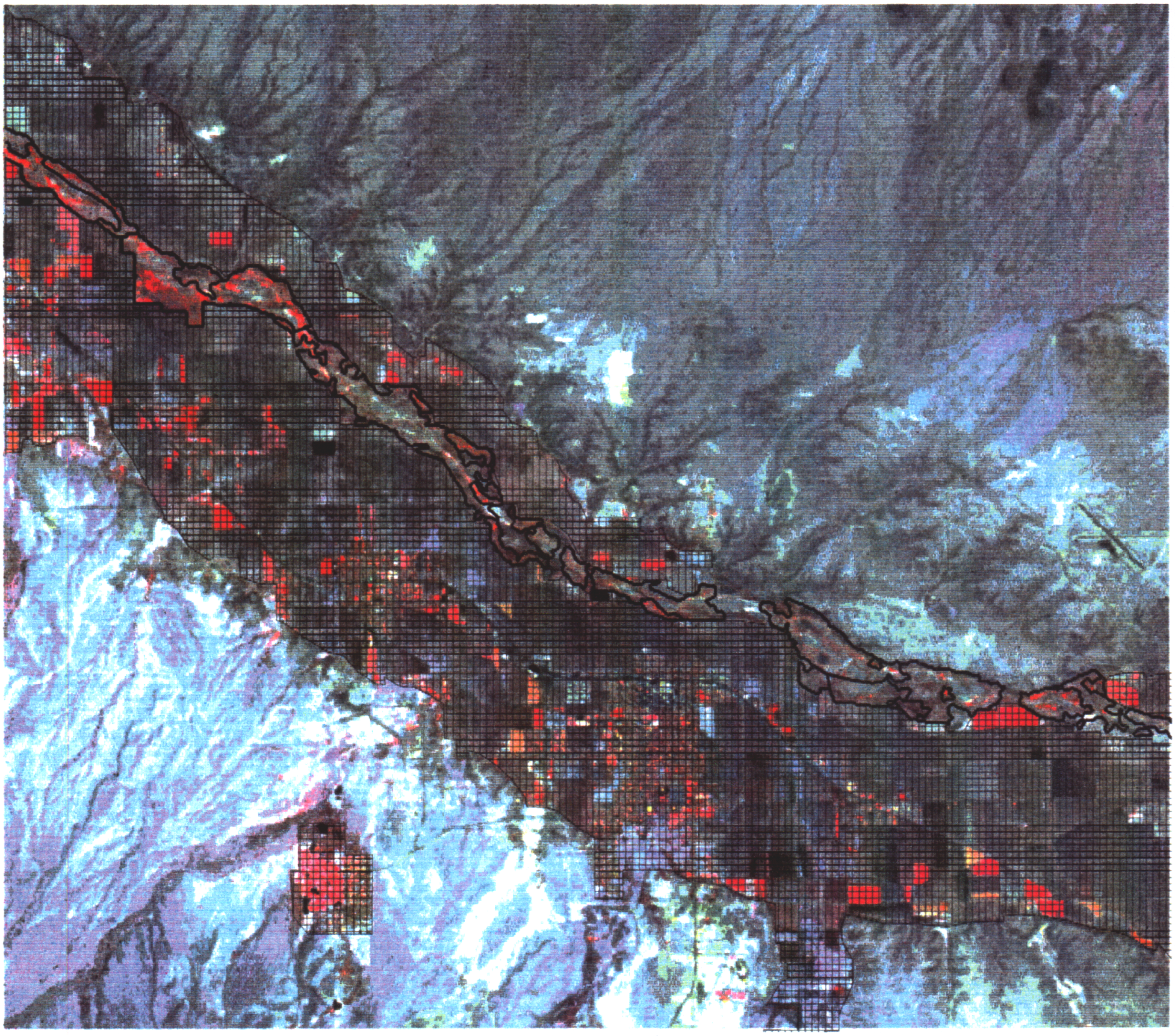
Figure 5. Representation of vector and raster data.



Polygons delineated by this process were then vectorized, a process that changes the square raster format into smooth-lined vector format (Figure 5). The map was manually checked and outliers were rejected. The finished product represents the extent of riparian vegetation in a stream corridor and differentiates the various types of vegetation found there. Figure 6 and Figure 7 represent sections of the Gila River and San Pedro River, respectively, after these processes have been completed. The vegetation polygons are outlined in black. The hatched pattern designates the extent of the agricultural and urban areas near the riparian corridor.

Once the vegetation extent map was completed from satellite imagery, aerial videography was used to classify the vegetation community that was found to occur within a given polygon. The application and use of aerial videography follows.

Example of Satellite Imagery along Gila River with Vegetation Polygons and Masking Layer



Land use mask applied to satellite imagery during image classification.

Vegetation polygons resulting from the imagery classification.

N

Vegetation data generated at UofA ART Lab.

Figure 6.

Example of Satellite Imagery along San Pedro River with Vegetation Polygons and Masking Layer

Land use mask applied to satellite imagery during image classification.

Vegetation polygons resulting from the imagery classification.

Vegetation data generated at UofA ART Lab.

Figure 7.

D. Vegetation Classification Using Aerial Videography

Multiple resolution aerial videography was obtained by flying pre-determined streams, lakes or wetlands in an airplane equipped with two professional grade 3-CCD Super VHS (S-VHS) video cameras. Areas to be flown were determined using the perennial waters map. These cameras produced true color S-VHS videotapes. One camera was set to record a wide-angle image, while the second camera was equipped with a remote controlled zoom lens that was used to record mid- to full 15X zoom subsamples. Aerial videography was recorded at a height of approximately 2000 feet above land surface. A zoom lens frame of video imagery represented a ground width of about 76.5 -109 yards. A wide-angle frame represented a ground width of about one-half mile.

The system integrated a global positioning system (GPS) that projected a time-code onto each video frame. GPS is a system of satellites that accurately determines coordinates of any ground location. The time-code corresponded to GPS positional data that was simultaneously logged to a file on a microcomputer. The GPS interface provided a number of important capabilities: (1) it assisted the pilot and camera operator in maintaining the proper course along a stream channel; (2) it identified the ground location at which the video recording was made; (3) GPS information allowed the wide-angle and zoom videotapes of an area to be synchronized for viewing purposes; (4) it allowed us to more accurately match a position on the satellite image to the video image.

Aerial videography served a dual purpose. Although wide-angle and zoomed video images were viewed simultaneously, they had different applications. The wide-angle view provided a broad perspective of the actual riparian vegetation occurring in a riparian area. This perspective allowed the interpreter to refine the mapping accuracy by comparing the size and extent of vegetation polygons on the satellite map with the actual vegetation communities, as seen on the video picture (Figure 8). Polygons representing vegetation communities were modified, added, merged or deleted as necessary to more accurately represent the actual vegetation as assessed by the interpreter.

Zoomed videography displayed a detailed picture of the vegetation, to an extent where individual plants could be differentiated. The person viewing the video (the interpreter) used the zoomed image to identify the type of vegetation occurring within a polygon. The interpreter then integrated the information from both views to assign a classification code to the polygon.

Because aerial views of vegetation often look quite different than at ground level, the interpreter had to initially discern the various plants that appeared on the video by working through a training process. This training process involved checking the identity of plants at specific locations on the ground. As the interpreter viewed the zoomed videos along a stream corridor, locations of specific plants, trees or clumps of similar looking vegetation were noted and GPS time codes for that particular video frame were recorded. These specific plants then were located and identified on the ground by biologists. In time, the interpreter built a reference log of information that contained plant species that had been ground-truthed and referenced to specific video frames (Figures 9 and 10). This reference library allowed the interpreter to recognize a plant or vegetation type by learning its aerial "signature," i.e., its unique color, texture, shape and size.

As previously discussed, the hierarchical classification system chosen for this mapping project was devised by Brown, Lowe and Pase. Because of the high resolution provided by the zoomed videography, classification was accomplished at the fifth level (see Table 1). This level of classification identifies distinctive vegetation series or communities, and is based on the determination of dominant plant species more or less local or regional in distribution (Brown et al. 1979). In some cases, classification was taken to the sixth level, or vegetation association level.

The protocol for identifying plant associations from the MRAV is as follows. The dominant plant species was identified as the species whose canopy cover was equal to or greater than 50% of the polygon area. A co-dominant situation was identified when two species covered approximately equal portions of the polygon area. The classification was further refined through evaluation of additional species found to be common in the polygon. These were termed associate species - species that were found throughout the area, but not in sufficient abundance to be noted as dominants. An associate species was named in the classification if it covered at least one-half as much area as the dominant species. An additional associate species was named in the classification if it covered at least half as much area as the first associate species.

During this process, the interpreter also assigned a code to each polygon representing the percent canopy coverage of vegetation. One of the following four categories was assigned to each polygon:

a = 1 - 25%	c = 51 - 75%
b = 26 - 50%	d = 76 - 100%

Percentages refer to the amount of canopy cover for total vegetation in the polygon.

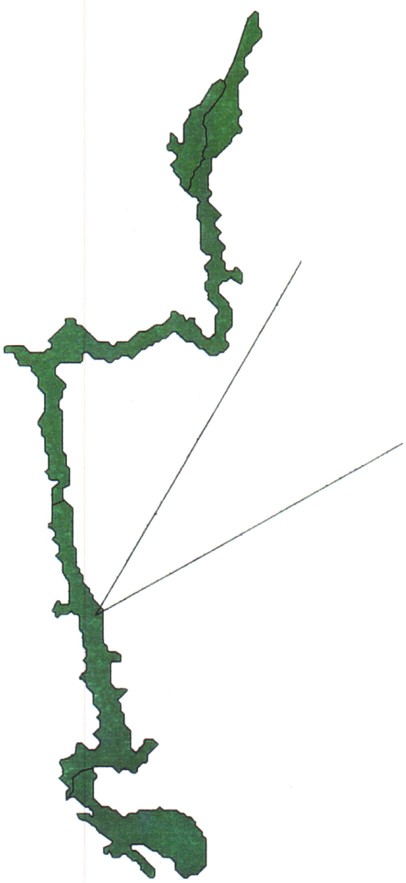


Figure 8. Sample of wide angle aerial videography of riparian vegetation along the Big Sandy River in Arizona.

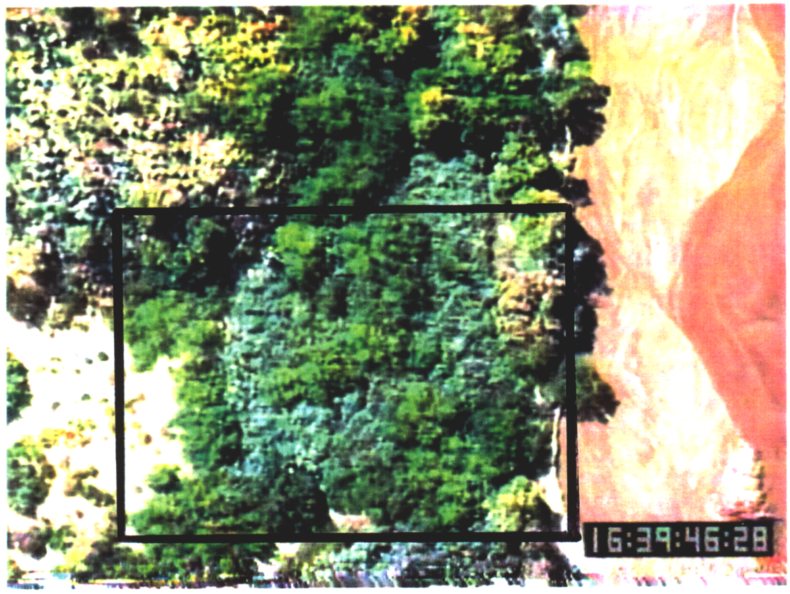


Figure 9. Example of midzoom aerial videography for rectangular area on wide angle photo.

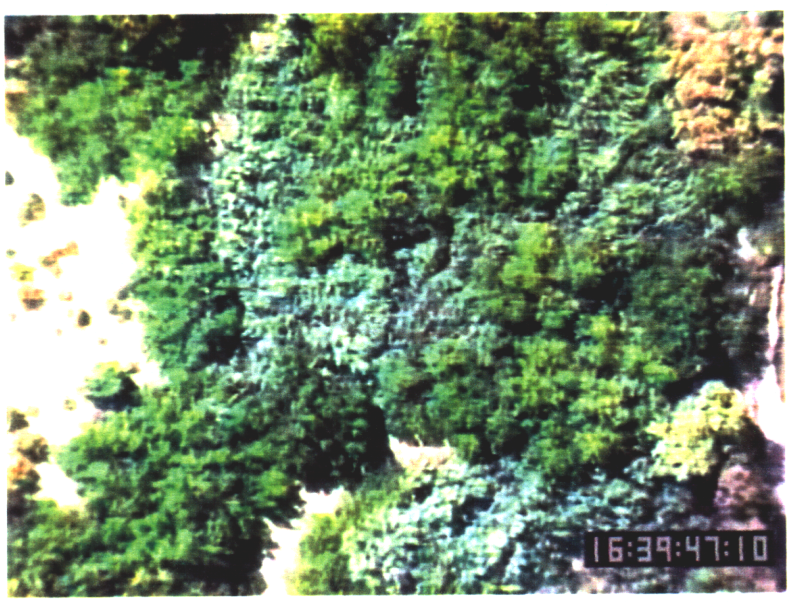


Figure 10. Example of zoom aerial videography for rectangular area on midzoom photo. The vegetation types represented include arroweed and tamarisk.

E. Map and Classification Accuracy

Field verification and ground-truthing efforts have been devised to assess the effectiveness of this remote sensing technique for mapping riparian areas. The method is briefly described here along with some of the results. A detailed reporting of methodology and results is in a separate technical document (AGFD in press).

Field verification is a process whereby biologists randomly select classified vegetation polygons in a stream corridor or watershed and verify the vegetation classification and polygon boundaries using ground-truthing techniques. Polygons are first stratified by vegetation classification type and polygon size. For each selected polygon, data were collected in a manner derived from field procedures developed by the Colorado Plateau Vegetation Advisory Committee (1992). In general, this method uses a technique based on "species prominence values," a rating that combines estimated dominance, biomass and frequency of occurrence. A prominence value is assigned to each species observed at the site on a scale of 1 through 5. Multiple sites are sampled within each polygon. The arithmetic mean and species frequency is calculated for each species group recorded in the polygon. This results in a set of values which assist in the determination of vegetation class. Additional vegetation data are also collected in the field such as height, size class frequency and distribution. General environmental and habitat conditions on the site are recorded as well as information on groundcover and adjacent vegetation types.

During the early development of sampling protocol, accuracy and data standards were established. Maps correctly classifying vegetation at least 80% of the time were deemed acceptable. We chose this level of accuracy because the overall accuracy of remote sensing derived data (satellite imagery) is generally considered to be no greater than 85% (Jensen 1986). It was also determined that a sample of 20 percent of all classified polygons would be taken. A conservative estimate of map accuracy is provided by sampling only 15.8% of the total polygons, i.e., the estimate is within 5% of the true value 90% of the time. However, the higher sampling rate was chosen because it allowed for a buffer should some polygons be unavailable or otherwise unsuitable for sampling.

To ensure consistency in ground-truthing effort, selected polygons were sampled using 0.5 acre plots (roughly equal in size to the minimum mapping unit). One plot was used for every 2.5 acres of polygon size, with an upper limit of ten for any single polygon. This maximum was established because of time limitations and was based on the fact that 71 percent of mapped polygons were 25 acres or less in size (Figure 11). Therefore, most polygons were sampled at a rate proportional to their size and only some at a rate lower than desired. Since biologists examined the entire polygon before choosing where to place representative plots, they were able to visually detect and note on video prints any inconsistencies in species composition of large polygons.

To date, the field verification process has been conducted on perennial waterways in southeastern Arizona. Area boundaries (inclusive) were the Gila River on the north (inclusive), New Mexico on the east, Mexico on the south, and the Santa Cruz River on the west (inclusive). These

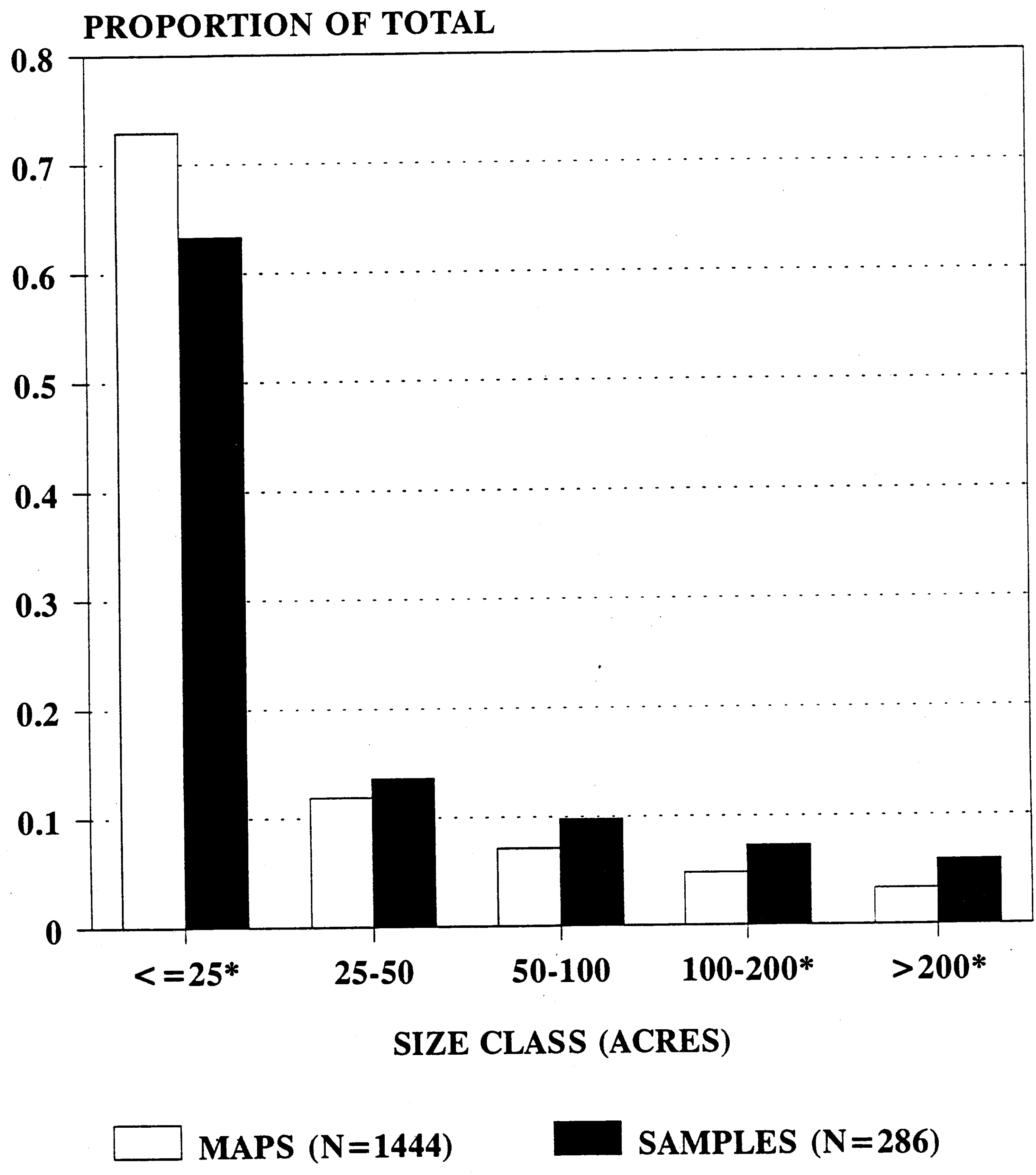


Figure 11. Comparison between map and sample polygon sizes. Asterisks mark size classes that have significantly different proportions (confidence level=90 percent).

waterways were the first areas to be mapped and classified by UA-ART. The verification area contained 1,444 riparian vegetation polygons (59,615 acres). Of these, 286 polygons (17,079 acres) were selected for verification. It was determined that 1,651 plots should be sampled.

AGFD biologists were given lists showing only an identification number, acreage and the required number of plots. In this way, their verification data could not be biased by prior knowledge of vegetation classification. After transferring some information from GIS to field maps, biologists were also aware of polygon shape and location. With this limited knowledge, biologists were then sent afield and were asked to accurately and consistently evaluate vegetation they found on site. Data were recorded on standardized report forms. Biologists also recorded on maps any boundary discrepancies they encountered while assessing polygons.

One of the most important aspects of the field verification process was to give feedback to the aerial video interpreter to help in finding and correcting classification errors during the mapping process. As errors were identified, information was provided to UA-ART for use in correcting maps. In this way, errors were minimized in later phases. Not only were specific polygons changed, but maps were re-evaluated and the corrections applied throughout. This step was critical to increasing the overall accuracy of the vegetation maps.

Data from comparison of field verifications to first draft maps is summarized in Table 4. The number of polygons in which errors or changes effected only a portion of the polygon area are shown in parentheses and are accounted for in acreage and plot values. Partial polygons are in addition to the number of whole polygons listed. Acreage and plot number has been adjusted up or down to account for portions of polygons impacted by various problems. A polygon is correctly classified when field data indicates that it is within the same vegetation community type as its map classification.

Initially, only about a third of the sampled polygons were found to be correctly classified. Initial accuracies ranged from 64% correct in some narrow mountain riparian areas to about 35% correct in large, low elevation rivers. It is important to realize that accuracy estimates calculated from the initial field sampling do not represent the end results of the mapping effort. Our goal was to attain at least 80% accuracy. Therefore, the next step was to re-evaluate mapping accuracy after field verification data were reported to the video interpreter and changes were made to maps. Once changes were made, the accuracy would increase. To measure this increase, a new sample set was selected from the San Pedro River and biologists applied the verification process on revised maps.

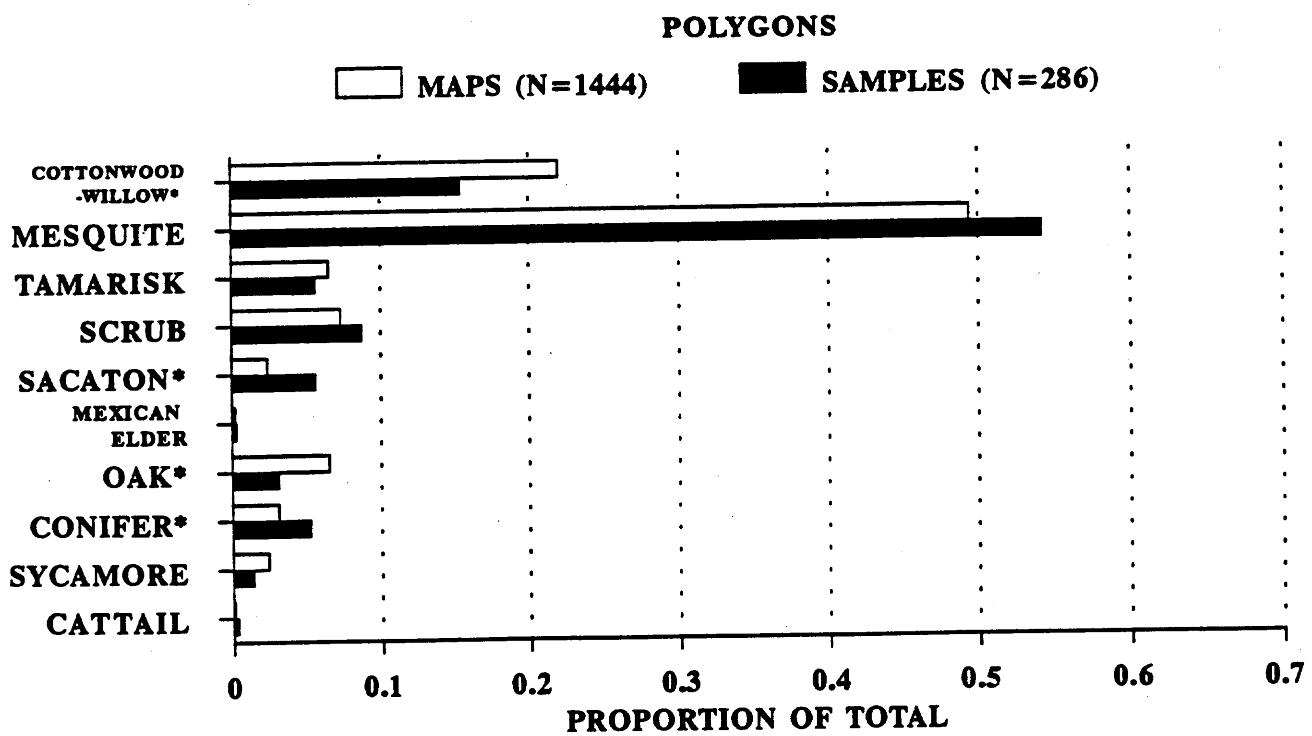
Our revised sample set on the San Pedro River showed an increase in accuracy by approximately 20 percent (Table 5). This change came primarily from a decrease in the misclassification of upland vegetation as riparian communities. Classification and boundary changes based on new field data will be incorporated into further map revisions and should substantially improve overall accuracy.

Table 4. Summary of sample results from initial ground-truthing. The number of polygons in which errors or changes affected only a portion of the polygon area are shown in parentheses and are accounted for in acreage and plot values. Partial polygons are in addition to the number of whole polygons listed.

	Number of polygons	Number of acres	Number of plots
Selected for sample	286	17,079.6	1,651
Unavailable	17 (22)	1,009.6	134
Missed	5 (4)	969.9	30
Total Sampled	**264 (26)**	**15,100.0**	**1,487**
Non-riparian (upland)	48 (36) 18.2%	4,812.2 31.9%	391 26.3%
Incorrect classification	127 (37) 48.1%	5,412.7 35.8%	599 40.3%
Correct classification	89 (22) 33.7%	4,875.1 32.3%	497 33.4%

Several types of errors were recognized in this process. As the verification process continues to be applied across the state, modifications are being made to reduce as many of these errors as possible. A summary of errors followed by proposed solutions is presented below.

Despite efforts to stratify samples by vegetation class, some vegetation classes were sampled more often (or less often) than desired (Figure 12). Data sets were received sporadically at AGFD as maps were completed at the UA-ART. Therefore, the number of riparian corridors, the variety of plant classifications, and the number of polygons and acreage differed within each set of data processed for random selection. Because of this, some small sized and/or infrequent vegetation classes often were not selected. They simply did not cover enough acreage within a data set to require sampling. However, when combined across all maps their "importance" increases (i.e. they were actually sampled less often than required). The fact that some small polygons were not chosen as often as they should have been is also supported by Figure 11. Polygons less than or equal to 25 acres were under represented in the combined sample, while all other size classes were either proportionally or over represented. This error can readily be minimized by using larger sets of polygons for sample selection.



