Interim Report
of the
Riparian Area Advisory Committee

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

ARIZONA DEPARTMENT OF ENVIRONMENTAL QUALITY

Fife Symington, Governor Edward Z. Fox, Director

August 11, 1994

Honorable Fife Symington
Governor of Arizona

Honorable Speaker Mark Killian
Arizona House of Representatives

Honorable John Greene
Arizona State Senate

Members of the Riparian Area Advisory Committee

In 1992 the Arizona State Legislature passed Senate Bill 1030 forming the Riparian Area Advisory Committee (RAAC). The RAAC is required to discuss the components of a riparian protection program in comparison with existing state and federal programs; assess alternative regulatory and nonregulatory strategies to protect riparian areas with an analysis of the fiscal, economic, and environmental impacts; and to evaluate reports submitted by the Arizona Department of Environmental Quality, Arizona Game and Fish and The Arizona Department of Water Resources. On behalf of the RAAC, I am pleased to submit the RAAC's findings of the above elements in the enclosed Interim Report.

A total of 396 alternative strategies were identified which range from nonregulatory to regulatory. These alternative strategies will be used by RAAC as they discuss major issues that affect riparian areas. Other alternatives are likely to emerge in the development of recommendations for protecting riparian areas. A comprehensive fiscal, economic, and environmental impact analysis for each of the possible alternative strategies was beyond the scope of this report. Once the possible alternative strategies have been narrowed, this analysis will be performed.

Information contained in this report will assist RAAC in developing an effective and well-balanced riparian protection program. This report, however, does not contain recommendations. Recommendations will be developed by the RAAC through a consensus process and submitted in December in the final report.

Sincerely,

Edward Z. Fox
Director

EZF:kr

Enclosure

ACKNOWLEDGMENTS

This report was produced through the efforts of several talented people. The many hours of hard work are expressed in the level of detail and thoroughness of information contained in this report. The following people are recognized for their contribution:

Riparian Area Technical Subcommittee
Kris Randall
Dave Meinhart
Stu Bengson
Jim Renthal
Matt Chew
Victor Gass
Jeanne Trupiano
Tricia McGraw
Steve Carmichael
Eric Swanson
Bill Werner
Anna Steiner
Lew Myers

The experience and knowledge of members from the School of Planning and Landscape Architecture at Arizona State University were provided to the RAAC through funds made available from the Arizona Game and Fish Department. Their efforts have assisted RAAC and are hereby acknowledged for the tremendous amount of information they have compiled.
Frederick Steiner
Jackie Rich
Ginny Coltman
Ruth Yabes

Development and preparation of this report was made possible with funds provided by the Arizona Department of Water Resources and a grant from the IIPAM portion of the Heritage Fund administered by the Arizona Game and Fish Department

DRAFT INTERIM REPORT OF THE RIPARIAN AREA ADVISORY COMMITTEE

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ACRONYMS AND ABBREVIATIONS

401	Clean Water Act Section 401
404	Clean Water Act Section 404
ADA	Arizona Department of Agriculture
ADEQ	Arizona Department of Environmental Quality
ADID	Advanced Identification
ADOT	Arizona Department of Transportation
ADWR	Arizona Department of Water Resources
AGFD	Arizona Game and Fish Department
AMA	Active Management Area
ARC	Arizona Riparian Council
ARS	Arizona Revised Statutes
ASLD	Arizona State Land Department
ASP	Arizona State Parks
ASPB	Arizona State Parks Board
ASU	Arizona State University
AWEB	Arizona Watershed Enhancement Board
BLM	U.S. Bureau of Land Management
BMPs	Best Management Practices
BOR	U.S. Bureau of Reclamation
CDEP	Colorado Department of Environmental Protection
CDNR	Colorado Department of Natural Resources
CDOW	Colorado Division of Wildlife
CEQA	California Environmental Quality Act
Corps	U.S. Army Corps of Engineers
CRP	Conservation Reserve Program
CWA	Clean Water Act
CWQCD	Colorado (Department of Health) Water Quality Control Division
CZM	Coastal Zone Management
CZMA	Coastal Zone Management Act
DWR	Department of Water Resources
EO	Executive Order
EPA	U.S. Environmental Protection Agency
EQA	Environmental Quality Act
ESA	Environmentally Sensitive Area
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
FLPMA	Federal Land Policy Management Act
GAO	U.S. General Accounting Office
GMA	Growth Management Act
GRHTF	Governor's Riparian Habitat Task Force
LWCF	Land and Water Conservation Fund
MDNR	Michigan Department of Natural Resources
MHW	Mean High Water mark

MN	Mostly Nonregulatory
MOA	Memorandum of Agreement
MOU	Memorandum of Understanding
MPDES	Montana Pollutant Discharge Elimination System
MR	Mostly Regulatory
NAS	National Audubon Society
NDOW	Nevada Division of Wildlife
NEPA	National Environmental Policy Act
NFIP	National Flood Insurance Program
NMFS	National Marine Fisheries Service
NPDES	National Pollutant Discharge Elimination System
NPS	Nonpoint Source
NR	Nonregulatory
NWI	National Wetlands Inventory
OHW	Ordinary High Water mark
R	Regulatory
RAAC	Riparian Areas Advisory Committee
RACC	Riparian Areas Coordinating Council
RATS	Riparian Areas Technical Subcommittee
RBMP	Riparian Best Management Practices
RHA	Rivers and Harbors Act
RPED	Riparian Planning and Enhancement District
RPMED	Riparian Planning, Management, and Enhancement District
SB	Senate Bill
SCORP	Statewide Comprehensive Outdoor Recreation Plan
SCS	U.S. Soil Conservation Service
SEPA	State Environmental Policy Act
SLIF	State Lake Improvement Fund
SMA	Shoreline Management Act
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
VRCP	Verde River Corridor Project
WCP	Wetland Conservation Plan
WDEQ	Wyoming Department of Environmental Quality
WDOE	Washington Department of Ecology
WRAP	Wetland and Riparian Areas Project
WWF	World Wildlife Fund

INTERIM REPORT OF THE RIPARIAN AREA ADVISORY COMMITTEE

EXECUTIVE SUMMARY

This report is an interim report prepared by the Arizona Riparian Area Advisory Committee as required by Arizona Revised Statutes (ARS 45-101). The report is being provided to Governor Symington, the President of the Senate and the Speaker of the House as required by state law.

The Riparian Area Advisory Committee (RAAC) was established by Arizona law. The RAAC is comprised of thirty-four (34) members from a very broad range of interests; including federal and state agencies, Indian tribes, industry, and various public and special interest groups. The RAAC was given the task of developing a program to protect riparian resources in Arizona in a manner that makes sense to Arizona. The Committee is required to furnish an interim report in July of 1994, and the final report is to be provided in December of 1994.

This interim report consists of summaries of agency reports from the Arizona Game and Fish Department, the Arizona Department of Water Resources and the Arizona Department of Environmental Quality. These are reports required by the law which provide a riparian area inventory, an analysis of the impacts of surface water and groundwater withdrawals on riparian areas, and a review of the types of activities that impact riparian areas, respectively. A section is also provided which reviews regulatory and nonregulatory programs which exist in Arizona and other states in the United States, which potentially protect riparian resources.

Finally, there is a section which presents four alternatives to riparian protection and discusses their impacts on the economy and environment. The four alternatives range from primarily nonregulatory means (incentives, etc.) to predominantly regulatory (permitting and other controls). Existing programs are included in the analysis which provides information on how riparian areas are currently protected either directly or indirectly.

There is no specific approach that is recommended in this interim report; a recommendation is required for the final report. The intent of this report is to provide a range of alternatives from which a final recommendation can be selected. Through a consensus process, the RAAC will be deliberating to determine an approach to recommend for Arizona in the final report. The final approach will likely be a mixture of the alternatives, with both regulatory and nonregulatory aspects, as determined appropriate by the RAAC.

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CHAPTER I - INTRODUCTION

PURPOSE OF REPORT

In 1992, the Arizona legislature passed legislation which amended Arizona Revised Statute (ARS) 45-101 (Appendix A). It called for the collection of scientific and economic data and the development of reports on riparian areas in the state of Arizona. These reports are to be used by the Riparian Area Advisory Committee (hereafter referred to RAAC) to make recommendations to the legislature concerning protection of riparian areas.

The legislation directed RAAC to study the components of a riparian area protection program; assess alternative regulatory and nonregulatory strategies to protect riparian areas with an analysis of the fiscal, economic and environmental impacts associated with each alternative; and evaluate the reports produced by three agencies. This interim report of the committee's findings is submitted to the Governor, President of the Senate, and Speaker of the House.

COMPONENTS OF REPORT

This interim report contains the following components: 1) summaries of reports prepared by the Arizona Department of Water Resources, Arizona Department of Game and Fish, and Arizona Department of Environmental Quality; 2) an overview of regulatory and nonregulatory programs that exist in Arizona and other states; 3) alternative regulatory and nonregulatory protection strategies for riparian areas possibly applicable to Arizona, including existing, or status quo, programs that address major issues regarding riparian areas in Arizona; 4) fiscal, environmental, and economic analysis of strategies; and 5) input from open house meetings with the public.

The legislation required the identification and classification of riparian areas based on functions and values and an assessment of the impact of various activities on riparian areas. These two tasks were assigned to three State agencies. The Arizona Game and Fish Department identified and classified riparian areas along perennial stream reaches. The Arizona Department of Water Resources assessed the impact of withdrawals of surface water and groundwater on riparian areas. The Arizona Department of Environmental Quality assessed the impact of land use activities on riparian areas. The three agencies each submitted reports to the RAAC and to the Governor, President of the Senate, and Speaker of the House.

Several alternative approaches to riparian area protection which apply to major issues that affect riparian areas are presented in this report. These approaches were developed by a team from the School of Planning and Landscape Architecture of Arizona State University under contract to assist the RAAC. The approaches range from predominantly nonregulatory, such as voluntary measures and incentives, to mostly regulatory, which would involve more specific controls such as permitting. Included in the analysis of strategies are programs that are currently in place at the local, state and federal level. These status quo programs provided information on current regulatory and nonregulatory programs in Arizona. Opportunities and weaknesses in regulations were identified.

The legislation required that a fiscal, economic, and environmental impact analysis be performed on each alternative. A total of 396 alternative strategies were identified. Although the team from ASU included individuals with economic and social science backgrounds, a comprehensive analysis was beyond the scope of this report. A general overview is provided on the alternative strategies. A more detailed analysis will be performed on the alternative strategies that are selected by the RAAC.

The next step, beyond this interim report, is for RAAC to recommend an approach for adoption in Arizona. This will be accomplished, through a consensus process, by evaluating the four approaches presented in this interim report and any modifications to these alternatives, and select elements from them which would comprise a recommendation to the Governor and the Legislature. It is important to note that **the final proposal will not necessarily be one of the four approaches presented in this report**. Most likely, the recommendations will provide a "menu" to establish a mixture of regulatory and nonregulatory elements for protecting riparian areas in Arizona. These recommendations will be submitted to the Governor and the legislature in a final report on December 1, 1994.

GOALS OF THE RIPARIAN AREA ADVISORY COMMITTEE

To facilitate the analysis of existing state and federal regulatory and nonregulatory programs in Arizona and in other states and development of alternative regulatory and nonregulatory strategies, the RAAC identified committee and conservation goals and guidance principles. These goals are shown in Table 1.

IDENTIFICATION OF ISSUES IMPACTING RIPARIAN AREAS

Five major issues and their associated activities that impact riparian areas were identified by RAAC (Appendix C). Developing protection measures for riparian areas can be better directed by seeing how they address these issues. These issues were:

- Water Availability
- Large-scale destruction or alteration of river channels
- Adjacent land uses
- Effluent and point sources
- Restoration and exotic species

These issues were used in the analyzing existing regulatory and nonregulatory programs in Arizona and other states. These issues were also used in developing alternative regulatory and nonregulatory strategies and identifying existing, or status quo, programs. Existing programs that are related to these issues were identified to provide understanding on how they directly or indirectly protect riparian areas.

Table 1. Goals of the Riparian Area Advisory Committee

Riparian Area Advisory Committee
May 26, 1993
Revised September 17, 1993

Committee Goals

1. Identify the kinds of measures that may be needed for a riparian area protection program in Arizona.

2. Assess alternative regulatory and non-regulatory strategies with an analysis of the fiscal, economic and environmental impacts of each, and consideration of different alternatives for different classes of landowners.

3. Evaluate the agency reports directed in the legislation.

4. Recommend a comprehensive strategy for the conservation and enhancement of Arizona's riparian areas including proposed statutory provisions.

Conservation Goal

To sustain and enhance Arizona's riparian areas by managing land, water and resource uses to protect ecological integrity.

Guiding Principles

1. The best available scientific and technical information should form the basis for riparian area management decisions.

2. Cooperative and consultative approaches to decision-making and action should be employed.

3. Full consideration of environmental, social and economic costs and benefits should be a part of decision-making.

4. There should be regulatory and non-regulatory measures as part of a comprehensive plan.

5. The legal rights of the private property owners must be respected.

6. The spirit of State Executive Orders 89-16 *Streams and Riparian Resources* and 91-6 *Protection of Riparian Areas* will serve as guidance for development of recommendations by the Committee.

PREVIOUS STUDIES ON RIPARIAN PROTECTION PROGRAMS

Developing riparian area protection for the State of Arizona has been a continuous effort since 1985. Previous studies that have been conducted are as follows:

1985 Governor's Task Force on Recreation on Federal Lands

The following recommendations were presented:

- State and federal agencies should work closely together to provide legal protection for instream flow of waterbodies in Arizona that have recreational use or potential
- Control of groundwater pumping
- Documentation of the connection between the extraction of groundwater and surface water uses
- Public ownership of streambeds to protect recreational uses and access
- Application of the public trust and state navigability doctrines
- Congressional designation of all qualifying Arizona rivers into the National Wild & Scenic Rivers System

1988 Arizona Wetlands Priority Plan (addendum to the 1983 SCORP) by Arizona State Parks

The plan identified agencies involved in the planning, monitoring, and regulation of the use of wetlands in Arizona and their effectiveness; wetland resources in Arizona including an assessment of wetland types, functions, values, and wetland trends; wetland priorities for protection; state and local alternatives for wetland protection; and national wetland issues.

1988 Commission on the Arizona Environment

Compiled information from a fifteen month intensive public participation project designed to assess the status, economic value, public opinion and solutions to the controversial issues surrounding the management of riparian resources.

1989 Statewide Comprehensive Outdoor Recreation Plans (SCORP) which included an Arizona Rivers, Streams, & Wetlands Study by Arizona State Parks

The objectives of this study were to: determine the role that streams and wetlands (including riparian areas) can play in meeting Arizona's growing recreational needs; identify problems pertaining to streams and wetlands recreation; and recommend actions that might be taken to enhance future recreational use of these important and limited resources. A conceptual strategy for management of critical streams and wetlands was presented which spanned a continuum from informal actions taken within existing management framework to more active and aggressive actions requiring legislation or some other form of formal authorization.

Governor Rose Mofford's Executive Order 89-16, *Streams and Riparian Resources* of June 10, 1989

Mandated the formation of the Governor's Riparian Habitat Task Force. The objectives of Executive Order produced several reports by the GRHTF.

1. State definition for riparian area.
2. A first step towards a classification system was the development of *Handbook of Riparian Measurements* which described minimum abiotic and biotic measurements to be used by all agencies when inventorying riparian areas.
3. A report entitled *Agency Authorities, Programs and Activities Impacting Riparian Resources* described state, county, and federal agencies and Indian tribes and their statutory authorities, policies and programs that affect riparian areas.

4. Adoption of a riparian area policy.
5. An inventory of possible state agency actions and legislation was compiled in the *Riparian Management - Implementation Tools Briefing Paper*. This paper described a variety of federal and state management tools and programs that could be implemented to achieve the goals of the Task Force's riparian protection policy. A second document *Riparian Management Implementation Strategies: Recommendations of the Steering Committee*, emphasized those activities of which are considered of primary priority.
6. Prepared a draft Executive Order for protection of riparian areas.

Governor Rose Mofford's Executive Order 91-6, *Protection of Riparian Areas* of February 14, 1991
Established an interagency Riparian Areas Coordinating Council (RACC) comprised of various state agencies. It directed specific state agencies to inventory and classify riparian areas, develop rules and legislation regarding instream flows, consider the protection of riparian areas regarding certifications under Section 401 of the Clean Water Act, and develop legislation mandating state riparian area protection. The legislation revising ARS 45-101 was developed by RACC.

The Interrelationship Between Federal and State Wetlands and Riparian Protection Programs
A report by Frederick Steiner, Scott Pieart, and Edward Cook of Arizona State University prepared for the Arizona Department of Environmental Quality funded by a grant from the U.S. Environmental Protection Agency. This project was initiated to determine whether ADEQ's role in wetlands and riparian areas could be strengthened and improved, specially through the Clean Water Act, Section 401 certification and Section 404 permitting programs.

The RAAC will utilize these studies to pull together a cohesive strategy for riparian area protection.

TRIBAL PARTICIPATION IN RIPARIAN RESOURCE PROTECTION

Great opportunity exists to work with Indian Tribes, as partners, in the collective protection of Arizona's riparian resources. Twenty-one separate Tribal governments exist in Arizona, each with sovereign management authority, altogether representing significant total watershed area and riparian habitat in the state. Several efforts have already begun and many opportunities exist to initiate mutually beneficial and cooperative management agreements with individual Tribes, at the local level. A draft report titled Riparian Resource Management on Indian Lands in Arizona was presented to the RAAC in May, 1994 (Appendix B). Partnerships with Tribes can be extended to a statewide level, as well, where mutual support of common goals and objectives is needed, and in the exchange of knowledge and resources which promotes riparian area protection.

