APPENDIX Q

TERRESTRIAL HABITAT CHARACTERIZATION

TABLE OF CONTENTS

Page

1.0 TERRESTRIAL HABITAT CHARACTERIZATION Q-1
- 1.1 INTRODUCTION Q-1
- 1.2 RIPARIAN ECOSYSTEMS IN ARID WEST Q-1
  - 1.2.1 Values of Riparian Ecosystems Q-1
  - 1.2.2 Threats to Riparian Ecosystems Q-3
- 1.3 BIOLOGICAL CHARACTERIZATION Q-6
  - 1.3.1 Riparian Characterization, Terrestrial Ecology Q-6
  - 1.3.2 Possible Approaches to Habitat or Vegetation Characterization Q-7
  - 1.3.3 Existing Vegetation Characterization Methods Q-8
  - 1.3.4 Other Terrestrial Characterization Methods Q-21
- 1.4 TERRESTRIAL HABITAT CHARACTERIZATION METHOD Q-23
  - 1.4.1 Goals and Objectives Q-23
  - 1.4.2 Recommended Characterization Method for Terrestrial Habitats Q-24
- 1.5 REFERENCES Q-27

LIST OF FIGURES

Q-1 Riparian Mapping System Characterization System (USFWS 1998)

Q-2 Riparian Mapping System Characterization System Modified for Water Quality Research Project Effluent-Dominated Streams in the Arid West

LIST OF TABLES

Q-1 Classification of Sample Points

APPENDIX Q

1.0 TERRESTRIAL HABITAT CHARACTERIZATION

1.1 INTRODUCTION

Several factors must be considered in the characterization of habitats associated with effluent-dependent or effluent-dominated riparian systems in and and semi-arid parts of the western United States. The field investigations and the historical data reviews have concentrated on physical, chemical, and biological aspects of the environments at the sites in this study. Each of these factors is important and must be considered in a complete characterization method that can be generalized to other similar sites in arid and semi-arid regions. Because of the inter-relationships among these factors, none of the factors is independent, and they cannot be evaluated without regard to the other factors. The only truly independent variables are those related to the volume and quality of the effluent stream.

1.2 RIPARIAN ECOSYSTEMS IN ARID WEST

1.2.1 Values of Riparian Ecosystems

Riparian ecosystems are extremely valuable habitats in the western United States. This value is primarily due to the presence of surface water or shallow groundwater in a region where water is scarce. The importance of these riparian areas is far greater than their relative area. For example, in Arizona there are only about 279,000 acres of riparian habitat (Szaro 1989). This area represents less that 0.4 percent of the total of 72,960,000 acres within the state. Throughout the western United States, only about 1 percent of the land is occupied by riparian habitats (Knopf et al. 1988). In the western United States, riparian areas are conspicuous belts of vegetation along ephemeral, intermittent, and perennial rivers and stream, and they are most obvious in steppe, shrub-steppe, and desert regions (Knopf et al. 1988). In contrast, riparian ecosystems in the eastern United States are often in broad zones referred to as floodplains or bottomlands (Knopf et al. 1988).

Riparian areas are similar to, and often include, wetland areas. Functions and values of wetlands have been discussed in detail by Williams (1990). In that discussion, “functions” are considered to be basic processes, including physical, chemical, biological, and socio-economic, and “values” are attributes that promote the general health or welfare of humans. Because most functions also have intrinsic value, it is often difficult to separate the two terms. For example, water quality improvement is a process within wetlands, but it has obvious value to human health. Fry et al.

(1994) have extended the function and value discussion to cover riparian habitats. The primary values of riparian areas are flood control, erosion control, water quality and quantity enhancement, wildlife habitat provision, and recreational opportunity. The vegetation in riparian areas provides bank stabilization, which improves flood control capabilities of a river by allowing the channel to deepen and meander naturally. A meandering channel will slow flood velocities, allowing more time for water absorption by vegetation or infiltration into the channel bed. Improved infiltration is particularly important for groundwater recharge in arid regions. Erosion control is related to flood control, with vegetated banks and lower flow velocities reducing the extent of erosion. Vegetation acts to increase bank stability and to trap sediments.

Riparian areas also can have beneficial influences on water quality and quantity enhancement. Vegetation will remove nutrients from the soil and water, and at the same time will remove pollutants such as nitrates, sulfur, and heavy metals. Vegetation in the stream or river channel can also act to trap sediments and reduce the downstream turbidity. Water quantity in a watershed can be enhanced by a healthy riparian zone. Dense vegetation can reduce water velocity and allow additional groundwater recharge.

Wildlife habitat is one of the more obvious functions of riparian habitats. It is estimated that between 60 and 75 percent of wildlife species in Arizona are dependent to some degree on riparian areas (Arizona Riparian Council 1990). Birds seem to be particularly attracted to riparian habitats. In northern Colorado, 82 percent of breeding bird species occur in riparian vegetation (Knopf 1985), and 51 percent of all species in the Southwest are dependent on this vegetation (Johnson et al. 1977). Johnson et al. (1977) has also estimated that the loss of the riparian component in the southwestern states could result in the loss of 47 percent of the bird species that breed in that region. In southeastern Arizona, Strong and Bock (1990) showed that riparian areas with cottonwoods and sycamores had significantly more bird species and greater density of birds than control areas with no riparian vegetation. These differences were consistent for both summer and winter. Riparian areas appear to be even more important to migrating birds. Stevens et al. (1977) found that riparian systems had more than ten times the number of birds that were found in surrounding upland sites.

Rice et al. (1984) showed that absolute riparian tree abundance and species composition were important factors in avian habitat selection along the lower Colorado River in Arizona. They suggest that desert riparian bird communities are different from those in eastern deciduous forests where early studies in bird-habitat relationships were studied. These differences could be attributed to the relative homogeneity of tree species composition in desert riparian habitats as opposed to heterogeneous eastern forests. Numerous other papers discuss the importance of

riparian habitats to avian populations (e.g., Anderson and Ohmart 1977; Carothers et al. 1974; Hall and Mannan 1999; Skagen et al. 1998; Stamp 1978; Szaro and Jakle 1985).

Although birds are the most heavily studied group of vertebrates, other groups are also dependent on riparian areas. In a study of small mammals in an area of vegetation enhancement on the Colorado River, Andersen (1994) found that populations of most species of small mammals and total biomass of small mammals increased during the study period. This area had been partially cleared of salt cedar and replanted with native species prior to the study. Andersen (1994) believed that revegetated riparian areas were ecologically valuable because of the high biomass of small mammals that they support. These small mammals form a prey base that will then support a larger biomass in higher trophic levels. His conclusions appear to be valid for the riparian zones developed in the wastewater streams of this project.

Jones (1988) compared the herpetofauna of natural and altered riparian zones in Arizona. The Hassayampa River has no significant impoundments, and it has a perennial reach near Wickenburg. The Salt River has four major dams that have altered the natural flow of the river and allowed changes in the riparian vegetation. Jones (1988) found that the natural system had nearly twice as many species, more than twice the number of individuals, and a greater species diversity index calculated by a modified Shannon-Weaver method. The herpetofauna of the Salt River was more similar to that of the surrounding Sonoran Desert than to the herpetofauna of the Hassayampa River.

The same characteristics that make riparian areas attractive as wildlife habitat also make them desirable as recreational sites for humans. Fishing is restricted to lakes and riparian zones, and hiking trails and campgrounds are frequently located in or near riparian areas. Particularly in the western United States, riparian areas are a focal point for recreation (Green 1998).

1.2.2 Threats to Riparian Ecosystems

Szaro (1989) discusses several potential disturbances to riparian ecosystems, including grazing, flooding, damming, and recreation. Other potential disturbances in the western United States include urbanization (Medina 1990), groundwater withdrawal (Stromberg et al. 1996), and channelization (Brooker 1985).

Cattle or other livestock grazing may be the primary cause of habitat disturbance in most riparian communities in the western United States (Szaro 1989). The inherent characteristics of riparian areas, adequate water, lush vegetation, and moderate microclimate, make them attractive to cattle. The primary impacts of cattle on riparian habitats are through removal and trampling of

vegetation. Other impacts can be through altered plant species composition through selective grazing by cattle or by differing tolerance to grazing by the plant species. Martin (1979) showed that cattle browsing on tree sprouts had an impact on reproduction, particularly when new leaves were fully developed on sprouts. In a review of livestock impacts on riparian ecosystems, Kauffman and Krueger (1984) report large decreases in small mammal populations in following grazing in a variety of riparian habitats. Taylor (1986) reported significant decreases of bird abundance and species richness with increased grazing pressure in riparian habitats in the semi-arid region of eastern Oregon.

Flooding and streamflow alterations related to dam construction have a major impact on riparian vegetation and vertebrate populations. Upstream from dams, the impoundment of water and accumulation of salts and sediments generally preclude the establishment of native vegetation on the shorelines (Szaro 1989). Large impoundments replace a free-flowing river with a large body of calm water. When the water rises behind a dam, the river habitat and large areas of upland habitat will be lost, leading to the direct loss of wildlife through drowning or displacement to unsuitable habitat (Heinzenknecht and Paterson 1978). The loss of river habitat maybe partially compensated by an increase in habitat for some species, such as waterfowl, but there is likely to be a net loss in complexity of the ecosystem (Heinzenknecht and Paterson 1978).

