APPENDIX A. DESCRIPTIONS OF VEGETATION ASSOCIATIONS

The following vegetation information was adapted from the *Southwest Regional GAP Analysis Project—Land Cover Data Legend Descriptions* (USGS 2005) and was used to analyze vegetation associations composing the WUI of the Maricopa County CWPP. For additional information, see the Southwest Regional Landcover Data Web site (http://ftp.nr.usu.edu/swgap/landcover.html).

DESERT SHRUB-SCRUB ASSOCIATIONS

S070 Sonora-Mohave Mixed Salt Desert Scrub

Concept Summary: This system includes extensive open-canopied shrublands of typically saline basins in the Mojave and Sonoran deserts. Stands often occur around playas. Substrates are generally fine-textured saline soils. Vegetation is typically composed of one or more *Atriplex* species such as *Atriplex canescens* or *Atriplex polycarpa* along with other species of *Atriplex*. Species of *Allenrolfea, Salicornia, Suaeda*, or other halophytic plants are often present to codominant. Graminoid species may include *Sporobolus airoides* or *Distichlis spicata* at varying densities.

S129 Sonoran Mid-elevation Desert Scrub

Concept Summary: This transitional desert scrub system occurs along the northern edge of the Sonoran Desert in an elevational band along the lower slopes of the Mogollon Rim/Central Highlands region between 750–1,300 m. Stands occur in the Bradshaw, Hualapai, and Superstition mountains among other desert ranges and are found above Sonoran Paloverde-Mixed Cacti Desert Scrub (CES302.761) and below Mogollon Chaparral (CES302.741). Sites range from a narrow strip on steep slopes to very broad areas such as the Verde Valley. Climate is too dry for chaparral species to be abundant, and freezing temperatures during winter are too frequent and prolonged for many of the frost-sensitive species that are characteristic of the Paloverde Mixed-Cacti Desert Scrub such as *Carnegiea gigantea, Parkinsonia microphylla, Prosopis* spp., *Olneya tesota*, *Ferocactus* sp., and *Opuntia bigelovii*. Substrates are generally rocky soils derived from parent materials such as limestone, granitic rocks, or rhyolite. The vegetation is typically composed of an open shrub layer of *Larrea tridentata, Ericameria linearifolia*, or *Eriogonum fasciculatum* with taller shrubs such as *Fourqueria splendens*, *Canotia holacantha* (limestone or granite), or *Simmondsia chinensis* (rhyolite). The herbaceous layer is generally sparse.

S063 Sonoran Paloverde-Mixed Cacti Desert Scrub

Concept Summary: This ecological system occurs on hillsides, mesas, and upper bajadas in southern Arizona and extreme southeastern California. The vegetation is characterized by a diagnostic sparse, emergent tree layer of *Carnegiea gigantea* (3–16 m tall) and/or a sparse to moderately dense canopy codominated by xeromorphic deciduous and evergreen tall shrubs *Parkinsonia microphylla* and *Larrea tridentata* with *Prosopis* sp., *Olneya tesota*, and *Fouquieria splendens* less prominent. Other common shrubs and dwarf-shrubs include *Acacia greggii*, *Ambrosia deltoidea*, *Ambrosia dumosa* (in drier sites), *Calliandra eriophylla, Jatropha cardiophylla, Krameria erecta, Lycium* spp., *Menodora scabra,* and *Simmondsia chinensis* and many cacti including *Ferocactus* spp., *Echinocereus* spp., and *Opuntia* spp.

(both cholla and prickly pear). The sparse herbaceous layer is composed of perennial grasses and forbs with annuals seasonally present and occasionally abundant. On slopes, plants are often distributed in patches around rock outcrops where suitable habitat is present.

S062 Chihuahuan Creosotebush, Mixed Desert, and Thorn Scrub

Concept Summary: This widespread Chihuahuan Desert land cover type is composed of two ecological systems the Chihuahuan Creosotebush Xeric Basin Desert Scrub (CES302.731) and the Chihuahuan Mixed Desert and Thorn Scrub (CES302.734). This cover type includes xeric creosotebush basins and plains and the mixed desert scrub in the foothill transition zone above, sometimes extending up to the lower montane woodlands. Vegetation is characterized by *Larrea tridentata* alone or mixed with thorn scrub and other desert scrub such as *Agave lechuguilla, Aloysia wrightii, Fouquieria splendens, Dasylirion leiophyllum, Flourensia cernua, Leucophyllum minus, Mimosa aculeaticarpa* var. *biuncifera, Mortonia scabrella (= Mortonia sempervirens* ssp. *scabrella), Opuntia engelmannii, Parthenium incanum, Prosopis glandulosa*, and *Tiquilia greggii*. Stands of *Acacia constricta, Acacia neovernicosa,* or *Acacia greggii* dominated thornscrub are included in this system, and limestone substrates appear important for at least these species. Grasses such as *Dasyochloa pulchella, Bouteloua curtipendula, Bouteloua eriopoda, Bouteloua ramosa*, *Muhlenbergia porter,* and *Pleuraphis mutica* may be common but generally have lower cover than shrubs.

S069 Sonoran Mohave Creosotebush-White Bursage Desert Scrub

Concept Summary: This ecological system forms the vegetation matrix in broad valleys, lower bajadas, plains, and low hills in the Mojave and lower Sonoran deserts. This desert scrub is characterized by a sparse to moderately dense layer (2%–50% cover) of xeromorphic microphyllous and broad-leaved shrubs. *Larrea tridentata* and *Ambrosia dumosa* are typically dominants, but many different shrubs, dwarf-shrubs, and cacti may codominate or form typically sparse understories. Associated species may include *Atriplex canescens, Atriplex hymenelytra, Encelia farinosa, Ephedra nevadensis, Fouquieria splendens, Lycium andersonii*, and *Opuntia basilaris*. The herbaceous layer is typically sparse but may be seasonally abundant with ephemerals. Herbaceous species such as *Chamaesyce* spp., *Eriogonum inflatum, Dasyochloa pulchella, Aristida* spp., *Cryptantha* spp., *Nama* spp., and *Phacelia* spp. are common.

SHRUBLANDS ASSOCIATIONS

S058 Apacherian-Chihuahuan Mesquite Upland Scrub

Concept Summary: This ecological system occurs as upland shrublands that are concentrated in the extensive grassland-shrubland transition in foothills and piedmont in the Chihuahuan Desert. It extends into the Sky Island region to the west and the Edwards Plateau to the east. Substrates are typically derived from alluvium, often gravelly without a well-developed argillic or calcic soil horizon that would limit infiltration and storage of winter precipitation in deeper soil layers. *Prosopis* spp. and other deep-rooted shrubs exploit this deep soil moisture that is unavailable to grasses and cacti. Vegetation is typically dominated by *Prosopis glandulosa* or *Prosopis velutina* and succulents. Other desert scrub that may codominate or dominate includes *Acacia neovernicosa, Acacia constricta, Juniperus monosperma*, or *Juniperus coahuilensis*. Grass cover is typically low. During the last century, the area occupied by this system has increased through conversion of desert grasslands as a result of drought, overgrazing by livestock, and/or decreases in fire frequency. It is similar to Chihuahuan Mixed Desert and Thorn Scrub (CES302.734) but is generally found at higher elevations where *Larrea tridentata* and other desert scrub are not codominant. It is also similar to Chihuahuan Stabilized Coppice Dune and Sand Flat Scrub (CES302.737) but does not occur on eolian-deposited substrates.

GRASSLANDS ASSOCIATIONS

S077 Apacherian-Chihuahuan Piedmont Semi-Desert Grassland and Steppe

Concept Summary: This ecological system is a broadly defined desert grassland, mixed shrub-succulent, or xeromorphic tree savanna that is typical of the borderlands of Arizona, New Mexico, and northern Mexico [Apacherian region] but that extends west to the Sonoran Desert, north into the Mogollon Rim, and throughout much of the Chihuahuan Desert. It is found on gently sloping bajadas that supported frequent fire throughout the Sky Islands and on mesas and steeper piedmont and foothill slopes in the Chihuahuan Desert. It is characterized by typically diverse perennial grasses. Common grass species include *Bouteloua eriopoda, B. hirsuta,B. rothrockii, B. curtipendula, B. gracilis, Eragrostis intermedia, Muhlenbergia porteri, Muhlenbergia setifolia, Pleuraphis jamesii, Pleuraphis mutica*, and *Sporobolus airoides*; succulent species of *Agave, Dasylirion*, and *Yucca*; and tall shrub/short tree species of *Prosopis* and various oaks (e.g., *Quercus grisea, Quercus emoryi, Quercus arizonica*). Many of the historical desert grassland and savanna areas have been converted, some to Chihuahuan Mesquite Woodlands Vegetation Associations.

WOODLANDS ASSOCIATIONS

S057 Mogollon Chaparral

Concept Summary: This ecological system occurs across central Arizona (Mogollon Rim), western New Mexico, southwestern Utah, and southeast Nevada. It often dominates along the mid-elevation transition from the Mojave, Sonoran, and northern Chihuahuan deserts into mountains (1,000–2,200 m). It occurs on foothills, mountain slopes, and canyons in drier habitats below the encinal and *Pinus ponderosa* woodlands. Stands are often associated with more xeric and coarse-textured substrates such as limestone, basalt, or alluvium, especially in transition areas with more mesic woodlands. The moderate to dense shrub canopy includes species such as *Quercus turbinella, Quercus toumeyi, Cercocarpus montanus, Canotia holacantha, Ceanothus greggii, Forestiera pubescens (= Forestiera neomexicana), Garrya wrightii, Juniperus deppeana, Purshia stansburiana, Rhus ovata, Rhus trilobata*, and *Arctostaphylos pungens,* and *Arctostaphylos pringlei* at higher elevations. Most chaparral species are fire adapted, resprouting vigorously after burning or producing fire-resistant seeds. Stands occurring within montane woodlands are seral and a result of recent fires.

