DRAFT

Reclassification of Vegetation Mapping Units

Sonoran Desert Conservation Plan May 2001

Pima County, Arizona
Board of Supervisors
Ann Day, District 1
Dan Eckstrom, District 2
Sharon Bronson, District 3
Raymond J. Carroll, District 4
Raúl M. Grijalva, Chairman, District 5

County Administrator
Chuck Huckelberry

MEMORANDUM

Date: May 21, 2001

To: The Honorable Chair and Members
Pima County Board of Supervisors

From: C.H. Huckelberry
County Administrator

Re: **Reclassification of Vegetation Mapping Units**

Background

The use of scientific studies and analysis of the Sonoran Desert Conservation Plan to plan future land uses in Pima County represents perhaps the largest scale application of this type of data in practical local land use decision making. One result of the use of such technical information in the policy realm is that we find we must understand the languages of geographic information systems and the subject matter of habitat and protected species relationships. Another result is that differences of opinion or variation in methodology that once might have been considered academic matters now have to be addressed and resolved so that this information can in fact become the basis of land use policy.

Study

The attached technical study, *Reclassification of Vegetation Mapping Units*, is one that is before us because Pima County assembled a comprehensive land cover map for the Sonoran Desert Conservation Plan, and in the process of doing so, we identified the strengths and weaknesses of prior mapping efforts. In order to combine the best aspects of past efforts, a common language had to be established among the classification systems. To make matters more complex, we are starting with a landscape that includes a number of biogeographic and climatic regions -- we live in a transition zone of major natural systems, and we have dramatic changes in elevation which create different systems at different levels. A relatively detailed map by Pima Association of Governments (PAG) relied on a classification system that is specialized and local. Another classification system exists -- known as Brown, Lowe, and Pase -- and it is a global classification system that relates to mapping across regions. The Brown, Lowe and Pase classification system is the basis of the Sonoran Desert Conservation Plan. Therefore, this study inquired into whether the PAG mapping effort can be translated into the more universal language of vegetation mapping, and after establishing that such translation can occur, the cross-walk from the past local method to the adopted universal method is described.

Conclusion

On one level *Reclassification of Vegetation Mapping Units* is a highly technical retrofitting of past local mapping classification systems to a more global method that is also widely respected, utilized and understood in the scientific community. On another level the study reflects that the basic components of the Sonoran Desert Conservation Plan are being built in a manner that establishes a better foundation not only for land use decision making in Pima County, but for the future scientific research, monitoring, inventories that will constitute the programs implemented upon Plan adoption.

Attachment

RECLASSIFICATION OF VEGETATION MAPPING UNITS FROM THE PIMA ASSOCIATION OF GOVERNMENTS LAND COVER MAPS

Prepared by Rex Wahl, Renee Tanner, and Angela Barclay,
Entranco

INTRODUCTION

Vegetation and land cover data are essential for assessing conservation gaps (unprotected plant or animal communities) and developing reserve designs since it is these data that describe habitat and determine in part, species distributions. Recognizing the importance of vegetation and land cover mapping to the development of a regional multi-species habitat conservation plan, the Science Technical Advisory Team (STAT) to the Sonoran Desert Conservation Plan (SDCP) identified the need to assess and improve existing data for Pima County.

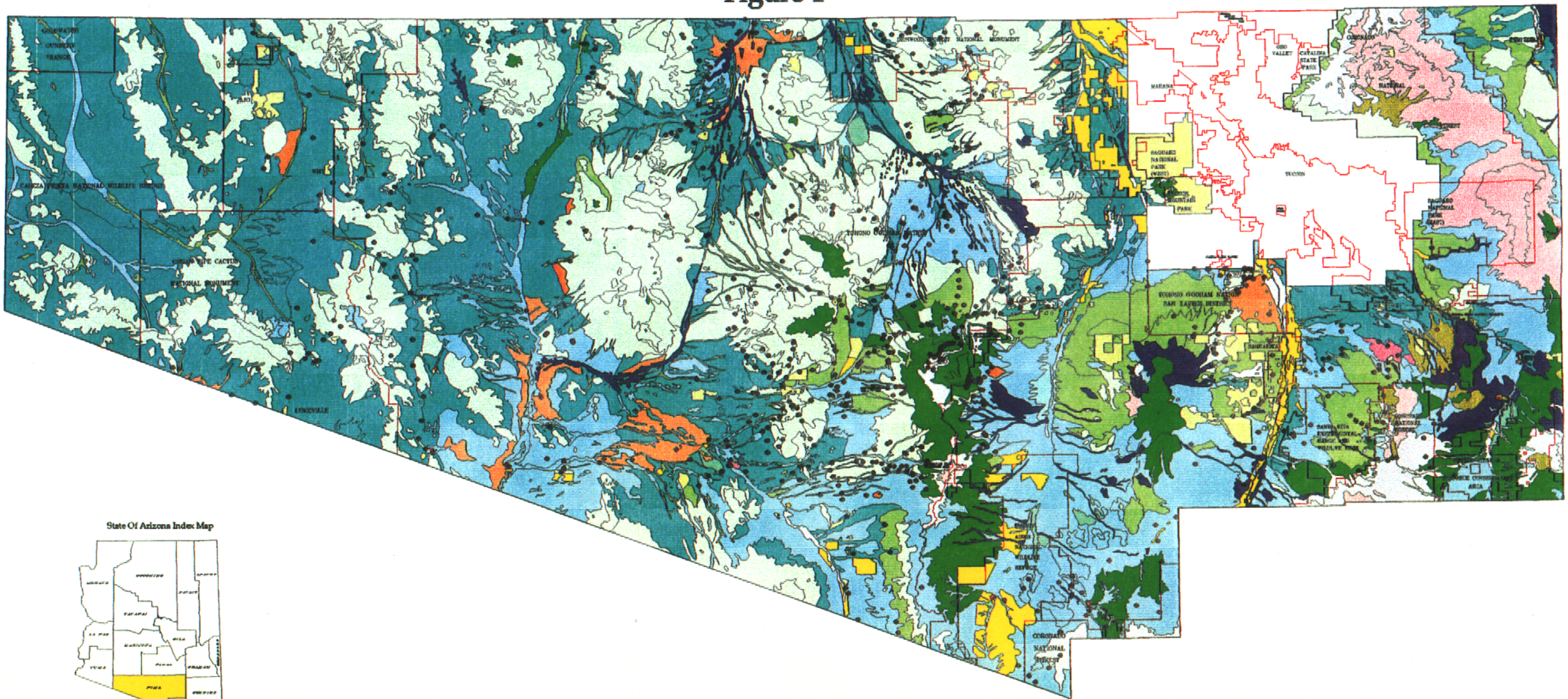
The STAT evaluated the suitability of previous mapping efforts for use in the SDCP (STAT 1999a). Four data sources were examined: Arizona Gap Analysis Program (GAP), Pima County Wildlife Habitat Inventory Phase 2 (WHIP2), Pima Association of Governments (PAG) 208 studies, and Pima County Riparian Habitat Mapping. A primary recommendation of this review was that the accuracy of vegetation delineation and classification could be improved for upland communities by combining multiple sources of vegetation data (riparian mapping has taken another trajectory, altogether).

The land cover data assessment report (RECON 2000) details efforts to produce the best possible land cover data layer from existing resources. Included in the report are recommendations to adopt and apply a standard classification system, develop a system for compiling multiple data sources into a single land cover data layer facilitating the incorporation of new data and assumptions, evaluate results, and prioritize map improvements necessary for achieving the goals of the SDCP.

Initial SDCP land cover mapping for Pima County included a single county-wide cover, the GAP, and using several local (sub-county) studies (e.g. San Pedro, Organ Pipe Cactus National Monument, WHIP and Cienega Creek) to attempt to refine the GAP mapping (RECON 2000). Comparisons of the GAP classification accuracy to more fine-scale mappings have shown that GAP accuracy is relatively weak in scrubland types (upland) and riparian forests (Kunzmann et al. 1998). Inspection of the scrubland types distribution on the GAP-based SDCP Composite map, at both best and series level, reveals a relatively homogeneous mapping on a large scale (Fig.7, RECON 2000). Inspection of the PAG mapping of desert scrub types (**Figure 1**) suggests that the PAG mapping has a finer resolution of the scrubland or desert scrub types.