Riparian areas downstream from dams also have been affected by the alterations in stream flow. A series of dams on the Salt River in central Arizona have altered the downstream flow patterns such that seedling survival of cottonwoods is virtually nonexistent for extended periods of time (Fenner et al. 1985). The primary cause of this failure appeared to be the change from natural heavy flows during winter to heavy summer flow to meet irrigation demands. A riparian zone along the Colorado River in the Grand Canyon was created by flow regulation at Glen Canyon Dam and the elimination of annual flood events (Stevens and Waring 1985). Subsequent prolonged flooding resulted in mortality of riparian vegetation through drowning and burial, with shallow-rooted species being most susceptible.

Channelization of rivers results in straightening the channels, eliminating meanders, reducing the floodplain, increasing the gradient, and removing bank vegetation (Brooker 1985). Subsequent impacts on wildlife include losses in abundance and diversity of riparian vegetation, fish, macroinvertebrates, birds, and mammals.

Some dams can have beneficial effects on riparian vegetation. For example, the Whitlow Ranch Dam on Queen Creek, Arizona, is managed for flood control and does not serve for long-term water storage (Szaro and DeBano 1985). The limited periods of inundation behind this structure have allowed the establishment of riparian plant communities in an area that was formerly

xeroriparian or desertscrub habitat. Shrub control measures in chaparral areas also can enhance riparian habitats on ephemeral stream channels by increasing the volume and duration of water in the channels (DeBano et al. 1984).

Because of their desirability as recreation areas, riparian habitats are subject to a variety of other impacts. Riparian areas with heavy recreational use show significant soil compaction, reduction in soil moisture, and loss of vegetation (Green 1998). These factors combine to produce significantly more surface runoff and transported sediments that on sites with light or moderate recreational use. An opinion survey of wilderness riparian recreation users found that the habitat qualities with highest desirability were generally those present in undisturbed ecosystems (Hoover et al. 1985). Similarly, attributes with high undesirability were those indicating degradation of the system, including cow manure, water pollution, litter, and vandalism.

Residential development has the potential to adversely affect riparian areas in the semi-arid West. As with wildlife habitat and recreation, streams are desirable locations for summer homes in the mountains of Arizona (Medina 1990). The increased water consumption for these residences can change streamflow patterns from perennial to ephemeral, with subsequent impacts on riparian vegetation. Urbanization and groundwater withdrawal also can threaten larger riparian systems. In southeastern Arizona, the San Pedro River is threatened by groundwater withdrawals related to a rapidly expanding population in the vicinity of Sierra Vista (Stromberg et al. 1996).

In order to address these threats to riparian ecosystems, Brown et al. (1977) offer several recommendations to maintain and enhance those valuable riparian communities with the most value to wildlife and public interest. The first proposal is to identify and classify riparian environments. Some of the many subsequent attempts at classification are discussed below. A second recommendation is to investigate factors that determine the limiting riparian constituents and communities. The third recommendation is to establish representative study areas containing all major riparian communities with their surface and groundwater requirements. Brown et al. (1977) recommend that grazing and other disruptive influences should be eliminated or controlled in riparian forests, woodlands, and marshlands. They also recommend that riparian and watershed management project planners should consider the actual and potential values of streamside vegetation prior to irreversible alterations, such as “phreatophyte clearing” projects. Their final recommendation is to increase the effort to avoid torrential flooding by more conservative use of grazing and timbering watershed resources.

1.3 BIOLOGICAL CHARACTERIZATION

The biological characterization of these sites can be divided into two major groups of factors. Some characteristics are primarily aquatic in nature, and others are primarily terrestrial. At the water's edge there will be overlap between these groups, and there are many possible interactions among factors in these groups. For example, emergent vegetation can be considered as a part of both aquatic and terrestrial habitats. Terrestrial predators may feed on aquatic vertebrates or invertebrates, and large trees can provide shading that can benefit the aquatic communities.

In addition, both aquatic and terrestrial systems are affected by physical and chemical properties in the water quality. High concentrations of some chemicals or low concentration of oxygen in the water might make a stream unsuitable for plants or animals. Hydrologic characteristics of surface or subsurface flow and the geomorphic structure of the channel and floodplain area will also have an effect on the structure and species composition of the riparian vegetation.

Although the following sections are focussed on the terrestrial ecology of these effluent-dependent and effluent-dominated riparian systems, these interactions will be considered and included where appropriate.

1.3.1 Riparian Characterization, Terrestrial Ecology

Riparian areas generally are considered to be areas of distinctive vegetation associated with flowing water. A broader interpretation can include areas of distinctive vegetation associated with intermittent or ephemeral streams or with non-flowing lakes or ponds. The National Wetlands Inventory (NWI) of the U.S. Fish and Wildlife Service (USFWS 1998) has proposed the following definition:

> "Riparian areas area plant communities contiguous to and affected by surface and subsurface hydrologic features of perennial or intermittent lotic and lentic water bodies (rivers, streams, lakes, or drainage ways). Riparian areas have one or both of the following characteristics: 1) distinctively different vegetative species than adjacent areas, and 2) species similar to adjacent areas but exhibiting more vigorous or robust growth forms. Riparian areas are usually transitional between wetland and upland."

In the arid and semi-arid regions of the western United States, evaporation rates are greater than precipitation rates, and the normal upland vegetation is adapted for drought conditions. Riparian areas have a more reliable water supply than the adjacent uplands, and they support different

vegetative associations. Perennial rivers or streams are more reliable and support a greater abundance and diversity of vegetation than those streams that are only intermittent or ephemeral.

The wastewater discharge sites selected for this study are located on river systems that would be intermittent or ephemeral if it were not for the anthropogenic factors. In some cases, the wastewater discharge is not the only water source related to human activity. For example, a significant portion of the flow in Las Vegas Wash is from irrigation runoff. In other cases, the rivers are now ephemeral because of historic human activities. The South Platte River in Denver and the Salt and Gila rivers in Phoenix are controlled by upstream dams and diversion systems.

The introduction of treated wastewater at all of the sites has created perennial flow with subsequent impacts on the vegetation patterns and wildlife use of the sites. One of the goals of the present study is to develop a habitat characterization method to describe these effluent-dependent or effluent-dominated streams. The characterization method should be broad enough in scope to be applicable to other similar sites throughout the semi-arid regions of the western United States.

1.3.2 Possible Approaches to Habitat or Vegetation Characterization

Existing vegetation or habitat characterization methods use a variety of measurable or observable characteristics to classify patterns in vegetation. These systems generally ar hierarchical in nature, with the highest level covering the broadest range of conditions or the widest geographic area. Progressively lower levels in these hierarchies describe regional or local conditions or specific plant associations.

One primary set of characteristics that can be used in classifying vegetation is described as physiognomic. These characters include factors such as life form, cover, plant structure, leaf structure, and seasonability. The life form is very broad-scale feature, based on whether trees, shrubs, or herbaceous plants dominate the landscape. The total cover of the dominant life form is a measure of the openness or density of vegetation. Plant structure can include factors describing the shape of the dominant life form, such as tall, conical trees or trees with rounded crowns. Leaf structure can separate needle-leafed species (primarily conifers) from broad-leaved species. Seasonality can separate evergreen species from species that are deciduous in cold weather or drought.

Floristic characteristics distinguish vegetative groups primarily by the dominant plant species. Lower level classifications are based on the associated plant species. Floristic systems are most appropriate for local or regional classifications with limited numbers of species.

A variety of other characteristics can be used to describe or classify vegetative habitats. Hydrogeomorphic characteristics are especially useful in classification of wetlands. These factors include standing or flowing water, extent and duration of inundation, depth of inundation, and the type of substrate (e.g., bedrock, gravel, sand, mud). Global climatic zones, including tropical, sub-tropical, temperate, and sub-polar, also may be used to subdivide vegetative groups. It is also possible to distinguish between naturally occurring habitats and those that are primarily influenced by human action (such as cultivated fields or tree plantations).

1.3.3 Existing Vegetation Characterization Methods

Numerous vegetation or habitat classification systems have been developed to describe or characterize patterns of vegetation. Most of these systems are hierarchical in nature, allowing a progression from very broad-based to very narrow habitat descriptions. Likewise, most of these systems make use of both physiognomic and floristic features. However, the emphasis on these factors vary depending on the objectives of the organization or individual designing the classification system. Several different systems are described below, with some discussion of their intended uses and distinguishing characteristics. The potential applications of these classification methods to the effluent-dominated or effluent-dependent riparian sites of this project are also discussed.

1.3.3.1 National Vegetation Classification Standard

The National Vegetation Classification Standard (NVCS) was developed by the Vegetation Subcommittee of the Federal Geographic Data Committee (FGDC 1997). This committee is chaired by the Department of the Interior, and it includes representatives from the Department of Agriculture, Department of Commerce, Department of Defense, Department of Energy, Environmental Protection Agency (EPA), and several other federal departments and agencies. This standard is based heavily on previous international vegetation classification standards by the United Nations Educational Scientific Cultural Organization (UNESCO 1973) and Driscoll et al (1984), with revisions by The Nature Conservancy (Anderson et al 1998; Grossman et al 1998).

The primary intent of this classification system is to establish a single system for classifying and describing vegetation that can be applied nationwide. Many federal agencies have responsibilities for mapping or classifying vegetative cover. As a result, many different, and often conflicting, methods have been used. The NVCS is intended to improve cooperation among federal agencies and to reduce duplication of efforts. Federal efforts at vegetation classification will be required to meet certain minimum standards and core components for data

collection that will allow the compilation and aggregation of data from multiple agencies at a national level.