S051 Madrean Encinal

Concept Summary: Madrean Encinal occurs on foothills, canyons, bajadas, and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, extending north into Trans-Pecos Texas, southern New Mexico, and sub-Mogollon Arizona. These woodlands are dominated by Madrean evergreen oaks along a low-slope transition below Madrean Pine-Oak Forest and Woodland (CES305.796) and Madrean Pinyon-Juniper Woodland (CES305.797). Lower elevation stands are typically open woodlands or savannas where they transition into desert grasslands, chaparral, or, sometimes, desert scrub. Common evergreen oak species include *Quercus arizonica, Quercus emoryi, Quercus intricata, Quercus grisea, Quercus oblongifolia*, *Quercus toumeyi,* and, in Mexico, *Quercus chihuahuaensis* and *Quercus albocincta*. Madrean pine, Arizona cypress, pinyon, and juniper trees may be present but do not codominate. Chaparral species such as *Arctostaphylos pungens, Cercocarpus montanus, Purshia* spp*., Garrya wrightii, Quercus turbinella, Frangula betulifolia (= Syn Rhamnus betulifolia),* or *Rhus* spp*.* may be present but do not dominate. The graminoid layer usually prominent between trees is grassland or steppe that is dominated by warm-season grasses such as *Aristida* spp., *Bouteloua gracilis, Bouteloua curtipendula, Bouteloua rothrockii, Digitaria californica, Eragrostis intermedia, Hilaria belangeri, Leptochloa dubia, Muhlenbergia* spp., *Pleuraphis jamesii*, or *Schizachyrium cirratum;* these species are typical of Chihuahuan Piedmont Semi-Desert Grassland (CES302.735). This system includes seral stands dominated by shrubby Madrean oaks typically with strong graminoid layer. In transition areas with drier chaparral systems, stands of chaparral are not dominated by Madrean oaks, however Madrean encinal may extend down along drainages.

S112 Madrean Pinyon-Juniper Woodland

Concept Summary: This system occurs on foothills, mountains, and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, in Trans-Pecos Texas, in southern New Mexico, and in southern and central Arizona from the Mogollon Rim south to the Sky Islands. Substrates are variable, but soils are generally dry and rocky. The presence of *Pinus cembroides, Pinus discolor*, or other Madrean trees and shrubs is diagnostic of this woodland system. *Juniperus coahuilensis, Juniperus deppeana, Juniperus pinchotii, Juniperus monosperma*, and/or *Pinus edulis* may be present to dominant. Madrean oaks such as *Quercus arizonica, Quercus emoryi*, *Quercus grisea,* or Quercus mohriana may be codominant. *Pinus ponderosa* is absent or sparse. If present, understory layers are variable and may be dominated by shrubs or graminoids

S115 Madrean Juniper Savanna

Concept Summary: This Madrean ecological system occurs in lower foothills and plains of southeastern Arizona, southern New Mexico, and extending into west Texas and Mexico. These savannas have widely spaced mature juniper trees and moderate to high cover of graminoids (>25% cover). The presence of *Madrean Juniperus* spp. such as *Juniperus coahuilensis, Juniperus pinchotii*, and/or *Juniperus deppeana* is diagnostic. *Juniperus monosperma* may be present in some stands, and *Juniperus deppeana* has a range that extends beyond this Madrean system into southern stands of the Southern Rocky Mountain Juniper Woodland and Savanna (CES306.834). Stands of *Juniperus pinchotii* may be short and resemble a shrubland. Graminoid species are a mix of those found in the Western Great Plains Shortgrass Prairie

(CES303.672) and the Apachierian-Chihuahuan Piedmont Semi-Desert Grassland and Steppe (CES302.735), with *Bouteloua gracilis* and *Pleuraphis jamesii* being most common. In addition, these areas include succulents such as species of *Yucca, Opuntia*, and *Agave*. Juniper savanna expansion into grasslands has been documented in the last century.

S036 Rocky Mountain Ponderosa Pine Woodland

Concept Summary: This very widespread ecological system is most common throughout the cordillera of the Rocky Mountains. It is also found in the Colorado Plateau region, west into scattered locations in the Great Basin, and north into southern British Columbia. These woodlands occur at the lower treeline/ecotone between grassland or shrubland and more mesic coniferous forests typically in warm, dry, exposed sites. Elevations range from less than (Ecological Systems: Copyright © 2003 NatureServe) 48500 m in British Columbia to 2,800 m in the New Mexico mountains. Occurrences are found on all slopes and aspects; however, moderately steep to very steep slopes or ridgetops are most common. This ecological system generally occurs on igneous-, metamorphic-, and sedimentary-derived soils, with characteristic features of good aeration and drainage, coarse textures, circumneutral to slightly acid pH, an abundance of mineral material, rockiness, and periods of drought during the growing season. These woodlands in the eastern Cascades, Okanagan, and northern Rockies regions receive winter and spring rains, and thus have a greater spring "green-up" than the drier woodlands in the central Rockies. *Pinus ponderosa* is the predominant conifer; *Pseudotsuga menziesii, Pinus edulis*, and *Juniperus* spp. may be present in the tree canopy. The understory is usually shrubby, with *Artemisia nova, Artemisia tridentata, Arctostaphylos patula, Arctostaphylos uva-ursi, Cercocarpus montanus, Cercocarpus ledifolius, Purshia stansburiana, Purshia tridentata, Quercus gambelii, Symphoricarpos oreophilus, Prunus virginiana, Amelanchier alnifolia*, and *Rosa* spp. as common species. *Pseudoroegneria spicata* and species of *Hesperostipa, Achnatherum, Festuca, Muhlenbergia*, and *Bouteloua* are some of the common grasses. Mixed fire regimes and ground fires of variable return interval maintain these woodlands, depending on climate, degree of soil development, and understory density.

EVERGREEN FOREST TYPES

S035 Madrean Pine-Oak Forest and Woodland

Concept Summary: This system occurs on mountains and plateaus in the Sierra Madre Occidentale and Sierra Madre Orientale in Mexico, in Trans-Pecos Texas, in southern New Mexico, and in southern and central Arizona from the the Mogollon Rim southeastward to the Sky Islands. These forests and woodlands are composed of Madrean pines (*Pinus arizonica, Pinus engelmannii, Pinus leiophylla* or *Pinus strobiformis*) and evergreen oaks (*Quercus arizonica, Quercus emoryi,* or *Quercus grisea*) intermingled with patchy shrublands on most mid-elevation slopes (1,500–2,300 m elevation). Other tree species include *Cupressus arizonica, Juniperus deppeana, Pinus cembriodes, Pinus discolor, Pinus ponderosa* (with Madrean pines or oaks), and *Pseudotsuga menziesii*. Subcanopy and shrub layers may include typical encinal and chaparral species such as *Agave* spp., *Arbutus arizonica, Arctostaphylos pringlei, Arctostaphylos pungens, Garrya wrightii, Nolina* spp., *Quercus hypoleucoides, Quercus rugosa*, and

Quercus turbinella. Some stands have moderate cover of perennial graminoids such as *Muhlenbergia emersleyi, Muhlenbergia longiligula, Muhlenbergia virescens*, and *Schizachyrium cirratum*. Fires are frequent with perhaps more crown fires than ponderosa pine woodlands, which tend to have more frequent ground fires on gentle slopes.

DECIDUOUS SOUTHWEST RIPARIAN ASSOCIATIONS

S098 North American Warm Desert Riparian Mesquite Bosque

Concept Summary: This ecological system consists of low-elevation (<1,100 m) riparian corridors along intermittent streams in the valleys of southern Arizona and New Mexico and adjacent Mexico. Dominant trees include *Prosopis glandulosa* and *Prosopis velutina*. Shrub dominants include *Baccharis salicifolia, Pluchea sericea*, and *Salix exigua*. Vegetation, especially the mesquites, tap groundwater below the streambed when surface flows stop. Vegetation depends on annual rise in the water table for growth and reproduction.

S097 North American Warm Desert Riparian Woodland and Shrubland

Concept Summary: This ecological system consists of low-elevation (<1,200 m) riparian corridors along medium to large perennial streams throughout canyons and the desert valleys of the southwestern United States and adjacent Mexico. The vegetation is a mix of riparian woodlands and shrublands. Dominant trees include *Acer negundo, Fraxinus velutina, Populus fremontii, Salix gooddingii, Salix lasiolepis, Celtis laevigata* var. *reticulata*, and *Juglans major*. Shrub dominants include *Salix geyeriana, Shepherdia argentea*, and *Salix exigua*. Vegetation depends on annual or periodic flooding and associated sediment scour and/or annual rise in the water table for growth and reproduction.

D04 Invasive Southwest Riparian Woodland and Shrubland

Description: *Tamarix* spp. Semi-Natural Temporarily Flooded Shrubland Alliance (A842), or *Elaegnus angustifolus* Semi-Natural Woodland Alliance (A3566).

Tamarix spp. Semi-Natural Temporarily Flooded Shrubland Alliance

Translated Name: Saltcedar species Semi-natural Temporarily Flooded Shrubland Alliance
Unique Identifier: A.842
Classification Approach: International Vegetation Classification (IVC)

Concept Summary: This alliance is composed of shrublands that form moderately dense to dense thickets on banks of larger streams, rivers, and playas across the western Great Plains, interior and southwestern United States, and northern Mexico. Stands are dominated by introduced species of *Tamarix*, including *Tamarix ramosissima, Tamarix chinensis, Tamarix gallica*, and *Tamarix parviflora*. Introduced from the Mediterranean, *Tamarix* spp. have become naturalized in various sites, including salt flats, springs, and especially along streams and regulated rivers, often replacing *Salix* or *Prosopis* spp. shrublands or other native vegetation. A remnant herbaceous layer may be present, depending on the age and density of the shrub layer. These species have become a critical nuisance along most large rivers in the semi-arid western United States. Because of the difficulty to remove, *Tamarix* spp. may have irreversibly changed the vegetation along many rivers.

Classification Comments: This broadly defined alliance is composed of many diverse *Tamarix* spp.-dominated vegetation communities from a wide variety of environments. Common species of *Tamarix* include *Tamarix ramosissima, Tamarix chinensis*, and *Tamarix parviflora*, but other species are reported from the western United States, such as *Tamarix africana, Tamarix aphylla, Tamarix aralensis, Tamarix canariensis, Tamarix gallica*, and *Tamarix tetragyna*.

OTHER COVER TYPES AND NONVEGETATED ASSOCIATIONS: ALTERED, DISTURBED, AND DEVELOPED

N21 Developed, Open Space–Low Intensity

Concept Summary: *Developed Open Space* includes areas with a mixture of some construction materials but mostly includes vegetation in the form of lawn grasses. Impervious surfaces account for less than 20 percent of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes. *Developed, Low Intensity* includes areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20–49 percent of total cover. These areas most commonly include single-family housing units.