It is recognized that there are 21 sovereign Tribal governments in Arizona. The legislation called for "one member representing an Indian tribe in this state." President Pattea, from the Ft. McDowell Indian Community, has acted to facilitate Tribal input in the RAAC process, but does not technically "represent" all of Arizona's Tribes.

MEMBERS OF THE RIPARIAN AREA ADVISORY COMMITTEE

Thirty-four people comprise the Riparian Area Advisory Committee and represent varied interests in riparian area issues. Nineteen members, appointed by the governor, represent industry, environmental organizations, user groups, agricultural improvement district, and Indian tribes. Seven of the members represent state agencies. In order to coordinate with existing federal programs that impact riparian areas, eight members from federal agencies were also represented. The following is a list of the members and their alternates of the RAAC.

Governor Appointed Members

Stuart Anderson
County w/ population less than 500,000

Judy Gignac
County w/ population less than 500,000

Dave Smutzer
County w/ population more than 500,000

Bill Chase
Municipality owns & operates wastewater treatment plant in AMA w/ pop. >1.5M

Clinton Pattea
President
Ft. McDowell Indian Community
(alternate - Stephanie Ostrom)

Don Colter
President
Arizona Association of Conservation Districts
(alternate - Jamie Gillum)

Lewis Tenney
Vice President
Precision Pine & Timber, Inc.
Timber Industry
(alternate - Bill Caskey)

Connie Wilhelm
Executive Director
Home Builders Association
Real estate development industry

Jim Slingluff
Recreational Users Organization

Jack Metzger
Arizona Cattlemen's Association
Actively engaged in livestock ranching as major source of income
(alternate - C. B. "DOC" Lane)

Roger Hooper
Actively engaged in farming as major source of income

David Chavez
CalMat
Sand and gravel industry

Patrick Maley
ASARCO
Metal mining industry
(alternate - Stu Bengson)

John Keane
Water Policy Executive
Agricultural improvement district

Juliet Stromberg
Arizona State University
Riparian researcher

Marty Jakle
President
Arizona Riparian Council
(alternate - Duncan Patten)

Anita MacFarlane
Northern Arizona Audubon Society
Environmental organization - Coconino County

Eva Patten
The Nature Conservancy
Environmental organization - Maricopa County
(alternate - Jim Walsh)

Barbara Tellman
Native Plants Society
Environmental organization - Pima County

State Agency Members

Edward Z. Fox - Chair of RAAC
Director
Arizona Dept. of Environmental Quality
(alternate - Brian Munson)

Duane L. Shroufe
Director
Arizona Dept. of Game and Fish
(alternate - Bruce Taubert)

Keith Kelly
Director
Arizona Dept. of Agriculture
(alternate - John Hagen)

Jean Hassell
Arizona State Land Dept.
(alternate - Robert Yount)

Bill Belt
Arizona Dept. of Transportation

Kenneth E. Travous
Director
Arizona State Parks Board
(alternate - Matt Chew)

Rita Pearson
Director
Arizona Dept. of Water Resources
(alternate - Herb Dishlip)

Federal Agency Members (serve as ex officio members)

Humberto Hernandez
U.S. Soil Conservation Service
(alternate - Gary Gross)

Doug Shaw
Southwestern Region,
Watershed and Air Management
USDA Forest Service

Lester K. Rosenkrance
Bureau of Land Management
(alternate - Jim Renthal)

Dennis E. Schroeder
Bureau of Reclamation
(alternate - Sandy Eto)

Clay Cunningham
National Park Service
(alternate - Kathy Davis)

Ronald MacDonald
US Army Corps of Engineers
(alternate - Cindy Lester)

Sam Spiller
U.S. Fish and Wildlife Service
(alternate - Frank Baucom)

Harry Seraydarian
U.S. Environmental Protection Agency
(alternate - Mary Butterwick)

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INTRODUCTION

This section is a summary of the reports prepared by Arizona Department of Water Resources, Arizona Game and Fish Department, and the Arizona Department of Environmental Quality. The reports were submitted to Governor, the Legislature, and to RAAC and provide background information on riparian areas.

The report prepared by the Arizona Department of Water Resources assessed the hydrologic effect of groundwater pumping and the effect of new surface water appropriations and changes in the use or point of diversion of existing surface water appropriations on riparian areas. Alternative regulatory programs designed to balance the protection of riparian areas with existing and future groundwater pumping and new surface water appropriations and changes in the use of point of diversion of existing surface water appropriations were also developed. The report prepared by the Arizona Game and Fish Department developed a system for classifying riparian areas, and mapped riparian areas along perennial streams and rivers in the state. The Arizona Department of Environmental Quality prepared a report which assessed the impacts of thirteen (13) land use activities and the direct and indirect effects they have on riparian areas.

SUMMARY OF THE DRAFT

RIPARIAN PROTECTION PROGRAM

LEGISLATIVE REPORT

Arizona Department of Water Resources

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INTRODUCTION

The Arizona Department of Water Resources (ADWR) produced a draft Riparian Area Protection Program Report. As outlined in the legislation, the three objectives of ADWR's studies were to evaluate:

1. The hydrologic effect of groundwater pumping on riparian areas.
2. The effect of new surface water appropriations and changes in the use or point of diversion of existing appropriations on riparian areas.
3. Alternative regulatory programs designed to balance the protection of riparian areas with:
   - existing and future groundwater pumping;
   - new surface water appropriations;
   - changes in the use or point of diversion of existing surface water appropriations.

The hydrologic studies focused on the first two objectives that directly require hydrologic and ecologic analyses. This in turn provided support and foundation for a regulatory program. Additionally, to evaluate alternative regulatory programs, the law also required the Department to consider:

- The economic impacts on various classes of landowners, including federal, state, private, and Indian Tribes.
- The impacts on existing water rights, pending water right adjudications and negotiated water settlements.
- The availability of alternative water supplies for existing and future users.
- The environmental costs and benefits of the program.
- The costs to ADWR in implementing such a program.

This sub-chapter (II.B) of the RAAC interim report provides a summary of the ADWR report that includes an overview of the interrelationship between riparian vegetation and stream-aquifer systems in Arizona. This is followed by a general discussion of the hydrologic effects of groundwater withdrawals and surface water diversions. Finally, alternative regulatory programs that may offer protection to riparian areas are presented with emphasis on examples of regulatory programs and economic impacts that may be expected from these programs.

RIPARIAN VEGETATION AND HYDROLOGIC INTERACTIONS

Riparian systems are dynamic by nature. Stream channels are continually aggrading (e.g. building up) and degrading (e.g. down-cutting), while riparian vegetation establishes episodically in response to flood flows and associated processes. Surface water and hydraulically connected groundwater all contribute to the type of riparian community present, influencing its density, vigor, composition, and ability to continue to regenerate and maintain itself at a given site. Surface water and groundwater are necessary together or individually, to initiate, maintain, and complete various plant lifecycle stages and functions. In return, riparian vegetation plays an important role in stream and alluvial aquifer system maintenance and development.

RIPARIAN VEGETATION/GROUNDWATER RELATIONSHIPS

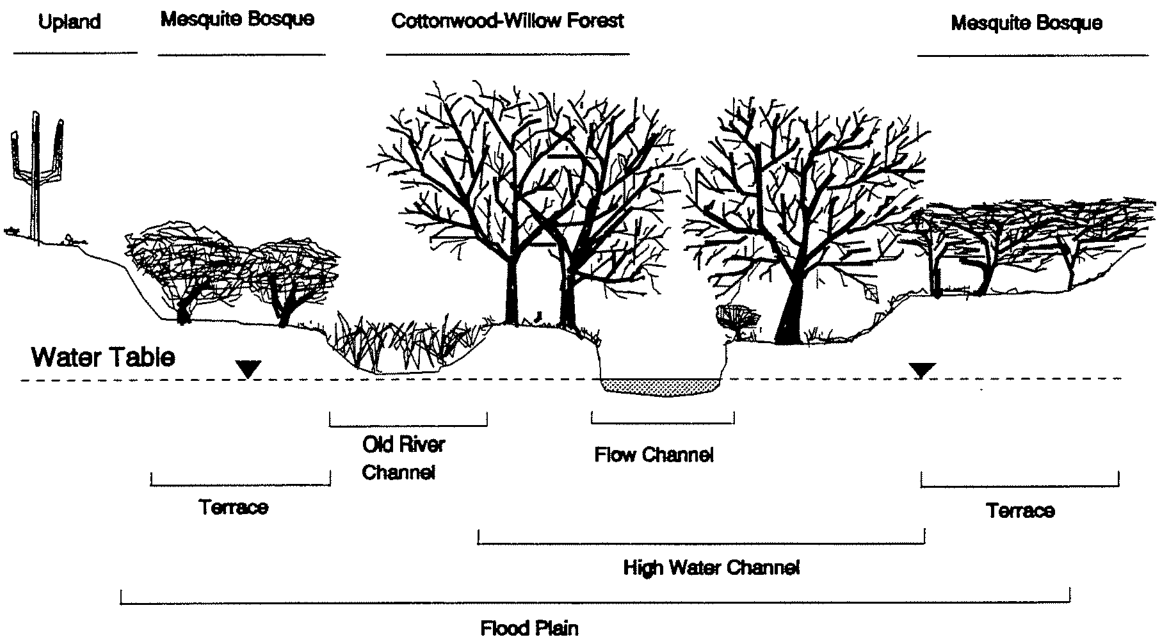
In southwestern deserts, where evaporation exceeds precipitation, groundwater is a critical source of water for maintenance of many riparian zones. Groundwater available for riparian vegetation occurs in alluvial aquifers which directly support riparian ecosystems. These areas are generally located adjacent to streams where water level elevations are essentially flat in the area of the riparian zone. The depth to water increases as the land surface elevation increases with distance away from a stream channel. Depth to groundwater plays an important part in the distribution of most riparian vegetation, therefore the greater the depth to water below the land surface, the less abundant the riparian vegetation.

Many types of riparian vegetation depend directly on water in floodplain aquifers and indirectly on groundwater in regional basin fill aquifers as a source of floodplain aquifer recharge (Figure 1). On many desert rivers, wide floodplain aquifers allow for extensive development of riparian vegetation. Sonoran riparian forests of Fremont cottonwood and Goodding willow, for example, grow hundreds of feet from the active channel in riparian zones where groundwater is only several feet below the floodplain surface. On many mountain streams, warm and cold-temperate mixed broadleaf forests form narrower riparian zones supported by a narrow floodplain aquifer. Within these riparian ecosystems, riparian plant species are distributed along gradients of depth to groundwater, because each species (and each life stage) has a unique rooting depth, unique tolerance for drought and soil saturation, and unique ability to absorb water from different parts of the riparian zone. Goodding willow and Fremont cottonwood, for example, are shallow-rooted trees that absorb water mainly from the saturated groundwater zone, and give way to deeper rooted mesquite as depth to groundwater increases. Just as the depth to groundwater is important to riparian vegetation, so too is the rate and extent of capillary water rise (or soil moisture) in the soil zone lying above the water table. Riparian sacaton grasslands, for example, grow in fine-textured floodplain soils which allow for extensive movement of capillary water into the root zone from the water table. Some vegetation types, found in cienegas (or marsh areas of very shallow groundwater), grow only where groundwater intersects the ground surface, and are very sensitive to water table fluctuation.

RIPARIAN VEGETATION/SURFACE WATER RELATIONSHIPS

Nearly every riparian vegetation type in Arizona is dependent on surface water. Surface flow laterally recharges riparian soils, moistens floodplain soil surfaces during overbank flood flows, and transports new sediments and seeds. Where surface water and groundwater are hydraulically connected in riparian ecosystems, surface water recharges alluvial aquifers and raises water levels.

Figure 1. Schematic of riparian floodplain



The water supply in a surface water system is controlled by precipitation and regulated through interactions between geology, soils and vegetation. Precipitation on impermeable soil and bedrock will enter a channel system rapidly. Conversely, precipitation on permeable, well-vegetated soil will enter the groundwater system and may not reach a main channel for many seasons. One way floodplain vegetation and a stream channel interact is through temporary water storage in the streambanks affected by normal and high flows. Both deep rooted woody and fibrous rooted herbaceous plant species aid to stabilize soils, increase organic matter content, and trap silt and clay which improves the water holding capacity of streambank soils. The available water storage capacity in some streambanks can be significant enough to reduce flood peaks. The resulting sustained flow and reduction in peak flood events aid to support healthy riparian ecosystems.

Watersheds that lack sufficient vegetative cover and have been subject to sheet and gully erosion can develop rapid, concentrated surface runoff which increases peak flows, promotes down cutting and produces large amounts of sediment. While channels transport increasingly more floodwater without significant overbank flooding, the elevated terrace adjacent to the eroded channel becomes increasingly more arid. In addition, as channels are downcut into alluvial aquifer systems, these systems release water into the channel until the water level in both the channel and the aquifer achieve stability. The result is an increased depth to groundwater and a channel that must widen prior to reassuming the aggradation process.

HYDROGEOLOGIC ANALYSIS OVERVIEW

To evaluate the response of riparian vegetation to groundwater withdrawals and surface water diversions, an understanding of the stream-aquifer system and related riparian ecosystem is necessary. For the purpose of this discussion the stream-aquifer system is generally composed of one or more aquifers in direct hydraulic connection with a perennial stream, and a riparian community dependent on the water resources.
Certain species of riparian vegetation survive only where perennial streamflow and shallow water levels provide a permanent source of water within reach of the plant's roots. A stream-aquifer system that supports this type of riparian vegetation is hydraulically connected, meaning water withdrawn from the aquifer directly impacts the stream, and the water level elevation in the aquifer is equal to the water surface elevation of the stream. The water table is essentially flat in the proximity of the stream, but water levels may be higher or lower than the stream with increasing distance laterally away from the stream.

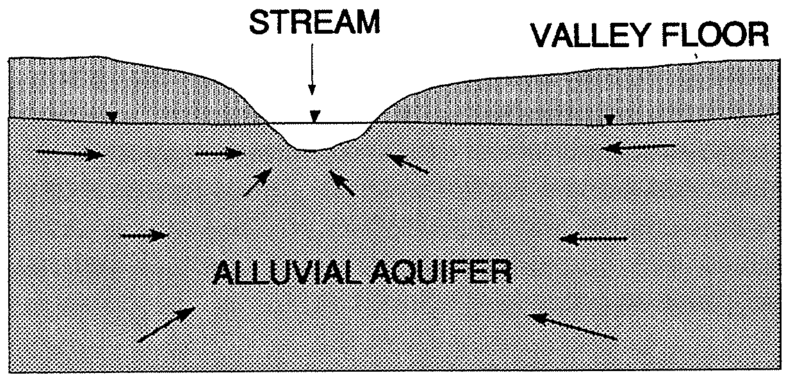
Surface Water

Surface water or streamflow is the occurrence of water in a natural channel. Water that comprises streamflow is ultimately derived from precipitation falling on the earth's surface, however this water may reach a stream channel through different routes. Streamflow is comprised of three main components including surface runoff, interflow, and base flow. Surface runoff is precipitation that flows over the land surface and accumulates in stream channels. Surface runoff from precipitation varies widely throughout Arizona depending primarily on elevation and geographic location. Interflow is precipitation that infiltrates and moves laterally through the unsaturated zone above the water table (vadose zone) until draining into a stream channel. Streamflow includes baseflow where the groundwater table intersects a stream channel and discharges groundwater to a stream. Stream reaches receiving baseflow are referred to as "gaining reaches" as shown in Figure 2.

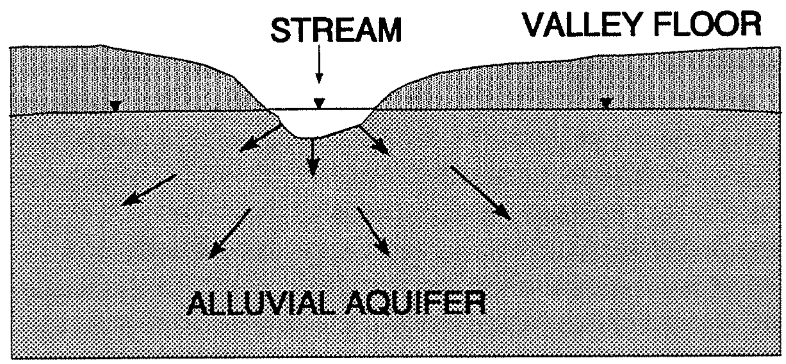
Baseflow can maintain streamflow during periods when there is negligible runoff, therefore, this component is critical for maintaining certain types of riparian areas. The proportion of direct runoff to baseflow varies between basins, with time, and from one location to another on a stream.

