CONDITIONS THAT DEFINE A RIPARIAN ZONE IN SOUTHEASTERN ARIZONA

by

Roy Leonard Jemison

A Dissertation Submitted to the Faculty of the

SCHOOL OF RENEWABLE NATURAL RESOURCES

In Partial Fulfillment of the Requirements
For the Degree of

DOCTOR OF PHILOSOPHY
WITH A MAJOR IN WATERSHED MANAGEMENT

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 8 9

THE UNIVERSITY OF ARIZONA
GRADUATE COLLEGE

As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Roy Leonard Jemison

entitled CONDITIONS THAT DEFINE A RIPARIAN ZONE IN SOUTHEASTERN ARIZONA

and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Peter F. Ffolliott	Date 4/14/89
Leonard F. DeBano	Date 4/14/89
Martin M. Fogel	Date 4/14/89
	Date
	Date

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Dissertation Director Peter F. Ffolliott — Date 4/14/89

STATEMENT BY AUTHOR

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or Dean of the Graduate College when in his or her judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Roy P. Jemison

ACKNOWLEDGMENTS

I wish to express my gratitude to Drs. Peter F. Ffolliott and Leonard P. DeBano for their helpful suggestions and guidance in conducting the study and in writing this manuscript.

Appreciation is extended to Drs. Martin M. Fogel, Donald F. Post, and Thomas C. Tucker for serving on my committee in addition to having been my instructors.

This dissertation was supported by a cooperative education grant from the USDA Rocky Mountain Forest and Range Experiment Station.

I wish to express special gratitude to my mother and sister for their encouragement throughout my graduate program.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

Riparian areas in Arizona have been centers for man's activities such as farming, cattle grazing, recreation, wildlife habitat, water, and cities, since the early 1800's. Representing less than one percent of Arizona's land resource base, riparian areas have received a disproportionately high amount of use and abuse. Public and private awareness of the necessity to preserve and manage riparian areas was aroused in the late 1960's by the Arizona Fish and Game Department and United States Forest Service with a study documenting that clearing of riparian areas was detrimental to wildlife habitats. Since the early 1970's national conferences, studies, and legislation concerning protection, preservation, and management of riparian areas have demonstrated the increasing public interest for riparian areas.

Proper management of riparian areas requires land managers to have information on the environmental parameters active in these areas. Riparian areas have been studied since the 1930's, but early studies looked mainly at how to increase water yields from riparian areas through vegetation management. It has only been since the 1970's that studies have been aimed at protection and preservation of riparian areas. This dissertation documents an added effort to broaden the existing knowledge on riparian areas in the southwest.

A riparian area bordering Paige Creek in southeastern Arizona was monitored for 24 months. Environmental data (e.g. precipitation, streamflow, watertable levels, soils, soil water status, and vegetation) were collected and analyzed with the objective, to determine if soil moisture content could be used as an indicator of a riparian area in the absence of typical riparian vegetation.

Statistical tests indicated soil moisture in the upper 48 inches of soil could not be used to indicate the riparian area. The position of existing riparian vegetation was controlled by the location of the watertable. Unless the location of the free water supply is known, soil moisture readings alone could prove misleading.

INTRODUCTION

Riparian areas, as defined by the Southwest Region of the United States Forest Service, are "geographically delineable areas with distinctive resource values and characteristics that are comprised of both the aquatic and riparian ecosystems" (USDA Forest Service 1986). Riparian areas occupy approximately 279,600 acres in Arizona, 100,700 acres of which are located along the Gila River (Babcock 1968). Riparian areas are represented in every life zone, from mountain alpine communities to subtropical Sonoran Desert scrub plains and valleys of the lower Gila and Colorado Rivers (Brown 1982). Riparian areas are unique in contrast to the communities which surround them because they are supplied with water, from permanent or semi-permanent sources, in excess of the amount received by the surrounding communities (Johnson et al. 1985). Vegetation, when present, can be distinct riparian species, or a mixture of species from the surrounding communities and riparian species (Szaro 1988; Lowe 1964). Riparian areas can transcend more than one environment, such as down a mountainside, allowing species from higher elevations to move down slope into cooler and moist environments (Lowe 1964; Minckley and Brown 1982; Swanson et al. 1982). Riparian areas can be small narrow strips along mountain canyons, meadows, or extensive floodplains at low elevations (Minckley and Brown 1982).

Riparian areas in the southwestern United States have a long history of use which began with the Native Americans who first cleared and settled riparian areas for farming and grazing (Carothers 1977; Horton and Campbell 1974). These areas, destine to become centers for man's activities, where further encroached upon with the arrival of Anglo-American settlers in the 1820s, who accelerated the process of land clearing as they prepared new lands for farming and grazing. Farming and ranching flourished in Arizona for over a century at the expense of the riparian areas. By the late 1920s, the majority of Arizona's population had changed from rural-agrarian to urban-industrial. At the same time, large-scale irrigation systems were put into use. These new institutions put increasing demands on Arizona's limited water resources.

Clearing of riparian areas and phreatophyte management research for increased water yields and control of Tamarix chinensis, an invader species were started in the 1930s and continued into the 1960s (Horton and Campbell 1974; Carothers 1977; Affleck 1975). Clearing of riparian areas was implemented even though adequate research had not be undertaken to determine if it was an appropriate management practice, from the standpoint of increasing water yields and the adverse affects that it could have on the entire riparian community (Bowser 1952). In 1968, personnel with the United States Forest Service and Arizona Fish and Game Department presented the first results of a study which demonstrated that vegetation removal practices were detrimental to wildlife communities that use riparian areas (Carothers 1977).

Widespread concern over how riparian areas should be managed has risen since the early 1970s, evidenced by increasing numbers of organized interest groups, studies, conferences, and legislations (Floyd 1987; Reichenbacher 1984; Huffman 1981; Larkin 1987; Barstad 1881; Johnson and Jones 1977; Johnson and McCormick 1978; Johnson et al 1985; Mutz and Lee 1987; Crumpacker 1985). The Importance, Preservation, and Management of Riparian Habitats was the name of and key issues discussed at a 1977 symposium held in Tucson, Arizona (Johnson and Jones 1977).

To preserve and manage riparian areas effectively, management objectives must be clear. Management objectives for riparian areas can be difficult to develop and implement due to the many concerns that must be addressed. Today, unlike the pioneer days, in addition to supporting farming and grazing, riparian areas also must support recreation, fish and wildlife management, forest products, roads, mining, supply water for domestic and agricultural use, and now more than ever be sustainable (Thomas et al. 1979) (figure 1). In many instances, riparian areas must be managed for several uses simultaneously (Johnson et al. 1985).

A systematic riparian classification method is needed to identify riparian areas in the field, make management decisions about them, and to facilitate the exchange of information between managers and users (Pase and Layser 1977; Szaro 1989). Several vegetation studies covering Arizona and New Mexico riparian areas and preliminary guides have laid the foundation for a classification system (Campbell and Green 1968; Pase and Layser 1977; Minckley and Brown 1982; Brown 1982; Szaro 1989; Maxwell et al. 1983). Szaro (1989) suggested that the lack of interest in this area may be due to the limited number and

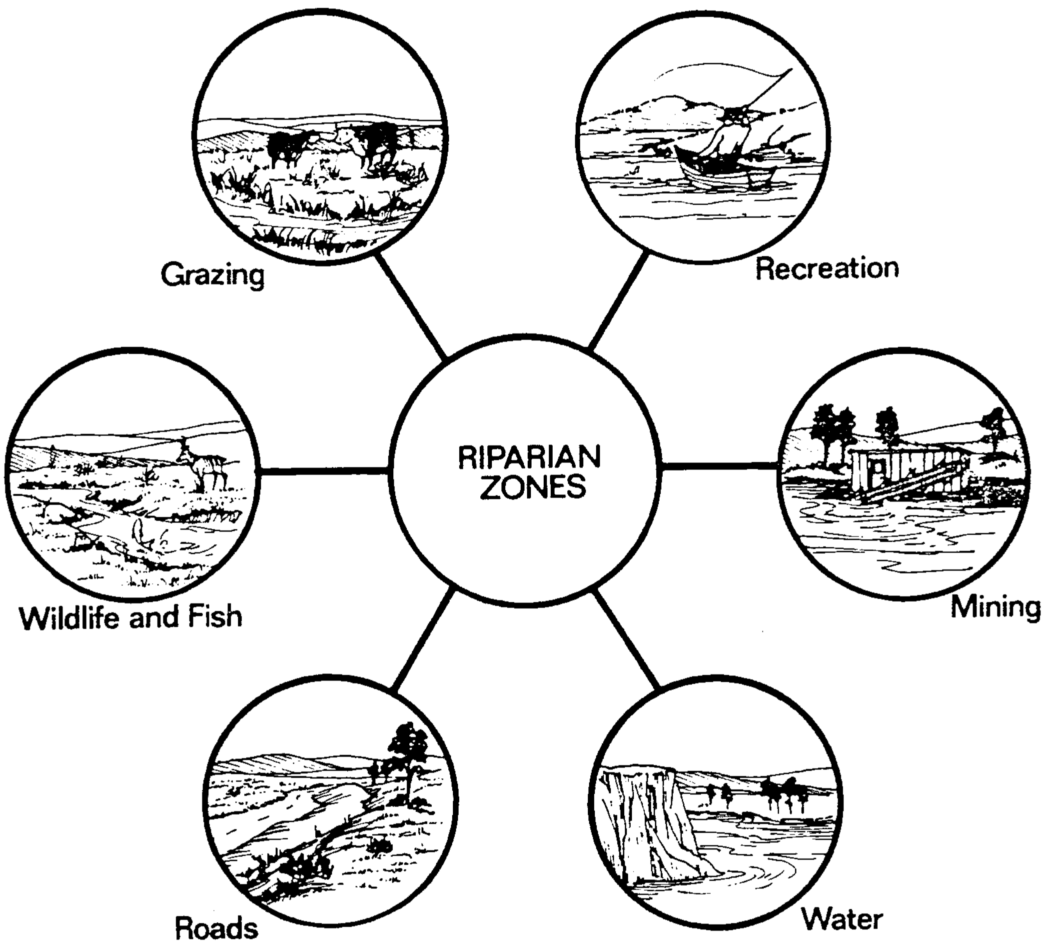


Figure 1. Riparian areas can be managed for many different uses, and often must be managed for multiple uses at the same time (Thomas et al. 1979).

small sizes of riparian areas. The complexity of the vegetative communities within some riparian areas could also be a limiting factor.

Implementation of riparian area management practices should be preceded by studies to understand how these areas operate. The results of these studies should guide the development of management practices. Past studies have indicated that the consequences of improper management can lead to permanent loss of some riparian areas (Lacey et al. 1975; Carothers 1977). Studies to understand how the riparian areas function should cover multiple disciplines including hydrologic inputs, soils, geomorphology, ecology, topography, wildlife, and surveys of present and past use (Reichenbacher 1984; Asplund and Gooch 1988; Bryan 1928; Brock 1985; Johnson and Lowe 1985; Anderson and Ohmart 1985; Swenson and Mullins 1985; Sweep et al. 1985).

The knowledge base on Arizona's riparian areas is impressive and has progressed a long way since the 1977 symposium held in Tucson, Arizona on "Importance, Preservation and Management of Riparian Habitat" (Johnson and Jones 1977). Crumpacker (1985) points out that public and private parties are more knowledgeable of the environment today due to technology transfer from the scientific sector and are more willing to preserve it. However, there are still gaps in our knowledge and understanding of riparian areas, and until these voids are filled any information that can broaden our knowledge base should be considered.

Objectives of Study

Riparian areas in southeastern Arizona receive considerable use by ranchers, hunters, wood cutters, and recreational users due to their proximity to Tucson, the second largest city in state. While there have been a number of studies looking at wildlife and the vegetation attributes of many of these riparian areas, few have concentrated on the soils and hydrologic inputs (Bowers and McLaughlin 1987; Cox and Morton 1985; Bock and Bock 1985; Adams 1985). The study presented in this dissertation was an effort to observe and record environmental parameters (hydrologic inputs, soils, and vegetation) that govern a riparian area in southeastern Arizona.

The first objective of this study was to determine and document the association that exists between soil moisture content and the riparian vegetation bordering sections of Paige Creek in Happy Valley, Arizona. The assumption was that soil moisture could be used as an indicator of a riparian area, even in the absence of typical riparian vegetation. The second objective was to collect and document information which would be useful in developing guidelines for the management of riparian areas in southeastern Arizona.

METHODS AND MATERIALS

Study Location

The study site was located on Paige Creek in Happy Valley, Arizona, in the southeastern part of the state (figure 2). Happy Valley is on the eastern side of the Rincon Mountains, approximately 30 miles east of downtown Tucson and 10 miles west of the San Pedro River valley. Access to the study area from Tucson is via Interstate Highway 10 east to near Benson, and then north on Forest Service road 35. Happy Valley was selected as the study site because it drains a defined watershed area, has a well established riparian community, and is similar to many riparian areas in southern Arizona used for grazing and recreation. In addition, the site represents a typical management type situation.