The NVCS is a hierarchical system with nine levels. From the broadest to the narrowest classifications, these levels are division, order, physiognomic class, physiognomic subclass, physiognomic group, subgroup, formation, alliance, and association. The top seven levels are based on physiognomic features, and the lowest two levels are based on floristic characters. At the division level, there are only two options, vegetated or not vegetated. Vegetated is defined as any habitat with greater than 1 percent vegetation cover.

The order level of this classification separates categories based on the dominant life form of the vegetation. The different orders include tree-dominated, shrub-dominated, herb-dominated, nonvascular dominated, and vegetation not dominant. Under these five orders there are a total of seven classes including closed tree canopy, open tree canopy, shrubland, dwarf-shrubland, herbaceous vegetation, nonvascular vegetation, and sparse vegetation. Tree- and shrub-dominated classes are divided into subclasses based on whether the dominant species are evergreen, deciduous; or a mixture of both. Subclasses within the herb-dominated order are based on dominance by perennial graminoid vegetation, perennial forbs, hydromorphic rooted vegetation, or annual graminoid or forb vegetation. Subclasses in the non-vascular class are dominated by bryophytes, lichens, or algae. In the sparse vegetation class, subclasses are based on geomorphic characteristics, including consolidated rock, unconsolidated boulders, gravel, cobbles, or talus, and unconsolidated soil, sand, or ash.

Groups within the tree- and shrub-dominated classes are distinguished by broad climatic zones (tropical, sub-tropical, temperate, sub-polar), by cold-deciduous or drought-deciduous species, or by xeromorphic leaf structures. Groups within the herbaceous vegetation class are also distinguished by broad climatic zones and by the presence of sparse tree or shrub layers. Nonvascular groups are also distinguished by climatic zones. Groups within the sparse vegetation order are distinguished primarily by geomorphic characteristic, including cliffs, bedrock, talus slopes, rock flats, sand dunes and flats, soil slopes and flats, and ash deposits.

Within each group, two subgroups are recognized. These are natural/semi-natural habitats, in which there is relatively little evidence of human activity, and planted/cultivated habitats that are a direct result of human actions. Within the natural/semi-natural subgroup, formations are distinguished by altitudinal range (lowland, sub-montane, montane, subalpine) and presence of water (temporarily flooded, seasonally flooded, saturated, tidal. The formations within the planted/cultivated subgroup include tree plantations, orchards, vineyards, herbaceous crops, and

landscaped urban, suburban, and rural areas. Nearly 500 formations have been defined within the United States (Anderson et al. 1998).

Floristic characteristics are used to distinguish plant alliances within the formations. Alliances represent an aggregation of associations, and they are characterized by one or a group of dominant species occurring in the dominant or uppermost layer of the vegetation. Associations are characterized by diagnostic species in all layers of the vegetation. Over 4,100 different associations have been defined in the United States (Anderson et al. 1998).

The NVCS is a comprehensive attempt to classify all possible plant associations within the United States. All federal agencies are being encouraged to use this system in order to standardize vegetation mapping and classification around the country. The multiple levels in the hierarchy allow this system to be used for mapping vegetation at any scale from a few acres up to an entire state or continent. In addition, the upper physiognomic levels of the system are broad enough to be applicable to plant communities on a global scale.

There are problems with applying the NVCS system directly to the effluent-dependent riparian habitats in the arid and semi-arid West. The primary difficulty is with the shear number of levels and units within the system. There is no need for nine hierarchical levels to categorize the limited number of sites that fit the conditions of this project. Likewise, of the over 4,100 associations and nearly 500 formations in the country, very few will be represented in the riparian zones of interest in this project. In addition, aquatic characteristics that can be used to distinguish wetland habitats are not included until the formation level of the NVCS, and wetland habitats are scattered throughout the classification system. A further difficulty is that there are no distinctions at the formation level to separate riparian habitats from upland habitats.

1.3.3.2 Brown, Lowe, Pase Classification System

The Brown, Lowe, Pase Classification (BLPC) system (Brown et al. 1979) is another hierarchical method for classifying ecosystems and plant communities from a global to a local scale. This system is based on earlier work by Brown and Lowe (1974). This system also uses a combination of physiognomic and floristic characters for classification, but the sequence is quite different from that in the NVCS.

The top level in the BLPC is the biogeographic realm, with a number assigned to each of seven global regions. These regions are the Nearctic (North America north of the tropics), Palearctic (Eurasia north of the tropics, Africa north of the Sahel), Neotropical (most of Mexico, Central America, South America), Oriental (Southeast Asia, India, Phillipines, Indonesia), Ethiopan

(Africa south of the Sahara), Australian (Australia, Tasmania), and Oceanic (Oceanic islands). The next level in the classification is based on vegetation and separates upland vegetation from wetland vegetation. This level also has categories for cultivated uplands and cultivated wetlands.

The next level of the BLPC is the formation type, which is roughly equivalent to the physiognomic class in the NVCS system. The six recognized formation types under upland vegetation include tundra, forest, scrubland, grassland, desertland, and nonvegetated. The six wetland formation types are wet tundra, swamp forest or riparian forest, swampscrub or riparian scrub, marshland, strandland, and submerged aquatic. The next lower level is based on climatic regions, including Arctic-boreal, cold temperate, warm temperate, and tropical-subtropical. Each formation type includes all of these possibilities, with the exception of the tundra and wet tundra, which are limited to the Arctic-boreal region.

The fourth level below the biogeographic realm is the major biotic community, or biome. Biomes are natural communities characterized by a distinct vegetation physiognomy. Each formation type and climatic region combination has its own set of biomes. The BLPC nomenclature generally includes geographic terms at this level. Some representative examples of biomes include Rocky Mountain montane conifer forest, Californian chaparral, Sonoran desertscrub, and interior southwestern riparian deciduous forest and woodland. Within each biome there are several series, which also have been referred to as climax series, cover types, or vegetation-types. A series is composed of one or more biotic associations that share climax-dominant species within the same formation, zone, and biome. Representative series associated with the biomes mentioned above include pine series, manzanita series, paloverde-mixed cacti series, and cottonwood-willow series, respectively. The series level is comparable to the alliance level of the NVCS.

The sixth level below the biogeographic realm in the BLPC is the association, which is comparable to the association of the NVCS. Representative associations within the biomes and series mentioned above are the *Pinus ponderosa* association, *Arctostaphylos glandulosa* association, *Ambrosia deltoidea-Cercidium inicorphyllum* mixed-shrub association, and *Populus fremonti-Salix* spp. association, respectively. This level in the hierarchy is appropriate for mapping of vegetation at a regional scale. Additional lower levels may be created and used as necessary to describe the structure, composition, density, or other attributes of dominant or associated species. The lowest levels would be suitable for detailed mapping at a local scale.

The BLPC system is a comprehensive attempt to classify all possible plant associations on a global scale, as well as within the United States (Nearctic realm). As with the NVCS, the multiple levels in the hierarchy allow this system to be used for mapping vegetation at any scale

from a few acres up to an entire state or continent. The lower levels of this classification (series and association) are comparable with the lower levels of the NCVS system (alliance and association), and vegetative groupings from one system can be translated to the other system relatively easily.

The major differences between these two systems appear to be in the upper levels of the hierarchy. The BLPC recognizes biogeographic realms at the highest level. NVCS does not make any mention of biogeographic realm, although all of the alliances and associations are within the Nearctic realm. The BLPC distinguishes cultivated areas and wetland or riparian vegetation from upland vegetation at a very high level. In addition, desertland is recognized as a distinct formation type, on the same level with forest, scrubland, and grassland. Because of the different organizational system, the BLPC is able to completely characterize plant associations with only seven hierarchical levels (including biogeographic realm), as opposed to nine levels in the NVCS system (not including biogeographic realm).

The BLPC system appears to offer some advantages over the NVCS system for classifying vegetation in the arid and semi-arid regions of the western United States. Separating upland vegetation from riparian or wetland vegetation at a high level would appear to simplify the process for characterizing riparian habitats and comparing them with adjacent or upstream upland habitats. Likewise, recognizing desertland vegetation at a high level is also useful for characterizing habitats in and regions.

As with the NVCS, the primary difficulty in applying the BLPC is with the large number of associations and series within the system. However, including riparian and desertscrub categories at high levels in the system make it possible to ignore large blocks of associations that are not represented in our study sites.

1.3.3.3 Classification of Wetlands and Deepwater Habitats

USFWS has developed a classification system for wetlands and deepwater habitats in the United States (CWDH) (Cowardin et al. 1979). This system is also hierarchical, but it has only three levels and it is based strictly on physiognomic characteristics. The uppermost level, the system, defines five broad categories of aquatic habitats, including marine, estuarine, riverine, lacustrine, and palustrine. Wiithin the marine and estuarine systems, there are subtidal and intertidal subsystems. The riverine sysem has four subsystems based on stream flow characteristics. These subsystems are tidal, lower perennial, upper perennial, and intermittent. The lacustrine system has limnetic and littoral subsystems, based on the depth of water and distance from shore. There are no subsystems in the palustrine system. Within the various subsystems, and within the

palustrine system, there are several classes, defined primarily on the nature of the substrate (e.g. rock bottom, unconsolidated bottom, aquatic bed, streambed) or the dominant type of vegetation (e.g. emergent, scrub-shrub, forested).

Each of these classes can be described further by the use of modifiers. Water regime modifiers for tidal classes include subtidal, irregularly exposed, regularly flooded, and irregularly flooded. Non-tidal water regimes include permanently flooded, intermittently flooded, intermittently exposed, semipermanently flooded, seasonally flooded, saturated, temporarily flooded, intermittently flooded, and artificially flooded. Other modifiers are available for water chemistry, soil, and other special circumstances.