N22 Developed, Medium–High Intensity

Concept Summary: *Developed, Medium Intensity* includes ncludes areas with a mixture of constructed materials and vegetation. Impervious surface accounts for 50–79 percent of the total cover. These areas most commonly include single-family housing units. *Developed, High Intensity* includes highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses, and commercial/industrial. Impervious surfaces account for 80–100 percent of the total cover (National Land Cover Data) draft legend, July 25, 2003).

N31 Barren Land Types, Non-specific

Concept Summary: (Rock/Sand/Clay) Barren areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits, and other accumulation of earthen material. Generally, vegetation accounts for less than 15 percent of total cover.

N80 Agriculture

Concept Summary: Agriculture—unable to make distinction between N81 and N82.

S013 Inter-Mountain Basins Volcanic Rock and Cinderland

Concept Summary: This ecological system occurs in the Intermountain western United States and is limited to barren and sparsely vegetated volcanic substrates (generally <10% plant cover) such as basalt lava (malpais), basalt dikes with associated colluvium, basalt cliff faces and uplifted "backbones," tuff, cinder cones, or cinder fields. It may occur as large-patch, small-patch, and linear (dikes) spatial patterns. Vegetation is variable and includes a variety of species depending on local environmental conditions, for example, elevation, age, and type of substrate. At montane and foothill elevations scattered *Pinus ponderosa, Pinus flexilis*, or *Juniperus* spp. trees may be present. Shrubs such as *Ephedra* spp., *Atriplex canescens, Eriogonum corymbosum, Eriogonum ovalifolium*, and *Fallugia paradoxa* are often present on some lava flows and cinder fields. Species typical of sand dunes such as *Andropogon hallii* and *Artemisia filifolia* may be present on cinder substrates.

D03 Recently Mined or Quarried

Concept Summary: 2 hectare or greater; open-pit mining or quarries visible on imagery.

APPENDIX B. NATIONAL FIRE DANGER RATING SYSTEM FUEL MODEL SELECTION KEY

I. Mosses, lichens, and low shrubs predominate ground fuels

A. Overstory of conifers occupies more than one-third of the site

Model Q

B. No overstory, or it occupies less than one-third of the site

Model S

II. Marsh grasses and/or reeds predominate

Model N

III. Grasses and/or forbs predominate

A. Open overstory of conifer and/or hardwoods

Model C

B. No overstory

1. Woody shrubs occupy more than one-third but less than two-thirds of the site

Model T

2. Woody shrubs occupy less than two-thirds of the site

a. Grasses and forbs are primarily annuals

Model A

b. Grasses and forbs are primarily perennials

Model L

IV. Brush, shrubs, tree reproduction, or dwarf tree species predominate

A. Average height of woody plants is 6 feet or greater

1. Woody plants occupy two-thirds or more of the site

a. One-fourth or more of the woody foliage is dead

(1) Mixed California chaparral

Model B

(2) Other types of brush

Model F

b. Up to one-fourth of the woody foliage is dead

Model Q

c. Little dead foliage

Model O

2. Woody plants occupy less than two-thirds of the site

   Model F

B. Average height of woody plants is less than 6 feet

1. Woody plants occupy two-thirds or more of the site
   a. Western United States

      Model F

   b. Eastern United States

      Model O

2. Woody plants occupy less than two-thirds but greater than one-third of the site
   a. Western United States

      Model T

   b. Eastern United States

      Model D

3. Woody plants occupy less than one-third of the site
   a. Grasses and forbs are primarily annuals

      Model A

   b. Grasses and forbs are primarily perennials

      Model L

V. Trees predominate

A. Deciduous broadleaf species predominate

1. Area has been thinned or partially cut, leaving slash as the major fuel component

   Model K

2. Area has not been thinned or partially cut
   a. Overstory is dormant; leaves have fallen

      Model E

   b. Overstory is in full leaf

      Model R

B. Conifer species predominate

1. Lichens, mosses, and low shrubs dominate as understory fuels

   Model Q

2. Grasses and forbs are the primary ground fuel

   Model C

3. Woody shrubs and/or reproduction dominate as understory fuels
   a. Understory burns readily

(1) Western United States

Model T

(2) Eastern United States

(a) Understory is more than 6 feet tall

Model O

(b) Understory is less than 6 feet tall

Model D

b. Understory seldom burns

Model H

4. Duff and litter, branch wood, and tree boles are the primary ground fuel

a. Overstory is over mature and decadent; heavy accumulation of dead debris

Model G

b. Overstory is not decadent; only a nominal accumulation of debris

(1) Needles are 2 or more inches long (most pines)

(a) Eastern United States

Model P

(b) Western United States

Model U

(2) Needles are less than 2 inches long

Model H

VI. Slash predominates

A. Foliage is still attached; little settling

1. Loading is 25 tons/acre or greater

Model I

2. Loading is less than 25 tons/acre but greater than 15 tons/acre

Model J

3. Loading is less than 15 tons/acre

Model K

B. Settling is evident; foliage is falling off; grasses, forbs and shrubs are invading

1. Loading is 25 tons/acre or greater

Model J

2. Loading is less than 25 tons/acre

Model K

APPENDIX C. EDUCATIONAL RESOURCES

Firewise Information and Web Sites

Firewise Communities/USA national recognition program. http://www/Firewise.org/USA.

Wildfire Defense Get in the Zone, Reduce Your Risk of Wildfire, pamphlet. The FireFree Program, sponsored by SAFECO Corporation. http://www.Safeco.com/Safeco/about/giving/firefree.org.

Living with Fire—A Homeowners' Guide. A 12-page tabloid, which is produced regionally by US Department of Interior agencies (Bureau of Indian Affairs, Bureau of Land Management, Fish and Wildlife Service, National Park Service), the US Forest Service, and state land departments. This is one of the most detailed pieces of Firewise information for landowners to reference when creating survivable space around their homes. http://www.or.blm.gov/nwfire/docs/Livingwithfire.pdf.

Fire Information Clearinghouse, San Juan Public Lands Center. http://www.SouthwestColoradoFires.org.

Best Management Practices and Tools for Collaboration

The Collaboration Handbook, Red Lodge Clearinghouse. http://www.rlch.org/content/view/261/49.

Ecosystem management Initiative at the University of Michigan. http://wwwsnre.umich.edu/ecomgt.collaboration.htm.

Western Collaborative Assistance Network. http://www.westcanhelp.org.

BLM Partnership. http://www.blm.gov/partnerships/tools.htm.

Forest Service Partnership Resource Center. http://www.partnershipresourcescenter, org/index.shtml.

International Association of Fire Chief's Leader's guide for Developing a Community Wildfire Protection Plan. http://wwwcsfs.colostate.edu/librar/.pdfs/cwpp/CWPP_LG.pdf.

Joint Fire Sciences Collaboration and CWPP Presentation. http://www.jfsp.fortlewis.edu/KTWorkshops.asp.

Grant Web Sites

Southwest Area Forest, Fire, and Community Assistance Grants. This Web site lists grants that are available to communities to reduce the risk of wildfires in the urban interface. http://www.SouthwestAreaGrants.org.

Department of Homeland Security. This Web site lists granting opportunities for Staffing for Adequate Fire and Emergency Services (SAFER) grants and provides other useful information. http://www.firegrantsupport.com.

ESRI Grant Assistance program for GIS users. http://www.esri.com/grants.

US Fire Administration—Assistance to Firefighters Grant Program. http://www.usfa.fema.gove/dhtml/inside-usfa/grants.cfm.

National Association of State Foresters Listing of Grant Sources and Appropriations. http://www/stateforesters.org/S&PF/FY_2002.html.

Stewardship and Landowner Assistance—Financial Assistance Programs. http://www.na.fs.fed.us/spfo/stewardship/financial.htm.

The Fire Safe Council. http://www.FireSafeCouncil.org.

Pre-disaster Mitigation Program. http://www/cfda/gov/public/viewprog.asp?progid=1606.

Firewise. http://www.firewise.org/usa/funding.htm.

Environmental Protection Agency. http://cfpub.epa.gov/fedfund.

Rural Fire Assistance and other State Forestry Grants. http://www.azsf.az.gov/grant_information.

Grant opportunities. http://www.grants.gov.

Arizona Wildfire and the Environment Series

Firewise publications from the University of Arizona: *Forest Home Fire Safety*; *Fire-Resistant Landscaping*; *Creating Wildfire-Defensible Spaces for Your Home and Property*; *Homeowners' "Inside and Out" Wildfire Checklist*; *Firewise Plant Materials for 3000 Feet and Higher Elevations*; *Soil Erosion Control After a Wildfire*; *Recovering from Wildfire*; *A Guide for Arizona's Forest Owners*; *Wildfire Hazard Severity Rating Checklist for Arizona Homes and Communities*. http://cals.arizona.edu; http://cals.arizona.edu/pubs.

Monitoring and Evaluation Resources

US Forest Service Collaborative Restoration Program—Multiparty Monitoring Guidelines. http://www.fs.fed.us/r3/spf/cfrp/monitoring/index.shtml.

Rural Voices for Conservation Coalition – Multiparty Monitoring Issue Paper. http://www.ri.uoregon.edu/programs/CCE/communityfireplanning.html.

Other

Federal Emergency Management Agency (FEMA) State Hazard Mitigation Offices. http://www.floods.org/shmos.htm.

National Fire Plan. http://www.fireplan.gov/community_assist.crm.

National Fire Protection Association (NFPA) standards: NFPA 299 (*Standard for Protection of Life and Property from Wildfire*); NFPA 295 (*Standard for Wildfire Control*); NFPA 291 (*Recommended Practice for Fire Flow Testing and Marking of Hydrants*); NFPA 703 (*Standard for Fire Retardant Impregnated Coatings for Building Materials*); NFPA 909 (*Protection of Cultural Resources*); NFPA 1051 (*Standard for Wildland Fire Fighter Professional Qualifications*); NFPA 1144 (*Standard for Protection of Life and Property from Wildfire*); NFPA 1977 (*Standard on Protective Clothing and Equipment for Wildland Fire Fighting*). http://www.nfpa.org; http://www.nfpa.org/Catalog.

National Fire Lab. http://www.firelab.org/fbp/fbresearch/WUI/home.htm.