Figure 2. Diagram showing perennial, intermittent and ephemeral stream types

Perennial Streams

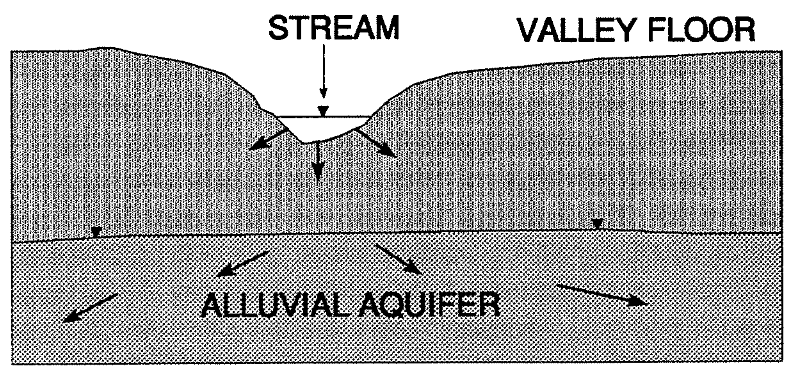


Gaining Reach



Losing Reach

Intermittent or Ephemeral Stream



Losing Reach

▼ WATER TABLE ← DIRECTION OF FLOW

Rivers and streams are classified as perennial, intermittent, or ephemeral depending on the duration of surface flow throughout the year (Figure 2). Perennial streams flow continuously throughout the year. Intermittent streams flow for long periods and are typically seasonal in nature, flowing continuously during most of the year when water is contributed from baseflow or surface runoff. Ephemeral streams flow only in immediate response to precipitation events and do not derive any of their flow from groundwater discharge. Many of Arizona's low-flow perennial streams exhibit "interrupted-perennial" reaches where streamflow at the surface is lost, but flow continues through the stream alluvium as subflow. These reaches are referred to as "losing reaches" (Figure 2).

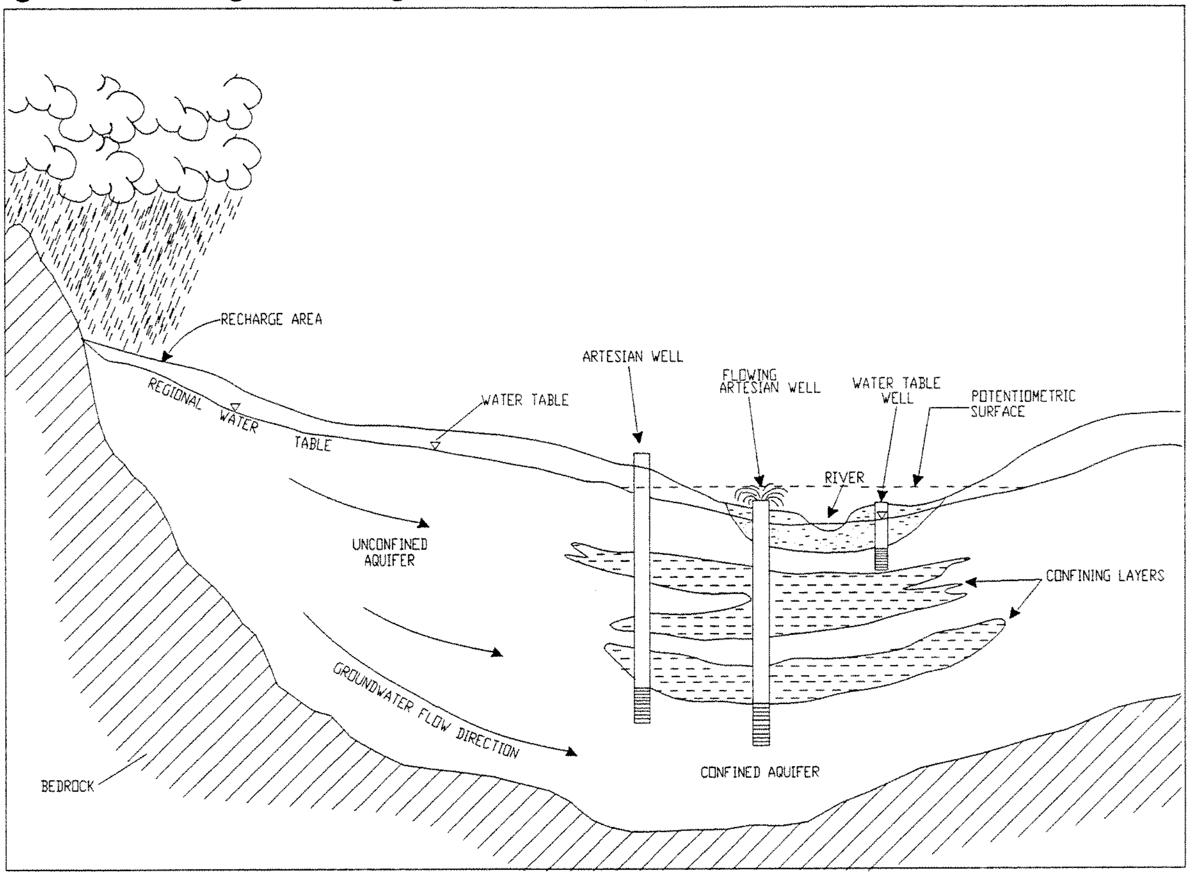
Groundwater

Underground water occurs in two zones, the unsaturated or vadose zone and the saturated zone. The vadose zone lies between the land surface and the saturated zone and contains a combination of water and air. Water in this zone is at less than atmospheric pressure (e.g., it would not flow freely into an open well). The unsaturated zone is an important conduit for water to reach the groundwater zone. Groundwater is the subsurface water that occurs beneath the water table in fully saturated soils and geologic formations.

Geologic formations or rock units that are saturated and yield usable quantities of water to wells or springs are called aquifers. Most commonly, aquifers in the alluvial basins of the southwest are composed of unconsolidated materials derived from weathered and eroded particles of clay, silt, sand, and gravel. This type of aquifer material makes up the majority of the alluvial valley-fill aquifers in the southwest. Groundwater occupies the pore spaces or voids that occur in the particles of silt, clay, sands and gravels that make up the alluvial material. Other aquifers that occur in the state consist of saturated consolidated formations or hardrock formations and may consist of various rock types. Water can occur in the fractures, joints, or solution cavities created both during and after the rocks were formed.

Groundwater may occur in an aquifer under unconfined or confined conditions (Figure 3), which will affect how the aquifer and the stream interact hydraulically. In unconfined aquifers, there are no hydrologic restricting units, therefore, groundwater levels are free to rise and fall in response to atmospheric pressure. The water table is the upper surface of the saturated zone and is usually measured as the static water level in wells. Confined or artesian aquifers consist of water-bearing material bounded by much less permeable material, such as an overlying clay layer (Figure 3). This less permeable layer is termed an aquitard or aquiclude, which simply means it either retards or prevents the vertical flow of water from one layer to another. Because confined aquifers are fully saturated and under greater than atmospheric pressure, they do not have a free water table. The pressure head or potentiometric surface, by definition, is always above the top of the confined aquifer. If a well is completed in a confined aquifer, the water in the well will rise to correspond to the pressure or potentiometric surface. If the potentiometric surface is above the land surface, water will flow naturally to the land surface (e.g., flowing artesian well) (Figure 3).

Figure 3. Diagram of regional alluvial aquifer system



Aquifers serve as underground reservoirs by storing water from precipitation that has infiltrated into the ground. This natural recharge or addition of water to the aquifer occurs from direct infiltration of runoff flowing across alluvial fans bordering mountain ranges, or along stream channels. Recharge can also occur by groundwater movement from another aquifer system (e.g., from an underlying or overlying aquifer). Recharge can vary with such factors as precipitation amount and timing, land use and evaporation.

Groundwater within undisturbed alluvial basins usually flows from mountain fronts located at basin margins to the center of the basin where it can be drained by a stream. Local barriers to flow, including pumping wells, may cause exceptions to the general flow directions in some basins. This can be quite severe as seen in the Salt River Valley, the Santa Cruz Valley, and in Pinal County. In these areas, groundwater discharge due to continuous well pumping for agricultural, municipal, and industrial purposes has severely lowered water tables in the surrounding aquifers to the point where groundwater can no longer discharge to a stream. Another primary cause of groundwater discharge is evapotranspiration by vegetation during the growing season.

Stream-Aquifer Systems

Two important types of stream-aquifer systems that are common in Arizona are: (1) narrow valleys developed in hardrock formations typically located in mountainous terrain, and (2) broad alluvial basins lying between mountain ranges typical of southern and central Arizona. The first type of stream-aquifer system consists of a narrow alluvial valley cut into impermeable hardrock. Stream alluvium composed of unconsolidated silt, sand, and gravel fill a channel and where saturated form a highly permeable aquifer. The impermeable hardrock forms a boundary that limits the extent of the aquifer. In this type of "single aquifer" system, a perennial stream developed on the alluvium is hydraulically connected to the underlying alluvial aquifer. Such an aquifer may be up to a few thousand feet wide and less than 100 feet thick and is characteristic of many of the aquifers found in the central and northern Arizona.

The second type of stream-aquifer system consists of a large alluvial basin which is comprised of multiple aquifers. These aquifers consist of basin fill alluvium that may be several thousands of feet thick and many miles wide. The basin fill alluvium can be separated into various aquifer units, depending on the site and complexity of the hydrogeology specific to each basin. Alluvial basin aquifer systems typically contain both confined and unconfined aquifers. Figure 3 provides an illustration of a multi-layered, alluvial basin aquifer system.

In addition to the multi-aquifer alluvial system, a floodplain aquifer is typically found within the central valley of a basin. A floodplain aquifer is formed from unconsolidated alluvial materials deposited by a stream. Floodplain aquifers can be several hundred feet thick and several miles wide within the basin. These stream-aquifer systems are dynamic and interact through a constant exchange of water, from both surface water infiltration from the stream which recharges the aquifer and from groundwater discharge from the aquifer to the stream which provides baseflow (see Figure 2). Riparian areas are usually found on the floodplain alluvium where shallow aquifers are present.

The amount of streamflow may differ from place to place along a river. For example, during seasonal low flow periods in some streams, flow may completely disappear for a distance and then reappear downstream. This variation in flow is strongly dependent on the occurrence and direction of groundwater movement in an adjacent underlying aquifer. The hydraulic gradient indicates whether water flows toward the stream to supplement streamflow or away from the stream to recharge the aquifer. When the elevation of the water table in the aquifer adjacent to a stream is above the elevation of the streambed, groundwater flows toward the stream and is discharged to the streambed (Figure 2). This system acts as a drain for the aquifer, allowing water to move from the aquifer to the stream where it is expressed as baseflow.

An intermittent stream does not exhibit continuous flow. Natural use of water by riparian vegetation and/or cultural diversions may cause the water table to drop below the elevation of the streambed during certain times of the year, inducing streamflow to infiltrate through the bed of the stream to recharge the aquifer. When losses from stream infiltration exceed surface flow, the stream will cease flowing. Even though the surface flow of the stream ceases, subflow can still be found at some depth in the permeable alluvial sediments beneath the stream.

HYDROLOGIC EFFECT OF GROUNDWATER WITHDRAWALS

In a natural, unimpacted hydrologic system, stream and aquifer systems achieve an equilibrium where long-term system inflows equal long-term outflows. In this type of balanced system, streamflow reductions would only occur during extended drought periods where below normal precipitation would result in a corresponding reduction in runoff and aquifer recharge. In developed watersheds, direct streamflow diversions and groundwater pumping can have an appreciable affect on the hydrologic system depending on the timing and magnitude of depletions and the location of these diversions. Often, depletions occur in or near riparian areas, where surface water is available and groundwater is close to the land surface.

Extensive pumping of groundwater results in depletion of streamflow by inducing infiltration of surface water through the streambed or interception of groundwater that would have recharged the stream. If the volume of water pumped exceeds the amount of natural recharge to the groundwater system, a deficit will occur causing a reduction in groundwater storage and declining water levels. A continuous trend of declining water levels indicates overdevelopment of groundwater resources. The degree of overdevelopment depends on the magnitude, duration, and distribution of withdrawals, as well as the hydraulic properties of the aquifer. Where multiple wells are clustered in close proximity to one another, the effect of pumping on the aquifer is compounded, as are impacts to any nearby stream.

Groundwater withdrawals by wells cause certain predictable aquifer responses. When groundwater is withdrawn through a pumping well, water is removed from storage creating a cone of depression in the affected aquifer. This causes water levels to drop in the vicinity of the well as indicated in Figure 4. Where multiple wells are withdrawing water from an aquifer, the individual cones of depression will interconnect to form a regional cone of depression.

Ideally, groundwater flows radially toward a cone of depression and is removed from an aquifer by the well. The shape of a cone of depression depends primarily on the characteristics of the aquifer, the duration and rate of pumping, and the proximity of the well to groundwater recharge or discharge boundaries. If a well is pumped at a high rate for an extended period of time, the cone of depression will expand outward until further expansion is limited by the transmissive and storage properties of the aquifer or by intercepting an aquifer boundary such as a stream or impermeable hardrock boundary.

If the cone of depression of a pumping well intersects a stream, drawdown of the affected aquifer will cease along the stream bank and water will be drawn from the stream.

Surface water will be induced to infiltrate through the permeable streambed to recharge the area of the aquifer dewatered by the pumping well. When the withdrawal rate of the well is balanced by induced stream recharge to the aquifer, the cone of depression will stop expanding in the direction of the stream. In some instances, pumping wells may change streamflow from perennial to intermittent or ephemeral by eliminating groundwater discharge to the stream and increasing streamflow infiltration.

Wells withdrawing groundwater from an aquifer that is hydraulically connected to a perennial stream will deplete or interfere with streamflow either directly or indirectly as illustrated in Figure 5. Direct interference occurs when a cone of depression expands into the stream alluvium of a river creating a groundwater gradient away from the stream. Streamflow losses increase as additional surface water infiltrates into the permeable alluvium to fill the area dewatered by the well. Indirect interference occurs when groundwater flowing toward the stream is intercepted by a cone of depression. Indirect interference has the affect of reducing the amount of groundwater that would have eventually discharged to the stream, thereby reducing baseflow. In both instances the well is depleting streamflow, either by inducing additional infiltration of streamflow, or by intercepting groundwater that would have discharged to the stream. In some areas, the impacts resulting from a pumping well adjacent to a stream are compounded by regional groundwater declines resulting from the combined affects of many pumping wells.

These declines can be quantified simply by measuring the surrounding groundwater levels in the floodplain and regional aquifers. These water level measurements can be used to determine impacts to the riparian areas associated with an adjacent stream. Figure 6 illustrates the species composition and relative depth to groundwater for typical southwestern riparian vegetation. As stated before, the farther away from the floodplain, the greater the distance between depth to groundwater and the land surface. Figure 6 also illustrates the general depth to groundwater requirements of various species of riparian vegetation.