The elevation of the of the study area is approximately 4,115 feet. The Rincon Mountains, west of the study area, rise to a height of 8,400 feet. Many small canyons with streams come down the side of the mountain, providing intermittent streamflow to the lower elevations. Paige Creek, which flows through the study area, begins at approximately 8,200 feet on the eastern side of Rincon Peak, the highest peak in the Rincon Mountain range. Paige Creek descends the mountain to an elevation of 4,200 feet where it is joined by Miller Creek before entering the study area. Miller Creek begins at an elevation of approximately 6,200 feet, just below Happy Valley Saddle in the Rincon Mountains. Miller Creek drains through Miller Canyon

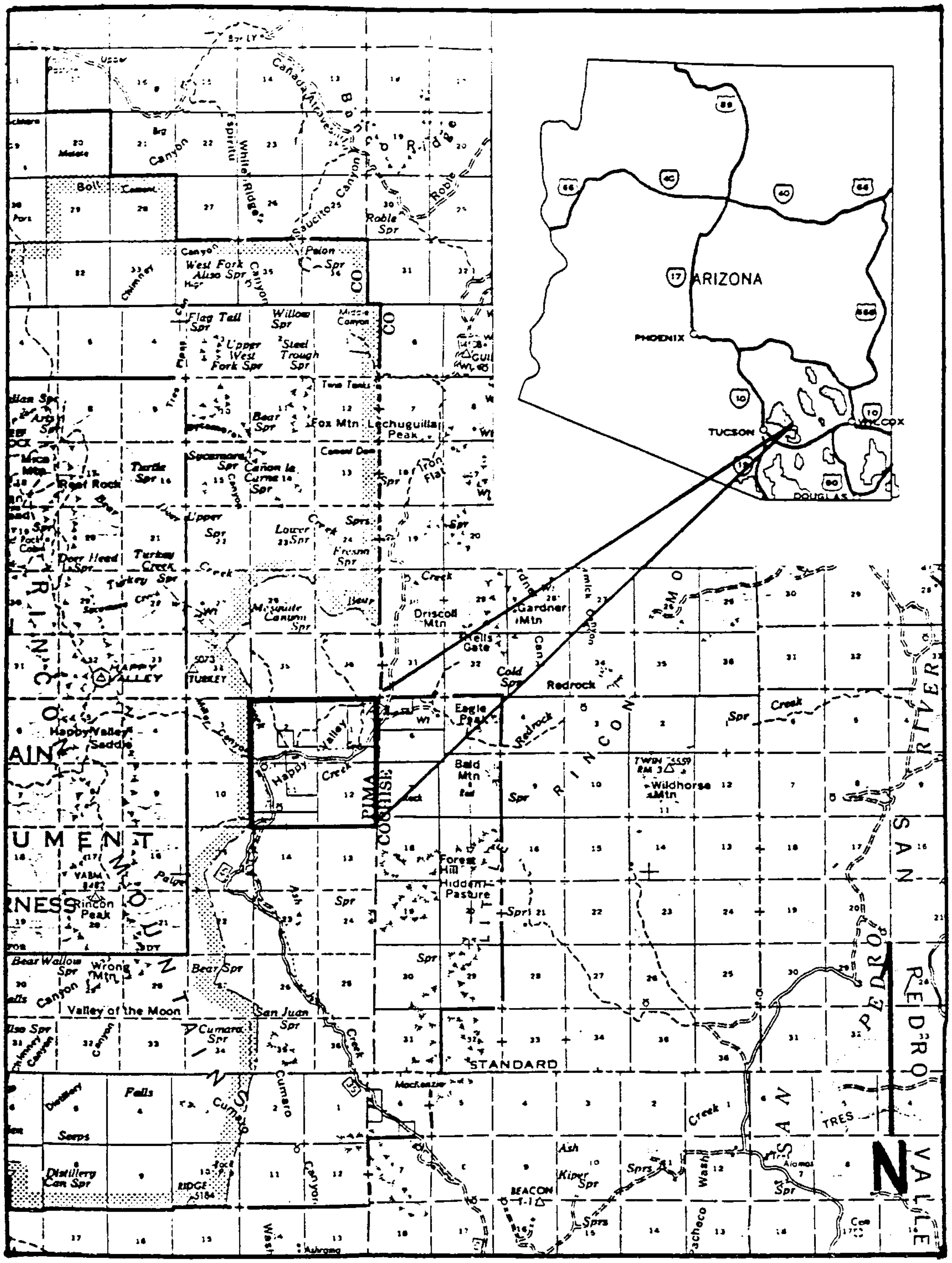


Figure 2. Map of Arizona with location of Happy Valley study site.
(Scale = 1:63,360).

and part of Happy Valley before joining with Paige Creek. Paige and Miller Creeks drain a combined watershed area of approximately 10 square miles.

Annual precipitation in Happy Valley is between 12 and 16 inches, occurring during two seasons (Clemmons 1973). July through September, localized, high intensity thunderstorms occur accounting for more than 50 percent of the annual rainfall. Precipitation again increases in November through February, but storms are widespread and of low intensity. Most months experienced some rainfall. No temperatures were on record for Happy Valley, but the site probably experienced similar or warmer temperatures than those recorded at the Santa Rita Experimental Range, 35 miles south of Happy Valley, at an elevation of 4,300 feet in the Santa Rita Mountains. Mean maximum and minimum daily temperatures for the month of January at the Santa Rita Experimental Range were 59.0 degrees and 37.3 degrees Fahrenheit, respectively. Maximum and minimum daily temperatures for the month of June were 92.0 degrees and 64.7 degrees Fahrenheit, respectively.

Soils bordering Paige Creek were Comoro-gravely sandy loams, ranging in depth from 10 to 40 inches, with an average slope of 3 percent (Clemmons 1973; USDA Soil Conservation Service 1979). These soils were of recent alluvium from mixed sources (e.g., granite, gneiss, limestone and shale). These soils were considered low in erosion hazard and had high potential for range production and revegetation. The Comoro soils were on the lower and upper terraces paralleling the stream channel.

North of the creek, beyond the Comoro soils, were Caralompi-very gravely sandy loam soils. Caralompi soils extend down to 46 inches in depth, with surface slopes between 30 and 50 percent. These soils had a high erosion potential classification, moderate range reproduction potential, and low range revegetation potential. South of Paige Creek was a steep granite rockland with small pockets of soil and slopes ranging from 25 to 75 percent. The granite rockland had a low erosion hazard classification and a low range production potential, and was unsuitable for range re-vegetation.

The riparian vegetation along Paige Creek included Platanus wrightii, Populus fremontii, Fraxinus velutina, Celtis reticulata, assorted perennial grasses, and forbs. Vegetation in adjacent upland areas included Prosopis juliflora, Quercus arizonica, Yucca baccata, assorted perennial grasses, and forbs (Clemmons 1973).

Happy Valley was on the Coronado National Forest, managed by the United States Forest Service, Catalina Ranger District, except for two sections of land that were privately owned. Historically, Happy Valley was used for cattle grazing, irrigated farming along some of the larger floodplain areas, and residential use. There were once three operating ranches in Happy Valley. At the time of this study, there were only two operating ranches and no irrigated farming in Happy Valley. The study site was located in an area bordering Paige Creek that had only been used for cattle grazing. In addition to cattle grazing and two ranches, Happy Valley was used for camping, hiking, and hunting on weekends.

Study Design

Two representative areas bordering Paige Creek were selected to serve as study sites (figure 3). The sites were representative from the standpoint of vegetation, soils, surface profiles, and land use. The sites were selected to represent the entire area, not to be matching pairs, and therefore, some variability existed between them. The sites generally had surface profiles with less than 3 percent slope except near the stream channel where they traversed a stream terrace.

Two transects were surveyed and marked across each of the two selected study sites, perpendicular to the stream channel. The four transects served as permanent references for the soil moisture measurements and vegetation surveys. The transects began in the center of the currently active stream channel and extended 300 feet, across the floodplain and adjoining upland area.

Soil Moisture Study

Soil moisture readings were measured monthly at 12, 18, 24, 30, 36, and 48 inches below the soil surface, at approximately 75-foot intervals along the transects (figure 3). At each 75-foot interval, two readings were taken 15 feet to each side of the transect center. Soil moisture readings were taken in 2 inch diameter galvanized access tubes using a Campbell Pacific Moisture Gage. Rubber stoppers were inserted in the tubes when not is use to prevent the entry of water and other objects.

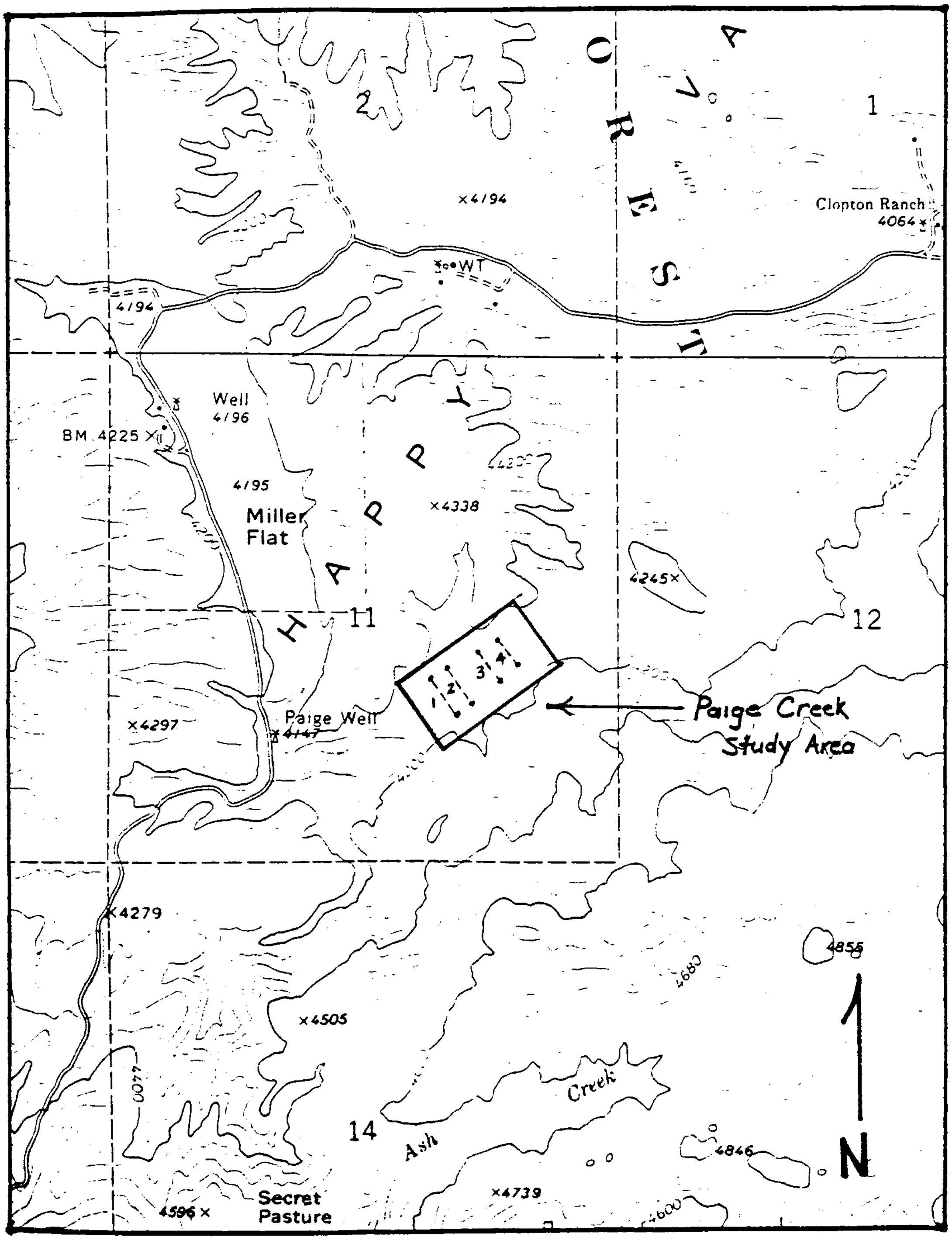


Figure 3. Map of Paige Creek study area in Happy Valley with locations of field transects. (Scale = 1:24,000).

Calibration of the soil moisture access tubes was done by first taking a reading with the moisture gage, then immediately collecting two intact soil samples of a known volume at the same depth below the soil surface, in a pit near the access tube. The soil samples were sealed and return to the laboratory for determination of percent water volume and bulk density.

In the laboratory, the soil samples collected in the field were weighed, oven-dried for 24 hours at 96 degrees centigrade, then reweighed. The percent water by volume in the soil samples and bulk density was determined as follows:

Percent Soil Water by Volume (grams per cubic centimeter) =

$$((SSW - SSD) / SSV) * 100 \qquad (1)$$

Soil Sample Bulk Density (grams per cubic centimeter) =

$$SSD / SSV \qquad (2)$$

where: SSW = weight of soil sample wet (grams),
SSD = weight of soil sample dry (grams), and
SSV = volume of soil sample (cubic centimeter)

The calculated percent soil water by volumes were correlated with the soil moisture readings collected in the field for the same soil samples; this relationship had a significant value of .75. The regression equation for the relationship between the calculated percent soil water by volumes and the field soil moisture readings was:

Percent Soil Moisture by Volume (grams per cubic centimeter) =

$$(0.011 * FSMR) + (-0.047) \qquad (3)$$

where FSMR is field soil moisture readings in "counts" by the Soil Moisture Gage. Counts refer to the number of slow neutrons detected by the soil moisture meter while taking a 30 second moisture reading (CPN 1984). Equation (3) was used to convert the soil moisture readings collected during the 24 month study to percent soil moisture by volume (figure 4).

Soil Survey

Soil pits where dug at 75-foot intervals along the surveyed transects to sample and describe the soils. The sample pits were dug to 6 feet in depth and wide enough to allow safe access. Soil horizons were measured and soil samples collected for a particle size analysis in the laboratory. The percent organic matter content in the surface horizon was estimated visually.

In the laboratory, the soil samples collected from the soil pits were oven-dried for 5 days at 96 degrees centigrade. Each soil sample was weighed, sieved using a 2 millimeter mesh screen to remove the portion of the sample greater than 2 millimeters in diameter, then reweighed. The weight of the soil sample portion greater than 2 millimeters in diameter was recorded. Particle size classes for the portion of the samples under 2 millimeters in diameter were determined by the Bouyoucos Hydrometer method (Foth et al. 1976). The particle size classes of the soil sample were used with a soil textural classification triangle to assign a textural classification to each soil sample (Buol et al. 1980). Soil sample data are summarized Appendix A.