Protect Your Home from Wildfire, Colorado State Forest Service. Publications to help assist you with wildfire prevention. http://www.colostate.edu/Depts/CSFS/homefire.html.

US Fire Administration, FEMA, US Department of Homeland Security. http://www.usfa.fema.gov; http://www.fema.gov/regions/viii/fires/shtm; http://www.fema.gov/kidswldfire.

Fire Education Materials. http://www.symbols.gov.

National Interagency Fire Center, National Park Service fire Web site. http://www.nifc.nps.gov/fire.

"Fire Wars," PBS NOVA. http://www.pbs.org/wgbh/nova/fire.

D'Goat Ranch, LLC. Jason Garn. (801) 440-2149. Leasing and goat herding for vegetative mitigation projects.

Woody Biomass Utilization Desk Guide. http://www.forestsandrangelands.gov/woody_biomass/documents/biomass_deskguide.pdf.

Pamphlets

Saving Homes from Wildfires: Regulating the Home Ignition Zone, American Planning Association (APA), May 2001. This issue of the APA's Zoning News examines the wildfire threat to the wildland urban interface zone and shows how development codes can be used to save residential areas.

Books

Everyone's Responsibility: Fire Protection in the Wildland Urban Interface, NFPA, 1994. This National Fire Protection Association book shows how three communities dealt with interface problems.

Firewise Construction Design and Materials Publication, sponsored by the Colorado State Forest Service (CSFS) and FEMA. This 38-page booklet details home construction ideas to make a home Firewise. Various other publications are available from the CSFS on wildland urban interface issues.

Is Your Home Protected from Wildfire Disaster? A Homeowner's Guide to Wildfire Retrofit, Institute for Business and Home Safety (IBHS), 2001. This IBHS book provides homeowners with guidance on ways to retrofit and build homes to reduce losses from wildfire damage.

Stephen Bridge, *Road Fire Case Study*, NFPA, 1991. Provides information to assist planners, local officials, fire service personnel, and homeowners.

Wildland Fire—Communicator's Guide. This is a guide for fire personnel, teachers, community leaders, and media representatives.

CD ROMs

Arizona Firewise Communities Educator's Workshop, Payson, AZ, February 18–19, 2003.

Burning Issues, Florida State University and the US Bureau of Land Management. 2000. Interactive multimedia program for middle and high school students to learn about the role of fire in the ecosystems and the use of fire managing rural areas.

Wildland Fire Communicator's Guide. This interactive CD-ROM compliments the book.

Other Publications

It Can't Happen to My Home! Are You Sure? A publication by the US Forest Service, Southwestern Region, 12 page document.

Wildfire Strikes Home! (Publication no. NFES 92075); *It Could Happen to You, How to Protect Your Home!* (Publication no. NFES 92074). Homeowners handbooks from the US Bureau of Land Management, the US Forest Service, and state foresters.

APPENDIX D. INFORMATION DATA SHEET AND CONTACTS

D.1. CWPP Base Information Data Source

Name	Type	Source	Contact / Web address
Wildland Fuel Hazards	Shapefile	Logan Simpson Design Inc.	Jared Wahlberg (480) 967-1343; jwahlberg@lsdaz.com
Wildland-Urban Interface (WUI)	Shapefile	Logan Simpson Design Inc.	Jared Wahlberg (480) 967-1343; jwahlberg@lsdaz.com
Vegetation Zones	Raster	Southwest Regional Gap Analysis Project (USGS 2005)	http://earth.gis.usu.edu/swgap/
Well Locations	Shapefile	ADWR	ADWR 602-771-8638 mxb@azwater.gov
Land Ownership	Shapefile	Arizona State Land Department	Land Resources Information System Published 20071029 Gary Irish (602) 542-2605
Land Parcel data	Shapefile		(602) 506-3406 http://www.maricopa.gov/Assessor
Ignition History	Shapefile	Bureau of Land Management	http://wildfire.cr.usgs.gov/firehistory/

All final-analysis GIS data—including flammability analysis, fuel hazards analysis, ignition history and density, community values analysis, cumulative risk analysis, treatment management units, and areas of elevated concern—are located at the Maricopa County Department of Emergency Management and at Logan Simpson Design Inc.

D.2. Maricopa County CWPP Contacts

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APPENDIX E. INVASIVE SPECIES

The following information is presented by the Core Teams to assist municipal, state, and federal land managers with basic recommendations for the management of invading saltcedar, red brome, cheatgrass, buffelgrass, and Mediterranean grass within Maricopa County. Information about invading tree species is from the USDA's online Fire Effects Information System (Zouhar 2003 and Hauser 2008), the *Strategy for Long-Term Management of Exotic Trees in Riparian Areas for New Mexico's Five River Systems, 2005–2014* (USDA FS and New Mexico Energy, Minerals and Natural Resources Department, Forestry Division 2005), and the *San Juan Basin Watershed Management Plan* (San Juan County Watershed Group 2005). Information for red brome, cheatgrass, and bufflegrass is from the USDA's online Fire Effects Information System (Hauser 2008). Additional information is available from *Invasive Non-Native Plants that Threaten Wildlands in Arizona: A Categorized List Developed by the Arizona Wildlands Invasive Plant Working Group* (AZ-WIPWG 2005) and from the *Southern Arizona Buffelgrass Strategic Plan* (Buffelgrass Working Group 2008).

Saltcedar

The continued degradation of native riparian plant communities from invading tree species is a significant concern to the citizens of Maricopa County.

Saltcedar is one of the most widely distributed and troublesome nonnative invasive plants along watercourses in the southwestern United Sates. Saltcedar reduces recreational usage of parks and riparian areas for camping, hunting, fishing, and agriculture. Since its escape from cultivation, saltcedar has spread primarily in the southwestern United States and northern Mexico, although its distribution extends into many parts of North America. It is especially pervasive in, and has dominated, many low areas bordering the channel of the Southwest river systems since the 1940s. More than 50 percent of the area covered by floodplain plant communities was dominated by saltcedar by 1970 (<www.fs.fed.us/database/feis/plants>). Saltcedar-dominated communities are often monotypic, though cottonwood and willow are common associates. Several studies in Arizona and New Mexico suggest that saltcedar communities do not support as high a density of native bird species as do native plant communities; however saltcedar provides habitat for a number of bird species including white-winged and mourning doves, summer tanager, yellow-billed cuckoo, and the endangered southwestern willow flycatcher. Saltcedar communities can trap and stabilize alluvial sediments, reducing the width, depth, and water-holding capacity of river channels. This can subsequently increase the frequency and severity of overbank flooding. These stands can have extremely high evapotranspiration rates when water tables are high but not necessarily when water tables are low or under drought conditions. Because saltcedar stands tend to extend beyond the boundaries of native phreatophytes and to develop higher leaf area index, water use by saltcedar on a regional scale might be substantially higher than for other riparian species. While the natural flood disturbance regime seems to promote native species and discourage saltcedar, consistent natural river-flow conditions through riparian areas is rarely sustained in the Maricopa County CWPP.

There is little quantitative information on prehistoric frequency, seasonality, severity, and spatial extent of fire in North American riparian ecosystems. Fires in low- to mid-elevation southwestern riparian plant communities dominated by cottonwood, willow, and/or mesquite are thought to have been infrequent.

Increases in fire size or frequency have been reported for river systems in recent decades. Fire appears to be less common in riparian ecosystems where saltcedar has not invaded. Increases in fire size and frequency are attributed to a number of factors including an increase in ignition sources, increased fire frequency in surrounding uplands, and increased abundance of fuels. The structure of saltcedar stands may be more conducive to repeated fire than that of native vegetation. Saltcedar can contribute to increased vertical canopy density that creates volatile fuel ladders, thereby increasing the likelihood of negative impacts of wildfire. Saltcedar plants can have many stems and high rates of stem mortality, resulting in a dense accumulation of dead, dry branches vertically within the canopy as well as within the fuel bed. Large quantities of dead branches and leaf litter are caught in saltcedar branches above the ground surface, enhancing the crowns' flammability. In summary, the likelihood of fire in southwestern riparian ecosystems is greatest with the combination of flood suppression, water stress, and saltcedar presence. The presence of saltcedar in southwestern riparian ecosystems may favor its own propagation by further altering the natural disturbance regime, thereby further decreasing the already limited extent of native cottonwood and willow communities. Additionally, in the absence of flooding, regeneration of native trees is impeded and organic matter accumulates, thus increasing chances for future fires that may further alter the species composition and structure of southwestern riparian systems and promote the spread of saltcedar and other fire-tolerant species (<www.fs.fed.us/database/fesi/plants/tree/tamspp/fire_ecology>).

Once established in large stands, saltcedar can rarely be controlled or eradicated with a single method, and many researchers and managers recommend combining physical, biological, chemical, and cultural control methods. Removing saltcedar must also be accompanied by an ecologically healthy plant community that is weed resistant and that meets other land use objectives such as wildlife habitat or recreational use benefits. The best phenological stage to burn and reburn saltcedar to reduce density, canopy, and hazardous fuel loads is during the peak of summer, presumably due to ensuing water stress. Use of fire alone to control saltcedar, however, is generally ineffective, only killing aboveground portions of the plant and leaving the root crown intact and able to produce vigorous sprouts. Saltcedar stands can burn hot with erratic fire behavior with numerous firebrands transported downwind from the headfire. Prescribe fire setup requires poorly receptive fuels downwind from the headfire. Saltcedar in dense stands that have not burned in 25–30 years exhibit extreme fire behavior and crowning due to closed canopy at any time of the year. They can have flame lengths exceeding 140 feet, resulting in near-complete fuel consumption. Stands reburned after 5 to 6 years show vastly different fire behavior, carrying fire only if there is adequate fine-fuel load and continuity. Due to the ability to transport fire brands at least 500 feet downwind, blacklines should be at least 700 feet wide, and headfires should be installed with temperatures of 65°F–95°F, relative humidity of 25–40 percent, and wind speeds less than 15 miles per hour.