This classification system is very useful for its intended purpose of classifying wetlands and other aquatic habitats. However, it cannot be extended to other habitats, such as riparian zones, where water is not a dominant characteristic of the system. In addition, this system provides no mechanism for distinguishing within classes based on floristics, thus limiting its value as a method for classifying vegetation communities.

1.3.3.4 Riparian Mapping System

The NWI of USFWS has developed a system for describing and mapping riparian areas in the western United States (USFWS 1998). This system is designed to complement Cowardin et al.'s (1979) classification method for wetland and deepwater habitats. The riparian mapping system (RMS) is a hierarchical method with five levels to characterize the riparian habitats typically present in the western United States.

The top level in the RMS is the system, which includes only the single category of riparian vegetation. This level is comparable to the system level in wetland classification, which includes riverine, palustrine, lacustrine, and open water categories. The next lower level is the subsystem, which is determined by the flow regime in the adjacent waterway. There are only two possible subsystem categories, lotic and lentic. The lotic subsystem is associated with moving water and would include the zone of riparian vegetation adjacent to a river. The lentic subsystem is associated with standing water and would include the zone of vegetation surrounding a lake or pond. Either of these subsystems can include any of the lower level categories.

The third level in the RMS is the class, which is defined by the physiognomy of the dominant vegetation type. The three possible classes are forested, scrub-shrub, and emergent. These classes are directly comparable with the classes in the CWDH. The forested and scrub-shrub classes are further defined by deciduous, evergreen, or mixed deciduous-evergreen subclasses. No

subclasses have been defined for the emergent class. Within each subclass, several dominance types have been defined. These dominance types are defined by the dominant one or two species in the dominant layer of vegetation. Because the classification of a stand may depend on its age, there is significant overlap between the forested and scrub-shrub dominance types. The dominance type of this classification is roughly comparable to the alliance level of the NVCS or the series of the BLPC.

The RMS is a relatively narrow classification of a limited number of plant associations within a specific region of the United States. The relatively few levels in the hierarchy constrain this system to mapping vegetation at regional or local scales. However, the hierarchy is designed to be open-ended, and other classes, subclasses, or dominance types could be added to meet the needs of a broader geographic range.

Because the RMS was designed to characterize riparian habitats in the western United States, it appears to be directly applicable to the effluent-dependent riparian habitats of this project. The limited number of hierarchical levels and dominance types make this system easy to apply to conditions as observed in the field, while avoiding the confusion of thousands of unnecessary plant associations. It is possible to place these habitats into the NVCS system, if necessary to satisfy federal requirements. However, there would be a loss of information in doing so because of the inability of the NVCS to distinguish riparian vegetation formations from upland vegetation formations. One limitation with the RMS is that its restriction to riparian systems precludes its use in the adjacent or upstream upland areas.

Johnson et al. (1981) proposed an earlier version of a riparian classification system based on the wetland classification system of Cowardin et al. (1979). This method is also hierarchical, with the riparian system as the top level. The term “riparian” as used by Johnson et al. (1981) is roughly equivalent to the term “palustrine” used by Cowardin et al. (1979). The three proposed subsystems are hydroriparian, mesoriparian, and xeroriparian. The hydroriparian and mesoriparian subsystems can have classes equivalent to the classes proposed by Cowardin et al. (1979), including rock bottom, unconsolidated bottom, aquatic bed, unconsolidated shore, moss-lichen wetland, scrub-shrub wetland, and forested wetland. The xeroriparian subsystem has all of these classes except for the aquatic bed and the emergent wetland. Johnson et al. (1981) define hydroriparian as wetlands with substrates that are never dry or dry for only short periods, and usually associated with perennial or intermittent water. Mesoriparian refers to wetlands with non-hydric soils and with a seasonally dry substrate, usually associated with intermittent water or ephemeral wetlands. Xeroriparian areas have average annual moisture higher than surrounding areas, but have surface moisture only on infrequent occasions.

The Johnson et al. (1981) classification system is similar to the subsequent RMS method. However, it uses different subsystem definitions, and it includes a greater variety of physiognomic classes. The Johnson et al. (1981) classification system does not identify the lower levels of subclass and dominance type, which are based primarily on floristics.

1.3.3.5 Stream Classification Systems

A stream classification based on morphological characteristics has been proposed by Rosgen (1985). In contrast to most other classification systems, this method is not hierarchical, but it depends on the evaluation of a series of criteria to assign a stream reach to a category. The primary criteria in this method are gradient, sinuosity, width to depth ratio, dominant particle size, channel entrenchment, and landform features based on soils and stability. Another set of criteria is used to determine stream sub-type, including organic debris in channel, stream size, riparian vegetation, flow regimen, depositional features, and meander patterns. While this system may be useful in classifying stream geomorpholgy, it has very little value for classification of terrestrial riparian habitats.

Frissell et al. (1986) proposed a method for stream classification based on a hierarchical framework. However, the hierarchy in this system is merely the scale of observation. From largest to smallest habitats, the systems are stream, segment, reach, pool/riffle, and microhabitat. Within each of these systems, habitats may be further classified by using information from biogeoclimatic region, geology, topography, soils, climate, biota, and culture. As with the method proposed by Rosgen (1985), this system has relatively little value for classifying terrestrial riparian habitats.

1.3.3.6 Riparian Community Types of Arizona and New Mexico

The U. S. Forest Service has developed a classification system for riparian forest and scrubland communities of Arizona and New Mexico (Szaro 1989). This classification system was based on a statistical analysis of 152 study sites in riparian areas across Arizona and New Mexico. A cluster analysis of the importance values of trees and shrubs created a diagram that identified 28 distinct community types. These types are named based on the dominant one or two tree or shrub species. These community types can be further grouped as riparian forest communities or riparian scrub communities. Within each of these groups, further distinctions are possible based on elevational range. This system provides a method for field data collection and a dichotomous key that allows the classification of other riparian communities within this geographic range.

Because this system is based on a quantitative analysis of characteristics that can be measured in the field, it should be relatively easy to collect data and assign a riparian stand to a specific community. The field data also provide other descriptive information about physical characteristics of the stands, including elevation, bearing and gradient of the stream channel, and area of the riparian stand. However, the highly specific nature of this method precludes the extension of this classification to riparian areas outside of Arizona and New Mexico. An additional drawback is that the original selection of sites was biased toward riparian areas with adequate water supplies, and xeroriparian systems do not fit into this classification.

1.3.3.7 Other Southwestern Riparian Classification Systems

Other systems have been proposed for classifying riparian habitats in Arizona and New Mexico. Pase and Layser (1977) proposed a hierarchical system based on the general vegetation classification system of Brown and Lowe (1974). This system is similar to the BLPC system subsequently developed (Brown, Lowe, and Pase 1979), but it is simplified by restriction to riparian habitats. This system includes six major biomes: boreal riparian mixed forest, temperate riparian deciduous forest, subtropical riparian evergreen forest, boreal riparian woodland, temperate riparian deciduous woodland, and subtropical riparian deciduous woodland. Each of these biomes includes one or more series, and each series include one or more associations. The series and associations are defined primarily by the dominant tree species. Disadvantages of this system are similar to those of the Forest Service system (Szaro 1989). This system is very specific for Arizona and New Mexico, it does not include categories for riparian systems dominated by shrubs, herbaceous vegetation, and it does not cover xeroriparian habitats.

Dick-Peddie and Hubbard (1977) proposed a relatively simple classification for riparian habitats in New Mexico. This system has four levels in a hierarchy, with the top level as the riparian formation. The three sub-formations include alpine, montane, and arroyo-floodplain. Within each sub-formation there are series and associations based on dominant plant species. This system is somewhat more flexible than the Pase and Layser system because it includes some shrub and herbaceous-dominated communities, and it includes xeroriparian arroyo scrub associations. However, this system is also limited by its restriction to a single geographic area.

1.3.3.8 Manual of California Vegetation

The Manual of California Vegetation (MCV), developed by the California Native Plant Society, includes a classification system to describe vegetation patterns (Sawyer and Keeler-Wolf 1997). The intent of this system is to provide a detailed description of vegetation patterns, with an emphasis on communities that may be rare or require special protection. Conserving rare or

unusual plant assemblages, maintaining biodiversity, and properly managing ecosystems are some of the goals of this society, and their approach to vegetation classification has been developed with these goals in mind.

This system focuses entirely on floristics and has only two levels in the hierarchy. The top level is the series, which is defined by one or two dominant species in the dominant vegetative layer. The series is roughly analogous to the alliance in the NVCS system, but no higher physiognomic levels are recognized. The current listing in the manual includes 275 distinct vegetation series. Twenty of these groupings are very unusual and are restricted to a single occurrence, are defined by the presence of a rare plant, or are structurally distinctive. These units are referred to as unique stands.

The variation within a series leads to the definition of associations, which are subsets of the series. Several associations may have the same dominant species in the dominant vegetation layer, but they may have very different sets of understory species. For example, within the Douglas-fir series there is be association with a huckleberry understory and an association with a sword-fern understory. This association in the MCV system is comparable to the association in the NVCS system.

To facilitate use of this system, the MCV includes a set of dichotomous keys to assign a particular set of plant species to the appropriate series. Three keys are provided for series dominated by herbaceous plants, shrubs, and trees. Within the tree and shrub keys, there are subkeys based on the presence of evergreen or deciduous species and the number of co-dominant species. These distinctions are somewhat analogous to the upper physiognomic layers of the NVCS system.