Figure 4. Diagram of a cone of depression in an aquifer

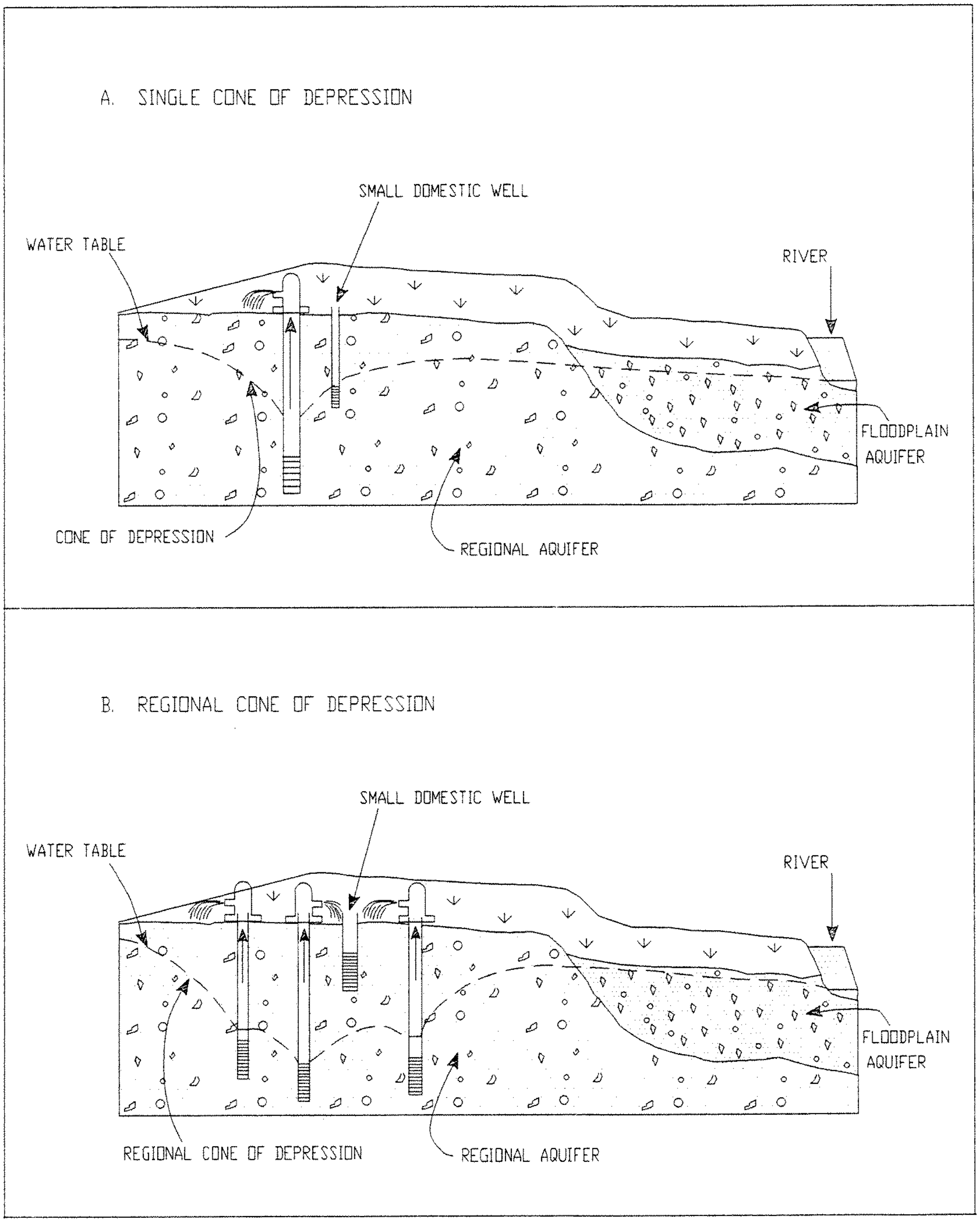
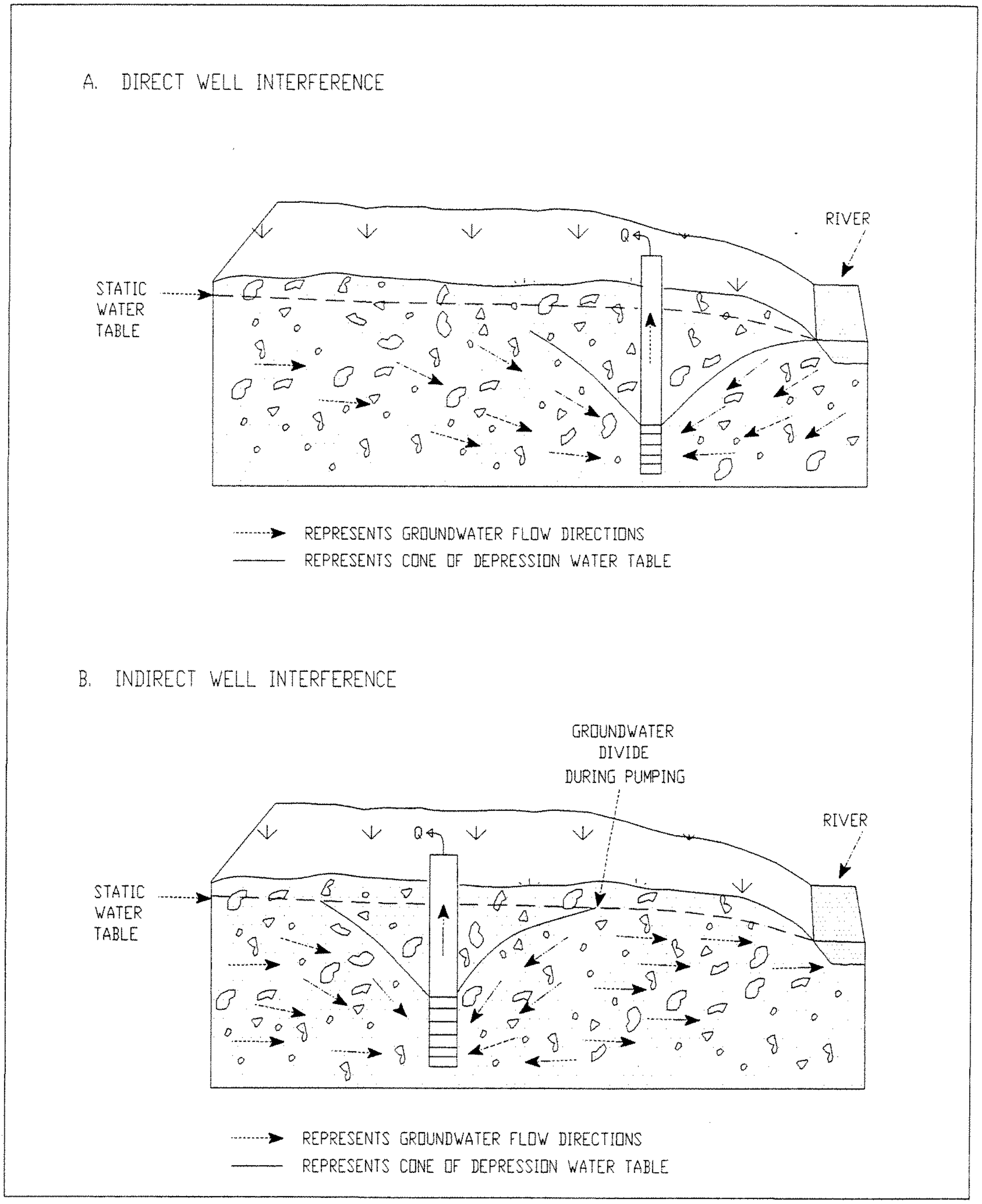


Figure 5. Diagram showing direct and indirect well interference

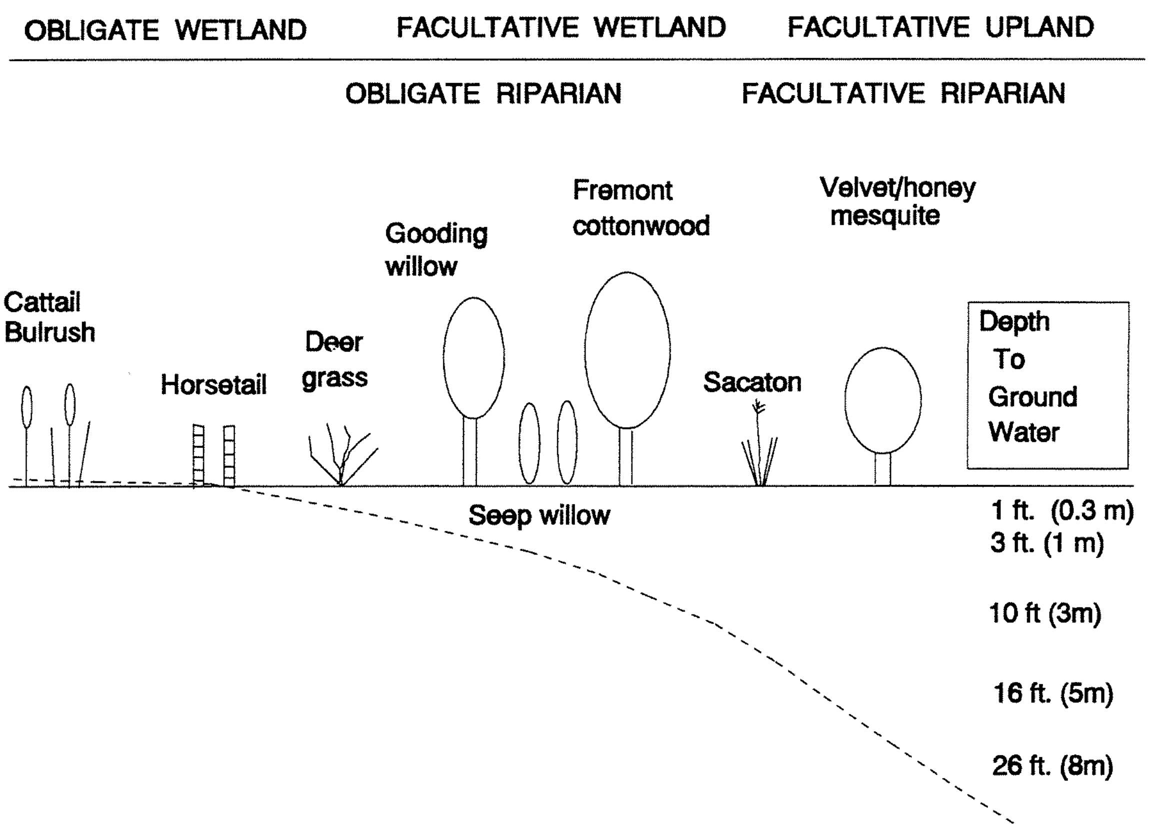


Most of Arizona's riparian ecosystems have been lost or degraded by lowering of groundwater tables and increase in water table fluctuation resulting from (1) pumping of groundwater from wells in alluvial (floodplain) or regional (basin fill) aquifers; (2) development of infiltration galleries that intercept subsurface flow; (3) diversion of surface flow; (4) construction of upstream dams; and (5) detrimental land use practices in the watershed or riparian zone. Some of the ecological impacts of this groundwater decline include:

- Increase in physiological plant stress, reduction in growth rate and loss of vigor;
- Reduced seedling establishment and loss of age-class diversity;
- Plant mortality and reduction in plant density and cover;
- Sequential loss of increasingly more drought-sensitive vegetation types (e.g., loss of wetland plants and obligate riparian species followed by loss of facultative riparian vegetation types and ultimately of all vegetation);
- Replacement of riparian vegetation by more drought tolerant or upland vegetation or by "weedy" exotic species such as saltcedar;
- Reduction in biomass and structural complexity of the vegetation;
- Reduction in riparian zone width;
- Loss of wildlife habitat;
- Streambank erosion and channel widening;
- Increased downstream flood damage;
- Reduced purification of water quality;
- General loss of riparian function.

Several steps can be taken to prevent further riparian degradation and loss of function from groundwater decline. There is sufficient information to put in place a program that protects riparian areas by incorporating known ecologic needs into the decision making process regarding groundwater pumping. For example, each riparian species or plant association has a known optimum range of groundwater depths and conditions over which it grows; and a wider tolerance range within which it will persist. It is also known that structural and functional attributes of the plant community vary with depth to groundwater, and that these attributes change along a continuum. Groundwater models identify these general thresholds for plant association type changes, particularly for Sonoran riparian ecosystems. The groundwater models also indicate optimum groundwater depths over which riparian plant species grow (and establish), as well as the changes in stand density and structure that occur as depth to groundwater increases. These relationships between groundwater and riparian vegetation have been quantified for many riparian species, although there is a need for additional study particularly of species in high elevation riparian zones.

Figure 6. Species change with increasing depth to groundwater in a sonoran riparian ecosystem.



HYDROLOGIC EFFECT OF SURFACE WATER DIVERSIONS

The effects of existing surface water diversions are not addressed in this report. However, the effects of current diversions provide insight to the potential effects of future diversions and changes in use and point of diversion. Streamflow diversions are not quantified for most areas of the state. Therefore, only a qualitative evaluation of the effects of new surface water diversions and changes in existing uses and points of diversion can be made.

As a general rule, surface water diverted from a stream is not available to support the natural hydrologic system below the point of diversion. Surface water diverted by an instream diversion structure diminishes the flow volume of the stream directly, that is, for every acre-foot of water diverted, streamflow is also reduced by one acre-foot. Indirect diversion of surface water can occur when water withdrawn from a well includes both surface water and groundwater components. In the case of indirect depletions by wells, streamflow depletion is not immediate, however, over the long-term, stream depletion may approach the amount pumped. In each case, not only is flow reduced downstream of the diversion, but downstream recharge is also diminished. Reduction of available flow for stream recharge may result in a decline in water levels in alluvial aquifers adjacent to impacted stream reaches. In instances where surface water is diverted from a stream and applied to irrigate crops on adjacent alluvial floodplains, a portion of the water that is not evaporated or transpired may return to the stream through deep percolation (irrigation return flows).

Streamflow diversions vary in volume from small irrigation ditches and instream pumps, which divert only a fraction of the total streamflow, to large diversion dams which divert the entire flow of a stream. In many natural perennial stream systems the stage (stream water surface elevation) and the adjacent aquifer in the stream alluvium are at equal elevations. In some instances however, water levels in an adjacent alluvial aquifer may be slightly above or below the river level within the riparian zone. For example, following the high flow season, saturated portions of the floodplain may temporarily exist above the river level and slowly drain back to the river sustaining flow during the low flow season.

When surface water is removed from the stream by a diversion structure, the stage of the stream is lowered. As stream stage declines, the water level gradient between the stream and alluvial aquifer steepens and water drains from the aquifer to the stream. In a hydraulically connected stream-aquifer system, drainage from the adjacent alluvial aquifer to the stream results in a water table decline and leads to an increase in the distance between the water table and land surface (unsaturated zone).

While surface water flows are critical for riparian vegetation maintenance and regeneration, riparian vegetation serves to stabilize hydrologic systems. When surface water is diverted and no longer available to support riparian ecosystems, riparian community densities are reduced or eliminated. Therefore, less vegetative cover and root structure support are available to slow flood flow velocities, stabilize soils and sustain lateral floodplain recharge. As a result, stream channels and associated floodplains become more susceptible to degradation and erosion processes, such as streambed scouring, and channel incision and widening. Channels impacted by these actions are highly erosive and carry greater sediment loads. Additionally, bank storage potential is reduced and therefore less discharge from stream alluvium is available to support baseflows in the stream during low flow periods. When flood events occur, the resulting system's inability to slow and retain some of the flow energy can result in greater flood related devastation.

Surface water also is of great importance to riparian vegetation. Many herbaceous riparian plants are rooted directly in the stream or depend on bank-stored stream water and are very sensitive to the loss of perennial flow. Many riparian trees use stream water at all life stages, while others use stream water as juveniles and as adults become indirectly dependent on surface water as a source of floodplain aquifer recharge. Surface flow variables that are important to riparian vegetation include the mean and median volume of flow during the year and particularly during the growing season; the base flow and the low flow volume during the dry season; the seasonal discharge pattern; the extent of annual fluctuation in flow; and the relative difference between low flows and peak flows. Whether or not the flow is perennial also is of major importance, as is the duration and timing of the no-flow period on non-perennial rivers. Frequency, duration, timing, and magnitude of peak flows also have ecological significance for riparian vegetation. Floods influence many ecosystem processes, and often serve as regeneration flows while other flows serve as maintenance flows.

Surface water has high variability in many of Arizona's rivers due to high climatic flux. Surface flow has been reduced or may become more variable as a result of: (1) surface flow diversion; (2) river damming; (3) removal of effluent from stream beds; (4) development of infiltration galleries in the channel; (5) groundwater pumping from the floodplain aquifer; (6) groundwater pumping in the regional aquifer that changes the direction of groundwater flow towards the cone of depression and away from the river or river aquifer; and (7) various watershed and riparian land uses. Surface water decline has caused the same types of riparian loss or degradation as described above for groundwater decline. Surface water decline has had greatest impacts for Sonoran riparian ecosystems (e.g., cottonwood-willow forests, mesquite bosques, riparian marshlands) because low elevation desert rivers have been strongly affected by river damming and diversion. Mixed broadleaf riparian forests along higher elevation mountain streams also have been degraded by surface water diversions for agriculture, municipal use, and more locally, hydropower production.

Riparian ecosystems also have been altered and degraded by flood flow alteration. Dams are the primary cause of flood flow alteration and have caused extensive changes in below-dam as well as above-dam riparian ecosystems. Peak flows also have been altered by channelization of river beds; compaction of soil and pavement of surfaces in the watershed; and reduction in floodplain and watershed plant cover. These factors serve to intensify flow magnitudes in the downstream reach, and can degrade riparian ecosystems by increasing mortality from flood flows and reducing their ability to recover after the flood.

ALTERNATIVE REGULATORY PROGRAMS DISCUSSION

A review of Arizona water law was necessary before potential alternative regulatory programs could be developed. A discussion of this is found in detail in Chapter V, the Regulatory Strategies Report, and illustrates the problems facing the state in trying to deal with the legal differences between surface water and "percolating groundwater." Surface water rights permits can be issued for waters that are put to beneficial uses such as domestic, municipal, irrigation, stockwatering, electric power generation, recreation, wildlife including fish, artificial groundwater recharge and mining uses.

Groundwater is regulated separately from surface waters within the state, and only in designated areas where long-term groundwater withdrawals have exceeded the natural replenishment of groundwater supplies. Several programs have been established in these areas to alleviate severe overdraft conditions.

In addition to state laws governing the use of surface waters and groundwaters, there are federal laws have an affect on how the water resources on federal lands are managed. Many agencies including the U.S. Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (USFWS), U.S. Forest Service (USFS), and the U.S. Environmental Protection Agency (EPA), can determine the fate of many riparian areas on lands owned by the federal government in Arizona. These agencies do this through their land management and how they affect land management practices. Several programs and laws which come into play include the Wild and Scenic Rivers Designation, the Clean Water Act (Section 404 permits), and the Endangered Species Act. Although these programs affect how an agency manages its lands, they may provide only limited levels of protection of riparian areas on federal lands. At issue are land management practices that may impact an entire hydrologic system and the riparian area rather than just a water resources or streamflow. Therefore, any riparian protection strategy developed for the state of Arizona not only has to recognize the gap between current surface and groundwater law, but also provide additional support to current federal programs where gaps exist.

Arizona is not the first state to grapple with these issues and it should look to protection strategies used by other states for program ideas that may be applicable to our specific situation. Each state approaches wetland protection in different ways depending on the nature of the state's economy and natural resources problems. North Dakota, for example, pursues a wetlands preservation policy which allows the creations of wetlands to substitute for drainage projects. Oregon, on the other hand, has many programs related to riparian protection and developing voluntary committees to plan for the management of riparian and wetland areas. Most riparian protection practices in Oregon focused on forestry and logging management, however, water rights applications have to be reviewed for riparian impacts. Oklahoma has created state funded commissions to protect, plan, and manage scenic river segments. The Oklahoma commissions have broad and flexible authority to develop and implement management plans. Florida vests its local water management districts with authorities similar to state engineers in the western states. These districts are required to consider the impacts of potential new diversions and groundwater pumping on wildlife and riparian areas.

TYPES OF PROTECTION PROGRAMS

The following is a brief overview of the different types of regulatory or non-regulatory programs that may be used in a riparian protection program. Generally the range of administrative options to regulate water rights includes three approaches: 1) a statutory non-permit system, 2) statutory permit system, or 3) a local area management authority.

Statutory non-permit system

This type of regulation sets guidelines or provisions in statute to which all water users have to adhere. For example, all persons making new diversions or groundwater withdrawals might be required to maintain groundwater tables at levels which do not cause diminishment of riparian vegetation.

The statute can set guidelines for enforcement. Any agency, such as ADWR or AGFD could be delegated the administrative authority to investigate complaints and enforce the statute. Sanctions could be set by statute. Enforcement could also be the responsibility of individual citizens. The statute might allow individuals to take civil action to enjoin groundwater users who may be causing damage to riparian areas through excessive withdrawals. The statute and court could establish who may sue, the criteria for showing damage and the limits to sanctions.