Managers must be prepared for extreme fire behavior in old decadent stands. Where high-intensity fire is not preferred due to the presence of less fire-resistant vegetative species, fuel reductions through mechanical and chemical controls are recommended. Ignited prescribed fire can be used to thin dense saltcedar stands to follow-up applications of mechanical and chemical controls (www.fs.fed.us/database/feis/plants/tree/tamspp/fire_effects). Mechanical and chemical methods are commonly employed for saltcedar control (*Low-Impact, Selective Herbicide Application for Control of Exotic Trees: Saltcedar, Russian Olive and Siberian Elm A preliminary Field Guide by Doug Parker and Max*

Williamson, USDA May 2003). November through January is the most effective time to achieve first time kills of saltcedar by cutting below the root collar, probably because the plants are entering dormancy at that time and translocating resources into their roots. Whole tree extraction through use of equipment such as the patented Boss Tree Extractor (www.bossreclamation.com) has achieved 90 percent mortality subsequent to initial treatment. In areas where native riparian vegetation species or other habitat issues create a need for agile specific treatment designs, whole tree removal may be considered as the preferred treatment. Herbicide application is most effective when applied immediately after cutting. Full-strength application of Garlon painted on cut stumps within 15 minutes of cutting or applied with a backpack sprayer using 20–30 percent mix of Garlon with Ag. Oil has been successful with the exception of spring months when sap is moving up from the root mass (Parker and Williamson 2003). Extraction and mulching of saltcedar will require treatments of resprouts by mechanical or chemical control methods. Changes in nature of disturbance from fire (frequency, intensity, and severity) have been affected by both saltcedar invasion and by other changes in the invaded communities. Fire frequency and fire behavior in saltcedar-invaded communities are thought to be different than in native plant communities. In the absence of flooding to remove debris, accumulation of woody material can increase to levels that may have a profound effect on the ecology of the system.

Red Brome

In general, red brome initiation and establishment is a direct response to fall rains. Initial growth is relatively slow, followed by a rapid increase in vegetative growth coinciding with warming spring temperatures. Flowering and fruiting generally occur in April and May. Seeds are disseminated in summer.

Red brome is commonly an early to mid-seral species in California chaparral. It is usually sparse in early succession chaparral systems of northern California but may increase rapidly in areas of low soil fertility and moisture. Peak population numbers require several years for seed dispersal into burns or buildup from on-site producers. Continued disturbance such as grazing and repeated low-severity fires favor red brome over native early-seral chaparral species.

Red brome generally shortens fire return intervals. The increased presence of red brome has promoted fires in areas where fire was previously infrequent due to insufficient fuels. Once established red brome may increase fire frequency by enhancing potential for start and spread. In general, red brome produces an abundant and continuous cover of persistent fine fuels, promoting fast and “hot” fires. Desert scrub-shrub and grasslands dominated by red brome are more susceptible to fire than areas dominated by native forbs. Dead red brome culms and blades are persistent (commonly 2 years); herbage of most desert annual species usually lasts 1 year or less. Red brome produces high amounts of persistent flammable fuels in perennial plant interspaces, promoting ignition and spread.

Heat generated by burning red brome is sufficient to ignite and consume dead stems of native desert forbs. Flames may also consume small shrubs such as white bursage (*Ambrosia dumosa*), winterfat (*Krascheninnikovia lanata*), white burrobush, and Anderson wolfberry (*Lycium andersonii*). However, flames fueled by red brome are generally insufficient to ignite large shrubs such as creosotebush. See Cheatgrass section below for additional information.

Within the Sonoran Desert, dead and dry red brome is easily ignited, supporting fast-moving surface fires. Fire return intervals are also shortened, changing the vegetal composition through increase of nonnative components and loss of native plant species. Arizona interior chaparral communities are composed of varying plant species compositions, enhanced by the predominant bimodal rainfall patterns of Maricopa County. Soils in this type are mostly shallow decomposed granite complexes that may hinder establishment of annual grasses. Red Brome can become a wildlife fire enhancing component in down slope desert scrub/shrub types in years of extraordinary rainfall.

Cheatgrass

Cheatgrass is most widespread in sagebrush-steppe communities of the Intermountain West. Many of the ecosystems that cheatgrass has invaded are seriously altered, and no longer support the vegetation of the potential natural community. Cheatgrass can maintain dominance for many years on sites where native vegetation has been eliminated or severely reduced by grazing, cultivation, or fire. The concept of potential natural communities based only on native species is seriously challenged by cheatgrass. Where cheatgrass is highly adapted, it might have to be recognized as a component of the potential plant community. In these situations, cheatgrass may remain the de facto climax dominant, regardless of site potential. The following discussion focuses primarily on component species of potential natural communities that cheatgrass has invaded, from low-elevation salt-desert shrub communities in the southern Great Basin into higher-elevation juniper (*Juniperus* spp.), pinyon-juniper (*Pinus*-*Juniperus* spp.), pine woodlands, and the coniferous forest zone of the Rocky Mountains.

According to Stewart and Hull in 1949 and Beatley in 1966, (Hauser 2008) only a few cheatgrass plants were found in black greasewood-shadscale (*Sarcobatus vermiculatus-Atriplex confertifolia*) and salt-desert shrub associations. Today, cheatgrass is common in these communities, especially in wet years. Associated species may include budsage (*Artemisia spinescens*), bottlebrush squirreltail (*Elymus elymoides*), Sandberg bluegrass (*Poa secunda*), and Indian ricegrass (*Achnatherum hymenoides*). Cheatgrass also occurs with blackbrush (*Coleogyne ramosissima*), galleta (*Pleuraphis jamesii*), and many other salt-desert species.

In the Intermountain West, and most specifically the sagebrush-steppe and bunchgrass zones, cheatgrass occurs in and often dominates large acreages of rangeland where native dominants include big sagebrush (*Artemisia tridentata*), bluebunch wheatgrass (*Pseudoroegneria spicata*), Thurber needlegrass (*Achnatherum thurberianum*), needle-and-thread grass (*Hesperostipa comata*), western wheatgrass (*Pascopyrum smithii*), basin wildrye (*Elymus cinereus*, Idaho fescue (*Festuca idahoensis*), rough fescue (*F. altaica*), bottlebrush squirreltail, low sagebrush (*Artemisia arbuscula*), spiny hopsage (*Grayia spinosa*), and rabbitbrush (*Chrysothamnus* spp.). Cheatgrass often co-occurs with Sandberg bluegrass and/or bottlebrush squirreltail and, on some Nevada sites, has replaced Indian ricegrass or blue grama (*Bouteloua gracilis*). By 1932 cheatgrass had replaced big sagebrush on burned-over areas in the Great Salt Lake region of Utah, and occupied these sites in dense stands associated with cutleaf filaree (*Erodium cicutarium*), rabbitbrush, broom snakeweed (*Gutierrezia sarothrae*), and several other relatively unpalatable species and annual weeds. Cheatgrass invades sites dominated by silver sagebrush (*A. cana*) and blue grama in Wyoming.

In pinyon-juniper and mountain brush lands, cheatgrass can be found growing among Rocky Mountain juniper (*J. scopulorum*), western juniper (*J. occidentalis*), singleleaf pinyon (*Pinus monophylla*), Utah juniper (*J. osteosperma*), Colorado pinyon (*P. edulis*), Gambel oak (*Quercus gambelii*), Emory oak (*Q. emoryi*), antelope bitterbrush (*Purshia tridentata*), curlleaf mountain-mahogany (*Cercocarpus ledifolius*), skunkbush sumac (*Rhus trilobata*), snowberry (*Symphoricarpos* spp.), serviceberry (*Amelanchier pallida*), and mountain big sagebrush.

Disturbance

Often the critical factor opening niches for cheatgrass invasion is a heightened disturbance regime. Cultivation and subsequent land abandonment, excessive livestock grazing, overstory removal, and repeated fires can interact, or act singly, to proliferate cheatgrass. Excessive grazing and frequent fires can damage biological soil crusts and many perennial plants, thus encouraging cheatgrass establishment, survival, persistence, and dominance. Where fires have occurred at higher elevations, bunchgrasses have recovered vigorously with little cheatgrass invasion. Cheatgrass is less invasive in mesic environments, where it does not compete as effectively with established perennial grasses.

Fire Adaptations

Cheatgrass establishes from soil-stored and transported seed after fire. It has long been known that cheatgrass is highly adapted to a regime of frequent fires. Cheatgrass has a very fine structure, tends to accumulate litter, and dries completely in early summer, thus becoming a highly flammable and often continuous fuel. By the time of burning most cheatgrass seeds are already on the ground, and those not near the heat of burning shrubs can survive and allow cheatgrass to pioneer in the newly burned area. Even if fire comes when cheatgrass plants are still green and kills them before they can set seed, there may be enough viable cheatgrass seed in litter and upper layers of soil for plants to reestablish.

Cheatgrass is a strong competitor in the postfire environment, where it takes advantage of increased resource availability and produces an abundant seed crop. A cheatgrass population may average around 1,000 plants per square foot (10,750 per m^2) prior to burning. During a wildfire, most of the cheatgrass seeds beneath a shrub canopy may be killed by the heat associated with the burning of the shrub. Some cheatgrass seeds located in the interspaces among shrubs are also consumed, while those that are buried or lying in cracks in the soil will likely survive. The next season, surviving seeds germinate and establish at a density of about 1 plant per square foot ($11/m^2$). These plants are released from competition, and have more water and nutrients available to them. The cheatgrass plants in this sparse population can produce abundant tillers, each supporting many flowers, thus producing a large seed crop.

Fire facilitates cheatgrass dominance on some sites by interrupting successional trajectories of postfire plant communities, and cheatgrass facilitates fire and can thus shorten the interval between fires. This grass/fire cycle is a serious ecological threat on sites where most native plant species are poorly adapted to fire and is recognized in many ecosystems worldwide. This cycle has been documented in the Great Basin since the 1930s, and has been reported in the Mojave and Sonoran deserts beginning in the early 1980s. The result is a type conversion from native shrub and perennial grasslands to annual grasslands adapted to frequent fires.

Fire Regimes

Cheatgrass expansion has dramatically changed fire regimes and plant communities over vast areas of western rangelands by creating an environment where fires are easily ignited, spread rapidly, cover large areas, and occur frequently. Cheatgrass promotes more frequent fires by increasing the biomass and horizontal continuity of fine fuels that persist during the summer lightning season and by allowing fire to spread across landscapes where fire was previously restricted to isolated patches. Fire in these habitats can have severe effects on native species of plants and animals, although the impact of fire regime changes may differ by region and ecosystem type due to differences in the composition and structure of the invaded plant communities and to climatic differences such as occurrence of summer thunderstorms.

