Chapter 1

Introduction

Daniel G. Neary, John N. Rinne, Alvin L. Medina, Malchus B. Baker, Jr.

Location

The UVR area of north-central Arizona overlaps the Central Highlands and the Plateau Uplands biogeographic provinces. The UVR area occupies about 6,700 km^2 (2,600 mi^2) of Yavapai and Coconino Counties (fig. 1.1), and its watershed encompasses the northern valley of the Verde River bounded by the escarpment of the Mogollon Rim to the north and northeast and by the Black Hills to the southwest. The Mogollon Rim escarpment is the boundary between the Plateau uplands province and the Central highlands province. It is a steeply sloping cliff that rises 310 to 610 m (1,000 to 2,000 ft) from the Verde Valley floor to elevations of 1,680 to 2,290 m (5,500 to 7,500 ft). The Rim is dissected by deeply incised canyons. South of the Rim, the landscape is characterized by many buttes and mesas.

The Verde River is the major stream that drains the study area. The UVR watershed begins 120 km (75 mi) to the northwest of the study area near Frazier Wells, but streamflow is only intermittent in that portion. Perennial flow begins in Section 15, Township 17 N., Range 1 W. The river flows along the foot of the Black Hills eastward to Perkinsville, then southeastward where it leaves the study area at Tapco, just upstream of Clarkdale and below its confluence with Sycamore Creek. For the purposes of this synthesis and the monitoring and research that has been conducted by RMRS, the UVR consists of the perennial flow reach from the dam at Sullivan Lake downstream to the boundary of the Prescott National Forest at Tapco (fig. 1.1). This includes a portion of what is labeled in fig. 1.1 as the Middle Verde River. The UVR coincides with the U.S. Geological Survey Hydrologic Unit Code (HUC) Watershed 15060202, Lower Colorado Region, Verde River Basin, UVR (fig. 1.2; http://water.usgs.gov/GIS/huc_name.html#Region15).

Elevations along the Verde River range from about 1,290 m (4,200 ft) where the perennial flow begins to about 1,040 m (3,400 ft) at Tapco. Perennial flow in the Verde River and its major tributaries is maintained by groundwater discharge.

The majority of the UVR watershed where flow is perennial is within the boundaries of, and managed by, the Prescott National Forest. Smaller areas in the upper elevations to the north, northeast, and east are managed by the Kaibab and Coconino National Forests. The western portion of the UVR, at the beginning of perennial flow and upstream in the ephemeral flow reaches of the Chino Valley, is mainly private and State of Arizona-owned lands.

Watershed Descriptions

The watershed of the UVR encompasses an area of diverse topography and lithology since it traverses the Transition Zone from highlands on the southwestern edge of the Colorado Plateau into a large basin that is more typical of the desert

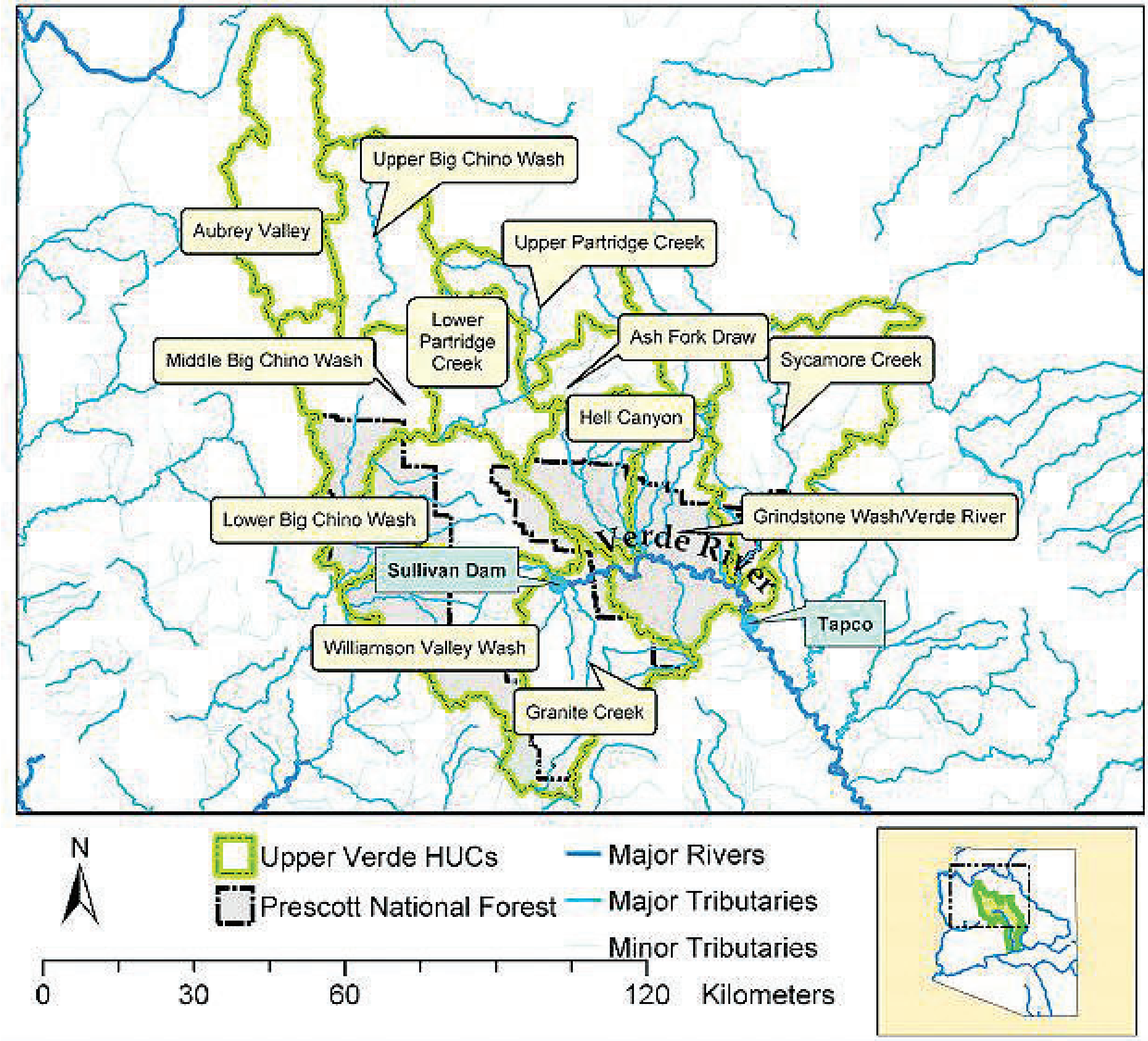

Figure 1.2—Sub-watersheds within the UVR, Prescott National Forest, Arizona. The UVR study area is in the easternmost portion of the Forest's lands shown in this figure. (Map courtesy of the Prescott National Forest.)

