

Noxious Weed Survey of the U.S. Air Force Academy and Farish Outdoor Recreation Area



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TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
OVERVIEW OF THE STUDY AREA	2
TOPOGRAPHY.....	2
CLIMATE.....	2
GEOLOGY.....	2
SOILS	3
LAND USE.....	3
FLORA.....	4
EXOTIC PLANT SPECIES	5
OTHER RESEARCH AT THE U.S. AIR FORCE ACADEMY AND FARISH OUTDOOR RECREATION AREA	6
METHODOLOGY	6
RESULTS AND DISCUSSION	9
WEED MAPPING.....	9
ASSESSMENT OF EFFECTIVENESS OF METHODOLOGY	10
RATIONALE FOR SUGGESTED MANAGEMENT PRIORITIES IN TABLE 3	13
NOXIOUS WEED STATUS BY SPECIES	14
<i>Bull Thistle (Cirsium vulgare)</i>	14
<i>Canada Thistle (Breea arvensis)</i>	14
<i>Diffuse Knapweed (Acosta diffusa)</i>	14
<i>Field Bindweed (Convolvulus arvensis)</i>	14
<i>Fuller’s Teasel (Dipsacus fullonum)</i>	15
<i>Hoary Cress (Cardaria draba)</i>	15
<i>Leafy Spurge (Euphorbia esula)</i>	15
<i>Musk Thistle (Carduus nutans)</i>	16
<i>Russian Olive (Eleagnus angustifolia)</i>	16
<i>Scotch Thistle (Onopordum acanthium)</i>	16
<i>Spotted Knapweed (Acosta maculosa)</i>	17
<i>St. Johnswort (Hypericum perforatum)</i>	17
<i>Tamarisk (Tamarix ramosissima)</i>	17
<i>Yellow Toadflax (Linaria vulgaris)</i>	18
AREAS UNAFFECTED BY NOXIOUS WEEDS	20
WEED MAPS BY SPECIES.....	21
RARE PLANT OBSERVATIONS.....	31
RECOMMENDATIONS.....	31
ACKNOWLEDGEMENTS	33
LITERATURE CITED	34

APPENDIX 1. THE NATURAL HERITAGE RANKING SYSTEM	37
APPENDIX 2: SUMMARY OF U.S. AIR FORCE ACADEMY WEED DATA.....	39
APPENDIX 3: INSTRUCTIONS FOR WEED MAPPING	45
APPENDIX 4: NEW AND UPDATED ELEMENT OCCURRENCE RECORDS..	49

EXECUTIVE SUMMARY

In the summer of 2002 the Colorado Natural Heritage Program (CNHP) mapped selected noxious weeds found on the US Air Force Academy (“the Academy”) and the Farish Outdoor Recreation Area (“Farish”). The project was undertaken to provide the US Air Force Academy Department of Natural Resources with information on noxious weeds that will serve as the basis for development of a formal Integrated Weed Management plan for U.S. Air Force Academy properties, and to meet the requirements of a comprehensive management plan. Unless specified, all statements in this report apply to both the US Air Force Academy base and the Farish Outdoor Recreation Area.

Fourteen species of weeds were mapped in the study area (see Table 2). Noxious weed species mapped include several of the top ten prioritized weed species listed in the Colorado Noxious Weed Act (see Table 1), species of concern to the Natural Resources Department of US Air Force Academy, and other newly documented weeds listed on the State Noxious Weed List. Mapping was conducted from June 13 to September 13 2002. Arcpad software (ESRI 2000) installed on a handheld mobile device with a GPS unit was used to map weed occurrences and record attribute data while traversing the range of topography and vegetation found at the Academy and Farish. These data are included in GIS files that accompany this report.

The targeted weed species are widespread at the Academy and Farish. The most prevalent weeds on both the Academy and Farish are yellow toadflax and Canada thistle. Significant infestations of diffuse knapweed, Russian olive, Fuller’s teasel, and musk thistle are also present on the Academy. Two previously undocumented weed species, Scotch thistle and St. Johnswort, were also found on the Academy and mapped. Four of the target species were found at Farish (yellow toadflax, musk thistle, Canada thistle, and leafy spurge). Based on their invasiveness, size of infested area, and difficulty of management, species were ranked as either high or moderate management priority. Communities and substrates were identified where yellow toadflax is less likely to be found, and plant communities that are less likely to be infested by weeds were also identified. Two occurrences of rare plants (Rocky Mountain cinquefoil and Rocky Mountain gay feather) were visited and documented, and the threats to those occurrences from noxious weeds were assessed.

OVERVIEW OF THE STUDY AREA

The study area covered by this report includes all lands included within the US Air Force Academy and the Farish Outdoor Recreation Area. The US Air Force Academy (referred to in this report as “the Academy”) is located north of the city of Colorado Springs in El Paso County, Colorado. The Academy lies within the Fountain Creek watershed and occupies most of T12SR67W, and small parts of T12SR66W and T13SR66W. The area of the Academy is ca 18,455 acres (7472 ha). Farish Outdoor Recreation Area (referred to in this report as “Farish”) lies directly to the west of the Academy, east of Woodland Park, Colorado. Farish occupies approximately 652 acres (264 ha). The following overview is paraphrased extensively from Ellingson *et al.* (1995).

Topography

Topography at the Academy is diverse. Local relief ranges from ca 6360 ft (1939 m) along Monument Creek at the southeastern corner of the base to almost 8000 ft (2424 m) in Stanley Canyon at the western boundary (DeFusco and Cassel 1988, Langois and Munson 1991, Ripley 1994). Local relief at Farish Outdoor Recreation Area in the Rampart Range to the west of the base varies from 9200 ft (2787 m) to 9360 ft (2836 m). Varnes and Scott (1967) recognized five topographic areas of the Academy. From west to east, these include: mountain slopes of the Rampart Range; ridges of sedimentary rock running parallel to the Rampart Range; mesas and ridges at the base of the mountains bisected by broad west-to-east oriented valleys; the Monument Creek valley running north-to-south; and the southwest-trending, gently sloping lands along the eastern part of the base (Ripley 1994).

Climate

The climate of the area is continental and semi-arid, yet strongly influenced by the mountains. Annual precipitation recorded at the Academy airfield averages 6.8 in (17.4 cm) but varies year-to-year (Ripley 1994). Average monthly temperatures recorded at the airfield range from 68.1 deg F (20 deg C) in July to 29.5 deg F (-1.4 deg C) in January (Ripley, 1994). The Colorado Springs area experiences some 250 days of sunshine per year (Rosenlund 1994). Sudden and extreme changes in atmospheric conditions may occur from hour to hour and day to day at any season of the year. High winds can occasionally damage structures and vegetation.

Geology

Geology is a fundamental factor influencing climate, soils, and ultimately the distribution of plant and animal communities. The geology of the eastern portion of the Academy is typical of the Colorado Piedmont, a broad band between the Rocky Mountains and the High Plains (Fitzgerald *et al.* 1994). Soils on base are often underlain by the Dawson Arkose sandstone (Ripley 1994), which can be seen along portions of Monument Creek where erosion has removed surface material.

The Rampart Range forms the western boundary of the Academy and is where the Farish Outdoor Recreation Area is located. The Range is composed of Pike's Peak granite, an ancient formation more than one billions years old (Ripley 1994). The Rampart Range Fault lies to the east of the base of the mountains and runs north-to-south. Rocks just east of the Fault are sandstone, limestone and shale deposits dating from the Paleozoic (Ripley 1994). The geologic series represented extends down to Precambrian granite. In descending order, the series is: Dawson, Laramie, Fox Hills, Pierre, Niobrara, Carlile, Dakota, Purgatoire, Morrison, Ralston, Lykins, Lyons, Fountain, Manitou, Sawatch, and Pike's Peak (Ripley 1994).