Postfire desert scrub-shrub plant communities are typically dominated by nonnative annual grasses, so burned areas are likely to be more susceptible to fire than unburned areas. Repeated fires stress and kill native perennials. Eventually wind and water erosion may occur, removing and diluting soil organic matter and attendant nutrient concentrations and safe sites around shrubs. After fire has eliminated native perennials, essential mycorrhizae may also be eliminated. Biological soil crusts are also killed by severe fire, and the unusually large, frequent fires associated with cheatgrass dominance can preclude crust species recolonization and succession.

Cheatgrass Fire Regime

Cheatgrass often dominates postfire plant communities, and once established, cheatgrass-dominated grasslands greatly increase the potential and recurrence of wildfires. Cheatgrass fires tend to burn fast and cover large areas, with a fire season from 1 to 3 months longer than that of native rangeland. The average fire-return interval for cheatgrass-dominated stands is less than 10 years. This adaptation to and promotion of frequent fires is what gives cheatgrass its greatest competitive advantage in ecosystems that evolved with less frequent fires. The cheatgrass-fire cycle is self-promoting, as it reduces the ability of many perennial grasses and shrubs to reestablish and furthers the dominance of cheatgrass. Moisture availability can affect cheatgrass productivity and thus affect fuel loads on a site. Drought years may reduce the dominance of cheatgrass in both recently burned and unburned areas, thus decreasing fuel loads and the chance of fire.

Immediate Fire Effect on Cheatgrass

Live cheatgrass plants are susceptible to heat kill, as with a flame thrower or handheld propane torch, though they are difficult to burn when green. When cheatgrass plants are dry enough to burn, they are already dead and have already set seed. Fire will then reduce cheatgrass plants to ash.

Cheatgrass seeds are also susceptible to heat kill, but can survive fires of low severity if the entire litter layer is not consumed or if seeds are buried deeply enough to be insulated from the heat. The amount of litter or ash left on a site is a good indicator of the amount of cheatgrass seed surviving on that site. Low density of cheatgrass immediately following fire indicates either low numbers of cheatgrass seed in the seed bank, or poor survival of seeds during fire.

Discussion and Qualification of Fire Effect

The effects of fire on cheatgrass plants and seeds vary with timing and severity of fire and the composition and density of the prefire plant community. If fire occurs when seed remains in panicles aboveground, most seeds will be killed and cheatgrass density will decline immediately following fire. The chances of seed surviving fire are enhanced once they have dispersed onto or beneath the soil surface. The woody biomass of some desert shrub, plus litter accumulations, provide sufficient fuel to elevate temperatures high enough for a long enough period to consume cheatgrass seeds on these microsites. Some cheatgrass seeds in the interspace zones are also consumed by fire, but many survive even though the cheatgrass herbage is completely consumed. Fire from herbaceous fuel alone is not usually hot enough to consume cheatgrass seeds. Although fires in pure cheatgrass stands, without woody fuel, are less severe, cheatgrass seed banks can be substantially reduced after fire.

Discussion and Qualification of Plant Response

Cheatgrass response to fire depends on plant community and seed bank composition, density, and spatial distribution; season of burning; fire severity, frequency and patchiness; scale of consideration; postfire management; and climatic conditions. Generalizations are difficult because each combination of climate, vegetation, and soil must be considered separately, as well as considerations of environmental differences both at the time of burning and during subsequent plant reestablishment.

Timing of Fire

If burned during a crucial time during seed ripening, fire can greatly reduce the density of the succeeding cheatgrass stand; however, postfire seed production may equal or exceed that of the prefire population, resulting in increased density the following year. Timing of fire is important also because of variable damage to potential competitors in the native community. For example, cool-season perennial grasses such as bluebunch wheatgrass and western wheatgrass may be less damaged by late-summer wildfires than by fires earlier in the growing season.

Fire Size and Frequency

Nonnative invasive grasses generally benefit from fire and promote recurrent fire. Fire kills biologic soil crusts, thereby allowing more germination sites for cheatgrass for several years or even decades, as crusts are slow to recover. Recurrent fires also tend to enhance cheatgrass dominance because native species cannot usually persist under a regime of frequent fires. Native plant assemblages are thus converted to nonnative annual grasslands. Frequency and size of fires is then further increased.

Fire-Management Considerations

As a management tool, fire can be used to either kill unwanted species or to simulate historical fire regimes and promote desired species. Historical fire regimes did not occur in the presence of many invasive plants that are currently widespread, and the use of fire may not be a feasible or appropriate management action if fire-tolerant invasive plants are present. For example, while fire may be an important natural component of the Great Basin ecosystem, its reintroduction by land mangers is complicated by the presence of invasive plants such as cheatgrass. Fire management should be conducted in ways that prevent establishment of invasive species, and the management of fire and invasive plants must be closely integrated for each to be managed effectively.

Rasmussen presents considerations (e.g., species composition, fuel load, fuel continuity, and weather) to be addressed when using prescribed fire in sagebrush steppes, and general prescriptions that could be used. When precipitation is below 12 inches (300 mm), caution should be used to ensure desired plant response. If the objective is to maintain the perennial herbaceous vegetation, prescribed burning is most effective when used before sagebrush dominates the site and effectively excludes perennial herbaceous plants. Such timing reduces the need for seeding following a burn. If the objective is to maintain the sagebrush, prescribed burning has very limited applicability.

Cheatgrass Fuels

In the absence of grazing, grass biomass during the fire season may represent 2 years of fuel accumulation, which appears to be optimal for grassland fires. Abundant, continuous cover of cheatgrass can lead to rapid spread of wildfires so that under conditions of high temperatures, low humidity, and wind, the fires are very difficult to suppress.

Brooks compared the roles of nonnative annual grasses and other annual plants in facilitating the spread of fires in the Mojave Desert. Landscapes dominated by nonnative annual grasses, especially annual bromes (*Bromus* spp.), are more flammable than those dominated by native forbs. Possible explanations for this include higher surface-to-volume ratio of grasses compared to forbs; more continuous vegetative cover; and the ability of alien annual grasses to remain rooted and upright longer than native forbs, allowing them to persist as flammable fuels into the summer when the threat of fire is highest. Thick layers of annual plant litter accumulate, and litter decomposes especially slowly in desert regions. Accumulations of litter led to particularly hot temperatures, long flame residence times, and continuous burn patterns in experimental fires in the Mojave Desert.

Cheatgrass provides a flammable link between open grasslands and forests. It cures early in the fire season and ignites readily during dry periods because of its finely divided stems and pedicels, and it responds readily to changes in atmospheric moisture because of its fine structure. Moisture content is the single most important factor influencing cheatgrass flammability, and varies with plant phenology and color change as follows:

Plant color	**Moisture content (%)**
Green	>100
Purple	30–100
Straw	<30

Since there is considerable variation in plant coloration in a stand, close inspection is necessary to determine the predominant coloration. Cheatgrass is not readily ignitable until it reaches the straw-colored stage. The time required for the moisture content to drop from 100 to 30 percent ranged from 8 days on a northern exposure in western Montana to 23 days on a southern exposure in different years, with an average of 14 days. The onset of purple coloring forewarns of hazardous fire conditions within about 2 weeks.

Cheatgrass ignites and burns easily when dry, regardless of quantity, and can support rapid rate of fire spread. Flammability of cheatgrass fuels depends primarily on moisture content, weight, and porosity.

Fuel Management/Fire Prevention

On areas where cheatgrass is abundant, special measures may be necessary to prevent recurrent fires, and thus prevent the elimination of fire-sensitive perennial grasses and forbs and other potential adverse impacts. Fire suppression can discourage invasion and spread of cheatgrass. Grazing management to reduce fuel loads and greenstripping are 2 methods employed to prevent large recurrent fires in areas dominated by cheatgrass. Additionally, herbicides are being tested for effectiveness in creating fuelbreaks in cheatgrass-dominated range.

Cattle grazing can reduce the accumulation of cheatgrass litter and thus lessen the fire hazard on a site. Grazing cheatgrass in winter can reduce cheatgrass herbage and seeds while protecting the dormant perennial grasses..

Greenstripping is a method of establishing fuel breaks to impede the flow of wildfires and thereby increase the fire-free interval on a site dominated by cheatgrass. These fuel breaks are 30 to 400 feet (10-120 m) wide, and are seeded with fire-resistant vegetation. As of 1994, 451 miles (16,280 acres) of experimental and operational greenstrips had been established in Idaho. The effectiveness of greenstrips, or any fuels modification project, in reducing wildfire spread is enhanced by 3 factors: (1) disrupting fuel continuity (e.g., by replacing cheatgrass with caespitose grasses such as crested wheatgrass, which have large spaces between individual shrubs); (2) reducing fuel accumulations and volatility (e.g., shrub stands are thinned to maintain a minimum distance of 10 feet (3 m) between plants); and (3) increasing the density of plants with high moisture and low volatile oil content, thus reducing both the potential for ignition and rate of fire spread. Plants used in greenstrips remain green and moist into late summer, making the greenstrip area less flammable for a longer time. Wildfire speed may slow when entering a greenstrip, thus allowing fire-suppression crews to extinguish the fire. Some wildfires burn into greenstrips and extinguish. Native plants in the Great Basin generally do not meet firebreak criteria. Crested wheatgrass and forage kochia are effective in retarding wildfire spread, compete well in a weedy environment, and have been the most successful species in greenstrips. Both plants can, however, be invasive and spread into areas where cheatgrass is being managed with prescribed fire.

Revegetation after Cheatgrass Fires

After wildfires or when planning prescribed burning in areas where cheatgrass is present, managers must decide whether the burned area should be seeded or whether sufficient perennial grasses are present to revegetate a site and successfully compete with cheatgrass. Seeding may not be necessary or desirable if native plant species are able to recover after fire. Cheatgrass-dominated communities tend to have extremely sparse perennial seed banks, however, and the cheatgrass seed bank generally recovers by the 2nd postfire year. In Utah, natural revegetation (no seeding) is most effective at higher elevations where sufficient moisture and a diverse population of perennial vegetation exist, especially on north- and eastfacing slopes. Below 6,000 feet (1,820 m) and in much of Utah's arid environment, cheatgrass and other weedy species readily invade and dominate burned areas. Seeding following fire may be needed to prevent cheatgrass dominance in Wyoming big sagebrush and pinyon-juniper communities, but not in mountain big sagebrush communities.