Southwest. This Report is limited to lands within the Prescott National Forest (fig. 1.2) since those are the areas for which the most data are available and for which the Prescott National Forest makes management decisions. The Tapco site is used as the lower boundary of the analysis in this report, just upstream of Clarkdale and below its confluence with Sycamore Creek. This area coincides with the first of three reaches included in the biological evaluation by the Prescott National Forest (2001).

The UVR Watershed encompasses twelve "5th code" HUCs (fig. 1.2) from the Big Chino Wash downstream to Tapco. Seven are within the U.S. Geological Survey's "4th code" HUC Watershed 15060202, UVR (fig. 1.3). The HUCs refer to the two digit sequences of nested watersheds that go from the Lower Colorado Region (#15), to the Salt River Subregion (#1506), to the Verde River Basin Accounting Unit (150602), to the UVR Cataloguing Unit (#15060202). For more details see the U.S. Geological Survey website http://water.usgs.gov/GIS/huc_name.html#Region15. The Williamson Valley Wash (HUC #1506020107), Hell Canyon (HUC #1506020202), and Sycamore Creek (HUC #1506020203) hydrologic units

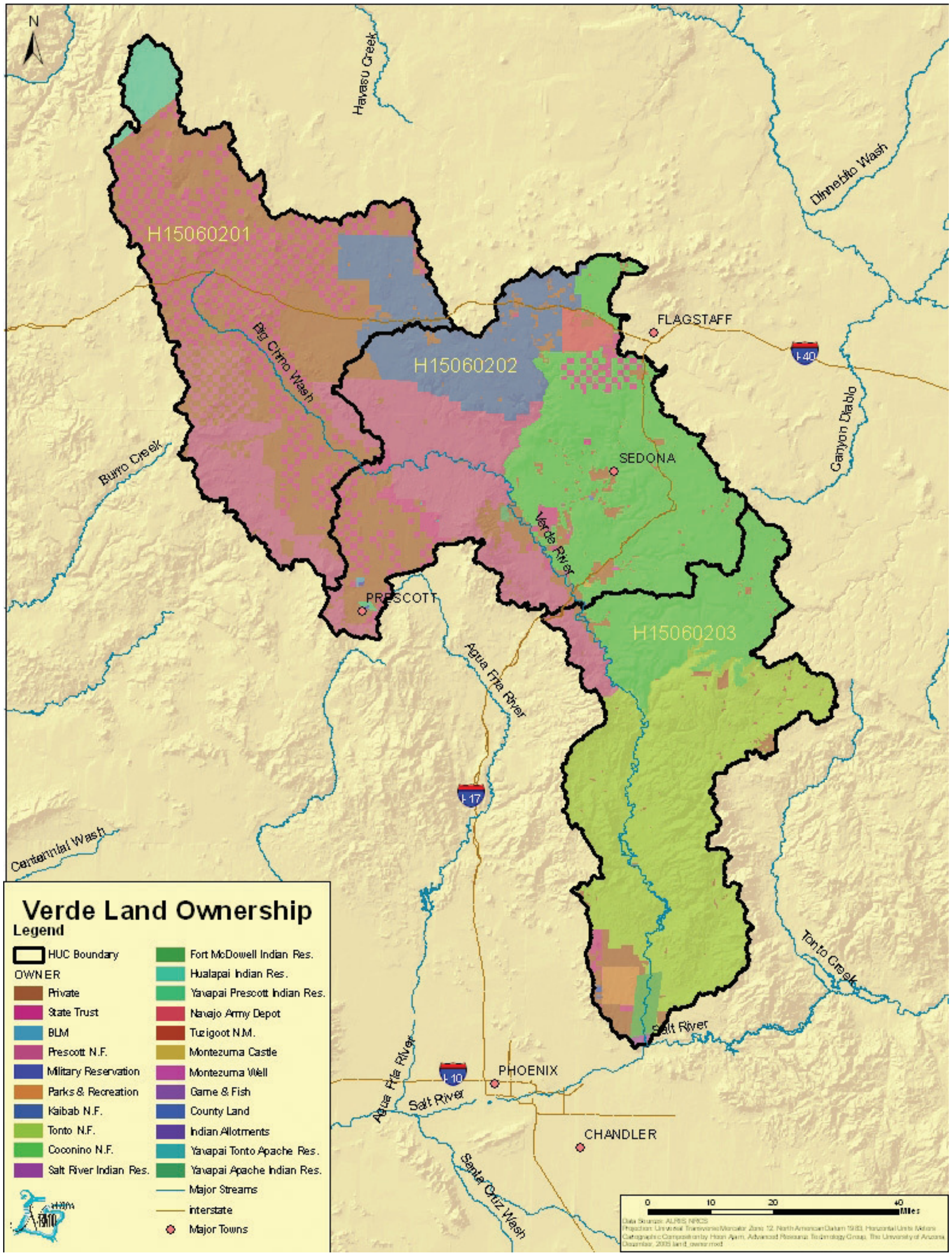

Figure 1.3—Land ownership within the U.S. Geological Survey Hydrologic Unit 4th Code watersheds for the Verde River, Arizona: Big Chino Wash (H15060201), Upper Verde River (H15060202) and Lower Verde River (H15060203). (Arisona NEMO 2012).

are true watersheds, but the Middle Big Chino Wash (HUC #1506020106), Lower Big Chino Wash (HUC #1506020108), Granite Creek/upper Verde River (HUC #1506020201), and Grindstone Wash/UVR (HUC #1506020204) hydrologic units are not, because parts of their watersheds are contained by other HUC watersheds. A major disadvantage of using HUCs that are not true watersheds is that their boundaries are arbitrary. Consequently, boundaries of some of the HUCs reported here do not coincide precisely with those used in Prescott National Forest's biological and National Environmental Protection Act evaluations.

The general condition of the UVR consists of a plateau with pinyon-juniper dissected by the entrenched Verde River (fig. 1.4). Some sections open out wider (e.g., Perkinsville and Burnt Ranch) before returning to the mostly canyon-bound condition.

Figure 1.4—Typical UVR landscape, Prescott National Forest, Arizona. (Photo by Daniel G. Neary.)