Soils

Soils at the Academy are mostly alluvial (water deposited) or residual (accumulated in place over disintegrating bedrock) (Ripley 1994). Two broad soil mapping units and 19 soil series are found at the Academy (Soil Conservation Service 1981). Soils are derived from the Dawson Arkose sandstone, a formation rich in feldspar originating from the Pike's Peak granite of the Rampart Range. The general soil types present include loam, clay loam, loamy sand, sandy loam, gravelly sandy loam, gravelly loamy sand, coarse sand loam, loamy coarse sand and gravel (Langois and Munson 1991, Ripley 1994). As of 1981, soils at Farish Outdoor Recreation Area had not been mapped by the USDA Natural Resources Conservation Service (Soil Conservation Service 1981). However, Rampart Range soil types include the Kutler Series, consisting of soils formed in place from materials weather from granite outcrops, interspersed with granite outcrops (Ripley 1994).

Land Use

Section lines were established on most of the present location of the Academy between 1864 to 1870 as a part of the Public Lands Survey (Armstrong and Stevens 2002). The notes from these survey crews suggest that fire played a major role in the ecology of the presettlement ecosystems of the area.

The land eventually comprising the US Air Force Academy was used for logging and ranching from the beginning of settlement in the 1860's (Ripley, 1994, Armstrong and Stevens 2002). Commercial logging has not occurred on the Academy since 1915 (Ripley 1994). Presently, forest stand inventories are periodically carried out to identify stands requiring prescriptive actions, such as selective cutting to control insects or diseases such as dwarf mistletoe on lodgepole pine or douglas fir, or for fuel wood reduction to protect housing (pers. comm. Muhlbachler 2002). Cuts have been made throughout the Academy, including the northern and western portions, near the golf course, and above Deadman's Creek close to its confluence with Monument Creek. Generally, forest stands in the southern part of the Academy are already thinner and less likely to require prescriptive intervention.

Several small communities were established on what is now the Academy, although little evidence of those communities remains today. Buildings are present at Farish which date

to around 1900 (Rosenlund 1994) and which still are in use today (pers. comm. Major Glen Pappas 2002).

Cattle grazing, dairy and crop farming, raising horses and dude ranching were also once dominant uses of the Academy site (Ripley 1994). Ranches were located at Pine Valley, Cathedral Rock, Douglas Valley and Jack's Valley, as well as the present site of Falcon Stadium (ESCO 1992, Ripley 1994). Originally, several active ranches were purchased to form the Academy. Cattle grazing ceased in the 1950's after the purchase of property to form the US Air Force Academy (Rosenlund 1994).

Around the Academy to the south and the east, ranching operations have been replaced by subdivisions as the city of Colorado Springs has expanded northward. The Academy is rapidly becoming an island of protected habitat including plant and animal communities that are quickly being altered or replaced elsewhere along the Front Range of Colorado.

Historic land uses have permanently changed the vegetation of the Academy and Farish. During the first half of the 20th century, much of the Academy property was cleared of vegetation and replanted with smooth brome (*Bromopsis inermis*) and ponderosa pine (*Pinus ponderosa*) (Armstrong and Stevens 2002). Historic land use practices have left a legacy of: 1) removal of all old growth forest and conversion of forest to second-growth stands; 2) degradation of natural hydrologic regimes of streams originally due to cattle grazing; and 3) invasion by exotic vegetation, particularly in riparian areas and transportation corridors.

Flora

The Academy is located in an area of transition from the mountains in the west to the plains in the east (i.e. the Colorado Piedmont), as well as from the Northern Great Plains and Central Rocky Mountains to the Southern Great Plains and Southern Rocky Mountains. As such, a complex mixture of environments exists which results in a unique diversity and combination of plant communities (ESCO 1992).

Plant communities at the Academy are typical of the foothills transition zone (Gregg 1963, Weber 1976, DeFusco and Cassel 1988, Mutel and Emerick 1992). Grassland tends to grow on finer, deeper alluvial soils of the eastern portion, while coniferous forest tends to grow on shallower, more coarse-grained residual soils of the western, mountainous portion of the base, where the climate is also cooler and wetter (ESCO 1992). A few plant species are found at the Academy at the edge of their geographical ranges. Gambel's oak and white fir, for example, are at their northern limit on the east side of the Continental Divide, and Parry oat grass and Colorado blue spruce at their southeastern limit. This further reflects the transitional nature of Academy plant communities (ESCO 1992).

Five broad vegetation types are recognized at the Academy and Farish (ESCO 1992): grassland, oak shrubland, oak/coniferous mixed forest, coniferous forest and riparian.

Each of these vegetation types occur more widely throughout North America, but at the Academy they occur in close proximity to one another, forming a unique mosaic of plant species (ESCO 1992). Their occurrence together is possible on the Academy property because of its diverse physiography and its location at an ecological transition zone. The following description of the vegetation types at the Academy and Farish follows that of ESCO (1992) unless otherwise noted.

Upland forests are composed of mixtures of ponderosa pine, Douglas fir, and white fir; additionally, Colorado blue spruce and aspen communities are found at Farish Outdoor Recreation Area. These are typical of Colorado Rocky Mountain forests. Ponderosa pine also occurs in small stands along the eastern edge of the Monument Creek flood plain.

Upland shrubland-dominated mosaics are shrub-dominated intermixtures of shrublands and grasslands. Gambel's oak and mountain mahogany are the dominant shrubs and are commonly found on west-facing slopes.

Upland grassland-dominated mosaics are grass-dominated intermixtures of grasslands and shrublands. Mountain muhly and parry oatgrass are the primary dominant grasses. Plant species richness is high in these types and they have a high biodiversity conservation value.

Upland grass vegetation types possess little woody species cover. The principle grasses found in these types are parry oatgrass (at Farish), big bluestem, prairie sandreed, and needle-and-thread grass. Blue grama is relatively widespread (Corn *et al.* 1995).

Riparian vegetation is found in moist bottomlands throughout the Academy and Farish. Shrub/tree vegetation types are dominated by willow and cottonwood species and occur along Monument Creek and its tributaries. Riparian grass/forb vegetation types are found in a narrow strip along stream margins and are dominated by grasses, sedges and rushes, with forbs well represented. Fen wetlands are broad zones of permanently saturated soils dominated by sedges and rushes. Riparian shrublands and woodland vegetation is generally dominated by willow or cottonwood, but snowberry, alder-willow (along Kettle Creek) and ponderosa pine/alder-dogwood-river birch (along West Monument Creek) vegetations occur as well (Corn *et al.* 1995).

Exotic Plant Species

Weeds have been identified as a serious concern at the US Air Force Academy and Farish Outdoor Recreation Area. They have already had considerable impacts to the quality and integrity of the natural ecosystems present at these locations. Weeds can alter the fire ecology, successional processes, and ecosystem function of the systems they invade. Some species have had such serious economic and biological impacts (Colorado Department of Agriculture 2001) that their control and management is mandated under Colorado State law. Species included on the top ten list of noxious weeds for Colorado (Colorado Noxious Weed Act 2000) were sought out in this study to facilitate the

management and eradication of populations of these species. Other species were included due their present or potential ecological impacts.

Non-native plant species other than the noxious weeds mapped in this study are present in all communities of native plants and originate from disturbance, reseeding programs using non-native seed, or from the effects of early settlement at the Academy (ESCO 1992). *Caragana arborescens* was first planted to provide shelterbelts for deer, for example. Stream banks retain native graminoid vegetation, but the herbaceous layer is often dominated by introduced species such as Kentucky bluegrass or smooth brome. Mature stands of crack willow have been established along Monument Creek (ESCO 1992, Corn *et al.* 1995). Grassland communities in the eastern portion of the Academy are composed of many non-native grasses and forbs, including smooth brome, cheat grass and introduced wheatgrasses (ESCO 1992). Fen wetland vegetation types along the eastern margin of the base often occur with weedy plant communities (Corn *et al.* 1995).

Other Research at the U.S. Air Force Academy and Farish Outdoor Recreation Area

A number of studies have been, and continue to be conducted by CNHP at the US Air Force Academy and Farish Outdoor Recreation Area. Included are those of Armstrong and Stevens (2002), Schorr (2001), Pague *et al.* (1996), Culver (1996), Ellingson *et al.* (1995), and Corn *et al.* (1995). Studies by Dr. Gerald Michels and others from Texas A&M University are directly addressing the problem of noxious weeds the Academy and Farish (Michels *et al.* 2000, Michels *et al.* 2001).