PAG Vegetation

Figure 1



State Of Arizona Index Map

Index Map Scale 1:3,000,000

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324.45
324.49

Resource Inventory Locations

HDMS Pima Pineapple Cactus locations

N

Scale 1:235,000

Figure 1

THE SEAL OF PIMA COUNTY ARIZONA

Plotted: 03/05/01

PIMA COUNTY DEPARTMENT OF TRANSPORTATION

TECHNICAL SERVICES

Pima County Technical Services
201 North Stone Avenue - 9th Floor
Tucson, Arizona 85701-1207
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/pygmyowl/pygmyowl2/sonora/depot/infotech/pag200_veg2.aml

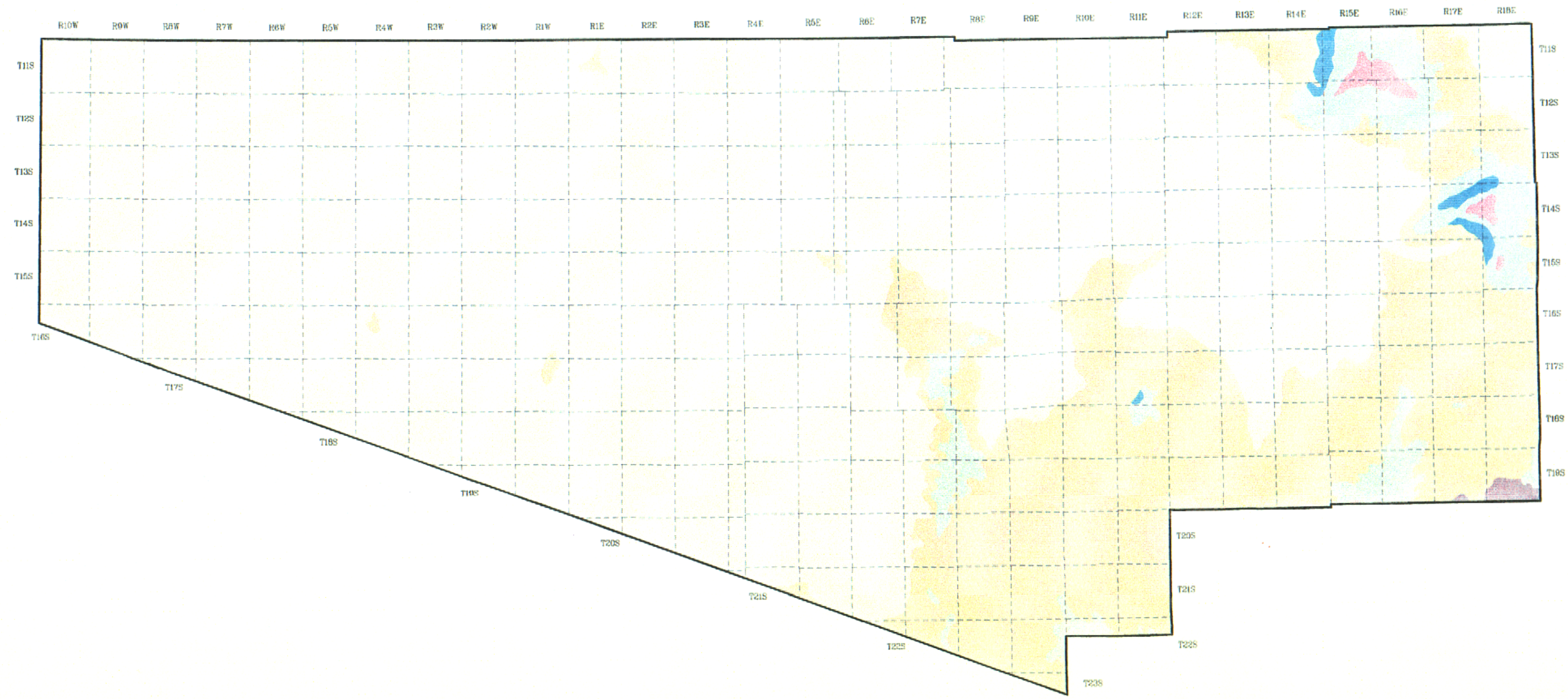
Perhaps the PAG mapping, or a combination of the PAG and GAP scrubland mapping will provide an improved mapping of the desert scrub (scrubland) types. To facilitate this effort, this report addresses whether PAG classifications can be fit into the Brown, Lowe, and Pase (1979) [BLP] classification adopted for the SDCP without undue loss of PAG polygon accuracy (See Appendix B). The report also addresses problems and issues that arise from the translation and its interpretation in a mapping application.

The object of this report is to present the methods of, and issues arising from, converting the PAG 208 (PAG 1977) classification system into the standard classification system of BLP. The PAG classification system was developed for an extensive land cover type mapping of Pima County. Because the PAG mapping represents substantial existing data on native plant land cover throughout Pima County, it is a valuable aid in cover type mapping if its classification can be adapted to the BLP community classification, adopted as the standard for SDCP mapping.

Pima County lies in a transition zone between several BLP biogeographic and climatic regions, which, in turn, means that numerous BLP biomes and formations are found in Pima County, complicating classification decisions. BLP climatic regions found in Pima County include cold temperate (due to elevation), warm temperate, and tropical-subtropical. Formations found, or likely in Pima County are: Sonoran, Chihuahuan, Rocky Mountain, Great Plains, Mogollon and Madrean (**Figure 2**).

Pima County Biomes

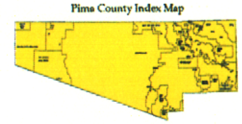
Figure 2



Based On: Brown and Lowe (1982) Biotic Communities of the Southwest

- Chihuahuan Biome
- Madrean Biome
- Mogollon Biome
- Rocky Mountain Biome
- Sonoran Biome
- Great Plains Biome

Figure 2



N

Scale: 1: 250,000

THE SEAL of PIMA COUNTY ARIZONA

PIMA COUNTY DEPARTMENT OF TRANSPORTATION
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/pygmyowl2/sonora/amls/natveg.aml

Plotted: 3/6/01

METHODS

Pima Association of Governments (PAG) composite land cover maps (on mylar) were digitized and attributed by Infotech, at the request of Pima County (Appendix A). The result was a single, georeferenced and edgemapped vector cover in ArcInfo. Attributes associated with the PAG land cover polygons include: land use/vegetation, landform, slope, geology and soils.

We reviewed the PAG methods and classification system explanation (PAG 1977, see Appendix B) to become familiar with the classification philosophy and methods. We reviewed the description of the BLP classification (Brown, et al, 1979) for its philosophy and methods. We used the Sonoran Desert Conservation Plan Composite Land Cover GIS list of BLP vegetation communities (RECON list) as an initial starting point for BLP classification in Pima County (RECON, 2000). Additions of BLP series and higher classifications were made to the RECON list for Pima County as needed to accommodate the PAG types.

Translation of the PAG classification into the BLP classification was conducted in a series of steps, with the most straightforward associations classed first. Peter Warren, The Nature Conservancy, made the first-cut translation. Dr. Warren had participated in the original PAG surveys, as a field crew, and thus had unique knowledge of the PAG information. Dr. Warren's review and discussion aided subsequent refinements in the classification translation by Pima County staff and their consultant for this work, Entranco.

The PAG plant associations and subunits (last two decimal places) were reviewed and compared with BLP classification series or association. Those with unambiguous assignment (same dominant plant species) were considered a match at the series or association level. Those PAG classes that fit more than one BLP series or association, or those with no obvious match at the series or association level were flagged as problematic.

In the problem areas, we looked at the higher PAG classification (1-3 digits) to see if they would provide information that would inform the assignment to a single BLP series or association, based on the original intent of the PAG classification. If it was clear that the PAG classification intended an identifiable formation or higher level in the BLP system, the taxon was assigned to an appropriate series or association in that group. If this approach did not provide a resolution we listed the PAG taxon in each of the BLP classification series or associations that corresponded with the dominant plant species listed. This led to a single PAG plant association being listed in several series, formations or higher level BLP classifications. We restricted the BLP formations considered to those biomes known (or suspected) to be represented in Pima County.

In the case of grasslands, the PAG classification did not contain specific dominant plant species ("indicators") at any of the lower levels, preventing assignment to the BLP series or association level, which are defined by dominant plant species. In this case, we arbitrarily assigned all grass types to the BLP Formation: Scrub Grassland (Semidesert Grassland). We did this to maintain the identity, and resolution, of any PAG "grass type" polygons, due to the high importance placed on conservation of grasslands.

PAG taxa that have no analog in the BLP system, or that were not mapped as polygons were noted (Remarks 3, Table 1, Table 2).

RESULTS AND DISCUSSION

In general, many of the PAG cover types at the 4th and 5th digit level could be translated unambiguously into the BLP classification at the association or series level (**Table 1**). Where PAG cover types depended on major dominant, or "indicator" plants the translation was straightforward. There were some types of conservation interest, however, that were not readily placed in the association or series level of BLP, due primarily to a lack of defining dominant plant species in the PAG description (e.g. "pure grass types").

A few PAG types were so general as to be unassignable to any BLP classifications (**Table 1**). We found that some of the PAG types were not mapped as polygons (**Table 2**), and should probably be deleted from the list. There were some PAG-style numbers in the Pima County GIS cover without corresponding descriptions or mapped polygons which are considered typographical errors in mapping.

Inspection of the misnumbered PAG polygons resulted in corrections for those numbered 329 and 342.42 to PAG 339 (Other non-desert Shrub) and PAG 324.42 (Mesquite-Foothill Paloverde-Chainfruit Cholla), respectively. Polygons labeled PAG 323.42 were not possible to re-number, based on the surrounding context. Though they are likely in the PAG 324 "series" (Thorny and Non-thorny Desert Shrub), all of which maps to a BLP Sonoran Desert Scrub series (see below).