Revegetation of burned areas is desirable to assure forage for livestock and wildlife, and to minimize the potential for erosion and/or invasion by nonnative species. Ideally, wildfire rehabilitation should enhance the recovery of native vegetation through the seeding of native plants adapted to local environmental conditions. Early seral species may provide managers with native plant materials that can successfully germinate and establish in the presence of invasive annuals and do well after subsequent fire. Bottlebrush squirreltail deserves consideration as a post-wildfire revegetation species because in greenhouse experiments, it has substantially greater growth in post-wildfire soil compared with unburned soil, and exhibits relatively higher growth rates in post-wildfire soil compared to cheatgrass. Restoration projects using native species mixes to provide a variety of above- and belowground growth forms, and sowing at high densities, may increase establishment of desirable plants while providing adequate competition against invasive plants. Federal policy currently encourages the use of native plant materials on public lands; but because the primary objective of wildfire rehabilitation on public lands is not ecological restoration but rather prevention of erosion and invasion by undesirable nonnative species, and because of the limited availability of native seeds, the use of native species is not mandatory for revegetation. Because of difficulties related to cost, handling, and reliability of native seed supplies in wildfire rehabilitation situations, many managers prefer nonnative plant materials and traditional seeding methods.

Many large areas have been seeded with nonnative, herbaceous forage species including crested wheatgrass, intermediate wheatgrass, tall wheatgrass (*Thinopyrum ponticum*), Russian wildrye (*Psathyrostachys juncea*), smooth brome, alfalfa, and yellow sweetclover (*Melilotus officinalis*). Seeds for these species are readily available and responsive to standard seeding methods; plants establish and grow rapidly, and have wide environmental tolerances. Many cultivars are also drought tolerant, grazing tolerant, and competitive against other, less desirable nonnative species. The most reliable and persistent grass for low-elevation, drought-prone areas of the Intermountain West is crested wheatgrass. It establishes rapidly even under relatively dry conditions and tends to persist for many years, although some sites seeded to crested wheatgrass return to cheatgrass dominance over time. Grasses that are most competitive against cheatgrass include 'Hycrest' crested wheatgrass, 'Luna' intermediate wheatgrass, 'Bozoisky' Russian wildrye, and smooth brome. The competitive advantage for establishment of crested wheatgrass seedlings is lost if burned areas are not seeded the year of the fire. Forbs such as alfalfa tend to have low persistence in rehabilitation seedings. Current goals of making wildfire rehabilitation objectives compatible with other management objectives on public lands may require careful planning of treatments and some modifications of standard practices, such as greater use of native plants. The identification and use of competitive native perennial plants for arid-land rehabilitation has become a priority for managers and researchers. In big fire years—such as 1996, when millions of acres burned—the scale of the demand for seed greatly exceeds the supply of native plant seed, especially of local genotypes. The competitive ability of nonnative species and the relatively low cost and high availability of their seed will continue to appeal to those faced with large-scale burns in cheatgrass-prone areas. If managers are able to predict large fires in advance, perhaps more efforts could be made to have more native seed available for specific sites.

Buffelgrass

Buffelgrass is native to Africa, India, and western Asia. It was introduced into Texas in the 1940s to stabilize overgrazed rangelands and provide livestock forage. It was introduced into Arizona in the 1930s and 1940s to control erosion. Buffelgrass also established in Arizona from seed dispersed from Sonora, Mexico, where over 1,000,000 acres (400,000 ha) of native desert and thornscrub vegetation was converted to buffelgrass pasture. Buffelgrass was first collected on the island of Hawaii in 1932. It was intentionally planted on Kaho'olawe Island, Hawaii in 1988 and 1990. The literature does not describe how buffelgrass arrived in other areas of the United States. Buffelgrass has also been introduced into Australia, where it is considered highly invasive.

Buffelgrass occurs in the southern United States from California to Florida (with the exception of Alabama, Georgia, and the panhandle of Florida), with outlying populations in Oklahoma, Missouri, and New York. It also occurs in Puerto Rico and Hawaii. In North America, buffelgrass is most prominent in the Sonoran Desert of southern Arizona and northern Mexico and in the Chihuahuan Desert of southwestern Texas. Buffelgrass occurs in desert and thornscrub communities in southern Arizona and northern Mexico. It occurs in communities dominated by brittlebush (*Encelia farinosa*), acacia (*Acacia* spp.), Arizona mimosa (*Mimosa distachya* var. *laxiflora*), honey mesquite (*Prosopis glandulosa* var. *glandulosa*) creosotebush (*Larrea tridentata*), saltbush (*Atriplex* spp.), bursage (*Ambrosia* spp.), desert ironwood (*Olneya tesota*), yellow paloverde (*Parkinsonia microphylla*), and/or saguaro (*Carnegiea gigantea*).

The two greatest impacts of buffelgrass in the United States are the alteration of plant communities and fire regimes in the Sonoran Desert. In a news article, United States Geological Survey researcher Julio Betancourt describes the establishment and spread of buffelgrass in the Sonoran Desert of Arizona as "one of the most impressive ecosystem conversions happening in North America." Williams and Baruch describe buffelgrass as "one of the world's most notorious invaders." Buffelgrass was introduced into Arizona by the Natural Resources Conservation Service in the late 1930s and early 1940s. The spread of buffelgrass in the Sonoran Desert of Arizona now is largely from seed from Mexico. On the plains of Sonora, buffelgrass distribution has expanded from 19,000 acres (7,700 ha) in 1973 to over 350,000 acres (140,000 ha) in 2000. As of 2006, as much as 4 million acres (1.6 million ha) has been seeded to buffelgrass in Sonora. Between 1990 and 1998, the Mexican government subsidized cattle ranchers to convert native desert and thornscrub to buffelgrass pastures. The vast conversion of native communities to buffelgrass pasture may facilitate the spread of buffelgrass not just into native communities in the Sonoran Desert of Mexico and Arizona, but also into the Mojave and Sonoran Desert of California and Baja California. Buffelgrass persistence and spread can lead to reduced richness and diversity in invaded communities in the Sonoran Desert. When native trees are replaced by buffelgrass, a large guild of associated plants and animals also disappears from the area. Unpublished data cited by Burquez and others indicate severe reductions of native plant richness and diversity and less vertical complexity in buffelgrass grasslands compared to native desert scrub. Large reductions in standing crop biomass were also calculated: from 5 to 20 Mg/ha in native vegetation, to 1 to 4 Mg/ha in buffelgrass. Most native vegetation that is removed for the establishment of buffelgrass pastures is burned, resulting in substantial losses of carbon from these ecosystems as CO^2. Thus the widespread conversion (both active and passive) of native desert scrub to buffelgrass grasslands may have implications for climate change.

Buffelgrass establishment and spread are associated with a reduction or loss of native plant species in the Sonoran Desert, the Lower Rio Grande Valley, Hawaii, and Australia. In areas where buffelgrass occurs, it often outcompetes native species for limited water and nutrient resources by germinating earlier, growing faster, and creating denser stands than native plants. Buffelgrass can negatively affect native plant species richness in areas where it is dominant.

According to the Buffelgrass Working Group (2008), buffelgrass impacts on native plant communities are greatest in the Sonoran Desert. In the Sonoran Desert of northwest Mexico, buffelgrass invasions in columnar cactus (*Pachycereus pecten-aboriginum*) stands severely affect cactus reproduction. While buffelgrass does not affect cactus seed production, seedlings fail to establish in buffelgrass stands. Buffelgrass established in the Organ Pipe Cactus National Monument, Arizona, during the 1970s and 1980s. By 1994, it occupied 20 to 25 square miles (50–65 km^2) of the monument and was spreading rapidly. At Organ Pipe Cactus National Monument, buffelgrass reduces abundance of native shrubs such as creosotebush, saltbush, and bursage, as well as abundance of associated native grasses and forbs.

Buffelgrass is described as a fire-adapted species. Fire adaptations vary with reproductive morphology, which varies among forms. Buffelgrass may establish, persist, and spread following fire. Buffelgrass may establish from on-site seed sources after fire. However, in Botswana, no buffelgrass seeds survived prescribed burning when harvested from a savanna and sown on the soil surface in a curlyleaf (*Eragrostis rigidior*) plant community before burning. It is possible that buried or protected buffelgrass seed may survive and germinate following fire. Buffelgrass seed is dispersed by multiple sources, so it may establish on burned sites via offsite seed sources. More information is needed on seed banking and heat tolerance of buffelgrass seeds.

Buffelgrass can persist after fire by sprouting from rhizomes, tillers, or buds that survive fire. Sources describe buffelgrass as simply “sprouting” or “rapidly resprouting” after fire, without indicating the source of sprouts. Esque and others state that buffelgrass resprouts rapidly from the root crown after fire. New buffelgrass growth can appear as soon as 5–10 days following complete top-kill by summer fires; however, postfire response of buffelgrass may depend on season of burning and postfire weather conditions. Buffelgrass fine fuel loads are generally much higher than fine fuel loads from native plants in desert environments. Thus, fires in buffelgrass stands may have longer flame lengths, greater rates of spread, and higher temperatures than fires in native desert vegetation, and cause high mortality in native flora and fauna. Buffelgrass stands burn “very hot” and can burn when green. In the Sonoran Desert, buffelgrass-fueled fires can reach temperatures so hot that the soil is scorched and the bedrock cracked. Headfires in buffelgrass stands can reach temperatures of 1,090 to 1,300°F (585°C–700°C). Esque and others state that buffelgrass grows into an “almost-woody subshrub,” accumulating flammable material over several years, “in effect unlinking fire frequency from annual climatic variability and increasing the fire intensity.”

Buffelgrass fuel loads in Saguaro National Park are large enough to carry fire and were found to be high in comparison to fine fuels from annuals in warm desert biomes of North America. Fine fuels from annuals (natives and nonnatives combined) typically range from 0 to greater than 625 lb/acre in warm deserts. In June 2003, buffelgrass fuel loads on 14 plots in 2 areas of Saguaro National Park (4 at Javelina Picnic Area and 10 at Panther Peak) were measured. During the year of the study, sites received less than 10.5 inches (267 mm) of rain and buffelgrass moisture content was very low (3.6%). Nevertheless, buffelgrass dry, aboveground biomass averaged 2,523 lb/acre and 2,213 lb/acre on the 2 sites.