METHODOLOGY

Fourteen species of weeds were mapped in the study area. Ten species of noxious weeds were initially selected for mapping based on three factors: Rank on the state noxious weed list (Table 1), current impact on the academy, and potential impact on the academy. Four other species were added during the field surveys that were found for the first time on the Academy. These were mapped because of the potential threat they pose to the Academy, and because at their current rarity there is now an opportunity to eradicate them before they become widespread. The complete list of species mapped is included in Table 2.

The data collected in the field conforms to standards established by NAWMA (North American Weed Management Association 2002) and is compliant with Federal Geographic Data Committee Content Standards for Digital Geospatial Metadata (version of June 8, 1994). It also meets the needs of the Colorado Department of Agriculture's statewide weed mapping (Colorado Department of Agriculture 2003). All data specified in the Montana Noxious Weed Survey Protocol (Cooksey and Sheley 1998) were gathered for each weed occurrence. The methodology specified in this mapping system was modified to suit the mobile device used to gather data for the project.

Table 1. Colorado Weed Ranks. The Colorado Noxious Weed Act, Title 35, Article 5.5, C.R.S. (2000) lists species designated as State Noxious Weeds in Colorado. All weeds listed in the act are ranked as follows:

A	State Noxious Weeds. These species have been identified by individual counties as problem weeds in the county's area or have been recommended for management through public testimony.
B	Top Ten Prioritized Weed Species. These weed species are recognized as the top ten prioritized weed species for Colorado. These species are the most widespread and cause the greatest economic impact in Colorado.
C	Not Yet Widespread. These weed species may not yet be present or are not yet widespread or causing great economic impact within Colorado. However, counties and local advisory boards are encouraged to contain and eradicate these species before they proliferate and significantly impact the economic and environmental values of the lands of the state.

Table 2. Weed species mapped at US Air Force Academy and Farish Outdoor Recreation Area. See Table 1 for an explanation of weed ranks under the State Noxious Weed Act.

USDA CODE	SCIENTIFIC NAME	COMMON NAME	RANK
CEDI3	<i>Acosta diffusa</i> (=Centaurea diffusa)	Diffuse Knapweed	B
CEBI2	<i>Acosta maculosa</i> (=Centaurea maculosa)	Spotted Knapweed	B
CIAR4	<i>Breea arvensis</i> (=Cirsium arvense)	Canada Thistle	B
CADR	<i>Cardaria draba</i>	Hoary Cress	B
CANU4	<i>Carduus nutans</i>	Musk Thistle	B
CIVU	<i>Cirsium vulgare</i>	Bull Thistle	A
COAR4	<i>Convolvulus arvensis</i>	Field Bindweed	B
DIFU2	<i>Dipsacus fullonum</i>	Fuller's Teasel	C
ELAN	<i>Eleagnus angustifolia</i>	Russian Olive	A
HYPE	<i>Hypericum perforatum</i>	Common St. Johnswort	C
LIVU2	<i>Linaria vulgaris</i>	Yellow Toadflax	B
ONAC	<i>Onopordum acanthium</i>	Scotch Thistle	A
TARA	<i>Tamarix ramosissima</i>	Tamarisk	A
EUES	<i>Tithymalus esula</i> (=Euphorbia esula)	Leafy Spurge	B

All weed occurrences were mapped in the field using ArcPad version 5.0.1, a portable version of ArcView GIS software that allows the user to create and edit shapefiles remotely. This software was installed on a 64MB Compaq iPAQ Pocket PC (model H3670) that was equipped with a dual PC card expansion pack. For data security, all digital files were saved on a PC card and downloaded from the iPAQ to a desktop PC at least once daily. These were also routinely burned onto cd's and sent via FTP to the Colorado Natural Heritage Program main office. Shapefiles generated in the field were edited and cleaned up nightly. A Teletype PC card GPS unit was installed in the other PC card slot on the iPAQ and provided locational data in ArcPad. This GPS unit is accurate to within 20 meters, but was found in field trials to be accurate most often to within 5 meters, even under heavy tree canopy. Although this unit is WAAS (wide area augmentation system) capable, it is shipped with the WAAS system disabled, and the manufacturer recommended against using this feature. Thus it was not enabled during this project. This feature differentially corrects GPS data "on the fly" by receiving a correction signal from geostationary satellites, but this signal is not easily received at this latitude. For details regarding data management procedures used in this project, please see Appendix 3.

Weed infestations were mapped using tolerances recommended by Cooksey and Sheley (1998). Large infestations (typically 5 or more acres) were mapped as polygons. Linear infestations, such as those following railroad tracks, roads, and lakeshores, were mapped as lines. All other infestations, which make up the majority of the infestations encountered in the study area, were mapped as points. Please see Appendix 2 for a more detailed discussion and figures illustrating the different feature types and tolerances.

Attributes were ascribed to all features mapped in the field. These include weed species, date, area of infestation, and density. Area was determined by documenting the radius of point occurrences, and by adding a buffer to line occurrences. All radii and buffers were determined in the field for each weed occurrence. Then the area was calculated using ArcView GIS software (ESRI 2000). Density is determined either as the number of shoots counted (for small populations) or as number of shoots per square meter (for large populations). Notes were taken about an infestation where unusual or noteworthy observations were made. All of these attributes are included in the attribute tables of the shapefiles accompanying this report.

Photographs were taken of representative infestations of most noxious weeds mapped, and other photos were taken to document the range of ecological variability observed in different weed infestations. Photos were also taken of rare plants observed during the study. Representative images are hotlinked to the ArcView project file included with this report. Please see Appendix 2 for instructions on accessing these files.

Collection of weed data at the Academy and Farish was subject to limitations imposed by manpower, time, and safety. Data were collected almost entirely by only one person covering 19,000 acres from June 13 through September 13, 2002. On a daily basis, ca 300-acre areas bounded by identifiable natural and man-made features such as ridges and roads, were arbitrarily defined. The goal each day was to make observations over as

much of each 300 acre area as possible, and to traverse the variation of topography and vegetation within those units. Each traverse then served as a random sample of the species, distribution and abundance of noxious weeds present within the topography and vegetation of that area. It must be emphasized that this methodology is best thought of as an intensive sampling procedure rather than a comprehensive inventory, since the large area of the Academy properties precluded the intensive search of every possible location for weeds.

Due to safety and difficulty of access, a few areas could not be mapped in the study. The median strip of I-25 was not directly accessed due to the danger posed by highway traffic, although many portions of the median were able to be thoroughly surveyed using binoculars. The observations made in the I-25 right-of-way suggested that searching the north- and southbound roadsides captured most of the weed infestations in the corridor. Additionally, a recently acquired 20-acre tract associated with Farish Outdoor Recreation Area was not surveyed because directions for access could not be provided. Due to restricted access from intensive military activity, the firing range within Jack's Valley was surveyed in its entirety in a single day, but the quality of data collected there was likely unaffected since the topography and vegetation permitted rapid assessment and mapping of weeds in the area.

Field notes served as the basis for estimates of shoot counts and area occupied for some mapped species for which attribute data was not recorded on Arcpad field forms, including leafy spurge, Scotch thistle, common St. Johnswort, bull thistle and tamarisk. Unless the number of shoots in an occurrence was specified in the notes for St. Johnswort, an assumption of 20 shoots/m² was used; similarly for leafy spurge, an assumption of 60 shoots/m² was used as a reasonable median figure taken from maps in Michels *et al.* (2000).

Populations of rare plants previously known to be present at the Academy and Farish were reassessed in 2002 when they were encountered. Field botanists did not actively seek to find previously unknown occurrences of rare plants, but they were documented when encountered while mapping the selected weed species. Previously unknown populations of two plant species of concern, *Potentilla ambigens* and *Liatris ligulistylis*, were found during the summer of 2002. Please see Appendix 1 for a summary of the natural heritage methodology for documenting and ranking rare plant occurrences. Please see Ellingson *et al.* (1995) and Doyle *et al.* (2001) for further information on the critical biological resources found at the Academy and Farish.