Table 1
Vegetation Classification
PAG

Brown, Lowe, and Pase Community Type	BLP No.	PAG No.	PAG Plant Commuity Type	Remarks
Cold Temperate Forests and Woodlands	122			
Rocky Mountain (Petran) Montane Conifer Forest	122.3			
**Populus tremuloides* subclimax association	122.314	351.3	Aspen Forest	
Great Basin Conifer Woodland	122.4	353	Mixed Coniferous and Non-Coniferous Woodland and Forest	
		352.9	Other Coniferous Types	3
Pinyon-Juniper Series	*122.41*	352.1	Juniper and/or Pinyon Pine Woodland	1,3
Madrean Montane Conifer Forest	122.6	353	Mixed Coniferous and Non-Coniferous Woodland and Forest	
Douglas-fir-Mixed Conifer Series	*122.61*	352.4	Mixed Conifer Types	
Populus tremuloides subclimax association*	122.613	351.3	Aspen Forest	1
Pine Series	*122.62*	352.3	Pine Types	
Madrean Evergreen Forest and Woodland	123.3	353	Mixed Coniferous and Non-Coniferous Woodland and Forest	
		352.9	Other Coniferous Types	3
		352.1	Juniper and/or Pinyon Pine Woodland	1,3
Encinal (Oak) Series	*123.31*	351.2	Encinal (Oak) Woodland	
Mixed Quercus (=*Quercus* spp.) Association		351.8	Oak-Mesquite Woodland	
		343.1	Encinal Types - Oak	
Oak-Pine Series	*123.32*	353	Mixed Non-Coniferous and Coniferous woodland and Forest Types	
Cypress Series	*123.52*			
Cupressus arizonica arizonica Association	123.521	352.2	Cypress Dominated Types (Cupressus arizonica)	
Sonoran Riparian woodland	124.7			
Mesquite Series (see also 224.52)	*124.71*	351.1	Mesquite Bosque	
Interior Chaparral	133.3	331	Arizona Chaparral	3
		339	Other non-desert shrub	3
		332	Non-Desert Shrub	
Cold Temperate Grasslands*	142			
Grama "short grass" series*	*142.1*	313.2	Pure (Grass) Types (part)	
Scrub-Grassland (Semidesert Grassland)	143.1	341	Shrub Grassland	
		342	Deciduous Tree Savana	
		314	Forb Grass Types	
		321	Cacti and Succulent Plant Types	
		340	Savanna, Savanna-like types and Shrub Grasslands	
		243.3		
		349	Other Savana or Savanna-like Types	
		313	Grass Types	
		313.1	Halophytic Types	
		313.3	Mixed Grass	
		361	Playas	3
Sacaton Scrub Series	*143.14*			
Sporoblus wrightii Association	143.141	313.2	Pure (Grass) Types	
Mixed Grass-Scrub Series	*143.15*	325.52	Ocotillo-Fairyduster-Sotol	
		343	Evergreen Tree Savanna (all: 243.1, .2, .3)	
		313.4	Yucca or Beargrass Grasslands	3
Mixed grass-*Yucca elata* Association	143.151	313.4	Yucca or Beargrass Grasslands	3
Shrub-Scrub Disclimax Series	*143.16*			
Applopappus tenuisectus-Prosopis juliflora Association	143.163	324.32	Mesquite-Halfshrub	
Prosopis sp.-*Acacia* sp. Association	143.166	324.34	Mesquite-Acacia	
		324.39	Other Mesquite Types	
Chihuahuan Desert Scrub	153.2			
Creosotebush-Tarbush Series	*153.21*			
Larrea divaricata-Parthenium incanium-mixed scrub Association	153.212		(None mapped as PAG polygons)	
Mixed Scrub Series	*153.26*	324	Thorny and Thorny-Non-Thorny Mixed Desert Shrub	1
		324.34	Mesquite-Acacia	1
		332.1	Sandpaper Bush-Fairyduster-Agave	
Sonoran Desert Scrub	154.1			
		325.9	Other Thorny Desert Scrub Types	3
Creosotebush-Bursage (Lower Colorado Valley) et al Series	*154.11*	323.1	Creosotebush Types	1
		323.39	Other Creosotebush Types	1
		323.2	Halfshrub Types (all: includes .21, .22, .23)	3
		323	Non-thorny and Creosotebush Dominated thorny Non-thorny mixed types	
Larrea divaricata Association	154.111	323.3	**Creosote-dominated**	
		323.12	Creosotebush-Halfshrub Types	
Larrea divaricata-Ambrosia dumosa Association	154.112	323.32	Creosotebush-Bursage-Cacti-Mesquite-Grass	1
Larrea tridentata-Ambrosia deltoidea-Fouquieria splendens Subassociation	154.1113	323.31	Creosotebush-Cacti-Ocotillo	2
		323.33	Creosotebush-Paloverde-Ocotillo	2
Larrea tridentata-Annuals Associatoin	154.1114	323.11	Pure Creosotebush Types	2
Paloverde-Mixed Cacti (Arizona Upland) Series	*154.12*	324.1	Paloverde Types with Creosotebush	2
		324.2	Paloverde Types with out Creosotebush (all)	2
		325.5	Non-mesquite Paloverde Types	2
		324.4	Mixed Mesquite-Paloverde Types	2
Ambrosia deltoidea-Cercidum microphullum-mixed scrub Associaton	154.121	324.11	Paloverde-Creosote-Ocotillo	2
		324.42	Mesquite-Foothills Paloverde-Cholla	2
		324.23	Paloverde, No Ocotillo	2
Ambrosia deltoidea-Cercidium microphyllum middle bajada Subassociation (1)	154.1211	324.11	Paloverde-Creosote-Ocotillo	1,2
		324.12	Paloverde-Creosote-Whitethorn Acacia	1,2
Ambrosia deltoidea-Cercidium microphyllum pediment mixed shrub (1)	154.1212	324.11	Paloverde-Creosote-Ocotillo	1,2
		324.12	Paloverde-Creosote-Whitethorn Acacia	1,2
Cercidium microphyllum-Ambrosia deltoidea-Simmondsia chinensis-pediment Subassociation	154.1213	324.22	Paloverde-Ocotillo-Jojoba-Bursage	
Acacia-Ambrosia ambrosioides Subassociation	154.1214	325.51	Acacia Types	
Prosopis glandulosa-Cercidium floridum Subassociation	154.1215	324.45	Mesquite-Paloverde	2
		324.49	Other Mixed Mesquite-Paloverde Types	2
		324.43	Mesquite-Paloverde-Creosotebush	2
		324.41	Mesquite-Blue Paloverde-Cholla	
		324.3	Mesquite Types	
		324.31	Mesquite Cholla Halfshrub	2
		324.32	Mesquite Halfshrub	2
Mixed shrub-*Cercidium microphyllum-Olneya tesota*-mixed scrub Association	154.127	324.13	Paloverde-Creosote-Ironwood-Bursage	2
		324.46	Paloverde-Mesquite-Bursage-Ironwood	2
		324.35	Mesquite-Ironwood	2

Table 1
Vegetation Classification
PAG

Brown, Lowe, and Pase Community Type	BLP No.	PAG No.	PAG Plant Commuity Type	Remarks
		324.13	Paloverde-Creosotebush-Ironwood-Bursage	2
Simmondsia chinensis-mixed scrub Association	154.123	324.44	Mesquite-Paloverde-Creosotebush-Jojoba	
Simmondsia-Encelia-Fouquieria Subassociation	154.1231	324.22	Paloverde-Ocotillo-Jojoba-Bursage	
Cercidium microphyllum-Ambrosia deltoidea-Lemaireocereus-Jatropha Subassociation	154.1272	324.24	Paloverde-Organpipe Cactus	
Saltbush Series	***154.17***	322	*Halophytic Types*	
		361	*Playas*	
		323.13	Creosote-Saltbush Types	
		324.33	Mesquite Saltbush	
		323.13	Creosote-Saltbush Types	
		324.33	Mesquite Saltbush	
Interior Southwestern Riparian deciduous Forest and Woodland	**223.2**	R351.4	Riparian Woodland	
Sonoran Riparian and Oasis Forests	**224.5**			
Mesquite Series	**224.52**	351.1	Mesquite Bosque	
Sonoran Deciduous Swamp and Riparian Scrub Associatioin	**234.7**			
Mixed Scrub Series	***234.71***			
****Tamarix disclimax series***	***234.72***	R351.5	Tamarisk Communities	
Warm Temperate Marshlands	**243**	315	Graminaceous and Tule Marshes	
		316	Meadows	3
Sonoran Interior Marshland	**244.7**			
Saltgrass Series	***244.75***	313.1	*Halophytic Types*	
***Strand Formation**	**250**			
*Warm Temperate Strands	253	365	Barren River Bottom	
*Tropical Subtropical Strands	254	365	Barren River Bottom	
***Sonoran Interior Strand**	**254.5**			
****Mixed Scrub Series***	***254.51***			
*Baccharis-Solanum-Nicotiana-Rumex Series	254.511	351.9	Other Non-coniferous Woodland and Forest Types.	
****Annual Series***	***254.72***	365	Barren River Bottom	
Unclassified, Mixed Lot, Unclassifiable	**None**	**310**	Herbaceous Types	
		311	Annual Plant Types	
		312	Forb Types	
		319	Other Herbaceous Types	
		320	Desert Scrub Types	
		350	Woodland and Forest Types	
		352	Coniferous Types	

Remarks Legend
1 = assignment to this level only possible with additional information.
2 = oversplit in PAG classification
3 = PAG type not mapped as polygon
*** BLP classification not included in SDCP GIS cover types.**

Table 2. PAG Classifications not mapped as polygons in the PAG Land Cover Map produced by Infotech.

PAG No.	PAG Descriptive Name
310	Annual Plant Types
312	Forb Types
313	Grass Types
320	Desert Scrub Types
325.9	Other Thorny Desert Scrub Types
330	Non Desert Shrub and Chaparral
339	Other Non-Desert Shrub
340	Savanna, Savanna-Like and Shrub Grasslands
349	Other Savanna or Savanna-Like Types
350	Woodland and Forest Types
R351.4	Riparian Woodland
352	Coniferous Types
352.1	Juniper and/or Piñon Pine Woodland
352.2	Cypress Dominated Types

Classification Issues

Translating from a specialized, local classification into a broader, regional classification is fraught with difficulties. The utility of any data associated with the classification system should be considered when re-classifying. The imperfect fit from one classification to another can result in loss of resolution of a particular type, or require pooling of types into a broader category. In this case, the PAG vegetation classification (see Appendix A) is a specialized regional classification designed for an express purpose and the BLP classification is a global, generalized classification with broad application (see Appendix B). Both classifications are hierarchical: each part of the digital numbering system contains information about membership in certain classes. Each taxon (named feature) in the digital combination is numbered in a nesting or step-down relationship.