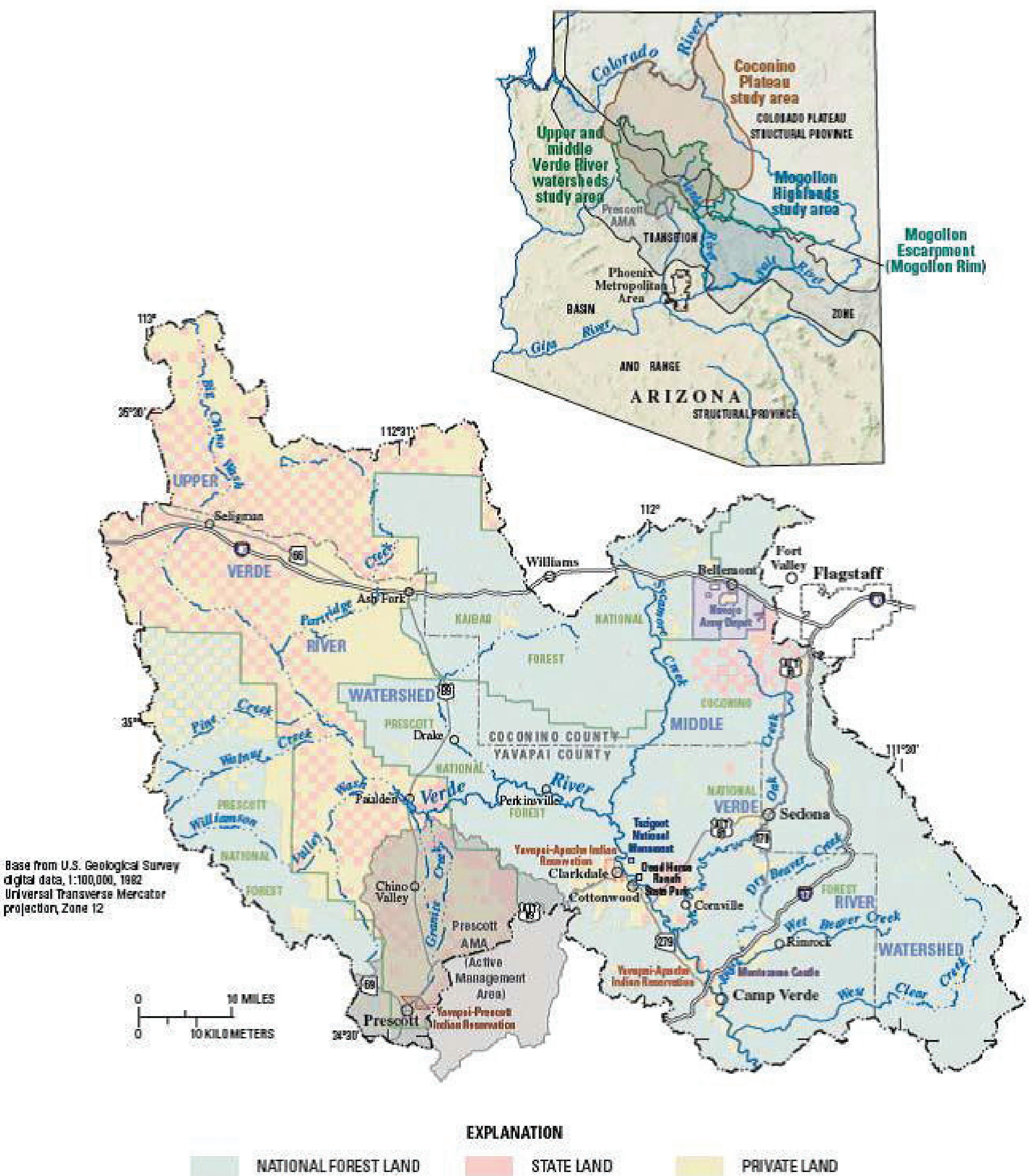

Figure 1.5—Land use patterns and major cultural and hydrologic features, Verde River, Arizona (From Blasch and others 2006).

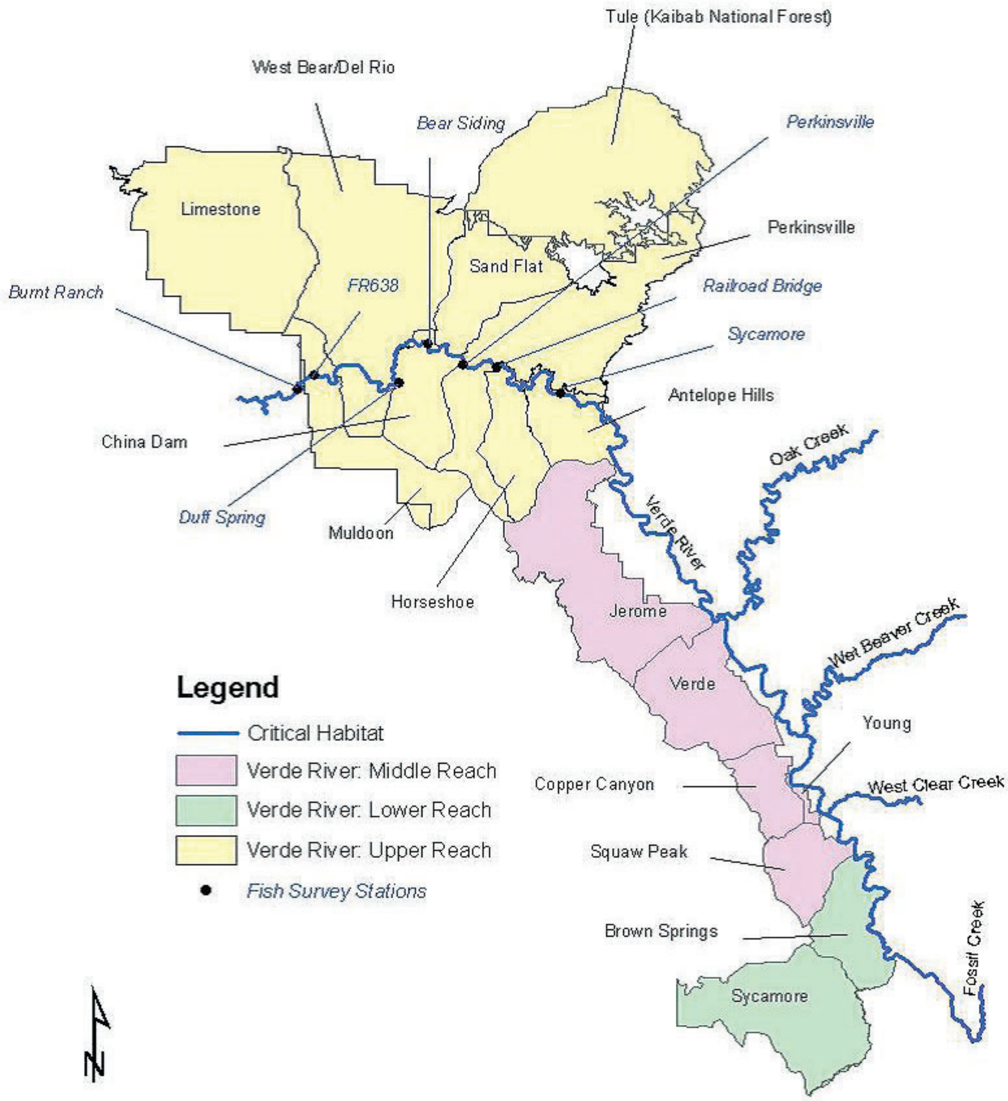

Figure 1.6—Prescott National Forest UVR grazing allotments.