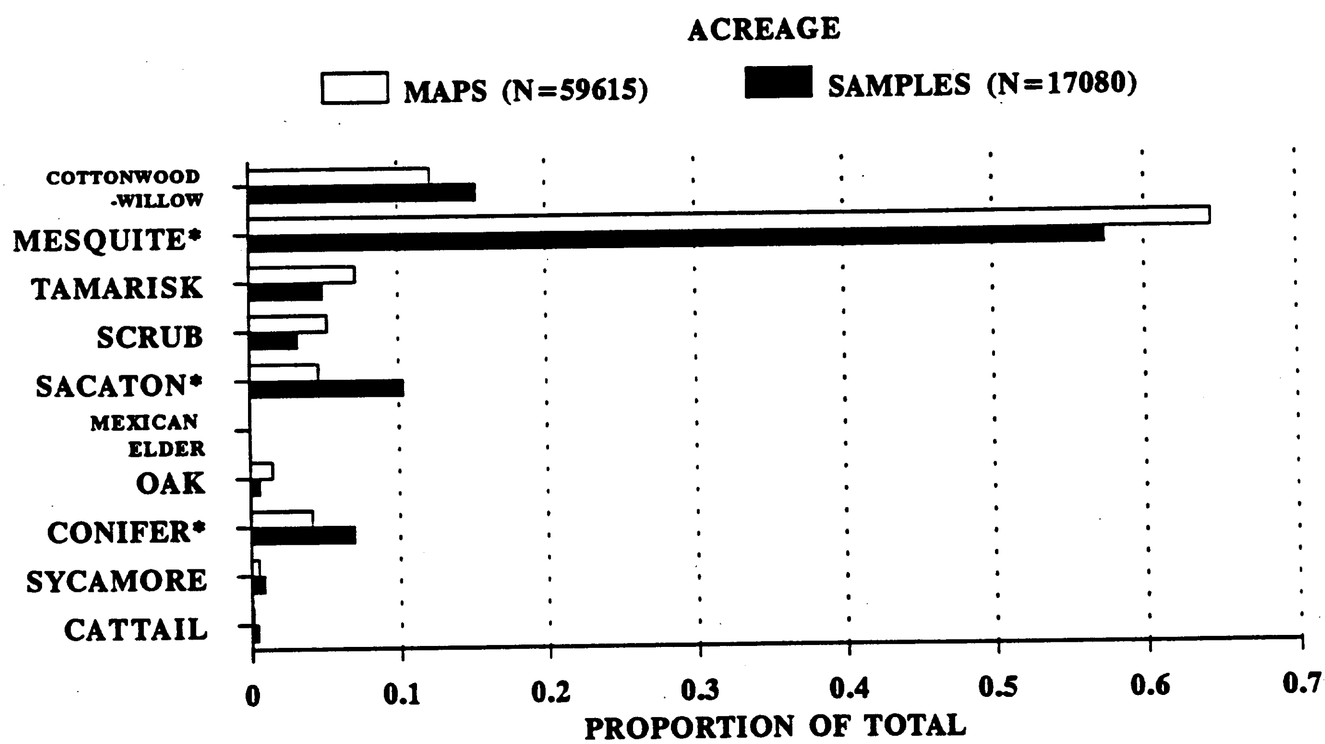


Figure 12. Comparison by plant community for map and sample polygon number and acreage. Asterisks mark pairs that have significantly different proportions (confidence level = 90 percent).

Table 5. Comparison of initial and subsequent verification of the San Pedro River. The number of polygons in which errors or changes effected only a portion of the polygon area are shown in parentheses and are accounted for in acreage and plot values. Partial polygons are in addition to the number of whole polygons listed.

	Number of polygons		Number of acres	
	Old	New	Old	New
Selected for sample	94	85	9,021.9	8,232.6
Unavailable	3(5)	2(4)	302.1	213.5
Missed	2	2(4)	902.6	181.1
Total Sampled	**89(5)**	**81(6)**	**7,817.2**	**7,838.1**
Non-riparian (upland)	26(13) 29.2%	12(11) 14.8%	4,135.4 52.9%	2,459.8 31.4%
Incorrect classification	32(11) 36.0%	25(10) 30.9%	1,767.9 22.6%	1,712.7 21.8%
Correct classification	31(6) 34.8%	44(20) 54.3%	1,913.8 24.5%	3,665.5 46.8%

A small amount of discrepancy resulted because the required sample size was rounded to the nearest whole number. In some cases, this increased the number of samples taken (i.e. they were sampled slightly more often than required).

From the outset, problems that might affect map accuracy were documented. Some polygons were not available for sampling because they had been scoured by floodwater and were devoid of vegetation. Others were underwater due to high reservoir levels. In a few cases, landowners chose to deny access. Biologists overlooked or missed a small number of polygons in the field. These factors resulted in a reduction in the number of polygons available for sampling to 264 (a minimum of 228 was needed).

The impact of flood events on riparian vegetation in 1993 was extensive. Much of the aerial videography was taken after the majority of floods occurred, with the exception of streams and rivers in southeastern Arizona. The satellite imagery, however, represented pre-flood vegetation. Because the videography is needed to identify vegetation community type, we were unable to identify areas scoured of vegetation during the floods. These areas are still considered as riparian areas but are identified as "flood scoured" on the maps. In most cases, field biologists found extensive regeneration of riparian species at these sites during ground-truthing.

Some classification errors were due to the incorrect identification of the extent of the riparian area. Nearly 32% of the acreage was classified as riparian vegetation when in fact it was upland vegetation, agricultural lands, or adjacent to rural dwellings. This type of error was more prevalent on maps for larger rivers, such as the San Pedro, than on maps for smaller drainages and was essentially non-existent for narrow mountain riparian areas. Most misclassifications of this type were in mesquite communities that transition from the riparian zone into the adjacent upland. Although plant stature and density differ between the two zones, the boundary was not always delineated on maps properly. Boundaries can be corrected through application of ground-truthing methods that include recording the coordinates of upland/riparian edges. Topographic maps may also help by showing contour lines that may approximate the boundary.

By randomly selecting polygons only from areas that have been identified as riparian, we made the assumption that the area mapped as upland or non-riparian was accurate. The process did not account for the amount of riparian vegetation that may be misclassified as non-riparian. In addition, the agricultural mask applied to areas adjacent to the riparian corridor early in the process may have actually obscured some riparian vegetation. This situation was especially true for areas where large acreages of agricultural lands occurred in the floodplain. Underestimation of the riparian zone was found to occur on the Santa Cruz River and the Verde River at Camp Verde. Aerial videography and modification to the ground-truthing process are being used to identify and correct this problem.

Some polygons likely will always be misclassified because many understory species are not visible from above, but they may have enough prominence to influence classification by field biologists. For example, several evergreen oaks often form a mid-level canopy underneath an upper canopy of pine. The video interpreter sees the pine, but not the oak.

Other misclassifications occurred because some species were indistinguishable from others when viewed on video. Two common errors were to confuse ash and walnut with cottonwood and to confuse mesquite with tamarisk. Adding to these difficulties was the fact that often these plants occurred close together or in mixes. The result was polygons assigned to the wrong series.

Both of these errors can be reduced by producing videography at different times of the year. Appearance changes through the year as plants grow new foliage, flower, gain autumn color and shed foliage. The sequence of change varies among plant species. Videography can be timed to take advantage of a time period when two usually similar appearing species look different. For instance, tamarisk blooms when mesquite does not and has a white or pink tint from its flowers.

Some improvement in classification would be expected if a more comprehensive photo reference log is provided to the video interpreter. A wide variety of situations should be illustrated so that species are recognizable whenever observed. Situations should include seasonal changes for a species, a species combined with a variety of other species, and a species at different densities. A reference log needs to evolve as new plants and situations are encountered.

Although great effort was made to ensure accurate positioning of biologists in the field, some error should be attributed to the ground-truthing process itself. The primary source of this error was improper location of polygons on the ground. This source of error is likely to be greater for small polygons than for large ones. Small polygons are more difficult to locate to begin with and often are a different density of the same vegetation as the surrounding area. Currently biologists have to rely on topographic maps, their own navigational skills and wide angle photos to locate points on the ground. The use of GPS in conjunction with a base station should more accurately confirm where biologists collected information. A base station allows differential correction of coordinates so that true location can be more accurately determined.

AGFD will continue to apply this process to the riparian vegetation maps and make modifications accordingly until all maps across the state are at 80% accuracy. Maps of the San Pedro River and Santa Cruz River have also been reviewed by staff at ADWR and the Center for Environmental Studies at Arizona State University. This has greatly assisted AGFD staff in identifying and correcting errors. This has also helped to sensitize us to other types of errors that might not be readily apparent from the field verification process. AGFD will continue to work with land managers and researchers across the state to verify the accuracy of these maps.

F. Presentation of Maps and Summary of Findings

Products of this riparian inventory include numerous GIS databases and aerial videotapes. Examples of some of these products are presented in this section, along with a summary of findings. These examples are intended to give the reader an idea of (1) the types of maps that can be produced, and (2) the types of data contained within these GIS databases.

Figure 13 is a representation of the total amount of riparian vegetation associated with perennial waters mapped during this first year of inventory. The inventory covered 4,628.95 miles of streams and mapped 266,786.39 acres of riparian vegetation. Portions of the Colorado River and its tributaries that are within Grand Canyon National Park have not yet been inventoried because of flight restrictions. This portion represents an additional 393.52 miles of regulated river. Table 6 shows the total number of perennial stream miles identified and stream miles divided into regulated, unregulated and effluent-dominated categories, while Table 7 divides them by landownership category (federal, state, private, tribal) and land management category (BLM, USFS, AGFD, etc).

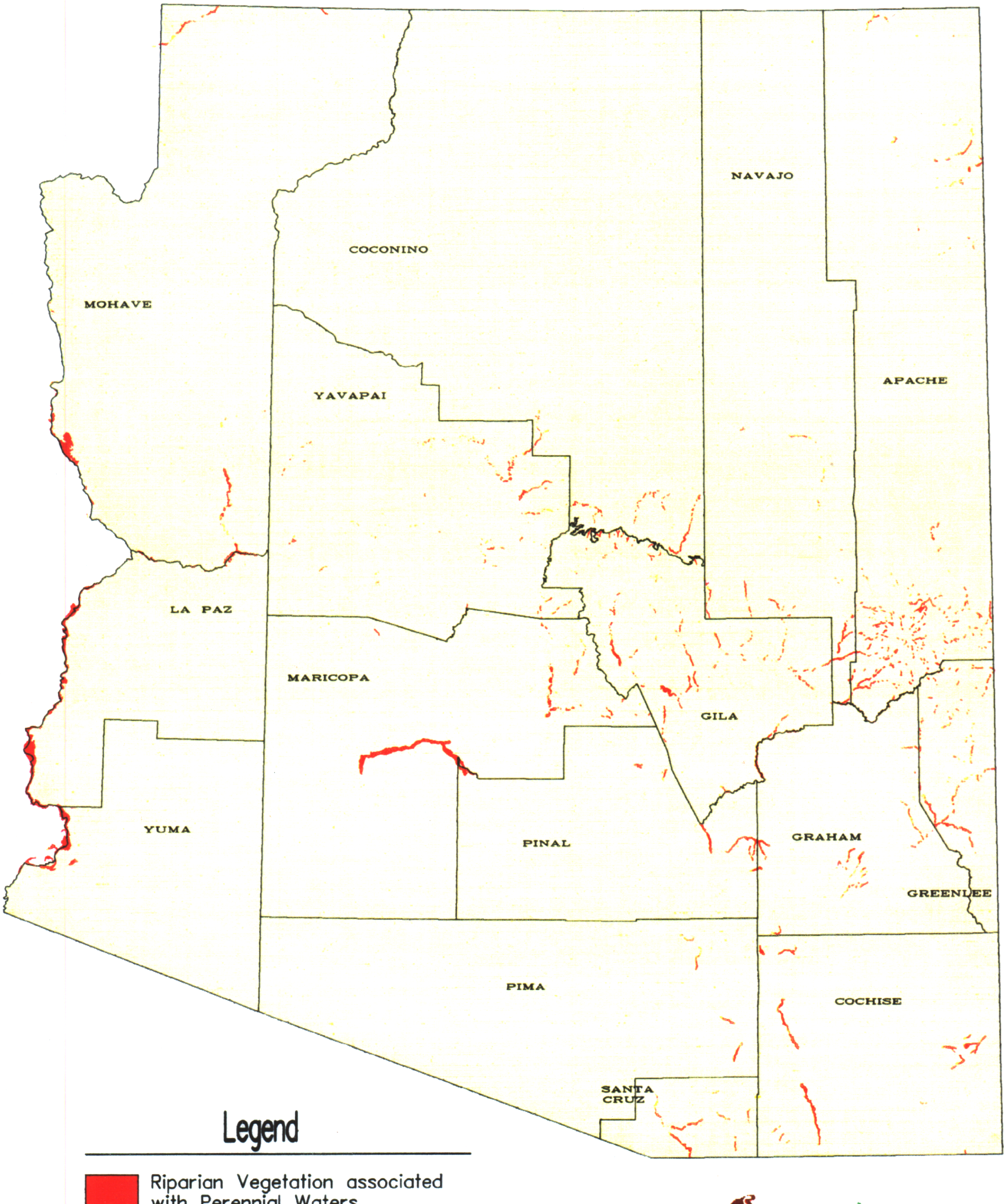
Based on the methods as described in this document, riparian vegetation associated with perennial streams comprises approximately 0.4% of the total land area of the state. Vegetation associated with most lakes and wetlands (marshes, cienegas) and with the excluded portions of the Colorado River are not represented in these numbers. **It should be noted that not all riparian vegetation, as defined by legislation was mapped during this first phase of the inventory.** A great deal of riparian vegetation is supported by intermittent waters in Arizona, but, these areas have not yet been inventoried. Figure 14 illustrates the fact that much of the riparian vegetation in Arizona is associated with intermittent waters. The maps represent a portion of the San Pedro River that alternates between perennial and intermittent flow, and the amount of riparian vegetation associated with each segment. (Intermittent segments of the San Pedro River were mapped to correspond with ADWR's case study area.) Although there are many factors affecting the amount of riparian vegetation at any one location, the maps help to illustrate the fact that the first phase of this inventory only covers a portion of the resource.

Table 6

Total miles of perennial streams inventoried	**4,628.95 miles**
Total miles of perennial streams identified	5,022.47 miles
Flow unregulated	3,961.26
Flow regulated	972.95
Effluent dominated	88.26

Riparian Vegetation

Associated with Perennial Waters in Arizona



Vegetation data generated at UofA ART Lab.

Figure 13.

Table 7. Miles of perennial waters by land ownership category*

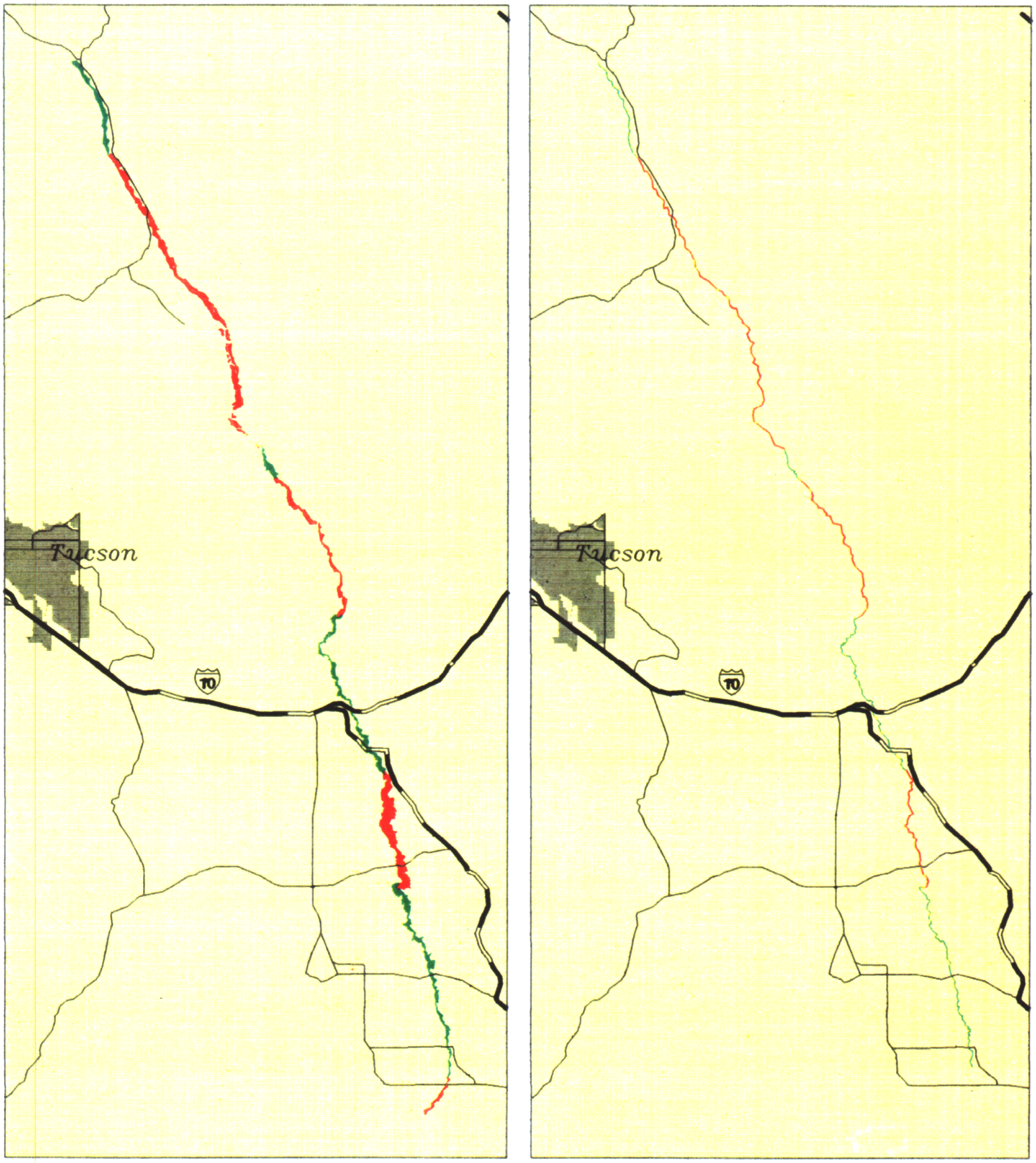
	Miles	Percent of Total Mapped
Total Federal	2,510.79	49.99
National Forests	1,573.50	31.33
National Parks	611.90	12.18
BLM	289.07	5.76
Wildlife Refuges	28.26	0.56
Military	8.06	0.16
Total State & Municipal	254.58	5.07
State trust/state sovereign	156.06	3.11
State & municipal parks	82.40	1.64
AGFD lands	16.12	0.32
Total Private	856.67	17.06
Total Tribal	1,408.80	28.05

**NOTE: These figures exceed 100% of the total miles of perennial streams because there are instances where landownership is different on each bank of a given length of stream. In those cases, stream mileage is included in both landownership categories.*

As previously discussed, riparian vegetation maps can be produced at a variety of scales. At a statewide scale it is impossible to show the detail contained on these maps. Therefore, several maps were produced at a larger scale to give a better indication of the mapping resolution. Riparian areas at three different locations are presented to illustrate various riparian vegetation community types found in the state. Cave Creek in the Chiricahua Mountains (Figure 15) represents a mountain stream, with elevation ranging from 7600 to 4700 feet above sea level. A segment of the upper San Pedro River (Figure 16) represents a large unregulated river system at an elevation of approximately 4000 ft. A portion of the Colorado River south of Lake Havasu (Figure 17) represents a regulated river at low elevations, approximately 500 ft. msl.

San Pedro River Vegetation Comparison

Vegetation | Water Course

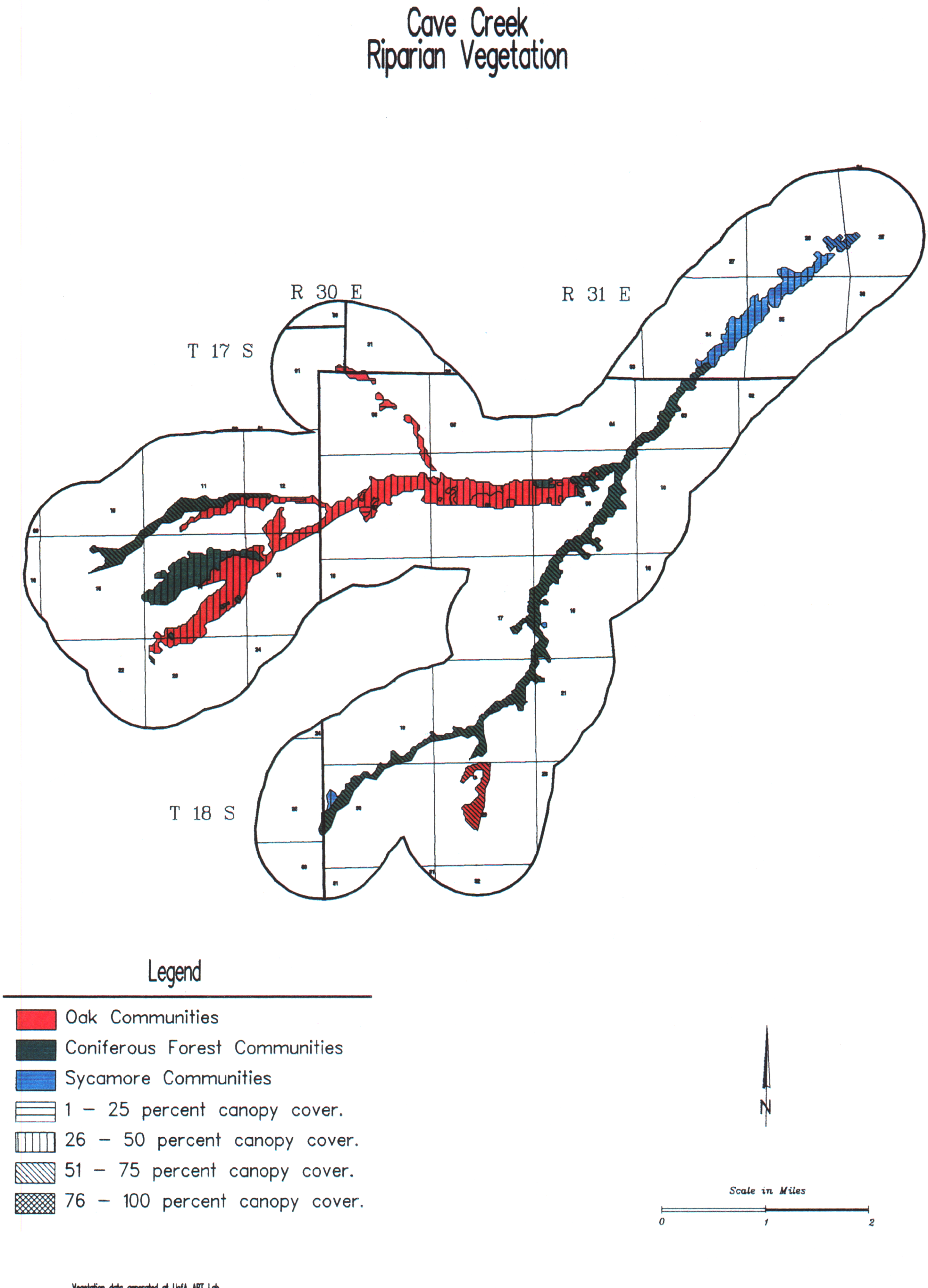


Vegetation associated with perennial streams = 12,238 acres.
Vegetation associated with intermittent streams = 19,159 acres.
Perennial Segments = 66 Miles.
Intermittent Segments = 80 Miles.

N

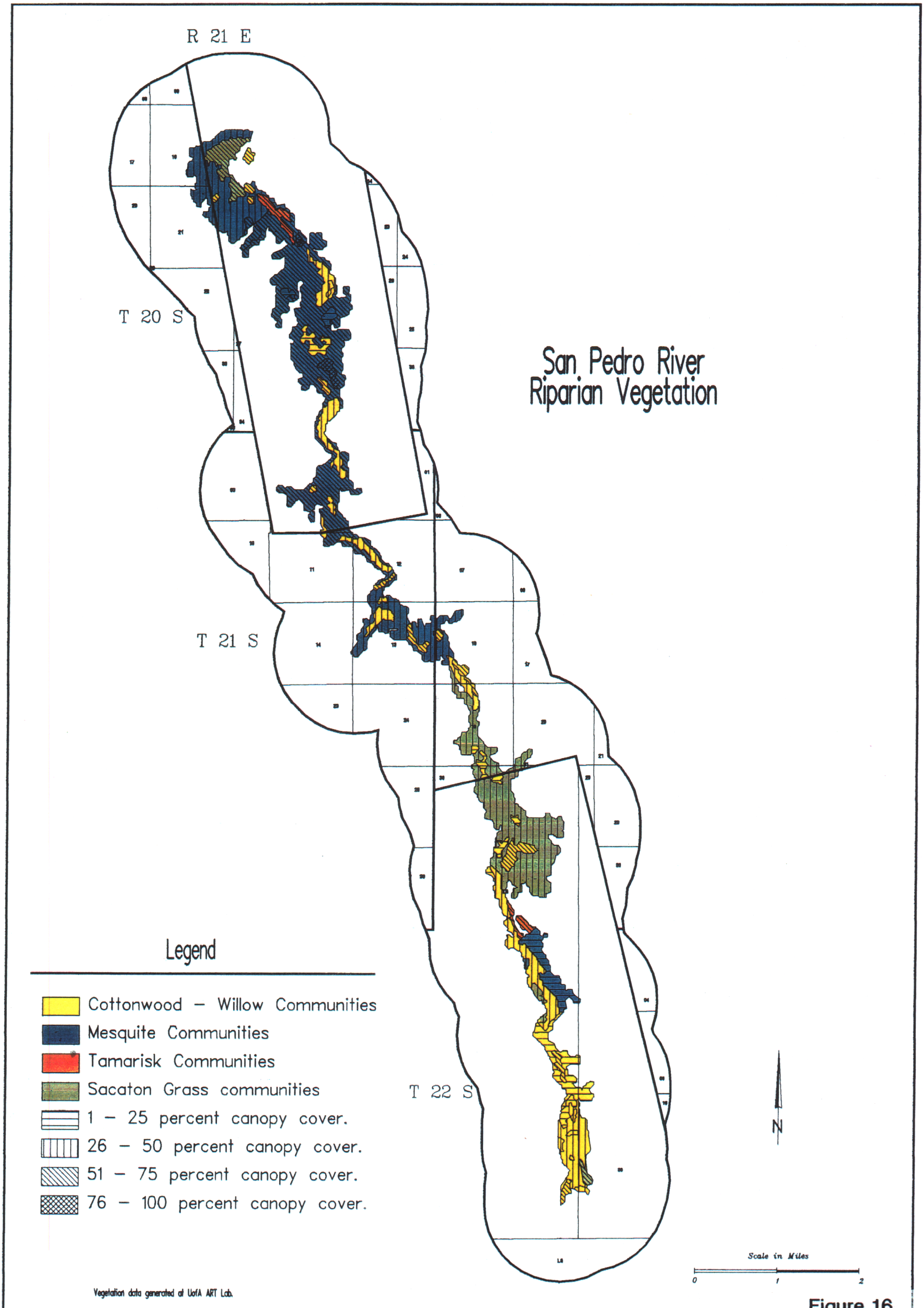
Figure 14.

Vegetation data generated at UofA ART Lab.