RESULTS AND DISCUSSION

Weed Mapping

It is likely that the 100-year drought of 2002 had major impacts on the degree to which weeds were apparent during this study. In comparison to what might be observed in a year of more normal precipitation, the depressing effect on growth of all mapped noxious weed species from this year's drought must be taken into account when interpreting

density and cover class results of this study. In a wetter year it is likely that a much larger infested area would have been determined. However, in some cases the noxious weeds appeared to be doing better than the native plants. Many native species remained dormant in 2002, so in many sites the weeds were the only species that seemed to be actively growing. Some weed species such as diffuse knapweed were stunted but still flowered profusely. This is typical of ruderal species, since they can adjust the allocation of resources such that they achieve at least some reproductive output, even in a poor year (Grime 2001).

While the total infested area determined by this study (Table 3) was relatively small, most of the Academy property is either infested or threatened by noxious weeds. The diffuse nature of the infestations of some species, particularly yellow toadflax, made it difficult to fully assess the extent and density of these species.

The tabular and map data elucidate several patterns in the distribution and abundance of weeds at the Academy and Farish. As previously recognized, the yellow toadflax infestations at the Academy and Farish are the largest infestations in the study area. While the infested area of yellow toadflax is only slightly larger than that of Canada thistle (Table 3), yellow toadflax is far more diffuse and is found in a wide range of habitats. Canada thistle is locally abundant but is concentrated in riparian areas and other wet sites. Most noxious weeds seemed to be spatially organized in a hierarchy of clumps. This was particularly apparent in clonal species such as yellow toadflax, Canada thistle, and leafy spurge, where a single clump is probably equivalent to one “genet” (genetically distinct individual). Very few stands were considered to be continuous in their distribution.

Density and cover class are attributes which are obviously interrelated and which varied due to the plasticity of the subject weed species and plant growth as summer progressed. Yellow toadflax is a case in point. In most locations this weed was found growing in stands of many smaller plants of a certain cover class. In locations more favorable for growth, or later in the growing season, stands of the same cover class might be comprised of fewer, larger plants.

Several point weed occurrences appear to be erroneously located in the waters of Reservoir Numbers 2 & 3. Due to the drought in the summer of 2002, the water level behind both of these structures was lower than in the year the aerial photographs were taken. The exposed shore thus offered open domain for weed growth.

Assessment of Effectiveness of Methodology

New technology was utilized in this project. To a very large degree, this technology (described in the methods section of this document) improved the accuracy and efficiency of the fieldwork. Much was learned by incorporating the use of the Pocket PC into this mapping exercise, but recent software and hardware improvements have addressed some of the problems encountered in this project. Proprietary incompatibility between the

version of ArcPad used for the project (5.0.1) and the GPS unit (Teletype PC card) made it impossible to capture GPS data for the creation of features in ArcPad. This probably decreased the precision of some map features. The precision of mapped weed occurrences depended upon the standard deviation of GPS technology, but also upon how precisely the technician was able to touch stylus to iPAQ screen, especially when delineating lines and polygons. Using ArcPad 6.0 (which was not released until after the field forms for this project were already created in ArcPad 5.0.1) would solve this problem.

The radius of a point occurrence or width of a line weed occurrence was as often as possible selected to be no less than the six meter estimated standard error of the GPS used in this study. Coincidentally, this distance usually seemed right for including most plants growing within stands of herbaceous noxious weeds. When surveying in oak scrub and coyote willow, however, a shorter radius of 4m came to be most commonly used for herbaceous weeds to better reflect the limitations of visibility in those vegetation types. Greater distances could effectively be used for Russian olive because the large size of the plants allowed them to be readily seen at those distances.

The evaluation of weed infestation attributes in the field depended to great extent upon the subjective view of the field technician. The attribute results of this survey are decidedly conservative: other technicians might have judged particular weed occurrences to possess continuous rather than patchy distribution, for example, or to belong to the next-highest cover class than the one assigned. Because the evaluation of all weed occurrences was attended by one technician (with periodic help from another), attribute results are internally consistent.

Table 3. Area Occupied by Weeds Sampled, Estimated Number of Shoots in Sampled Area, Invasiveness, and Suggested Priority for Management of weed species mapped at the US Air Force Academy and Farish Outdoor Recreation Area. Due to overlap in the presence of the selected weed species, the total occupied area is less than the sum of the occupied area of the individual weed species.

Common Name	Scientific Name	Area Occupied (acres)	Estimated Number of Shoots in Sampled Area	Number of mapped features	Invasive-ness at the Academy/Farish	Suggested Priority for Management
U.S. Air Force Academy:						
Yellow Toadflax	<i>Linaria vulgaris</i>	102.93	2,665,871	2093	High	Moderate
Canada Thistle	<i>Breea arvensis</i> (= <i>Cirsium arvense</i>)	101.43	529,103	543	High	Moderate
Diffuse Knapweed	<i>Acosta diffusa</i> (= <i>Centaurea diffusa</i>)	56.41	141,805	328	High	High
Russian Olive	<i>Eleagnus angustifolia</i>	49.79	1,310	269	High	High
Fuller's Teasel	<i>Dipsacus fullonum</i>	18.34	1,693	35	High	High
Musk Thistle	<i>Carduus nutans</i>	16.16	2,244	280	Moderate	Moderate
Bull Thistle	<i>Cirsium vulgare</i>	5.54 *	596*	73	Moderate	Moderate
Spotted Knapweed	<i>Acosta maculosa</i> (= <i>Centaurea maculosa</i>)	4.68	3,485	54	High	High
Hoary Cress	<i>Cardaria draba</i>	3.58	21,012	16	High	High
Leafy Spurge	<i>Tithymalus esula</i> (= <i>Euphorbia esula</i>)	1.09	20,914*	38	High	High
Scotch Thistle	<i>Onopordum acanthium</i>	.17 *	52*	7	High	High
Common St. Johnswort	<i>Hypericum perforatum</i>	<0.1 *	363*	5	Moderate	High
Tamarisk	<i>Tamarix ramosissima</i>	<0.1	1	1	High	High
Field Bindweed	<i>Convolvulus arvensis</i>	NA	NA	78	Moderate	Moderate
TOTAL (Academy):		330.43		3,820		
Farish Outdoor Recreation Area:						
Yellow Toadflax	<i>Linaria vulgaris</i>	5.25	99,924	93	High	High
Musk Thistle	<i>Carduus nutans</i>	0.85	57	14	High	High
Canada Thistle	<i>Breea arvensis</i> (= <i>Cirsium arvense</i>)	0.23	3,488	8	High	High
Leafy Spurge	<i>Tithymalus esula</i> (= <i>Euphorbia esula</i>)	**	**	1 known	High	High
TOTAL (Farish):		6.22		116		
GRAND TOTAL (Academy and Farish):		336.66		3,936		

* number of shoots and area occupied estimated from field notes

** the small occurrence of leafy spurge at Farish was not visited by field botanists in 2002.

Rationale for Suggested Management Priorities in Table 3

Goals 2 and 3 of Colorado's Strategic Plan to Stop the Spread of Noxious Weeds (Colorado Department of Agriculture 2001, pg. 1) constitute the philosophical basis for the management priorities suggested in Table 3 for noxious weeds mapped in 2002 on Academy properties. These goals are to "Prevent the establishment of newly introduced noxious weed species in Colorado" and to "stop the spread of weed species that are already so well-established within Colorado that statewide eradication is no longer possible." For some of the mapped species, it is early enough to prevent these weeds from becoming problems at the Academy and Farish; for others, a strategy of containment is the best to be hoped for.

High Management Priority Species

Several species are given high management priority because of their small population sizes or limited distribution on the Academy. Aggressive management now could eradicate them from the Academy, preventing future costly management efforts and ecosystem degradation. Among these species are tamarisk, Scotch thistle, St. Johnswort, and hoary cress. Russian olive is given a high management priority because of its slow growth, ease of discovery of individuals, and for the threat it poses to the riparian areas throughout the Academy.

Although diffuse and spotted knapweeds have become somewhat widespread at the Academy, they remain somewhat localized, mostly along roads and railroad right of way areas, and eradication is still feasible. These species have demonstrated their ability to become serious economic and environmental problems, and thus warrant serious attention while they remain somewhat manageable.