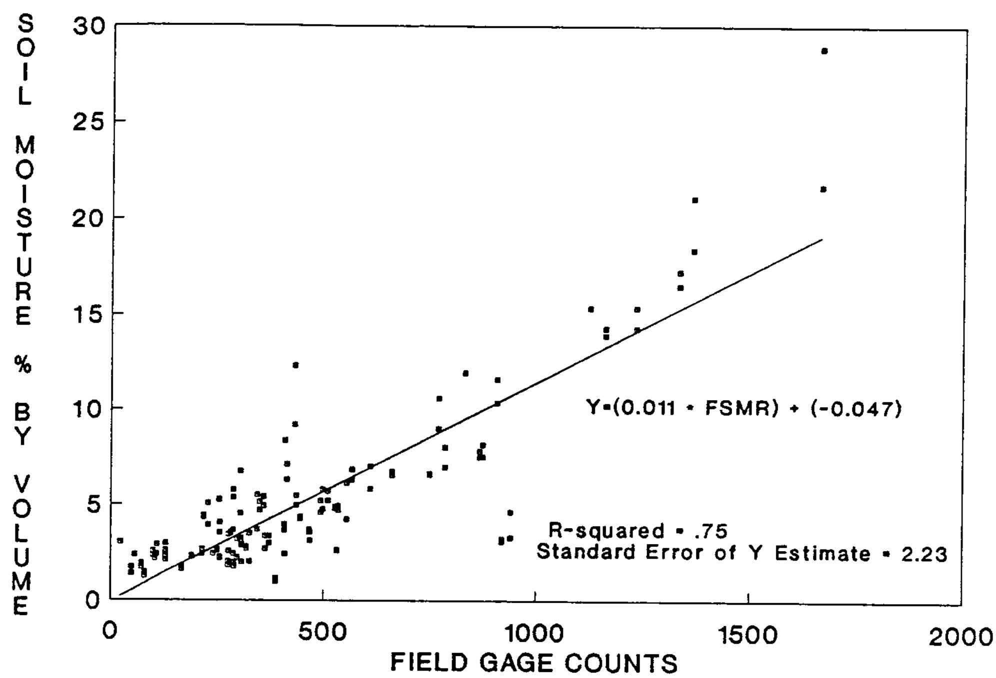


Figure 4. Correlation between measured field moisture counts and laboratory determined soil moisture content from field soil samples.

Hydrologic Inputs

Three sources of soil water recharge were monitored during the study, precipitation, streamflow, and watertable recharge. Daily precipitation was measured at three locations in the study area using Belfort recording rain gages. Thirty-day strip charts were used in the recording rainfall gages. In the office, the recorded rainfall charts were read using a digitizer. The rainfall readings from the three recording rainfall gages were averaged for use in this study. Monthly rainfall summaries are presented in Appendix B.

Streamflow was recorded continuously throughout the study using a Belfort FW-1 recording water level gage. The FW-1 recorder charts were changed every two weeks. The FW-1 water level recorder was mounted on a stand pipe, along a straight section of the stream channel, at the up stream end of the study area. In the office, the recorded FW-1 charts were digitized and the average daily stage recorded. Summarized stream stage data are presented in Appendix C.

The watertable level was recorded continuously throughout the study using two Belfort FW-1 recording water level gages located 50 and 190 feet away from the stream channel. The water level gages were mounted on stand pipes that penetrated the soil to the depth of the water table. The recorder charts on the water level gages were changed every two weeks. In the office, the FW-1 water level charts were digitized and the data were summarized as daily and monthly average stage. Readings from the three FW-1 water level recording gages were used to construct a profile of the water level across the riparian area. Summarized water table level data are presented in Appendix C.

Vegetation Survey

The vegetation along each of the four transects was surveyed using blocks, transects, and microplots (Appendix D). Beginning at the channel edge, two 50 by 100 feet (5,000 square feet) blocks were marked and sampled along each transect. One block or replicate was on each side of the transect center line. The blocks extended the full length of the transects, so that the entire transect was sampled. Inside each block, three equally spaced 100-foot transects were marked. Along each of the 100-foot transects, 5 equally spaced micro-plots centers were marked.

Sampling in each block took place in three phases. First, the percentages of perennial grasses, forbs, litter, rock cover, and bare ground were estimated using a 1-square-foot wooden frame placed on the ground around the marked micro-plot center point. The Daubenmire Cover Scale was used to record cover classes in the field (Mueller-Dombois and Ellenberg 1974). Next, percent shrub cover was estimated using line intercept on the three 100-foot transect lines. Finally, total tree basal area was measured and recorded for each block.

Vegetation data for trees, forbs, grasses, and shrubs were recorded in the field by species. A specimen of each plant species recorded during the vegetation survey was collected and pressed. The pressed plant collection was used in making identifications of each plant specimen, at the Arizona State University Herbarium in Tempe, Arizona. Vegetation data are summarized in Appendix E.

Data Analysis

Data documenting hydrologic inputs, soils, vegetation, and physical orientation of observations in the field were continuous (e.g., streamflow stage and precipitation) and discreet (e.g., distance and date) in nature. Statistical methods used to test relationships between the environmental parameters monitored were correlation (R) for testing continuous variables, analysis of variance (ANOVA) for testing balanced discreet and/or continuous variables, and a general linear model (GLM) for testing unbalanced ANOVA models. Tests of significance were calculated at an alpha level of .05, unless indicated otherwise. For ANOVA models in which there were significant differences between means, Fisher's least-significant-difference test and Duncan's multiple-range test were applied to explain the differences. Chi-square analysis was used to test relationships between species occurrence and distance from the stream channel.

RESULTS AND DISCUSSION

Riparian areas in the southwestern United States are oases in the desert (Floyd 1987). Without a continuous supply of water, most of the desert regions of Arizona would be uninhabitable. Proper management of riparian areas requires an understanding of the environmental parameters at work and how they interact. The results and discussion in this section are presented in an effort to broaden the knowledge base on riparian areas in the southwest.

Soils

The soils sampled at the Paige Creek study area were classified into two families. Bordering the stream channel were sandy, mixed, thermic ustic Torrifluvents, ranging in width from 0 to 100 feet away from the stream channel. The soils beyond the Torrifluvents, moving north away from the stream channel, were sandy to coarse, loamy, mixed, thermic, cumlic Haplustolls.

The Torrifluvent soils bordering the stream channel were recent geologically, in comparison to the soils further away from the stream channel (USDA Soil Conservation Service 1975). The Torrifluvent soils were made up of alternating layers of mixed sands and gravels, exhibited no evidence of structure, were light in color, and contained less than 1 percent organic matter. Cobbles ranging from 2 to 4 inches in diameter were observed below 47 to 52 inches from the soil surface. Torrifluvent soils located on the lower terraces bordering the stream channel were sites of active deposition and aggradation caused by seasonal stream flow.

Data from the watertable level recorder in the Torrifluvent soil indicated the watertable level on occasion had risen to within 5 feet of the soil surface on the upper terrace, near the stream channel. Streamflows exceeding 3 feet in depth on occasion flooded the lower riparian area terrace. No standing water was present in the soil at the time of the soil survey, although there was evidence of mottling. Roots of perennial grasses and forbs were observed throughout the upper 18 to 24 inches of surface soil. Roots of *Platanus wrightii* and *Populus fremontii* up to 2 inches in diameter were observed throughout the sample pits.

The Haplustoll soils, located beyond the Torrifluvents and perpendicular to the stream channel, differed from the Torrifluvents in that they were finer textured, hard, and compacted in the subsurface layers and darker in color. The darker color was due in part to a noticeably higher organic matter content, 3 to 4 percent, but most likely due to a different parent material. The Haplustoll soils, in contrast to the Torrifluvents soils, were not being influenced by the depositional and aggradational effects of the stream except in limited areas. Rocks and cobbles ranging from 2 to 4 inches in diameter were observed below 52 to 60 inches from the soil surface in the sample pits. Roots of perennial grasses and forbs dominated the upper 18 inches of soil. Several large roots of *Prosopis juliflora* and *Quercus emoryi* were observed below 36 inches from the soil surface.

Torrifluvents and Haplustolls have been described by the USDA Soil Conservation Service (1979). In the description on Torrifluvents, it was mentioned that permeability is moderately rapid to moderately slow, and available water capacity is moderate to very low. The Haplustolls, were noted to have a permeability that is moderately slow, and available water capacity is low or moderate. Observations made by the Soil Conservation Service (1979) and Brock (1985), indicating soil moisture is higher in the Haplustolls and permeability is more rapid in the Torrifluvents, agrees with the measurements and observations collected during this study on the same soil series.

Hydrologic Inputs

Precipitation, streamflow, and capillary water movement up from the watertable were the primary sources of soil water recharge in the study area. The monthly averages for these three water sources are presented in figure 5.

Annual precipitation during the study was 13.2 inches, which was low in comparison to the 6-year period prior to the study during which precipitation varied between 13 and 27 inches annually (USDA Forest Service 1986). Happy Valley had two rainy seasons, a summer rainy season from June to September, which peaked in August, and a winter rainy season from November to February, which peaked between November to January. The summer precipitation events were observed to be high intensity, short duration events, lasting less than one hour. The winter precipitation events were observed to be low intensity,

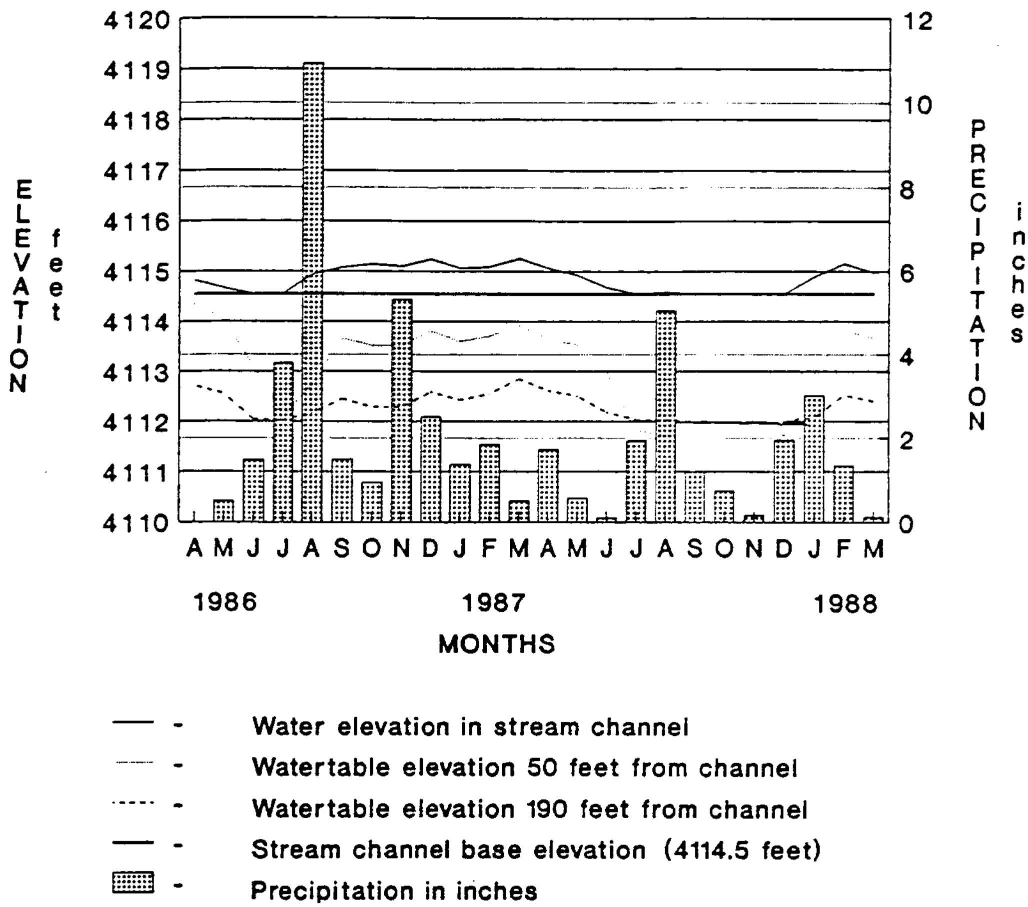


Figure 5. Monthly precipitation, streamflow, and watertable levels for Paige Creek in Happy Valley, Arizona, April 1986 through March 1988.

sometimes lasting more than 8 hours. These observations on precipitation were consistent with observations made by Carpenter (1921).

Coefficient of correlation (R) for the relationships between precipitation and soil moisture were significant at 12 and 18 inches below the soil surface (table 1). This test indicated precipitation primarily benefited the upper soil layers occupied by perennial grasses and forbs. It was observed during several precipitation events that most of the rain that fell in the study area infiltrated in-situ. The sandy textured surface soils combined with the shallow hillslope profiles (3 to 4 percent) did not encourage runoff. Brock (1985) measured flow rates in Torrifluvent and Haplustolls soils at 0.4, 0.6, and 0.9 inches per minute for fine sand, coarse sand, and cobbley sands, respectively.

Paige creek flowed approximately 6 to 8 months annually (figure 5). The average stage for the months when flow occurred was 0.5 feet (2.0 cubic feet per second) (figure 6). During the summer of 1986, several flow events exceeded 3 feet in depth, although those events only lasted a few hours. Only one "minor flow event" occurred during the summer of 1987; the stream did not flow the remainder of the year. No flow events exceeded the channel banks during this study, however, stream deposited debris at higher levels indicated that the stream has exceeded its banks in past years. Spring snow melt and runoff from the Rincon Mountains also elevated streamflow. Spring flows averaged 0.55 feet (2.3 cubic feet per second), and flowed constantly for several weeks. Correlation between streamflow

Table 1. Coefficients of correlation (R) for the relationship between precipitation and soil moisture by depth.

Depth of observation in inches below the soil surface	R	df
12	.282*	246
18	.219*	246

* Correlations significant at alpha = .05.