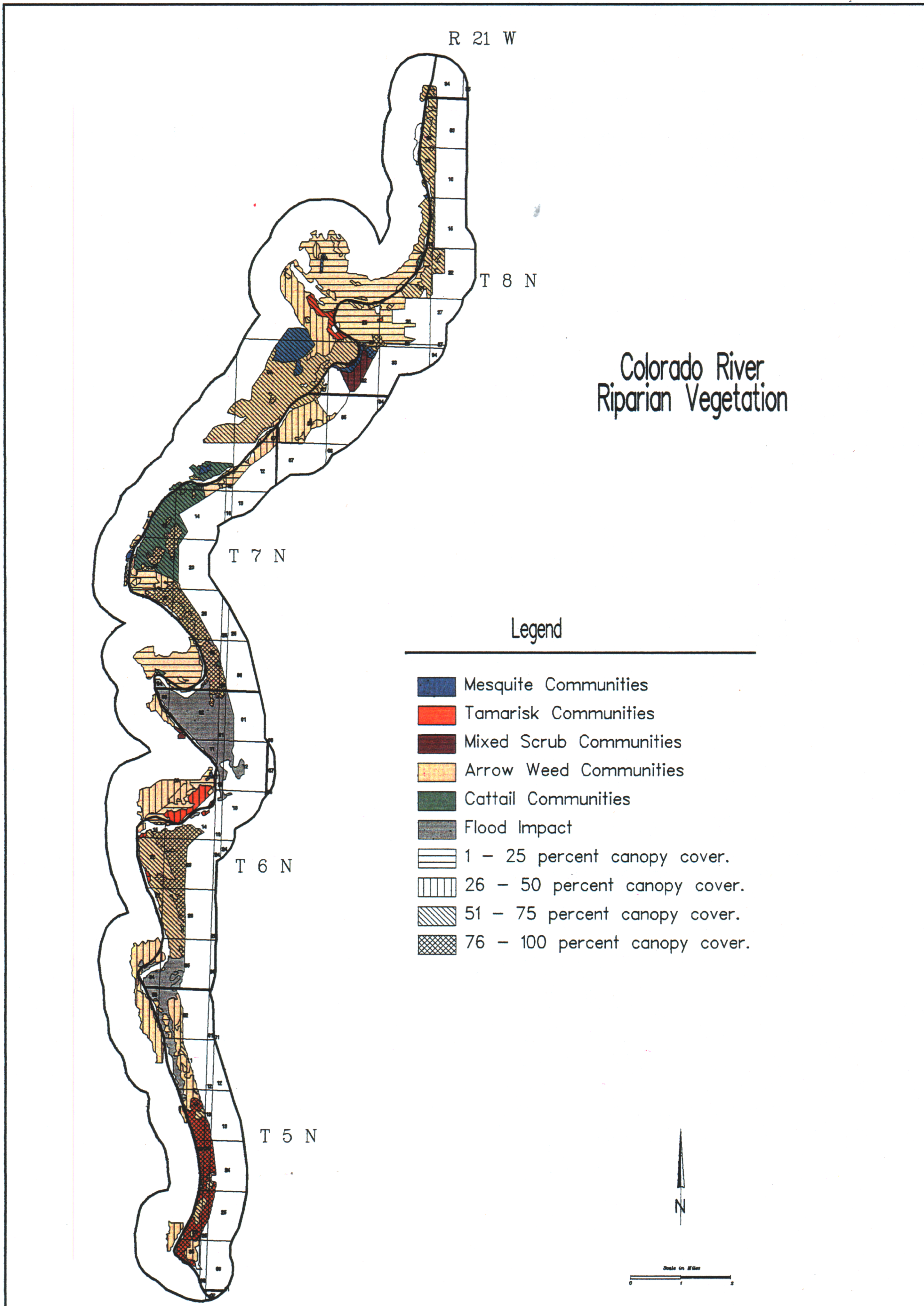
Cave Creek
Riparian Vegetation
R 30 E
R 31 E
T 17 S
T 18 S
Legend
Oak Communities
Coniferous Forest Communities
Sycamore Communities
1 – 25 percent canopy cover.
26 – 50 percent canopy cover.
51 – 75 percent canopy cover.
76 – 100 percent canopy cover.
N
Scale in Miles
0
1
2
Vegetation data generated at UofA ART Lab.

Figure 15.



R 21 E
T 20 S
T 21 S
T 22 S
San Pedro River
Riparian Vegetation
Legend
Cottonwood – Willow Communities
Mesquite Communities
Tamarisk Communities
Sacaton Grass communities
1 – 25 percent canopy cover.
26 – 50 percent canopy cover.
51 – 75 percent canopy cover.
76 – 100 percent canopy cover.
N
Scale in Miles
0
1
2
Vegetation data generated at UofA ART Lab.

Figure 16.



R 21 W
T 8 N
T 7 N
T 6 N
T 5 N
Colorado River
Riparian Vegetation
Legend
Mesquite Communities
Tamarisk Communities
Mixed Scrub Communities
Arrow Weed Communities
Cattail Communities
Flood Impact
1 – 25 percent canopy cover.
26 – 50 percent canopy cover.
51 – 75 percent canopy cover.
76 – 100 percent canopy cover.
N
Vegetation data generated at UofA ART Lab.

Figure 17.

Table 8. Relative amounts of riparian vegetation communities associated with perennial waters in Arizona.

Total acres of riparian vegetation associated with perennial waters as inventoried by AGFD in 1992-1993: 266,786.39 acres

Vegetation Community	Percent	Vegetation Community	Percent
Tamarisk	20.3	Russian olive	<1.0
Mesquite	17.5	Reed	<1.0
Arrowweed	14.8	Sacaton grass	<1.0
Conifer	11.2	Mixed canyon scrub	<0.5
Mountain meadow	6.3	Acacia	<0.5
Oak	4.4	Desert willow	<0.5
Cottonwood-willow	4.2	Mexican elder	<0.5
Mixed scrub	3.0		
Cattail	2.1	Flood scoured*	7.4
Sycamore	1.2	Unlabelled**	5.4

* *Vegetated according to satellite data, but scoured by winter flooding before classification with videography.*

** *Not classified due to lack of videography coverage.*

This inventory revealed seventeen (17) riparian vegetation community types (series level), and approximately 85 vegetation associations in Arizona. Accuracy on vegetation data is still being verified and should be completed by June 1994. Conversion of vegetation classes to the Brown, Lowe and Pase (1979) system is currently underway. Table 8 shows riparian vegetation community types as a percentage of the total amount of riparian vegetation mapped during this phase of the inventory. Although the inventory is not complete, these percentages begin to give a picture of the relative amounts of the various riparian vegetation community types found in Arizona. More detailed data on vegetation classifications will be available from AGFD when all components have been verified.

Section III

Land Use and Land Ownership Maps

A. Introduction

General land ownership and land use maps for Arizona are presented in this section. As directed by the legislation, the land ownership map displays federal, state, private and tribal lands. Although the legislation did not specify land uses to be mapped, AGFD attempted to locate data sources for mapping the land use activities listed in the Waters - Riparian Protection Program law (Section 6, chapter 298, Laws 1992). In some cases, limitations on data availability restricted our ability to map land uses. In other instances, such as for recreational activities, it was difficult to delineate specific geographic areas where an activity was taking place That is, some activities can realistically occur almost anywhere.

Maps presented in this section are:

(1) Arizona Land Ownership
(2) Commercial Grazing Activities
(3) Commercial Wood Harvesting Activities
(4) Urban, Industrial and Agricultural Lands
(5) Public Recreation
(6) Current and Historical Mining Locations
(7) Active Mining Locations
(8) Sand and Gravel Mine Locations
(9) Mineral Potential

Accompanying each map is a brief description of what is depicted. Data sources, methods of verification, and limitations on use of the maps are discussed. If additional data or maps are expected to be completed in the near future, that information is also provided.

Specific land uses occurring on private and tribal lands could not be identified because no comprehensive data sets exist for these areas. Even though activities on these lands are not represented on maps, many of the land use activities presented here can potentially occur on them. Potential activities include recreational activities, development, agriculture, grazing, and timber or fuelwood cutting.

These maps display areas where various land use activities occur statewide. We felt it was important to map the entire state so that land use activities within the watershed could be analyzed in conjunction with those within the riparian area proper. At the end of this section, we address how the information can be analyzed within each riparian corridor. A series of maps are presented as examples of how GIS can assist in the analysis of land use impacts on riparian corridors.

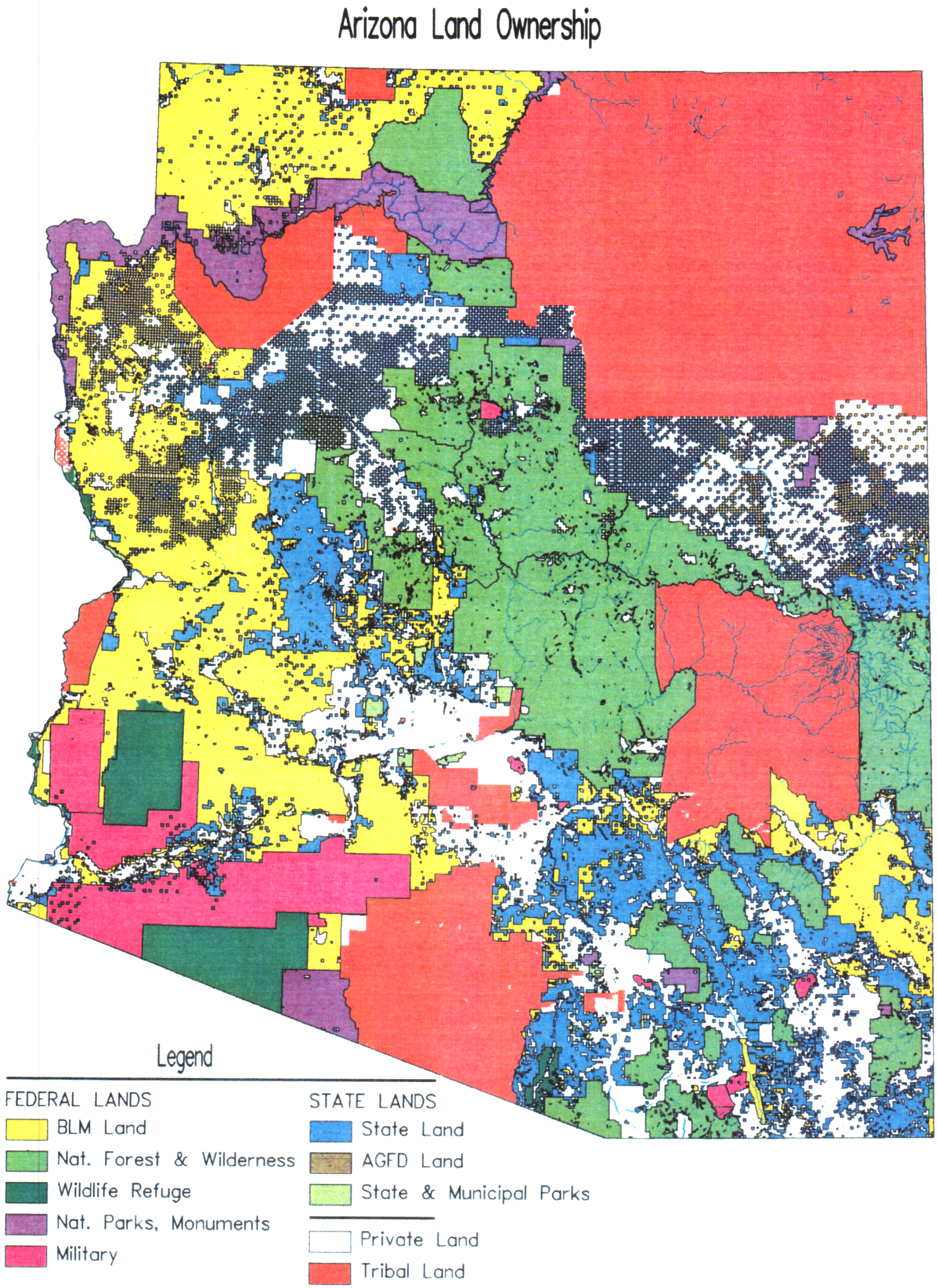
B. Arizona Land Ownership

The land ownership map presented in Figure 18 displays land ownership according to the following categories. Federally owned lands are differentiated by the land management agency responsible for the management of an area. These federal land managers include the BLM, USFS, military bases, national parks and monuments and national wildlife refuges. State owned lands include state trust lands and state sovereign lands managed by the ASLD, state wildlife areas managed by the AGFD, state park lands operated by the Arizona State Parks Board (ASPB), miscellaneous state owned lands and some municipal parks. All lands owned by Native American tribes are represented on this map under the category "tribal lands". The "private lands" category groups all lands under private ownership. Individual owners are not identified or delineated in this database.

Land ownership statistics were computed from the various land ownership databases and compiled at AGFD. Land acreages attributed to each ownership and management category are listed below:

	Acres		Acres
Federal	30,386,374	**State**	9,590,923
BLM	12,130,966	ASLD	9,388,373
USFS	11,238,805	State/Municipal Parks	178,087
National Parks	2,517,464	AGFD	24,463
Military	2,796,646	**Private**	13,448,643
Wildlife Refuges	1,702,493	**Tribal Lands**	19,685,226
		TOTAL ALL	73,111,166

Data Source:	1991-1992 "Land" Database contained in the Arizona Land Resource Information System (ALRIS) at the ASLD.
Verification Method:	Verification occurs at ALRIS on an annual basis. No additional verification was undertaken by AGFD.
Data Limitations:	Recent changes in land status may not be represented on this map. All federal land was last updated in 1991 except for USFS and Bureau of Indian Affairs lands which were updated in 1992. Arizona state lands were updated in 1991.



Arizona Land Ownership
Legend
FEDERAL LANDS
BLM Land
Nat. Forest & Wilderness
Wildlife Refuge
Nat. Parks, Monuments
Military
STATE LANDS
State Land
AGFD Land
State & Municipal Parks
Private Land
Tribal Land

Figure 18.

C. Commercial Grazing Activities

The map presented in Figure 19 displays public lands by current livestock grazing status. No comprehensive source of geographic data was found to exist for private and tribal lands. Therefore, they are represented under a category of "no data" on this map.

Because livestock grazing management practices and intensities vary so greatly, we approached the task of data collection by attempting to identify areas where livestock grazing is prohibited. In other words, areas mapped as "no grazing" are lands that have been specifically removed from consideration for grazing for the foreseeable future. Grazed areas are those lands available for livestock grazing, whether or not there was livestock grazing occurring on the land at the time these data were compiled. Grazed lands are not differentiated by livestock type, stocking rate or grazing system used on that land.

In general, livestock grazing occurs on USFS, BLM and ASLD lands. National Park Service, ASPB, U.S. Fish and Wildlife Service refuges, and U.S. military bases reported no livestock grazing activities occurring on their lands. With only a few exceptions, AGFD lands are not grazed. All grazing information was collected at a point in time and may vary from what may occur in the future. Public lands management practices are especially subject to change to meet management goals.

Although USFS and BLM have established allotment boundaries, they are not in digital form. Therefore, they were not used to delineate areas on this map. Past experience at digitizing allotment boundaries has shown large boundary discrepancies between land management areas. These discrepancies made digitizing the boundaries impossible for this report.

A few small areas along the Gila River were coded to the "no grazing" category because they have historically not been used for grazing. However, according to agency representatives, these areas will be opened to grazing upon request if the proposed activity meets the management objectives of the administering agency. These areas could potentially add 118,208 acres of land to the "commercial grazing" category and remove the same amount from the "no commercial grazing" category.

Listed below are acreages for each category represented on the map and the number of perennial stream miles that intersect lands in each category.

	Acres	Perennial Stream Miles
Commercial grazing	31,021,328	1,729
No commercial grazing	9,051,411	1,082
No data (private and tribal)	33,038,427	2,211

Data Source:	Grazing activities were investigated according to general land management or ownership categories, as discussed under the Land Ownership Map. Primary sources of information came from ASLD, USFS, and BLM. AGFD, National Park Service (NPS), ASPB, and the U.S. Military also provided information regarding their lands. The map was generated from allotment boundary maps, USFS and BLM management plans, ASLD digital data files and additional written and verbal information obtained from range and land-use planners in each agency.
Verification Methods:	Each major land ownership was broken up into areas of management responsibility. Data collected from the above sources were mapped and verified through personal contact with land managers. After verifying with agencies involved, data were refined and updated.
Data Limitations:	Due to the minimum mapping unit, graphic display overestimates ASLD grazed areas in some locations. In other areas, recent land status changes result in an overall under-estimation of ASLD grazed lands. However, grazing statistics are based on actual data as compiled by ASLD as of June 1993. No comprehensive source of geographic data was found for activities on private lands and tribal lands.

Commercial Grazing Activities

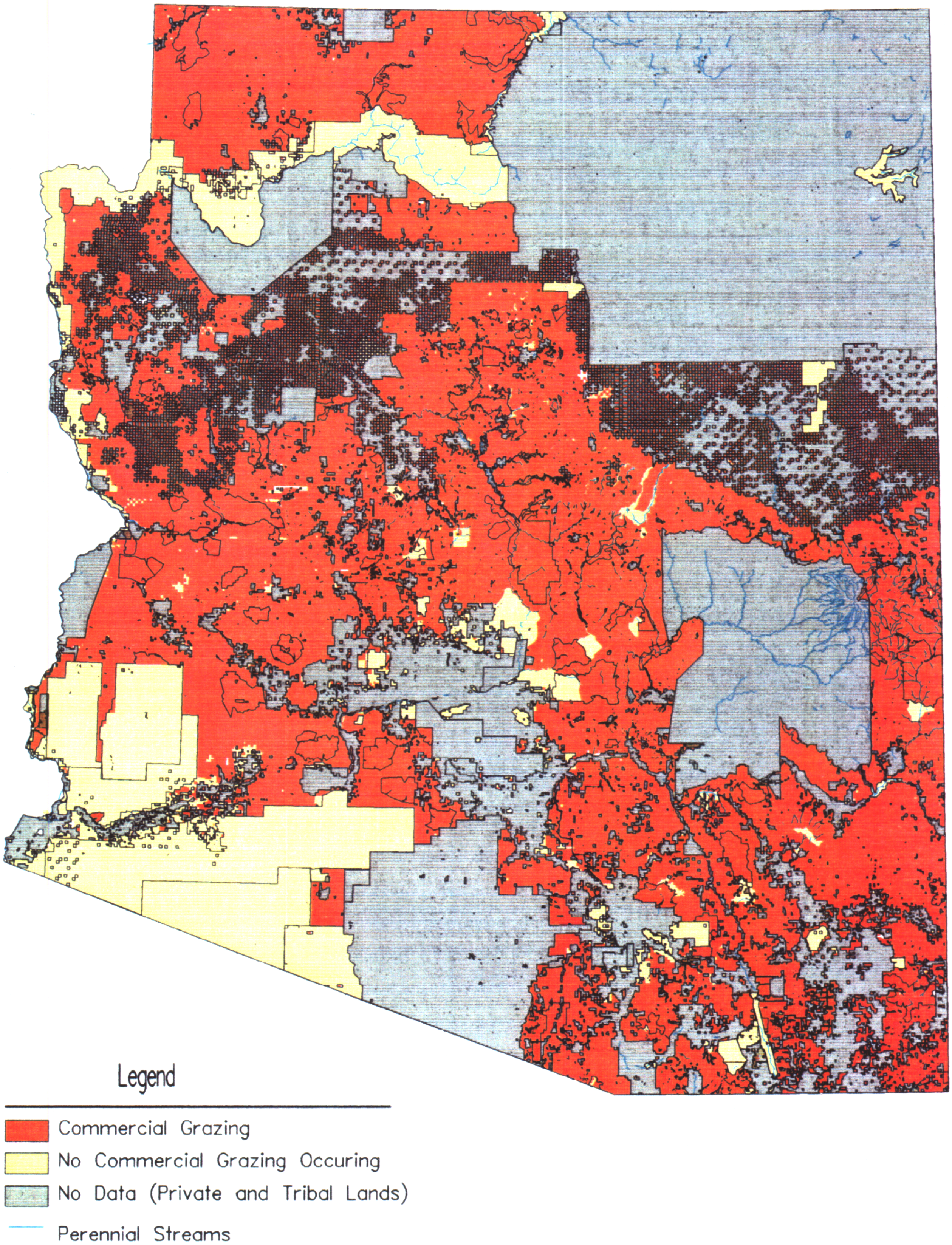


Figure 19.

D. Commercial Wood Harvesting Activities

The map presented in Figure 20 displays areas that are open to timber or fuelwood harvesting on public lands. Again, no comprehensive geographic data exists for activities on private and tribal lands.

The identification of timber and fuelwood harvesting areas was based on the potential for the activity to occur at a given location. That is, any area which may potentially host this activity was classified as a harvesting area. Some areas included in the "open to harvest" category are not currently active but are scheduled for future harvesting.

Much of the area shown as "no harvest" is actually unsuitable for timber harvesting (i.e., desert scrublands). Due to the minimum mapping unit, some of the areas delineated as open to harvesting have small inclusions of unsuitable area. These unsuitable areas are primarily a factor of slope and are fairly minor in extent. Some unreported fuelwood harvesting may be occurring on lands identified as "no harvest" areas.

Timber harvesting occurs primarily on USFS lands. Although, the ASLD has no land specifically closed to timber harvesting, they have only issued permits for timber harvesting on a few tracts of land near Flagstaff. Since there were no additional records of harvesting activities in the ASLD database, all other ASLD lands are shown as "no harvest."

All areas are subject to changes in agency management goals. All areas mapped have restrictions and limitations addressing harvest methods and allowable cut. Refinements such as these are not represented on this map or in an associated database. Riparian areas are not exempt from harvest, but normally riparian corridors are delineated as zones requiring harvest prescriptions different from those of adjacent uplands. Typically, these are more restrictive and harvests are used as "enhancement" of riparian areas. Land management agencies also have the prerogative to cut timber in areas currently closed to timber harvesting for emergency management purposes, such as disease control, and fire management. National forests have detailed forest stand information. Please refer to the agency management plans for more detail.

Listed below are acreages for each category represented on the map and the number of perennial stream miles that intersect lands in each category.

	Acres	Perennial Stream Miles
Open to commercial wood harvesting	8,056,906	901
Commercial wood harvesting not occurring	32,015,477	1,919
No data (private and tribal lands)	33,038,783	2,211

Data Source:	Timber harvesting activities were investigated according to general land management or ownership categories, as discussed under the Land Ownership Map. Primary sources of information came from ASLD, USFS, and BLM. AGFD, NPS, ASPB, and the U.S. Military also provided information regarding their lands. Data was collected using BLM and USFS management plans, timber allotment boundaries, written and verbal information.
Verification Methods:	Each category of land ownership was divided into areas of management responsibility. Data collected from the above sources were mapped and verified through personal contact with land managers. After verifying with agencies involved, data was refined and updated.
Data Limitations:	Due to the minimum mapping unit, some unsuitable lands are included within harvested areas. There is no representation of activities on private and tribal lands.

Commercial Wood Harvesting Activities

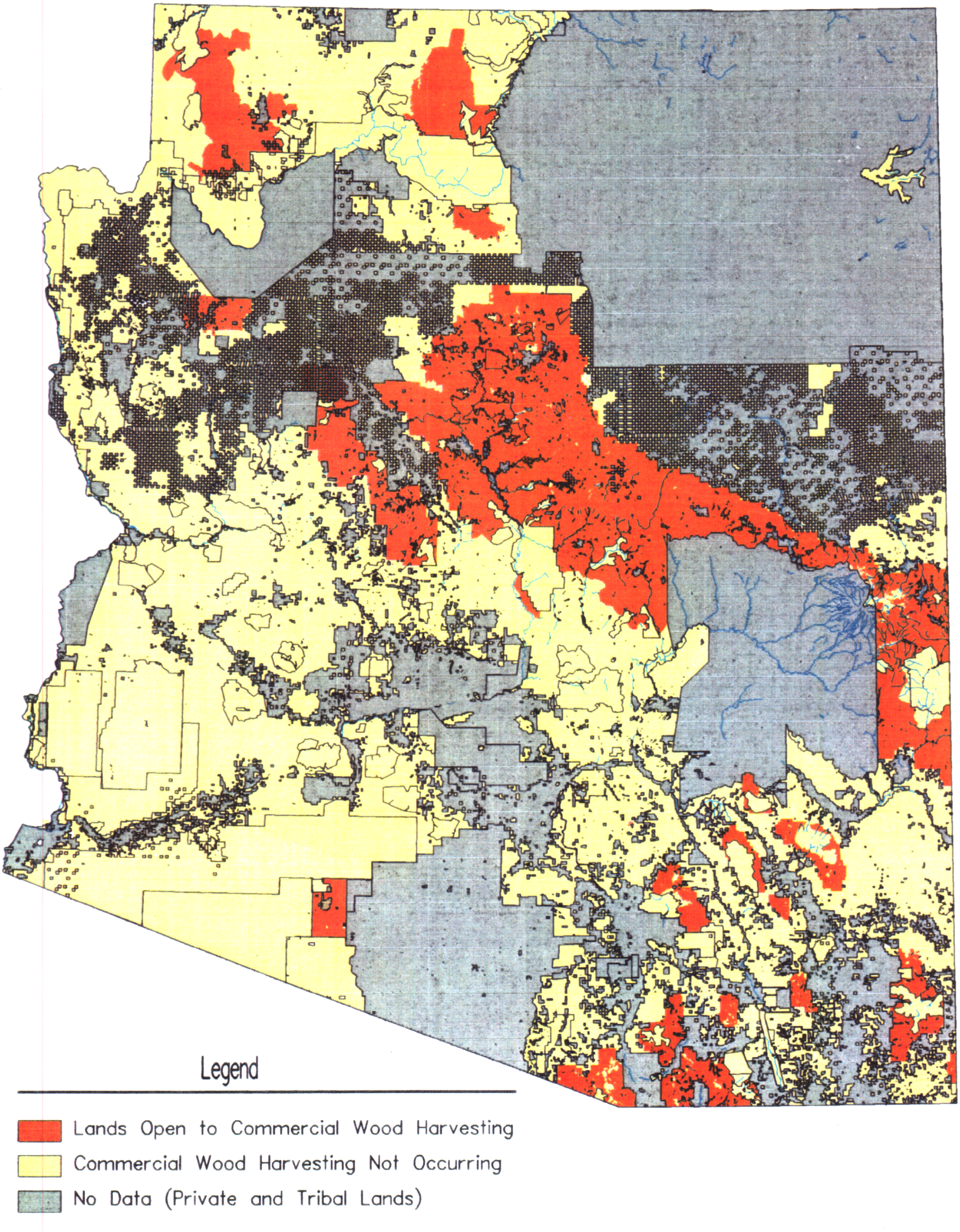


Figure 20.

E. Urban, Industrial and Agricultural Lands

The map presented in Figure 21 displays urban, industrial, agricultural and mixed land uses. The mixed land use category is applied to areas where a combination of the other three land uses occur in such close proximity that individual uses are difficult to distinguish. The urban lands category represents all populated areas in the state as identified by 1990 census data. This includes cities, small towns, villages, etc., and represents 2,728,273 acres. Urban areas overlap areas represented as mixed land use because the data sets are contained in two separate databases. Of the 1,099,185 acres of mixed land use, 648,722 acres overlap with urban areas on the map. Where there is no overlap between urban and mixed categories, the mixed category is displayed. Industrial, mixed use and agricultural lands were identified and delineated from false color composite satellite imagery.