This type of regulatory system provides limited control to protect individuals' property and rights. In a complex ecosystem, it may be difficult to prove that groundwater withdrawals are affecting riparian habitats. The ability to manage excessive withdrawals may be difficult since damage to riparian areas must occur before action can be taken. Any civil action may also be costly and time-consuming which may limit the effectiveness of the process.

Statutory-Permit System

A statutory-permit system is the most common method of water rights governance. In this type of system, the statute requires the State to issue a permit before water can be used or diverted. Normally, the statute lists specific conditions which applicants must meet to obtain a permit. However, the statutory conditions might allow the departmental director to use broad discretionary powers to judge whether a permit should be issued. The statutory requirements are interpreted and implemented by administrative rule. Usually the court reviews contested administrative decisions of an agency director which may lead to court interpretations of the statutes. A permit system generally requires that the public be informed that an application to use or divert water has been made. The statutes define who may comment and what may be contested.

The conditions of a permit can be enforced by an agency through administrative action which might include cease and desist orders, fines or revocation of permits. The limits of an agency's authority can be set by statute. Colorado and New Mexico have a similar regulatory system however, enforcement is different. In both states the state engineer is given broad enforcement authority to control diversions, including directly opening and closing gate structures, however neither state has riparian protection authority.

A statutory permit system provides extensive control and dispute resolution depending on the statutory limitations. The development of a regulatory system is flexible. The legislature can establish very specific requirements to guide agency decisions or delegate very broad discretionary responsibilities. The level of sanctions can be limited or expanded by the legislature.

Local Area Management

Where intensive water rights management has been necessary to avoid conflicts, different types of management authorities have been formed to oversee the distribution of water. In some cases, an irrigation district has administered the water rights system by scheduling and accounting for water deliveries which are set by court decree. In Arizona, ADWR has been given the authority to measure and account for the use of groundwater in AMAs. Local area management authorities are often governed by elected or appointed boards whose authorities are described in statute. The boards establish operating policies in accordance with statutory provisions. Often the boards have the ability to generate revenues to support their activities. These activities may include preparing studies, building facilities and executing contracts or intergovernmental agreements. Local area management authorities have the ability to enforce regulations and ordinances. Often they are given the same authorities as municipalities.

CURRENT EXAMPLES OF REGULATORY SYSTEMS

The following provides current examples of regulatory systems that could be adapted and used as a template for a riparian protection program.

Statutory Non-permit System - Well Drilling Permit Example

Current Program Description

This type of regulatory system is used for new exempt wells (small domestic type) and replacement wells within AMAs and all wells outside of AMAs. An applicant who wishes to drill a well must notify the Department that a well is being drilled, its location and pertinent data. However, the Department can take no action other than to endorse the notice of intention to drill. The primary purpose of the notices of intention to drill is to maintain a current registry of the location of the wells for public informational purposes. The well must be drilled by a licensed well driller and be drilled according to well construction rules adopted by ADWR. The owner is responsible for compliance with all well drilling standards. Compliance investigations are only begun if there is a complaint.

Alternative Regulatory System to Protect Riparian Areas
This type of regulatory program could be expanded to require the development of rules for the protection of groundwater levels which support riparian habitats. Enforcement of the rules could be through an administrative process including arbitration, cease and desist orders, and fines.

The effectiveness of this program is dependent on being able to create rules which quantify the groundwater levels necessary to support riparian habitat areas. If scientific data were available, specific rules could be written for different stream reaches throughout the state.

Problems which might be expected with enforcement of these rules include inadequate monitoring of water levels and accounting for water level changes due to regional water table declines or normal drought conditions. Monitoring water level conditions in riparian areas would probably only be feasible in selected areas or pursuant to complaints. If water level declines were observed, a potential complainant may claim that declines are due to regional effects of many wells, increased stream diversions, or reduced stream flows due to normal drought cycles. It would then be up to the injured party to prove otherwise. These types of extenuating circumstances may reduce the effectiveness of compliance activities. Compliance activities for this type of regulatory program take place after damage has been incurred.

Statutory Permit System - Surface Water Appropriations/Groundwater Withdrawal Permits
Current Permit Systems
All new diversions of surface water in the State require an application to appropriate water for a beneficial use. If the director finds the proposed use conflicts with vested rights, is a menace to public safety, or is against the interests and welfare of the public, the application shall be rejected. An application may be approved for less water than applied for, and may not be approved for more water than is needed for the beneficial use.

A water right, except instream flow rights, may be severed from the land to which it is appurtenant and transferred to another location, but only if the proposed transfer does not affect other vested rights, and it has the approval of the governing body of an irrigation district, agricultural improvement district, or water users association within which the water right is located. Such governing bodies must also approve severs-and-transfers within the watersheds or drainage areas which supply or contribute water for the irrigation of lands within their boundaries.

Within AMAs the ADWR can issue permits to withdraw groundwater if the proposed withdrawal does not unreasonably harm surrounding well owners. The criteria for determination of harm is established by rule. The type of analysis for establishing harm is specific to a newly proposed withdrawal and does not necessarily account for the regional effects of many wells.

The current regulatory permit system for surface water appropriations and diversions allows landowners to obtain instream flow rights which presumably will protect riparian habitat. Landowners can apply for new permits to appropriate, but they may not obtain existing water rights which would have more senior dates of appropriation and change the use to an instream flow (although a state agency can do so). Once a permit to appropriate is approved and a certificate is issued, subsequent permits may not be approved which would cause damage to the water right.

Currently, compliance with permit requirements is investigated pursuant to complaint. Enforcement action is a civil court proceeding. ADWR has no administrative process to address complaints, or statutory authority to investigate compliance and take enforcement action.

The current regulatory system may not guarantee minimum stream flows during times of drought if senior upstream water right holders divert water flows. Irrigation districts may veto any proposed sever-and-transfer. Water quality is not protected by the water right. Withdrawals from wells are not necessarily controlled to protect groundwater levels near streams. Unless groundwater withdrawals are proven to show direct and appreciable reductions in surface flows, no action can be taken to enjoin groundwater pumpers from impacting water levels near streams.

Alternative Regulatory Programs to Protect Riparian Areas

Standards designed to protect riparian areas by requiring specific groundwater levels and stream flow volumes could be added to the statute. These standards could be used to determine whether a new permit to appropriate would be issued. Also, riparian consumptive uses of water could be recognized as a beneficial use to the State and permits to appropriate could be issued for this specific purpose.

Present permits to withdraw groundwater and drill wells could be modified to address riparian areas. Any applicant who applies for a permit could have to demonstrate that they would not substantially impact the groundwater levels in riparian zones. Standards for determining substantial impact should be set by statutes. Sever and transfer of water rights to increase stream flow for instream or riparian uses could be allowed unless there is a finding of substantial negative impact on senior water right holders. The denial of severs-and-transfers by irrigation districts for applicants intending to change use for instream flow or riparian uses could require a finding of substantial negative impact as well.

The state, through one of its agencies, could be allowed to obtain and hold water rights for instream or riparian purposes. If the state held such rights in public trust, presumably actions to coordinate the protection of riparian and instream rights with other water rights may be enhanced.

A permit system could include standards which specify certain flow conditions for rivers and streams throughout Arizona. Minimum flows could be established for streams based on mean or median monthly flows. Streams in certain critical areas could be subject to special designation and applications for new wells or diversions would not be accepted. In addition, compliance and enforcement of permit conditions could be changed to require an agency to monitor and take administrative action to ensure compliance.

Local Area Management - Flood Control Districts/Active Management Areas
Current Regulatory Program
Management of riparian habitat and stream flow for fish, flora, fauna and recreation protection could be under the jurisdiction of special districts or agencies.

Special districts could be given many different authorities from taxing and land acquisition to monitoring and measurement of riparian conditions. Currently no examples of special districts for riparian protection exist in Arizona, but two models of broadly based local management include county flood control districts, and Active Management Areas.

County Flood Control Districts
County flood control districts have broad duties and powers to delineate floodplains, regulate development within the flood plain, acquire property and build flood control structures. They actively coordinate and confer with federal and state agencies which have specific regulatory responsibilities in floodplain areas. They create and enforce rules and regulations regarding land use and water use.

A similar type of district might be established for riparian protection. Such a district might be given the responsibilities to establish riparian protection zones where land use, groundwater withdrawals, surface water diversions and reservoir operations would be subject to minimum flow regulations, groundwater depth regulations, monitoring and compliance activities.

This type of district can provide comprehensive planning and management of riparian areas. It could also coordinate federal, state and local activities affecting critical areas. The limits of its power can be prescribed by statute. This type of district can be required to implement its programs consistent with the current water rights regulations of the state. If necessary, it could acquire property and water rights to preserve critical areas, or implement rules and permit programs to manage land and water uses. Such a district could enter into intergovernmental agreements with federal agencies to implement and coordinate projects.

Active Management Areas
Measurement, control and management of groundwater withdrawal and diversions could be carried out by the state through local management area authorities similar to Active Management Areas. The Director of ADWR could be required to inventory and assess the need for intensive water rights management in critical riparian areas, then create a management plan to control groundwater withdrawals and diversions. Advice about how critical riparian areas should be protected could be provided by an advisory board which

is appointed by the governor. The advisory board might consist of local water users, other agency representatives and other experts.

Duties and responsibilities of the Department would be delineated by statute, but all rules and regulations would be developed through a water management planning process. Rules and regulations would have to be consistent with the statutory provisions governing water rights. Such an entity could only affect water rights issues.

ECONOMIC IMPACTS OF A RIPARIAN AREA PROTECTION PROGRAM

In order to assess the potential economic impacts of a riparian area protection program, several economic activities were evaluated. These activities were grouped into four major categories separated by planning regions for the entire state (Figure 7). The major economic activities included municipal and industrial, irrigated agriculture, mining, and power industry activities. These broad sectors of the economy were chosen because they also represent the major water using sectors of the state. Water use for these economic sectors are projected to require 835,000 acre-feet of water to meet the projected demand in 50 years. This demand is projected to occur in the AMA and the Upper and Lower Colorado River Planning areas. This projected demand and water use was then evaluated relative to the employment sectors throughout the state by planning regions.

Current population and employment data for counties indicate the general size and structure of the economy. Grouping the population and employment data by county into the water planning areas demonstrates the relationship between water use and the economy on a very general level. Figure 8 contrasts the relative size of employment with water demand for each of the water planning regions.

Water demand and employment by the general categories described above can be contrasted. In Arizona, municipal and industrial water demand accounts for 17 percent, mining and power, for 3 percent, and agriculture, for 80 percent of total water demand. On the other hand, "all other" employment is 97 percent of state employment, including "hotels, lodging and other" of 2.5 percent. Agriculture employment is about 2.5 percent and mining about 0.8 percent of total state employment.

The relationship between water demand and total employment by planning region is illustrated by Figure 8. Maricopa County employment (approximation for Phoenix AMA) for 1990 was 63.3 percent of the state whereas water demand in the Phoenix AMA in 1990 was only 35 percent of water demand statewide. Pima County (18.2 percent) combined with Santa Cruz County (0.6 percent) were 18.8 percent of total state employment and water demand in the Tucson AMA was 4 percent of the State. The Pinal AMA consumed 15 percent of the State's water in 1990 while employing only 2.2 percent of the state's workers.

As can be seen from Figure 8 the majority of water use and the highest levels of employment within the state occur in the two major metropolitan areas of Phoenix and Tucson. However, water demand is also high in the Pinal AMA due to the amount of irrigated agriculture. Employment and water demand for the rest of the state is low and most likely reflects the rural character of these areas. The other exception to this is the Colorado River planning area, where water demand is high but employment remains relatively low.

The economic analysis was further refined on a planning region basis by analyzing water use, land ownership, and employment specific to these areas. Water resource data and information was collected and analyzed for groundwater basins for each water resource planning area. Population estimates and projections correspond to the planning areas, whereas economic data such as employment was reported by county. For this study, population by basin and planning area, and employment by county was used generally to describe the baseline economic conditions in the water resource planning areas. Changes in the economy are approximated by population projections to the year 2040.

PLANNING AREA ECONOMIC AND WATER RIGHT TRADEOFFS

Riparian protection regulations will affect water users only if the proposed withdrawal, diversions or uses of water will change the pattern of streamflow in such a way as to negatively impact riparian vegetation. The flow of water in the major perennial stream reaches in Arizona must be maintained in order to fill senior downstream water right demands. Therefore, most streamflow patterns cannot be impacted by new diversions and changes in use, or place of diversion under the current water rights regulations. However, if new groundwater withdrawals are permitted, the potential effects on streamflow vary depending on where and when the withdrawals take place.

Economic tradeoffs may occur if potential new withdrawals or diversions are prohibited to protect riparian areas. The types of changes that might occur to streamflow patterns and the resulting tradeoffs of which might occur if riparian protection regulations are enforced and described as follows.

Even if an existing withdrawal of water is prohibited in order to protect a perennial reach of stream, alternative water supplies may be available to meet all of the water demands. However, associated costs may be higher. A significant impact would be predicted if all of the following would occur: alternative water supplies were not available, the volume of water withdrawn supported many users, and the prohibition occurred immediately.In the case of groundwater withdrawals, existing and future withdrawals may have to be managed to protect riparian areas, or substitute water supplies may have to be found to continue or expand water uses. The potential for conflict or tradeoffs between riparian protection and projected water use is different for each planning area.

Figure 7

GROUNDWATER BASINS OF ARIZONA BY COUNTY AND PLANNING REGION

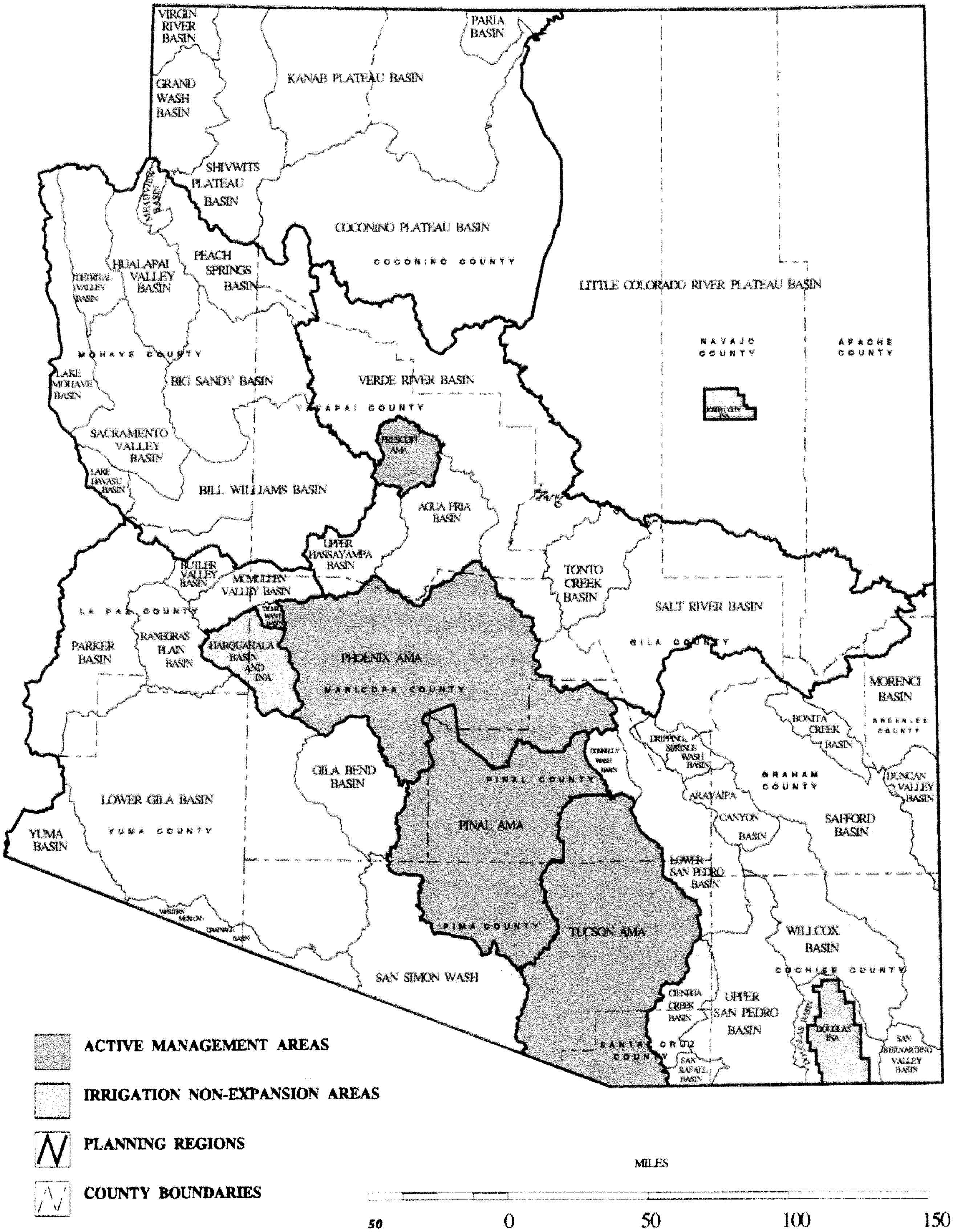
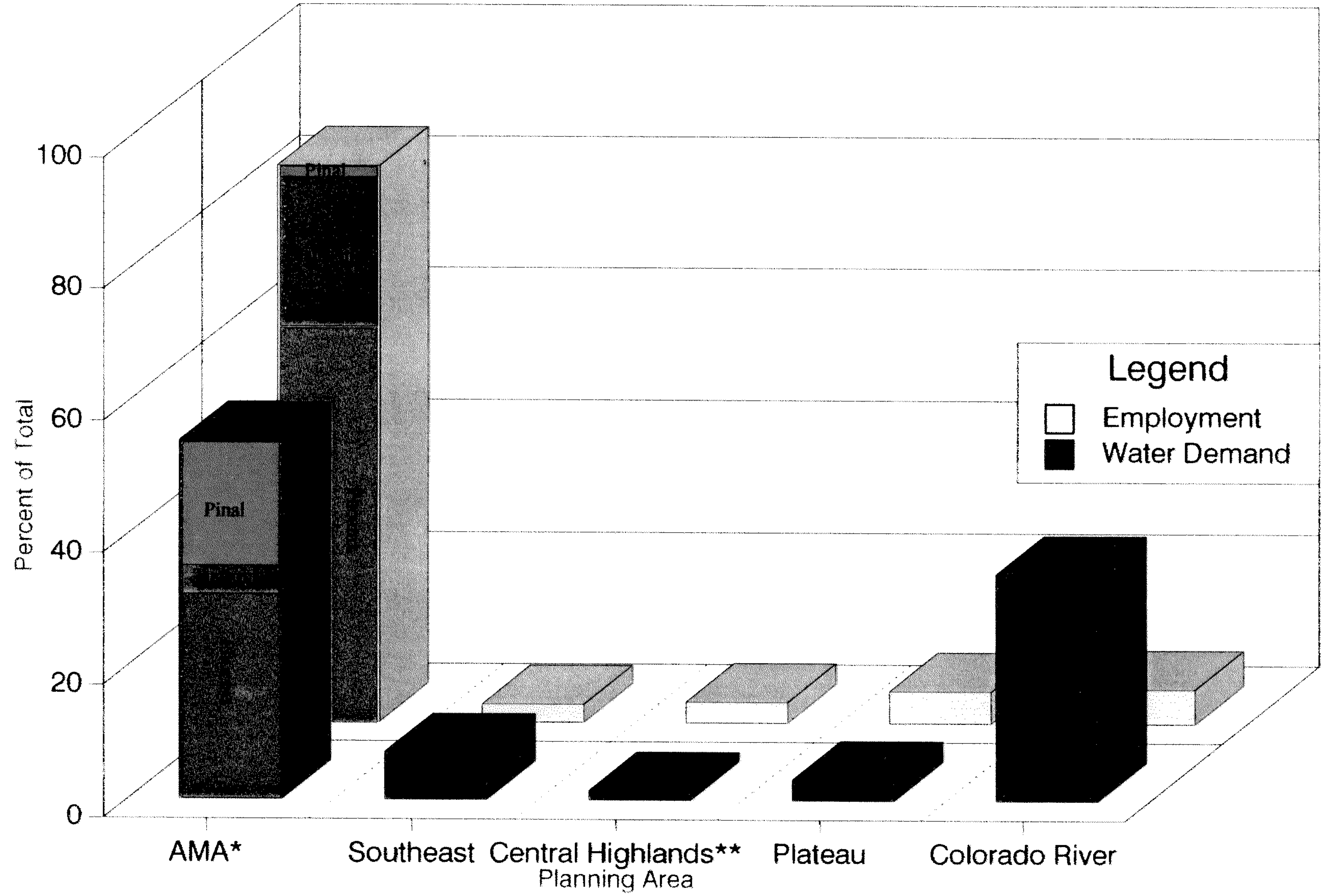