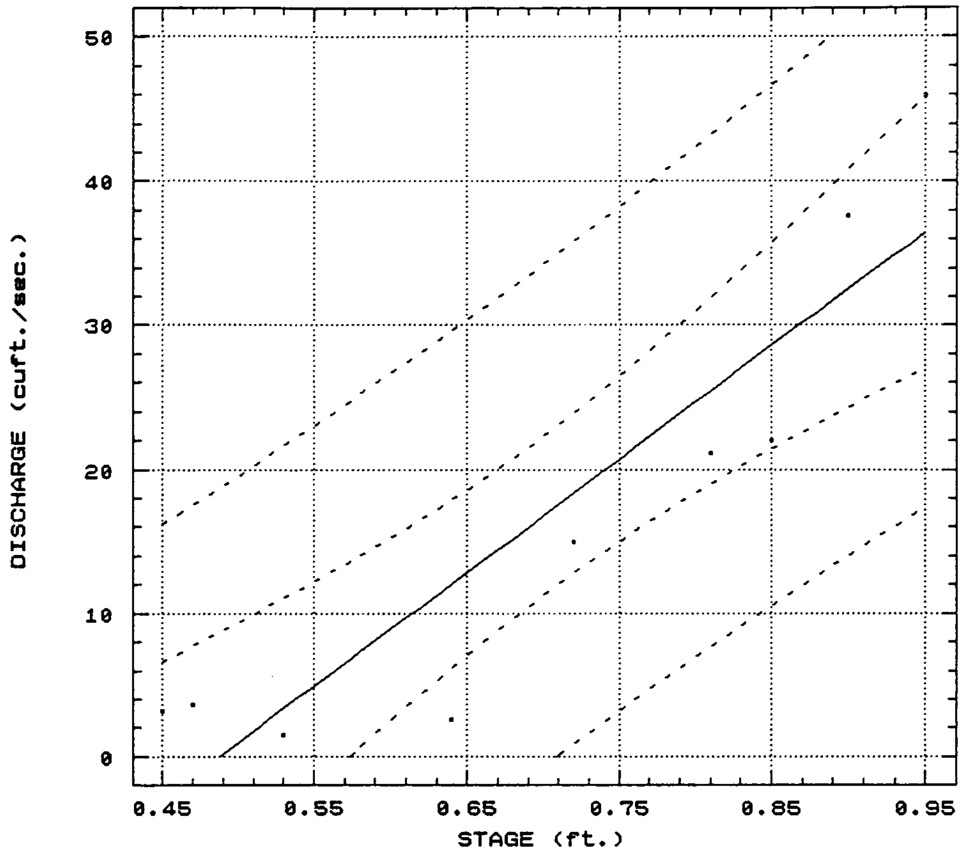


Figure 6. Scatter plot diagram and regression line for stream stage vs discharge for Paige Creek.

and on-site precipitation was insignificant. Uncorrelated streamflow and rainfall patterns are not uncommon occurrences in desert areas, where intermittent flow events can be produced by localized precipitation events miles away (Branson et al. 1981).

The watertable in the study area was linked directly to streamflow. R values for the relationships between the streamflow level and the watertable levels in observation wells at 50 feet and 190 feet away from the stream channel were significant (table 2). The average water levels in the three recording wells, at any point in time, had a declining profile, moving perpendicular away from the stream channel. The declining profile of the watertable level, moving away from the stream channel, indicated that water from the stream recharged the watertable. Declining watertable levels, moving away from the stream channel are common features to many central and southern Arizona streams (figure 7) (Reichenbacher 1984). The fact that the water levels in the three level recording wells were correlated indicated there was good hydrologic conductivity, in the soil. Coarse sandy soils typically have good hydrologic conductivity as demonstrated by Brock (1985). Coarse soils allow water to pass through rapidly in the lateral and downward directions in response to gravity, however, capillary movement of water upward and water holding capacity are not as high in coarse soils as in finer textured soils (Donahue et al. 1977).

Streamflow ceased from June through mid-August in 1986, and again from July through December in 1987. During the same time intervals that the stream was not flowing the water levels in the two

Table 2. Coefficients of correlation (R) for the relationships between streamflow and watertable levels along Paige Creek. Values are significant at alpha = 0.05, n = 24.

Test	R
Stream elevation * watertable elevation at 50 feet away from the stream channel	0.77
Stream elevation * watertable elevation at 190 feet away from the stream channel	0.70
Watertable elevation at 50 feet away from stream channel * watertable level at 190 feet away from the stream channel	0.86

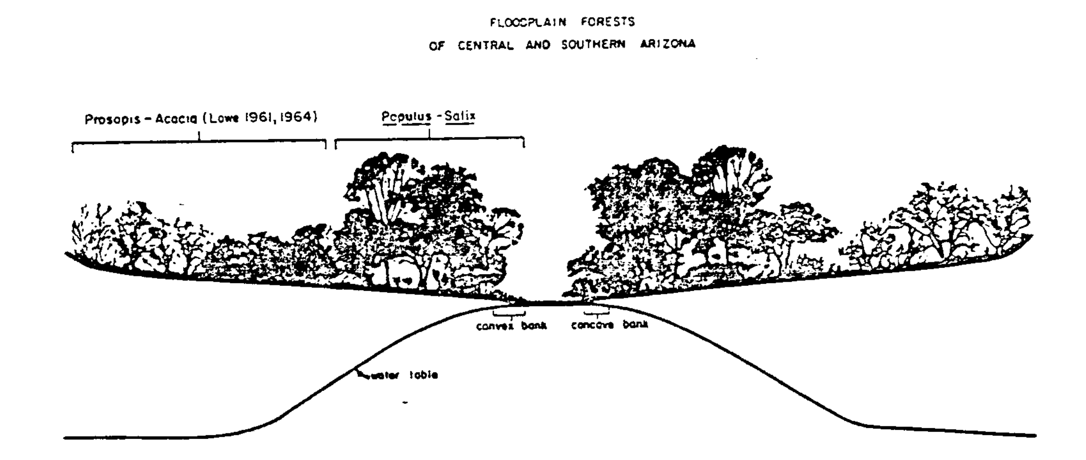


Figure 7. Diagram of a typical stream to watertable relationship found in central and southern Arizona riparian areas (Reichenbacher 1984).

watertable level wells descended below the well bottoms, more than 8 feet below the ground surface. It was not determined how far below the well bottoms the watertable descended. It was assumed, however, at whatever depth the watertable descended, the roots of the *Platanus wrightii* and *Populas fremontii* were still in contact with it. Meinzer (1927) reported that *Platanus* and *Populas* species typically maintain contact with a permanent water source. Streamflow was the only semi-permanent to permanent water source in the study area, and given the fact that *Platanus* and *Populas* species must be able to access water except for brief interruptions, it was concluded that the water flowing in Paige Creek was the primary water source for the riparian vegetation bordering the stream channel. *Quercus emoryi*, which occupied the transition zone between the riparian woodland and upland areas, sometimes is considered an indicator species for the presence of a watertable, but generally at deeper levels than occur with the typical riparian species (Meinzer 1927). No *Quercus emoryi* were present further away from the stream channel than several measured between 250 and 300 feet away, which could have indicated the distance at which the watertable became unavailable to free-water loving plants.

Soil Moisture Condition

Soil moisture changed significantly across the riparian woodland and grassland areas with respect to soil type, distance from the stream channel, date of observation, and depth (table 3).

Table 3. Analysis of Variance (ANOVA) for relationship between soil moisture and date of observation, distance from the stream channel, depth below the soil surface and soil textural classification.

Source	df	SS	MS	F
Date of observation	18	12539.4	696.6	70.4*
Distance from stream channel	7	4099.7	585.7	59.2*
Depth of measurement	5	2406.7	481.3	48.6*
Soil textural classification	11	4603.3	418.5	42.3*
Error	1402	13879.3	9.9	
Total	1443	37528.4		

* significant at alpha = 0.05, n = 1,444, mean soil moisture = 10.9

Mean separation tests for the soil moisture data indicated that average soil moisture content increased, from 9.2 percent at 12 inches below the ground surface to 12.3 percent at 48 inches below the ground surface. Average soil moisture content also increased, from 5.6 percent in a sandy to sandy-loam Torrifluvent soil to 18.6 percent in a finer textured loam Haplustoll soil. Average soil moisture content increased with distance away from the stream channel, from 9.1 percent at 50 feet away from the stream channel in a Torrifluvent soil to 13.6 percent at 160 feet away from the stream channel in a Haplustoll soil. Soil moisture percent in general was highest in March of 1987, at 15.9 percent, and lowest in December of 1987, at 6.8 percent.

Vegetation

The vegetation in the study area was classified into two distinct plant communities. Bordering Paige Creek was a riparian woodland with an overstory of Platanus wrightii and Populas fremontii. The understory cover in the riparian woodland had numerous forbs and perennial grasses, including Bouteloua aristidoides, Mulhlenbergia rigens, an unidentified Panicum, Wyethia arizonica, Heterotheca psammophila, and Conyza canadensis. Upland of the riparian zone was a grassland, dominated by Bouteloua rothrockii and Aristida divaricata. Overstory species included Prosopis juliflora, Fraxinus velutina, and Quercus emoryi. A few large individuals of Quercus emoryi were scattered intermittently along the transition area between the riparian woodland and grassland areas. Vegetation and ground cover data are summarized in table 4.

Table 4. Vegetation survey summary data for Happy Valley, Arizona.

Distance to Channel	% Grass Cover	% Forb Cover	% Shrub Cover	Tree Basal Area	% Ground Cover		
					Bare	Rock	Litter
0-50	6.57	9.26	11.00	7.30	38.89	31.55	22.58
50-100	11.01	14.65	10.67	13.78	35.93	13.03	38.72
100-150	15.80	22.52	16.12	24.11	32.12	0.46	49.07
150-200	38.11	24.57	21.84	13.29	37.72	1.03	43.54
200-250	49.94	23.97	20.05	2.53	40.90	1.18	37.62
250-300	37.01	16.24	12.58	4.71	25.3	0.19	35.19

* Tree basal area in square feet.

Vegetation change between the riparian woodland area bordering the stream channel and the grassland area further upslope were observed easily in the field. There were significant changes in the percentages of grass cover and tree basal area with increased distance away from the stream channel (table 5). The percent grass cover increased from 6.6 percent on the Torrifluvent soils, near the stream channel, to 37.0 percent on the Haplustoll soil in the grassland. The grasses were taller and denser in percentage cover further away from the stream channel, probably in response to decreased shading by overstory trees and shrubs, increased organic matter content, and the greater amount of available soil water in the Haplustoll soil.

Tree basal area changed significantly across the riparian woodland area, increasing with distance away from the stream channel (table 6). Basal area reached a maximum of 24.1 square feet per acre between 100 to 150 feet away from the stream channel. The area between 100 to 150 feet away from the stream channel in the riparian woodland area corresponded with the upper terrace bordering the stream channel and was occupied primarily by <u>Platanus</u> <u>wrightii</u> and <u>Populas fremontii</u>, representing 71 percent and 16 percent of the tree total basal area in the riparian area, respectively (table 6).

Shrub and forb cover percentages did not change significantly with increased distance away from the stream channel. However, the composition or frequency of species changed with increased distance from the stream channel for the forbs, shrubs, and trees (table 7). Changes in the composition of shrubs and forbs with increased distance from the stream channel probably were related to plant preference to

Table 5. Analysis of variance (ANOVA) for the relationships between cover (e.g. grass and trees) and distance from the stream channel.

Source			F	df	Mean
Percent grass cover	vs.	Distance	11.31*	5	27.6
Tree basal area	vs.	Distance	4.15*	5	11.4

* significant at alpha = .05   Error degrees of freedom = 17

Table 6. Tree basal area in square feet per acre for riparian woodland and grassland areas species along Paige Creek.

Tree Species	Distance From Channel Center (feet) 0-50	50-100	100-150	150-200	200-250	250-300
<u>Celtis reticulata</u>						
Mean	0.0	1.9	0.0	0.3	0.0	0.5
Std.	0.0	2.1	0.0	0.4	0.0	0.9
<u>Fraxinus velutina</u>						
Mean	0.5	0.4	0.4	1.2	0.9	1.4
Std.	0.8	0.7	0.8	2.1	1.5	2.4
<u>Juglans major</u>						
Mean	0.2	0.0	0.4	0.0	0.0	0.0
Std.	0.4	0.0	0.4	0.0	0.0	0.0
<u>Juniperus deppeana</u>						
Mean	0.1	0.0	1.1	0.0	0.0	0.1
Std.	0.2	0.0	1.9	0.0	0.0	0.1
<u>Platanus wrightii</u>						
Mean	4.6	9.7	18.0	5.2	0.0	0.0
Std.	4.5	9.8	7.4	9.0	0.0	0.0
<u>Populas fremontii</u>						
Mean	1.5	1.5	4.2	2.0	0.0	0.0
Std.	2.3	2.6	4.2	3.5	0.0	0.0
<u>Prosopis juliflora</u>						
Mean	0.0	0.1	0.1	0.7	0.2	1.2
Std.	0.0	0.2	0.1	1.2	0.3	1.4
<u>Quercus emoryi</u>						
Mean	0.0	0.1	0.1	3.8	1.3	1.6
Std.	0.0	0.1	0.2	6.7	2.3	2.7
<u>Salix exigua</u>						
Mean	0.2	0.0	0.1	0.0	0.0	0.0
Std.	0.2	0.0	0.1	0.0	0.0	0.0
Total Mean By Dist.	7.1	13.7	24.4	13.2	2.4	4.8
Average Std.	1.4	3.0	5.5	1.8	0.5	0.6
	<---- Riparian Area	---->		Transition Area	Grassland Area	

Std. = Standard deviation

Table 7. Chi-square values for cover type vs increased distance away from the stream channel.