Listed below are acreage for each category represented on the map and the number of perennial stream miles that intersect lands in each category.

	Acres	Perennial Stream Miles
Urban	2,728,273	297
Agricultural	1,568,855	63
Mixed Use	1,099,185	88
Industrial	118,593	9

Data Source:	Urban lands were compiled from the ASLD (ALRIS) "Azplaces" database. This database consists of census designated place boundaries for the state. The data were extracted from 1990 U.S. Census Bureau Tiger files. All other categories were derived from the UA-ART "AzGap" database. This database was generated using false color composite satellite imagery from 1991 and 1992.
Verification Method:	"Azplaces" was verified at the ASLD (ALRIS) through normal quality control procedures following the creation of the database. "AzGap" will be verified by UA-ART upon completion of the Arizona GAP Analysis Project (expected completion date, June 1994).
Data Limitations:	The "Azplace" database was created from 1990 data, so it does not represent changes that may have occurred since then. The "Azgap" database has a similar limitation in that it was created from 1991-1992 satellite imagery. Satellite imagery resolution is 31.4 yds. x 31.4 yds., thus limiting the accuracy of data at smaller resolutions.

Urban, Industrial, and Agricultural Lands

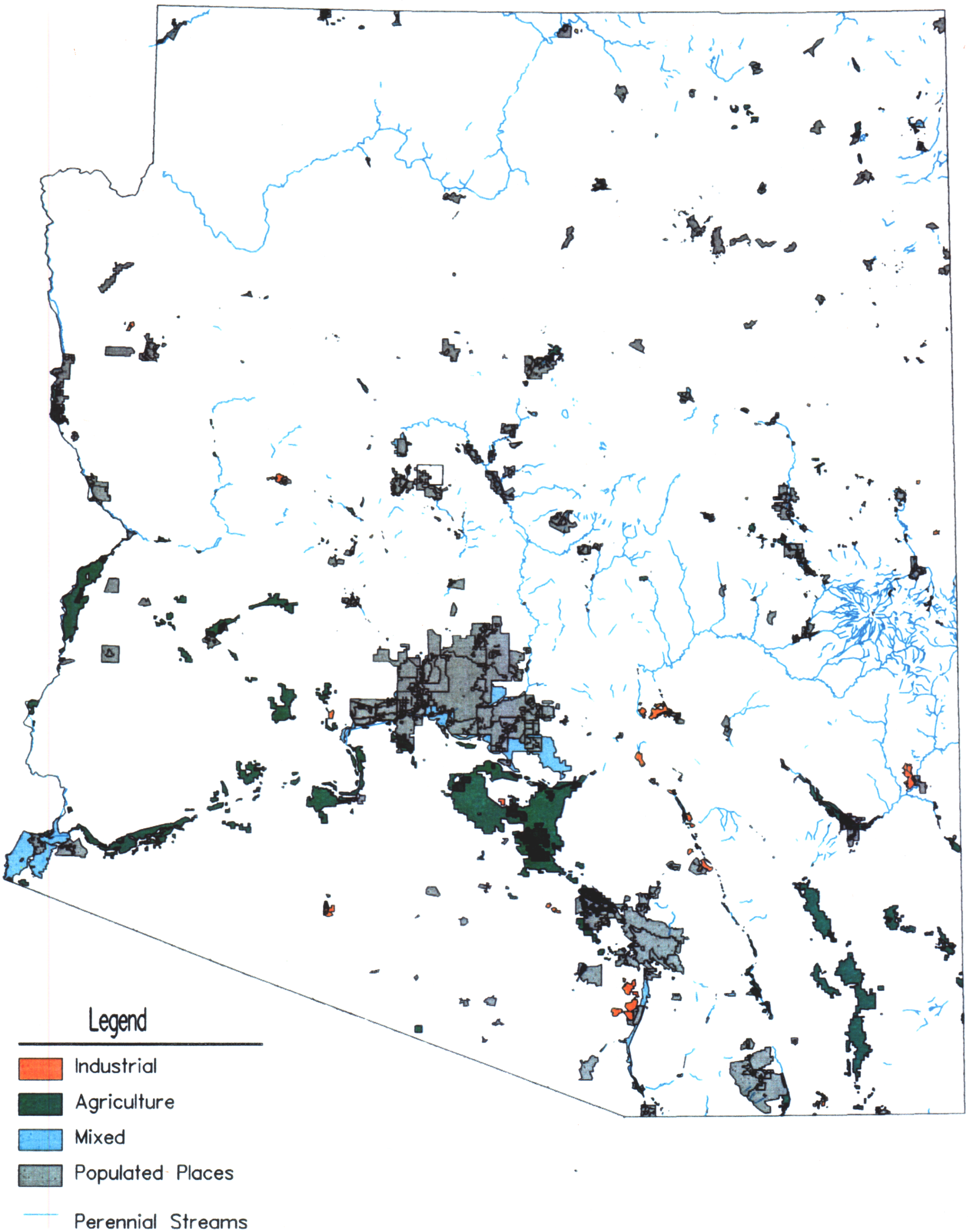


Figure 21.

F. Public Recreation

Recreational activities, such as hiking, birdwatching, hunting, fishing, camping, ATV riding, and horseback riding, tend to be dispersed over broad geographic areas. Because they are not associated with specific locations, they do not adapt well to mapping. In addition, there is no comprehensive source of locational data on this topic, especially activities occurring on private lands.

Therefore, the map presented in Figure 22 represents recreational areas in the state that the general public can access and that can be geographically referenced. These include developed campgrounds and picnic sites on public and tribal lands, state and municipal parks, wildlife refuges, wilderness areas, national parks, national forests and BLM lands. Recreational lakes are also shown.

Lands under the management of ASLD are available for various land use activities but are accessible by permit only. State lands are not openly accessible for recreational activities so they are not represented on this map. However, we acknowledge that these lands are regularly used for hunting and fishing. Properly licensed hunters and anglers lawfully taking wildlife on state lands are considered permittees.

The information is presented on the map in two ways. First, developed recreation sites, such as public campgrounds and picnic areas, are indicated by point locations. A point location does not show the actual physical boundaries of an area and is simply indicated by a single point. A total of 352 point locations of recreational sites are represented on the map. All other categories (parks, refuges, wilderness areas, national forests, and lakes) are represented by actual geographic boundaries.

Data Source:	National parks, monuments, historical sites, and state parks were extracted from the ALRIS "Land" database. State parks not represented in the "Land" database were digitized from ASPB maps into a separate database by AGFD staff. Point locations were digitized from the 1992 Western Geographic "Topographical Recreational Map of Arizona."
Verification Method:	State parks missing from the ALRIS "Land" database were located and verified with the assistance of ASPB staff. Point locations of recreational sites were verified against USFS 1:62,500 scale maps and USGS 7.5 minute quadrangle maps to insure locational accuracy by AGFD staff.
Data Limitations:	This map represents only a portion of the locations where recreational activity occurs in the state.

Public Recreation

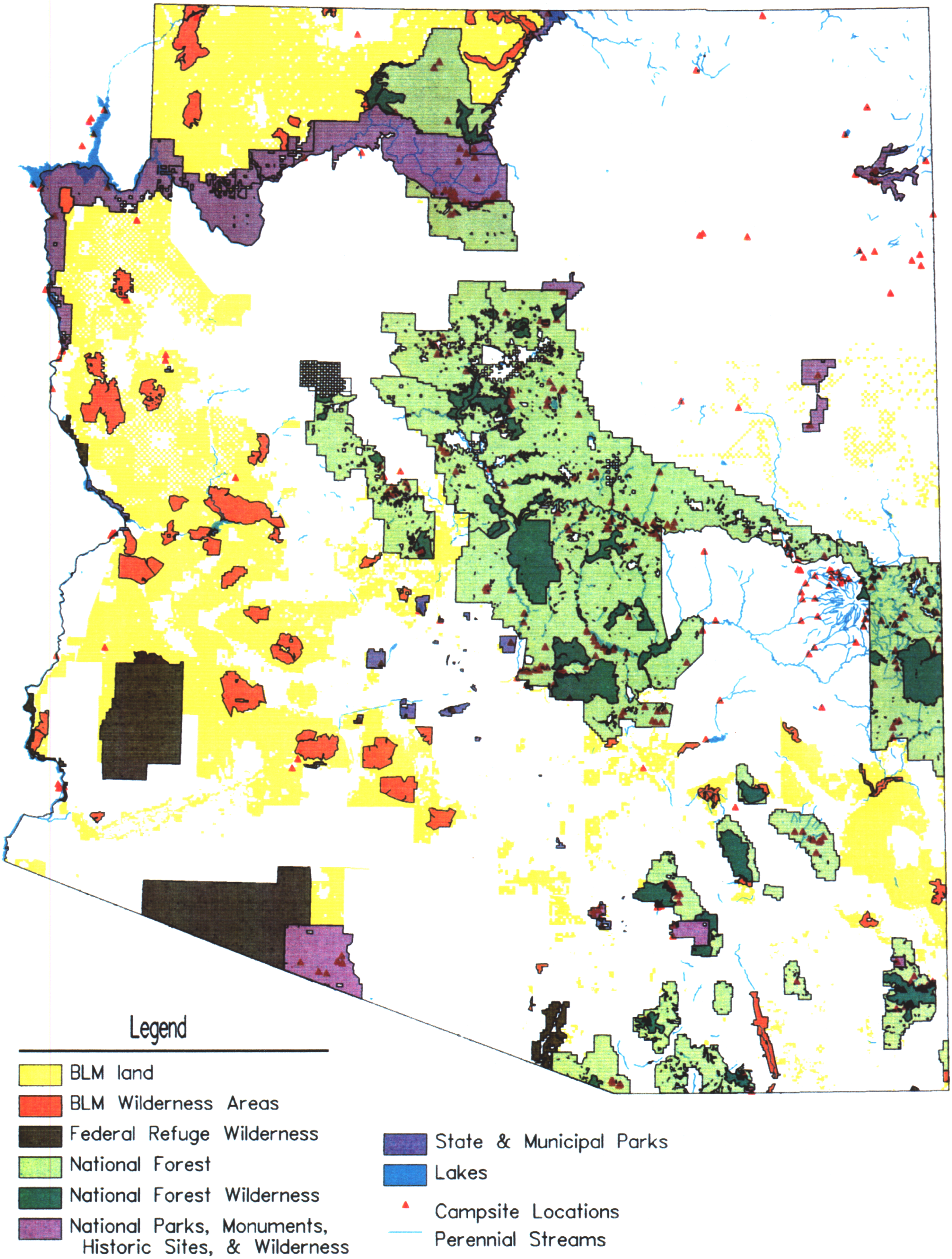


Figure 22.

G. Current and Historical Mining Locations

Figure 23 displays current and historical mining sites in Arizona. These sites represent locations of mines, prospects, quarries, processing mills and plants. As of August 1993, 10,341 mining sites were recorded in Arizona. Current and historical status have not been differentiated on this map because the accuracy of this information was found to be variable in the source data. The accompanying database contains the following information for each location: primary mine name; mineral extracted; and status of the mine (producer, past producer, current producer).

Data Source:	"AzMILS" database from the Arizona Department of Mines and Mineral Resources (ADMMR). The database acronym stands for Arizona Mineral Industry Location System. The database file was converted from Dbase to an Arc/Info format at AGFD.
Verification Method:	This database is updated and verified by the ADMMR on a continuous basis.
Data Limitations:	Accuracy of descriptive data may vary and should be verified with ADMMR.

Current & Historical Mining Locations

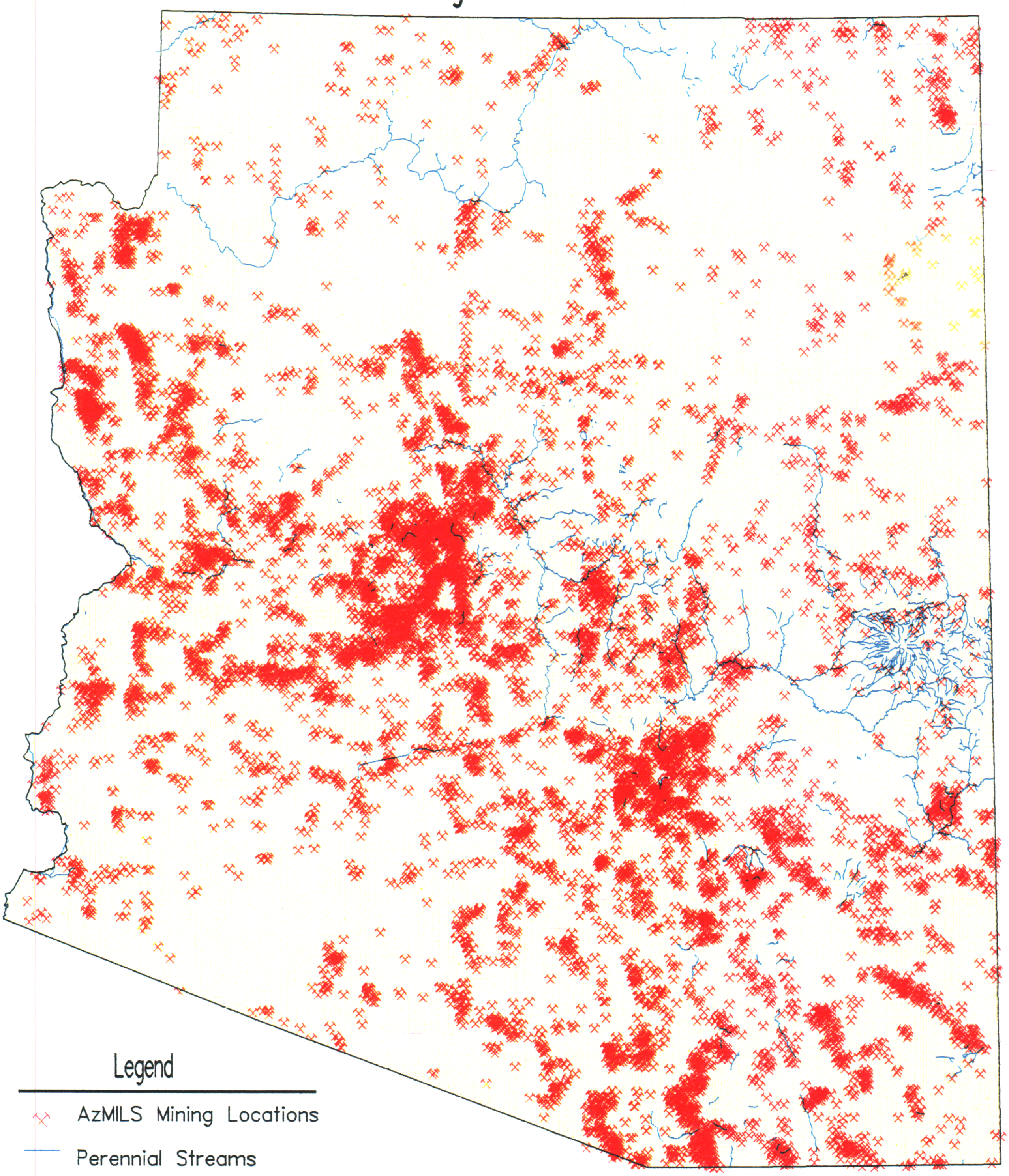


Figure 23.

H. Active Mining Locations

The map presented in Figure 24 displays point locations for all metal and nonmetal mines and processing plants that were active in Arizona as of November 1992. A total of 103 mining locations is recorded on the map. Active mine data were compiled from current records by the ADMMR. The ADMMR database lists the primary name used for the mine and the owner. The "Directory of Active Mines in Arizona," a publication prepared by ADMMR, contains detailed information on these mines such as the type of minerals extracted, amount extracted, and the type of mining process used at the site.

Data Source:	ADMMR, current records in the "Directory of Active Mines in Arizona 1993." AGFD staff digitized the data from a 1:1,000,000 scale hard copy map.
Verification Method:	The map and database were verified by the ADMMR. The database is updated on an annual basis.
Data Limitations:	A new map will be available after November 1993 at which time this map will be out of date.

Active Mining Locations

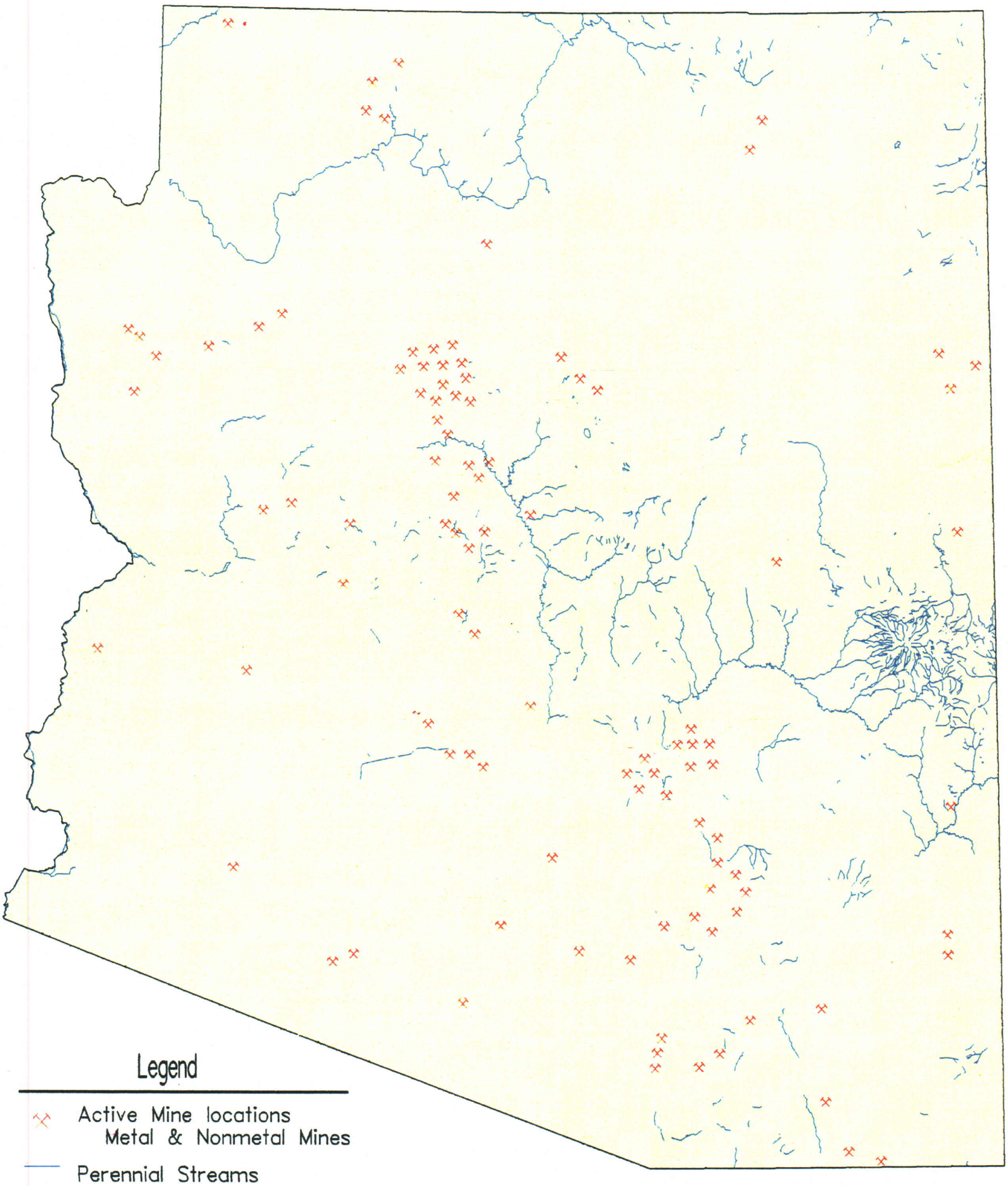


Figure 24.

I. Sand and Gravel Mine Locations

The map presented in Figure 25 is a subset of mine locations from the AzMILS at ADMMR. The mine locations shown on this map represent all mines coded as sand and gravel in the AzMILS database as of August 1993. A total of 582 mining locations are represented on the map. The map does not differentiate current and historical status of the sites depicted because the accuracy of this data was found to be variable in the data source.

The sand and gravel mining locations shown are not to be considered inclusive of all locations for this activity in the state. In 1994, ADMMR plans to have a database of active sand and gravel mine locations in Arizona, similar to the Active Mines database shown in Figure 24.

Data Source:	Sand and gravel mining sites were extracted from the "AzMILS" database at ADMMR.
Verification Method:	This database is updated and verified by the ADMMR on a continuous basis.
Data Limitations:	Due to inaccuracies in the "status" field, current and historical sites cannot be accurately differentiated. The map represents data as of August 1993.

Sand & Gravel Mine Locations

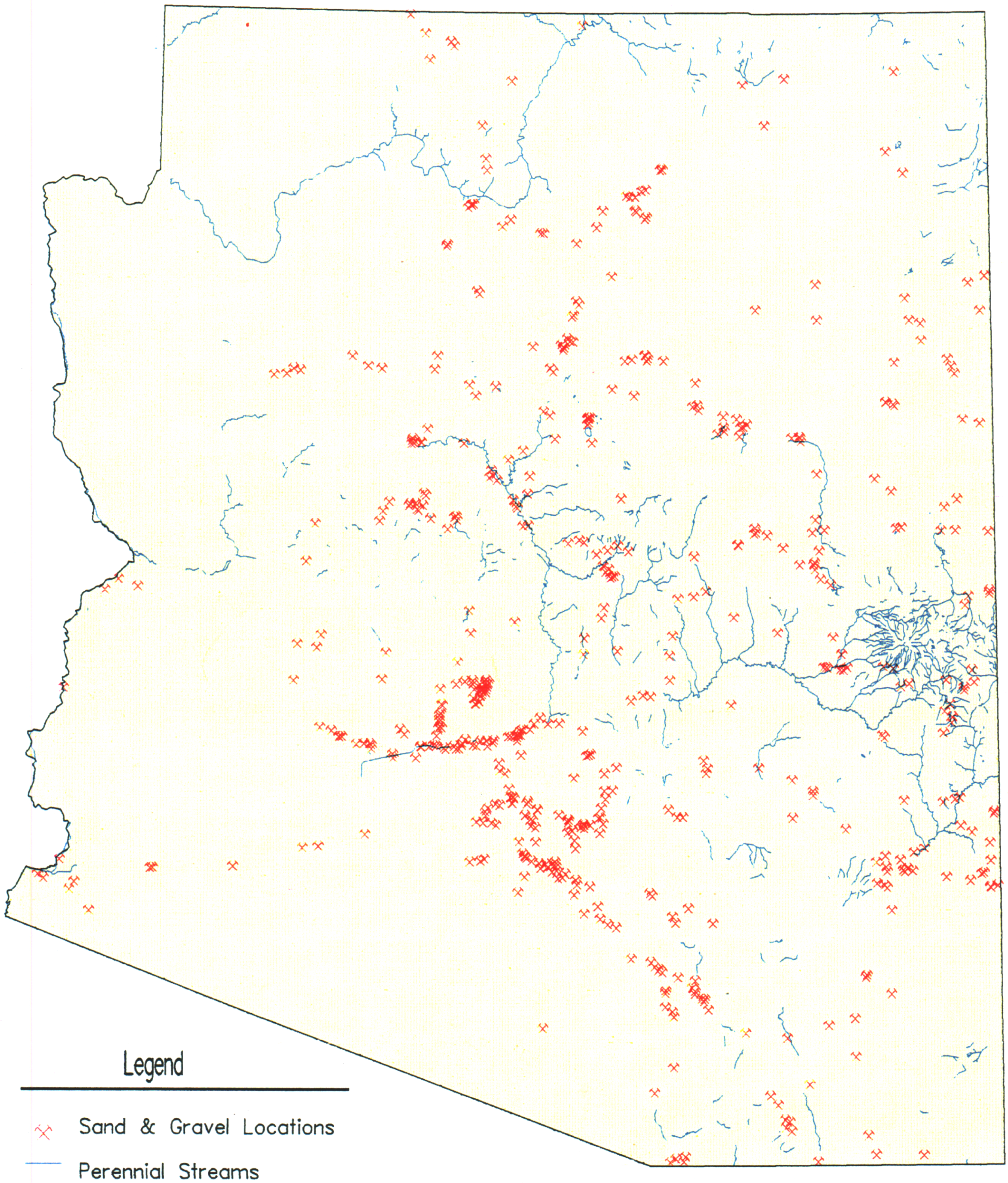


Figure 25.

J. Mineral Potential

The map presented in Figure 26 identifies potential areas for mineral discovery and development for both metallic and nonmetallic resources across the state. This data indicate areas favorable for future discovery and development of mineral deposits for land use planning considerations.

The determination of "highly favorable" or "favorable" status for the discovery of mineral deposits is based on data from past production of mineral districts, ADMMR file data, polling of the mineral exploration industry and compilation of exploration targets. Past production represents additional areas of past metallic mineral production. Low potential areas are estimated to have relatively less potential for metallic-nonmetallic mineral deposits based on available data as of October 1984.

Listed below are acreage for each category represented on the map and the number of perennial stream miles that intersect lands in each category.

	Acres	Perennial Stream Miles
Highly Favorable	2,625,757	173
Favorable	14,775,563	868
Past Production	445,777	9
Low Potential	55,086,045	3,972

Data Source:	The data were compiled by ADMMR in 1984 and digitized from a 1:500,000 scale blueprint by AGFD staff.
Verification Method:	The map was verified in 1984 by the ADMMR.
Data Limitations:	The database does not include areas for potential uranium development.