Fuller's teasle can form very dense stands and may outcompete native riparian vegetation. It has not yet begun to seriously affect the quality of the riparian areas along Monument Creek, but it is given high management priority for its potential to degrade these areas.

All weed species found at Farish were given high management priority because their management (for Canada thistle and yellow toadflax) and eradication (for leafy spurge) offer the potential for substantial improvements at a reasonable cost.

Moderate Management Priority Species

Two species, yellow toadflax and Canada thistle, have become so entrenched on the Academy that significant progress towards their eradication will be costly and require a long-term commitment. Bull and musk thistle are also given moderate priority because they have not thus far demonstrated a tendency to form large or dense stands. Nonetheless, these species should be watched closely. As a non-rhizomatous species, they are more easily managed than yellow toadflax and Canada thistle, so removal of individuals when found is likely to produce favorable results.

Noxious Weed Status by Species

Bull Thistle (*Cirsium vulgare*)

Similar to Canada thistle, bull thistle commonly can be found at trace to low cover classes in both intermittent and permanent natural wetlands, and wherever supplemental watering occurs. Bull thistle is a significant problem on the Eisenhower Golf Course along the margins of fairways, where overspray from non-adjustable heads of the course irrigation system waters the surrounding natural vegetation as well as the fairway turf grass (Canada thistle and yellow toadflax are serious problems at those same sites for the same reason). For some years course maintenance personnel have sought funds to install an updated irrigation system with adjustable heads on the course to save water and reduce overhead. Installation of such a system would also promote DNR efforts to manage weeds at the Academy.

Canada Thistle (*Brea arvensis*)

Both Canada thistle and yellow toadflax have insinuated themselves inextricably into the herbaceous layer of many of the plant communities throughout most Academy properties. Canada thistle likely can be found in trace to high cover class in every permanent and intermittent wetland and in any area receiving supplemental watering. For instance, the entire length of Monument Creek and shoreline of Ice Lake probably include some trace cover of Canada thistle, especially within stands of coyote willow. Notable dense stands of this weed are found along the intermittent creeks and seeps near the Aardvark Air Strip, the margins of fairways on the Eisenhower Golf Course, and in locations near the athletic fields.

Diffuse Knapweed (*Acosta diffusa*)

Diffuse knapweed is widely distributed at trace cover class, yet locally common at greater densities. Roadsides, creek sandbars and other human- and naturally disturbed areas are particularly susceptible to infestation. Notable occurrences are along the I-25 corridor, and at the water filtration plant on the western boundary of the Academy.



Field Bindweed (*Convolvulus arvensis*)

This weed is locally common at trace to low cover class in more heavily developed areas. The population in front of Academy High School is a representative occurrence. This year's drought seems to have reduced shoot growth of bindweed. Thus, in a normal year the percent cover of this weed might be significantly greater than that observed in 2002. This weed does not yet represent a serious threat, but should be monitored and managed where possible.

Fuller's Teasel (*Dipsacus fullonum*)

Fuller's teasel is generally not widely distributed. The weed normally is found at trace cover class where it grows, principally on the floodplains of Monument and Kettle Creeks, and below adjacent seeps. A noteworthy large stand grows on a seep on the east side of Monument Creek just north of North-Gate Boulevard.

Hoary Cress (*Cardaria draba*)

Hoary cress is locally common along Monument Creek in the vicinity of the sewage treatment plant. This weed appears to be extending its range north and south along Monument Creek. It was observed in highly disturbed areas and also in natural vegetation. This species poses a significant threat to the riparian areas along Monument Creek. It is easiest to observe in the spring and early summer (May-June) while flowering.



Leafy Spurge (*Euphorbia esula*)

This serious weed is locally common in a number of sites toward the northwestern quadrant of the base, especially in Jack's Valley near FERL. Notable moderately large stands grow south of FERL and north of North-Gate Boulevard, along the powerline access road south of the firing range, and east of the athletic fields roughly along Deadman's Creek. The weed seems to be extending its range on base. Many scattered small stands, some consisting of only a few ramets (shoots), can be found as far south as Douglas Valley, and it was found this year for the first time as far east as Monument Creek.



The biocontrol program begun at the Academy by Texas A & M University (Michels *et al.* 2000, 2001) offers hope for managing this weed. The program is still in its infancy, though, and populations of predatory insects likely still have to increase to effective levels and become permanently established (Michels *et al.* 2000, Michels *et al.* 2001). The three notable stands of leafy spurge previously mentioned would be good candidates for expanded biocontrol releases.

Musk Thistle (*Carduus nutans*)

Musk thistle is widely distributed on Academy properties at trace cover class, but occasionally grows at greater density, especially along natural and man-made drainages. Notable large populations were found along the intermittent creeks near Aardvark Air Strip, and on the east side of Monument Creek north of the South-Gate Bridge.

Russian Olive (*Eleagnus angustifolia*)

For decades Russian olive was a widely used for landscaping at the Academy, but has escaped and become naturalized. Russian olive has been locally common to very common along a number of drainages at the Academy. Notable infestations include portions of Monument Creek and Kettle Creek, and especially Pine Creek. Additionally, plants have volunteered north of Community Center Drive, and scattered individuals have been found throughout the base, some in odd locations. At the time of this writing, Russian olive will have been removed from many areas at the Academy.



However, trees left in Pine Valley, at the Community Center and on the main campus will continue to serve as a source of seeds, which will demand constant management to prevent reinfestation. Base-wide extirpation would greatly reduce the management costs for this species, freeing up resources for the management of other noxious weeds. In areas where Russian olive was removed, periodic monitoring will help detect new individuals arising from the seed bank. Control of Russian olive could prove particularly successful due to the slow rate of growth and high visibility of individual plants.

There is some evidence of hybridization between Russian olive and its close relative silverberry (*Shepherdia argentea*) at the Academy. Intermediates were observed on the east-facing slope above Monument Creek, north of North-Gate Boulevard and east of the Jacks Valley Training Complex access road. Special attention must be paid to careful identification of Russian olive during management efforts to avoid accidental impacts to silverberry populations. Silverberry is uncommon on the eastern slope in Colorado (Weber and Wittmann 2001) and has incurred significant loss of habitat due to residential development along the Front Range.

Scotch Thistle (*Onopordum acanthium*)

Scotch thistle was located in only a handful of sites and at only trace cover on the Academy. Thus, it is currently feasible to extirpate this species from the Academy. The most notable occurrence of this serious weed was at the recovered area immediately



east of the athletic fields. Individual plants are vulnerable to physical removal and spot spraying, and should be destroyed as encountered.

Spotted Knapweed (*Acosta maculosa*)

The dispersal and cover class patterns of spotted knapweed are similar to those of diffuse knapweed. Spotted knapweed is less common than diffuse knapweed overall, and while it grows in similar disturbed situations, is found more toward the central and western portions of the base. A noteworthy occurrence of spotted knapweed grows in the rip-rapped drainage channel of the intermittent creek on the south side of Parade Loop. Plants at trace cover class of both knapweed species, as well as Fuller's teasel and even musk thistle, might be susceptible to digging or spot spraying by trained members of community service organizations. Such control action would disrupt dispersal and gene flow through isolated individual plants and lessen the establishment of pioneer populations distant from locations of heavier infestation. As with leafy spurge, the knapweeds are a target for biocontrol at the Academy (Michels *et al.* 2001). Herbicide treatment must thus be used advisedly, since predatory insect populations require the presence of the plants to complete their life cycles.

St. Johnswort (*Hypericum perforatum*)

St. Johnswort was found at the Academy this summer for the first time. Stands are located principally in the Kettle Creek floodplain, with one stand along the service road north from North-Gate Boulevard toward Aardvark Air Strip. The weed is uncommon, although some stands are moderately large. A program of biocontrol has already been initiated to manage it. The small number of plants found, or the limited extent of infestation of this species (and also Scotch thistle and tamarisk) might allow them to be extirpated completely from the base. This species has become extremely problematic elsewhere (i.e., the Pacific Northwest) (Washington Department of Agriculture 1997).