Cover Type Frequency Cell Chi-Square	Distance Away From Channel 0-50	50-100	100-150	150-200	200-250	250-300	Totals Total
FORBS	29 10.45	38 0.14	49 0.22	54 0.77	49 3.16	55 3.46	274 18.22*
SHRUBS	32 0.85	29 0.00	27 3.02	45 3.23	39 4.96	25 1.08	197 13.17*
TREES	89 28.57	48 1.95	66 4.49	28 7.36	12 16.82	23 8.29	266 67.51*

* significant at alpha = 0.05, df= 5.

site, changes in overstory shading, differences in soil organic matter content and the water holding capacity of the soil.

Summary

The data collected generated as many questions as they answered. However, the primary question to be answered by this study was whether the association that existed between the soil moisture content and the riparian vegetation bordering Paige Creek be used to determine the presence of a riparian area, even in the absence of typical riparian vegetation? A summary of the environmental parameters observed will help in answering this question.

Vegetation was the initial environmental factor that lead to the selection of Paige Creek in Happy Valley as a study area. Typical riparian species, such as *Platanus wrightii*, *Populus fremontii*, and a few other riparian trees, shrubs, grasses, and forbs, created a riparian woodland which bordered Paige Creek in a band that extended out to 150 feet away from the stream channel. Bordering the riparian woodland and further away from the stream channel was a grassland dominated by *Bouteloua rothrockii* and *Aristida divaricata*. A transition zone with a few scattered *Quercus emoryi* separated the riparian woodland and grassland areas. In a distance of less than 300 feet from the stream channel, the vegetation changed significantly. Why?

The soil survey of the study area identified two families of soils. Bordering the stream channel the soil was a sandy, mixed, thermic, ustic Torrifluvent ranging from 0 to 150 feet in width across the riparian area. Torrifluvents are soils of recent alluvium, coarse textured, low in organic matter, and low in water holding capacity. The average annual moisture content of the Torrifluvent soils in the study area were estimated at 5.6 percent. Most of the riparian vegetation along Paige Creek were on Torrifluvent soils. A sandy to coarse, loamy, mixed, thermic, cumlic Haplustoll soil bordered the Torrifluvent soil to the side corresponding to the grassland area. The Haplustoll soils were finer textured soils than the Torrifluvents, and were higher in water holding capacity than the Torrifluvent soils. The higher water holding capacity of the Haplustoll soils helped explain why the perennial grasses were denser and larger in the grassland area. In addition, there was reduced overstory shading in the grassland area. Texture and waterholding capacity of the Torrifluvent and Haplustoll soils did not explain why riparian areas were where they were, nor do they serve as direct indicators of riparian conditions, except that they were water transported materials.

There were three hydrologic inputs into the Paige Creek riparian system, precipitation, streamflow, and capillary movement of water up from the watertable. Precipitation, while variable throughout the year was relatively uniform across the site. Infiltration of rainfall on both the Torrifluvents and the Haplustolls was observed to be moderately rapid, producing little runoff. Significant R values for the relationship between precipitation and soil moisture at 12 and 18 inches below the soil surface indicated that precipitation was the primary moisture source for the upper soil layers and, therefore, was the likeliest candidate as the source of water for shallow rooted perennial grasses and forbs in the grassland and the riparian woodland areas. Due to the higher water holding capacity of the Haplustoll soils in the grassland area, more of the water that entered the soil was retained there to benefit the plants. Insignificant R values for the relationships between streamflow and precipitation, and the watertable levels and precipitation indicated the rain falling in Happy Valley was not the source of water for streamflow and groundwater recharge. Precipitation, therefore, could not be used as an indicator of the riparian area.

Paige Creek flowed approximately 6 to 8 months per year with an average stage of 0.5 feet. Paige Creek drained a 10-square-mile watershed on the eastern side of the Rincon Mountains. Significant R values for the relationships between stream stage and watertable stage indicated streamflow was correlated with the watertable level. A declining profile constructed from the water levels of the stream and watertable wells at 50 and 190 feet away from of the stream channel indicated the stream was recharging the watertable.

The watertable furnished a permanent to semi-permanent supply of water to riparian plants at depths ranging from ground level in the stream channel to 8(+) feet at 190 feet away from the stream channel. The coarse textured Torrifluvent soils bordering the stream channel conduct minimal amounts of soil water upward, by capillary action, to benefit the perennial grasses and forbs. The depth of the watertable beneath the grassland area was too deep to benefit the perennial grasses and forbs in the grassland.

Given the results presented above on the hydrologic inputs, soil moisture condition, soils, and vegetation, the only environmental parameter that could have served as an indicator of the riparian area in the absence of typical riparian vegetation was water, from a permanent or semi-permanent source.

CONCLUSIONS

There are approximately 279,600 acres of riparian areas in Arizona, less than 1 percent of the state's land area. It is important to preserve and manage these areas because of their many uses. Management of riparian areas requires understanding the environmental parameters. This study was an effort to broaden the understanding of riparian areas in southeastern Arizona and provide information useful in developing guidelines for managing these areas.

Statistical tests on the environmental parameter data collected indicated a significant correlation between increased precipitation and increased soil moisture content in the upper 18 inches of soil, a significant correlation between increased streamflow level and increased watertable level, and a significant decrease in the level of the watertable moving away from the stream channel. Grass cover increased significantly with increased distance away from the stream channel, while tree basal area increased with distance to approximately 150 feet away from the stream channel and then declined. Average annual moisture content between 0 to 48 inches below the soil surface increased with distance away from the stream channel, corresponding with the change in soil from the Torrifluvent soil bordering Paige Creek to the Haplustoll soils further away.

The results of this study indicated that the riparian area bordering Paige Creek in Happy Valley was similar to other riparian areas in central and southeastern Arizona. The driving mechanisms of the Happy Valley riparian area were Paige Creek and a 10 square mile watershed on the eastern side of the Rincon Mountains that fed the stream. Precipitation that fell on the study area replenished soil water in the upper 18 inches of soil, and provided moisture for the perennial grasses and forbs in the riparian woodland and grassland areas. Riparian woodland species (such as Platanus wrightii and Populas fremontii) received their water needs directly from the watertable. The watertable was recharged directly by the stream. A transition area species, such as Quercus emoryi, sometimes used as an indicator of deep water sources, probably received moisture from the watertable, but at greater depths below the soil surface than the riparian species.

Only two environmental parameters provided evidence of riparian conditions or the possibility thereof, water and the existing riparian vegetation. The presence of riparian vegetation, however, could be misleading, because conditions present at the time of the study may have differed from when the riparian vegetation became established. For example, the stream may have been at a higher elevation than or in a different position in the floodplain. Riparian areas can change slowly and undetected for years, and they can change quickly in response to major flow events.

Management Implications

Management and development practices for riparian areas can be site specific and dependent on the intended use of the area. However, some lessons learned in one riparian area can and should be considered in other areas. A lesson learned at Happy Valley was that soil moisture content in the upper 48 inches of soil is not a good indicator of a riparian area, in the absence of typical riparian vegetation.

While vegetation is the most visible indicator of a riparian area, one should proceed carefully because situations that existed when the present riparian community was established may not be the same as currently found. For example, some riparian species require wet conditions during germination and early growth. The same riparian trees, once established with roots near the watertable, can tolerate drier surface conditions.

The second best visible indicator of a riparian area is water, the driving mechanism for all riparian areas; without it, there would be no riparian areas. Everything related to this essential hydrologic input into the riparian system should be known, including the source, seasonal fluctuations of depth and supply, flood frequency, quality, relationship to watertable (e.g., gaining or losing), and destination.

Riparian soils are typically stream deposited materials, such as Torrifluvents and Haplustolls, with low water holding capacities and low organic matter contents. Establishing vegetation in riparian soils could be difficult without surface irrigation and soil amenities to improve the water holding capacity.

Land use by man and wildlife should be considered carefully. Whereas man can readily adapt to major changes in living conditions, some wildlife species simply become extinct.

APPENDIX A

SOIL SURVEY AND TEXTURAL CLASSIFICATION SUMMARY

HOLE ID+	HORIZON DEPTH (inches)	SAND %	CLAY %	SILT %	SOIL % >2 mm.	TEXTURAL CLASS*
1020	0-9	72.4	8.0	19.6	28.0	SL
	9-34	74.4	9.0	16.6	39.8	SL
	34-60	62.2	16.1	21.7	13.2	SL
	60-72	74.4	6.0	19.6	40.8	LS-SL
1021	0-6	87.6	9.9	2.5	13.0	S
	6-16	90.9	9.1	0.0	24.0	S
	16-32	90.7	8.4	0.0	41.4	S
	32-72	72.6	15.4	12.0	9.4	SL
1030	0-7	73.4	15.6	11.0	8.9	SL
	7-21	78.6	11.4	10.0	24.4	LS-SL
	21-31	65.4	20.6	14.0	17.8	SL-SCL
	31-38	63.4	22.6	14.0	13.1	SCL
	38-72	70.4	18.6	11.0	33.0	SL
1040	0-8	82.6	11.4	6.0	27.8	LS
	8-22	80.8	12.2	7.0	43.9	SL-LS
	22-38	74.4	14.6	11.0	34.4	SL
	38-45	74.6	15.9	9.5	27.9	SL
	45-72	80.4	15.6	4.0	53.4	SL
2021	0-3	84.4	11.6	4.0	36.9	LS
	3-17	87.8	10.7	1.5	41.9	LS
	17-22	76.8	15.2	8.0	37.7	SL
	22-45	88.8	11.2	0.0	72.3	LS
	45-72	89.7	10.3	0.0	63.7	S
2030	0-9	79.4	13.6	7.0	13.9	SL
	9-27	88.8	9.2	2.0	10.2	LS-S
	27-33	82.2	13.8	4.0	5.9	LS
	33-35	87.9	10.6	1.5	18.1	LS
	35-50	69.2	15.8	15.0	4.5	SL
	50-62	83.2	11.8	5.0	43.0	LS
	62-72	89.4	9.6	1.0	20.2	S

(Continued--)

(--Continued from previous page)

HOLE ID	HORIZON DEPTH (inches)	SAND %	CLAY %	SILT %	SOIL % >2 mm.	TEXTURAL CLASS
2041	0-17	74.4	15.6	10.0	27.0	SL
	17-49	70.2	17.8	12.0	13.0	SL
	49-50	88.2	10.8	1.0	21.0	SL
	50-72	84.4	12.1	3.5	33.5	LS
2050	0-1	58.4	19.6	22.0	11.7	SL
	1-17	58.4	21.6	20.0	19.9	SCL
	17-34	56.4	21.6	22.0	7.0	SCL
	34-46	58.6	23.9	17.5	8.4	SCL
	46-55	62.4	20.6	17.0	15.5	SCL-SL
	55-72	70.4	16.6	13.0	15.0	SL
	72 >	87.2	10.8	2.0	28.8	LS
3010	0-4	68.4	16.1	15.5	16.9	SL
	4-27	79.2	13.8	7.0	15.0	SL
	27-30	87.8	9.2	3.0	17.4	LS
	30-32	77.8	13.2	9.0	20.9	SL
	32-41	72.6	14.4	13.0	18.4	SL
	41-47	88.4	10.6	1.0	16.9	LS
	47-48	85.9	11.6	2.5	10.6	LS
	48-72	76.6	13.4	10.0	17.6	SL
3020	0-9	63.9	16.1	20.0	19.2	SL-SCL
	9-19	73.9	8.0	18.1	39.7	SL
	19-28	76.0	6.0	18.0	6.1	SL
	28-40	74.0	10.0	16.0	47.2	SL
	40-53	60.0	15.8	24.2	12.3	SL
	53-65	75.9	8.0	16.1	21.4	SL
	65-69	59.9	19.2	20.9	12.5	SL
	69-72	78.0	4.0	18.0	66.5	LS
3031	0-12	71.4	16.6	12.0	25.8	SL
	12-30	88.2	10.8	1.0	44.5	LS
	30-32	78.2	13.8	8.0	14.4	SL
	32-42	88.4	10.6	1.0	47.8	LS
	42-55	46.4	22.6	31.0	0.0	L
	55-72	82.6	11.4	6.0	5.6	LS

(Continued--)

(--Continued from previous page)

HOLE ID	HORIZON DEPTH (inches)	SAND%	CLAY%	SILT%	SOIL % > 2 mm.	TEXTURAL CLASS
4010	0-6	68.4	16.1	15.5	16.8	SL
	6-16	76.4	14.6	9.0	23.1	SL
	16-30	87.6	9.9	2.5	29.3	LS
	30-34	58.6	17.9	23.5	8.1	SL
	34-39	89.4	9.6	1.0	7.4	S-LS
	39-48	68.4	17.6	14.0	2.1	SL
	48-52	78.4	12.6	9.0	38.3	SL
	52-72	82.4	10.6	7.0	45.9	LS
4011	0-28	74.4	14.1	11.5	18.7	SL
	28-34	87.4	9.6	3.0	26.8	LS
	34-47	80.8	11.7	7.5	7.0	LS
	47-56	88.4	9.6	2.0	19.3	LS
	56-60	78.4	13.6	8.0	8.8	SL
	60-72	89.8	9.2	1.0	50.0	S
4020	0-1	70.4	15.1	14.5	7.5	SL
	1-27	62.2	23.8	14.0	6.7	SCL
	27-35	86.4	11.6	2.0	23.4	LS
	35-51	76.4	14.6	9.0	6.8	SL
	51-55	75.8	19.2	5.0	2.6	SL
	55-63	84.4	11.6	4.0	18.2	LS
	63-64	63.8	19.2	17.0	6.1	SL
	64-72	90.4	9.6	0.0	24.6	S
4030	0-1	75.4	14.6	10.0	21.4	SL
	1-34	88.4	10.6	1.0	12.0	LS
	34-37	60.4	19.1	20.5	8.9	SL
	37-46	84.4	11.6	4.0	3.1	LS
	46-55	82.4	11.6	6.0	39.1	LS
	55-72	86.4	11.6	2.0	49.7	LS

* S = Sand, SL = Sandy Loam, LS = Loamy Sand, SCL = Sandy Clay Loam, and L = Loam.