Land Use and Tenure

Within Yavapai County, Arizona, 38% of the UVR watershed is managed by the USDA Forest Service. The State of Arizona manages 24.5%, and the Bureau of Land Management is responsible for another 11.5%. Private holdings account for 25%, and a mixture of public agencies and Indian Nations manage the remainder (Blasch and others 2006). The majority of the land within the UVR study area considered for this report is managed by the Prescott National Forest (fig. 1.5). Private in-holdings occur mainly at Perkinsville, the Verde River Ranch, and the higher reaches of the UVR where Arizona Game and Fish Department and other private land ownerships occur.

Most of the UVR lands within the Prescott National Forest are managed under grazing allotments. Nine grazing allotments border a total of about 60 km (38 mi) of the UVR (fig. 1.6, table 1.1). The allotments cover an altitude range of 1,280 m (4,200 ft). Two allotments—Limestone and Tule—do not border the main stem of the UVR but are within the watershed. Permitted maximum stocking levels range from 428 to 10,200 AUMs per allotment (animal unit months; Scarnecchia 1985)

Table 1.1—Grazing allotments of the UVR, Prescott National Forest (from King 2002).

Allotment	AUMs[1]	Area ha	Area ac	River length km	River length mi
Limestone	428	23,321	57,627	0.0	0.0
West Bear/Del Rio	10,200	29,265	72,315	15.5	9.7
Muldoon	2,340	9,710	23,995	5.8	3.6
China Dam	1,260	6,454	15,947	4.8	3.0
Sand Flat	1,500	9,353	23,111	2.7	1.7
Tule	2,250	24,406	60,309	0.0	0.0
Perkinsville	3,192	20,919	51,692	2.6	1.6
Antelope Hills	936	5,826	14,397	23.4	14.6
Horseshoe	2,700	5,927	14,646	5.4	3.4
TOTAL	24,806	135,181	334039	60.2	37.6

[1]AUMs = animal unit months (Scarnecchia 1985)

but are often well below these levels due to climate conditions and forage production (table 1.1).

Recreation is another important land use but its frequency is low, concentrated mainly at several limited access points. The Verde River Railroad runs up the river as far as Perkinsville before moving out of the river valley. Mining of flagstones is becoming a larger land use in the Grindstone Wash portion of the watershed. Above the UVR study area, the Big Chino Wash is becoming urbanized.

Water consumption in the UVR area is mainly through groundwater use. Annual withdrawals in the Big Chino and Little Chino sub-basins that provide much of the source flow for the UVR average 6.1 to 9.8 x 10^6 m^3 (about 4,900 to 7,900 ac-ft), respectively. Residential water usage from domestic wells and commercial water suppliers adds another 0.6 and 9.8 x 10^6 m^3 (500 to 7,900 ac-ft), respectively (Blasch and others 2006).

Climate

The climate of the UVR is governed by the climate of the Southwest United States in that it is characterized by a cyclic climatic regime of winter precipitation, spring drought, summer precipitation, and fall drought (Ffolliott and Davis 2008; Hendricks 1985). Precipitation usually comes from the northwest in the winter and from the southeast in the summer. It is bi-modally distributed with more precipitation occurring in the winter season (October through April) than during the summer season. Winter precipitation, often snow at higher elevations, is associated with frontal storms moving into the region from the Pacific Ocean. Surface thermal heating in the winter is less pronounced than in the summer; upslope air movement is relatively slow; cloudiness is common; and precipitation is usually widespread and relatively low in intensity.

The major source of moisture for summer rains is the Gulf of Mexico. This moisture moves into Arizona from the southeast, passes over highly heated and mountainous terrain, rises rapidly, cools, and condenses. Summer storms, primarily convectional, are often intense and local rather than widespread. Summer rains typically begin in early July, breaking the prolonged spring drought and providing relief to the hot weather of June and July.

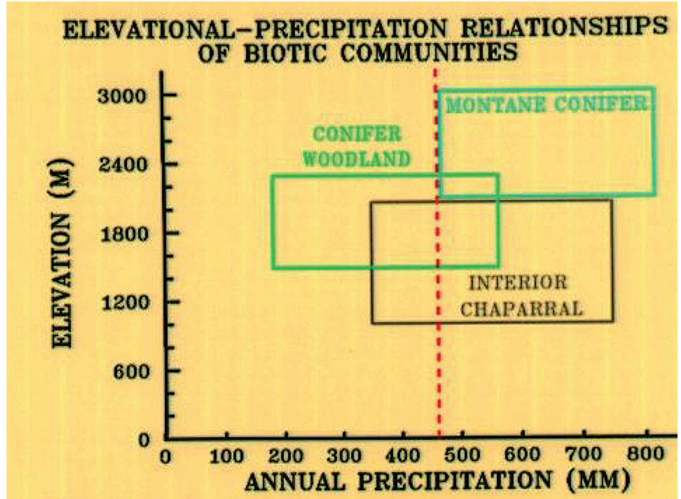

Figure 1.7—Central Arizona Highlands vegetation versus altitude relationships of biotic Communities (Baker 1982).

Winter precipitation is more variable than summer precipitation in both amount and time of occurrence from year to year. However, yearly variations in precipitation generally decrease with increase in elevation. Winter precipitation is generally less intense than summer precipitation so it has less energy to detach and transport sediment. Spring drought is often more detrimental to most plants and animals in the region than fall drought due to the higher temperatures and wind conditions during the beginning of the active growing season. Total precipitation increases with altitude and has a strong influence on both the types and productivities of vegetation communities (fig. 1.7).

Average annual precipitation in the central highlands ranges from 250 mm (10.0 in) in the lower desert shrub types to 760 mm (30.0 in) and 1,140 mm (45.0 in) in the highest mixed conifer forest areas (Baker 1982; fig. 1.7). The majority (80 to 95%) of the resulting streamflow occurs during the winter period either from melting snow or rainfall of moderate to low intensity (Baker 1982, 1999; Baker and others 2003). Little runoff is produced in the desert shrub types. Summer runoff is the product of intense, convective cells that cover relatively small areas (about 2.5 km^2 or 1 mi^2). These storm events may result in "flash floods," which are capable of producing localized flooding, significant erosion and sedimentation, property damage, and loss of life.