Figure 8

1990 Arizona Employment & Water Use



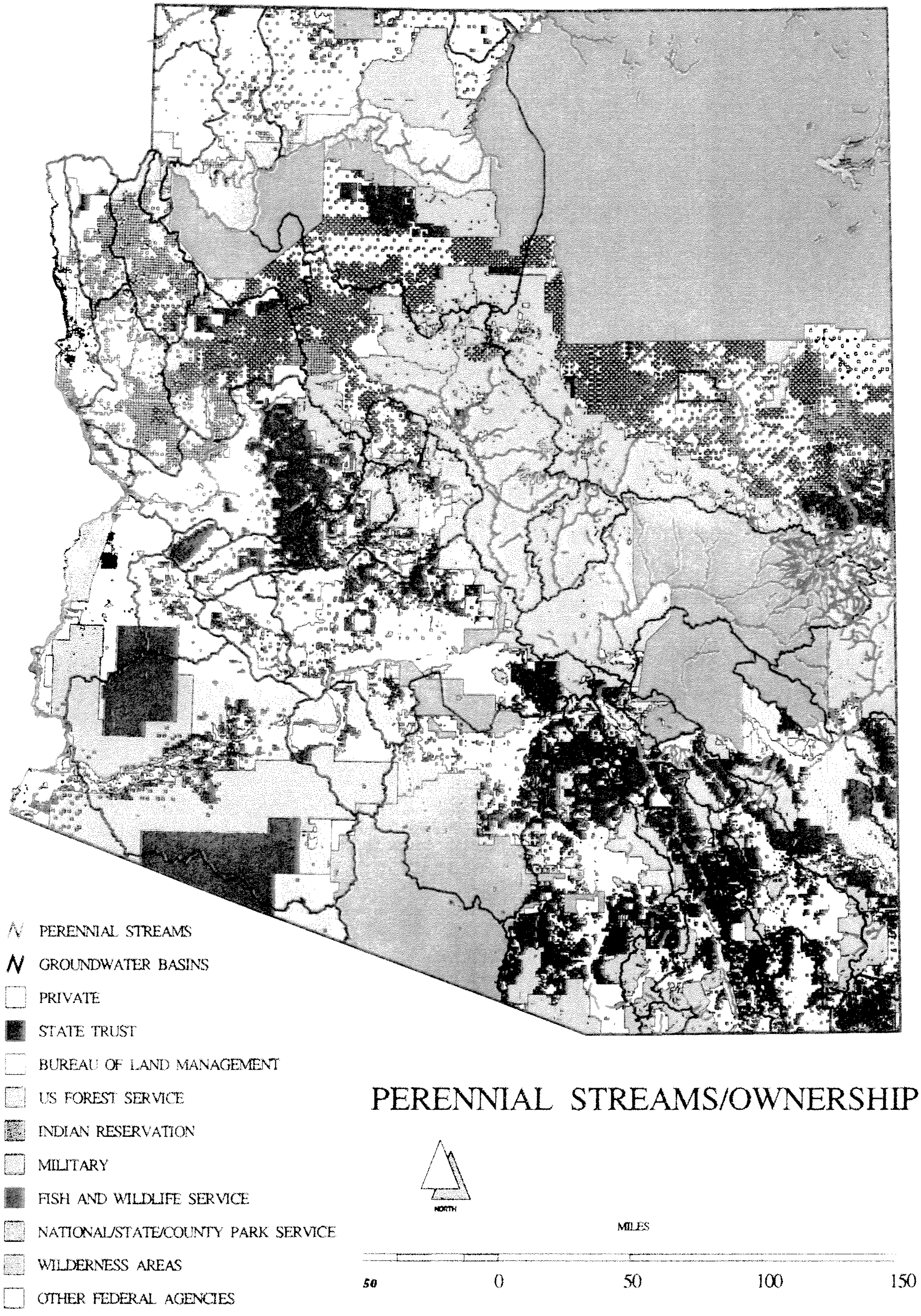
* - Does not include Prescott AMA

** - Includes Prescott AMA

Potential impacts arising from the above mentioned withdrawals are also conditioned by the ownership of lands located along perennial water courses. The results of measuring perennial streams by land ownership are given in Figure 9. Statewide in Arizona, out of a possible 5,013 miles of perennial streams, only 857 miles or 17.1 percent is owned by private interests and 146 miles or 2.9 percent is owned by the State of Arizona. The remaining 80 percent of perennial streams are located on public lands managed by the BLM, USFS, USFWS and National Park Service or on Indian lands held in trust by the Government of the United States. The management of the streams on public lands is governed by strict processes such as USFS forest plans, which must undergo a rigorous public review process. It is unlikely that future major groundwater withdrawals or diversions of perennial waters would occur on federal land. Therefore, any new restrictive state water law would probably only be relevant to private and state owned reaches of perennial streams, or approximately 1,000 perennial stream miles (20% of total).

Given the broad span of possible regulations and the diverse water use patterns within the state, impacts can vary widely. Generally, any riparian water right protection strategy will be expected to require maintenance of minimum flows in certain stream reaches. Maintenance of minimum flows enhances or ensures the availability of water for downstream water right holders without regard to their date of priority. New diversions may be precluded upstream of protected riparian areas. Existing and future groundwater withdrawals which may interfere with instream flows might be subject to increased management or reductions of withdrawals over time. But the exact nature and amount of potential reductions cannot be known without intensive data collection and scientific analysis. Little or no impact may occur for decades in some areas, but groundwater withdrawals in other areas may immediately affect local reaches of a stream if the withdrawals are large enough and if the stream is hydraulically connected to the aquifer. These types of studies must be conducted on a very site-specific basis to provide the necessary information to base riparian protection while mitigating other concerns.

Figure 9


PERENNIAL STREAMS
GROUNDWATER BASINS
PRIVATE
STATE TRUST
BUREAU OF LAND MANAGEMENT
US FOREST SERVICE
INDIAN RESERVATION
MILITARY
FISH AND WILDLIFE SERVICE
NATIONAL/STATE/COUNTY PARK SERVICE
WILDERNESS AREAS
OTHER FEDERAL AGENCIES
PERENNIAL STREAMS/OWNERSHIP
NORTH
MILES
50
0
50
100
150

SUMMARY

The following statements are drawn from the hydrologic chapter of the ADWR report.

1. Groundwater and surface water were historically considered as separate and distinct resources in Arizona. Water laws were created to manage the water resources based on this concept. However, in reality, groundwater and surface water form an interconnected hydrologic system in which quantities of water are exchanged between a stream and an aquifer based on changing hydrologic conditions. It is critical to have an accurate representation or conceptualization of the interconnected surface water and groundwater system in order to quantify any impacts.

2. The effects of natural climatic variability on components of the hydrologic cycle are unevenly distributed through time, and therefore the magnitude of streamflow expressed in a particular stream reach and the volume of groundwater in storage within an aquifer naturally fluctuate through time. This natural climatic variability was not assessed in detail in this report, but it is important to keep in mind the impacts that could occur during drought cycles or periods of low runoff or streamflow.

3. The concept of an "interrupted-perennial" stream reach is important because: (1) this type of flow has been included as appropriable surface water by the Department in the adjudication process, and (2) even though a stream may not have been "mapped" as perennial flow by AGFD, subflow may still sustain a riparian ecosystem (e.g., the San Pedro River).

4. It is often difficult to determine streamflow characteristics for streams throughout the state other than at USGS streamgage locations. In addition, not all streams are gaged by the USGS. This in turn makes it difficult to accurately determine impacts to streamflow between gage locations. Furthermore, many gage records are fragmentary and discontinuous and the data do not reflect the entire range of streamflow conditions as they presently exist (e.g., many gages throughout the state are used to measure flood flows and are not set up to monitor more prevalent low flow conditions).

5. Long-term groundwater withdrawals have created regional groundwater declines areas such as the Salt River Valley, Pinal County, and Santa Cruz Valley. In these areas, continuous groundwater pumping for agricultural, municipal, and industrial purposes has severely lowered water tables in the surrounding aquifers. Groundwater levels have been lowered to the point where they are no longer connected to surface water flows.

6. Undisturbed stream-aquifer systems achieve an equilibrium where long-term inflows equal long-term outflows. In this type of balanced system, streamflow reductions only occur during extended drought periods where below normal precipitation results in a corresponding reduction in runoff and aquifer recharge.

In a developed watershed, direct streamflow diversions and groundwater pumping can have an appreciable affect on the hydrologic system depending on the timing and magnitude of depletions and the location of these diversions. Often, depletions occur in or near riparian areas, where surface water is available and groundwater is close to the land surface.

7. Extensive groundwater pumping results in depletion of streamflow by inducing infiltration of surface water through the streambed or interception of groundwater that would have discharged to the stream. If the volume of water pumped exceeds the amount of natural recharge to the groundwater system, a deficit will occur causing a reduction in groundwater storage and declining water levels. A continuous trend of declining water levels indicates overdevelopment of groundwater resources. The degree of this groundwater mining depends on the magnitude, duration, and distribution of withdrawals, as well as the hydraulic properties of the aquifer. Where multiple wells are clustered in close proximity to one another, the effect of pumping on the aquifer is compounded, as are impacts to any nearby stream.

8. A statewide network of observation wells (index wells) is monitored annually to assess changes in hydrologic conditions through time. There are approximately 1,160 index wells throughout the state. However, most of these wells are not ideally located to monitor groundwater levels in or near riparian areas. In addition, out of the total number of wells in the state, a very small percentage of them are monitored on a regular basis. Of the few that are, an inadequate number of monitor wells occur in the riparian areas being assessed, and many of the wells that are present in riparian zones may not be effective monitoring tools for the particular area, depending on well construction and purpose. Most of the wells throughout the state penetrate more than one aquifers. Water levels from these wells reflect a regional, rather than a specific aquifer system. Usually, aquifer-specific data is not available, and when available, is spatially non-contiguous.

9. Direct well interference occurs when a cone of depression expands from the pumped well into the stream alluvium of a river creating a groundwater gradient away from the stream. Streamflow losses increase as additional surface water infiltrates into the permeable alluvium to fill the area dewatered by the well. Indirect interference occurs when groundwater flowing toward the stream is intercepted by a cone of depression. Indirect interference has the affect of reducing the amount of groundwater that would have eventually discharged to the stream, thereby reducing baseflow. In both instances the well is depleting streamflow, either by inducing additional infiltration of streamflow or by intercepting groundwater that would have discharged to the stream. In some areas, the impacts resulting from a pumping well adjacent to a stream are compounded by regional groundwater declines resulting from the combined affects of many pumping wells.

10. The effects of groundwater withdrawals on a stream do not occur the instant a well begins pumping and do not stop immediately after pumping ceases. A stream's

response to pumping can lag considerably after pumping has ceased. Even if pumping is continuous, it can take decades for water levels to decline to the point where indirect interference becomes direct, perhaps changing perennial streamflow to intermittent or ephemeral. Once withdrawals have been discontinued, water will continue to fill the cone of depression created by the pumping, thereby continuing to deplete streamflow by either reducing the volume of water discharged to the stream or inducing streamflow infiltration.

11. There are several methods that can be used to assess the effects of groundwater withdrawals on an aquifer and an adjacent stream. Most methods depend on mathematical equations to describe the interaction between an aquifer and a pumping well. These methods require data regarding the storage and water yielding properties of an aquifer and the pumping parameters of a well. All of the methods have a common foundation in the fundamental theories of hydrology that describe groundwater flow through porous geologic material (e.g., silt, sand and gravels that comprise alluvial aquifers). Differences between the various methods are due to simplification of the limiting assumptions that may not always exist in nature. Selection of the appropriate method depends largely on the type of information being sought, the availability of accurate hydrologic data with sufficient coverage, and the level of detail required. Currently, these methods can be used to effectively evaluate hydrologic impacts and changes to riparian areas.

The following conclusions and findings are drawn from the ecologic chapter of ADWRs report.

Groundwater

1. In a regional aquifer, groundwater sustains riparian vegetation indirectly. However, in floodplain aquifers, groundwater directly sustains riparian vegetation. It is well established that the health, vigor, composition, structure and abundance of riparian vegetation varies with depth to water in the floodplain aquifer. The response of the riparian vegetation to groundwater declines can be quantified. A continuous and direct relationship exists between riparian vegetation health and depth to groundwater. Therefore, as groundwater levels decline, riparian vegetation becomes stressed, resulting in the sequential loss of shallow-rooted plants followed by deep-rooted plants, reduction in tree density and canopy development, and the eventual loss of the riparian area. Such degradation and loss has been documented along many of Arizona's rivers.

2. Although vegetation characteristics changes along a continuum, there are certain thresholds of change that can be recognized. General depth to water criteria were determined by this study for many plant associations of Sonoran riparian ecosystems and warm-temperate riparian zones found in southern Arizona. Some of the depth to water criteria that have been determined are as follows:

    - Cienegas/marshlands: water tables should remain at about 0.5 (½) ft above or below the floodplain surface.
    - Goodding willow and Freemont cottonwood: for established or well

developed floodplain forests groundwater tables should at a minimum be no deeper than 10 feet.

- Mesquite bosques: to maintain high structural development groundwater tables should be no deeper than 25 feet.

There is need for additional study of vegetation-groundwater relationships, particularly for plant associations located in higher elevation riparian zones.

3. To maintain riparian plant associations over the long-term, conditions must be met for survivorship of adult plants and regeneration of new plants. A different set of water table requirements must be met to allow a new generation of riparian plants to establish. For example, to allow for establishment or continued regeneration of Fremont cottonwood and Goodding willow, portions of the floodplain must be seasonally saturated and water tables maintained within 2 to 3 ft below the water surface for several months at least once every several years. The establishment requirements for many other riparian plant species need to be determined.

4. Some riparian plant/groundwater relationships have been extensively studied. Results of these studies indicate that relationships are transferrable between like streams. For example, groundwater conditions associated with the establishment of Fremont cottonwood are very similar between rivers located in approximately the same elevation and climatic zones. Additional study is needed to determine whether this and other such relationships are "robust" in the sense that they are transferrable between streams located in different climatic zones (e.g., southern versus northern Arizona) or that differ in the floodplain's ability to hold and transmit water.