The MCV system appears to be very useful for classifying vegetation units within California, and it is particularly valuable for identifying rare or unusual plant assemblages. Because the series and associations within this classification are analogous to the alliances and associations of the NVCS, it is relatively easy to assign these units to categories in the national standard. However, because of the highly specific nature of this system and the large number of vegetation units that are present only in California, this system is not appropriate for use outside of California.

1.3.3.9 California Wildlife Habitats

Another habitat classification system emphasizing wildlife habitat relationships has been developed for California (CWHR) (Mayer and Laudenslayer 1988). The latest listing of habitats

in this system includes a total of 59 possible terrestrial and aquatic habitats (California Department of Fish and Game [CDFG] 2000). This list includes 27 habitats based on tree types, 12 shrub types, 6 herbaceous types, 4 aquatic types, 9 agricultural and developed habitats, and 1 non-vegetated type. This system was developed to classify and predict habitat values for vertebrate wildlife species.

The CWHR system is a simple listing of habitat types and has no hierarchical organization. These habitat types are defined bases on a combination of hydrologic, physiognomic, and floristic characteristics. Some representative habitats based on hydrology include fresh emergent wetland, desert riparian, montane riparian, and wet meadow. Some representative habitats based on physiognomy include alpine dwarf-shrub, desert scrub, mixed chaparral, and Sierran mixed conifer. Representative developed habitats include irrigated grain crops, vineyard, and urban.

The habitat types of the CWHR system do not fit neatly within the hierarchical structure of the NVCS system. Some habitat types might cover one or more formations, but other habitat types might be equivalent to alliances or associations. The number of habitat types in the CWHR system is relatively small compared with the number of plant series in the MCV system, and it is much smaller than the possible number of plant associations. Thus, the CWHR system is less useful as a vegetation classification system, although its broader scale is appropriate for mapping wildlife habitats and predicting wildlife use. Like the MCV system, a drawback of the CWHR system is that it is focussed on California, and it would be difficult or impossible to extend this system to cover other geographic areas.

1.3.3.10 Lower Colorado River Multi-species Conservation Program

A vegetation classification system has been proposed for the Lower Colorado River Multispecies Conservation Program (LCRMSCP) (Ogden Environmental and Energy Services Co., Inc. 2000). This system was designed to describe the vegetation and habitats within a very limited geographic region and to accommodate a variety of planning objectives for this region.

The LCRMSCP classification system is a hierarchical system with three layers. The uppermost layer is the watershed-level classification. Categories at this level are based on a combination of physiognomic, hydrologic, and human impact characteristics. Of the 12 categories at this level, only 6 (desert scrub, riparian, forest, open water, agriculture, and urban/developed) are represented by lower level categories. Four watershed-level categories (montane scrub/chaparral, grassland, meadow, and alpine) are not represented in the Lower Colorado River vicinity. Two other categories (dunes/sand fields and playas) have little or no vegetation. The watershed-level classification is not directly comparable to any single level in the NVCS system.

The second level of this system is the river-level classification, which is intended to provide categories at an appropriate scale for analysis within a river system. The 15 categories within this level are primarily within the desert scrub and riparian watershed-level categories. Desert scrub categories include creosote bush, blackbrush, saltbush, catclaw acacia, and atriplex. Riparian categories include cottonwood-willow, arrowweed, marsh, and various combinations of salt cedar and mesquites. Other river-level categories include urban/developed, agriculture, and pine. The river-level classification is generally comparable to the alliance level of the NVCS, except for the marsh category.

The most detailed level of the LCRMSCP system is the reach-level classification, which is intended for a detailed analysis and classification of a relatively limited area. At the present time the 38 categories within this level emphasize riparian habitats. Nine of the river-level categories are subdivided into two or more reach-level structural types. In addition, the open water category in the watershed-level classification is broken into river, lake/reservoir, and backwater reach-level types. The reach-level classification is roughly comparable to the association level of the NVCS, except for the open water and marsh categories.

The LCRMSCP system is well suited for classifying vegetation units adjacent to the Colorado River within California and Arizona. Because the various categories within a river level or the reach level are not always comparable, it could be difficult to assign these units to categories in the NVCS. The three levels of this system could include up to eight levels in the NVCS system. In addition, because of the highly localized and specific nature of this system, it is not directly applicable for use outside of the lower Colorado River Valley. However, the general framework might be useful, if additional river and reach-level categories were created for other geographical areas.

1.3.3.11 Other Classification Methods

Several other regional vegetation classification schemes are available in the literature. The Texas Gap Analysis Project (TX-GAP) vegetation classification scheme is based on the Nature Conservancy classification system, and the physiognomic levels appear to be identical with the NVCS system (Texas Cooperative Fish and Wildlife Research Unit 1997). The alliances listed under each formation in this scheme are specific for the state of Texas. The Great Plains vegetation classification scheme was developed by the Nature Conservancy and relies heavily on their classification system (Schneider et al. 1997). The physiognomic levels of division, class, subclass, and group are identical with the NVCS system, but the system is limited to the categories that occur within the Great Plains.

The state of Virginia Gap Analysis Project (VAGAP) classification scheme is based on the UNESCO system, which is also the foundation for the NVCS system (Mensler 2000). The upper levels of the VAGAP system from the class through the formation are identical to those of the NVCS system. Below the formation level, the VAGAP system uses Society of American Foresters (SAF) forest cover types for consistency with vertebrate species distribution information. In addition, because it was felt that the alliance was too detailed for mapping with remote sensing, this system included a "super-type" level between the formation and alliance.

The state of Arkansas Gap Analysis Project (AR GAP) classification scheme is also based on the UNESCO system, but it also incorporates aspects of systems in use by the Nature Conservancy, Arkansas Natural Heritage Commission, Arkansas Game and Fish Commission, Society of American Foresters, and United States Forest Service (AR GAP 1994; Foti et al. 1994). The upper levels of this hierarchical system are similar to the physiognomic levels in the NVCS, and the categories could be converted easily. The lowest levels in the Arkansas system are the cover type and the community type, which are comparable to the alliance and the association in the NVCS system. A major difference in this system is that wetland communities are distinguished at the highest level, which recognizes terrestrial, palustrine, riverine, and lacustrine systems.

This approach simplifies the classification of wetland vegetation communities, which are mixed in at a low level with all terrestrial communities in the NVCS system.

The Maine Gap Analysis Project (ME GAP) uses a land cover classification scheme based on Anderson et al. (1976) and Jennings (1993). This system is a four level hierarchy based almost exclusively on physiognomic characteristics. One of the primary objectives of this system is to map land cover types with remote sensing methods. At the highest level the classification separates agricultural lands from forestlands. Within the forestland category there are groups based on hardwoods or softwoods, clear-cut regeneration, wetlands, unforested areas, and urban or residential areas. The categories within this classification system could be converted to the NVCS system with some effort.

EPA has developed a very specific vegetation classification for the midwest oak ecosystems (EPA 1995). This classification system uses the basic framework of the Nature Conservancy classification, but it concentrates on the floristic levels of classification. It is limited to relatively few woodland, savanna, and shrubland alliances. Within each of these alliances, one to four associations of specific groups of oaks and other species are defined. This system was developed for a reasonably well-defined set of vegetation communities in the tallgrass prairie and prairie-forest border from Canada to Texas. This system would not be applicable in other plant communities or other geographic areas.

1.3.4 Other Terrestrial Characterization Methods

1.3.4.1 North American Landscape Characterization

The North American Landscape Characterization (NALC) project is a component of the National Aeronautics and Space Administration Landsat Pathfinder Program. This project is a joint effort by the National Aeronautics and Space Administration (NASA), U.S. Geological Survey (USGS), and EPA to use remote sensed data sets to support investigations of changes in land cover. The data available from this project could be used for many purposes, one of which is vegetation classification and mapping. However, the minimum pixel size in this data set is 60 meters by 60 meters, which is an area of approximately 1 acre. While this level of resolution may be adequate for broad scale vegetation analysis and mapping, it would not be adequate for detailed analysis of narrow riparian areas.

1.3.4.2 National Hierarchical Framework of Ecological Units

The U.S. Forest Service within the U.S. Department of Agriculture developed a hierarchical framework of ecological units as a tool for ecosystem management (Cleland et al 1997; U.S. Department of Agriculture undated;). This system defined a set of eight levels of ecological units for various objectives and uses. These units correspond to different scales of planning and analysis. At the ecoregion scale, the global, continental, and regional planning scales correspond to domain, division, and province ecological units, respectively. Ecological subregions are represented by section and subsection units. The landscape scale corresponds to the landtype association, and the land unit includes landtype and landtype phase ecological units.

In this system, domains are broad units on a subcontinental scale with similar climatic conditions. The four domains in this system are Polar, Dry, Humid Temperate, and Humid Tropical. The divisions within a domain are defined primarily as areas of definite vegetational affinities within the same regional climate. Additional factors are the amount of water deficit and the winter temperatures. Examples of divisions include Steppe, Savannah, Desert, Mediterranean, Marine, and Tundra. Within the divisions, the provinces are units that correspond to broad vegetation regions, conforming to climatic subzones controlled by continental weather patterns. Provinces are usually given a binomial name consisting of a geographic location and vegetative type, such as Bering Tundra, California Dry-steppe, and Eastern Broadleaf Forest.

Subregions are characterized by combinations of climate, geomorphic processes, topography, and stratigraphy. Sections are broad areas of similar geomorphic process, stratigraphy, geologic origin, topography, and regional climate. Sections names generally describe the predominant

physiographic feature of the ecological unit, such as Flint Hills, Great Lakes Morainal, Bluegrass Hills, or Appalachian Piedmont. Subsections are smaller units with similar surficial geology, lithology, geomorphic processes, soil groups, subregional climate, and potential natural communities. Subsection names are usually derived from geologic features, such as Plainfield Sand Dune, Tipton Hill Plain, or Granite Hills.