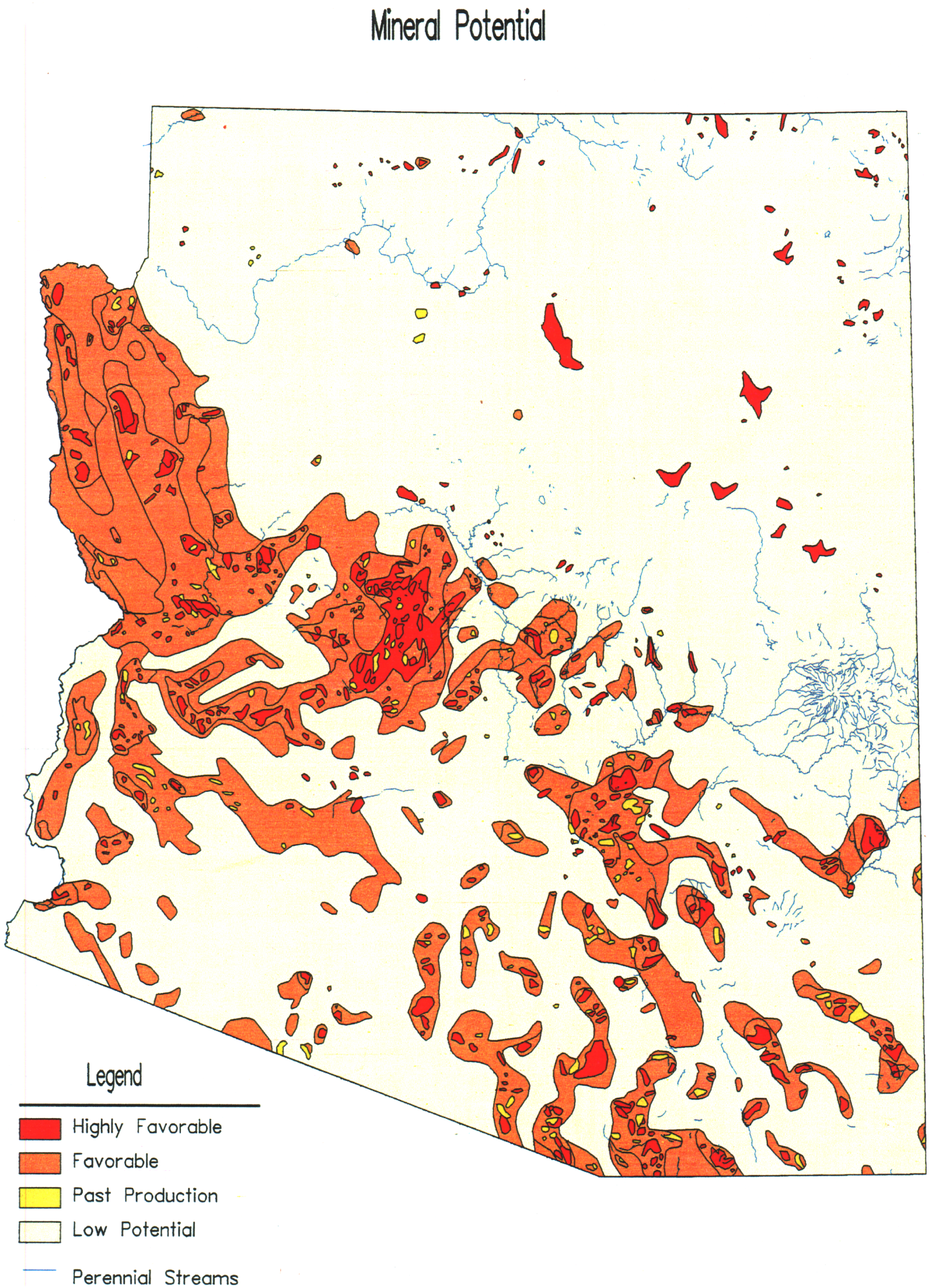

Mineral Potential
Legend
Highly Favorable
Favorable
Past Production
Low Potential
Perennial Streams

Figure 26.

K. Examples of Map Applications

The purpose of compiling land ownership and land use data was to identify activities occurring in and adjacent to riparian areas across the state. Several examples are presented in this section to illustrate the application of these data to evaluate land use influences on a riparian area (Figures 27 and 28). A portion of the Verde River was selected and the various GIS land use and land ownership maps were overlaid on the riparian vegetation map. This section of the Verde River was chosen because all the mapped land use activities occur to some extent within this region and could, therefore, be illustrated.

The first map (Figure 27a) shows riparian vegetation and land ownership along the Verde River from Clarkdale to Camp Verde. Private lands predominate along the river except for some State Parks lands and minor amounts of USFS lands. In the second map (Figure 27b), urban, industrial, agricultural and mixed land use patterns are identified within the corridor. Most of this area is identified as mixed land use because of the patchwork of residential/industrial development and agricultural fields. The majority of the agricultural fields in this region are included in the mixed land use area. Two of the five agricultural fields shown are within the State Park boundaries.

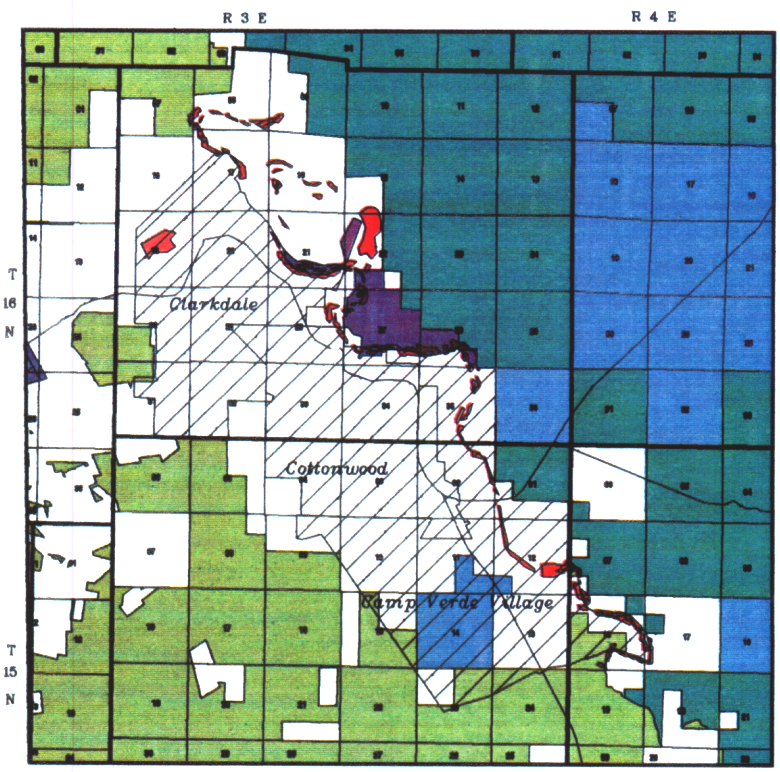
The first map in Figure 28a is a compilation of grazing, timber and mining activities in the same corridor. Mine locations are represented by point data and are not delineated by geographic extent. However, the industrial and mine tailings category on the previous page indicates geographic extent of some of the mining activities in the area. Most of the wood harvesting in this area is for fuelwood cutting, because the vegetation is not suitable for commercial logging. The lack of data for private lands is especially notable in this region.

Parks, recreation and special management areas are shown on the second map in Figure 28b. Dead Horse Ranch State Park and the Verde Greenway are indicated on the map. Some small municipal parks are not included in this database and, therefore, are not shown on the map. Under wildlife management areas, we added Tavasci Marsh, portions of which are currently being managed by the AGFD through an agreement with the private landowner. We also added a Research Natural Area which is under special management by the USFS.

These maps were produced at a scale which shows the various land uses and land ownership patterns affecting a rather large portion of the Verde River. Maps of finer resolution can be produced to conduct a more detailed evaluation of an area. However, when working with these statewide databases, data limitations as outlined in this section must be taken into consideration. In many cases, the databases used to create these maps are constantly being updated. When conducting a regional or local level evaluation, one should refer to the data sources listed in this section to get the most up-to-date information.

Examples of Riparian Vegetation with Land Use Overlays along a portion of the Verde River

Land Ownership & Population Centers

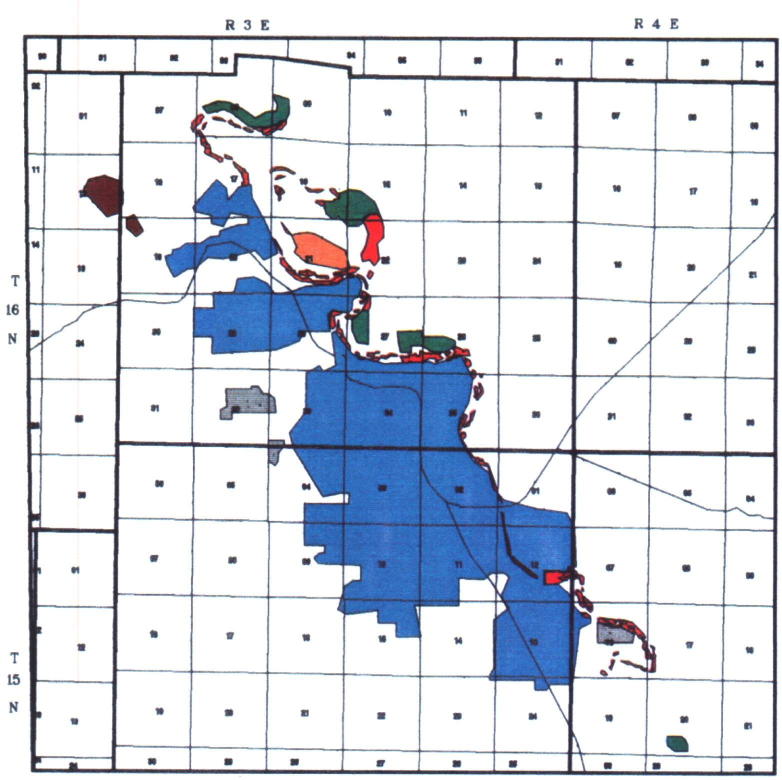


Legend

- Private Lands
- State Trust
- Prescott National Forest
- Coconino National Forest
- Tuzigoot National Monument
- State Parks
- Yavapai Indian Reservation
- Riparian Vegetation
- Urban Development
- Roads

Figure 27a.

Urban, Industrial, & Agricultural Lands



Legend

- Agriculture
- Urban Development
- Industrial
- Mine Tailings
- Mixed Land Use
- Riparian Vegetation
- Roads

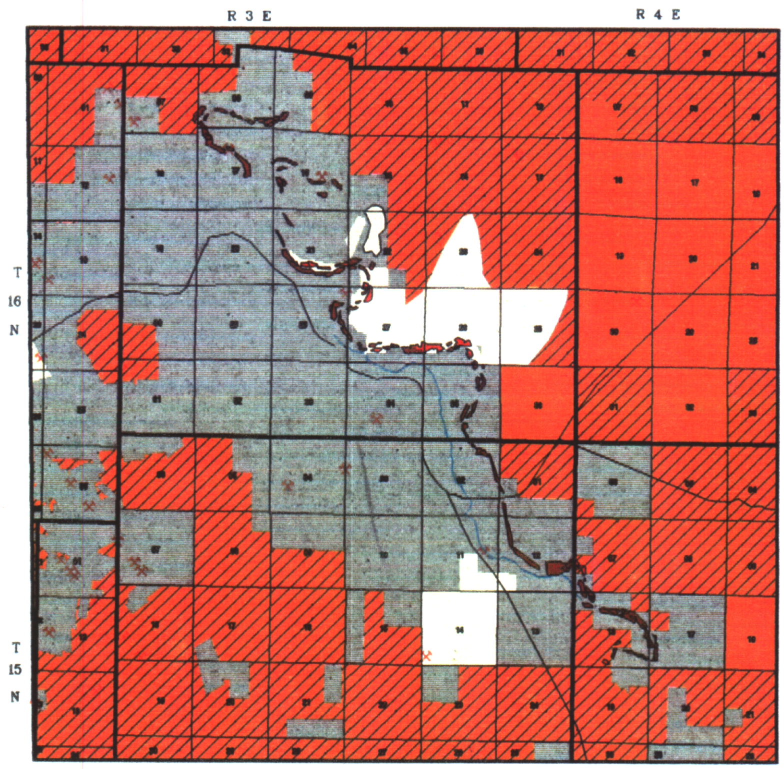
N

Figure 27b.

Vegetation data generated at UofA ART Lab.

Examples of Riparian Vegetation with Land Use Overlays along a portion of the Verde River

Grazing, Timber, & Mining Activities

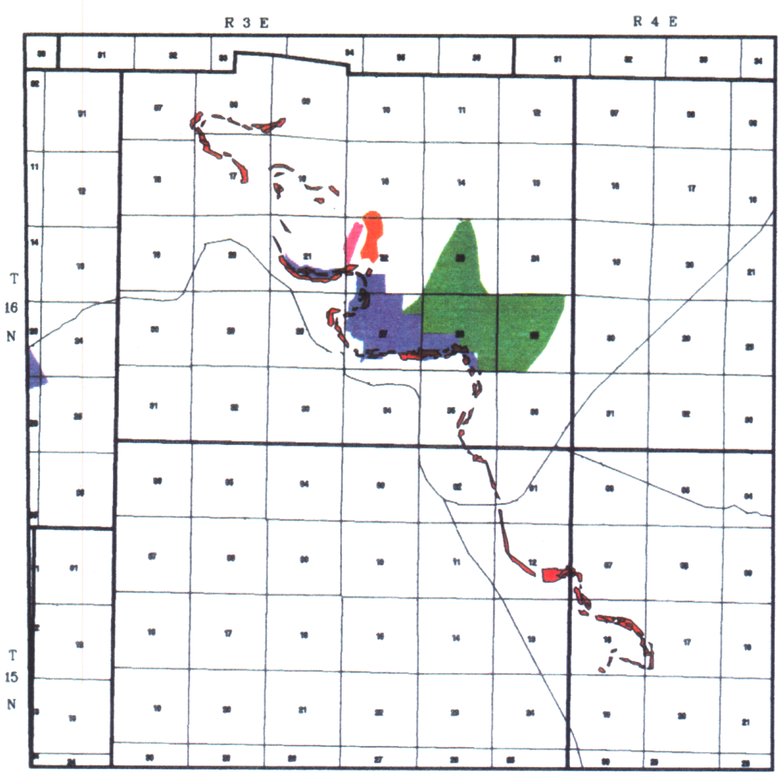


Legend

- Grazing
- No Grazing
- No Data–Private & Tribal Lands
- Lands Open to Wood Harvesting
- Riparian Vegetation
- Roads
- Diversion Ditch
- Current & Historic Mines

Figure 28a.

Parks, Recreation & Special Management Areas



Legend

- Wildlife Management Areas
- State Parks
- Tuzigoot National Monument
- USFS Research Natural Area
- Riparian Vegetation
- Roads

N

Figure 28b.

Vegetation data generated at UofA ART Lab.

Section IV

Riparian Areas and Wildlife Habitats

A. The Riparian Ecosystem

Although riparian areas cover only a small percentage of the landscape, they are among the most biologically productive of all lands. A basic knowledge of riparian ecosystems and the functions that occur within these systems is essential to understanding their biological importance.

An ecosystem can be defined as a discrete geographic unit of the landscape consisting of various biotic and abiotic components which are related through interchanges of chemical nutrients and energy (Collier et al. 1973, Bailey 1982). More simply, an ecosystem consists of a community of organisms together with its physical habitat. The boundaries of ecosystems are open and permeable to allow for the transfer of energy and materials to or from other ecosystems.

Riparian areas are found at the interface between terrestrial (upland) and aquatic ecosystems and, therefore, interact with both. Because of their transitional location within the landscape, riparian areas are especially complex. This transitional zone, or ecotone, is influenced by changes in upland activities as well as by changes occurring in the stream channel, lake or marsh bed. The biotic and abiotic components of the riparian system are inextricably linked to groundwater, surface water and hydrologic processes in the aquatic environment and to changes in vegetative cover, rates of erosion and surface water run-off in upland ecosystems.

Riparian systems can also be viewed as being connected linearly, forming corridors along the network of water courses within a watershed. These water courses provide a means of transferring energy, nutrients, genetic material and abiotic components along the system. The associated riparian area provides natural travel corridors for wildlife movement and a linear patchwork of wildlife habitats that, in desert areas, is dramatically different than the adjacent upland vegetation (Figure 29). These travel ways keep areas from becoming reproductively isolated.

The linear connectedness and the ecotonal nature of riparian areas illustrate the principle that changes in one part of the system may directly influence other parts of the system. In other words, a stand of riparian vegetation is influenced by surface and ground water, flood events, nutrient availability, the actions of invertebrates and wildlife, adjacent land uses and numerous other components. Because one aspect cannot and should not be viewed in isolation of other components, riparian areas should be examined within the context of the entire watershed.

Riparian areas are intimately tied to the watercourse along which they are located. As dynamic features of the landscape, they are constantly adjusting in response to geologic and hydrologic forces (Brown et al. 1978). Disturbances of both upland and fluvial origin, such as flood and

Figure 29. Cienega Creek in Pima County, Arizona supports a corridor of riparian vegetation that winds through semi-desert grasslands.

debris flows, affect riparian areas. Some of the hydrologic forces influencing riparian ecosystems are:

1) periodicity and duration of flow (surface and groundwater),
2) depth and fluctuation of the water table,
3) interaction of regional and local groundwater flow systems,
4) rate of surface flow,
5) chemical composition of inflows (both surface and groundwater) and
6) temperature of the water and surrounding environment (Cooper et al. 1990).

Geologic influences include:

1) depth of valley alluvium and degree of channel cutting,
2) width of valley floor,
3) valley and stream channel gradients,
4) channel sediments and floodplain soils and
5) interaction of regional water table with local aquifers and the topographic surface (Cooper et al. 1990).

Geomorphic events include debris flows, sediment transport, scouring, sediment deposition, channel migration and erosion.

Understanding disturbance is critical to understanding riparian ecosystems primarily because ecologically diverse areas are maintained by these natural disturbances (Naiman 1992). Because the biotic community found in riparian ecosystems has had to adapt to constantly changing conditions, a high degree of ecological diversity results (Kalliola et al. 1992). The high degree of diversity in riparian areas is particularly evident in the vegetative communities found there. Numerous studies of vascular plants in riparian areas show unusually high levels of biodiversity (Nilsson 1986, Salo et al. 1986, Kalliola and Puhakka 1988, Nilsson et al. 1989, Raedeke 1989, Tabacchi et al. 1990, Gregory et al. 1991, Kalliola et al. 1992, Nilsson 1992, Decamps and Tabacchi 1993, Naiman et al. 1993, Stromberg 1993a). One explanation for this apparent diversity is that riparian vegetation occupies one of the most dynamic areas of the landscape. Distribution and composition of riparian vegetative communities reflect:

1) the intensity and frequency of floods;
2) variations in climate as streams flow from high to low altitudes or across biomes;
3) disturbances imposed on the riparian corridor by upland environments (debris flows, erosion), and;
4) small-scale variations in topography and soils as a result of lateral migration of river channels (Naiman et al. 1993).

Collectively, these forces create a mosaic of plant communities and provide a variety of habitats in which a diversity of species are able to co-exist. Plant species richness and diversity tend to greatly influence terrestrial and aquatic wildlife.

Factors influencing the composition, size and function of riparian areas are also found to change with elevation. The Brown, Lowe and Pase (1979) classification system described in Section I, can be used to classify riparian plant communities according to where they are located on a valley longitudinal profile. For instance, in the upper reaches of a valley, channel gradients tend to be steep and stream energy is high. Very little sediment deposition occurs so floodplains and riparian ecosystem development is minimal, usually occurring in narrow bands along the stream corridor. The vegetation is dominated by scrub willows with conifers and aspen invading from the adjacent uplands (Neff et al. 1979). At high elevations where valley gradients level off, wet meadows are often formed. Some of these wet meadows are spring-fed and occur at the base of mountains. They tend to be too wet for major tree encroachment and are dominated by a mix of grasses, sedges and an assortment of forbs (Subirge no date).

The mid-portion of the stream is characterized by the development of a narrow but distinct floodplain. Within this zone, the floodplain tends to constantly adjust to changes in channel aggradation and degradation processes (Cooper et al. 1990). These areas may be vegetated by either mixed broadleaf deciduous communities or cottonwood-willow communities (Neff et al. 1979). Cave Creek and Turkey Creek in the Chiricahua Mountains are examples of this zone.

At lower elevations, the stream gradient levels out and sediment depositional processes dominate. It is within this area where the floodplain reaches its maximum development. Large streams or rivers that occur lower in the watershed are characterized by larger and more diverse vegetative communities that develop in response to wide, geomorphically complex floodplains. These broad floodplains are formed by hydrologic and geomorphic processes that result in seasonal flooding, lateral channel migration, sediment deposition or aggradation, and formation of backwaters and marshes (Naiman 1992). They tend to be dominated by cottonwood-willow communities and mesquite bosques. In disturbed systems, cottonwood-willow may be replaced by salt cedar. In Arizona, the San Pedro River and the lower Verde River provide excellent examples of this type of riparian corridor.

We begin to see, then, that ecological linkages between the terrestrial and aquatic ecosystems occurring in riparian areas take place within the context of the fluvial and geomorphic processes that occur there. Modification of landforms by the actions of these processes may occur slowly over long periods of time or may occur as large-scale, episodic events. Their spatial scale may range from a localized shift in a stream channel to a basin-wide flood event. The result of these events is the mosaic of landforms that characterize riparian areas such as stream channels, floodplains, channel bars, terraces and alluvial fans. In fact, the shape and area of each of these features is directly influenced by its location within the drainage network, the amount of streamflow and local geology and geomorphology (E. Swanson et al. 1988).

Component processes of riparian ecosystems take on a pattern of interdependency with geomorphic and hydrologic factors influencing development of riparian vegetation, and riparian vegetation influencing the animal community, hydrologic and geomorphic factors. The following statements illustrate these relationships. Disturbances and processes within the ecosystem determine the spatial pattern and successional development of riparian vegetation. In the presence of sufficient water, riparian area development increases as the width and depth of valley alluvium increases (Cooper et al. 1990). Valley floor landforms and associated riparian vegetation form an array of physical habitats within the active channels and floodplains. The streamside plant communities that occupy these habitats determine the abundance and quality of nutritional resources for aquatic ecosystems (Gregory et al. 1991). Riparian vegetation, in turn, influences the evolution of geomorphic surfaces. Networks of roots from grasses and woody vegetation that cover the banks of streams and lakes increase resistance to erosion. Aboveground stems of streamside vegetation increase channel roughness during overbank flow and may decrease the erosive action of floods and actually cause deposition of sediment. This interrelatedness between riparian vegetative communities, and fluvial and geomorphic processes characterizes the riparian ecosystem. The complexity of relationships that exists between riparian areas and adjacent streams and uplands makes it mandatory that any assessment of riparian areas be based on an ecosystem approach, evaluating the total functional condition of the system as opposed to a singular component.

The ADWR report mandated by this legislation (ADWR 1993) addresses the relationships between riparian vegetation and hydrology including the effects of changes in water availability and streamflow on riparian vegetation. It is our intent to present information in this section that supports the ADWR report, but that focuses more heavily on relationships between riparian areas and wildlife.

B. Functions and Values of Riparian Areas

Factors that affect landform, and vegetative and wildlife diversity consequently influence the diversity of functions occurring within a riparian area (Naiman et al. 1993). These factors are the key to functional assessment of riparian areas. The term "functions" refers to biological, chemical, or physical processes that occur in riparian areas and wetlands as a result of the geomorphic, topographic, physiographic and hydrologic position in the landscape (Jakle 1991). Functions are part of the self-sustaining properties of the ecosystem. They operate within a riparian area whether or not they are viewed as important to society (Adamus et al. 1991). Some functions may also have a corresponding societal value. However, "value" denotes the social significance of an attribute. This dichotomy is the origin of the commonly used phrase "functions and values."

Some examples of riparian values include importance to wildlife, recreation, scenic and aesthetic qualities, water quality, commercial/agricultural activity, waterborne commerce and urban development. Because values are determined by society, this factor is subject to change over time as societal views of resource values change. Therefore, it is important to separate out the evaluation of function and the determination of value. Functional assessment should be firmly grounded in the natural and physical sciences. Indicators of value should be developed by the appropriate discipline (i.e., economic indicators are quite different from biological indicators.).

Some functions of riparian areas are very well understood while others may be virtually unknown. Much of the discussion about functions of riparian areas has been inferred from research on wetlands or more mesic riparian ecosystems. The Wetland Evaluation Technique (WET) developed by the U.S. Army Corps of Engineers (COE) is an example (Adamus et al. 1991). The technique is a rapid approach to wetland evaluation based on information about correlative predictors of wetland functions. Predictors, or indicators, are based on extensive review of wetlands research. Because this technique was created for nationwide application, it did not take into account regional variations in wetlands and riparian areas.

Riparian areas in the arid and semi-arid Southwest sometimes "behave" differently than riparian areas in the eastern, midwestern and coastal areas. In actuality, these "behavioral differences" are the result of the system's response to a unique set of climatic, ecologic, hydrologic and geomorphic factors influencing the ecosystem. Consequently, scientists and land managers have had to exercise caution in applying studies conducted on wetlands or riparian areas that developed under one set of conditions to areas that developed under a different set of conditions.

One of the most complete evaluations of existing data on riparian functions in western ecosystems was conducted by Cooper et al. (1990) for the U.S. Environmental Protection Agency (EPA). The study first assessed the extent of scientific literature that exists on the subject of riparian area functions in the Intermountain West. This exercise was followed by a discussion of the functions and values associated with wetlands, as listed in WET (Adamus et al. 1991) and an evaluation of their applicability to western riparian areas. In addition, the study discusses whether there are sufficient scientific data to suggest that riparian areas perform a particular function and how to evaluate that function.

Cooper et al. (1990) attributed the following broad classes of functions to riparian areas:

1) sediment stabilization;
2) water quality functions;
3) production export;
4) flood flow alteration;
5) groundwater recharge/discharge, and;
6) terrestrial wildlife and aquatic diversity/abundance.

Both Cooper et al. (1990) and Adamus et al. (1991) provide detailed discussions regarding these functions. For purposes of this report, a brief description of each function is presented below. This is by no means a comprehensive summary of riparian and wetland functions. For additional discussions on riparian and wetland functions and values, the reader is encouraged to review Brown and Lowe (1978), Jahn (1978), Knight and Bortorff (1984), Soil Conservation Service (1987), DeBano and Schmidt (1989), Chaney et al. (1990), Williams (1990), Brinson (1992), Pitt (1992), and Finch and Ruggiero (1993).

1. Sediment Stabilization

Sediment stabilization includes consideration of two processes. The first is the removal of sediment from the water column and the second is the prevention of sediment from entering the water column. Sediment removal is accomplished through bed load or suspended sediment deposition within the channel or through overbank flooding. The type and density of riparian vegetation, both on the bank and in the channel, increases channel roughness which decreases the velocity of water, slowing erosion and enhancing deposition of sediments. Other factors affecting channel roughness are bed material, channel geometry, obstructions and degree of meandering.

Sediment contributions to a stream are typically from bank erosion and surface runoff. Riparian areas may modify water quality impacts from other stream reaches or upland areas by assisting the processes of sediment deposition, removal and filtration. Riparian vegetation plays an important role in preventing sediment deposition into the stream channel by stabilizing stream banks and stream beds. Trees and shrubs are excellent protectors of bank soil because their roots penetrate deeply and often provide a physical barrier between the stream and soil. Rushes, sedges and reed grass are especially effective in stabilizing submerged soil while reducing the erosive impact of waves and stream current (Seibert 1968).

Buffer strips of riparian vegetation serve to trap sediments from upland erosion reducing the amount that enters the stream. The width necessary for effective filtering (buffer zone) depends on characteristics of both the erosional area and the buffer area. In the riparian area, type and distribution of ground cover, slope and resistance of the buffer zone to deterioration are factors important to buffer zone effectiveness.

2. Water Quality Functions

Water quality functions include retention and removal of sediments and toxins as well as retention and transformation (cycling) of nutrients. Some wetlands and riparian areas accomplish these functions on either a net annual basis or during the growing season by:

1) physically or chemically trapping and retaining inorganic sediments;
2) physically or chemically trapping and retaining chemical substances generally toxic to aquatic life;
3) retaining or transforming inorganic phosphorus into an organic form;
4) retaining or transforming nitrogen into an organic form or transforming (removing) nitrogen into a gaseous form (Cooper et al. 1990).

Removal of metals from the water column requires processes such as ion exchange and adsorption to sediments and dissolved organic matter, precipitation as oxides, pH changes, and plant and microbial uptake (Cooper and Emerick 1987, Cooper et al. 1990).