Tamarisk (*Tamarix ramosissima*)

Tamarisk was found at the Academy this summer for the first time. Only one non-flowering sapling was discovered at the eastern periphery of the base near Research Boulevard. While this individual plant neither grows on the main part of the base nor directly beside a watercourse, it should nonetheless be destroyed to avoid initiation of a pioneer population of tamarisk along Pine Creek.

Yellow Toadflax (*Linaria vulgaris*)

Yellow toadflax is without doubt the most common noxious weed, possessing a broad ecological amplitude which allows it to thrive in a wide range of habitats.

While highly pervasive, yellow toadflax shows a predictable pattern of distribution upon the landscape, and certain shrubs, subshrubs, and grasses can be useful as negative indicators of the likelihood of occurrence.

Yellow toadflax is more likely to be found within the herbaceous layer beneath a number of woody shrubs or trees, including Gambel's oak (*Quercus gambelii*), skunkbrush (*Rhus aromatica* ssp. *trilobata*), ponderosa pine (*Pinus ponderosa*), douglas fir (*Pseudotsuga menziesii*), and cottonwood (*Populus deltoides* ssp. *monilifera*). It is especially prevalent under Gambel's oak, and within dense oak stands yellow toadflax typically grows nearer the open margins of the stand. The weed is uncommon beneath scrub oak and elsewhere in tree-dominated plant communities where oak is obviously a subordinate component of the shrub understory. The weed may be found more commonly on south-facing than on north-facing slopes or ridgetops, but most often at toe slopes or upon broad, flat uplands or lowlands. Yellow toadflax seems least likely to be found on slopes with thin, rocky soil, and in the presence of mountain mahogany (*Cercocarpus montanus*), yucca (*Yucca glauca*), prickly pear (*Opuntia* spp.) or kinnikinnick (*Arctostaphylos uva-ursi*). It also seems to compete poorly with smooth brome (*Bromopsis inermis*), and is rarely associated with this grass (see photos on the following page). None of the preceding observations, however, precludes at least a few ramets of yellow toadflax being found nearly anywhere at the Academy.



Light and moisture requirements might explain much of the distribution of yellow toadflax at the Academy and Farish. It seems to grow best in locations where light is less impeded and the soil moisture regime more mesic. On the Academy, the latter environmental characteristic may be tied to soil depth and texture, since deeper, finer soils possess greater water holding capacity. The lower likelihood of encountering yellow toadflax in these landscape positions, and in the presence of the plant species mentioned above is consistent with shallow, coarse soils. More favorable edaphic conditions may promote the well being of a mycorrhizal associate in whose presence yellow toadflax is better able to thrive (Nadeau and King 1991).



Gambel's oak as shrub understory component – east of stables, horse area. Yellow toadflax is seldom found in this plant community.



Mountain mahogany and yucca with Gambel's oak on thin rocky soil – south-facing slope, horse area. Yellow toadflax is seldom found in this plant community.



Mountain mahogany and prickly pear with Gambel's oak on thin rocky soil – south-facing slope, horse area. Yellow toadflax is seldom found in this plant community.

Areas Unaffected by Noxious weeds

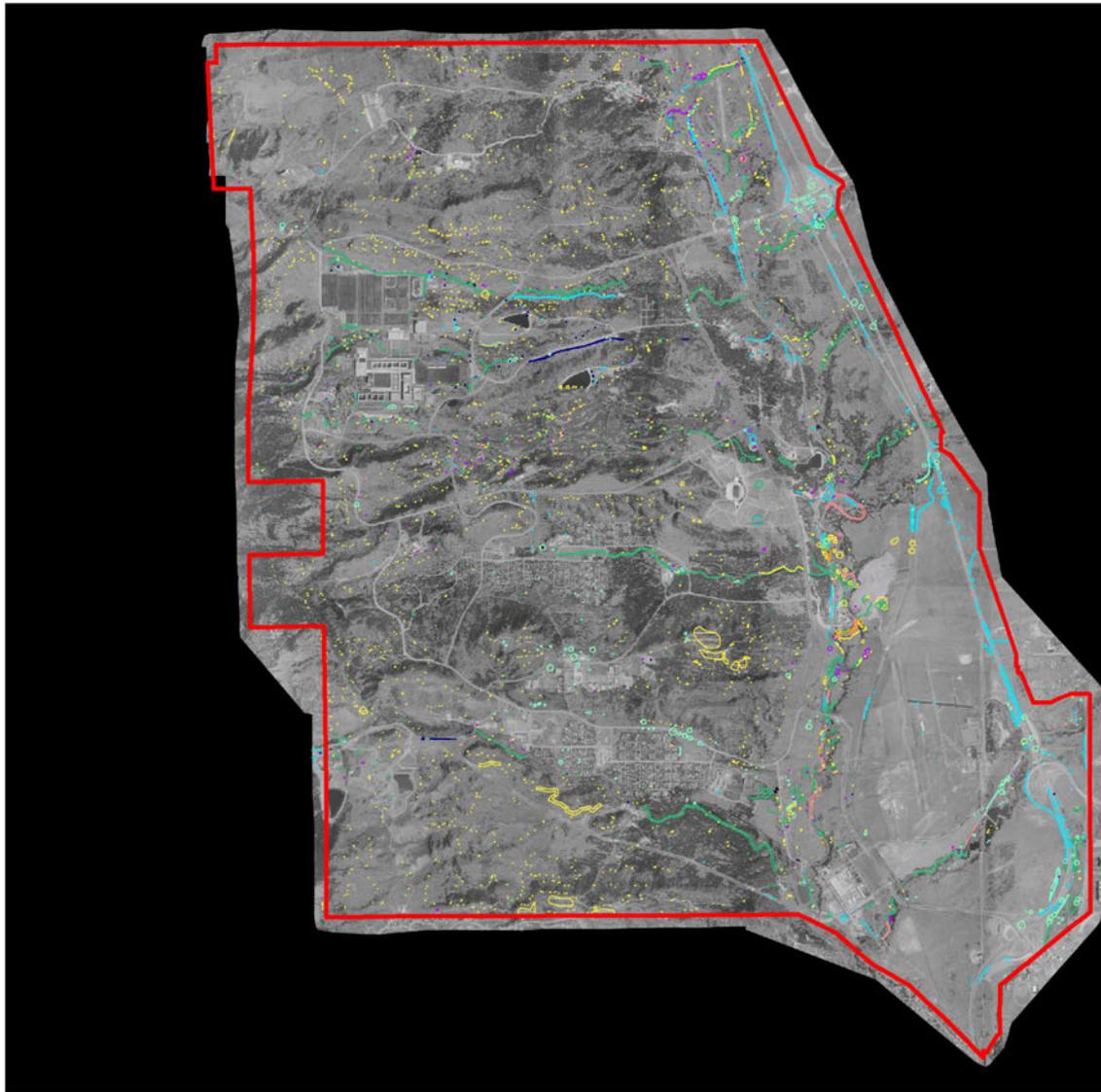
Although weed infestation is widespread in the Academy and Farish, some community types were noted where weed infestation was not often observed. The upland forest at both Farish and the Academy, and the oak/coniferous mixed forest, and ponderosa pine parklands with smooth brome in the middle to western portions of the Academy, are largely weed-free. Noxious weeds are likewise absent from the upland shrubland-dominated mosaic on the Academy which includes a high frequency of mountain mahogany.



Kinnikinnick with Gambel's oak on thin rocky soil - west-facing slope, hill with water tank east of Stanley Creek.



Smooth brome beneath Gambel's oak – west end, West Monument Creek.