Several issues in classification translation were encountered. Each has implications in using and understanding the mapping of polygons that were classed under the PAG system into a system using the BLP classification. An understanding of these issues will assist in preventing an unwanted loss of information in translating from the PAG system to the BLP system. Three major issues in classification were identified:

- Absence of a biogeographic component in the PAG system, relevant to the BLP System.
- Over-split plant associations in the PAG system.

- PAG types that did not specify dominant ("indicator") plants at the lowest classifications, contrary to the stated methods of the PAG classification system (see PAG Methods, Appendix A).

Classification Differences

At each level of classification, the definition of the classes, or the characteristics used to classify into that level can greatly influence the ability to translate into another classification. The PAG classification concentrates on growth form or physiognomy at the higher classes (2nd and 3rd digit) and dominant plant species (association) in the lower classes (4th and 5th digits) [see PAG methods].

The BLP classification incorporates much more diverse information into the higher classes; integrating biogeographic, physiognomic (ecological), climatic, and geographic (biome) information. The lower levels of BLP classification are dependent on plant species and associations of plant species. **Table 3** compares the respective differences in information content of the two classifications.

Table 3. Comparison of PAG classes with BLP classes of similar information content.

Digit	PAG Class	Equivalent BLP Class
1st	Natural Vegetation Cover	None
2nd	Growth Form (physiognomic)	3rd level: Formation (approximate)
3rd	Physiological specialization (thorns, coniferous, halophytic)	None
4th	Indicator Plants (dominants)	5th level: Series (characteristic species)
5th	Other dominant or characteristic plants	6th level: Association (species association)

These differences between criteria used in the higher order classifications create problems in translating. For example, the PAG classification emphasis on growth form (e.g. presence or absence of thorns; typically shrub form dominant, etc.) contains no information on geographic or ecological classes that are present in the BLP system. Thorny shrubs are an ecological response (physiognomy) of plants in a variety of geographic and ecological settings. Likewise, broadleaved trees (non-coniferous) are found in a diversity of biomes and ecological settings. Thus, for example, *Acacia* sp. (a thorny shrub) dominated associations may be placed appropriately in any of several biomes (e.g. Chihuahuan or Sonoran), climates (e.g. warm temperate or tropical) and formations (e.g. Nearctic or neotropical) of the BLP classification. Absent other information, these associations from the PAG classification must be considered to be members of each of the several BLP classes in which they fit. Another example; coniferous woodlands of the PAG classification may be found in any of several biomes (Great Basin, Rocky Mountain, or Madrean) of the BLP classification.

In some cases, the dominant species (e.g. *Prosopis* sp., *Juniperus* sp.) of the PAG classification may be found in any of several BLP biomes, or formations, thus the dominant species information can not help resolve which is the appropriate class in going from the PAG to the BLP classification. The solution is to include the PAG taxon into several of the suitable BLP classes, absent other information.

By using other information associated with the PAG plant community classification it may be possible to narrow the assignment of PAG polygons into a specific BLP classification. PAG geographic, elevation, and soils information allow placement of PAG polygons into biogeographic, climatic and biome classes of the BLP system. Geographic and indirect climatic information (elevation, soil, slope and aspect) was gathered with the PAG mapping, thus the information to accurately assign PAG associations to appropriate BLP associations is available and may improve the interpretation of data. However the information content of the PAG classification, alone, does not allow this assignment. For example: PAG Creosotebush (*Larrea tridentata*) association can not be accurately classed into the Chihuahuan or Sonoran biome based solely on the information content of the PAG classification (e.g. PAG 323.1: Desert Scrub, Creosotebush type, *Larrea* sp. dominated). However, with inclusion of associated PAG information on the polygon location within the county and elevation, it becomes possible to class the plant association into the appropriate BLP biogeographic, climatic, and biome classes.

Put another way, PAG 323.1 classed polygons in eastern Pima County between ca. 3000–5000 ft. elevation can be reliably assigned to the BLP cold temperate climate, Chihuahuan biome: 153.21.

Thus, by using other information available with the PAG polygons (e.g. location, elevation, aspect, etc.) or overlaying information from other sources (e.g. BLP biome boundaries as a GIS layer) it will be possible to assign problematic PAG plant associations (and polygons) accurately to an appropriate BLP classification.

Because the higher levels (digits 1-3) of the PAG classification emphasize physiognomy (physical adaptations and growth form) they may include plant associations that belong in different BLP formations or series. Thus, in some cases we were able to assign each lower taxon of a class to an appropriate BLP association or series, but the higher level will not fit neatly into any single BLP Formation or series (**Table 3**).

Table 3. Higher level PAG classes that were not readily assignable to a single BLP Series or Formations. Most or all lower level (4^{th} digit and beyond) units within these classes were assigned to a BLP series or association.

PAG Higher Classification		**Unassignable Because**
310	Herbaceous Types	Too broad
311	Annual Plant Types	Too broad
312	Forb Types	Too generic
319	Other Herbaceous Types	Too broad
320	Desert Scrub Types	Possible in several biomes
350	Woodland and Forest Types	Possible in several biomes
352	Coniferous Types	Possible in several biomes

Over Splitting

In some cases, especially desert scrub, the PAG classification is very finely split at the lowest levels (last two PAG digits); the result is a profusion of plant associations characterized only by the ordered sequence of the same suite of dominant plants. For example, in the PAG Desert Scrub Types (320) there are three Paloverde-with-Creosotebush taxa (324.11, 324.12 and 324.13), three "Creosotebush Types" (323.11, 323.12, and 323.13) and four Creosotebush-dominated taxa (323.31, 323.32, 323.33 and 323.39). The Sonoran Desert Scrub biome of the BLP classification includes a single series for Creosotebush-dominated scrub (154.11) and there is a *Larrea-divaricata*–mixed scrub association (154.124) within the Paloverde-mixed cacti series (154.12).

Our solution was to place the Creosotebush-Paloverde taxa of PAG into the BLP Paloverde-mixed cacti series, with a few exceptions (see below). Thus, PAG taxa with Paloverde were "lumped" into the BLP series encompassing most Paloverde associations. The remaining Creosotebush PAG groups were lumped into the BLP Creosotebush-Bursage series. Those PAG associations containing Ironwood (*Olneya tesota*) were all placed in the BLP Mixed shrub-Paloverde-Ironwood mixed shrub association (154.127) to distinguish all PAG polygons with ironwood.

Generally, lumping into a series or association was the solution to the diversity of types in the PAG Desert Scrub class. In mapping of PAG desert scrub, the PAG taxa at the lowest level (species associations or facies) could be considered subassociations within the assigned BLP classification and their identity maintained to retain the resolution of the diversity of desert scrub polygons.

Broad PAG Classes

In the case of grasslands, the PAG classification did not rely on dominant plant species to define the lower classifications, contrary to the stated PAG classification methods (Appendix A). Instead, the lowest classifications became: "pure (grass) types", "halophytic types", and "mixed grass types". Without dominant species information, it is impossible to translate these types into an appropriate BLP series or association. These types must be translated, lumping up, into the broadest BLP category that applies; the biome level. Thus we assigned these types to the scrub-grassland biome which encompasses all of the grassland communities likely to be encountered in Pima County. It may be possible to refine these polygons into specific series or associations of the BLP system by referring to the PAG field data sheets, which list dominant species observed. Additionally, location, elevation, topographic and landform data may be helpful in further refining these types into an appropriate BLP association.

RECOMMENDATIONS

The PAG classification may be translated into the BLP classification for use in the Sonoran Desert Conservation Plan Land Cover Mapping with the following recommendations:

- Utilize other information associated with the PAG data and other Pima County GIS data related to biogeography and climate to refine the appropriate BLP classification for some PAG associations (e.g. Chihuahuan desert scrub, Scrub-grassland, Scrub-grassland disclimax). See below.

- Lump many of the PAG Desert Scrub Types into appropriate BLP series or associations. This is done in Table 1.

- Retain PAG's Desert Scrub Types "species associations" identity as a subassociation within the BLP series or association to preserve the potentially meaningful variation of the PAG polygons.

- Consider entering all of the PAG field data into a database, to provide more attribute information for the PAG sample points (and polygons). These data may provide another means of supervising (or improving) the SDCP composite mapping of land cover types.

For the PAG classes that were difficult to assign to a BLP series or association level using just the PAG Community Type we used elevation and location in the county (BLP Biome, see Figure 2) to assign each polygon to an appropriate BLP association. We recommend these polygons be assigned the appropriate BLP class (Table 4).

Table 4. PAG classes that were assigned BLP association based on elevation and location in Pima County, a supervised classification of the existing PAG data. These reassignments were not field verified.