5. Although information gaps exist, adequate information is available on many vegetation groundwater relationships to determine when groundwater level changes become ecologically significant. Groundwater vegetation data can be used in conjunction with groundwater models and/or groundwater monitoring programs to identify vegetation-limiting groundwater conditions.

   Additional or predicted declines in water tables below thresholds for each riparian vegetation type or indicator species can serve as a "red-flag" that signals the need to modify pumping or diversion activities. This approach is similar to that currently being undertaken in Owens River Valley, California. Information on water requirements of vegetation, including data on rooting depths of riparian plants, can be used as a basis for modifying pumpage when unacceptable depths to groundwater are reached. This type of riparian protection approach necessitates the development of riparian monitoring programs.

6. It is recommended that riparian monitoring programs be established in Arizona to prevent groundwater decline from degrading riparian ecosystems. These programs should include groundwater and ecological monitoring components.

For the groundwater component:

Groundwater depths should be monitored at pumped sites and at control sites using continuous recording groundwater level instruments. Monitoring wells should be established within the floodplain alluvium that supports riparian ecosystems, as well as in regional aquifers that recharge that alluvium. Additionally, numerical groundwater models should be developed for streams of concern to enable prediction of long-term trends that may affect alluvial aquifers.

For the ecological component:

Vegetation parameters, including new recruitment and vegetation changes from baseline conditions, should be measured over time. Although ecologically stressful groundwater levels can be determined in advance for some species, as described in no. 5 above, riparian ecosystems also should be monitored directly for changes in their ecological condition. Direct monitoring of riparian vegetation is particularly valuable for those associations and species for which relatively little is known about their groundwater relationships.

7. There is a need for systematic study of riparian zone water table conditions, including existing and impending threats. A monitoring program such as described in no. 6 above would help to identify "at-risk" aquatic and riparian habitats located throughout the state.

8. In addition to continued study of vegetation groundwater relationships, development of riparian monitoring programs and surveys for "at-risk" habitats should be established. This could be accomplished by establishing a series of "reference" watersheds that are managed for their natural values. Such watersheds should include a variety of riparian plant communities. Riparian zones in such watersheds provide an index of the species composition, plant abundance, and community structure that are expected for each type of riparian community under "natural" or unmodified hydrologic conditions.

Surface Water

9. Surface water reductions, like groundwater declines, cause loss and degradation of riparian plant communities. Although surface water declines have caused much riparian loss in Arizona, quantification of the instream flow needs of riparian vegetation has received comparatively little study in contrast to other types of instream flow studies (e.g., instream flow requirements for fish). Nonetheless, it is clear that abundant riparian vegetation changes along a continuum with changes in surface water flow volumes. In other words, the amount of riparian vegetation increases as surface flows increase, except in sites where other factors constrain riparian development. Conversely, riparian abundance declines continuously as the amount of diversion increases. Species composition also changes along a continuum depending on surface flow rates.

10. To minimize riparian loss and degradation, new diversions should be minimized, particularly during drought years and during the growing season. Seasonal and annual flow patterns should closely track historical hydrograph information (e.g., seasonal high flows should remain in spring and late summer, or otherwise follow the natural seasonal flow pattern, and the magnitude of flood flows relative to the low flow rate should not be altered). It also should be remembered that often the combination of surface flows and groundwater together sustain large, healthy riparian vegetation zones, and thus surface waters should be allowed to remain hydraulically connected to groundwater.

11. Riparian vegetation instream flow models such as those described in this report (see Verde River Case Study) can be used in conjunction with hydrologic models to predict some of the effects of flow diversion or groundwater pumping on Sonoran and warm-temperate riparian forests, including changes in overall riparian abundance (e.g., canopy foliage area) or abundance of particular species (e.g., Fremont cottonwood). The vegetation/surface flow models developed for this study can be used as a planning tool to predict riparian vegetation declines or identify flow requirements for riparian vegetation. The instream flow models are to some degree transferable between watersheds that do not greatly differ in elevation, climate, and stream and valley morphology. However, greatest accuracy would be obtained when using watershed-specific models.

    Instream flow models should be developed for cold-temperate riparian forest-types. When using such models to predict changes, it is important to be aware that surface water volume in Arizona highly variable due to climatic variation.

12. Other types of models could also be developed to predict the response of individual species to changes in flow in specific rivers. Instream flow models that relate tree growth to flow volume (using tree-ring studies) have been used to identify minimum annual flows needed to prevent cottonwood tree death and have documented flows necessary to maintain healthy cottonwood communities. Also, demographic studies of seedling establishment should be undertaken to refine our knowledge of flow requirements for riparian regeneration. Instream flow studies also should be undertaken on effluent-dominated streams to further knowledge of relationships between volume and timing of effluent flow release, and riparian stand size and composition.

13. It is also recommended that riparian monitoring programs be initiated on rivers of concern. Monitoring should include a physical and biological component. Discharge in many streams is monitored by USGS streamgages, although there is a need to expand and upgrade this streamgage network. In addition, other groups monitor instream flows through the use of streamgages, such as The Nature Conservancy along the Hassayampa River and other river preserves, and the BLM along the San Pedro River. Many high elevation streams, however, are not gaged, nor is there much quantification at any elevation of streamflow losses resulting from diversions. There is a need to obtain and analyze such flow data in terms of riparian vegetation requirements and to focus on flow reduction trends

that impact these communities. Riparian vegetation health and status should also be directly monitored on streamflow potentially or actually affected by diversions or from groundwater pumping.

Flood Flows

14. Floods are a natural process in riparian zones. Native riparian plant communities are altered by changes in flood magnitude, frequency, and timing associated with river damming and diversion. For example, because diverted streams have less plant cover, flood velocities are often higher and more destructive. Watershed and floodplain management activities that reduce the natural resistance and resilience of riparian zones to flood events ultimately increase flood damage and reduced riparian ecosystem recovery ability.

15. For maximum ecological benefit, Arizona rivers could be managed so that their flow patterns closely resemble natural hydrographs. For example, diversion dams are a major factor modifying flood flows. Flow regimes of above-dam control sites are frequently monitored and could be used as templates for potential below-dam flow regimes. The results of the programs could be used to modify the pattern or rate of peak flows or baseflows released from a dam. If ecological stress is apparent, flow releases may need to be modified to benefit the downstream ecosystem. Determination of the release pattern will require site-specific study or review. Hydrologic studies can indicate which floodplains are inundated by flood flows of various magnitude and the rate water tables recede in response to flood flow reduction. Appropriate riparian management can be accomplished using hydrologic studies combined with biologic information on factors such as timing of tree seed dispersal, germination, and seedling requirement for various rates of water table recession.

16. The response of the vegetation in reference watersheds (see comment no. 8) can be used as an indication of the biological potential of riparian vegetation to resist and recover after floods. Riparian abundance and survivorship should be monitored at sites where floodplains or watersheds are impacted by varying types of land uses that may modify flood flow intensities or by diversions that reduce vegetation cover. If flood mortality is unnaturally high in comparison to the control or reference watershed, land and water uses in the impacted watershed and riparian zone should be investigated to determine possible factors causing riparian degradation.

Water Quality

17. Although water quantity is the primary determinant of riparian abundance and composition in semi-arid region riparian zones, water quality also plays an important role in influencing species composition. In many cases, water quality changes as water quantity changes. For example, soil salinity in riparian zones soil salinity often increases as a result of flow reduction or river damming. For some water quality parameters, sufficient information is available to identify ecological threshold levels (e.g., salinity levels) that are related to riparian compositional changes and that warrant corrective measures (e.g., release of

flushing flows from dams). Additional research is needed to determine the relationship of other water quality parameters (e.g., nutrients and heavy metals) to riparian vegetation and wildlife.

18. Water quality, particularly salinity, alkalinity, nutrient levels, and heavy metals, should be monitored in surface water, groundwater, and riparian zone soils in areas suspected of undergoing water quality changes, such as dammed rivers, effluent-dominated rivers, rivers receiving irrigation return flow or CAP water, or rivers undergoing other types of interbasin water transfers. Water quality is presently measured in several rivers (e.g., Colorado River, per the Colorado River Compact; rivers designated as "Unique Waters" pursuant to the Clean Water Act; and rivers monitored as part of the USGS stream monitoring program), however, this program could be expanded.

The following conclusions and summary statements were drawn from the regulatory strategies chapter of ADWRs report.

1. Current law in Arizona does not allow for administrative enforcement of surface water diversions. Surface water right disputes are adjudicated and administered by court decree.

2. Groundwater withdrawals are not regulated outside of Active Management Areas and <u>indirect impacts</u> of groundwater withdrawals on senior surface water right holders <u>are</u> allowed. Current law does not recognize direct, long-term impacts of groundwater depletions on streamflow.

3. Any landowner may apply for instream flow water rights to establish minimum flows for stream reaches appurtenant to their land if the water is put to beneficial use such as recreation or wildlife, including fish.

4. Approximately 80% of perennial stream reaches are located adjacent to or on land managed by the federal government or owned by Indian Tribes. The U.S. Forest Service (USFS) and the U.S. Bureau of Land Management (BLM) manage their lands through a 10 year planning process. In addition, their management actions are regulated by federal laws, such as the Endangered Species and National Environmental Protection Acts. Both agencies are actively seeking instream flow and other water rights to protect sensitive wildlife habitat areas and streams possessing wild and scenic values. State laws can assist these agencies with their protection plans, but the federal government can also provide some riparian area protection through their own legislative authorities. Currently, both these agencies have withdrawn selected land from mining, timber harvesting, and/or grazing use. In addition, they can restrict a use or require mitigation for unavoidable resource impacts resulting from a permitted use. Many of these actions could affect current or planned land uses including mining, grazing, logging as well as permits for roads and utility distribution corridors.

5. Other states have enacted laws to protect minimum streamflows, wild and scenic values, and riparian restoration. The most comprehensive of these programs provide for strong state leadership coupled with local management. Oregon, Florida and Oklahoma have programs which provide protection and restoration of riparian areas. These programs include land use regulations, building structures (e.g., constructing fences, developing water resources away from riparian areas), and comprehensive planning to protect riparian areas.

6. Riparian area protection regulations that depend solely on water rights legislation will not restore lost or degraded riparian areas or protect instream flow rights from senior appropriators exercising their water rights.

7. Many potential changes to Arizona state water rights law could be used to protect riparian areas. Two of these are (1) to require well permit applicants to provide proof that proposed withdrawals would not affect groundwater levels in aquifers supporting riparian vegetation located on public or private land, unless written permission is obtained from the landowner(s) acknowledging potential impacts and permitting their occurrence; and (2) to set by statute and/or rule allowable decline rates and volumetric reductions for groundwater levels. These statutory changes would have the added benefit of protecting other surface water rights.

8. Several changes could also be made to surface water law. For example, the statutory definition for "beneficial use" could be expanded to include appropriation for maintenance or restoration of riparian vegetation. Instream flow water right applicants would be required to determine the amount of streamflow needed to support riparian vegetation located along a claimed stream reach and provide streamflow data that shows required flows would be available.

   Currently, sever and transfer of an existing consumptive use water right to fish, wildlife, and/or recreational use is limited to landowning state agencies or political subdivisions of the state. This law could be changed to include any water right holder which would allow individuals and other agencies to convert an existing diversionary right to an instream flow right and thereby allowing conversion of an older priority date.

9. Water rights management could be accomplished through a state management authority. The management structure of the authority could be similar to that established for groundwater Active Management Areas. The authority would be responsible for developing a water management plan with supporting rules and regulations designed to protect riparian resources from long-term groundwater depletion and new diversions, including changes in places-of-use and points-of-diversion. In addition, the authority could have regulatory enforcement capabilities.

   Another management strategy that would allow more local control and funding could be modeled after the states's county flood control districts. These districts are able to raise revenues through taxation, enter intergovernmental agreements with federal agencies, develop plans, own land, and obtain water rights.

10. Potential impacts resulting from statutory changes designed to protect riparian areas cannot be forecast without site specific studies. Further studies should address long-term water supplies and demand, including the development of alternative water supply strategies and water conservation plans.

11. Riparian protection laws may necessitate conversion of existing agricultural water rights to municipal and industrial uses to help support future growth and development. These conversions will probably result in a reduction in agricultural employment opportunities. However, the reduction would probably be nominal from a statewide perspective, with some job losses offset by job opportunities resulting from municipal and industrial development.

12. Riparian protection legislation may preclude the development of new surface water diversions upstream of protected riparian areas. However, the probability of constructing new diversions, in most planning areas of the state is limited. This is because many remaining perennial or intermittent stream reaches are either located in remote headwater areas, or streamflow within these reaches are claimed by senior water right holders with diversions located downstream. In addition, some of these streamflows are controlled by existing court decrees.

13. The projected growth of many cities and towns should not affect existing riparian areas with <u>proper planning and management</u>. However, growth of many other areas, including those in the Verde Valley and along Oak Creek, may continue to threaten existing riparian habitat unless water management strategies that require retirement and conversion of some agricultural water rights to residential and industrial uses and recycling of water back to the river are developed and implemented.

    Riparian vegetation located along the San Pedro River may sustain some long-term impacts resulting from water withdrawals associated with growth and development in the Sierra Vista/Fort Huachuca area. Existing and future groundwater withdrawals may require management if riparian areas are to be protected from long-term groundwater depletion. Groundwater use can be minimized through effluent use, and development of other alternative water supplies.

    Even if water withdrawals are prohibited to protect a critical stream reach, alternative water supplies may be available to meet all water demands, but at a potentially higher cost. A significant impact, resulting from riparian protection, would be predicted for an area if all of the following conditions were to occur: (1) alternative water supplies were not available; (2) the volume of water withdrawn supported many users; and, (3) the prohibition occurred immediately.

14. Efforts to maintain riparian areas could enhance rural lifestyles in many areas of the state with potential increased tourism and recreational activities providing additional employment opportunities. As metropolitan areas in Arizona continue

to expand, these opportunities would increase as progressively more people look to rural locations for recreation.

15. Current Arizona state law does not allow interbasin transportation of groundwater to offset groundwater withdrawals in areas which may negatively impact riparian areas.

SUMMARY OF THE

ARIZONA RIPARIAN INVENTORY AND MAPPING PROJECT

ARIZONA GAME AND FISH DEPARTMENT

SUMMARY OF THE ARIZONA RIPARIAN INVENTORY AND MAPPING PROJECT

The Arizona Game and Fish Department's report on the Statewide Riparian Inventory and Mapping Project (Valencia et al. 1993) was submitted on December 1, 1993 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 directed the Arizona Game and Fish Department (AGFD) to conduct investigations relating to Arizona's riparian areas and to report on its findings. Specifically, it mandated 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 tribal, 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).

Identification, Classification and Mapping of Riparian Areas:

Our primary charge was to identify, classify and map riparian areas which the Act 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). To accomplish this, 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 methodology chosen was determined to be the best technology available to map riparian vegetation on a statewide basis given the time requirements of the legislation.

The resulting maps show the extent of riparian vegetation along perennial stream corridors in Arizona. First, the riparian area is identified through the manipulation of satellite data. This process is called satellite image processing and is based on the computers ability to differentiate areas based on relative vegetation biomass, moisture gradients and topographic and elevational changes. The results of image processing are also used to define natural groupings, or polygons, of vegetation within the riparian area. This is referred to as an unsupervised classification. Aerial videography is then used to identify the dominant vegetation that exists within each of these polygons. Eventually, each polygon is assigned to a vegetation group in the classification system based on dominant vegetation, biogeographic region, climatic zone, biotic community, and vegetation community structure.

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. The hierarchical sequencing permits mapping at various scales and maintains the needed flexibility for application to a statewide classification and mapping effort.

Although this process separates riparian vegetation into distinct units, there is usually no single point or line where a riparian area ends and upland vegetation begins. In nature, riparian areas form a transitional zone between aquatic and upland zones. At the outer extent of the riparian zone, vegetation blends 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 area. In these cases, supplemental information, such as depth to groundwater, topography, soils and plant morphology, is used to distinguish the riparian area.

Remote sensing techniques require some ground verification to ensure accuracy. This is called ground-truthing. For this project, AGFD devised a method to assess the accuracy of the riparian vegetation maps through ground-truthing. Mapped vegetation was first stratified by polygon size and vegetation type. Then, the computer was used to randomly select 20% of the mapped areas. These areas were visited, vegetation data were collected, and field data were compared to the classification assigned through the remote sensing process. Stream corridors in the southeastern portion of the state were investigated during 1993. Results of that effort are presented in the report. Ground-truthing has been conducted continuously since the publication of the report and modifications have been made to the maps based on data collected through this process. Maps will be released to the public in June 1994, except for areas in Coconino, Navajo, Apache and Greenlee Counties. The riparian areas in these counties are at higher elevations and can only be ground-truthed during summer months. Therefore, we anticipate these maps will be available on or before October 1, 1994.

The riparian maps created through this process represent the general location and type of riparian vegetation that existed along a watercourse at a single point in time, (i.e., at the time the satellite images were taken). The maps will not delineate every tree and shrub in the riparian corridor. They are intended to provide us with (1) data on the amount and general type of riparian vegetation existing at a given time in the state, (2) the location and percentage of various riparian vegetation community types in the state, and (3) baseline data for change analysis studies (comparing general trends or changes among years).

Mapping of riparian areas is being completed in a phased approach. During 1992 and 1993, priority was given to mapping riparian areas associated with perennial waters. The first phase of the inventory covered 4,629 miles of streams and mapped 266,786 acres of riparian vegetation. Portions of the Colorado River and its perennial tributaries within Grand Canyon National Park have not yet been inventoried because of flight restrictions. This portion represents an additional 393 miles of 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

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.*

Based on preliminary data, riparian vegetation associated with perennial streams comprises approximately 0.4% of the total land area of the state. Vegetation associated with the excluded portions of the Colorado River are not represented in this number.