At the landscape scale, ecological units are defined by general topography, geomorphic processes, surficial geology, local climate, and soil and potential natural communities. Landtype associations are groupings of landtypes based on similarities in geomorphic process, geologic rock type, soil complexes, stream types or wetlands, and vegetation communities. Landtype association names are usually based on geomorphic history and vegetation community. Landtypes are subdivisions of landtype associations or groupings of landtype phases based on similarities of soils, landforms, rock type, geomorphic processes, and plant associations. Landtype names should include a biotic and an abiotic component. Landtype phases are the most narrowly defined units based on topographic criteria, hydrologic characteristics, soil associations, and plant associations. In riparian mapping, landtype phases can be used to distinguish different stream environments.

Although the names are different, these units are analogous with the physiognomic and floristic levels of the NVCS. One significant difference in the two systems is that this hierarchical framework places more emphasis on abiotic factors in the environment. No attempt was made to apply this system to a real set of ecological units.

1.3.4.3 Avian Richness Evaluation Method

EPA's Environmental Research Laboratory has developed a technique for evaluating wetlands of the Colorado Plateau based on factors that predict avian species richness (Adamus 1998). The avian richness evaluation method (AREM) can be used to predict the number of bird species in a wetland, list the potential species likely to occur in a wetland, and list the species with particular characteristics likely to occur in a wetland. These predictions are based on collection of data in the field on water conditions, trees, shrubs, herbaceous vegetation, special habitat features, and other parameters. One of the potential uses that has been suggested for this technique is to assist with a wildlife-based classification of wetland habitats for scientific or administrative purposes. A major limitation of this procedure is that it is designed for wetlands on the Colorado Plateau of western Colorado and eastern Utah, and significant effort would be required to extend this technique to other parts of the western United States. Another limitation is that avian biodiversity does not directly correlate with diversity of plants or other animal groups.

1.4 TERRESTRIAL HABITAT CHARACTERIZATION METHOD

1.4.1 Goals and Objectives

A primary objective of this phase of the Water Quality Research Project is to develop a characterization method for effluent-dependent streams in the semi-arid parts of the western United States. Although the final characterization must account for chemical properties of the effluent stream, physical properties of the stream channel, and aquatic biology, this section discusses only characterization of the terrestrial biology of the effluent-dependent riparian corridor.

The first step in developing this characterization method is to establish a set of goals and objectives for terrestrial biology characterization. The primary goal is to create a hierarchical set of categories that can simply and concisely describe any of the riparian habitats associated with the effluent-dependent streams. A secondary goal is to create a characterization system that can be easily integrated with characterization methods for physical, chemical, and aquatic biology components of the system. The following objectives can direct efforts toward these goals:

- The characterization system should be hierarchical.
- The characterization system should have as few categories as necessary to describe the range of habitats.
- The characterization system should have the flexibility to add new categories if the geographic range or range of habitats is expanded.
- If possible, the characterization system should be based on an existing system that is acceptable to federal and state agencies.
- For conformity with nationally accepted classification systems, categories within the characterization system should be consistent with and transferable to the NVCS.

A hierarchical structure provides a logical means of organizing any classification system. The higher levels of the system should describe broad ecological characteristics, and the lower levels should be increasingly detailed and specific. For a vegetation classification system, one approach is for the upper levels to be based on structural characteristics of the community, such as forest, shrubland, or grassland. For simplicity, a higher-level category should not be included if it includes no lower level habitats or communities. Species composition of a community would be considered only at the lower levels of the system. This type of a structured approach provides the

flexibility of creating additional, categories at the lower levels, if necessary, without changing the entire framework of the system. A hierarchical structure is also compatible with theNVCS, if the upper levels of the system are carefully selected.

1.4.2 Recommended Characterization Method for Terrestrial Habitats

Of all of the possible vegetation classification methods reviewed above, only one appears to be appropriate for the habitats in this project. The RMS developed by USFWS satisfies the objectives listed above and will meet the goals for a habitat characterization system for the effluent-dominated streams. As described above, this system is a hierarchical system with five levels, as shown on **Figure Q-1**. As noted above, this system was designed to be compatible with Cowardin et al.'s (1979) classification system for wetlands and deepwater habitats. This compatibility is essential because the riparian habitats are by definition closely associated with wetlands or deepwater habitats.

The uppermost level in this system has one category, riparian (Rp), to distinguish this system from other wetland or upland habitats. The subsystem level separates riparian habitats based on the presence of flowing water (lotic – 1) or ponded water (lentic – 2). Either of these conditions can support forested (Fo), scrub-shrub (Ss), or emergent (Em) classes. Within the forested and scrub-shrub classes, there are deciduous (6), evergreen (7), or mixed (8) subclasses. No subclasses are defined or necessary for the herbaceous class. Within the emergent class and the deciduous and evergreen subclasses, specific riparian communities are defined by dominance types of particular tree, shrub, or herbaceous species. No dominance types are defined for the mixed subclasses. The only dominance types defined in the RMS for the herbaceous class are alkali sacaton (AK), western wheatgrass (WW), and Great Basin wild rye (GB). As an example of this system, a willow thicket along a stream would be designated as Rp1Ss6WI (riparian/ lotic/scrub-shrub/deciduous/willow).

Very few modifications are necessary to adapt this system to the effluent-dominated streams of the Water Quality Research Project (**Figure Q-2**). The subsystem "Lentic" has been deleted because all of the effluent-dependent streams are by definition flowing water. For the third class, RMS uses the term "emergent" to be consistent with the wetland classification system, but "herbaceous" might be a more appropriate term for riparian floodplain communities that are rarely inundated. The primary differences are in the lists of dominance types. Dominance types that were not observed and are not expected in these streams have been deleted from the lists. Other dominance types have been designated as necessary to include all possible riparian communities in the Water Quality Research Project study areas. Although no evergreen dominance types were observed at any of the sample locations, this subclass is retained because

Figure 1. Riparian Mapping System Characterization System (USFWS 1998)