Vegetation

Vegetation types in the Central Arizona Highlands include mixed conifer forests, ponderosa pine forests, mountain grasslands, pinyon-juniper woodlands, chaparral shrublands, and desert shrub ecosystems (Baker 1999; Baker and others 2003). The mixed conifer forests, ponderosa pine forests, and mountain grasslands that make up the montane conifer biotic community are located above the elevations of the UVR study area except for small portions of the Tule Allotment (fig. 1.6). The desert shrub community is confined to the Lower Verde River and is not represented in the UVR. The elevation and precipitation limits for the conifer woodland and interior chaparral vegetation types are illustrated in fig. 1.7. These biotic communities provide a range of ecosystem services, including water, wood, forage, recreation opportunities, and wildlife habitats for a variety of big and small game animals, rodents, and game and non-game birds. A diversity of riparian ecosystems occur in, or adjacent to, stream systems and their floodplains that cut across both the conifer woodland and interior chaparral communities.

Figure 1.8—Pinyon-Juniper woodlands of the UVR region, Prescott National Forest. (Photo by Daniel G. Neary.)

The evolution of the American Southwest plant communities during the past 100 million years derived from major Tertiary geofloras that resided over a much greater subcontinental area than exists today (Brown 1982). The native vegetation of North America was composed of three great geofloras: (a) a mesophytic, broad-leafed evergreen Neotropical-Tertiary geoflora in the south half of the continent; (b) a temperate conifer and mixed-deciduous Arcto-Tertiary geoflora in the north; and between them, (c) an emerging sclerophyllous and microphyllous Madro-Tertiary geoflora that appearing on drier sites within and bordering the Neotropical Tertiary geoflora. Even the most pristine conditions within the derivative biomes are, for the most part, remnants of once-greater biotic communities of a greatly expanded geographic Southwest. The Southwest forests of relict conifers, montane conifers, subalpine conifers, and riparian deciduous trees are now relatively simplistic and depauperate modern derivatives of the more generalized and diverse temperate Arcto-Tertiary geoflora.

Conifer Woodlands—Woodlands containing pinyon pine and juniper species constitute the majority of the vegetation of the UVR area (figs. 1.4 and 1.8). They are below the signature ponderosa pine forests, at elevations of 1,370 to 2,290 m (4,500 to 7,500 ft), and constitute the largest forest type in the Southwest (fig. 1.8). Colorado pinyon (*Pinus edulis*) is found throughout, with singleleaf pinyon (*Pinus monophylla*) occurring on limited areas (Baker 1999). North of the Mogollon Rim, Utah juniper (*Juniperus osteosperma*), Rocky Mountain juniper (*J. scopulorum*), and one-seed juniper (*J. monosperma*) are intermixed with pinyon, while alligator juniper (*J. deppeana*) and Utah juniper are found south of the Mogollon Rim. Annual and perennial grasses and grass-like plants, forbs, half-shrubs, and shrubs abound beneath the woodland overstories when the tree cover is not overly dense or when grazing intensity is moderate to low. Recreation, a resource in these woodland areas, is limited by summer temperature and the relative lack of water. These woodlands are also an important source of firewood. Livestock, which spend

Figure 1.9—Chaparal shrublands of the UVR region, Prescott National Forest. (Photo by Malchus B. Baker, Jr.).

summers at higher elevations, graze in the woodlands in winter. These woodlands are also seasonal and yearlong habitats for many wildlife species.

There are wide fluctuations in weather patterns throughout the pinyon-juniper woodlands. Annual precipitation varies from 310 to 610 mm (12.0 to 24.0 in) (Baker 1999). Winter precipitation is usually rain with occasional snow. Evapotranspiration rates are relatively high in the growing season. Only during the coldest months of December through February is precipitation greater than the evapotranspiration rates. About 80 to 85% of the runoff produced in these woodlands occurs during the winter period (Clary and others 1974).

Soils are derived from basalt (Typic Chromusterts Vertisols–Springerville series), limestone, and sandstone parent material (Hendricks 1985). Pinyon-juniper woodlands generally occupy extensive areas of gently rolling topography. With the exception of steep canyon walls, few slopes exceed 20 to 25%. All aspects are well represented.

Chaparral Shrublands—Chaparral shrublands occur on rough, discontinuous, mountainous, terrain south of the Mogollon Rim (fig. 1.9; Baker 1999). Chaparral stands consist of a heterogeneous species mix in many locations, but often only one or two species dominate. Shrub live oak (Quercus turbinella) is the most prevalent species, while true (*Cercocarpus montanus*) and birchleaf mountain mahogany (*Cercocarpus betuloides*), Pringle (*Arctostaphylos pringlei*) and pointleaf (*A. pungens*) manzanita, yellowleaf (*Garrya flavescens*), hollyleaf buckthorn (*Rhamnus crocea*), desert ceanothus (*Ceanothus greggii*), and other shrub species can be included in the chaparral mixture of shrubs (Baker 1999). Annual and perennial grasses, forbs, and half-shrubs are present, particularly where the overstory canopy is open or only moderately dense. Although the recreational value (hiking, camping, and hunting) of chaparral is less than the higher-elevation vegetation types, its close proximity to major population centers gives it the advantage of providing a much larger recreation resource. Research has also determined that chaparral areas are marginal and intermittent sources of water supply for municipalities if vegetation control is employed to reduce tree densities (Baker 1984; Poff and Neary 2008). Chaparral rangelands are often grazed year-long by livestock and wildlife because evergreen plants common to the shrublands provide a continuous forage supply. A variety of wildlife species are found in chaparral shrublands, with comparatively high populations often concentrated in ecotones between chaparral and ponderosa pine forests at higher altitudes and grasslands at lower altitudes.

Average annual precipitation varies from about 380 mm (15.0 in) at the lower limits of the chaparral shrublands (910 m or 3,000 ft) to over 640 mm (just over 25.0 in) at the higher elevations (1,830 m or 6,000 ft) (Baker 1999). Approximately 60% of the annual precipitation occurs as rain or snow between November and April. The summer rains fall in July and August, which are the wettest months of the year. Annual potential evapotranspiration rates can approach 890 mm (35.0 in) (Hibbert 1979). Eighty-five percent of the annual runoff occurs

during the dormant season (November through April). Streams originating in the chaparral zone are ephemeral.