+ HOLE ID numbers correspond with ID numbers and site data on vegetation cover summaries in Appendix E.

APPENDIX B

HAPPY VALLEY PRECIPITATION RECORD

APRIL 1986 - MARCH 1988

Year	Month	Precipitation (inches)
1986	APR	0.00
	MAY	0.50
	JUN	1.49
	JUL	3.80
	AUG	10.92
	SEP	1.50
	OCT	0.95
	NOV	5.33
	DEC	2.51
1987	JAN	1.37
	FEB	1.86
	MAR	0.50
	APR	1.73
	MAY	0.56
	JUN	0.10
	JUL	1.94
	AUG	5.06
	SEP	1.21
	OCT	0.75
	NOV	0.17
	DEC	1.96
1988	JAN	3.02
	FEB	1.34
	MAR	0.11

APPENDIX C

HAPPY VALLEY STREAM AND WATERTABLE ELEVATIONS

APRIL 1986 - MARCH 1988

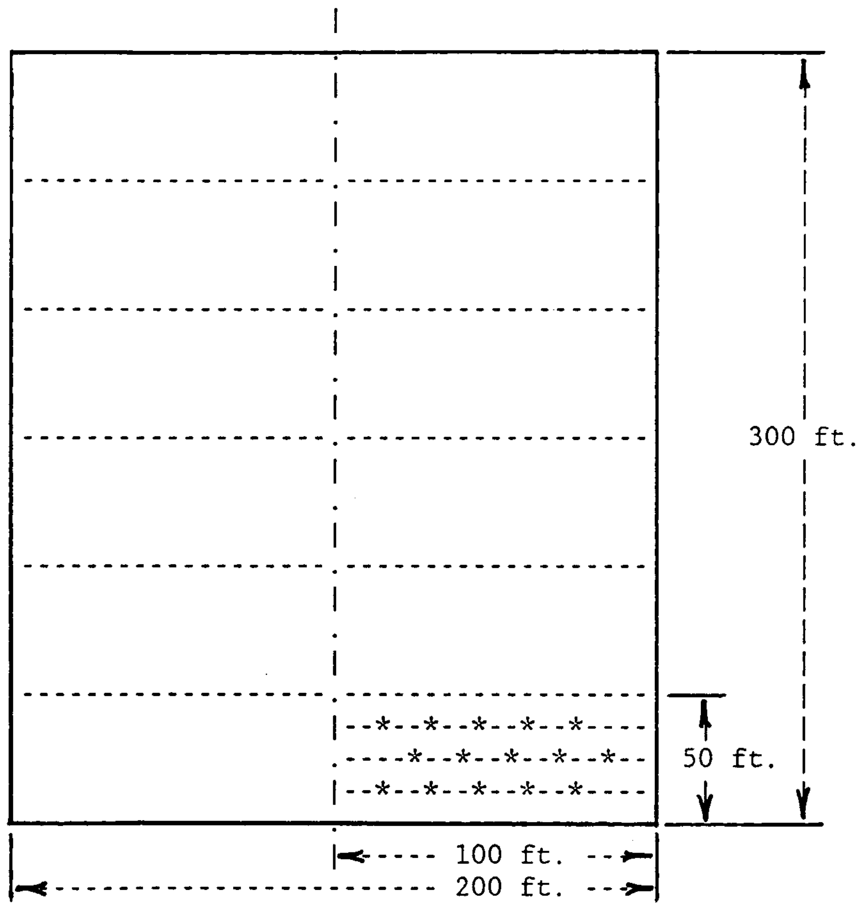
(All distances and depths are in feet)

YEAR	MONTH	STREAM STAGE LEVEL (feet)*	WATERTABLE STAGE AT AWAY FROM THE STREAM 75 feet#	190 feet@	STREAM CHANNEL LEVEL (feet)
1986	APR	4114.8	4114.3	4112.7	4114.5
	MAY	4114.6	4114.0	4112.5	4114.5
	JUN	4114.5	4113.1	4112.0	4114.5
	JUL	4114.5	4112.1	4112.0	4114.5
	AUG	4114.9	4112.7	4112.1	4114.5
	SEP	4115.0	4113.6	4112.4	4114.5
	OCT	4115.1	4113.5	4112.2	4114.5
	NOV	4115.1	4113.5	4112.2	4114.5
	DEC	4115.2	4113.8	4112.5	4114.5
1987	JAN	4115.0	4113.6	4112.4	4114.5
	FEB	4115.0	4113.7	4112.5	4114.5
	MAR	4115.2	4113.9	4112.8	4114.5
	APR	4115.0	4113.6	4112.6	4114.5
	MAY	4114.9	4113.5	4112.5	4114.5
	JUN	4114.6	4112.9	4112.1	4114.5
	JUL	4114.5	4111.8	4112.0	4114.5
	AUG	4114.5	4111.7	4112.0	4114.5
	SEP	4114.5	4111.7	4112.0	4114.5
	OCT	4114.5	4111.7	4112.0	4114.5
	NOV	4114.5	4111.7	4112.0	4114.5
	DEC	4114.5	4111.7	4112.0	4114.5
1988	JAN	4114.9	4112.9	4112.0	4114.5
	FEB	4115.1	4113.8	4112.5	4114.5
	MAR	4114.9	4113.6	4112.4	4114.5

* Ground elevation = 4114.7 feet, Gage elevation = 4124.2 feet
\# Ground elevation = 4119.5 feet, Gage elevation = 4122.4 feet
@ Ground elevation = 4120.3 feet, Gage elevation = 4123.6 feet

APPENDIX D

VEGETATION SURVEY FIELD PLOT PLAN



| - Transect survey center line
--- - 100 foot line intercept survey transects.
-*- - 1 square foot vegetation survey micro-plot centers.

Diagram of vegetation survey field plot layout. Grass and forb cover were estimated in 1 square foot microplots. Shrub cover was determined along 3 - 100 foot transects. Total tree basal area was measured for each block.

APPENDIX E

VEGETATION AND GROUND COVER DATA BORDERING PAIGE CREEK, HAPPY VALLEY, ARIZONA.

The vegetation data are presented in four sections:

A. Percent grass cover by species, transects and blocks.

B. Percent forb cover by species, transects and blocks.

C. Percent shrub cover by species, transects and blocks.

D. Percent tree cover by species, transects and blocks.

PERCENT GRASS COVER BY SPECIES, TRANSECT AND BLOCKS

	TRAN - BLOC	1-1	1-2	1-3	1-4	1-5	1-6	2-1	2-2	2-3	2-4	2-5	3-1	3-2	3-3	3-4	3-5	3-6	4-1	4-2	4-3	4-4	4-5	4-6
	CHANNEL DIST.	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	250-300
	ELEVATION	4115.5	4119.1	4117.6	4119.0	4120.5	4121.1	4113.4	4114.7	4113.7	4115.9	4117.0	4102.1	4105.5	4108.3	4108.1	4108.0	4108.1	4100.3	4100.5	4101.9	4107.8	4107.8	4107.3
	SOIL TYPE	-	S-SL	-	LS-SL	SL-LS	-	LS	LS-S	SL	SCL	-	-	LS	SL	SL	-	-	-	-	LS	SCL	SL-LS	-
	HOLE ID	-	0102	-	0103	0104	-	0202	0203	0204	0205	-	-	0303	0302	0301	-	-	-	-	0403	0402	0401	-
	GROUND COVER																							
	-Bare	33.95	35.83	29.58	35.63	27.32	25.85	48.73	24.97	50.08	31.90	48.17	51.49	59.75	28.35	33.92	41.23	43.25	21.37	23.17	20.45	49.43	46.88	32.22
	-Rock	36.52	16.30	1.35	1.62	0.50	0.50	22.87	-	-	2.37	3.48	24.67	16.70	0.47	0.12	0.73	0.12	42.13	19.13	-	-	-	0.12
	-Litter	20.47	35.42	38.48	38.85	43.73	37.23	22.65	48.32	30.82	42.45	31.17	16.25	14.72	51.65	52.12	37.32	45.20	30.93	56.40	75.33	40.72	38.25	58.33
GRASSES:																								
Aristida	divaricata	0.62	-	6.05	3.08	7.35	5.97	1.50	3.37	4.73	11.55	12.65	0.50	8.57	5.73	24.03	11.03	13.12	-	-	0.35	2.55	7.18	5.58
Bouteloua	curtipendula	-	-	0.50	1.75	-	0.50	0.62	-	-	4.58	1.25	-	-	-	-	-	-	-	-	0.23	-	-	-
Bouteloua	aristidoides	1.00	1.25	2.85	-	-	-	-	1.75	1.25	2.25	-	-	1.12	-	0.73	4.92	2.25	-	-	-	-	-	0.62
Bouteloua	rothrockii	-	-	1.23	3.87	14.45	24.03	-	0.12	0.50	7.08	17.78	-	-	-	10.88	34.02	28.45	-	-	0.12	22.28	20.36	7.57
Cenchrus	pauciflorus	-	0.97	2.83	3.75	0.50	0.12	0.23	6.45	3.75	0.50	-	-	-	4.33	9.12	7.27	-	-	2.50	0.62	2.20	-	1.25
Chloris	virgata	-	-	-	-	-	-	-	-	0.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cynodon	dactylon	0.50	0.50	-	-	-	-	1.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Echinochloa	colonum	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50	4.98	4.83	-	-	-	-	0.50	-	2.87
Eragrostis	intermedia	0.50	3.20	-	-	-	-	0.50	-	-	-	-	1.12	-	-	-	-	-	0.23	0.23	-	-	-	1.25
Eragrostis	cilianensis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.25	-	-	-	-	-	0.23
Eragrostis	intermedia	0.12	-	0.50	1.12	3.00	-	-	-	0.50	-	-	-	0.50	-	0.50	-	-	-	-	-	-	-	-
Leptochloa	dubia	-	-	-	-	-	4.33	-	0.50	-	-	-	-	-	-	0.12	-	-	-	-	-	1.60	6.67	5.70
Mulhlenbergia	rigens	0.62	1.75	-	-	-	-	2.93	-	-	-	-	5.62	-	-	-	-	-	0.70	-	-	-	-	-
Panicum	capillare	-	-	1.35	0.50	-	-	-	-	-	-	-	-	-	-	1.23	0.12	0.12	-	-	-	-	0.62	1.37
Panicum	sp.	-	-	-	-	-	-	1.25	-	-	-	-	-	-	-	-	-	-	2.50	-	-	-	-	-
Panicum	(scribnerianum)	-	-	-	-	-	-	-	-	-	-	-	-	0.85	0.12	2.60	4.20	7.60	-	-	-	2.10	1.23	1.12
Paspalum	stramineum	0.25	0.12	6.85	6.25	5.87	1.12	2.00	7.20	9.53	7.00	0.50	0.62	-	-	0.12	0.50	0.62	-	-	-	-	-	8.03
Schizachyrium	hirtiflorum	0.50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Setaria	grisebachii	-	-	0.62	0.12	-	-	-	2.50	1.12	0.12	-	-	-	0.35	-	-	-	-	-	0.12	3.00	-	1.75
Sitanion	hystrix	-	-	0.62	0.12	-	-	-	0.62	1.25	-	-	0.50	-	2.58	0.23	0.12	1.12	-	-	-	-	-	1.23
Sporobolus	cryptandrus	0.12	-	-	-	5.87	4.98	-	-	1.00	6.83	15.25	-	-	0.12	0.50	5.05	9.28	-	-	0.50	2.70	7.18	4.62
SUBTOTALS 1	% GRASS COVER >	4.22	7.78	23.40	20.55	37.03	41.05	10.28	22.50	24.13	39.92	47.43	8.35	11.04	13.73	55.05	72.05	63.80	3.43	2.73	1.93	36.93	43.24	43.19
	NUMBER OF GRASSES >	9	6	10	9	6	7	8	8	10	8	5	5	4	7	12	10	9	3	2	6	8	6	14