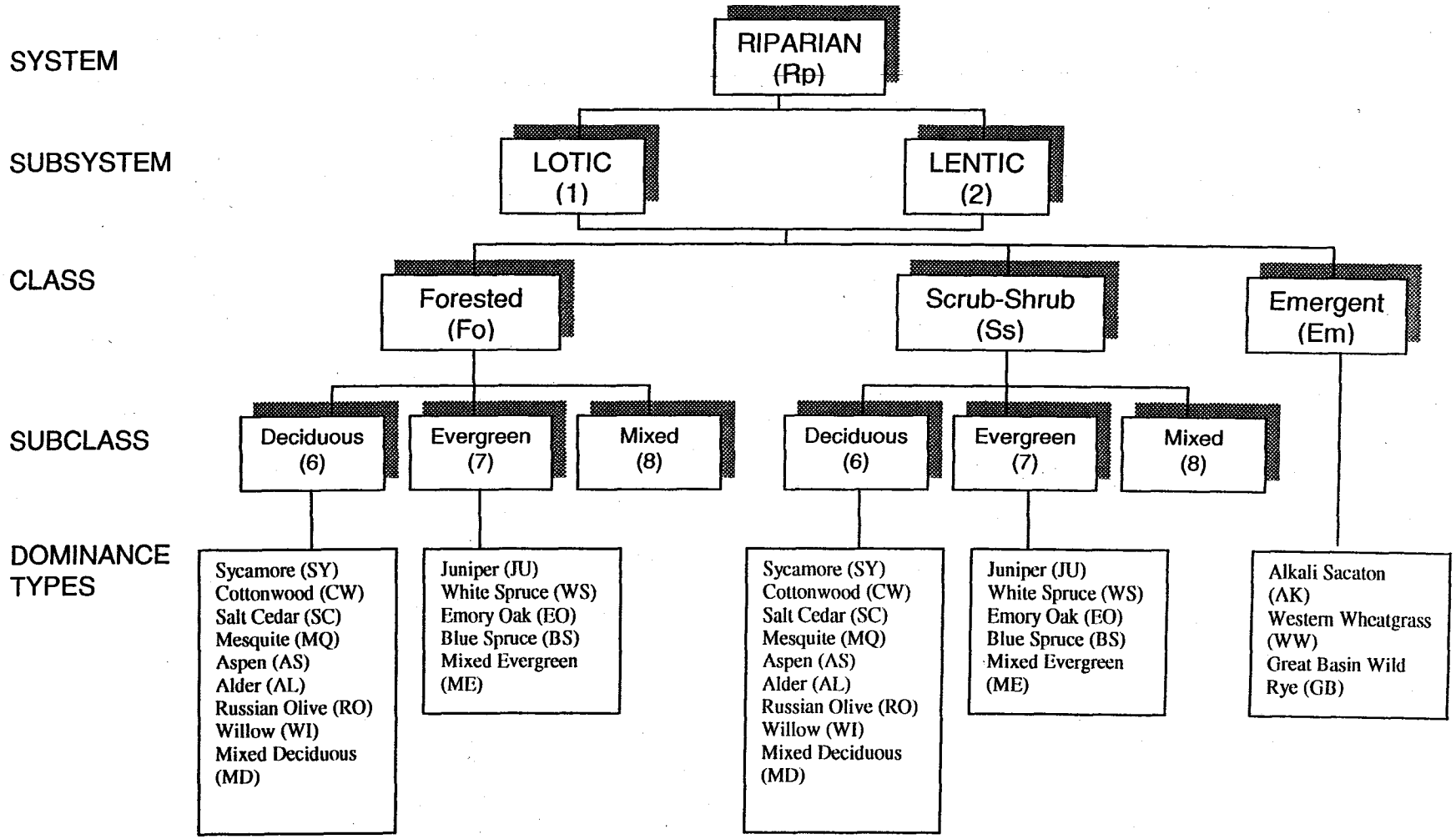
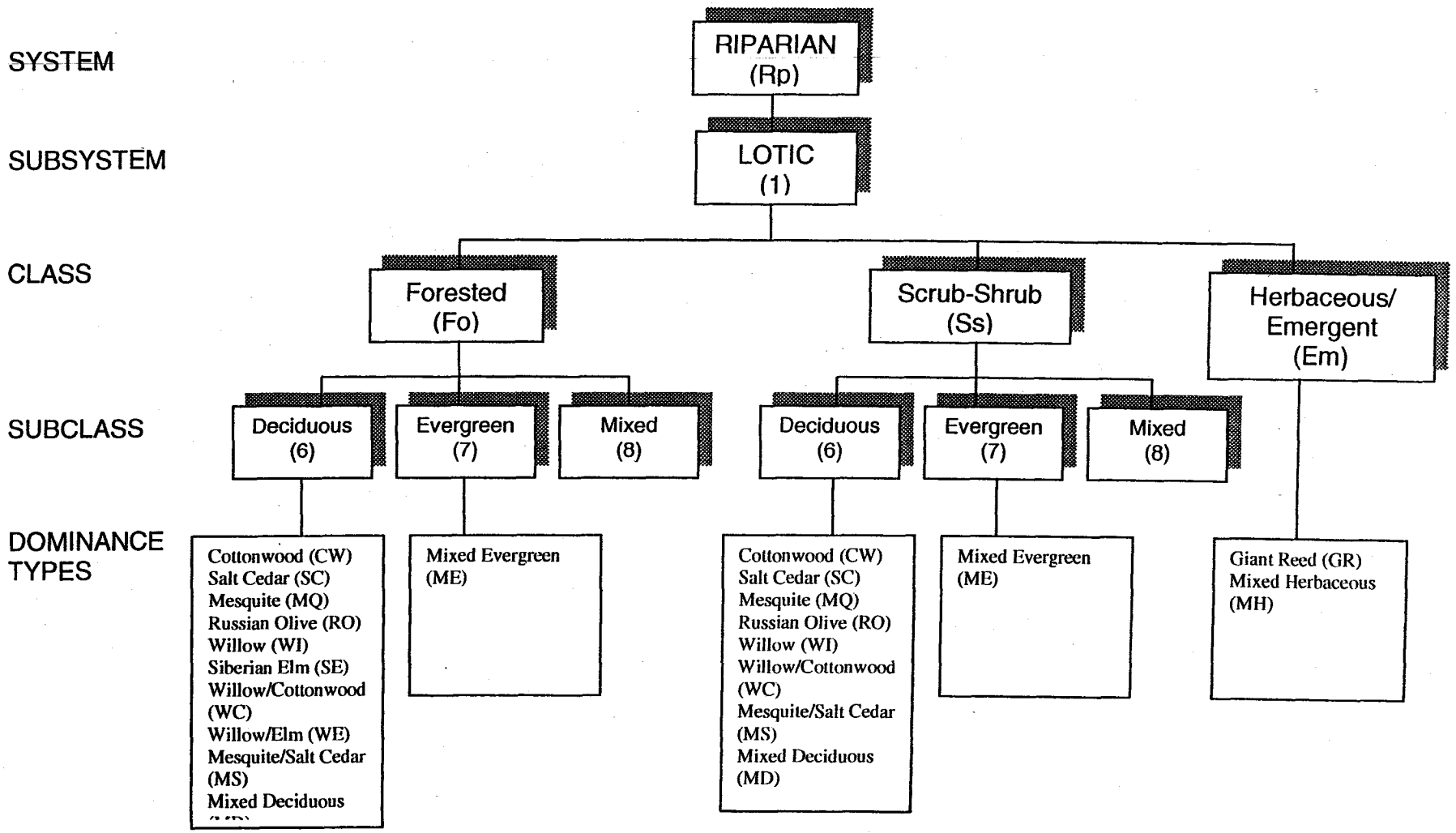


Figure 2. Riparian Mapping System Characterization System modified for Water Quality Research Project effluent-dominated streams in the arid west.



of the possibility of this habitat occuring in other effluent-dominated streams. This system could be easily extended to cover other effluent-dominated streams in the semiarid West by designation of additional dominance types. This system has been applied to each of the sample points at the eight study sites, with the results listed on Table Q-1. In this table, all of the categories are riparian and lotic, and the Rpl designation is deleted for convenience.

Table Q-1
Classification of Sample Points*

Study Site	Sample Point Number				
	1	2	3	4	5
Santa Ana River, San Bernardino, California	EmGR Ss6WI	EmGR Ss6WI	Ss6MD EmGR	Ss6WI	-
Las Vegas Wash, Las Vegas, Nevada	Fo6SC	Fo6SC	Fo6SC	Fo6SC	Ss6SC
Gila-Salt Rivers, Phoenix, Arizona	Fo6MS	Fo6WC	Fo6MD	Fo6SC	Fo6MD
Santa Cruz River, Tucson, Arizona	No riparian vegetation	Fo6Md	Ss6WI	Ss6MD	Fo6Md
Santa Cruz River, Nogales, Arizona	Fo6Md	Fo6Md	Fo6Md	Fo6Md	Fo6Md
Santa Fe River, Santa Fe, New Mexico	Ss6MD	Fo6RO	Ss6MD	Fo6RO	Fo6SC
Carrizo Creek, Carrizo Springs, Texas	Fo6MD	Fo6WI	Fo6MD	Fo6WI	-
Fountain Creek, Colorado Springs, Colorado	Fo6WC	Fo6WE	Fo6WC	Fo6CW	Fo6WC
South Platte River, Denver, Colorado	Fo6SE	Fo6WE	Fo6WE	Fo6WC	Fo6WC
Crow Creek, Cheyenne, Wyoming	Ss6MD	Ss6WI	EmMH	F06WI	F06WI

* Because all points are riparian-lotic, the Rpl is implied but not stated for each classification.

1.5 REFERENCES

Adamus, P. R, 1998. User's Manual: Avian richness evaluation method (AREM for lowland wetlands of the Colorado Plateau. Environmental Research Laboratory, U.S. Environmental Protection Agency. EPA web page: http://www.epa.gov/owow/wetlands/wequial/arem man/. Accessed March 27, 2000.

Andersen, D. C. 1994. Demographics of small mammals using anthropogenic desert riparian habitat in Arizona. Journal of Wildlife Management 58(3):445-454.

Anderson, B. W. and R. D. Ohmart. 1977. Vegetation structure and bird use in the Lower Colorado River Valley. Pp. 23-34 in Johnson, R. R. and D. A. Jones (technical coordinators). 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, Colorado. 217 pp.

Anderson, J.R.; E.E. Hardy, J.T. Roach, and R.E. Witmer. 1976. A land user and land cover classification system for use with remote sensor data. U.S. Geological Survey, Professional Paper 964.

Anderson, M., P. Bourgeron, M. T. Bryer, R. Crawford, L. Engelking, D. Faber-Langendoen, M. Gallyoun, K. Goodin, D. H. Grossman, S. Landaal, K. Metzler, K. D. Patterson, M. Pyne, M. Reid, L. Sneddon, and A. S. Weakley. 1998. International slassification of ecological communities: terrestrial vegetation of the United States. Volume II. The national vegetation classification system: list of types. The Nature Conservancy, Arlington, Virginia.

Arizona Riparian Council. 1990. Arizona Riparian Council Fact Sheet No. 1. Edited by Tanna Thomburg. Center for Environmental Studies, Arizona State University, Tempe, AZ.

Arkansas Gap Analysis Project. 1994. Natural vegetation classification system of Arkansas. Internet site http://www.cast.uark.edu/cast/projects/gap/landcover/vegclass.html. Accessed April 26, 2000.

Brooker, M. P. 1985. The ecological effects of channelization. Geographical Journal 151:6369.

Brown, D. E. and C. H. Lowe. 1974. The Arizona system for natural and potential vegetation - illustrated summary through the fifth digit for the North American Southwest. Journal of the Arizona Academy of Science, 9:1-7.

Brown, D. E., C. H. Lowe, and J. F. Hausler. 1977. Southwestern riparian communities: their biotic importance and management in Arizona. Pp. 201-211 in Johnson, R. R. and D. A. Jones (technical coordinators). 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, Colorado. 217 pp.

Brown, D. E., C. H. Lowe, and C. P. Pase. 1979. A digitized classification system for the biotic communities of North America, with community (series) and association examples from the southwest. Journal of the Arizona-Nevada Academy of Science 14 (Suppl. 1):1-16.

California Department of Fish and Game. 2000. Wildlife habitats, California wildlife habitats relationships systems. Internet site http://www.dfg.ca.gov/whdab/cwhr/cwhrhab.html. Last updated February 2000. Accessed March 17, 2000.

Carothers, S. W., R. R. Johnson, and S. W. Aitchison. 1974. Population structure and social organization of southwestern riparian birds. American Zoologist 14:97-108.

Cowardin, L. M., V. Carter, F. C. Golet, and E. T. LaRoe. 1979. Classification of wetlands and deepwater habitats of the United States. Office of Biological Services, Fish and Wildlife Service. FWS/OBS-79/31. 131 pp.