Large quantities of nitrogen in the water column can result in degraded water quality through promotion of algal blooms and enhancement of populations of undesirable species (Sather and Smith 1984). The primary mechanism for removal is nitrification or denitrification by bacteria. Nitrogen compounds are effectively removed by saturated, low gradient wetlands where nutrients come into contact with reduced, fine-textured or organic soils (Cooper et al. 1990). It is not known whether well-drained, sandy alluvial soils along streams and rivers support this function. However, according to Skinner et al. (1984), soils near stream edges, even along high gradient streams, are usually wetter, with more abundant organic matter and little dissolved oxygen, and may be important sites for the regulation of nutrient inputs into surface waters. Thus, while the main portions of riparian forests and floodplains do not perform nitrogen removal functions, smaller portions of these ecosystems may.

3. Production Export

Production export pertains to the flushing of organic plant material from wetland and riparian lands into streams. The plant material is a food source for aquatic organisms. According to Cooper et al. (1990), very few studies address key questions on the value of riparian vegetation for food chain support. Research points to the importance of debris dams and other retention devices such as boulders, branches and roots in retaining litter in the streams where it can be processed to support large populations of aquatic insects. Beavers can also play an important role in retaining sediment and organic matter, thereby reducing the amount of nutrients going downstream.

4. Flood Flow Alteration

Flood flow alteration refers to the storage of water on or in the floodplain and or alteration of its velocity. The primary result of flood flow alteration is a reduction in downstream flood peaks and decreased frequency of downstream overbank flooding. This process can also result in an improvement in water quality as sediments are deposited outside the stream channel where they can be stabilized. Cooper et al. (1990) state that there are only a few reports on observed effects of riparian lands on flood flows. However, they present a number of methods to calculate flood flows at gaged and ungaged sites using various models and techniques. Characteristics or measurements used to calculate or estimate flood flows include stream type, source of flood (e.g., snowmelt, thunderstorm, etc.), drainage area, mean basin elevation, average annual precipitation, basin slope, bankfull width and land use.

5. Groundwater Discharge/Recharge

Groundwater discharge occurs when there is a net movement of groundwater to the surface. Groundwater will discharge into a riparian area when the regional or local water table is higher than the surrounding water table (Cooper et al. 1990). When this discharge occurs in a riparian area or wetland, the alluvial soils have the ability to store the water. It is then slowly released to surface systems (streams or marshes) at low water periods. The overall effect on low flows will depend on the amount of surface storage area available in the soils or alluvium.

Groundwater recharge is the net movement of surface water into groundwater. The groundwater may be at a considerable depth, such as a regional aquifer. In the arid and semi-arid Southwest, recharge to the alluvium tends to occur during high flow events. In mountainous areas, snowmelt is an important factor in providing a large and consistent supply of water for streamflow and recharge into alluvial aquifers.

6. Terrestrial Wildlife and Aquatic Habitat

Distinctions between wildlife functions and wildlife values are often clouded by incorrect use of terms in the literature. Wildlife may perform or support certain processes within the context of the ecosystem. This is a function. However, riparian areas may be valued for providing high quality wildlife or fisheries habitats. For this discussion, we group wildlife and fisheries diversity and abundance with riparian functions because of the precedent set by Adamus et al. (1991) and Cooper et al. (1990). This choice is due to the fact that development of indicators of wildlife diversity and abundance are based in the natural and physical sciences, as are other functional indicators, and are formulated in a similar manner.

Wetland and riparian areas are very productive ecosystems and provide important habitat for many wildlife species in Arizona (Brown et al. 1979, Ohmart and Anderson 1982, Anderson and Ohmart 1984). That productivity and importance is at least partly a reflection of the availability of water and rich alluvial soils. The combination of water and soils sets the stage for development of potentially diverse and structurally complex vegetative communities. Structural diversity (different layers of vegetation, different ages of plants, and ground litter) in the plant community provides a wide diversity of habitats for wildlife (Kupchella and Hyland 1986).

Riparian areas provide many critical life support functions for wildlife. They may provide habitat components dealing with defense, escape cover, food or prey, feeding substrate, nest or birthing substrate, reproduction, resting substrate, and temperature regulation (Jones 1986). Different wildlife species require different situations to meet their specific habitat needs. Because of vegetative diversity and close proximity to water, riparian areas typically provide a wide variety of habitat components. Riparian areas, therefore, typically meet the needs of more wildlife species than the adjacent upland areas.

Some species of wildlife are tied to riparian areas throughout their lives (obligates), while others only depend on them during certain periods of their lives (facultative). Ohmart and Anderson (1986) report that more than 60 percent of vertebrates in the arid Southwest are obligate users of riparian areas. Another 10 to 20 percent are facultative users.

Obviously, fish require water, but they are dependent upon riparian areas for more than just water. Shade, escape and hiding cover, and food items (insects and organic debris) may be products of the surrounding riparian plant community (Meehan et al. 1977, Wesche et al. 1985). Indeed, the capability of streams to produce or support fish often is correlated with condition of riparian vegetation (Cuplin 1986). Riparian vegetation is an important food source for stream organisms (Mahoney and Erman 1984). Macroinvertebrates that consume aquatic vegetation and detritus provide fish with most of their food (Cuplin 1986). Leaf fall provides much of the detritus found in streams.

Amphibians are dependent on water for reproduction, but other life support functions may be provided by either water or the surrounding riparian area (Jones 1986). In the Sonoran Desert, about 80 percent of amphibian species are obligate or facultative users of riparian areas (Ohmart and Anderson 1982). Some reptiles are also tied to riparian areas during their life cycles (Jones and Glinski 1985, Jones et al. 1985). Of these, only two turtle species, one lizard species, and three snake species are considered riparian obligates (Ohmart and Anderson 1982). Reduction of naturally-occurring water and modification of habitats has been shown to affect composition of reptile and amphibian species in riparian areas (Jones 1988).

A number of studies have shown that riparian areas support very high densities of breeding birds, including neotropical migrants (Carothers et al. 1974, Anderson and Ohmart 1984, Johnson and Jones 1977, Hehnke and Stone 1978). The bald eagle, common black-hawk, gray hawk and zone-tailed hawk are four raptor species in Arizona that are dependent on riparian areas for nesting and foraging (Ohmart and Anderson 1982, Kochert 1986).

For some mammals, the presence of running water is more important than the associated plant community. Species dependent on perennial water include river otter, beaver, muskrat and water shrew. Associated with riparian areas but less dependent on water are some bats, ringtail cat, raccoon, Arizona gray squirrel and Apache fox squirrel (Minckley and Brown 1982, Hoffmeister 1986). Beaver dams create conditions that increase growth and vigor of woody riparian species that, in turn, provide important habitat for breeding birds and other animals (Stromberg 1993a).

Not all riparian areas provide habitat for all wildlife. First, because they differ in plant species composition, in maturity, and in degree of disturbance, riparian areas differ in what habitat components they may provide. Second, animal species differ in what habitat components they require. Because of this, riparian areas are not equal wildlife habitats. It is difficult to assign ranking to riparian areas because habitat value varies according to which animal guild or species is selected for evaluation. The same riparian area may be excellent habitat for a particular species, but totally unsuitable for another species. Since riparian areas are mosaics of diverse plant communities, they provide some habitat components for most wildlife species most of the time. Following are examples of how riparian areas differ in providing wildlife habitat.

Cottonwood-willow riparian communities are generally recognized as being important habitat for nesting birds and neotropical migrants (Carothers et al. 1974, Ohmart and Anderson 1982, Anderson and Ohmart 1984). Tree species diversity in Sonoran cottonwood-willow riparian communities is low, but age class and structural diversity is high. And often these communities support an understory assemblage of plants that is more diverse than other riparian types (Stromberg 1993a). Reduction in the diversity of size and age classes adversely affects the abundance and diversity of birds and mammals that require a particular strata within the canopy (Ohmart and Anderson 1986). Some animals (e.g. yellow-billed cuckoo and blue-throated hummingbird) are almost entirely restricted to cottonwood-willow communities (Neff et al. 1979).

Mesquite bosques typically have three vegetational strata that include a tree canopy, a shrub and vine stratum, and an herbaceous understory (Stromberg 1993b). High diversity of plant species and high density of foliage at many heights contribute to an abundance and diversity of the avian community associated with bosques (Ohmart and Anderson 1986). Bosques have high productivity that is partly expressed by the production of abundant flowers and fruits. Flowers support a great number of insects that provide food over a long period of time for birds, bats and other animals. Fruits provide abundant and highly nutritious food for mammals such as javelina, coyote and cattle. Most mammals use a variety of habitats, but the range of at least one species (mesquite mouse) is restricted to mesquite bosques (Stromberg 1993b).

Interior mixed broadleaf communities typically occur at elevations above the previous two riparian communities. They consist of a wide variety of broadleaf trees such as walnut, ash, sycamore, and alder interspersed in varying degrees with oaks and conifers from adjacent mountains (Minckley and Brown 1982). Intensive wildlife studies are generally lacking for this riparian community, but numerous wildlife species are totally or primarily dependent on it (Neff et al. 1979). For example, the Arizona gray squirrel and Apache fox squirrel are largely confined to mixed broadleaf forests (Minckley and Brown 1982).

Wildlife relationships with riparian scrub communities are also poorly investigated, but there appears to be considerable interaction with animal populations from adjacent upland areas (Neff et al. 1979). For instance, thickets in low elevation riparian areas often support high densities of upland game species such as desert cottontail and Gambel's quail (Minckley and Brown 1982). Tamarisk (saltcedar) may dominate some riparian scrub communities and generally provides poor habitat for most wildlife species because there is low plant diversity, low canopy height, and low structural complexity (Rosenberg et al. 1991). Willow thickets at high elevations, on the other hand, may support a diverse bird community during part of the year (Carothers 1968).

C. Development of Indicators - A Methodology for Rapid Assessment of Riparian Area Wildlife Values

According to Cooper et al. (1990), to determine whether an area is supporting a particular function, the function (1) can be directly measured, (2) can be deduced from site specific data, or (3) inferred from the system's membership in a particular category. For example, nesting habitat for a neotropical migratory bird species may be implied if (a) a nesting pair of birds was observed, (b) suitable characteristics for a nesting site as well as abundant food supplies were observed, or (c) the area was categorized as a cottonwood-willow gallery forest, known to be preferred as nesting sites for this species. Obviously, the potential for error increases with the type of generalization applied.

Direct measurement of many of functions described in the previous section can be a time-consuming and expensive endeavor. Therefore, functions are often deduced from the characteristics of a site or inferred from scientific measurements made on a similar area. The broader levels of analysis (types 2 and 3, above) may require evaluation of more features or characteristics than the straight-forward measurement. Yet, this broader type of approach can be very effective in differentiating and identifying functional processes and attributes.

Assessment of functions at a broad level often involves the establishment of indicators. Indicators are features or characteristics which have a known or hypothetical correlation with an item or event of interest. Indicators are not intended to replace general knowledge about characteristics of an area, but rather to provide shortcuts to predicting whether a process is occurring or whether it has the potential to occur. Establishment of a reliable indicator requires verification through research and testing (direct measurements). Once a correlation is established between a functional process and its effect on the system, and the process is well understood, then indicators of a functional process can be identified.

Riparian evaluation procedures used by the EPA, COE, USFS and the BLM all depend on the application of indicators to varying degrees. In addition, these approaches each acknowledge the utility of the three levels of assessment ranging from general to specific, as listed above. In fact, USFS and BLM approaches structure their data collection and evaluation to reflect these levels. Data collection proceeds from the more general to the more specific, with evaluation occurring at whatever level of specificity is required for a particular application. The decision to pursue a general level evaluation over a specific level is typically driven by the purpose or objectives of the evaluation. That is, the type of evaluation applied will depend on the scale of the endeavor (statewide, regional, local), the necessary precision or accuracy, the time frame allotted for the analysis and the data collection and financial resources available. For instance, intensive, site-specific field data would need to be collected to answer specific questions such as species habitat requirements or species food preferences. The purpose of a general level inventory might be to locate, quantify and broadly classify riparian ecological sites (Myers 1989).

The broadest level of evaluation begins with the assembly and interpretation of existing maps and data. Features and characteristics of an area can be derived from topographic maps, vegetation data, water quality data, remotely sensed data, historical accounts, databases or field accounts. Inferences can be made from features observed in the field, such as high water marks, nesting sites, species occurrences or valley shape. Data collection and evaluations occurring at this level are useful for identification, categorization and general classification of areas based on general features or characteristics. Once areas are grouped into categories reflecting similarities, inferences can be made about areas where very little detailed data have been collected. General level inventories are also used to identify priorities for more intensive inventories based on resource values and site characteristics.

Because of the Arizona Game and Fish Commission's legislated authority and the Department's mission, our efforts this past year were focused on evaluating methods to assess biological life support functions and wildlife values provided by riparian habitats for vertebrate wildlife (fishes, amphibians, reptiles, birds and mammals).

AGFD sought a method that could be employed to rapidly assess the relative values of riparian areas

- without intensive commitment of personnel,
- that could be carried out with only a moderate amount of training,
- that was not overly subjective in its application, and
- that could correlate with mapping activities being undertaken by the Department.

A number of methods or techniques of assessing wildlife functions and values of wetland or riparian areas have been developed. Many of these techniques require complex, extensive, site-specific measurements or are not specific to Arizona (Table 9). Selection or development of a wildlife function/value methodology is one important contributor to development of an overall, hierarchical designation system.

An approach that was specifically developed for Arizona, and that can be evaluated rapidly in the field was conceived by Anderson and Ohmart (1984) for the Bureau of Reclamation (USBR). Ohmart and Anderson subsequently reviewed alternate methodologies for AGFD and attempted to further develop their own technique to provide a single index value that would allow comparison among riparian habitat types. The methodology they developed was specific to riparian forest and riparian scrub habitats. Their work in development of this technique is summarized in three reports to the AGFD:

The development of an Arizona habitat evaluation model with wildlife values (Anderson and Ohmart 1993),

Functions and values of riparian habitats to Arizona wildlife (Ohmart and Zisner 1993), and

Literature review of functions and values of riparian habitat to wildlife in Arizona (Ohmart and Zisner 1993).

All three reports will be available for inspection through the Habitat Branch of the Arizona Game and Fish Department.

The method described is based on description of vegetation and vegetation structure. Key features of the assessment method include vegetation species composition, foliage density, and vertical height diversity (i.e., the percentage of existing foliage occupying each of three vertical layers) (Figure 30).

The field inventory methods are described in Anderson and Ohmart (1984). In that report, they separated riparian structural types into 6 discernable categories (I-VI). For purposes of creating a wildlife habitat index, those structural types were collapsed into three categories.

As Ohmart and Anderson proposed to further develop an index of wildlife value provided by riparian areas based upon vegetation attributes as determiners of wildlife function, their challenge was to express that value as a simple index. We required that the index value be applicable to classification methods selected by the Department for our riparian mapping and that the classification system developed by Brown, Lowe, and Pase (1979) would be incorporated as a predictor variable in their index model.

Because they proposed to develop an index rather than select an existing methodology, it was essential that the index could be generated in a very short time-frame. To that end, Anderson and Ohmart's (1993) existing data on wildlife utilization specific to riparian habitats was readily available and relatively complete. Their survey data for their Colorado River studies included avian as well as some reptile and small mammal utilization. Data available from other sites was generally restricted to avian utilization, but they argued that general associations between wildlife value and value to birds could be drawn from their Colorado River data and applied to bird survey data collected elsewhere.

Table 9. Description and Comparison of Various Riparian Habitat Evaluation Models reviewed by Ohmart and Zisner (1993).

NAME OF METHOD AUTHORSHIP	BASIS OF METHOD	INTENSITY OF EFFORT	TARGET HABITAT	AREA OF USE
HABITAT EVALUATION SYSTEM Corps of Engineers (1980)	index of wildlife species richness	HIGH, requires site specific field measurements	wetland and riparian areas, based upon plant communities including wooded swamps and bottomland hardwoods	Lower Mississippi River Valley, would require modification and field verification for Arizona
WILDLIFE HABITAT APPRAISAL PROCEDURE Frye (1984)	index of wildlife species diversity	LOW, designed for rapid assessment	wetland and riparian areas, based upon soils, vegetative structure and diversity and scarcity of plant community type	Texas, would require some modification and field verification for Arizona
STREAM CORRIDOR INVENTORY AND EVALUATION SYSTEM Garcia *et al.* (1984)	index of wildlife value of stream corridors, wildlife species richness and density	HIGH, requires significant site specific data collection, some may be derived from remote sensing, best applied by interdisciplinary team	riparian habitats, flexible method designed specifically for riparian inventory	
HABITAT SUITABILITY INDEX (HSI) FOR WILDLIFE SPECIES RICHNESS IN SHELTERBELTS Schroeder (1986)	index of wildlife species richness	MODERATE, requires measurements of vegetation structure, plant diversity and shelterbelt size	Shelterbelts including woody riparian habitats	Minnesota shelterbelts, would require modification and field verification in Arizona.
WILDLIFE WETLAND EVALUATION MODEL Golet (1976)	index of wildlife diversity and productivity in wetlands	HIGH, requires some specific field measurements of water regime and water chemistry	wetlands	Northeastern US
WILDLIFE SPECIES RICHNESS IN WETLANDS Adamus (1983)	index of year-round wildlife species richness	MODERATE, requires some specific field measurement, other features can be derived from maps and remote sensing	wetlands, only designed to compare wetlands of the same type	48 contiguous Untied States

NAME OF METHOD AUTHORSHIP	BASIS OF METHOD	INTENSITY OF EFFORT	TARGET HABITAT	AREA OF USE
HABITAT EVALUATION INDEX Graber and Graber (1976)	comparison of plant community conditions	LOW, limited fieldwork, requires mapping and classifying the state and determination of average condition	All plant communities, meant to compare areas against a standard of average condition	Illinois, would require significant mapping and classification across Arizona before could be used
ARIZONA GUILD LAYERS OF HABITAT MODELS Short (1984)	index of habitat suitability for guilds of animals	MODERATE, wildlife species indicators must be guilded, requires field measurement of eight habitat layers based on vegetation height and density	desert and riparian habitats	Southwestern US, deals mostly with Sonoran Desert habitats.
INDICATOR SPECIES IN COLORADO Hoover and Willis (1984)	index of wildlife species richness	MODERATE, requires measurement of habitat variables for specific indicator species	forested habitats (17 communities) with specific indicator wildlife species	forest communities of Colorado

Table 9 (cont'd.)

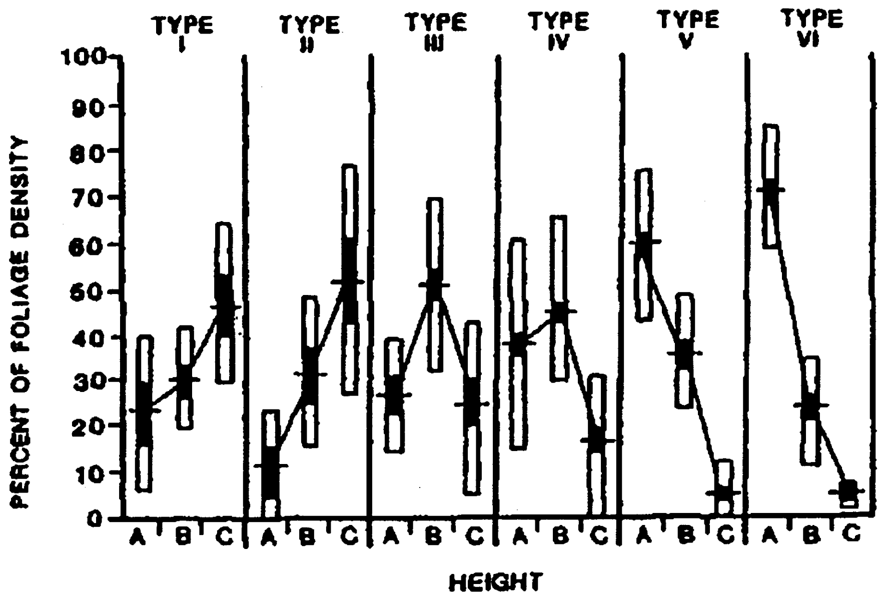


Figure 30. Structural classes of vegetation (A) lower (0-2 ft above ground level), (B) middle (2-15 ft), and (C) upper layers (above 15 ft) of riparian forest (Anderson and Ohmart 1986).

To document this they used principle components, correlation, and regression analyses to determine:

- If survey data for birds from their data sets could be explained by plant community type,
- If a relationship existed between overall wildlife value (i.e., birds, mammals, and reptiles) and value of community types to birds, and
- If a relationship existed between overall wildlife value (i.e., birds, mammals, and reptiles) and value of community types to mammals.

Anderson and Ohmart (1993) concluded from analyses of their Colorado River data that these relationships all existed and were significant.

To derive their index of wildlife value associated with riparian areas, Ohmart and Anderson constructed a regression model that placed a dimensionless index of value upon categories of riparian community types (Anderson and Ohmart 1993). They used existing wildlife data from their work on the Colorado River (Anderson and Ohmart 1984) and data sets from the Gila

River (Hunter 1988) and the Tonto National Forest (Higgins and Ohmart 1981) to derive an indicator of value to wildlife (based heavily upon cavity-nesting birds). The goal of their efforts was to associate existing wildlife data with rank-quantified riparian plant community types (based on structural composition).

Ohmart and Anderson recognized that elevation, latitude, and longitude were also potential determiners of wildlife value. Data assembled for riparian areas represented elevational (Tonto National Forest), latitudinal (Gila River), and longitudinal (Colorado River) gradients across Arizona.

There are several assumptions and limitations implicit in the development of the index proposed by Anderson and Ohmart (1993).

1) The index is developed for terrestrial wildlife, and thus is limited to riparian forest and scrub communities. No data for fishes or aquatic wildlife were included, and value of riparian areas to their associated aquatic components is only inferred rather than explicitly evaluated.

2) It is assumed that value to birds and mammals is correlated with value to all forms of wildlife. Anderson and Ohmart's (1993) data represent rather complete, long-term survey of birds and other wildlife in riparian areas. However, the data sets in areas other than the Colorado River do not represent complete surveys for mammals, amphibians, and reptiles. If the value of riparian areas to birds can be determined, then Anderson and Ohmart assume that value to all terrestrial wildlife can be computed based upon their analyses of Colorado River data. In fact, Anderson and Ohmart's analyses are based heavily upon their data recording cavity nesting bird utilization of riparian habitat.

3) It is assumed that the specific index of wildlife value can be applied uniformly at elevations below 3,500 feet msl because data used to develop the index all came from riparian areas at or below this elevation. While the approach to developing an index value may be applicable in higher elevation areas, it requires the collection of data in riparian areas found within that elevation range. Until then, there is less confidence in using the index at higher elevations than were tested, and thus the model requires field testing at elevations above 3,500 ft.

4) The indexed wildlife value represents value to wildlife across all seasons and across years. Riparian areas which are valuable to wildlife seasonally may be under valued to some extent.

5) Anderson and Ohmart assumed that riparian plant community types can be rank-quantified. An important factor in determining wildlife value is the relative value of plant species composition in the riparian area. The quantification is a ranking based upon wildlife densities associated with plant community types observed by

the authors in previous studies.

6) The model does not account for acknowledged high value habitats of wetlands or cienegas. These areas do not fit into the structural types proposed by Anderson and Ohmart.

Anderson and Ohmart (1993) report a multiple regression model that provides an index value for wildlife that allows comparison among riparian forest/shrub community types. For ease of use, they proposed a look-up table with values evaluated for specific community types (Brown, Lowe and Pase series level), altitudes, and regions of the state. A brief excerpt from their look-up table is presented in Table 10. Index values in the table range from approximately +3 (highest value) to approximately -3 (lower value). Anderson and Ohmart are careful to caution that lower values or 0 values of the index do not reflect an absence of value to wildlife, but simply lesser value when compared to riparian forest/scrub habitats of highest value. The data necessary to generate an index value are quantified vegetation type (Brown, Lowe and Pase series level), vegetation structure type, altitude, and longitude and latitude. Vegetation structure types (Type 1 and 2 = 2, Type 3 and 4 = 4, and Type 5 and 6 = 6) are illustrated in Figure 30. Altitude, longitude, and latitude were used as categories.

The utility of a simple index of wildlife value for riparian areas is multifold. It could be used to provide a range of potential wildlife values based on identified vegetative community type (Brown, Lowe and Pase series level). Remotely sensed data combined with ground-truthing can provide additional information to decision-makers. AGFD will continue to evaluate the utility of a simple index of wildlife value. Anderson and Ohmart's report to AGFD is still being finalized and must undergo final internal review.

Table 10. Example look-up table for wildlife value index generated by Anderson and Ohmart (1993). Values are dimensionless and provide comparison among Vegetation Structure types by altitude and area of the state. Wildlife values range from -3 to +3.

			LONGITUDE/LATITUDE ZONE (from Fig. 2)					
VEGETATION TYPE	STRUCTURAL TYPE	ALTITUDE (FT)	1	2	3	4	5	6
Populus- Salix and mixes (Series 1)	2	0-600	3.0	2.9	3.0	3.0	3.2	3.2
	4	0-600	2.6	2.5	2.7	2.7	2.9	2.9
	6	0-600	2.4	2.3	2.5	2.5	2.7	2.7

Section V

Development of A Hierarchical Designation System

A. Introduction

AGFD was instructed to incorporate a hierarchical designation system based on relative functions and values into the development of a classification system for riparian areas (Chapter 298, Laws 1992). The development of such a system has long been discussed and debated by scientists and land managers across the nation. In the past, formulation of a designation system was limited primarily by a lack of comprehensive data and information on riparian functions and values. This was complicated by the fact that many different methods of collecting and analyzing data have been applied by scientists and land managers. These data collection efforts have been driven by a variety of designation and classification systems devised to meet a wide variety of objectives.

Because of the land base managed by federal agencies in Arizona, a state designation system should not be formulated without evaluation and consideration of approaches taken by federal land management agencies. The BLM has responsibility for more than 12 million acres of public lands in Arizona. About 289 perennial stream miles occur on those BLM managed lands. National forest lands cover more than 11 million acres and include almost 1,600 perennial stream miles, many of which are headwaters of stream systems in the state. National parks, wildlife refuges and military bases add another 7 million acres to lands and over 600 perennial stream miles under management of federal agencies within the state. In contrast, private and state lands combined comprise only about 23 million acres and 1,100 perennial stream miles. The amount and type of data that will be generated by federal efforts, as well as the type of management practices applied on these lands will have critical implications to state-level efforts.

The USFS, BLM, EPA and COE have all been struggling with the formulation of a riparian evaluation system that is applicable to arid and semi-arid regions of the U.S. The Southwestern Region of the USFS developed the "Riparian Area Survey and Evaluation System" (RASES) (USDA 1989) and the Intermountain Region developed the "Integrated Riparian Evaluation Guide" (USDA 1992) as a means to evaluate the need for adjustment in land management practices to improve conditions in riparian areas under their jurisdiction. In Arizona, RASES has been modified by at least three National Forests, resulting in further fragmentation in approaches.

The Bureau of Land Management devised the Ecological Site Inventory (ESI) approach to meet its goals for the inventory and management of riparian and wetland resources (see Batson et al. 1987, Myers 1989, Leonard et al. 1992, Gebhardt et al. 1990, Prichard et al. 1993). It is important to note that the BLM procedures have been incorporated into the Standards and Guidelines section of the Rangeland Reform Act '94 (USDI 1993). The "Riparian-Wetland

Initiative for the 1990s" (USDI 1991) established national goals and objectives for managing riparian and wetland resources on public lands. One of the primary goals of the initiative is "to restore and maintain riparian-wetland areas so that 75 percent or more are in proper functioning condition by 1997" (USDI 1993).