Chaparral soils are typically coarse-textured, deep, and poorly developed (loamy-skeletal, mixed, nonacidic, mesic Lithic Ustorthent). The term *soil* as used here includes all porous material (regolith) in which weathering and roots are active (Hibbert and others 1974). The distinction between soil depth and solum depth (A and B horizons) is critical since most of the soil supporting chaparral is in the C horizon. Usually, the A horizon is only a few centimeters thick and the B horizon is absent. The C horizon, which can be as much as 9 to 12 m (30 to 40 ft) deep, is hydrologically important, even though total porosity may only be 20 to 25%. Because of deep weathering, this zone is able to store much of the winter rain, which the deep-rooted shrubs use during dry periods Soil texture in the chaparral type varies from cobbly and gravelly loamy sand to gravelly loam. Slopes of 60 to 70% are common, and all aspects are represented.

Riparian—Chapters 6 and 7 contain more extensive discussions of woody and herbaceous riparian vegetation. This section is intended to be a brief overview since riparian vegetation is part of, and reflects the condition of, the upland portions of the watersheds. Three riparian ecosystems, delineated by elevation, are recognized in the Central Arizona Highlands. Riparian vegetation that occurs along the flood plain of stream channels is typically composed of herbaceous species of sedges (*Carex* spp.), spikerushes (*Eleocharis* spp.), rushes (*Juncus* spp.), and bulrushes (*Scirpus* spp.) (Baker 1999). These species produce the characteristic dark green edge found along channel systems. Woody plants, including saltcedar (*Tamarix* spp.), sycamore (*Platanus wrightii*), and cottonwood (*Populus fremontii*), that are often associated with riparian ecosystems are typically found higher up on the terraces adjacent to the flood plains.

In riparian ecosystems below 1,070 m (3,500 ft), many of the ephemeral streams have broad alluvial floodplains that can potentially support herbaceous plants and terraced bottoms that often support high densities of deep-rooted trees including saltcedar, sycamore, cottonwood, palo verdes (*Cercidium* spp.), and other species. Riparian ecosystems between 1,070 and 2,130 m (3,500 and 7,000 ft) contain the greatest number of plant species and the greatest canopy cover (fig. 1.7; DeBano and Schmidt 1989). Besides the characteristic herbaceous plants along the flood plain, cottonwood, willow (*Salix* spp.), sycamore, ash (*Fraxinus velutina*), and walnut (*Juglans major*) are typically found on the terraces, with three or four species often occurring together.

Above 2,130 m (about 7,000 ft), herbaceous species of sedges, spikerushes, rushes, and bulrushes predominate along the edge of the stream channels. Willow, chokecherry (*Prunus virens*), boxelder (*Acer negundo*), Rocky Mountain maple (*Acer glabrum*), and various coniferous tree species occupy the higher terraces.

Because of the abundance of water, plants, and animals, riparian areas provide valuable recreation opportunities as well as forage for livestock and wildlife in an

(A)

(B)

Figure 1.10—Riparian vegetation typical of the UVR region, Prescott National Forest: (a) Canyon-bound reach below Perkinsville, and (b) sedge-lined E-channel below the Verde River Ranch. (Photo by Alvin L.Medina.)

otherwise arid environment (fig. 1.10). Riparian ecosystems are "prime" habitats for many game and non-game species of wildlife and fishes.

Collectively, climatic characteristics of riparian ecosystems exhibit a wide range of conditions due to the large elevational differences and distributions of associated mountain ranges and highlands. The key characteristic of the riparian system is the availability of water throughout the year or at least during the growing season, which makes these ecosytems so highly productive.

Soils in riparian ecosystems at the higher elevations generally consist of consolidated or unconsolidated alluvial sediments derived from parent materials of the surrounding uplands. Depths vary depending upon the stream gradient, topographic setting, and parent materials. Soils on the flood plains at lower elevations consist of recent depositions, tend to be uniform within horizontal strata, and exhibit little development. The alluvial soils in all of these ecosystems are subject to frequent flooding and, as a consequence, are characterized by a range of textures. However, they are often very fertile. Riparian ecosystems in the UVR vary from narrow, deep, steep-walled canyon bottoms, to intermediately exposed sites with at least one terrace or bench, to exposed, wide valleys with meandering streams.

Riparian Ecosystems

Riparian Health

Southwestern riparian areas, where water is present a majority of the time, are fairly resilient to the multiple natural and anthropogenic disturbances that commonly occur in these ecosystems. The term "riparian health" refers to the stage of vegetative, edaphic, geomorphic, and hydrologic development, along with the degree of structural integrity, exhibited by a riparian area (DeBano and Schmidt 1989). A healthy riparian system is one that maintains a dynamic equilibrium between streamflow forces acting to produce change and vegetative, geomorphic, and structural resistance to change. Dynamic equilibrium results from the internal adjustment among factors operating simultaneously in the riparian system (e.g., climate, geology, vegetation, hydrology, and stream morphology) to increased flow or sediment movement (Heede 1980). Excessive short-term runoff from the upland watershed can increase channel flow volume and velocity, which can cause channel erosion and deposition in the riparian communities. However, when the riparian areas are healthy, flows in excess of channel capacity frequently overflow onto floodplains where riparian vegetation and associated debris provide substantial resistance to flow and act as filters, or traps, for sediment (Medina 1996). During these bank overflows, opportunities are available for germination and establishment of a wide assortment of phreatophyte and riparian plant species, ranging from herbaceous (e.g., species of sedges and rushes) to tree species (ash, cottonwood, willow, and alder; Brady and others 1985).

A healthy riparian area reflects a dynamic equilibrium between channel erosion (degradation) and sediment deposition (aggradation) processes (Heede 1980). A riparian area in a healthy state maintains a dynamic equilibrium between streamflow forces acting to produce change and vegetative, geomorphic, and structural resistance to these changes (Lane 1955; Heede 1980; Rosgen 1980; DeBano and Schmidt 1989).

When a "natural" or functional riparian system is in dynamic equilibrium, it is sufficiently stable so that internal adjustments can occur without producing changes in the system that overwhelm this equilibrium. This resistance to rapid change results from several factors acting together in the riparian area and throughout the watershed. Excess runoff reaching the channel increases flow volume and velocity, and this short-term increase in flow causes an oscillation in the equilibrium between erosion and deposition in the riparian area. While the balance tips back and forth, it is quickly dampened by the channel characteristics and results in no major change in the central tendency toward maintaining a dynamic equilibrium. When the resilience, or elasticity, of the system is not violated, a different dynamic equilibrium condition can be quickly reestablished. Most important of these factors is the native riparian vegetation (Medina 1996). Native riparian species (i.e., sedges, rushes, and other aquatic plants) have long, thick, fibrous root systems that can resist flood flows and hold the soil. They also have flexible stems that can fall over in flood conditions and protect the soil surface. The healthy riparian area is also characterized by a shallow water table, which is necessary to sustain healthy riparian plant communities on nearby floodplains (fig. 1.10).