DeBano, L. F., J. J. Brejda, and J. H. Brock. 1985. Enhancement of riparian vegetation following shrub control in Arizona chaparral. Journal of Soil and Water Conservation 39:317-320.

Dick-Peddie, W. A. and J. P. Hubbard. 1977. Classification of riparian vegetation. Pp. 85-90 in Johnson, R. R. and D. A. Jones (technical coordinators). 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, Colorado. 217 pp.

Environmental Protection Agency. 1995. Midwest oak ecosystems recovery plan: a call to action. Appendix A. EPA web page: http://www.epa.gov/grtlakes/oak/oak95/app-a.htm. Accessed March 17, 2000.

Federal Geographic Data Committee. 1997. Vegetation classification standard. Internet site http://www.nbs.gov/fgdc.standards/vegstd.htm. Accessed March 20, 2000.

Fenner, P., W'. W. Brady, and D. R. Patton. 1985. Effects of regulated water flows on regeneration of Fremont cottonwood. Journal of Range Management 38(2)135-138.

Foti, T., Xiacjun Li, M. Blaney, and K. G. Smith. 1994. A classification system for the natural vegetation of Arkansas. Arkansas Gap Analysis Project. Internet site http://www.cast.uark.edu/gap/foti.html. Accessed March 20, 2000.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management 10(2):199-214.

Fry, J., F. R. Steiner, and D. M. Green. 1994. Riparian evaluation and site assessment in Arizona. Landscape and Urban Planning, 28:179-199.

Green, D. 1V1. 1998. Recreational impacts on erosion and runoff in a central Arizona riparian area. Journal of Soil and Water Conservation 53(1):38-42.

Grossman, D. H., D. Faber-Langendoen, A. S. Weakley, M. Anderson, P. Bourgeron, R. Crawford, K. Goodin, S. Landaal, K. Metzler, K. D. Patterson, M. Pyne, M. Reid, and L. Sneddon. 1998. International slassification of ecological communities: terrestrial vegetation of the United States. Volume I. The national vegetation classification system: development, status, and applications. The Nature Conservancy, Arlington, Virginia.

Hall, L. S. and R. W. Mannan. 1999. Multiscaled habitat selection by elegant trogons in southeastern Arizona. Journal of Wildlife Management 63(2):451-461.

Heinzenknecht, G. B. and J. R. Paterson. 1978. Effects of large dams and reservoirs on wildlife habitat. Pp. 101-147 in Chadwick, W. L. (chairman) Environmental Effects of Large Dams. American Society of Civil Engineers, New York. 255 pp.

Hoover, S. L., D. A. King, and W. J. Matter. 1985. A wilderness riparian environment: visitor satisfaction, perceptions, reality, and management. Pp. 223-226 in Johnson, R. R. C. D. Ziebell, D. R. Patten, P. F. Ffolliiot, and R. H. Hamre (technical coordinators). Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 523 pp.

Jennings, M.D. 1993. Natural terrestrial cover classifications: assumptions and definitions. Gap Analysis Technical Bulletin 2. U.S. Fish and Wildlife Service, Idaho Cooperative Fish and Wildlife Research Unit, University of Idaho, Moscow, ID.

Johnson, R. R., L. T. Haight, and J. M. Simpson. 1985. Endangered species vs. endangered habitats: a concept. Pp. 68-79 *in* Johnson, R. R. C. D. Ziebell, D. R. Patten, P. F. Ffolliiot, and R. H. Hamre (technical coordinators). Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 523 pp.

Kauffman, J. B. and W. C. Krueger. 1984. Livestock impacts on riparian ecosystems and streamside management implications .... a review. Journal of Range Manangement 37(5):430-438.

Knopf, F. L. 1985. Significance of riparian vegetation to breeding birds across an altitudinal cline. Pp. 105-111 in Johnson, R. R. C. D. Ziebell, D. R. Patten, P. F. Ffolliiot, and R. H. Hamre (technical coordinators). Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 523 pp.

Knopf, F. L., R. R. Johnson, T. Rich, F. B. Samson, and R. C. Szaro. 1988. Conservation of riparian ecosystems in the United States. Willson Bulletin 100(2):272-284.

Martin, S. C. 1979. Evaluating the impacts of cattle grazing on riparian habitats in the national forests of Arizona and New Mexico. Pp. 35-38 *in* Cope, O. B. (editor). Proceedings of the Forum - Grazing and Riparian/Stream Ecosystems. Trout Unlimited, Inc., Denver, Colorado.

Mayer, K. E. and W. F. Laudenslayer (eds.). 1988. A guide to wildlife habitats of California. State of California, Resources Agency, Department of Fish and Game, Sacramento, California. 166 pp.

Medina, A. L. 1990. Possible effects of residential development on streamflow, riparian plant communities, and fisheries on small mountain streams in central Arizona. Forest Ecology and Management 33/34:351-361.

Mensler, J. 2000. Virginia's classification scheme. Virginia Gap Analysis Project, Virginia Tech. Internet site http://fwie.fw.vt.edu/WWW/vagap/news/classif.htm. Accessed March 20, 2000.

Ogden Environmental and Energy Services Co., Inc. 2000. Lower Colorado Multi-species Conservation Program (LCRMSCP). Proposed vegetation classification. Internet site http://Icrmsep.org/Download/veg.html. Accessed March 20, 2000.

Pase, C. P. and E. F. Layser. 1977. Classification of riparian habitat in the Southwest. Pp 5-9 in Johnson, R. R. and D. A. Jones (technical coordinators). 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, Colorado. 217 pp.

Rice, J., B. W. Anderson, and R. D. Ohmart. 1984. Comparison of the importance of different habitat attributes to avian community organization. Journal of Wildlife Management 48(3):895-911.

Rosgen, D. L. 1985. A stream classification method. Pp. 91-95 in Johnson, R. R. C. D. Ziebell, D. R. Patten, P. F. Ffolliiot, and R. H. Hamre (technical coordinators). Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 523 pp.

Sawyer, J. O. and T. Keeler-Wolf. 1997. A manual of California vegetation. California Native Plant Society. Internet site http://endeavor.des.ucdavis.edu/cnps/. Accessed March 20 and 28, 2000.

Schneider, R. E., D. Faber-Langendoen, R. C. Crawford, and A. S. Weakley. 1997. The status of biodiversity in the Great Plains: Great Plains vegetation classification. Supplemental Document 1, in: W. R. Ostlie, R. E. Schneider, J. M. Aldrich, T. M. Faust, R. L. B. McKim, and S.J. Chaplin, The status of biodiversity in the Great Plains. The Nature Conservancy, Arlington, VA. 75 pp. Great Plains Program web page: http://greatplains.org/resource/biodiver/gpclass/. Accessed March 20, 2000.

Skagen, S. K., C. P. Melcher, W. H. Howe, and F. L. Knopf. 1998. Comparative use of riparian corridors and oases by migrating birds in southeast Arizona. Conservation Biology 12(4);896-909.

Stamp, N. E. 1978. Breeding birds of riparian woodland in south-central Arizona. Condor 80:64•71.

Stevens, L. E. and G. L. Waring. 1985. The effects of prolonged flooding on the riparian plant community in Grand Canyon. Pp. 81-86 in Johnson, R. R. C. D. Ziebell, D. R. Patten, P. F.

Ffolliiot, and R. H. Hamre (technical coordinators). Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-1'20. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 523 pp.

Stromberg, J. C., R. Tiller, and B. Richter. 1996. Effects of groundwater decline on riparian vegetation of semiarid regions: the San Pedro, Arizona. Ecological Applications 6(1):113131.

Strong, T. R. and C. E. Bock. 1990. Bird species distribution patterns in riparian habitats in southeastern Arizona. Condor 92:866-885.

Szaro, R. C. 1989. Riparian forest and scrubland communities of Arizona and New Mexico. Desert Plants 9(3-4):69-138.

Szaro, R. C. and L. F. DeBano. 1985. The effects of streamflow modification on the development of a riparian ecosystem. Pp. 211-215 in Johnson, R. R. C. D. Ziebell, D. R. Patten, P. F. Ffolliiot, and R. H. Harare (technical coordinators). Riparian ecosystems and their management: reconciling conflicting uses. USDA Forest Service General Technical Report RM-120. Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado. 523 pp.

Szaro, R. C. and M. D. Jakle. 1985. Avian use of a desert riparian island and its adjacent scrub habitat. Condor 87:511-519.

Taylor, D. 1VI. 1986. Effects of cattle grazing on passerine birds nesting in riparian habitat. Journal of Range Management 39(3):254-258.

Texas Cooperative Fish and Wildlife Research Unit. 1997. Vegetation classification scheme for TX-GAP. Texas Tech University. Internet site http://www.tcru.ttu.edu/txgap/vegclass/index.html. Accessed March 20, 2000.

U. S. Department of Agriculture, Forest Service. Undated. National Hierarchical Framework of Ecological Units. Environmental Protection Agency webpage: http://www.epa.gov/grdwebpg/bailey/bailey_summary.html. Accessed March 17, 2000.

UNESCO. 1973. International classification and mapping of vegetation, series 6, ecology and conservation. Paris, France.

U. S. Fish and Wildlife Service, National Wetlands Inventory. 1998. A system for mapping riparian areas in the western United States. Internet site http://www.nwi.fws.gov/Riparian.htm. Accessed March 23, 2000.

Williams, M. (editor). 1990. Wetlands: A Threatened Landscape. Basil Blackwell, Cambridge, MA.