In addition to these, there are many other approaches being applied at federal, state and local levels across the nation. However, to date, no system has been devised that is universally acceptable to all entities involved in the assessment and evaluation of wetlands and riparian areas in the arid and semi-arid Southwest. Even as this report was being written, information was being received about new developments in evaluation procedures.

Although the federal agencies have fairly recently begun to apply their evaluation procedures to riparian areas and wetlands within their jurisdiction, there is a growing body of knowledge and data on riparian resources on a number of streams across the state. The lack of consistency in approach, the fact that these efforts are not yet complete and the lack of a centralized repository for this information makes it more difficult, but not impossible, to extrapolate this data to riparian resources on a statewide basis.

B. GIS - An Evaluation Tool

As discussed earlier in this report, compiling natural resource data into a GIS expands our ability to evaluate these areas because it has the capacity to display geographically-based data at a variety of scales. We can view the entire state or we can zoom in on a specific area. In addition, a database can be linked to a geographical location allowing the incorporation of detailed data on a particular site. In fact, the current technology even allows us to overlay a photographic image of a location while viewing the corresponding computerized map on a computer screen.

The potential to reference site specific data to a map location expands our ability to compile and analyze information. More importantly, we can expand this database to incorporate information on sites collected by other agencies or researchers, as long as the data are compatible and can be georeferenced. (Care must be exercised in the incorporation of data to ensure that the date of data collection is referenced.) In addition, the database can be expanded to include new fields for data that can be derived from existing maps or GIS databases or for data that become available in the future. For instance, orientation, stream order and valley confinement can be derived from topographic maps and added to the database. One very important data set that is not available at this time, but that could be added in the future is soils information. Soils data have been digitized for a few areas, but specific data are not yet available on a statewide basis.

GIS gives us a powerful evaluation tool that allows us to combine various levels of data, from general to more specific. However, precision of data can often be a problem, therefore, data should **always** be field verified. That means the site represented on a map should be visited to ensure that information is correctly represented.

During the riparian map verification process, field biologists collected general site information while ground-truthing riparian vegetation. This information included a list of all woody species present categorized by size class, frequency of size class, and height. In addition, they listed adjacent land uses, special habitat features, adjacent upland vegetation and land uses evident at the site. Presence of seedlings and saplings of native riparian woody vegetation was noted as was the presence of emergent aquatic plants. General habitat condition was rated based on bank stability, bank vegetative stability, streamside cover and pool/riffle factors. Field biologists gathered general stream information including channel substrate and presence of special features such as organic debris, beaver dams, backwater marshes and man-made structures. When entered into a database, these data can be referenced to the map site at which it was collected. Because field biologists will be checking 20% of the total acreage of riparian vegetation mapped, this will give us an excellent information source on a number of characteristics of riparian areas. Details on the type and method of data collection are being compiled in a technical document (AGFD in press).

C. Assessment of Functionality - Two Approaches

Based on direction from the legislation, the approach to a riparian designation system must take into account an assessment of functionality. This aspect of riparian evaluation systems has been greatly neglected. However, two recent federal reports describe approaches to assessing functions of riparian and wetland areas. They are BLM's "Process for Assessing Proper Functioning Condition" and COE's "A Hydrogeomorphic Classification for Wetlands" (Brinson 1992). A brief discussion of each is presented here.

The BLM approach is based on an assessment of the riparian areas's capability and potential. Capability is defined as "the highest ecological status a riparian-wetland area can attain given political, social or economical constraints." Potential is "the highest ecological status an area can attain given no political, social or economical constraints, often referred to as potential natural community (PNC)" (Prichard et al. 1993). The approach is based on data and information collected during the Ecological Site Inventory process and is used to analyze whether a riparian area is properly functioning based on the following definition:

"Riparian-wetland areas are functioning properly when adequate vegetation, landform, or large woody debris is present to:

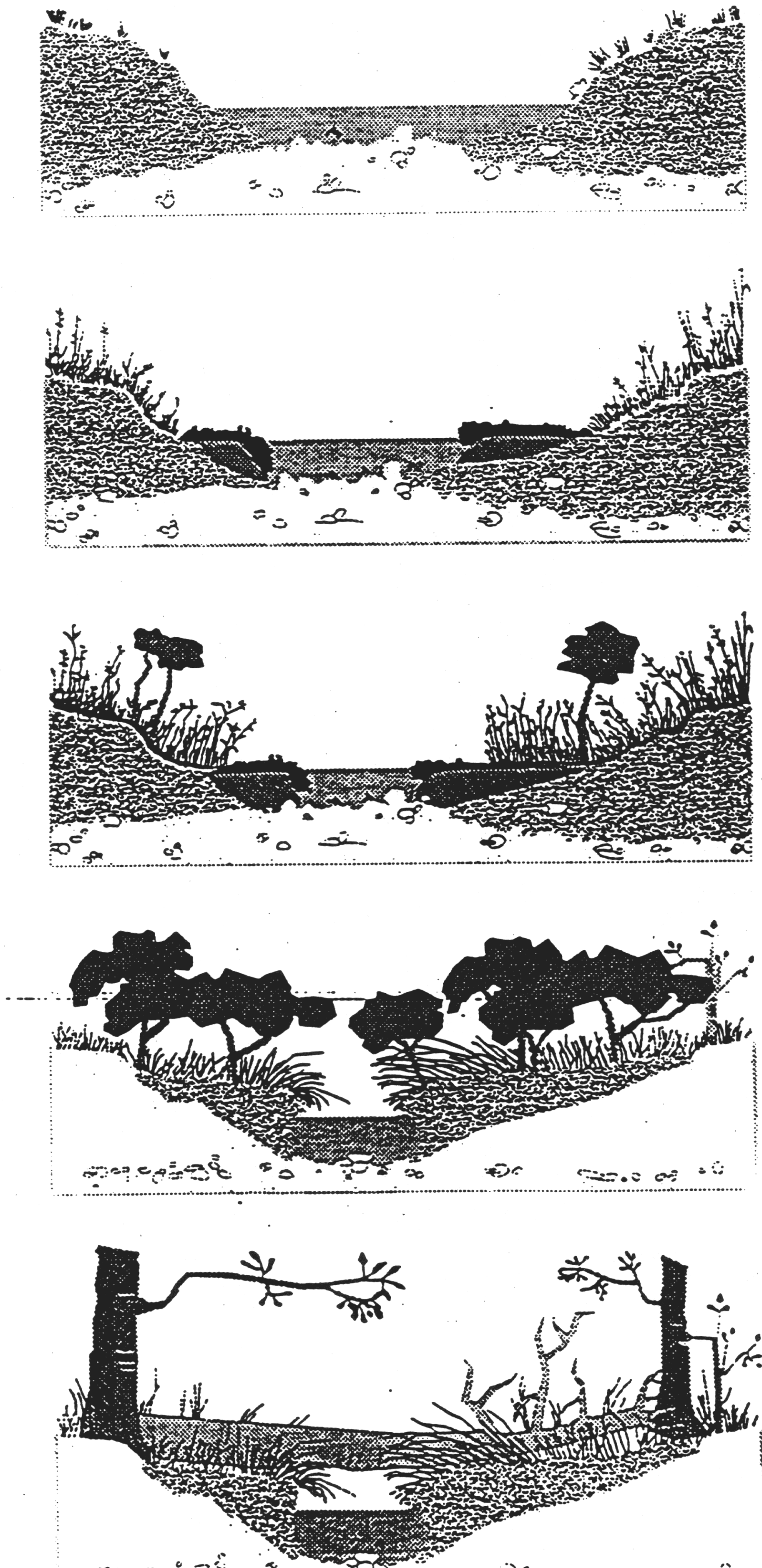
1) dissipate stream energy associated with high waterflows, thereby reducing erosion and improving water quality;
2) filter sediment, capture bedload, and aid floodplain development;
3) improve floodwater retention and groundwater recharge;
4) develop root masses that stabilize streambanks against cutting action;
5) develop diverse ponding and channel characteristics to provide a habitat and the water depth, duration and temperature necessary for fish production, waterfowl breeding, and other uses, and;
6) support greater biodiversity" (Prichard et al. 1993).

The next step in the assessment is to analyze the attributes and processes occurring in the riparian-wetland area according to five general categories: (1) hydrogeomorphic factors, (2) vegetation factors, (3) erosion/deposition factors, (4) soil factors and (5) water quality characteristics. The results of this procedure will allow the land manager to determine which one of the following functional categories is represented at that site:

1) The area is properly functioning.
2) The area is functional-at-risk. Trend is also reported in this category (recovery versus continued degradation) and is a key consideration in interpreting the data.
3) The area is nonfunctional, most of the riparian values have already been lost.
4) Condition unknown.

The functional categories have direct management implications. Areas identified as functional-at-risk with a downward trend tend to be the highest management priorities for BLM. In these cases, a change in management practices may reverse the decline, especially when the system has not been so degraded as to lose its resiliency, i.e., its natural ability to recover from disturbance. Functional-at-risk areas exhibiting an upward trend of recovery are often a priority for monitoring to ensure that the recovery continues. Areas determined to be properly functioning are evaluated to determine whether they are meeting site specific objectives. This involves evaluation of riparian vegetation seral stage. Seral pertains to a succession of plant communities in a given habitat leading to a particular climax association (Figure 31). Prichard et al. (1993) explain that, if the objective is to maximize wildlife diversity in the area, the site will be managed so that vegetation advances to late seral stage. If the intent is to maximize vegetation for grazing, the intent is to maintain the system in proper functioning condition, but to limit the development of vegetation to early seral stages (Prichard et al. 1993).

Figure 31. **Seral stages of riparian vegetation along a stream channel (Prichard et al. 1993).**



A
Bare Ground

B
Early Seral

C
Mid-Seral

D
Late Seral

E
PNC or PPC

A totally different approach, termed the hydrogeomorphic approach, is currently being developed by the COE (Brinson 1992). A draft of the report is available for review but further modifications may be made to this document. For our purposes, it is assumed that the general approach outlined in the draft report is the direction that will ultimately be proposed for classification and evaluation of riparian and wetland areas.

The hydrogeomorphic system is basically a means of developing an assessment methodology. Brinson (1992) proposes an approach that categorizes wetlands and riverine systems based on similarity in functional properties. To do this, a more simplified concept of wetlands and riparian areas must be applied. This requires a broad-scale evaluation of these areas recognizing that, while each area may be unique, there are characteristics by which streams and wetlands can be grouped. Brinson states that these characteristics should include consideration of geomorphic setting, water source and its transport and hydrodynamics. There are no pre-set categories under this approach because, as it is applied in various physiographic regions, different categories of wetlands and riparian areas will emerge.

Categorization of wetlands and riparian areas into functional groups requires the use of indicators and other surrogates of ecosystem function. Indicators help in determining the type of wetland or riparian area and in evaluating the ecological significance of the area. Slobodkin et al. (1980) suggest that the development of a species list for an ecosystem is the most useful approach to answering questions about function. That is, the habitat and life cycle requirements of a species can provide useful insight and information about the environmental conditions at that site.

The first step in this approach is to establish the functional attributes for a given category. This is accomplished by establishing a system of reference areas and then providing a detailed analysis of those areas. Reference areas are sites where "indicators have been tested, measured and related to corresponding ecosystem functions" (Brinson 1992). These are areas where research efforts should be focused to facilitate the development of better indicators or to discover unknown functions. Reference areas represent benchmarks against which other wetlands are to be compared.

The detailed analysis of these areas is termed "profile development." Profile development is a description of the reference site presented in a narrative form. In this way, any and all information and data collected at a site can be incorporated into the profile, ranging from a site visit to a detailed study. Profiles are intended to be the goal or endpoint of this approach. The intention is for a particular region of the country to develop an array of profiles to describe the various categories of wetlands and riparian areas occurring within the region. The development of this information base should begin to reveal dominant hydrologic processes and their relationships to ecological factors within the ecosystem. This information is then used to define the categories of wetland and riparian types.

The resulting categories would be identified with a unique list of functions and associated indicators. All efforts should be made to include types of wetlands or riparian areas that presently occur within a region or occurred there at one time. Once identified, these areas need to be protected and monitored to facilitate our understanding of these systems and to provide a "type specimen" of this type of ecosystem. Other wetlands or riparian areas within the same category can then be compared to these representative areas for purposes such as assessment, training and mitigation.

This approach incorporates the following factors.

1) It provides a management assessment procedure.
2) It provides standards to evaluate wetland and riparian area construction and restoration projects.
3) It is useful for training scientists who will be working on permit review, assessment of functions, construction of new wetlands and restoration of degraded ones.
4) The structure of the approach can be modified as new data become available and the systems become better understood.
5) It can be adapted to a variety of physiographic and geographic regions.

The process of establishing reference areas must take into consideration that the functional potential of most rivers in Arizona has been greatly reduced and that even the best reference sites may be functioning below their potential. Regardless, it is imperative to identify reference sites for the various riparian vegetation and geomorphic stream types in the state and manage them so as to enhance their natural biological potential by excluding factors that could potentially decrease this potential. This is the only way one can begin to discriminate between degraded versus healthy ecological condition and to truly assess the impacts of various land and water use activities through comparison with a non-degraded control site.

D. Recommended Approach

In summary, the development of a hierarchical designation system based on riparian functions and values should take into account a number of items.

1) New information on riparian functions is almost constantly being presented as research continues on this subject. Therefore, the approach should be flexible enough to allow for the incorporation of new information.

2) According to the legislation, the approach must incorporate functions and values of these resource areas. Use of indicators and rapid assessment methods has been discussed.

3) Because there is so much federal land in the state, the approach should be compatible with federal activities, or should be able to incorporate the data and information collected by federal agencies into the approach. Federal agencies have begun to collect a variety of data and information about riparian and wetlands across the state. Some regions have been inventoried more intensively than others, but, in general, there is a growing body

of information about Arizona's riparian resources. However, at this time, data collection techniques appear to be inconsistent and incompatible.

4) Completion of the three project areas under this legislation (AGFD, ADWR, ADEQ) adds a great deal of information to our knowledge base. Riparian vegetation, land ownership and land use maps are contained in a digitized format. Additional data can be calculated from topographic maps and GIS covers to add to this information source. Upon completion of ground-truthing, general data on 20% of riparian vegetation across the state will be input into a database and geographically referenced to the maps. This provides us with a powerful tool to apply to riparian assessment.

5) Recent controversial proposals included in the Clean Water Act reauthorization have attempted to classify or rank wetlands according to their functions and values, and then regulate these categories differently. The primary question is whether all wetlands should be treated the same or not. If all wetlands have some functions and values, do some have more than others, and consequently should those with lesser values be accorded less stringent regulatory protection? This controversy raises issues directly applicable to riparian area protection strategy development for Arizona.

   Advocates of ranking contend that not all wetlands are of equal ecological or social value and therefore are not deserving of equal protection. Regulatory approaches are currently being challenged on the basis of uncertainty and a perceived unfairness in regulating wetlands with little apparent public value. Opponents of ranking point out that it is impossible to place values on individual wetlands, much less compare or evaluate different wetlands locally or regionally. To develop a system of ranking would require years and tremendous expense, not to mention the administrative burden on resource agencies. Further, because rankings are overly simplistic and scientifically invalid, legal challenges would be a likely outcome. Because wetland restoration efforts have generally not been successful, eliminating the "low-value" wetlands from protection will inevitably result in net loss of wetland resources.

6) The designation system chosen should address a number of other considerations.

   (a) A consistent geographic unit of evaluation should be discussed. Some approaches use an ecological unit which roughly equates to a stream reach and is based on similarities in hydrology, geomorphology and vegetation. Others are based on management objectives.
   (b) The evaluation system should have a systems perspective and should be able to take into account the effect of upstream and downstream activities of an assessment area.
   (c) It should be capable of dealing with potential functions since systems are often degraded.
   (d) Temporal variability of the system needs to be considered because the system is dynamic.

7) One of the most important items for consideration is that several federal agencies are in the process of formulating functional assessment methods for application to riparian areas. These methods have been devised by interdisciplinary teams of scientists and land managers and are currently undergoing public review. We cannot and should not ignore this work, nor can we speculate on their final form and content after public review and comment. However, these approaches represent the best available methods for assessing functionality within riparian and wetland systems at this time.

8) Information needs should be balanced with the development of action strategies. "Enough information needs to be amassed to allow for sound policy choices, but collecting too much information can stall action. It's important to remember that decisions can be made and actions taken before all the needed information has been gathered. Gathering information can take a lot of time and resources, delaying strategy development for years. To the extent possible, a state should draw on existing data and the professional judgement of people familiar with the state's wetlands. As gaps in data are identified, objectives can be set for collecting and analyzing any missing data and information" (World Wildlife Fund 1992).

Based on these considerations, AGFD proposes a preliminary outline as a first step in the development of a hierarchical designation system for riparian assessment based on functions and values. The preliminary approach is outlined below and illustrated by the flowchart in Figure 32.

Step 1. Assess the functional condition of a given unit of riparian area (stream and terrestrial land area).

(a) Functional assessment should be based on hydrologic, geomorphic, vegetative and biotic features of a riparian ecosystem.

(b) The assessment should be based on the application of reference areas, profile development and formation of general riparian categories as proposed by Brinson (1992).

(c) Other data sources should be brought into consideration to complete determinations of functional condition. An interdisciplinary, interagency team should be brought together to discuss data and information about various riparian areas within their jurisdiction to facilitate the choice of reference areas, profile development and categories. Team discussions may also facilitate determinations of functional condition of a riparian area based on previous data collection and research efforts.

(d) Determinations of functional condition should take into account the capability and potential of the areas. Definitions of these terms were presented previously in this report (see Prichard et al. 1993.)

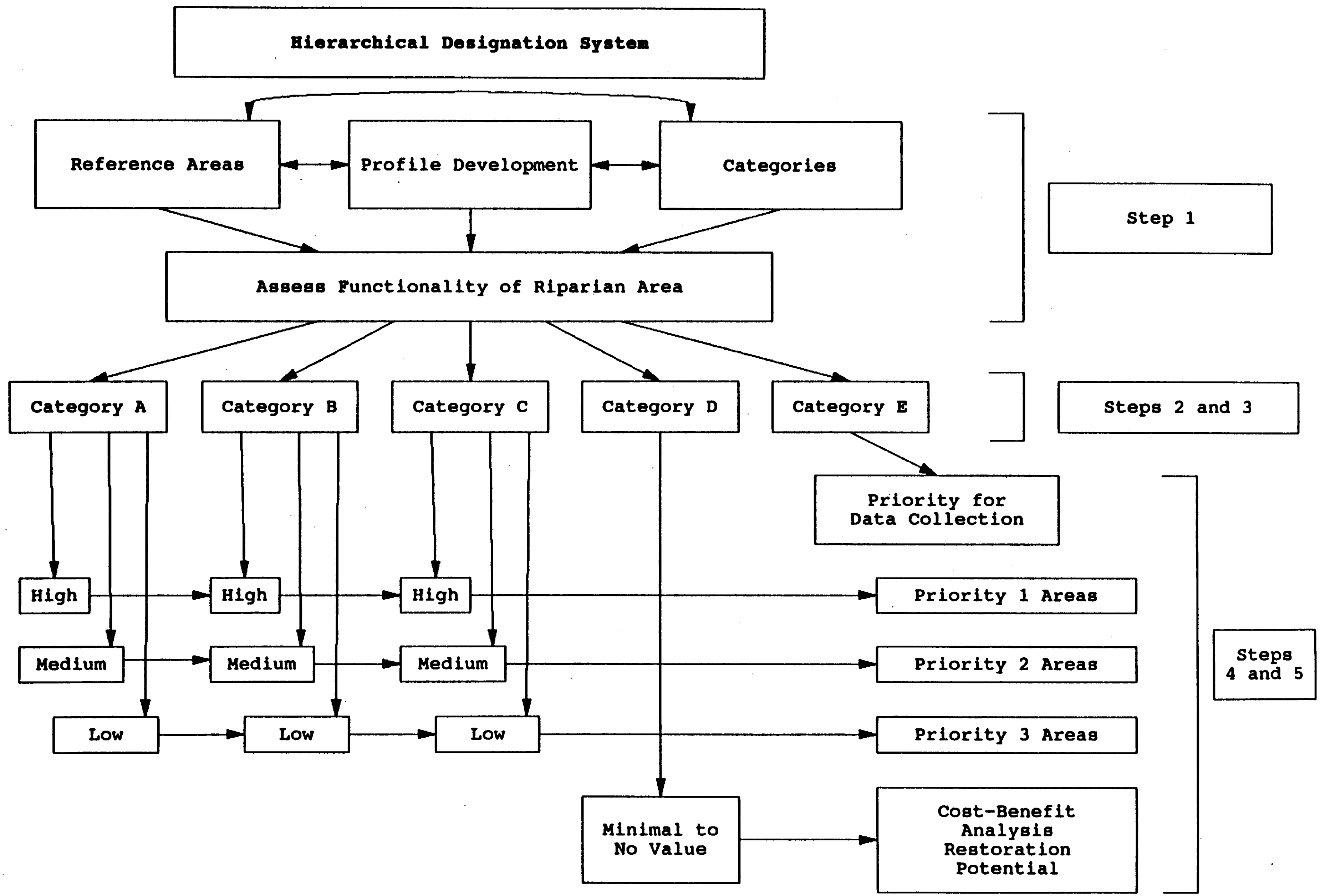


Figure 32. Flowchart of steps in the preliminary hierarchical designation system.

Step 2. Categorize areas based on their general functional condition (BLM approach).

CATEGORY A:	The area is determined to be properly functioning.
CATEGORY B:	The area is functional-at-risk, trending toward recovery.
CATEGORY C:	The area is functional-at-risk, trending toward further degradation.
CATEGORY D:	The area is nonfunctional, most of the riparian values have already been lost.
CATEGORY E:	Condition unknown.

Step 3. Each of these categories has implications as to protection and management actions, as follows.

CATEGORY A:	Actions may include monitoring of condition and quality to ensure the area does not degrade, or protection as a reference area. These represent our highest quality areas, but they may already be degraded from their potential.
CATEGORY B:	Actions may include support of management practices that are contributing to the positive trend toward recovery. Identify and minimize effects of negative influences on system.
CATEGORY C:	Actions may include modifying or eliminating those activities that are contributing to degradation.
CATEGORY D:	Actions may include a cost-benefit evaluation to assess whether restoration is feasible or desirable. These represent our most degraded systems.
CATEGORY E:	Additional data or information is needed on these areas to properly assess their condition. These areas may become priorities for further study.

Step 4. Within each category, assess whether high, medium or low values exist.

(a) The types of values to be assessed must be determined. Typically, areas are evaluated on the basis of wildlife and aquatic habitat, recreational value, and aesthetic value. However, there are other commercial and economic values. Assessment methods for values should be devised by proper experts in each area.

(b) AGFD has dealt with determining value for wildlife habitat in this report and will continue to refine a rapid assessment methodology for that component. Additional information available for use in determining valuable wildlife habitat includes:

(1) locational data on critical habitat and sensitive species contained in the AGFD Heritage Data Management System, and;

(2) location of areas of high biodiversity from the GAP Analysis Project (Graham in prep.) to be completed in June 1994.

It should be noted that sensitive species data are based on intensive survey data and may not be comprehensive for the state, because not all areas of the state have been equally surveyed for all species.

(c) Possible data sources for determination of recreational and aesthetic values include the Arizona Rivers Assessment Database (ASPB) and various Arizona-based documents related to proposals under the Wild and Scenic Rivers Act.

Step 5. Prioritize areas for protection or management action based on assessment of values and functional category.

(a) Priority ranking should be based on the number of high values given to an area, not on a numerical average. This will produce a range of priority rankings, the number of which will depend on the number of values assessed. For instance, if wildlife, recreation and aesthetic quality are assessed, priority rankings may range from 3 high quality determinations to 3 low quality determinations with a number of combinations in between.

(b) Since priority rankings will occur within each functional category, determinations must be made as to which category takes priority. In other words, do areas that are fully functional with high value rankings take priority over areas that are degrading but possess high value rankings? There has been much discussion among scientists and land managers regarding this very issue. Some propose that functional-at-risk areas should get first priority so that trends of degradation can be reversed before the area becomes totally nonfunctional. Others state that fully functional areas should be given priority because so few of them are protected or monitored and they represent the best examples of functional systems. Still others believe that risks to the system should be evaluated and priority should be given to those areas with highest values that are most at risk of degradation or destruction.

E. The Next Step

The completion of this report does not signal the completion of AGFD's work on inventorying and assessing riparian areas in Arizona. In fact, in the next year, AGFD staff will be working toward bridging information gaps that will help us achieve an implementable hierarchical designation system. The following is a list of action items that are either in process or are proposed for next year:

1) AGFD will continue to refine the perennial database and map riparian areas in Arizona, including areas associated with intermittent waters. The map verification process will continue until map accuracy reaches at least 80%.

2) Although a great deal of information necessary to achieve the goal of a designation system is currently available, it must be compiled and assessed. AGFD will continue to assess the full capability of the remote sensing technology and accompanying databases and videotapes.

3) To assist with our understanding of riparian functions, AGFD applied for and was awarded a grant from the EPA under the Clean Water Act, 104(b)(3) Wetlands Grant Fund. The grant will allow us to develop a functional assessment methodology and a methodology to determine status and trends of riparian areas statewide.

4) An interdisciplinary, interagency team should be brought together to:

   (a) identify possible reference areas and to exchange data and information about status of riparian areas;

   (b) develop minimum data collection needs for referencing riparian data to GIS.

   AGFD proposes that this action item be a component of investigations occurring in conjunction with wetlands grant activities listed in item 3.

Section VI

Existing Options for Riparian Protection

A. Introduction

The legislation under which this report is prepared requires that AGFD identify "existing options for protecting riparian areas in each ownership category that may be available under existing state and federal laws." The following listings (inventory) of state and federal riparian and wetland protection programs and mechanisms includes those currently being used in Arizona as well as potential programs. Potential programs are those existing national programs that have not been, but potentially could be, applied in Arizona. Protection mechanisms are grouped into the following categories: regulation; policy and guidelines; acquisition; planning; restoration, creation and management; incentives and disincentives; technical assistance, education and outreach; and research. Also indicated are the land ownership category (federal, state, tribal, and private) that each of the protection mechanisms apply to either directly or indirectly. These lists were developed based on previously compiled listings from a variety of local and national reports as well as recent input AGFD gathered from participating state and federal agencies serving on the Riparian Areas Advisory Committee.

This section does not attempt to assess existing programs as to their particular effectiveness nor does it describe each of the programs. Additional information sources are noted under item E of this section: Synopsis of Wetland/Riparian Protection Program Reports. These reports include information on each of the listed protection options, who administers them, and how and where they may be used for wetland/riparian protection. Further, some of the reports include evaluations of the effectiveness of specific programs and propose strategies for improving their effectiveness in protecting riparian areas.