PAG Class	Reclassification to BLP Class
313.2 Pure Grass Types	142.12 Grama "short-grass" Series (part), and 143.141 *Sporobolus wrightii* Association (part)
323.1 Creosotebush Types	154.11 Creosotebush-Bursage Series
323.32 Creosotebush-Bursage-Cacti-Mesquite-Grass	154.11 Creosotebush-Bursage Series
323.39 Other Creosotebush Types	154.11 Creosotebush-Bursage Series
324 Thorny and Thorny-non-Thorny Mixed Desert Scrub	143.166 *Prosopis-Acacia* sp. Disclimax Association (part), and 154.12 Paloverde-Mixed Cacti Series (part)
324.34 Mesquite-Acacia	143.166 *Prosopis-Acacia* sp. Disclimax Association (part), and 224.52 Mesquite Series (part)
351.3 Aspen Forest	Misclassified, not aspen forest.

Inspection of the location of the several polygons mapped as PAG Pure Grass Types (313.2) allowed assignment of each polygon to a probable BLP classification, based on elevation and geographic position in the county. Four polygons in Southeastern Pima County were assigned to the Grama "short-grass" Series (142.12) of BLP. Others, located at lower elevation in western and central Pima County were assigned to *Sporobolus wrightii* Association (143.141), the likely community in this topographic and geographic setting.

Polygons in PAG classes: Creosotebush Types (323.1), Creosotebush-Bursage-Cacti-Mesquite-Grass (323.32), and Other Creosotebush Types (323.39) (Table 4) were plotted along with the Pima County Boundaries and BLP biome borders (Figure 3). By inspecting the location of these polygons in the county relative to elevation and BLP biome borders (e.g. geographic and topographic position) it was clear that these polygons belonged in Sonoran Desertscrub biome. The BLP Sonoran Desertcrub type dominated by Creosotebush is Creosotebush-Bursage Series. Thus, all were assigned to BLP 154.11 Creosotebush-Bursage Series, the appropriate series-level class for Sonoran Desertscrub with Creosotebush dominating.

PAG polygons mapped as 324 Thorny and Thorny-non-Thorny Mixed Desert scrub were plotted. Based on geographic location and elevation, these were assigned to two BLP types. Those found in Southeastern Pima County were considered to be grassland disclimax communities of mesquite and *Acacia* sp., BLP 143.166. The rest, in central and western Pima County, were considered Sonoran Desertscrub and placed in BLP 154.12 Paloverde-Mixed Cacti Series.

Polygons mapped as PAG 324.34 Mesquite-Acacia were split into two BLP associations, depending on geographic location, elevation and polygon shape. Those polygons in southeastern and northeastern Pima County at elevations generally over 3,000 ft. were considered to be grassland disclimax communities dominated by Mesquite and *Acacia* sp. (whitethorn or catclaw). Linear shaped polygons in PAG 324.34 were considered to be BLP Mesquite Series (224.52).

One polygon was mapped as aspen (PAG 351.3), however it is in an area and at an elevation (ca. 4000 ft.) where aspen would not be found. This polygon is mislabeled and cannot be reliably classified without a field visit to determine the vegetation cover.

CONCLUSIONS

PAG-classified vegetation cover polygons may be carefully assigned to a BLP series or association level classification for most of Pima County for use as a vegetation cover database in support of the Sonoran Desert Conservation Plan. In certain cases, cited above, the PAG polygon classification in BLP is ambiguous or unclear and should be informed by other, readily available information to assist in decisions on cover classification. The SDCP vegetation cover database derived from PAG cover, GAP, and other sources should be viewed as a starting point for conservation planning on a landscape scale. The land cover database will serve as an important tool for focusing more fine-grained, regional studies on plant communities of conservation interest (e.g. ironwood communities, grasslands, oak-savannas, and salt-bush communities).

A land cover database derived from PAG polygons and other information may also provide an economy in conservation planning. By focusing more extensive, relatively expensive studies on areas of greatest potential for the plant community or communities of interest, limited research money may go further. Land cover, combined with ownership information, may serve to identify those plant communities with the least existing protection and serve to prioritize conservation planning.

Ideally, the resulting land-cover database should be field verified (ground-truthed) for classification and mapping accuracy. Given the multiple-inputs and scales of the databases used for the land cover database, one would not expect pinpoint mapping accuracy or exact plant community composition. Care should be exercised in using the PAG field observation forms, collected in 1977, to verify cover classifications because these field observations were used to classify the PAG polygons, and are thus not random or independent samples.

Used appropriately, and with a view toward its limitations, the SDCP land cover database should provide a very useful tool for planners, land managers and the public in understanding Pima County's native diversity. It will aid in focusing conservation studies and planning and in educating those who will inherit the SDCP and our wonderful desert someday.

Acknowledgments

The authors thank Peter Warren of The Nature Conservancy for his initial, expert "first-cut" cross-walk of the PAG classification. Peter also kindly reviewed subsequent refinements of the cross-walk. Leslie Smith of RECON, Julia Fonseca of Pima County Flood Control District and Ken Kingsley of SWCA, Inc. kindly reviewed the draft report. John Regan and other Pima County GIS staff prepared the GIS coverages shown in the figures. Neva Connolly of Pima County Flood Control District and Julia Fonseca wrote and edited portions of Appendix C. Tammy Jacobs and David Scalero (Pima County Flood Control District) helped with report preparation. Entranco GIS staff, Brian Mickel and Mark Schnaufer, assisted with GIS data manipulation.

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Appendix A
Report by Infotech on the Digitizing and Attrributing of the PAG 208 Vegetation Maps

Appendix B
PAG 208 Vegetation Classification Methods

The PAG vegetation classification has five hierarchical levels, which allows enough detail to approach the Plant Association taxon. The following decision criteria generally apply to the five levels of the classification:

First Digit - Natural vegetation as opposed to cultural land uses.

Second Digit - Broad physiognomic (plant growth form) categories such as trees, shrubs, herbs.

Third Digit - More specific variations in growth form such as evergreen as opposed to deciduous trees, thorny as opposed to non-thorny shrubs, and grasses as opposed to forbs (broad leaf herbaceous plants). In some instances, physiological adaptations such as tolerance to salinity or water were used.

Fourth Digit - Indicator plants (those particularly diagnostic for the type).

Fifth Digit - Other dominant or characteristic species.

In the 1970s, Pima Association of Governments commissioned a set of maps for the county (excluding metropolitan Tucson) delineating vegetation, landform, slope, geology, and soils. Maps were compiled by the Applied Remote Sensing Program at the Office of Arid Lands Studies (OALS), University of Arizona, and completed in 1977. Resource boundaries were delineated using 1972 and 1973 aerial stereophotographs and registered to USGS 15-minute quadrangles. Vegetation and soils were classified based on 1,000 field records plus ancillary data (STAT 1999). Field records were logged on data cards which are associated with point data in a GIS coverage. All polygon mapping remains in hard copy format. Vegetation classification is based on dominant/subdominant species and gross physiognomy, which together with data cards could be cross-walked to BLP biome or series for many types.

PAG land cover mapping was compared with GAP and the Cienega Creek Natural Preserve study to determine whether PAG maps could be useful in improving GAP mapping (June 1999). This comparison showed that PAG mapping is not reliable in riparian areas since these have changed significantly since the 1970s. And upland areas are not comparable since PAG vegetation classification is unique. PAG data cards could be useful in improving vegetation classification, but it would be unclear where to draw the boundary for these classes, and PAG's relatively course scale (20-acre minimum mapping unit) does not help resolve mapping issues for small areas. Given the level of effort required to digitize these hard copy maps, PAG data should be used only for very specific investigations (i.e., searching for a particular feature).

Natural Vegetation and Sparsely Vegetated Areas

300

Areas covered by either native or a mixture of native established exotic plant species. Various successive stages may be manifested due to combinations if historical and current used by man. The primary management objective is to maintain a cover of predominately native plants in contrast to cultivated plants. Areas usually referred to as "Barren Lands" are included in this category because they typically exhibit at least a sparse cover of annual plants, and because the geomorphical names generally applied to these areas are incorporated into the LANDFORM classes of the fractional legend (see Appendix 1. B).

It was necessary to expand this vegetation classification to the fifth level in order to include all of the information collected. This level of detail approaches the Plant Association taxon. In keeping with hierarchical format, the following decision criteria generally apply to the five levels of the classification:

First Digit	Natural vegetation as opposed to cultural land uses.
Second Digit	Broad physiognomic (plant growth form) categories such as trees, shrubs, herbs.
Third Digit	More specific variations in growth form such as evergreen as opposed to deciduous trees, thorny as opposed to non-thorny shrubs, and grasses as opposed to forbs (broad leaf herbaceous plants). In some instances, physiological adaptations such as tolerance to salinity or water were used.
Fourth Digit	Indicator plants (those particularly diagnostic for the type).
Fifth Digit	Other dominant or characteristic species.

In summary, vegetation types are identified by both indicator plants and other dominant species. Dominance can be defined by life form and/or abundance. Those plants listed for the type are always present (although the relative proportions are variable), but other dominants may also be present in particular types (i.e., the type is not distinguished by the absence of any species). The proper class number is assigned by proceeding through the hierarchy level by level, until the most appropriate category is reached. If no subclass is suitable, then the numerical designation of the next higher (more general) class is applies.

Because many plant species are plant assemblages occur in both riparian and non-riparian situations, separate subclasses for riparian vegetation were not I incorporated into the classification. Rather, by an "R". A riparian plant community is one which occurs in or adjacent to a drainageway and/or its floodplain, and is characterized by species and/or growth forms different from the immediately adjacent climax vegetation type. (Lowe, 1964)

Dominant and indicator plant species are ranked on the maps by four- letter botanical acronyms. The first two letters of the generic name and the second two letters are the first two letters of the specific name. For example:

Prosopis juliflora = Prju

If the species is not known, the first five letters of the generic name are all capitalized. For example:

Opuntia spp. = OPUNT

The entire scientific names of all plants referenced on the maps are included in the Descriptive Legend (Appendix 1, A) along with the common name and acronym.