Buffelgrass growth and spread are greatest in wet years. In northwestern Sonora, Mexico, buffelgrass production was measured in summers of below- and above-average precipitation. On northwestern Mexican rangelands, peak growth is in August. Production ranges from 1,000 lbs/acre in dry years to 6,000 lbs/acre in wet years. Average summer (July-September) precipitation in Sonora is 7.56 inches (192 mm). During the summer of 1987, precipitation was 5.75 inches (146 mm) below average and buffelgrass biomass production was 465 kg/ha. During the summer of 1986, precipitation was above average by 14.1 inches (358 mm), and buffelgrass biomass production was 3,025 kg/ha. On the Desert Laboratory grounds of Tucson, Arizona, buffelgrass “greatly” expanded its range following 2 unusually wet summers. Buffelgrass had been on the site since 1968.

Although buffelgrass has been in North America for many decades, in the last couple of decades it has spread to the point of altering fuel characteristics and impacting fire regimes of native desert communities. Research regarding its impacts on native fire regimes is limited at the time of this writing (2008), although abundant anecdotal evidence is available. A 2001 review article by Brooks and Pyke describes how buffelgrass and other nonnative plants are beginning to alter fire regimes in the Sonoran Desert. Brooks and Esque warn that shortened fire-return intervals caused by invasive grasses, including buffelgrass, pose a serious threat to plants and animals in the Sonoran Desert.

While buffelgrass occurs in many of the southern States, the majority of buffelgrass fire ecology information comes from areas in the Sonoran Desert, including central and northern Sonora, Mexico, and southern Arizona. In these areas, buffelgrass invasion can increase the biomass and continuity of fine fuels, resulting in large and frequent fires. Buffelgrass also fuels frequent fires in Hawaii and Australia. In central Australia, buffelgrass produces 2 to 3 times as much flammable material as native grasses on some sites. Historically, watercourses were natural firebreaks, but the expansion of buffelgrass in watercourses from water-dispersed seed have turned these areas into “wicks” for fire.

Historically, fires were rare in the Sonoran Desert because fine fuels were sparse and discontinuous and rarely carried fire. The primary carriers of contemporary fires in the Sonoran Desert are introduced perennial plants. In contrast to native species, buffelgrass produces a large amount of continuous, fine fuel, thereby increasing the potential for frequent, intense, and large fires. The buffelgrass fire season in the Sonoran Desert begins at the end of the summer rainy season in late September and continues until the following July when the summer rains return. During winter rains and the cool-season growth period, however, buffelgrass-fueled fires are fewer than in the warm, dry months.

The fire hazard caused by buffelgrass in the Sonoran Desert of Arizona and northern Mexico is increasing. In a news article, a fire inspector in Tucson, Arizona, said, “buffelgrass is like taking a kiddie pool, filling it with gas, and putting it in your front yard.” He claimed that buffelgrass fires can go from 4-foot (1 m) flames to 30-foot (10 m) flames in 20 seconds. He described the desert surrounding Tucson as formerly “fire resistant", but 15 to 20 buffelgrass-fueled fires occurred within a 6-week period during the summer of 2007. Similarly, in Hermosillo, Sonora, Mexico, fires were virtually unknown prior to the establishment of buffelgrass in the 1940s. By the 1960s, sporadic buffelgrass-fueled fires were reported. By the late 1990s, buffelgrass-fueled fires had increased to 1 fire every 2 days during the dry summer months.

If buffelgrass continues to spread in the Sonoran Desert, it is likely to lead to a grass/fire cycle, negatively impacting the persistence of native vegetation. While some Sonoran Desert plants can establish or sprout following fire, many cannot. Native plant establishment via seed may take 20 or more years after fire to return to prefire vegetative cover. Buffelgrass can sprout quickly after fire and "outcompete" or even replace native plants. Cacti in the Sonoran Desert may be able to survive a single fire; however, a second fire within 10 years may be "catastrophic" to cacti. Buffelgrass-fueled fires may lead to decline of saguaro, yellow paloverde, and other native Sonoran Desert plants. In a review, West and Nabhan reported that buffelgrass burns so hot in the Sonoran Desert Biological Reserve that desert ironwood (*Olneya tesota)* trees are completely consumed, and the native desert vegetation is replaced by a dry grassland with no recruitment of native perennials. Esque and others also describe buffelgrass-fueled fires near El Batamote, Mexico completely incinerating desert ironwood and fragrant bursera (*Bursera fagaroides*) trees.

Fire in the Sonoran Desert negatively affects bird habitat quality. Buffelgrass fuels frequent and intense fires that remove native vegetation crucial for some bird species. Buffelgrass fires in national parks and national wildlife refuges in Texas and Arizona threaten desert tortoises, jaguarondis, and ocelots, and other animals that depend upon woody plants or dense litter. Clearing native vegetation and replacing it with buffelgrass in southern Sonora, Mexico, has caused a decline in the Tarahumara frog. The conversion of desert scrub and foothill thornscrub to buffelgrass pastures in the Sonoran Desert is "devastating" to the Sonoran Desert tortoise. Fires that generally follow the transformation of native vegetation to buffelgrass are converting vast areas of tortoise habitat into tracts of nonnative grasslands. In Australia, the expansion of buffelgrass is associated with a decrease in vertebrate and invertebrate diversity.

Control

Given that buffelgrass has only become a problematic species in the United States within the last 10 to 20 years, research on its control is limited. At the time of this writing (2008), physical removal of buffelgrass seems to be the best control method available. Some research suggests that buffelgrass can be controlled by herbicide applications. Physical removal may be the best method of controlling buffelgrass. Based on research by Ward and others, manual removal of buffelgrass should take place at least 4 days after periods of precipitation that exceed roughly 0.67 inch (17 mm).

Physical removal of buffelgrass can be successful if sites are treated for at least 2 years. In year 2, seedlings need to be removed prior to maturity. In 1994, physical removal (hand pulling and digging with a shovel) of buffelgrass at Organ Pipe Cactus National Monument was initiated in a test plot. The following winter, many buffelgrass seedlings were removed from the site. By 1996, seedlings were not found at the site. At west Quitobaquito Springs, physical removal of buffelgrass resulted in almost no reestablishment. Large-scale physical removal of buffelgrass in the monument has proven successful. Sites where buffelgrass is most likely to reestablish following physical removal include burned sites, buffelgrass stands at least several years old, areas near a seed source, areas where vehicles or humans move through a site, areas with white-throated woodrat middens, or areas with topsoil loss due to erosion or bulldozing.

There is very little information on the prevention of buffelgrass establishment and spread. Further information on this topic is needed. On Tumamoc Hill, Arizona, a group known as the “Weedwackers” has initiated a program of revegetating disturbed areas with native species to prevent buffelgrass establishment. The program has been successful at eliminating buffelgrass stands in washes; leading to the reestablishment of native vegetation.

An integrated management program at 2 sites on the island of Hawaii successfully removed buffelgrass, allowing the establishment of native pili grass. Burns were conducted in February 1998, then reburned once or twice in the next 4 years. On some plots, burning was combined with hand pulling or glyphosate treatment. All sites were seeded with pili grass 3 weeks after the first burn, and watered to counteract effects of drought. In 2002, 4 years after the initial treatments, pili grass cover was less than 10% on unburned and burn-only plots, but was approximately 34% on plots from which buffelgrass had been removed.

Beginning around 2000, the group “Weedwackers” physically removed 4,600 tons (4,200 t) of buffelgrass and other exotic species from roadsides, vehicle pullouts, and washes in Tucson Mountain Park, Arizona. Using National Park Service funding, volunteers removed over 40 tons (40 t) of buffelgrass from Organ Pipe Cactus National Monument between 1994 and 2004.

Mediterranean Grass

Two similar species are known as Mediterranean grass, *Schismus barbatus* and *Schismus arabicus*. Mediterranean grass is a low growing tufted grass (under 20 cm tall) that is abundant in many areas of the desert southwest. According to *Invasive Non-Native Plants that Threaten Wildlands in Arizona* (Arizona Wildlands Invasive Plant Working Group 2005), both species of *Schismus* are ranked as a medium threat level for Arizona’s wildlands. A medium ranking means that these species have a substantial impact on Arizona’s ecosystems; have invasive attributes that are conducive to moderate to high rates of dispersal, often enhanced by ground disturbance; and are found with a diversity of ecosystems and the distribution with those ecosystem can range from limited to widespread.

APPENDIX F. NATIONAL FIRE AND AVIATION EXECUTIVE BOARD APPROPRIATE MANAGEMENT RESPONSE

National Fire and Aviation Executive Board

Memorandum

To: Fire Management

From: National Fire and Aviation Executive Board

Date: June 20, 2007

Subject: Clarification of Appropriate Management Response

The National Fire and Aviation Executive Board (NFAEB) provides the following clarification for implementing the Appropriate Management Response (AMR) under current Federal Wildland Fire Management Policy and agency directives. The intent is to clarify Federal Wildland Fire Management Policy, to enable agency administrators to take full advantage of the flexibility afforded by existing policy.

Key Points to Clarify Policy:

The Interagency Strategy for the Implementation of Federal Wildland Fire Management Policy (2003) is the primary wildland fire policy reference source. Agencies have incorporated policy intent and direction from that source in respective directives, manuals, handbooks, and interagency operations guides.

The Federal Fire Policy requires all wildland fires from unplanned ignitions to be managed for either protection objectives (wildfire) or resource benefit objectives (wildland fire use). Under current policy, a single fire cannot be managed for both objectives concurrently.

Appropriate Management Response (AMR) encompasses all of the response actions necessary to manage a wildfire or wildland fire use event for the duration of the event. In implementing the AMR, the full spectrum of tactical options, from monitoring a fire at a distance to intensive suppression actions are available to the fire manager. Beginning with the initial response to any wildland fire, decisions will reflect the goal of using available firefighting resources to manage the fire for the most effective, most efficient and safest means available.

The AMR strategies and tactics used to manage a wildland fire will be based on objectives identified in the Land/Resource Management Plan and/or Fire Management Plan.

The AMR strategies and tactics will consider firefighter and public health and safety, fire cause, current and predicted weather, current and potential fire behavior and fire effects, values to be protected from fire, management priorities, resource availability, cumulative effects of the fire, and cost effectiveness. Direct assessment of resource benefits from fire is currently allowed only where wildland fire use has been identified in the Land/Resource Management Plan and/or Fire Management Plan as an acceptable strategy.

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