B. Listing of State and Federal Riparian Protection Mechanisms in Arizona

STATE MECHANISMS APPLIED IN ARIZONA
By Category and By Landownership
(F=federal, S=state, I=Tribal, P=private)

F	S	I	P	Mechanism
				Regulation
				ARS Title 49 - Water Quality Control
X	X		X	Water Quality Standards for Waters of the State
X	X		X	CWA Section 401 Water Quality Certification
X	X		X	CWA Section 402 Point Source Discharge (NPDES)
X	X		X	CWA Section 208 and 319 - Nonpoint source pollution impacts
X	X		X	ADEQ Aquifer Protection Program
X	X		X	ARS 17-237 - Pollution of Waters
	X		X	State Flood Control Statutes: ARS 45-1401 through 1501
	X		X	ARS 48-3601 through 3628 - County Flood Control Districts: Flood Control Planning and Management
X	X		X	ARS 37-1101 through 1156 - Ownership of Streambeds
X	X		X	ARS 9-21-303 - Unique Waters
X	X		X	ARS 9-21 - Water Pollution Control
X	X		X	ADEQ Point and Nonpoint Source Programs
				ARS Title 45 - Water Rights:
X	X		X	Adjudication of surface water
X	X		X	Sever and transfer
X	X		X	Instream flow rights
X	X		X	Groundwater Management Act
				Policy and Guidelines
	X			Executive Order No. 89-16: Streams and Riparian Resources
	X			Executive Order No. 91-6: Protection of Riparian Areas
X	X		X	ADEQ Best Management Practices for grazing; and for sand and gravel operations - DRAFT
X	X		X	AZ Water Quality Control Council Policy for Construction and Related Activities in Water (1977)
				Acquisition
X	X	X	X	AGFD and ASPB Heritage Fund and Natural Area Programs
X	X		X	Waterfowl Conservation Fund (AZ Duck Stamp)

F	S	I	P	
				Planning
	X			Report of the Governor's Riparian Task Force 1990
X	X		X	Verde River greenway/corridor plans
X	X		X	Santa Cruz River greenway/corridor plans-initial study phase
	X			ASLD Riparian Ecosystem Strategic Plan 1989
X	X		X	State Comprehensive Outdoor Recreation Plan (SCORP) 1989
X	X		X	ASPB Arizona Wetlands Priority Plan 1988
X	X		X	ASPB Arizona Rivers Assessment - DRAFT
	X			ADOT Wetlands Preservation Policy
	X			AGFD Policies for: Riparian Habitat, Verde River, Wildlife Compensation Policies
				Restoration, Creation, and Management
X	X		X	ADEQ Water quality programs - Unique waters, Antidegradation standards, Nonpoint Source Management Zones
X	X		X	AGFD Game, Nongame, Fish and Endangered Species Fund
X	X	X	X	AGFD and ASPB Heritage Fund and Natural Areas Programs
X	X		X	State Lake Improvement Fund (SLIF)
X	X		X	Waterfowl Conservation Fund (AZ Duck Stamp)
		X		Wastewater treatment projects
				Potential-
X	X		X	AZ Navigable Stream Adjudication Commission Riparian Trust Fund
X	X	X	X	CAP Environmental Trust Fund*
				Incentives and Disincentives - none identified
				Technical Assistance, Education, and Outreach
X	X	X	X	Environmental Education Act
X	X	X	X	Interagency Committee on Environmental Education
X	X	X	X	AGFD and ASPB Heritage Fund
X	X	X	X	AGFD Project Wild, Aquatic Project Wild
X	X	X		ASPB Arizona Rivers Assessment and Natural Areas inventory
X	X	X	X	ASPB Verde River and Santa Cruz River corridor studies
X	X	X	X	AGFD Heritage Data Management System
X	X	X		Natural Resource Conservation Districts

F	S	I	P	
				Research
X	X	X	X	State universities
X	X	X	X	Scientific and policy research programs
X	X		X	AGFD Game, Nongame, Fish and Endangered Species Fund

* The Governor's Central Arizona Project Advisory Committee Final Report and Recommendations (October 1993) included a proposal for an Environmental Trust Fund to be administered by ADWR for the maintenance, enhancement and restoration of aquatic, wetland and riparian habitats.

FEDERAL MECHANISMS APPLIED IN ARIZONA
By Category and By Landownership
(F=federal, S=state, I=Tribes, P=private)

F	S	I	P	Mechanism
				Regulation
				Clean Water Act (CWA):
X	X	X	X	Section 404
				Regional and General Conditions
				General Permits
				Advanced Identification
				Guidelines (Mitigation/Monitoring, Mitigation Banking)
X	X	X	X	Section 401 (Water Quality Certification)
X	X	X	X	Section 402 (National Pollutant Discharge Elimination System)
X	X	X	X	Section 301 and 303 (State Water Quality Standards)
X	X	X	X	Rivers and Harbors Act - Section 10 (Colorado River only)
X	X	X	X	Endangered Species Act
X	X		X	Federal Power Act:
				Federal Energy Regulatory Commission (FERC)
				Electric Consumers Protection Act
X		X		Federal Reserve Water Rights
X	X	X	X	Fish and Wildlife Coordination Act (FWCA)
X	X	X	X	National Environmental Protection Act (NEPA)
X	X	X	X	National Flood Insurance Program
X				Water Resources Development Act
X	X		X	Wild and Scenic Rivers Act
X	X		X	Wilderness Act
				Acquisition
X	X			Emergency Wetlands Resources Act
X	X			Federal Aid in Sport Fish and Wildlife Restoration Acts
X	X			Land and Water Conservation Fund (LWCF) Act
				Potential-
X	X	X	X	North American Wetlands Conservation Act
	X	X	X	Watershed Protection and Flood Prevention Act

F	S	I	P	
				Planning
X	X			Emergency Wetlands Resources Act - National Wetlands Priority Conservation Plan
X	X	X	X	Endangered Species Act
X	X	X	X	EPA Wetlands Program State Development Grants
X	X			Land and Water Conservation Fund (LWCF) Act
				State Comprehensive Outdoor Recreation Plans (SCORP)
				State Wetland Priority Plans
		X		National Flood Insurance Program
X				BLM San Pedro National Riparian Conservation Area
X	X	X	X	Verde River Advanced Identification - Section 404
X				Wetland/riparian management policies for BLM, USFS, SCS, and USBR
				Restoration, Creation, and Management
	X			BIA Fish, Wildlife and Recreation Program
X				Executive Order 11988: Floodplain Management
X				Executive Order 11990: Protection of Wetlands
X	X	X		Federal Aid in Sport Fish and Wildlife Restoration Acts
X				Federal Land Policy and Management Act
X	X		X	Flood Control Act
X				Multiple Use Sustained Yield Act
X				National Forest Management Act
X				National Wildlife Refuge System Act
X	X		X	North American Waterfowl Management Plan
X				Organic Administrative Act
		X		Private Lands Assistance and Restoration Program
X				Public Rangelands Improvement Act
X	X	X		Resource Conservation and Development Program:
				Natural Resource Conservation District programs
X	X		X	Soil Conservation Service guidelines
		X		Wastewater Treatment Projects
X				Water Resources Development Act
X	X		X	Wild and Scenic Rivers Act
				Potential-
X				North American Waterfowl Management Plan
				Food Security Act (Farm Bill):
		X		Conservation Reserve Program
		X		Wetlands Reserve Program
X	X	X	X	North American Wetlands Conservation Act
		X		Stewardship Incentive Program
	X		X	Watershed Protection and Flood Prevention Act

F	S	I	P	
				Incentives and Disincentives
		X		National Flood Insurance Program
		X		Internal Revenue Code
X	X		X	Soil Conservation Service programs
				Potential-
				Food Security Act (Farm Bill):
		X		Swampbuster
		X		Agricultural Conservation Program
				Technical Assistance, Education, and Outreach
X	X	X		Emergency Wetlands Resources Act
				National Wetlands Inventory (NWI)
	X	X		EPA Wetlands Program State Development Grants
X	X	X	X	EPA technical assistance programs: Wetlands Protection Hotline
X	X		X	Wild and Scenic Rivers Act
X	X		X	Various Agency Programs by BLM, NPS, USFS, USFWS, USBR, COE, SCS, and USDA

C. Discussion

These relatively long lists of riparian protection mechanisms give the deceptive impression that sufficient protection is already in place for Arizona's diminishing riparian resources. Doppelt et al. (1993) state that "all levels of government have failed to stem the degradation of America's riverine systems and the extinction of riverine-riparian biodiversity. ...[T]here are no national policies that mandate coordinated federal, state, and private management and conservation of whole riverine systems. ...[N]o policies effectively integrate riverine protection and restoration with local economic benefits and community revitalization." While this latter perspective applies to the nation, a recent report by the Riparian Habitat Task Force (1990) substantiated the fact that there are no specific statutory mandates to protect riparian ecosystems in Arizona. What we do have is a mixed assortment of agency programs that are very restrictive in scope and effectiveness and at best offer limited or indirect levels of protection.

Existing riparian protective mechanisms are generally a component of a broader natural resource program with few mechanisms being riverine-riparian specific. Protective mechanisms tend to focus on reducing, and not necessarily eliminating, the negative effects of projects and activities on riparian areas. Many of Arizona's existing riparian protection mechanisms address only one or a few of the functional aspects of riparian areas such as:

- flood control
- water quantity
- water quality
- wildlife habitat
- biological diversity
- groundwater recharge
- erosion control
- bank stabilization
- recreation

Further, other programs apply only to specific land ownership categories, management agencies, discrete stream segments or are merely planning or policy guidelines that afford no real protection.

The Statewide Wetlands Strategies guidebook (World Wildlife Fund 1992) suggests that conducting an inventory of current programs, such as presented in this report, is a fundamental step in developing a statewide protection strategy and should lead to the following:

1) Identifying and establishing contact with groups whose programs affect riparian areas.
2) Discovering successful programs that may serve as models.
3) Identifying areas where cooperative efforts are possible.
4) Identifying weaknesses of programs or inconsistencies and gaps among them.
5) Locating sources of technical information and other useful resources.

After this information is gathered, the next logical step is to make existing programs more effective. Improving the effectiveness and efficiency of existing programs is an essential and important first step leading towards increased protection of riparian areas in Arizona. These improvements include intra- and interagency programmatic changes.

Intra-agency problems with existing riparian protection mechanisms include a lack of funding and personnel resources, technical support, authority, monitoring and evaluation capability, enforcement, consistency, predictability and timeliness. Furthermore, programs and guidelines for federal, state and local entities often conflict, are redundant, and are uncoordinated. These conflicts result in delays, case by case reconciliation, or worse, inaction. Some protection programs are cumbersome in that they are adopted haphazardly and incoherently, or have significant limitations that include large gaps in protection.

Interagency improvements of existing programs will require a high degree of cooperation and coordination with various agencies and groups--likely encountering many institutional barriers, policy and program conflicts, and limited or constrained resources. Making existing programs work better will require consideration of the following approaches.

Comprehensive approach requires: 1) coordination, integration and collaboration of various programs to achieve an overall goal for riparian area protection, 2) full utilization of the entire range of available mechanisms, 3) broaden scope of protection to include watershed or ecosystem, and 4) expansion of agency authority over riparian areas.

Flexible approach provides for: 1) a combination of programs and approaches as necessary and appropriate for an area, and 2) refining and coordinating programs by expanding successful programs and eliminating redundancy and inconsistencies in others.

Regional focus calls for the development of site specific, customized solutions while accounting for a variety of conflicting and competing local interests.

Doppelt et al. (1993) suggests that while improving existing policies is important, this will still not provide the strategies and policies needed to initiate an era of comprehensive watershed restoration leading to long-term maintenance and health of riparian ecosystems. There simply are no existing protection mechanisms that effectively protect all critical functions of riparian areas.

As a case in point, the Clean Water Act Section 404 program, while recognized as the nation's primary mechanism for protecting and improving water quality, is generally applied only to the low flow channel (ordinary high water) of streams in Arizona and delineated wetlands (which do not include riparian areas). Even within these applicable areas, many activities damaging to riparian areas are exempted from Section 404 regulatory authority or allowed to occur when prescribed terms and conditions are followed. Further, the large majority of Arizona's riparian areas lie outside Section 404 jurisdictional areas and therefore are not included within its limited regulatory protection.

The reader should note that there are also a few existing local and private mechanisms that afford some degree of riparian area protection within Arizona. Pima County has a Floodplain and Erosion Hazard Management Ordinance, a Comprehensive Plan including open space, and a Trail System Master Plan. A Tucson ordinance limits developments within areas of listed washes. The City of Scottsdale has an Environmentally Sensitive Lands and a Native Plants Ordinance. Nonprofit conservation organizations such as the Nature Conservancy, Sierra Club, American Rivers, Arizona Riparian Council, Trout Unlimited, Arizona Wildlife Federation and others have acquired riparian areas, obtained instream flow water rights, provided technical and educational information, and/or provided funds for protection, restoration and management.

D. Summary of Findings

While this listing of regulatory and nonregulatory riparian programs in Arizona appears extensive, it is important to recognize that there are no regulatory programs at any level of government) specifically developed or implemented for the protection of riparian areas. Existing programs have only limited applicability to the protection of important riparian area functions by focusing only on the management and planning of water, soil and/or landscape--typically within a small geographic area. Furthermore, even though most of the listed programs have been in place for some time, it is widely recognized that some greater degree of riparian area protection is needed to preserve and maintain the health and integrity of our existing, yet declining, riparian resources in Arizona.

E. Synopsis of Wetland/Riparian Protection Program Reports

Arizona State Parks, Statewide Planning Section. 1988. Arizona wetlands priority plan - an addendum to the 1983 SCORP.

A plan developed to comply with the Emergency Wetlands Resources Act of 1986 and to be compatible with Statewide Comprehensive Outdoor Recreation Plans (SCORP) and the National Wetlands Priority Conservation Plan. This Arizona planning document includes: a description and an assessment of federal, state, local and private program effectiveness in protecting wetlands; a discussion of wetland resources; priorities for wetlands protection; state and local alternatives for wetlands protection;

Commission on Arizona Environment. 1991. Final report on agency authorities and programs relating to riparian resources. Prepared for the Arizona Governor's Riparian Habitat Task Force by the Arizona Department of Environmental Quality. (January)

A supporting document based on an instate survey of 10 state, 2 county and 11 federal agencies and Indian communities conducted for the Arizona Governor's Riparian Habitat Task Force. The report provides narrative summaries of agency and tribal statutory authorities, policies, programs and activities, and identifies problems associated with riparian management in Arizona.

Doppelt, B., M. Scurlock, C. Frissel, and J. Karr. 1993. Entering the watershed: a new approach to save America's river ecosystems. The Pacific Rivers Council. Island Press.

This newly released book is the product of a project to develop new federal river protection and restoration policy alternatives and represents one of the first national publications dealing strictly with riparian ecosystem protection strategies. The book assesses the capability of the nation's riverine conservation approaches and policies to address impacts to, and depletion of, riverine-riparian biodiversity. The authors conclude that existing riverine protection laws and policies are inadequate and have failed. A comprehensive new approach is proposed that includes: a strategic national community- and ecosystem-based watershed restoration initiative. The appendices include an extensive assessment and description of the nation's existing federal, state and local riverine policies and programs on federal, state and private lands.

Environmental Protection Agency. 1992. The private landowner's wetlands assistance guide: voluntary options for wetlands stewardship in Maryland.

A description of existing voluntary options and programs for private landowners who are interested in conservation with information about Federal, State, and private/nonprofit assistance programs which are available. The guide may be viewed as a way to help private landowners conserve and manage wetlands and other natural resources while attempting to simultaneously meet their economic needs and goals. Assistance includes technical information, financial incentives, and education and outreach opportunities.

Governor's Riparian Habitat Task Force. 1990. Final report and recommendations of the Governor's Riparian Habitat Task Force.

A multi-agency collaborative report with recommendations on establishing a comprehensive program of riparian resources management and preservation in Arizona. Recommendations include: approval of a state riparian policy, adoption of an Executive Order for the protection of riparian areas, implementation of priority management strategies, and coordination with federal and local agencies, tribal councils, and private organizations.

Governor's Riparian Habitat Task Force. 1990. Draft briefing paper: riparian management--implementation tools.

This paper explores programs, rules and policies currently available to implement six riparian area protection and enhancement Task Force policy statements. These policy statements represent the basis for a moderately comprehensive, yet practicable riparian protection program for Arizona. Information is provided on short and long term implementation and associated funding for: a statewide riparian inventory and classification, creation of a Watershed Enhancement Board, development of a State Riparian Area Protection Law, pursuing special protective designations for key riparian areas, enhancing local floodplain management planning, and legislation for a State Environmental Policy Act.

Kusler, J. A., C. Ray, M. Klein, and S. Weaver. In Draft (1993). State wetland regulation: status of programs and emerging trends. The Association of State Wetland Managers.

A report summarizing state or cooperative state/local wetland regulatory programs for all 50 states. Also indicated are trends and possible future directions for state programs based upon experience to date. The report includes summaries of wetland programs in each state as submitted by respondents, an evaluation of common and key components of state wetland regulatory statutes, emerging issues, and special projects, programs and nonregulatory initiatives.

National Audubon Society. 1992. Saving wetlands: a citizens' guide for action in California. Western Regional Office.

This manual is designed to guide individuals who are beginning their first action to protect wetlands, and to serve as a reference resource for long-time wetlands advocates. Included are chapters on: action strategies; wetland functions and values; federal, state and local levels of government regulatory and protective programs; loopholes and gaps in existing protection programs; and development of protection programs by the private sector. This manual is a supporting document for the Save Our Wetlands Campaign by the National Audubon Society.

Rich, J., and V. Coltman. 1991. Summary and recommendations: Clean Water Act Section 404 Discharge of Dredged and Fill Materials and Section 401 Water Quality Certification Programs in Arizona. Prepared for Arizona Department of Environmental Quality. (August 30, 1991)

An evaluation report on whether ADEQ's role in wetlands and riparian area protection could be strengthened and improved through Clean Water Act Section 401 certification and 404 permitting programs. Included are summaries and evaluations of Section 401 and 404 programs in Arizona and recommended procedural and regulatory protection improvements to make these programs more effective in protecting riparian areas.

Steiner, F., S. Pieart, and E. Cook. 1991. The interrelationship between Federal and State wetlands and riparian protection programs. Arizona State University Herberger Center. Prepared for Arizona Department of Environmental Quality. (July 26, 1991)

The report summarizes the results of a nationwide survey of state wetland and riparian protection programs. Regulatory and nonregulatory programs were queried and summarized by state. Federal Clean Water Act, Section 404 programs were also surveyed.

Want, W. 1990. Law of wetland regulation. Clark Boardman, Co., New York.

A treatise of wetlands law and regulation describing and analyzing protection regulations, case law, judicial decisions and agency regulations. The treatise includes practical advice on how to proceed through the regulatory process. Comprehensive and understandable, the treatise is a one-stop shoppers' source collection of all federal wetlands law.

World Wildlife Fund. 1992. Components of a California wetlands strategy - lessons from other states. Prepared for the California Resources Agency.

The report provides information about how other states have addressed the wetlands conservation issues now facing California. Sections include description of state wetland programs, state assumption of the Section 404 program, incentive programs, state acquisition and restoration programs, local and regional wetlands planning, state program general permits, Section 401 certification, and state and local wetlands regulatory programs. The information will be used to assist in the development of a statewide comprehensive wetlands protection strategy.

World Wildlife Fund. 1992. Statewide wetlands strategies: a guide to protecting and managing the resource. Island Press.

A management and planning guidebook on developing comprehensive, statewide wetland strategies. Sections include: creating a statewide wetlands strategy and selecting an overall goal; organizing a strategy development process; federal, state, local and private programs for wetland protection and management; and wetland data sources and collection methods.

List of Abbreviations

ADEQ	Arizona Department of Environmental Quality
ADMMR	Arizona Department of Mines and Mineral Resources
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
AGFD	Arizona Game and Fish Department
ALRIS	Arizona Land Resources Inventory System
ARS	Arizona Revised Statues
ASLD	Arizona State Land Department
ASPB	Arizona State Parks Board
ATV	All Terrain Vehicle
AzMILS	Arizona Mineral Industry Location System
BLM	Bureau of Land Management
CAP	Central Arizona Project
COE	United States Army Corps of Engineers
CWA	Clean Water Act
DLG	Digital Line Graph
EPA	Environmental Protection Agency
ESI	Ecological Site Inventory
FERC	Federal Energy Regulatory Commission
FWCA	Fish and Wildlife Coordination Act
GIS	Geographical Information System
GPS	Global Positioning System
LWCF	Land and Water Conservation Fund
MMU	Minimum Mapping Unit
MRAV	Multiple Resolution Aerial Videography
NDVI	Normalized Difference Vegetation Index
NEPA	National Environmental Protection Act
NPS	National Park Service
NWI	National Wetlands Inventory
PNC	Potential Natural Community

RASES	Riparian Area Survey and Evaluation System
SCORP	State Comprehensive Outdoor Recreation Plan
SCS	Soil Conservation Service
SLIF	State Lake Improvement Fund
S-VHS	Super Video Home System
TM	Thematic Mapper
UA-ART	University of Arizona-Advanced Resource Technology Laboratory
USBR	United States Bureau of Reclamation
USDA	United States Department of Agriculture
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WET	Wetland Evaluation Technique
WWF	World Wildlife Fund

Glossary of Terms

Abiotic: Not pertaining to life; non-biological.

Aggradation: The process wherein a stream deposits its excess load to its channel (Cole 1983).

Alluvium: Any stream deposited sedimentary material (McKnight 1990).

Aquifer: A permeable subsurface rock layer that can store, transmit, and supply water (McKnight 1990).

Bed load: The part of a stream load that is rolling and sliding along because it is too heavy to be carried by suspension (Cole 1983).

Brightness value: Remote sensing systems record the amount of reflected or emitted energy exiting from the earth's surface. These data are stored as digital values on computer compatible tapes for digital image processing purposes. The greater the brightness of the scene (or return from the scene), the higher the digital value. Hence the values stored on the computer compatible tapes are often referred to as brightness values (Jensen 1986).

Biotic: Of or pertaining to life; biological (Steen 1971).

Classification: The process of assigning individual pixels of a multispectral image to discrete categories (Jensen 1986).

Clustering: The statistical analysis of a set of pixels to detect their inherent tendency to form clusters in multidimensional measurement space (Jensen 1986).

Degradation: Erosion of a stream channel; the opposite of aggradation (Cole 1983).

Denitrification: Reduction of nitrates to free nitrogen (McKnight 1990).

Digital data: Data displayed, recorded, or stored in binary notation (Jensen 1986).

Digitization: The process of converting material from a continuous into a discrete format (Jensen 1986).

Ecosystem: A natural unit of living and nonliving components which interact to form a stable system in which a cyclic interchange of materials takes place between living and nonliving units (Steen 1971).

Ecotone: A transition zone (Steen 1971).

Electromagnetic spectrum: The ordered array of electromagnetic radiation extending from short cosmic waves into radio waves (Jensen 1986).

Episodic: Events occurring on an irregular basis and without clear relationship to other events.

Fluvial: Pertaining to running water, including both overland and stream flow (McKnight 1990).

Ground truth: Term used in a remote sensing investigations to imply that the data collected in the field are without error (Jensen 1986).

Geographic Information System: A data base management system used to store, retrieve, manipulate, analyze and display spatial information (Jensen 1986).

Geomorphic: Of or pertaining to the figure of the earth or the forms of its surface (Cooperrider et al. 1986).

Guild: A group of species having similar ecological resource requirements and foraging strategies and therefore having similar roles in the community (Cooperrider et al. 1986).

Hydrologic: Relating to the science dealing with the properties, distribution, and circulation of water on the surface of the land, in the soil and underlying rocks, and in the atmosphere (Cooperrider et al. 1986).

Image: The representation of one object by something else. Usually, the recorded representation of a scene by optical, electro-optical, optical mechanical, or electronic means (Jensen 1986).

Landsat: Unmanned, polar orbiting, U. S. earth resources satellite (Jensen 1986).

Maximum likelihood rule: A statistical decision criterion to assist in the classification of overlapping signatures; pixels are assigned to the class in which they have the highest probability of being a member (Jensen 1986).

Mesic: Characterized by moderately moist conditions; neither too moist nor too dry (Steen 1971).

Multispectral: Refers to remote sensing in two or more spectral bands, such as visible and near-infrared regions of the spectrum (Jensen 1986).

Nitrification: The process of oxidizing ammonia to nitrite, and nitrite to nitrate (Cole 1983).

Physiographic: Pertaining to a description of the features and phenomena of nature (Neufeldt and Guralnik 1986).

Pixel: A picture element having both spatial and spectral properties. The spatial variable defines the apparent size of the resolution cell (i.e., the area on the ground represented by the data values), and the spectral variable defines the intensity of the spectral response for that cell in a particular band (Jensen 1986).

Raster: A cell data structure composed of rows and columns, with the value of each cell representing a feature value. Groups of cells are used to represent each feature (Environmental Systems Research Institute 1991).

Reduced soils: Soils in which one or more electrons are gained or soils having an addition of hydrogen atoms or a loss of oxygen atoms (Steen 1971).

Reflectance: The ratio of the radiant energy reflected by a body to that incident on it (Jensen 1986).

Remote sensing: The measurement or acquisition of information of some property of an object or phenomenon by a recording device that is not in physical contact with the object or phenomenon under study (Jensen 1986).

Satellite: An object in orbit around a celestial body (Jensen 1986).

Sensor: Any device that gathers energy, electromagnetic radiation or other, converts it into a signal, and presents it in a form suitable for obtaining information about the environment (Jensen 1986).

Seral: Pertaining to a succession of plant communities in a given habitat leading to a particular climax association ; a stage in a community succession (Cooperrider et al. 1986).

Signature analysis techniques: Techniques that use the variation in the spectral reflectance or emittance of objects as a method of identifying the objects (Jensen 1986).

Spectral band: An interval in the electromagnetic spectrum defined by two wavelengths or frequencies (Jensen 1986).

Spectral reflectance: The reflectance of electromagnetic energy at specified wavelength intervals (Jensen 1986).

Spectral response: The response of a material as a function of wavelength to incident electromagnetic energy, particularly in terms of the measurable energy reflected form and emitted by the material (Jensen 1986).

Spectral signature: Term referring to the spectral characteristic of an object in a scene, which infers that each object reflects radiation in a unique and identifiable manner (Jensen 1986).

Suspended sediment: The very fine particles of clay and silt that are in suspension and move along with the flow of water without touching the stream bed (McKnight 1990).

Thermal cover: Features that reduce the amount of energy expended by an animal to adapt to extreme changes in temperature and wind.

Topographic: Pertaining to a representation of surface features of a region on maps and charts (Guralnik 1984).

Vascular plant: Any plant possessing a system of vessels (xylem and phloem) to conduct water and food (Steen 1971).

Vector: A coordinate-based data structure commonly used to represent map features. Each linear feature is represented as a list of ordered x,y coordinates. Attributes are associated with the feature (as opposed to a raster data structure, which associates attributes with a grid cell) (Environmental Systems Research Institute 1991).

Wavelength: Wavelength = velocity/frequency. In general, the mean distance between maxima (or minima) of a roughly periodic pattern. specifically, the least distance between particles moving in the same phase of oscillation in a wave disturbance. Optical and infrared wavelengths are measured in nanometers, micrometers, and angstroms (Jensen 1986).

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