Many phreatophyte species (e.g., cottonwood, willows, alders, and saltcedar) not only can shade out the herbaceous, aquatic species, but they can also affect erosion of the channel banks and terraces. Woody species generally have ridged stems that often result in increased turbulence in streamflow and, consequently, increased erosion around these stems and exposed root systems during flood flows if the soil surface is not sufficiently protected by herbaceous, riparian plants.

When sufficiently large changes in erosion and depositional processes occur, riparian areas can be thrown out of equilibrium, or, in extreme cases, may be permanently altered because they are no longer able to quickly adjust to change. Riparian health can be thrown out of equilibrium faster and more permanently during channel degradation processes than during stream aggradation phases. Excessive channel incision can intercept and drain existing water tables, which are close to the surface and support healthy riparian ecosystems. Loss of the water table, in turn, can rapidly desiccate the site, destroy the riparian ecosystem, alter plant composition, reduce plant diversity, and create an unhealthy or dysfunctional riparian system. On the other extreme, when excessive deposition occurs, channels become braided and are so shallow that they easily shift locations with resulting bank and channel erosion (Cooperrider and Hendricks 1937; Heede 1980). Once the disturbance factor is eliminated, it is easier for the aggraded system to "flush out" the excess sediment than for the degraded system to reestablish its original channel level.

The interrelationship between watershed condition and riparian health is well substantiated by historical accounts of many riparian areas in the Southwest that were portrayed as stable, aggrading stream networks containing substantial amounts of organic debris and supporting large beaver populations (Cooperrider and Hendricks 1937; Leopold 1951; Minckley and Rinne 1985). Under these conditions, forested headwater tributaries provided a continual supply of small and large organic debris that formed log steps in smaller streams and large accumulations of logs and other organic debris along higher-order, low-elevation mainstreams. Naturally occurring floodplain and channel structures, along with living, aquatic plants, dissipated energy, controlled sediment movement and deposition, and thereby tended to regulate and sustain flow that provided an environment sufficiently stable for maintaining and perpetuating healthy riparian ecosystems (fig. 1.10). Energy dissipation decreased flow velocities in stream channels and on floodplains, resulting in improved percolation of water into subsurface storage. This delaying effect was likely enhanced because many stream channels were above fault-fracture zones that lead to underground aquifers. Water stored in high-elevation aquifers was available and, when slowly released, supported late-season flows in downstream riparian areas.

This discussion might lead to the impression that conditions are either all "good" or all "poor." In reality, riparian ecosystems in the Southwest, as in general, are quite varied. With any reference to a given condition, one must realize that there is a continuum in all landscapes. In Cooperrider and Hendrick's (1937) evaluation of the Upper Rio Grande Watershed in New Mexico and Colorado, areas of the watershed were grouped by degrees of soil erosion potential (normal, moderate, advanced, and excessive). Normal erosion was assumed to take place under the cover of "natural" vegetation. Only 25% of the land analyzed by Cooperrider and Hendricks (1937) had sufficient plant cover to control erosion within normal and moderate limits in 1937. Soil erosion was in the advanced stage on about 35% of the area, and rapid land destruction was in progress on 40% of the Upper Rio Grande Watershed. Forage production had also been reduced 50%, principally as a result of overgrazing and accelerated erosion.

Leopold (1941, 1951) stated that the idea of verdant vegetation cover everywhere in the Southwest that deteriorated as a result of man's activities led to excessive optimism concerning the possible recovery of riparian ecosystems from the effects of grazing. Recovery of vegetation density in 1951 on depleted ranges, even after protection for years, was spotty and in many places, disappointing. At that time, the roles and interactions of drought, fire, and natural grazing in controlling vegetation productivity were not well understood. Many people, even today, still hope to restore large areas to levels of vegetation density that were originally attained only in selected localities.

Riparian Soils

The soils of the riparian area described by Stein (2001) include Typic Ustifluvents, Typic Fluaquents, Oxyaquic Ustifluvents, Aquic Ustochrepts, and Oxyaquic Haplustalfs. Typic Ustifluvents are the dominant streambank soil type in the uppermost reaches while Typic Fluaquents are more common in the lower reaches of the Verde River. The soils typically support dominant bulrushes (*Schoenoplectus americanus* and *S. pungens*) but also are noted for dense stands of sedges (*Carex praegracilis*, *C. pellita*, *C. simulata*, and *C. Nebraskensis*) and rushes (*Juncus articus*, *J. mexicanus*, and *J. tenuis*).

Oxyaquic Ustifluvents are found on some streambanks and may be indicative of an underlying aquic soil. Their droughty and sandy character limits perennial graminoid establishment on floodplain locations; but near water, these soils are readily inhabited by bulrushes and assorted annuals, e.g., beardless rabbitfoot grass (*Polypogon viridis*).

Aquic Ustochrepts are a minor inclusion on the river, but they exhibit strong soil development with stable non-eroding fluvial conditions. These soils are associated stable sinuous channels typical of the "E-type" (Rosgen 1994) and wetland sites with dense stands of sedges and rushes. These habitats were evident prior to recent floods and establishment of woody vegetation. Remnant habitats exist only in localized areas with gaining reaches, e.g., Verde Ranch and Duff Springs (fig. 1.10).

Oxyaquic Haplustalfs occur in association with other colluvial upland soils. These soils are very close to the older Paleustalf classification and are indicative of relatively old soils that have also been largely undisturbed during the last 100 years (Stein 2001).

Watershed Condition

Watershed condition can be defined as the physical and biological "state" of a watershed (DeBano and Schmidt 1989; Lafayette and DeBano 1990; Reynolds and others 2000). It involves such factors as vegetation cover, flow regime, sediment and nutrient output, and site productivity on the watershed. Climate, geology, soils, and native vegetation can exert varying degrees of natural control on watershed condition, and human activities can have strong negative and positive influences on watershed condition.

A watershed in "good" or proper functioning condition absorbs rainfall energies, maintains high infiltration rates of water into the soil, has a large temporary water storage capacity, and releases storm water slowly into the channels (Barrett and others 1993; Horton 1937). It also has a minimal channel density necessary for conveying runoff from the watershed. These factors combine to provide desirable base flows while minimizing peak flows.

A watershed in "poor" or dysfunctional condition has an expanded channel (or gully) network (Barrett and others 1993) that produces greater amounts of sediment-laden runoff water because a sparse vegetation cover permits detachment of soil particles, sealing of soil pores, and increases in runoff and erosion. The resulting base flows are reduced while peakflows increase in magnitude and volume.