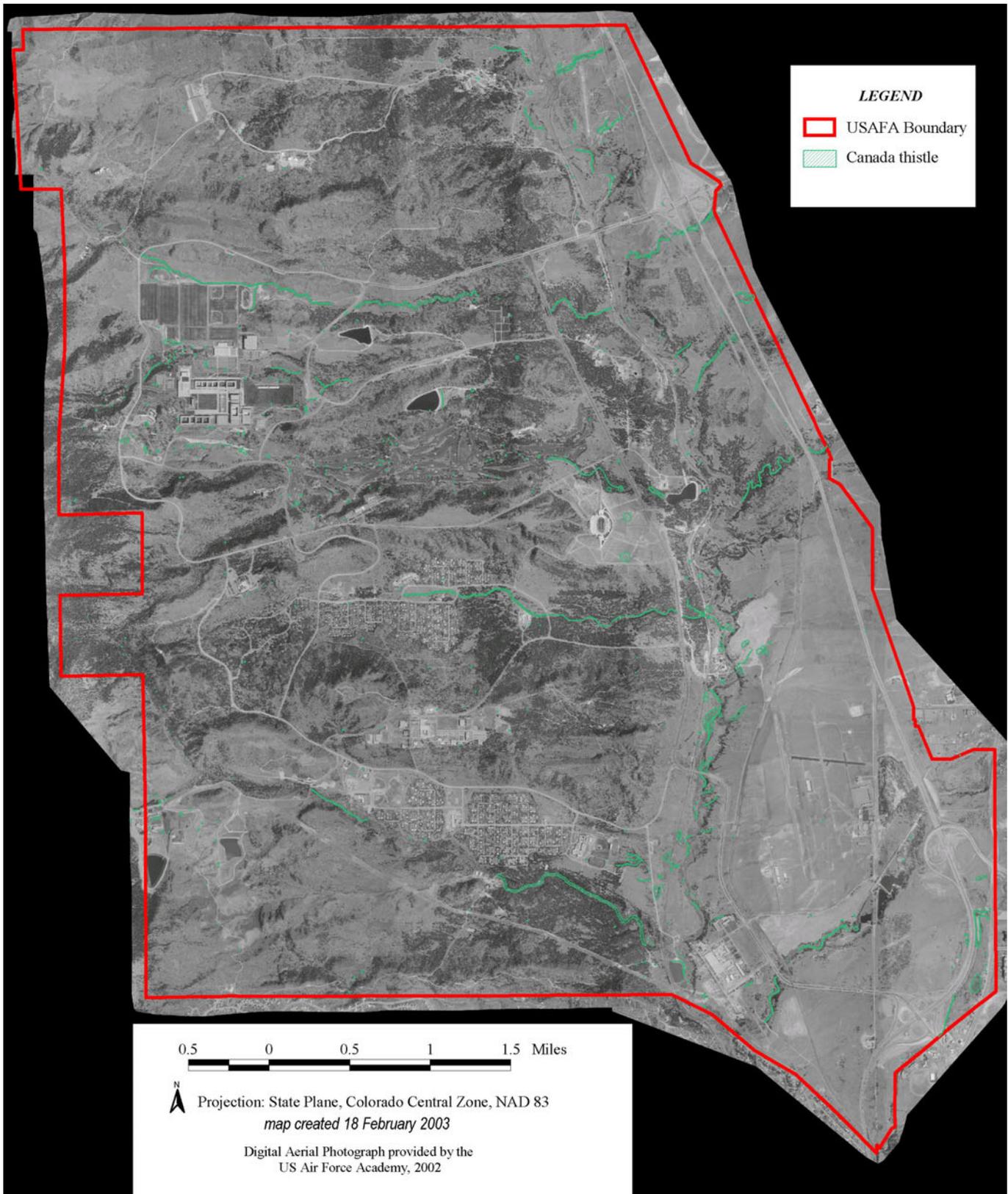
Projection: State Plane, Colorado Central Zone, NAD 83

<p>Colorado Natural Heritage Program Colorado State University College of Natural Resources 254 General Services Building Fort Collins, CO 80523</p>  <p>map created 18 February 2003</p>	<p>LEGEND</p> <ul style="list-style-type: none">  USAFA Boundary  Fuller's teasel  butter-and-eggs  Russian olive  leafy spurge  Canada thistle  diffuse knapweed  spotted knapweed  musk thistle  white top  Other  2001 Biocontrol Sites <p>Digital Aerial Photograph provided by the US Air Force Academy, 2002</p>	<p>Location in Colorado</p> 
<p>Disclaimer</p> <p>The data contained herein are provided on an as-is, as-available basis without warranties of any kind, expressed or implied, including (but not limited to) warranties of merchantability, fitness for a particular purpose, and non-infringement. CNHP, Colorado State University and the State of Colorado further expressly disclaim any warranty that the data are error-free or current as of the date supplied.</p>		

Map 1. All the mapped species of noxious weeds at the U.S. Air Force Academy.

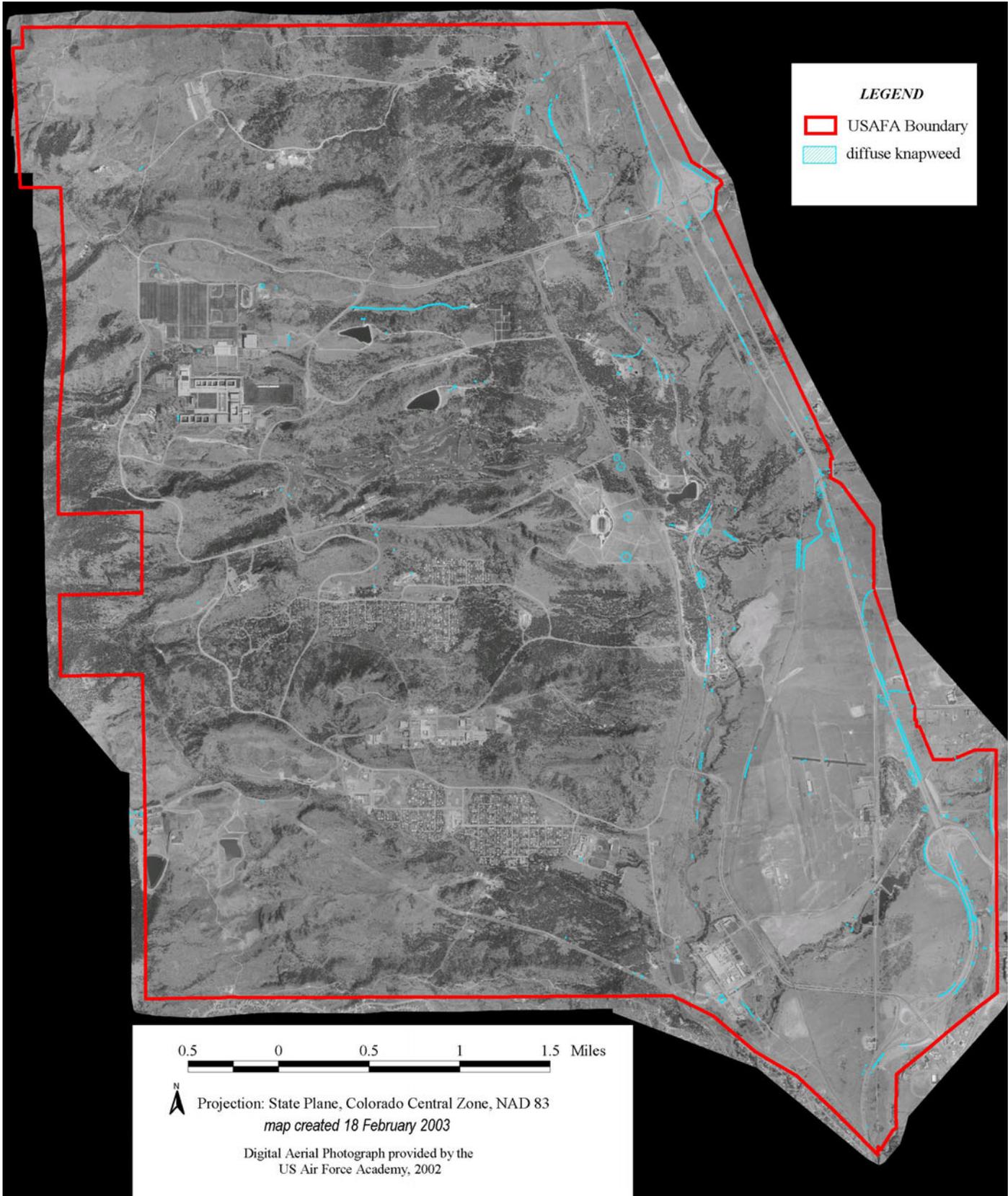
Map 2. Distribution of yellow toadflax (*Linaria vulgaris*) at the U.S. Air Force Academy in 2002.