PERCENT FORB COVER BY SPECIES, TRANSECT AND BLOCK

	TRAN - BLOC	1-1	1-2	1-3	1-4	1-5	1-6	2-1	2-2	2-3	2-4	2-5	3-1	3-2	3-3	3-4	3-5	3-6	4-1	4-2	4-3	4-4	4-5	4-6
	CHANNEL DIST.	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	250-300
	ELEVATION	4115.5	4119.1	4117.6	4119.0	4120.5	4121.1	4113.4	4114.7	4113.7	4115.9	4117.0	4102.1	4105.5	4108.3	4108.1	4108.0	4108.1	4100.3	4100.5	4101.9	4107.8	4107.8	4107.3
	SOIL TYPE	-	S-SL	-	LS-SL	SL-LS	-	LS	LS-S	SL	SCL	-	-	LS	SL	SL	-	-	-	-	LS	SCL	SL-LS	-
	HOLE ID	-	0102	-	0103	0104	-	0202	0203	0204	0205	-	-	0303	0302	0301	-	-	-	-	0403	0402	0401	-
	GROUND COVER																							
	-Bare	33.95	35.83	29.58	35.63	27.32	25.85	48.73	24.97	50.08	31.90	48.17	51.49	59.75	28.35	33.92	41.23	43.25	21.37	23.17	20.45	49.43	46.88	32.22
	-Rock	36.52	16.30	1.35	1.62	0.50	0.50	22.87	-	-	2.37	3.48	24.67	16.70	0.47	0.12	0.73	0.12	42.13	19.13	-	-	-	0.12
	-Litter	20.47	35.42	38.48	38.85	43.73	37.23	22.65	48.32	30.82	42.45	31.17	16.25	14.72	51.65	52.12	37.32	45.20	30.93	56.40	75.33	40.72	38.25	58.33
FORBS:																								
Acalypha	neomexicana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	1.12	4.87	2.72	1.58
Allionia	incarnata	-	0.50	-	-	-	-	-	0.12	0.50	-	-	-	0.12	0.85	0.70	1.60	0.50	-	-	0.50	2.60	2.48	1.23
Amaranthus	palmeri	-	-	-	-	0.50	0.62	-	-	-	0.12	0.12	-	-	-	-	-	-	-	-	-	-	-	0.62
Ambrosia	confertiflora	-	-	-	-	-	-	-	-	-	-	0.50	-	-	-	-	-	-	-	-	-	-	-	-
Argemone	platyceras	-	-	-	-	-	-	-	-	-	0.50	1.12	-	-	-	-	-	-	-	-	-	-	-	-
Bidens	leptocephala	-	-	0.50	-	1.25	-	-	1.62	0.12	1.23	2.60	-	-	2.60	3.12	-	0.12	-	-	3.00	5.23	10.23	0.97
Bidens	aurea	1.00	0.50	-	-	-	-	1.75	-	-	-	-	2.48	-	-	-	-	-	1.00	-	-	-	-	-
Brayulinea	densa	-	-	-	-	0.50	0.50	-	0.50	-	1.73	-	-	-	-	-	-	-	-	-	-	-	1.25	4.23
Carex	sp.	-	-	-	-	-	-	-	1.75	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.33
Cassia	sp.	0.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50	-	-	-	-	-	-
Cassia	leptocarpa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.12	1.00	-	-	-	-	-	-	-
Chenopodium	murale	-	-	-	-	-	0.50	-	-	-	-	0.50	-	-	-	-	-	0.50	-	-	-	-	0.12	0.50
Commelina	dianthifolia	-	0.50	-	-	-	-	-	1.73	-	0.62	-	-	0.12	0.97	5.05	-	-	-	-	3.20	16.53	6.73	1.62
Conyza	canadensis	1.12	0.35	3.70	1.00	0.50	1.00	0.35	4.50	2.00	3.25	5.33	0.12	-	2.25	2.20	-	-	3.97	1.70	0.50	0.50	0.12	1.00
Croton	pottsii	-	-	-	1.23	2.93	1.62	0.12	2.23	2.25	-	0.97	-	0.47	0.35	1.08	4.40	6.27	-	-	1.50	0.12	0.97	1.08
Cyperus	pringlei	1.37	0.62	1.85	3.48	0.50	-	0.50	1.87	1.75	1.48	-	0.12	-	-	-	-	-	-	-	-	-	-	1.25
Dalea sp.	(lachnostachys)	-	-	1.12	1.75	2.58	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.12	-	-	-
Datura	discolor	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50	-	-	-	-	0.50	-	-
Diodia	teres	-	0.12	-	-	-	-	0.12	-	-	-	-	-	-	-	-	-	0.50	-	-	-	-	-	-
Erigeron	neomexicanus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.00	-	-	-	-	-
Euphorbia	heterophylla	-	-	-	-	-	-	-	-	-	-	-	-	-	0.73	0.85	0.12	1.25	-	-	1.62	-	-	0.12
Gaura	parviflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.25	-	-
Glandularia	gooddingii	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50	-	-	-
Gnaphalium	wrightii	-	1.00	0.12	0.62	-	-	-	-	3.23	4.32	0.50	0.12	6.08	0.12	0.12	-	-	-	-	-	-	-	-

(Continued--)

PERCENT FORB COVER BY SPECIES, TRANSECT AND BLOCK (Continued--)

	TRAN - BLOC	1-1	1-2	1-3	1-4	1-5	1-6	2-1	2-2	2-3	2-4	2-5	3-1	3-2	3-3	3-4	3-5	3-6	4-1	4-2	4-3	4-4	4-5	4-6
	CHANNEL DIST.	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	250-300
	ELEVATION	4115.5	4119.1	4117.6	4119.0	4120.5	4121.1	4113.4	4114.7	4113.7	4115.9	4117.0	4102.1	4105.5	4108.3	4108.1	4108.0	4108.1	4100.3	4100.5	4101.9	4107.8	4107.8	4107.3
	SOIL TYPE	-	S-SL	-	LS-SL	SL-LS	-	LS	LS-S	SL	SCL	-	-	LS	SL	SL	-	-	-	-	LS	SCL	SL-LS	-
	HOLE ID	-	0102	-	0103	0104	-	0202	0203	0204	0205	-	-	0303	0302	0301	-	-	-	-	0403	0402	0401	-
	GROUND COVER																							
	-Bare	33.95	35.83	29.58	35.63	27.32	25.85	48.73	24.97	50.08	31.90	48.17	51.49	59.75	28.35	33.92	41.23	43.25	21.37	23.17	20.45	49.43	46.88	32.22
	-Rock	36.52	16.30	1.35	1.62	0.50	0.50	22.87	-	-	2.37	3.48	24.67	16.70	0.47	0.12	0.73	0.12	42.13	19.13	-	-	-	0.12
	-Litter	20.47	35.42	38.48	38.85	43.73	37.23	22.65	48.32	30.82	42.45	31.17	16.25	14.72	51.65	52.12	37.32	45.20	30.93	56.40	75.33	40.72	38.25	58.33
FORBS (continued)																								
Heterotheca	psammophila	2.60	4.22	3.55	2.33	2.25	2.60	-	3.08	4.00	0.62	10.90	-	10.83	8.53	2.35	4.12	1.12	1.70	2.23	2.37	1.98	12.95	11.08
Ipomoea	coccinea	0.50	-	-	-	-	-	-	-	-	-	-	-	0.50	3.37	2.57	0.23	0.50	0.23	-	3.98	1.12	0.62	0.35
Ipomoea	costellata	-	-	-	-	-	-	-	-	-	-	-	-	1.12	1.23	0.50	0.23	-	-	-	0.50	-	-	-
Juncus	interior	0.50	-	-	-	-	-	2.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Linum	neomexicanum	-	-	-	-	-	-	-	-	-	-	-	-	-	1.37	0.12	-	-	-	-	-	-	0.35	0.50
Machaeranthera	gracilis	-	-	-	-	1.50	-	-	-	-	1.25	-	-	0.12	-	-	-	4.07	-	-	0.50	0.62	0.12	-
Melilotus	indicus	-	-	-	0.50	-	0.50	-	-	-	-	0.50	-	-	-	-	0.12	-	-	-	-	-	-	-
Mirabilis	longiflora	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.23	10.75	4.67	-	2.25
Monarda	austromontana	-	-	0.62	0.12	-	-	-	0.12	-	-	1.00	-	-	-	0.62	-	-	-	-	-	-	-	-
Oenothera	hookeri	0.62	0.50	0.62	2.20	-	-	0.50	3.08	3.95	1.75	0.50	1.12	-	-	-	-	0.62	-	-	1.25	0.50	-	-
Oxalis	albicans	-	-	0.12	1.00	-	2.08	-	0.12	0.50	1.12	2.87	-	-	-	-	-	-	-	1.00	0.12	-	-	1.48
Passiflora	mexicana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.25	-	-	-	-	-	-	-
Physalis	hederaefolia	-	-	-	-	-	0.50	-	-	-	-	-	-	-	-	-	0.12	-	-	-	1.00	-	-	-
Polanisia	dodecandra	-	0.62	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portulaca	suffrutescens	-	0.12	-	0.12	0.12	0.23	-	-	1.00	0.12	-	-	0.12	-	0.50	-	-	-	-	-	-	-	-
Stachys	coccinea	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Verbesina	encelioides	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.50	-	-	-	-	-	1.25	2.58
Wyethia	arizonica	1.98	1.73	-	4.95	-	-	4.82	-	1.12	0.50	1.75	0.50	-	-	-	-	-	4.73	1.47	2.60	-	-	2.08
SUBTOTAL 2	% FORB COVER >	9.80	10.77	12.18	19.30	12.63	10.15	10.15	20.72	20.42	18.60	29.15	4.45	19.47	22.37	19.88	14.18	16.93	12.63	7.63	35.12	40.48	39.90	37.87
	NUMBER OF FORB SPECIES >	9	12	9	12	10	10	8	12	11	14	14	6	9	11	14	12	12	6	5	18	14	13	19

PERCENT SHRUB COVER BY SPECIES, TRANSECT AND BLOCKS

TRAN - BLOC		1-1	1-2	1-3	1-4	1-5	1-6	2-1	2-2	2-3	2-4	2-5	3-1	3-2	3-3	3-4	3-5	3-6	4-1	4-2	4-3	4-4	4-5	4-6
	CHANNEL DIST.	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	250-300
	ELEVATION	4115.5	4119.1	4117.6	4119.0	4120.5	4121.1	4113.4	4114.7	4113.7	4115.9	4117.0	4102.1	4105.5	4108.3	4108.1	4108.0	4108.1	4100.3	4100.5	4101.9	4107.8	4107.8	4107.3
	SOIL TYPE	-	S-SL	-	LS-SL	SL-LS	-	LS	LS-S	SL	SCL	-	-	LS	SL	SL	-	-	-	-	LS	SCL	SL-LS	-
	HOLE ID	-	0102	-	0103	0104	-	0202	0203	0204	0205	-	-	0303	0302	0301	-	-	-	-	0403	0402	0401	-
	GROUND COVER																							
	-Bare	33.95	35.83	29.58	35.63	27.32	25.85	48.73	24.97	50.08	31.90	48.17	51.49	59.75	28.35	33.92	41.23	43.25	21.37	23.17	20.45	49.43	46.88	32.22
	-Rock	36.52	16.30	1.35	1.62	0.50	0.50	22.87	0.00	0.00	2.37	3.48	24.67	16.70	0.47	0.12	0.73	0.12	42.13	19.13	0.00	0.00	0.00	0.12
	-Litter	20.47	35.42	38.48	38.85	43.73	37.23	22.65	48.32	30.82	42.45	31.17	16.25	14.72	51.65	52.12	37.32	45.20	30.93	56.40	75.33	40.72	38.25	58.33
Acacia	greggii				1.33	5.33	4.33				8.00	8.50												
					1	3	1				6	13												
Arctosta-aphylos	pungens	1.30			1.33																			
		2			1																			
Baccharis	glutinosa	6.00																						
		5																						
Cletis	reticulata	0.70	2.67	8.00	1.67				9.00	4.33	21.67	0.67	1.67								5.67			6.00
		1	5	5	1				7	4	10	1	2								2			1
Fraxinus	velutina																				1.00			
																					1			
Juglans	major																					0.33		
																						1		
Juniperus	deppeana				0.67					16.83		3.00												
					1					7		1												
Mimosa	biuncifera																						0.67	
																							1	

(Continued--)

PERCENT SHRUB COVER BY SPECIES, TRANSECT AND BLOCKS (Continued--)

TRAN - BLOC	1-1	1-2	1-3	1-4	1-5	1-6	2-1	2-2	2-3	2-4	2-5	3-1	3-2	3-3	3-4	3-5	3-6	4-1	4-2	4-3	4-4	4-5	4-6
CHANNEL DIST.	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	250-300
ELEVATION	4115.5	4119.1	4117.6	4119.0	4120.5	4121.1	4113.4	4114.7	4113.7	4115.9	4117.0	4102.1	4105.5	4108.3	4108.1	4108.0	4108.1	4100.3	4100.5	4101.9	4107.8	4107.8	4107.3
SOIL TYPE	-	S-SL	-	LS-SL	SL-LS	-	LS	LS-S	SL	SCL	-	-	LS	SL	SL	-	-	-	-	LS	SCL	SL-LS	-
HOLE ID	-	0102	-	0103	0104	-	0202	0203	0204	0205	-	-	0303	0302	0301	-	-	-	-	0403	0402	0401	-
GROUND COVER																							
-Bare	33.95	35.83	29.58	35.63	27.32	25.85	48.73	24.97	50.08	31.90	48.17	51.49	59.75	28.35	33.92	41.23	43.25	21.37	23.17	20.45	49.43	46.88	32.22
-Rock	36.52	16.30	1.35	1.62	0.50	0.50	22.87	0.00	0.00	2.37	3.48	24.67	16.70	0.47	0.12	0.73	0.12	42.13	19.13	0.00	0.00	0.00	0.12
-Litter	20.47	35.42	38.48	38.85	43.73	37.23	22.65	48.32	30.82	42.45	31.17	16.25	14.72	51.65	52.12	37.32	45.20	30.93	56.40	75.33	40.72	38.25	58.33
Opuntia sp.									2.33														
									1														
Pluchea sericea								4.00				3.67											
								1				5											
Prosopis juliflora		5.33		4.67	9.00		1.67	19.67		23.67	27.34				11.00	17.00	7.67			10.33	12.67	8.67	30.00
		2		3	5		1	10		8	8				3	3	2			4	7	4	13
Rhus radicans		0.12	1.37									0.12	0.12										
		1	1									1	1										
Salix exigua	5.00																						
	1																						
Vitis arizonica												2.08		16.00	0.50					26.00	0.50		
												1		1	1					1	1		
UNKNOWN	13.00	2.00					11.00																
	3	2					10																
TOTALS	26.00	10.12	9.37	10.00	14.33	6.66	12.67	32.67	23.49	53.34	39.51	7.54	0.12	16.00	11.50	17.00	7.67	0.00	0.00	43.00	13.50	9.34	36.00
	12	10	6	8	8	3	11	18	12	24	23	9	1	1	4	3	2	0	0	8	9	5	14