310 HERBACEOUS TYPES

Annual, biennial and/or perennial grasses, grass-like plants and forbs predominate. Woody shrubs and trees contribute less than 5% crown cover excepting members of the Amarylidacae (century plants) and Liliaceae (yuccas) families.

311 Annual Plant Types

Vegetative cover usually most prevalent after rainfall events; the area may be devoid of vegetation during some seasons. This subclass is used only if the associated I landform is not specified under Sparsely Vegetated Areas Class, 360.

312 Forb Types

Forbs are broadleaf, herbaceous plants.

313 Grass Types

313.1 Halophytic Types

Grasses such as alkali sacaton, *Sporobulus airoides* (Spai) which are usually associated with, but not restricted to, alkaline or saline sites.

313.2 Pure Types

Examples include tobosa swales, *Hilaris mutica* (Himu); blue grass, *Bouteloua gracilus* (Bogr); and lovegrass, *Erogostis lehmanniana* (Erle).

313.3 Mixed Grass Types

313.4 Yucca or Beargrass Grasslands

Yucca spp. Or beargrass, N*olina microcarpa* (Moal).

314 Forb-Grass Types

315 Graminaceous and Tule Marshes

Grasses, sedges, rushes associated with permanent standing water.

316 Meadows

Areas associated with high water tables and moist soils, but typically not standing water, except seasonally; species of grass and sedge predominate.

319 Other Herbaceous Types

320 DESERT SCRUB TYPES

Small-leaved (microphyllous) thorny or non-thorny shrubs and half-shrubs adapted to dry environments are the dominant species. However, the herbaceous component may also be important. Plants such as creosotebush, palo verde, mesquite and cacti are common.

321 Cacti and Succulent Plant Types

Use of this subclass was restricted to communities where the cactiform growth form clearly dominated the appearance of the type. If cacti were only co-dominant with other scrub species, a subclass of 324 was used.

322 Halophytic Types

Scrub types dominated by saltbush, *Atriplex* spp. (ATRIP) or other salt tolerant plants generally indicating alkaline or saline areas. Many of these indicator plants are facultative rather than obligatory halophytes, i.e., they can exist in, but are not restricted to alkaline or saline area. Non-halophytic species are of ten co-dominant.

322.1 Non-Thorny and Creosotebush Dominated Thorny-Non-Thorny Mixed Types

Non-Spinescent plant species, especially creosotebush and half-shrubs such as snakeweed and burroweed, clearly dominate the appearance of the type. If thorny species are present, they are only a minor component of the vegetation.

322.2 Creosotebush Types

Larrea Tridentata (Latr).

323.11 "Pure" Creosotebush Types

Annual species are typically the only other associated plants.

323.12 Creosotebush-Halfshrub Types

Typical halfshrubs are bursage, *Franseria deltoides* (Frde)* and desert zinnia, *Zinnia pumila* (Zipu).

*Recently classified as *Ambrosia deltoids* (Ande).

323.13 Creosotebush-Saltbush Types

Larrea tridentata-Atriplex spp.

Latr-ATRIP.

322.3 Halfshrub Types

Low (under ½ meter) woody, perennials are the dominant growth form.

323.21 Snakeweed or burroweed

Gutierrezia spp. or *Halopappus* spp.

GUTIE or HAPLO

323.22 Bursage

Franseria deltoidea Frde.

323.23 Desert Zinnia

Zinnia pumila Zipu.

322.4 Creosotebush dominated Thorny-Non-Thorny Mixed Types

Although thorny plant species are present, creosotebush still dominated the community.

323.31 Creosotebush-Cacti-Ocotillo

Larrea tridentata-Opuntis spp.-*Fouquieris splendens,*

Latr-OPUNT-Fosp

323.32 Creosotebush-Bursage-Cacti-Mesquite-Grass

Larrea tridentata-Franseria deltoides.

Opuntia spp.-Prosopis juliflora.

Latr-Frde-OPUNT-Prju

323.33 Creosote-Paloverde-Ocotillo

Larrea tridentata-Cercidium spp.-*Fouquieria splendens,*

Latr-CERCI-Fosp

323.39 Other Creosotebush Dominated Types

324 Thorny and Thorny-Non-Thorny Mixed Desert Scrub Thorny Plant Species Dominate

Thorny plant species dominate.

324.1 Paloverde Types with Creosotebush

Although creosotebush is present, it is either co-dominate or subordinate to paloverde. Mesquite, if present, is definitely a subordinate species.

324.11 Paloverde-Creosote-Ocotillo

Cercidium microphyllum-Larrea tridentata- Fouquieria splendens.

Cemi-Latr-Fosp

324.12 Paloverde-Creosotebush-Whitethorn Acacia

Cercidium microphyllum-Larrea tridentata-Acacia constricta.

Cemi-Latr-Acco

324.13 Paloverde-Creosotebush-Ironwood-Bursage

Cercidium microphyllum-Larrea tridentata-Olneya tesota-Franseria deltiodes.

Cemi-Latr-Olte-Frde

324.2 Paloverde Types Without Creosotebush

324.21 Paloverde-Ocotillo

Cercidium microphyllum-*Fouquieria splendens.*

Cemi-Fosp

324.22 Paloverde-Ocotillo-Jojoba-Bursage

Cercidium microphyllum-*Fouquieria splendens*

Simmondsia chinensis-Franseria deltoides.

Cemi-Fosp-Sich-Frde

324.23 Paloverde, No Ocotillo

Cercidium spp.

CERCI

324.24 Paloverde-Organpipe Cactus

Cercidium spp. – Lemaireucereus thurberi

CERCI-Leth

324.3 Mesquite Types

Paloverde, if present, is definitely a subordinate species.

324.31 Mesquite-Cholla-Halfshrub

Prosopis juliflora-Opuntia spp.-halfshrub

Prju-OPUNT-halfshrub

324.32 Mesquite-Halfshrub

Prosopis juliflora-halfshrub

Cacti, if present, are definitely subordinate.

Prju-halfshrub

324.33 Mesquite-Saltbush

Prosopis juliflora Atriplex spp.

Prju-ATRIP

324.34 Mesquite-Acacia

Prosopis juliflora-Acacia greggii or A. constricta

Prju-Acgr or Acco

324.35 Mesquite-Ironwood

Prosopis juliflora-Olneya tesota

Prju-Olte

324.39 Other Mesquite Types

324.4 Mixed Mesquite – Paloverde Types

324.41 Mesquite-Blue Paloverde-Chainfruit Cholla

Prosopis juliflora-Cercidium floridum-Opuntia fulgida

Prju-Cemi-Opfu

324.42 Mesquite-Foothills Paloverde-Chainfruit Cholla

Prosopis juliflora-Cercidium microphyllum-Opuntia fulgida.

Prju-Cemi-Opfu

324.43 Mesquite-Paloverde-Creosotebush

Prosopis juliflora-Cercidium microphyllum-Larrea tridentata

Prju-Cemi-Latr

324.44 Mesquite-Paloverde-Creosotebush-Jojoba

Prosopis juliflora-Cercidium microphyllum-Larrea tridentate-Simmondsia chinesis

Prju-Cemi-Latr-Sich

324.45 Mesquite-Paloverde

Prosopis juliflora-Cercidium spp.

Prju-CERCI

This subclass includes either or both of the species of paloverde.

324.46 Paloverde-Mesquite-Bursage-Ironwood

Cercidium microphyllum Prosopis juliflora-Franseris deltoida-Olneya tesota.

Cemi-Prju-Frde-Olte

324.47 Other Mixed Mesquite-Paloverde Types

325.5 Non-Mesquite-Paloverde Thorny Desert Scrub

325.51 Acacia Types

325.52 Octotillo-Fairyduster-Sotol

325.9 Other Thorny Desert Scrub Types

330 NON-DESERT SHRUB AND CHAPARRAL

Communities occurring at mid-elevations (3500-6500 feet) within the County; typical desert scrub species (320) do not dominate. Chaparral types ate dense shrublands comprised of this leaved evergreen species.

331 Arizona Chaparral

This dense shrub type occurs above 5000 feet and is characterized by such species as scrub oak (*Quercus terbinella*), manzanta (Archstaphylos spp.), sumacs (*Rhus* spp.), wait-a-minute bush (*Mimosa biuncifera*), yuccas, agaves, and other evergreen shrubs.

332 Non-Desert Shrub

This type also occursa above 3500 feet and is characterized by such species as agaves, sotol (*Dasylirion Wheeleri*), beargrass (*Nolina microcarpa*), fairyduster (*Calliandra eriophylla*), turpentine bush (*Happlopappus Laricifolius*), and usually scattered junipers or oaks on mesic slopes. In this project, Chihuahuan Desert Scrub species such as sandpaper bush (*Mortonia scabrella*) were included in this type. Only one subtype was distinguished.

332.1 Sandpaper Bush-Fairyduster-Agava

Mortonia scabrella-Calliandra eriophylla

Agave spp.

Mosc-Caer-AGAVE

339 Other Non-Desert Shrub

340 SAVANNA, SAVANNA-LIKE TYPES AND SHRUB GRASSLANDS

Any area covered by vegetation of any two major life forms (trees, shrubs, herbs), with the herbaceous layer being dominant. This category is distinguished from HERBACEOUS TYPES, 310, because the shrub and/or tree crown cover is greater than five percent.