The balance between watershed condition and riparian health can be defined in terms of four combinations: (1) good watershed condition-healthy riparian, (2) good watershed condition-unhealthy riparian, (3) poor watershed condition-healthy riparian, and (4) poor watershed condition-unhealthy riparian (DeBano and Schmidt 1989). Some of these combinations are more likely to occur than others. Over long periods of time, misuse of riparian areas can lead to channel incision and the extension of a gully network throughout the surrounding watershed. It is least likely that a healthy riparian area is present when the surrounding watershed is in poor condition, but installing structures and excluding grazing may temporarily improve riparian areas on these watersheds (Heede 1986).

Historical misuse of both watersheds and associated riparian areas throughout the West shifted the balance between watershed condition and riparian health (Cooperrider and Hendricks 1937; Leopold 1951). A common scenario leading to degradation of these riparian ecosystems was as follows:

- Overgrazing or improper timber harvesting practices led to a loss of protective plant cover and increased soil compaction throughout the watershed, including the riparian areas.
- Where plant removal and soil compaction was severe, infiltration was reduced and overland flow was increased.
- Excessive overland flow from upland hillslopes delivered more water to the channels, increased flood flows, exceeded channel capacity, and resulted in channel enlargement and downcutting. This is a natural process of channel incision that has been aggravated by many human activities on the landscapes of the Southwest.

The downcutting of drainages and natural gullies have often been used as a diagnostic feature of watershed condition deterioration. Downcutting of gullies can proceed to and through the local water table, resulting in lowering of the water table, drying or dewatering of the riparian system, loss of riparian plant species, and replacement of hydric with mesic species

A number of land management activities have resulted in expanded drainage networks that maintained undesirable flashy runoff and increased available sediment. Wildfire and episodic storm events had a role in natural watershed condition degradation, and intensive grazing brought additional stresses on watershed condition. Overland flow was further concentrated when roads and trails were developed as part of various landscape uses, which further increased water delivery to the channels. Incising channels intercepted and drained existing water tables, many of which were close to the surface and supported healthy riparian ecosystems. Lowering water tables led to dewatering, alteration and destruction of riparian ecosystems, and an overall reduction in site productivity (Cox and others 1984). Meanwhile, on lower-elevation main streams, logging, agricultural development, urbanization, and more subtle impacts of desiccation from stream incision, impoundment, and channelization, along with over-pumping of regional groundwater aquifers, were responsible for the widespread destruction of riparian areas (Cooke and Reeves 1976; Bahre and Hutchinson 1985; Minckley and Rinne 1985).

The condition of a watershed is important because it influences the quality, abundance, and stability of downstream riparian resources and habitats. This influence results from controlled sediment and nutrient production, influencing streamflow, and modified distribution of nutrients throughout the environment. It should be remembered, of course, that not all areas have the same vegetation potential and productivity. Climate, geology, and soils will always limit vegetation potential, productivity, and cover, and sparseness of vegetation is not always an indicator of poor watershed condition.

The following chapters discuss and summarize available information concerning the current watershed conditions within the UVR and potential restoration conditions that are believed to be possible for these areas. Information derived from 30 years of research on the Beaver Creek Watersheds in the Middle Verde River and on other sites in the Central Arizona Highlands, such as Workman Creek at Sierra Ancha, was used to support this analysis (Baker 1999). A more complete discussion of watershed condition in the UVR can be found in Chapter 4.

Watershed Management Issues

The research and monitoring documented in this Report were conducted on behalf of the Prescott National Forest to assess the impacts of grazing on the watershed condition of the uplands and on the channels of riparian corridor of the UVR. This has been the primary land use issue on Forest lands as expressed by Prescott National Forest staff over a number of years (Rinne 1999b; Fleischner 2002; King 2002). Of particular concern to the Prescott National Forest is the impact of land management activities on the spikedace (*Meda fulgida*)—a small fish species that is part of the native fish fauna of the UVR (see Chapter 9; Rinne 1999a). The spikedace is a Federally listed threatened species that occurs in only four isolated stream and river systems in Arizona (Douglas and others 1994; Rinne 2005). It was once widespread and locally abundant in streams and rivers of the Gila River Basin. Rinne (1991a, 1991b, 1996, 2005) and Rinne and Stefferud (1995) noted the important role of large predatory nonnative fish species (e.g., smallmouth bass, catfish, common carp, and green sunfish) and smaller nonnative fish, such as the red shiner and fathead minnow, in producing adverse effects on the spikedace. Despite lacking definitive evidence of direct links between current grazing activities and stocking levels and declines of spikedace populations (Rinne 1999b), the focus of regulatory and environmental concern has continued to be the extrinsic (out-of-channel) factor of grazing and its potential impacts on watershed condition (table 1.2). Thus, one focus of the monitoring and research reported in this publication is watershed condition and immediate channel impacts.

The ecosystem factors that might produce potential impacts on the spikedace fall into categories of intrinsic, extrinsic-natural, and extrinsic-human related,

Table 1.2—Factors potentially influencing the spikedace and other fishes in the UVR watershed.

Uplands Extrinsic–natural	Ecosystem influences River Intrinsic	Uplands Extrinsic–human related
1. Climate	1. Nonnative fish	1. Grazing
2. Geology	2. Other nonnative fauna	2. Mining
3. Soils	3. Streamflow	3. Roads
4. Vegetation	4. Water quality	4. Forestry
5. Groundwater	5. Geomorphology	5. Urban development
6. Runoff	6. Sediment regime	6. Agriculture
7. Natural Sediment	7. Macroinvertebrates	7. Recreation
8. Wildlife	8. Riparian vegetation	8. Water engineering

relative to the river (table 1.2). Intrinsic factors are operative within or immediately adjacent to the aquatic environment of the river channel. Extrinsic factors operate in the terrestrial uplands of the watershed. Watershed condition integrates the extrinsic-natural factors and reflects the extrinsic-human impacts. The extrinsic (human-related) influence that is the most controversial management issue is grazing. However, urban development has the potential to be a much greater issue and of far greater impact due to its potential to de-water a substantial portion of the UVR. Chapter 9 discusses and highlights the research that demonstrates that the major threats to the spikedace and associated native fishes are intrinsic (in-channel) factors.

Objectives

The objectives of this volume are two-fold. The first is to summarize 15 years of research and monitoring on the UVR conducted by Rocky Mountain Research Station staff in Project RMRS-4302, Watersheds and Riparian Ecosystems of Forests and Woodlands in the Semi-Arid West (now the Southwest Science Team; Air, Water, and Aquatic Environments Science Program). The research and monitoring began after floods that occurred in early 1993 and re-set the UVR in a 75-year flood event. The second objective is to make recommendations to the Rocky Mountain Research Station, the Prescott National Forest, and the Southwest Region of the USDA Forest Service on future research and monitoring on the UVR. Although a lot of knowledge has been gained over the past 15 years, much work remains to be accomplished. The information presented here will help focus future efforts.