TREE BASAL AREA BY SPECIES, TRANSECT AND BLOCKS

	TRAN - BLOC	1-1	1-2	1-3	1-4	1-5	1-6	2-1	2-2	2-3	2-4	2-5	3-1	3-2	3-3	3-4	3-5	3-6	4-1	4-2	4-3	4-4	4-5	4-6
	CHANNEL DIST.	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	0-50	50-100	100-150	150-200	200-250	250-300	0-50	50-100	100-150	150-200	200-250	250-300
	ELEVATION	4115.5	4119.1	4117.6	4119.0	4120.5	4121.1	4113.4	4114.7	4113.7	4115.9	4117.0	4102.1	4105.5	4108.3	4108.1	4108.0	4108.1	4100.3	4100.5	4101.9	4107.8	4107.8	4107.3
	SOIL TYPE	-	S-SL	-	LS-SL	SL-LS	-	LS	LS-S	SL	SCL	-	-	LS	SL	SL	-	-	-	-	LS	SCL	SL-LS	-
	HOLE ID	-	0102	-	0103	0104	-	0202	0203	0204	0205	-	-	0303	0302	0301	-	-	-	-	0403	0402	0401	-
	GROUND COVER																							
	-Bare	33.95	35.83	29.58	35.63	27.32	25.85	48.73	24.97	50.08	31.90	48.17	51.49	59.75	28.35	33.92	41.23	43.25	21.37	23.17	20.45	49.43	46.88	32.22
	-Rock	36.52	16.30	1.35	1.62	0.50	0.50	22.87	0.00	0.00	2.37	3.48	24.67	16.70	0.47	0.12	0.73	0.12	42.13	19.13	0.00	0.00	0.00	0.12
	-Litter	20.47	35.42	38.48	38.85	43.73	37.23	22.65	48.32	30.82	42.45	31.17	16.25	14.72	51.65	52.12	37.32	45.20	30.93	56.40	75.33	40.72	38.25	58.33
Cletis	reticulata		2.74	0.03					4.95	0.04	1.05	0.10						2.17				0.17		
			1	2					2	2	2	2						4				1		
Fraxinus	velutina	0.06	1.67					1.92												0.09	1.78	4.87	3.52	5.51
		4	1					2												2	7	2	1	2
Juglans	major														0.76				0.90		0.65			
															1				5		2			
Juniperus	deppeana			0.04								0.23							0.41		4.32			
				4								4							2		1			
Platanus	wrightii	4.87	3.46	22.33				0.42	25.42	21.94	20.74		1.37		22.49				11.93	10.09	5.21			
		6	8	17				4	13	5	5		3		4				34	13	6			
Populas	fremontii	0.18						0.48							7.28	8.10			5.53	5.98	9.43			
		6						5							2	2			8	6	6			
Prosopis	juliflora							0.08	0.38	0.32	0.08	0.29						1.35				2.75	0.67	3.46
								1	1	3	3	2						1				12	2	7
Quercus	emoryi			0.44	15.39	5.20	6.34							0.32	0.05				0.08					
				1	1	1	3							1	1				1					
Salix	exigua	0.55																	0.43		0.31			
		7																	1		2			
	TOTALS	5.66	7.87	21.84	15.39	5.20	6.34	2.90	30.75	22.30	21.87	0.72	1.37	0.32	30.58	8.10	0.00	3.52	19.28	16.16	21.70	7.79	4.19	8.97
		23	10	24	1	1	3	12	16	10	10	8	3	1	8	2	0	5	51	21	24	15	3	9

REFERENCES

Adams, K.R. 1985. Annual Phenological Profiles of Plants in and Adjacent to Two Riparian Habitats in Southeastern Arizona. In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 485-488.

Affleck, R.S. 1975. Potential for Water Yield Improvement in Arizona Through Riparian Vegetation Management. Unpublished Ph.D. Dissertation. University of Arizona. Tucson, AZ.

Anderson, B.W. and R.D. Ohmart. 1985. Managing Riparian Vegetation and Wildlife Along the Colorado River: Synthesis of Data, Predictive Models, and Management. In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM.-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 123-127.

Asplund, K.K. and M.T. Gooch. 1988. Geomorphology and Distributional Ecology for Fremont Cotton (Populus fremontii) in a Desert Riparian Canyon. Desert Plants 9:1. pp. 17-27.

Babcock , H.M. 1968. The Phreatophyte Problem in Arizona: Arizona Watershed Symposium Proceedings 12:34-36.

Barstad, J.F. 1981. Factors Controlling Plant Distribution in a Riparian Deciduous Forest in Southeastern Arizona. Master's Thesis, Arizona State University. Tempe, AZ.

Bock, J.H. and C.E. Bock. 1985. Patterns of Reproduction in Wright's Sycamore. In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 493-494.

Bowers J.E. and S.P. McLaughlin. 1987. Flora and Vegetation of The Rincon Mountains, Pima County, Arizona. Desert Plants 8:2.

Bowser, C.W. 1952. Water Conservation Through Elimination of Undesirable Phreatophyte Growth. American Geophysical Union Transaction 33:72-74.

Branson, F.A., G.F. Gifford, K.G. Renard, and R.F. Hadley. 1981. Rangeland Hydrology. Society for Range Management. Denver, CO.

Brock, J.H. 1985. Physical Characteristics and Pedogenesis of Soils in Riparian Habitats. In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 49-53.

Brock, J.H. 1984. Final Report: Some Autoecological Studies on Regeneration and Maintenance of Selected Riparian Plant Species. Rocky Mountain Forest and Range Experiment Station. Tempe, AZ.

Brown, D.E. 1982. Biotic Communities of the American Southwest-United States and Mexico. Desert Plants 4:1-4.

Brown, S., M.M. Brinson, and A.E. Lugo 1978. Structure and Function of Riparian Wetlands. In: Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. USDA Forest Service Gen. Tech. Report GTR-WO-12. pp. 17-31.

Buckman, H.O. and N.C. Brady. 1969. The Nature and Properties of Soils. 7th ed. MacMillan Company, Toronto, Ontario.

Bryan, K. 1928. Change in Plant Associations by Change in Ground Water Level. Ecology 9:4.

Buol, S.W., F.D. Hole, and R.J. McCracken. 1980. Soil Genesis and Classification, Second Edition. The Iowa State University Press. Ames, IA.

Carothers, S.W. 1977. Importance, Preservation and Management of Riparian Habitat: An Overview. In: Importance, Preservation and Management of Riparian Habitat: A symposium. USDA Forest Service General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station. Fort Collins, Co. pp. 2-4.

Carpenter, E.J. 1921. Soil Survey of the Benson Area, Arizona. USDA Department of Agriculture. Bureau of Soils. Washington, DC.

Clemmons, S.D. 1973. Soil Resources Inventory: Rincon Mountains. Santa Rita Ranger District, Coronado National Forest, AZ.

Cox, J.R. and H.L. Morton. 1985. Above-Ground Biomass Quantities and Livestock Production at Big Sacaton Riparian Areas in Southeastern Arizona. In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 305-309.

CPN. 1984. Operator's Manual: 501-DR Depthprobe Moisture Depth Gauge. Campbell Pacific Nuclear Corporation. Pacheco, CA.

Crumpacker, D.W. 1985. A Summary of Biological and Physical Science Presentations at the First North American Conference on Riparian Ecosystems and Their Management. In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 3-5.

Cunningham, G.L., J.G. Fraser, R.E. Grieve, and H.G. Wolfe. 1973. A Comparison of Rates of Water Loss Through Transpiration of Several Southern New Mexico Phreatophyte Species. New Mexico Water Resources Research Institute Technical Completion Report No. 025.

Donahue, R.L., R.W. Miller, and J.C. Shickluna. 1977. Soils: An Introduction to Soils and Plant Growth. 4th Edition. Prentice-Hall, Inc. Englewood Cliffs, NJ.

Ewel, K.C. 1978. Riparian Ecosystems: Conservation of Their Unique Characteristics. In: Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. USDA Forest Service Gen. Tech. Report GTR-WO-12. pp. 56-62.

Floyd, D. 1987. The Desert Oasis. Arizona Land and People. Summer 1987. College of Agriculture, University of Arizona. Tucson AZ. pp. 11-18.

Foth, H.D., L.V. Withec, H.S. Jacobs, and S.J. Thien, 1976. Laboratory Manual for Introductory Soil Science, 4th ed., W.M.C. Brown Publishing Company, Dubuque, IA.

Gatewood, J.S., T.W. Robinson, B.R. Colby, J.D. Hem, and L.C. Halpenny. 1950. Use of Water by Bottom-land Vegetation in Lower Safford Valley, Arizona. USDI Geological Survey, Water-Supply Paper 1103.

Horton, J.S. 1972. Management Problems in Phreatophyte and Riparian Zones. Journal of Soil and Water Conservation. 27:2. 57-61.

Horton, J.S. and C.J. Campbell. 1976. Management of Phreatophyte and Riparian Vegetation for Maximum Multiple Use Values. USDA Forest Service Research Paper RM-117. Rocky Mountain Forest and Range Experiment Station. Fort Collins CO.

Huffman, R.T. 1981. Technical Delineation of Wetland Boundaries within California Riparian Systems. In: California Riparian Systems Ecology, Conservation, and Productive Management. Warner, R.E. and K.M. Hendrix editors. University of California Press. Berkeley, CA. pp. 889-894.

Johnson, R.R., C.D. Ziebell, D.R. Patton, P.F. Ffolliott, and R.H. Hamre. 1985. Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO.

Johnson, R.R. and C.W. Lowe. 1985. On the Development of Riparian Ecology. In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 112-116.

Johnson, R.R. and J.F. McCormick. 1978. Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. Symposium Proceedings. USDA Forest Service. General Technical Report WO-12. Washington, DC.

Johnson, R.R. and D.A. Jones. 1977. Importance, Preservation and Management of Riparian Habitat: A symposium. USDA Forest Service General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO.

Kearney, T.H. and R.H. Peebles. 1951. Arizona Flora. University of California Press, Berkeley, CA.

Knopf, F.L., R.R. Johnson, T. Rich, F.B. Samson, and R.C Szaro. 1988. Conservation of Riparian Ecosystems in the United States. Wilson Bulletin 100:2. pp. 272-284.

Larkin, G.J. 1987. Factors Influencing Distribution and Regeneration of Riparian Species Along Mountain Streams in Central Arizona. Master's Thesis. Arizona State University. Tempe, AZ.

Lehr, J.H. 1978. A Catalogue of the Flora of Arizona. Desert Botanical Garden, Phoenix, AZ.

Maxwell, J., W. Moir, A. Renfro, J. Stefferud, R. Szaro, and J. Tower. 1983. A Guide to Identifying, Classifying, and Analyzing Riparian Areas in the Southwest. USDA Forest Service, Region 3. Albuquerque, NM.

Minckley, W.L. and D.E. Brown. 1982. Wetlands. In: Biotic Communities of the American Southwest-United States and Mexico. Desert Plants 4:1-4.

Meinzer, O.E. 1927. Plants as Indicators of Ground Water. USDI US Geological Survey. Water Supply Paper 577. Washington, DC.

Mueller-Dombois, Dieter and H. Ellenberg. 1974. Aims and Methods of Vegetation Ecology. John Wiley & Sons, NY.

Mutz, K.M. and L.C. Lee. 1987. Wetland and Riparian Ecosystems of the America West. Eight Annual Meeting of the Society of Wetland Scientists. Proceedings. Planning Information Corporation. Denver, CO.

Odum, E.P. 1978. Opening Address: Ecological Importance of the Riparian Zone. In: Strategies for Protection and Management of Floodplain Wetlands and Other Riparian Ecosystems. USDA Forest Service General Technical Report GTR-WO-12. pp. 2-4.

Parker, K.F. 1972. An Illustrated Guide to Arizona Weeds. University of Arizona Press. Tucson, AZ.

Pase, C.P. and E.F. Layser. 1977. Classification of Riparian Habitat in the Southwest. In: Importance, Preservation and Management of Riparian Habitat: A symposium. USDA Forest Service General Technical Report RM-43. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 5-9.

Qashu, H.K. and D.D. Evans. 1967. Water Disposition in a Stream Channel with Riparian Vegetation. Soil Science Society of America Proceedings. 31(2). pp. 263-269.

Reichenbacher, F.W. 1984. Ecology and Evolution of Southwestern Riparian Plant Communities. Desert Plants. 6:1. pp. 15-22.

Richards, L.A. and S.J. Richards. 1957. Soil Moisture. In: Soil: The 1957 Yearbook of Agriculture. 85th Congress, 1st Session, House Document No. 30. USDA. Washington, DC. pp. 49-60.

Sebenik, P.G. and J.L. Thames. 1967. Water Consumption by Phreatophytes. Progressive Agriculture 19(2). pp. 10-11.

Sellers, W.D. and R.H. Hill. 1974. Arizona Climate 1931-1972. The University of Arizona Press. Tucson, AZ.

Swanson, F.J., S.V. Gregory, J.R. Sedell, and A.G. Campbell. 1982. Land-Water Interactions: The Riparian Zone. In: Analysis of Coniferous Forest Ecosystems in the Western United States. US/IBP Synthesis Series No. 14. Hutchinson Ross Publishing Company, Stroudsburg, PA. pp. 267-291.

Swenson, E.A. and C.L. Mullins. 1985. Revegetating Riparian Trees in Southwestern Floodplains. In: Riparian Ecosystems and Their Management: Reconciling Conflicting Uses. First North American Riparian Conference. Symposium Proceedings. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station. Fort Collins, CO. pp. 135-138.

Szaro, R.C. 1989. Riparian Forest and Scrubland Community Types of Arizona and New Mexico. Desert Plants (in press).

Thomas, J.W., C. Maser, and J.E. Rodiek. 1979. Wildlife Habitats in Managed Rangelands--The Great Basin of Southeastern Oregon. Riparian Zones. General Technical Report PNW-80. USDA Forest Service Pacific Northwest Forest and Range Experiment Station. La Grande, OR.

Tromble, John M. 1972. Use of Water by a Riparian Mesquite Community. In: Watersheds in Transition. American Water Resources Association and Colorado State University. pp. 267-270.

USDA Forest Service. (Undated). Management of Moist-Site Vegetation for Water. Past History, Present Status and Future Needs.

USDA Soil Conservation Service. 1975. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Agricultural Handbook No. 436. USDA Soil Conservation Service. Washington, DC.

USDA Soil Conservation Service. 1979. Soil Survey of Santa Cruz and Parts of Cochise and Pima Counties, Arizona. USDA Soil Conservation Service and Forest Service. Washington, DC.

USDA Forest Service. 1986. U.S. Department of Agriculture, Forest Service Manual Section 2526.05, Definitions. FSM 3/86 Amend.