341 Shrub Grassland

Any non-tree woody perennial species occurring as a subordinate cover plant over a predominately herbaceous layer, which is typically grass. The shrubs can include cacti and halfshrubs.

342 Deciduous Tree Savanna

Typically mesquite and/or acacia trees occurring as widely spread canopy plants in a grassland community.

343 Evergreen Tree Savanna

Oak, juniper, and/or pine forms the subordinate canopy in these grasslands.

343.1 Encinal Types – Oak, *Quercus*

343.2 Coniferous Types – Pine and Juniper

343.3 Mixed Evergreen Tree Savanna

349 Other Savanna or Savanna-Like Types

Appendix C
BLP Series Descriptions for Pima County

Pima County supports approximately over 23 different BLP series due to a varied topography, climate and biogeographic position. BLP Series are described by typical plant communities found within a biome. Natural, climax (mature) plant species are usually used to name a series. Within the series, there are distinctive plant associations based on the occurrence of particular dominant or co-dominant species.

Except where noted, series descriptions are modified from Bennett, Kunzmann, and Graham, 1999.

122.41 Pinyon-Juniper Series (Great Basin Conifer Woodland)

The pinyon-juniper series occurs at elevations between 4000 and 7000 feet. Typical sites range from slick rock (sandstone), to gravelly shallow soils, to steep slopes. Soils are usually shallow, rocky and well-drained. Dominant plants are Pinyon (*Pinus edulis*, *P. fallax*) and Juniper (*Juniperus* sp.), typically small trees with crowns round to oval in shape. The Pinyon component tends to increase with increasing elevation (effective moisture). The understory is composed of sclerophyllous (thick-leaved), evergreen shrubs (oak, mountain mahogany, manzanita, etc.) ranging from 3 to 6 feet tall. Perennial grasses and smaller shrubs may also occur as understory in this series.

An example of this series can be found on the Mount Lemmon Highway.

122.61 Douglas-Fir-Mixed Conifer Series (Madrean Montane Conifer Forest Biome)

This series is found at elevations between 6000 and 8700 feet, but may extend lower on north facing slopes or in deep canyons. Soils are usually shallow, rocky, and either igneous or sedimentary in origin. Dominant species include Douglas Fir (*Pseudotsuga menziesii*), White Fir (*Abies concolor*) and any of several pines (Pinus sp.). Fire plays a role in maintaining typical stand structure and age classes. The presence of aspen, oaks, and manzanita are indicators of frequent fire. Mature mixed conifer forests are often dense, with high canopy coverage and heavy litter layer which restricts growth (Brown). All of Arizona's major mountain ranges have this series, but it is best developed on the White Mountains.

An example of this series type can be found on Catalina Highway near Bear Canyon (Lowe).

122.62 Pine Series (Madrean Montane Conifer Forest Biome)

This series occurs at elevations between 7000 and 8400 feet. The pine community is found on warmer, less protected south, west, and southwest facing slopes or flats. This series abuts the Spruce-Fir Series upslope and the Madrean Oak-Pine Series below. The forest burns periodically, killing less fire-tolerant species, and creating an open park-like effect. Fire frequency has declined markedly with the colonization of the region by Europeans (Allen and Swetnam 1999, Covington et al. 1994). There are three primary types of yellow pine found in this series: Apache Pine (*Pinus engelmannii*), Arizona Pine (*Pinus arizonica*), and Ponderosa Pine (*P. ponderosa*). Oak are common understory trees, including Silver-leaf Oak *(Quercus hypoleucoides),* Arizona White Oak *(Q. arizonica),* and Gambel Oak *(Q. gambellii).* This association is commonly found near Flagstaff, and also typified at the San Pedro Vista on the Catalina Highway (Lowe). Pines may grow to 80 feet high in favorable conditions.

123.31 Encinal Oak (Madrean Evergreen Forest Biome)

Encinal is derived from the spanish: 'encino'-live oak, and 'al'-place of. This series is found at 4500 to 6000 feet in elevation in Arizona. Encinal occupies thin, coarse-textured (stony) soils. Five types of live-oaks (drought deciduous) occur in variable proportions: Silver-leaf Oak *(Quercus hypoleucoides),* Arizona White Oak *(Q. arizonica),* Netleaf Oak *(Q. rugosa),* Emory Oak (*Q. emoryi*), and, often, Alligatorbark Juniper (*Juniperus deppeana*). At lower elevations the trees are less dense, giving an open, woodland aspect with a herbaceous understory of grasses and shrubs. At higher elevations, the tree canopy may be nearly closed and a layer of shrubs maybe present beneath the tree canopy. Encinal is usually of relatively low stature, often under 29 feet.

123.32 Oak-Pine Series (Madrean Evergreen Forest Biome)

This series occurs between 5500 and 7500 feet on gently to moderately steep slopes and may extend into cool canyons. Soils are deep and well-drained, derived from volcanic (igneous) substrates. This series lies below the Pine and above the Encinal Series. Winter temperatures are mild and snowfall is light. The dominant trees are pines (*Pinus* sp.), sometimes with Arizona Cypress (*Cupressus arizonica*). Tree crowns may reach 39 to 79 feet high at maturity. Sub-dominate trees are various oaks, pinyon, juniper (*J. deppeana, J. scopulorum*), and occasionally Madrone (*Arbutus* sp.) ranging from 17 to 49 feet high at maturity. Dominant trees do not form a closed canopy. The subdominant tree layer is usually open. The stand structure may include several distinct layers of vegetation. Animal and plant species diversity in this series is high.

133.32 Manzanita Series (Mogollon Chaparral Scrubland)

This series is widely distributed between elevations of 4100 and 8500 feet. It occurs on non-calcareous soils from the Grand Canyon National Park south to the Chiricuahua Mountains. This series is successional, often forming extensive, nearly pure manzanita (*Arctostaphylos pungens*) stands within the Encinal and Pinyon-Pine Series. Such stands appear to be quickly replaced with tree dominated vegetation, although manzanita remain. Typical stands of this type are dense, woody stands of uneven shrubs usually 3 to 6 feet high. Grasses are usually present between shrub clumps. This type may be seen on the Mt. Lemmon Highway near astronomy lookout.

133.36 Mixed Evergreen Sclerophyll (Mogollon Chaparral Scrubland)

This series occurs from 4100 to 8500 feet in elevation, from the Grand Canyon to the Chiricahua Mountains. This series abuts the Encinal and Juniper-Pine Series. Dominants include Scrub oak (*Quercus turbinella*), manzanita, Mountain-lilac (*Ceanothus greggi),* Mountain Mahogany *(Cercarpus* sp.) Sumac (Rhus sp.), and many other shrubs. Typical stands are clumpy and dense with an uneven canopy about 3 to 8 ft. in height. Vegetation may be a fire disclimax, though none of the plants are extremely flammable. *Arcotostaphylos pungens*, *Ceanothus* sp., and *Cercocarpus* sp. produce seeds which seldom germinate without being fire scarified.

Where moisture is sufficient and deep soils are present, dense scrub typically covers 70 to 85 percent of the ground. This series generalizes and categorizes all of the Arizona chaparral, other than those dominated by manzanita. The Chaparral communities are small, patchy, and fine grained. Examples of Mixed-Evergreen Scelerophyll can be found in the Rincon Mountains near Devil's bathtub and Heartbreak Ridge Trail.

143.12 Sacaton-Scrub

Semi-desert grassland adjoins 3 Arizona deserts: The Chihuahuan, Sonoran, and Mohave deserts, but has the greatest affinity for the Chihuahuan Desert. This series is widely distributed. Dominant grasses occur on semi-saline as well as normal soils. Best developed on floodplains, bolsons, and intermittent drainages. This series varies from nearly closed to open stands of perennial grasses dominated by taller, coarse perennial bunch-grass, scattered shrubs, and short trees. An example of this grassland can be found on the Empire Ranch in southeast Pima County.

143.15 Mixed Grass-Scrub

This series occurs between 3500 to 4900 feet in elevation on a variety of soils. This semidesert grassland adjoins Sonoran, Mojave and Chihuahuan desertscrub, but like the Sacaton Series, has the greatest affinity with the Chihuahuan Desert. This is the most important type of grassland in the state.

Cattle grazing during the last 200 years has altered the appearance of this grassland, in some cases extremely. Heavy grazing reduced bunch grass vigor, disturbed soil encouraged establishment of annual grasses, and favored growth of plants unpalatable to cattle. Suppression of fires has protected non-fire resistant plants at the expense of fire-tolerant grasses. Even light fire will check the growth and spread of these thin barked species, such as mesquite. Heavy grazing and fire exclusion have permitted proliferation of invasive shrubs and cacti.

Mixed stands of perennial bunch-grasses and annual grasses of uniform statue with scattered shrubs and succulents. Total vegetation cover ranges from 15 to 85 percent. Grass height ranges from .9 to 2 feet tall, with shrubs reaching up to 9 feet tall. During good winter rain years, this series has a spectacular wildflower display. An example of this grassland can be found in the Empire Ranch area.