It should be noted that not all riparian vegetation 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 yet to be inventoried. Mapping of riparian vegetation associated with intermittent waters will be initiated in June 1994.

Land Ownership and Land Use Maps:

General land ownership and land use maps for Arizona were compiled and presented in the 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).

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 occurring within the identified riparian area.

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

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. Specific land uses occurring on private and tribal lands could not be identified on a statewide basis because no comprehensive data sets exist for these areas. Potential activities not depicted for private and tribal lands include recreation, development, agriculture, grazing, and timber or fuelwood cutting.

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.

Assessment of Relative Functions and Values:

The term "functions" refers to the physical, chemical and biological processes that occur in riparian areas and wetlands. Functions are part of the self-sustaining properties of the riparian ecosystem. They operate within a riparian area whether or not they are viewed as important to society. Some functions may also have a corresponding societal and economic 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 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 functions 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).

The following broad classes of functions have been attributed 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.

These functions are briefly described in the report and references are provided for more in depth research on this topic.

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. 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. 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.

Development of A Hierarchical Designation System

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 wetlands assessment 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 Bureau of Land Management's "Process for Assessing Proper Functioning Condition" (Prichard et al. 1993) and U.S. Army Corps of Engineers' "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 continually 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 are discussed in the report.

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. At this time, data collection techniques appear to be inconsistent and incompatible.

4) Completion of the three project areas under this legislation (AGFD, Arizona Department of Water Resources, Arizona Department of Environmental Quality) adds a great deal of information to our knowledge base. Riparian vegetation, land ownership and land use maps are contained in a digitized format. Geographic Information System (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 or not all wetlands should be treated the same. 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. 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 proposed 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). A functional assessment is a scientific process to evaluate the processes occurring within the riparian ecosystem.

Step 2. Categorize areas based on their general functional condition. (Properly functioning, functional-at-risk, nonfunctional, and condition unknown.)

Step 3. Each of the categories in Step 2 has implications as to protection and management actions required to restore them to functionality or to maintain them in the present condition.

Step 4. Within each category, assess whether high, medium or low values exist. Since values represent the social significance placed on these streams, this step requires a broader input of opinions. The Riparian Areas Advisory Committee may serve in such a capacity.

Step 5. Prioritize areas for protection or management action based on the assessment of the functional condition (step 2) and the associated value placed on that stream segment (step 4).

Existing Options for Protecting Riparian Areas:

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.

Continuation of Work:

Since completion of the report, AGFD has completed ground-truthing the majority of riparian areas associated with perennial waters. These maps will be available to the general public in June 1994. Areas above the Mogollon Rim, in the White Mountains and on the Navajo Reservation have not yet been completed. Most of these areas are at higher elevations and cannot be adequately ground-truthed until summer. Maps of these areas will be available after October 1, 1994.

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. AGFD staff will also be working on bridging information gaps that will help us achieve an implementable hierarchical designation system. 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.

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SUMMARY REPORT OF THE
EVALUATION OF ACTIVITIES OCCURRING IN RIPARIAN AREAS

Arizona Department of Environmental Quality

SUMMARY REPORT OF THE EVALUATION OF ACTIVITIES OCCURRING IN RIPARIAN AREAS

INTRODUCTION

This report evaluates selected activities occurring in riparian areas in the State of Arizona. In 1992, the Legislature of the State of Arizona assigned the following duties to the Arizona Department of Environmental Quality (ADEQ):

> ...identify activities, operations and uses that occur on land in riparian areas of federal, state and private property in this state that involve removing or depositing material, removing vegetation or otherwise obstructing, altering or destroying riparian areas. The department shall evaluate at least the following activities:
>
> 1. Timber harvesting
> 2. Agricultural land clearing
> 3. Recreational use and development
> 4. Commercial, industrial and residential development
> 5. Road and bridge construction
> 6. Dam and reservoir construction and operation
> 7. Channelization and bank stabilization
> 8. Sand and gravel extraction
> 9. Wetland drainage
> 10. Grazing
> 11. Landfills and sewage treatment facilities
> 12. Mining and metallurgical operations
>
> (A.R.S. §45-101.6.A.)

Riparian areas are important for both ecological and economic reasons, a fact that is amplified by the passage of the riparian legislation (A.R.S. §45-101 et. seq.). They are unique parts of the ecosystem that are limited in size and number. Many human activities both rely on and impact riparian area resources.

This report identified various activities for their impacts on riparian areas. It is not intended to be an in-depth, scientific reference. It is presented as background information for individuals involved with decisions on protecting riparian areas. It was written within the limitations of information availability, access to data and the existing levels of scientific references. Professional judgement has been used in areas where uncertainty or conflicting interpretations exist.

DEFINITIONS

In this report, **evaluate** means to identify effects, both direct and indirect, of activities on riparian areas. The effects identified are on the major functions and ecological components of these areas. Activities were evaluated in relation to the removal or deposition of material, removal of vegetation, or other obstruction, alteration or destruction of riparian areas as suggested in A.R.S. §45-101.6.A.

The following definition of **riparian area** has been used in the evaluation process:

> "Riparian Area" means a geographically delineated area with distinct resource values, that is characterized by deep-rooted plant species that depend on having roots in the water table or its capillary zone and that occurs within or adjacent to a natural perennial or intermittent stream channel or within or adjacent to a lake, pond or marsh bed maintained primarily by natural water sources. Riparian area does not include areas in or adjacent to ephemeral stream channels, 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 collections systems. (A.R.S. §45-101.7)

The United States Geological Survey (USGS) describes stream classifications for surface water hydrology. A **perennial** stream is one which flows continuously. An **intermittent or seasonal** stream is one which flows only at certain times of the year. This type of stream flows when it receives water from springs or from some surface source such as melting snow.

METHODOLOGY

The method used for this evaluation consisted of four steps. The steps are described as follows.

Step 1. Identify activities that could effect riparian areas. The riparian legislation (A.R.S. §45-101) listed the activities to be evaluated and was considered complete. The only change was the splitting of the landfills and sewage treatment facilities activity into two activities, and sewage treatment was changed to wastewater treatment facilities.

Step 2. Verify that activities occur in and around potential riparian areas. It was determined that all the activities occur or potentially occur in or near perennial or intermittent streams in Arizona.

Step 3. Evaluate each activity relative to potential effects, direct and indirect, based on reviewing published data and communication with land managers. Each activity was evaluated based on the worst case scenario. Management measures that could be used to prevent, reduce, or mitigate effects were outlined for each activity.

Step 4. Summarization of the analysis of activities and effects was compiled so that activities can be compared with each other. The summary provides a comprehensive and succinct presentation of the complex interaction between the various activities and their effects on riparian areas.

CONCLUSIONS

This report evaluated various activities and the effects they have on riparian areas. The effects of activities are complex and variable. This is primarily due to the fact that each activity is unique in its frequency, intensity, duration, individual site size and statewide spatial extent.

SUMMARY OF EFFECTS

A matrix is presented that summarizes the direct effects of activities as discussed in the report. The effects are grouped according to hydrologic, channel and floodplain, biotic, and water quality functions. Some effects occur for all or most of the activities evaluated. These effects, in decreasing order of frequency, are: the removal of riparian vegetation, soil disturbance in the floodplain, alteration of the channel geometry, increase contaminants in the water and removal of upland vegetation. It is interesting to note that the hydrologic effects are scattered with no particular effect having a significantly higher frequency than another.

Other observations regarding this evaluation are as follows:

- Water is the key component of riparian areas for both intermittent and perennial streams. Activities which **influence runoff** such as grazing, timber harvesting, and urban development, **control flows** such as dams and channelization, or **use diverted water** such as agriculture and urban development, effect riparian areas by limiting surface and subsurface water flow.

- Activities that typically occur within stream channels and change the channel geometry or disturb the soil, have a higher potential of causing direct effects. These activities are sand and gravel extraction, road and bridge construction, dam and reservoir construction and operation, and channelization and bank stabilization. Dam construction has had the most profound effect on streamflow patterns.

- Activities which remove riparian vegetation alter the terrestrial and aquatic habitat. However, if streamflow has not been altered, vegetation has a high probability to recover. This resilience is a natural component of the dynamic environment found in riparian areas.

- The intensity of any one activity often varies from site to site. Depending on this intensity, the results range from little change to a complete alteration of the riparian area. The effects of activities are found not only in the immediate proximity to the sites, but can extend far downstream (e.g dam and reservoir construction, wetland drainage).

- The degree of effects vary over time and space and the effects can be cumulative. An example of these cumulative effects on the Salt River through Phoenix are: agricultural land clearing (removed vegetation); dam and reservoir construction (removed water); road and bridge construction, sand and gravel operations and channelization (modified the channel); commercial, residential and industrial land uses (covered soil surface of the floodplain); and landfills and sewage treatment facilities (sited on floodplains). The final result is a totally modified riparian area.

Table 1. Summary of direct effects activities have in riparian areas.

Direct Effects	Timber Harvesting	Agricultural Land Clearing	Recreation Use & Development	Commercial, Residential, Industrial Development	Road & Bridge Construction	Dams & Reservoir Construction/Operation	Channelization / Bank Stabilization	Sand & Gravel Extraction	Wetland Drainage	Grazing	Landfill Facilities	Wastewater Treatment Facilities	Mining & Metallurgical Operations
HYDROLOGY													
Remove / divert water		X				X		X	X				
Lowers groundwater table								X					
Obstruct streamflow					X	X		X					
Discharge to stream				X								X	X
Increase runoff, erosion, water yield	X							X					
Alter water drainage				X	X								X
CHANNEL/FLOODPLAIN													
Soil disturbance		X	X	X	X			X		X	X	X	X
Impervious surface/soil compaction			X	X	X		X						
Increase stability of floodplain						X	X		X				
Alter channel geometry			X		X	X	X	X	X	X			X
Alter channel materials					X	X	X	X		X			
Line channel							X						
BIOTIC													
Remove riparian vegetation	X	X	X	X	X	X	X	X	X	X	X	X	X
Remove upland vegetation	X	X								X	X	X	
Reduced effects of cattle						X							
Decrease wildlife			X		X								
Increase wildlife								X					
WATER QUALITY													
Increase fecal material										X		X	
Increase contaminants into water	X	X	X	X	X		X	X		X	X	X	X

Activities can be grouped according to their site preference, which is dependent on resources and operation or function. The site preferences for the activities are presented in a table. Activities that occur directly in or over riparian areas can significantly affect water flows or channel and floodplain structure in a direct manner. Such activities as dams, channelization and bank stabilization, and bridges always occur along some type of drainage or channel. Other activities such as sand and gravel extraction can usually be found in close proximity to drainages or on the surrounding lowlands because that is where alluvial materials are

Table 2. Site preference of activities.

RIPARIAN AREA EVALUATION	
ACTIVITY	**SITE PREFERENCE**
Dams Wetland drainage Channelization and bank stabilization Bridges	Directly in / over riparian or wetland areas
Sand and Gravel Operations Irrigated Agriculture Wastewater Treatment Facilities	Close proximity to channel or riparian areas
Grazing Commercial, residential, industrial development Roads and highways	Riparian areas and uplands
Timber Harvesting	Uplands
Recreation Landfills Mining	Multiple preferences or no preferences

deposited. Wastewater treatment facilities occur in lowlands because it is logistically easier to allow water to run downhill. Grazing, road building and development occurs in both lowland and upland areas, but there is tendency to occur more often on the lowland areas. Activities such as timber harvesting are often found in the uplands for reasons such as type and quality of trees.

Some activities can occur in many places or are dependent upon other factors. Recreation can occur across the landscape. Many factors determine locations of landfills including economics, politics and environmental impact. Mining and metallurgical operations are dependent upon the natural occurrence of ore bodies and other economic considerations such as the costs of transportation.

PROPOSED MANAGEMENT PRACTICES

The number of effects or intensity is greater the closer an activity is to a riparian area. As the distance from the riparian area increases, the effects decrease.The relationship between the effects of an activity and the activity's proximity to a riparian area is illustrated in **Figure 1**. The vertical axis represents the total intensity of effects. The horizontal axis represents how close the activity is to a riparian area.

Direct and indirect effects can impact riparian areas. The relationship of two types of effects, direct and indirect, relative to an activity's proximity to a riparian area is illustrated in **Figure 2**. Activities located close to riparian areas have more direct effects on the area. An activity located further from a riparian area may not have as many direct effects but may have indirect effects.

Management strategies that could be used to protect riparian areas are illustrated in **Figure 3**. They are avoidance, restrict activities, technological controls, and BMPs. For those activities having the greatest number and intensity of effects directly in or near riparian areas, avoidance of riparian areas may be the most effective management tool; particularly for high quality riparian areas. Restrictions of activities (such as controlled access) may be used for those activities which may directly affect riparian areas; particularly those of lesser quality. Reduction of indirect effects using technological or other management tools may be more appropriate for activities which are farther away from riparian areas. For those activities which occur primarily on the upland, the use of Best Management Practices (BMPs) can help reduce the indirect effects. Of course, BMPs, technological controls, restriction of activity and avoidance of riparian areas can be used in any combination by all activities to protect riparian areas.

Direct disruption of water supply or alteration of the channel and floodplain are most effectively managed by proper siting. Further, activities that physically effect either the water supply to a riparian area, the physical setting of the riparian area, or the riparian vegetation would probably consider avoidance or minimization of impacts to high value riparian areas. For activities in lower value riparian areas, minimization or compensation mitigation may be a more appropriate strategy.

For activities that do not directly effect the physical setting of the riparian area, avoidance may not be an appropriate or reasonable strategy. Minimization of effects is more likely the most effective strategy. For example, a metal mine located in an upland area that drains to a riparian area may indirectly effect the groundwater and surface water quality supporting the riparian area. This potential risk could be minimized through water treatment or runoff containment.

This report is the first in a series of reports describing various aspects of riparian areas. The effects of certain activities on riparian areas and strategies to manage these areas is presented. The compilation of information provided in this report and in forth coming reports from Arizona Game and Fish Department and Arizona Department of Water Resources, will provide a framework on which a reasonable strategy for riparian protection will be developed.

Figure 1. Effects of activities versus the activities' proximity to riparian areas.

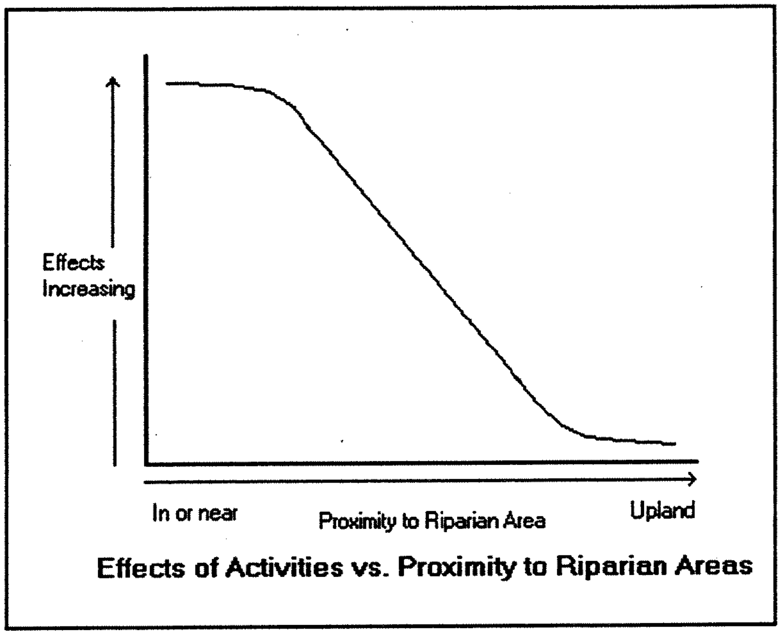

Figure 2. Types of effects of activities in relation to the proximity to riparian areas.

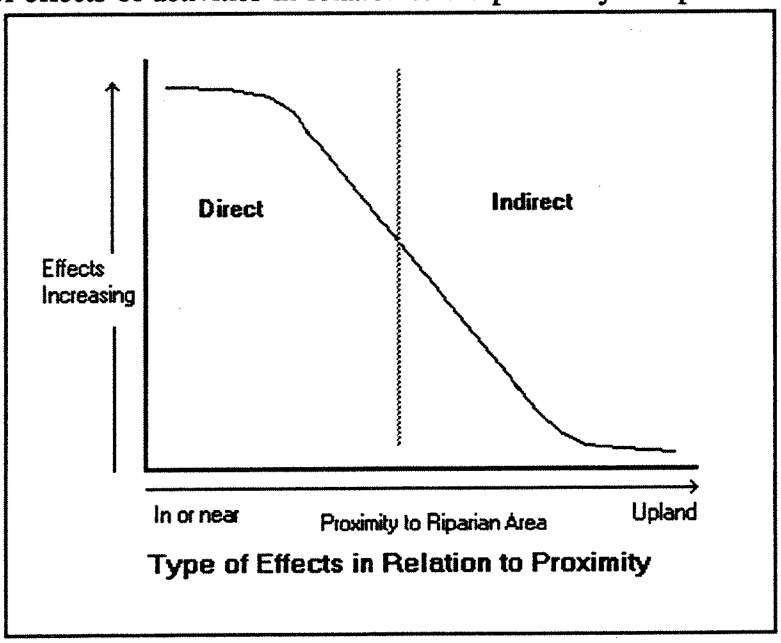

Figure 3. Management strategies to protect riparian areas.