143.16 Shrub-Scrub Disclimax Series

The Shrub-Scrub Disclimax Series occurs in the 143.1 Scrub-Grassland (Semidesert Grassland) biome. Historically, this biome consisted of perennial bunch grasses separated by bare ground. Heavy grazing has altered this structure and has been displaced with annuals and low-growing sod grasses. This series (Shrub-Scrub Disclimax) usually occurs in areas with higher summer rainfall than winter, and indicate an increase in shrubs, small trees, and cacti replacing and outnumbering grasses (Guertin 1998). Species commonly occurring in this series include Velvet Mesquite (*Prosopis velutina*), One-seed Juniper (*Juniperus monosperma*), Graythorn (*Ziziphus obtusifolia*), Ocotillo (*Fouquieria splendens*), Yucca species, and *Opuntia* species (Guertin 1998). This series can be seen in many areas that have been overgrazed by cattle.

153.21 Creosote-Tarbush Series

This series is found in the Chihuahuan Desert, in elevations between 4000 and 5000 feet in the southeastern portion of Pima County. The vegetation averages 3 feet tall with some taller plants. Widespread scrub series include Creosote Bush (*Larrea tridentata*), Mariola (*Parthenium incanum*), Acacia (*Acacia constricta*), and Narrow-leaf Yucca (*Yucca elata)*. Tarbush (*Flourensia cernua*) is uncommon or absent in Pima County. This series is found near the Cienega Creek Natural Preserve and Empirita Ranch; historic photographs show this was Mixed Grass-Mixed Scrub series.

153.26 Mixed Scrub

This series is found on rocky south and west facing foothill slopes with shallow rocky soil in between elevations of 4200 and 5200 feet. The soil is derived from tuffs and other acidic extrusive volcanics. Ocotillo (*Fouquieria splendens*), False Mesquite (*Calliandra eriophylla*), Cane Cholla (*Opuntia spinosior*), Prickly Pear (*O. phaeacantha*), Velvet Mesquite (*Prosopis velutina*), Lippia (*Aloysia wrightii*) and Cat-claw Acacia (*Acacia greggii*) are common species in this series. Velvet mesquite and acacia are more often found in xeroriparian washes. Shrub height varies from 0.5 to 6.5 feet with shrub cover ranging from 10 to 40 percent. Herbaceous cover varies from 20 to 40 percent. The series includes xeroriparian associations which are important to vertebrates whose density and diversity is 2 to 3 times greater in these areas than the surrounding desert. This series occurs on hillsides in the Empire-Cienega Ranch.

154.11 Creosote-Bursage Series

This series is widespread throughout the Sonoran Desert. It occurs on level to gently sloping soils of silty or sandy texture at elevations between 1080 to 3200 feet. Typically found on bajadas and in dry desert valleys often on desert pavement. Stands are typically very open, with widely spaced plants. Dominant species in this series includes triangle leaf bursage (*Ambrosia deltoidea*), White Bursage (*Ambrosia dumosa*), Creosotebush (*Larrea tridentata*), Jumping Cholla (*Opuntia fulgida*), Saguaro (*Carnegiea gigantea*), and Ocotillo (*Fouquieria splendens*). Dominants may occur in monotypic stands, or in mixed stands. This series abuts the Paloverde-Mixed Cacti and the Saltbush Series. The distribution of the several series of Sonoran Desertscrub is based largely upon soil types.

154.12 Palo Verde-Mixed Cacti Series

This series typifies the Sonoran Desert and is found in elevations from 1075 to 3500 feet. The series develops on rock soils of middle and upper bajadas where soils are well-drained and of cobbly, gravelly texture. This series abuts the Creosotebush-Bursage Series and the Saltbush Series. Species found in this series include Saguaro, Foothills Paloverde (*Cercidium microphyllum*), Triangle-leaf Bursage, Ironwood (*Olneya tesota*), and Velvet Mesquite. This series include a diverse mixture of leguminous trees, shrubs, and cacti. Vegetation cover ranges from 15 to 45 percent. The height of the trees range from 9 to 20 feet, with cacti heights ranging from 0.4 to 27 feet tall. An example of this series can be found throughout much of Tucson but is exemplified in Saguaro National Park.

154.17 Saltbush Series

This series was once widely distributed over the southwestern and western portions of Arizona, but has been reduced by conversion to agriculture. This series is found in scattered patches, often in dry valley floors. Saltbush series are found on fine-textured soils which are easily detached. Severe erosion is seen in grazed stands. Soils of this community tend to be alkaline due to the high evaporation rate and closed-basin drainage typical of this series's range. The Saltbush Series is commonly found adjacent to the Creosote-Bursage Series and less commonly near the Palo Verde-Mixed Cacti Series.

Plant families common in this series include Chenopodiaceae and Amaranathaceae, and also include plant species that are indicators of disturbance, Russian thistle, *Suaeda* (Seepweed), *Atriplex* (Saltbush), *and Amaranthus* (Amaranth). Weedy species may be expected in grazed or farmed areas in this series. Vegetative cover varies from 10 to 20 percent. Disturbed communities may have almost 100 percent cover. Shrub stands are usually uniform with shrub heights of 2 to 3 feet. This series usually has low species diversity. Examples of this series can be found in the floodplain above the Santa Cruz River off of Ina Road, and northwest of the parking lot in Christopher Columbus Park.

223.21 Cottonwood-Willow Series

This series is found at elevations between 4000 and 5500 feet. This community is typically exposed to full sunlight and warm, dry air, and is found on open mesoriparian canyons or on bajadas. Species found in this series include Fremont cottonwood (*Populus fremontii*), Goodding Willow (*Salix gooddingii*), Velvet Ash (*Fraxinus velutina*), and Netleaf Hackberry (*Celtis reticulata*). This series is an open to very open broadleaf deciduous forest with total vegetation cover of 30 to 70 percent. An example of this series can be found along the Santa Cruz River in the vicinity of Tubac and upstream.

223.22 Mixed Broadleaf Series

This riparian series is typically found at elevations of 4000 to 6000 feet in sheltered hydro- and mesoriparian canyons and washes where humidity is high. Species diversity is very high with the most important trees being Fremont Cottonwood, Goodding Willow, Velvet Ash, Arizona Black Walnut (*Juglans major*), and Arizona Sycamore (*Platanus wrightii*). This series is important for wildlife. This type can be seen in Pine and Sabino Canyons.

224.52 Mesquite Series

This riparian series occurs at low to middle-elevations (1,500-4,000 ft) along desert washes and intermittent streams where subsurface water is sufficient to support common overstory species such as Velvet Mesquite and Netleaf Hackberry. Along perennial and intermittent streams, this type may occupy a higher elevation stream terrace, located above cottonwood-willow riparian habitats. Stands may be dominated by mesquite, or contain many other associated species, most commonly: Desert Hackberry (*Celtis pallida*), Net-leaf Hackberry (*Celtis reticulata*), Mexican

Elderberry (*Sambucus mexicana*), and *Acacia* sp. Understory species consist of Wolfberry (*Lycium spp.*), Graythorn (*Ziziphus obtusifolia*), and other grasses and forbs. These areas typically form bosques, with mesquite trees forming a closed upper canopy and an open or dense understory. Mesquite bosques are found on old alluvial floodplains. Typically, bosques require groundwater no deeper than 45 feet. Mesquite bosques once lined the major watercourses of Arizona, although almost 90 percent of the bosques have been cut for firewood, charcoal, or converted to agricultural use.

Examples of this type may be found along Pantano Wash and the upper Rillito Creek.

224.53 Cottonwood-Willow Series

Found between elevations of 1075 and 2500 feet, this series occurs along hydro- and mesoriparian drainages. This forest type formally lined perennial and intermittent streams throughout lower elevations in Arizona. Over 90 percent of the historic area of this plant community has been lost due to the lowering of the water table by groundwater pumping. This series is highly diverse and is of high value to wildlife.

Plants commonly found in this series include Fremont Cottonwood, Cat-Claw Acacia, Goodding Willow, Sandbar Willow (*Salix exigua*), Canyon Grape (*Vitis arizonica*), and seep willow (*Baccharis* sp.). Typical stands are dense with multiple canopy layers; often grass/forb, shrub, and one or two tree canopy layers.

234.71 Mixed Scrub Series

This is an uncommon series found in southwestern Arizona. Confined to areas with abundant moisture, these habitats are becoming less common as riparian lands are converted to agriculture.

Plants found in this community include Catclaw Acacia, Burrobush (*Hymenoclea monogyra*), Desert Hackberry (*Celtis pallida*), Desert Broom (*Baccharis sarothroides*), and various Mesquite species. Shrub height averages 4 to 7 feet, with scattered plants reaching 12 feet tall. Total vegetative cover can vary from 50 to 100 percent.

244.71 Cattail Series

Cattail communities are typical along the shores of ponds or lakes with a stable water level at all elevations between 1075 and 6000 feet. Cattails are less commonly found around springs and cienegas, especially those with constant water levels. Soils are typically anaerobic or hydric.

Cattail species (*Typha latifolia or T. domingensis*) are dominant, but may be mixed with Bulrush species (*Scirpus spp.*), Reed (*Juncus spp.*), and Sedge (*Carex spp.)* species. This series generally forms closed single-layer stands of perennial plants reaching heights of 5 to 16 feet. Total vegetation cover is 30 to 100 percent. This series occurs at Arivaca Cienega.

244.75 Saltgrass Series

This series occurs in the Sonoran Interior Marshland Biome. The dominant species is Saltgrass (*Distichlis spicata*), a short, rhyzomatous grass that can form monotypic stands. The type is typical of areas with fine soils that are periodically flooded or saturated and tend to be alkaline. The Saltgrass Series occurs in Organ Pipe Cactus National Monument near Quitobaquito Springs and several other springs in the Monument.