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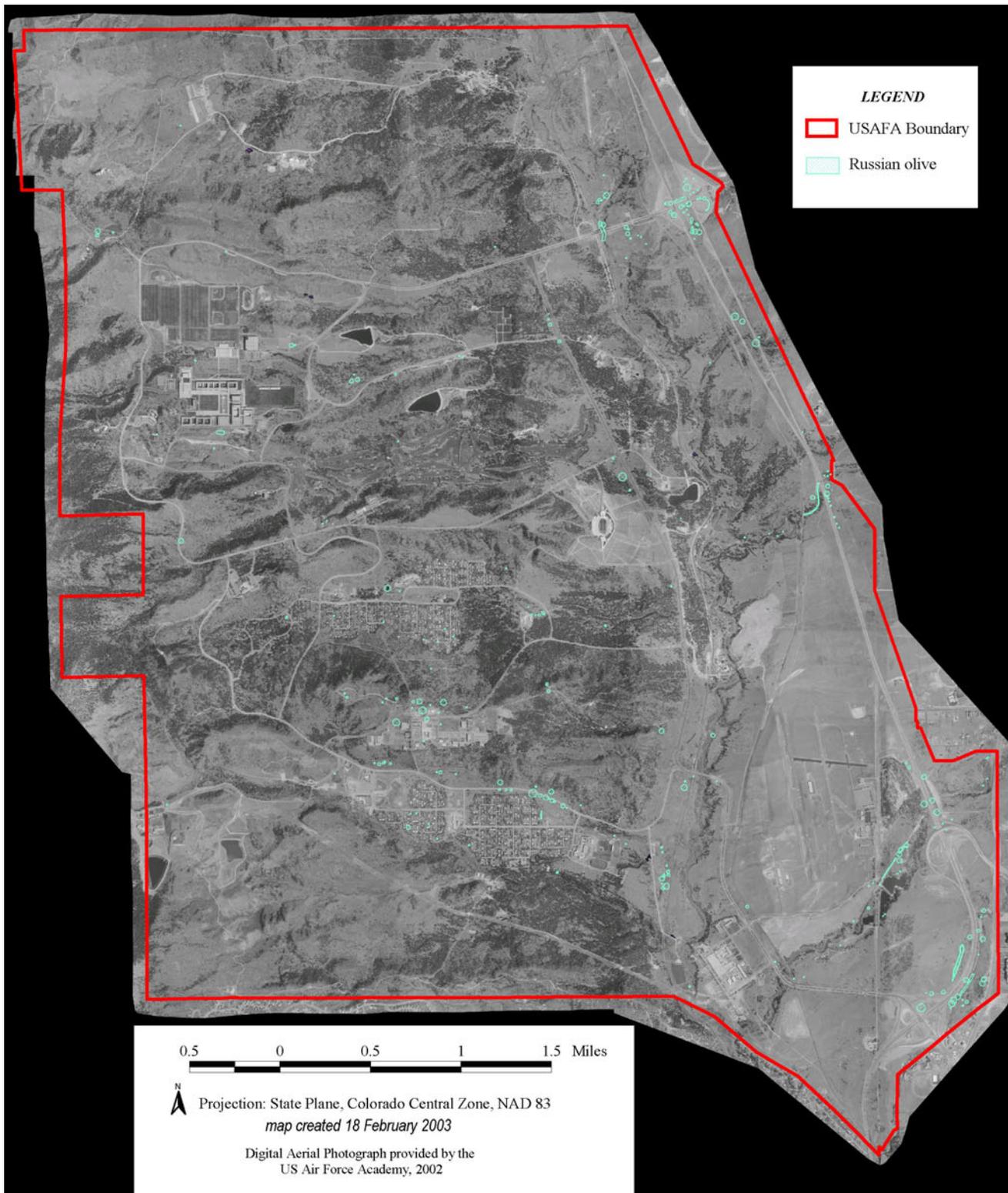
Map 3. Distribution of Canada thistle (*Breea arvensis*) at the U.S. Air Force Academy in 2002.

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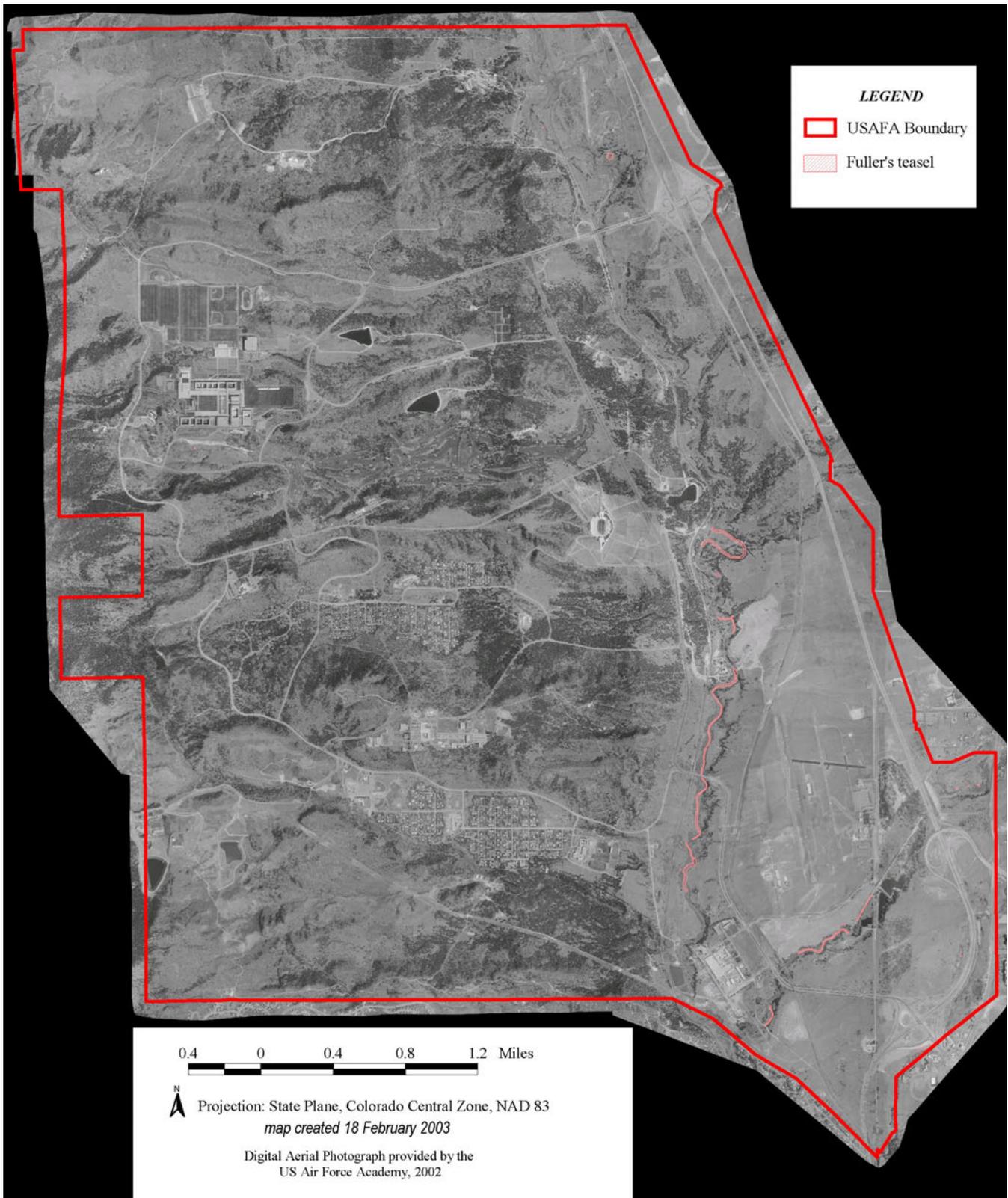
Map 4. Distribution of diffuse knapweed (*Acosta diffusa*) at the U.S. Air Force Academy in 2002.

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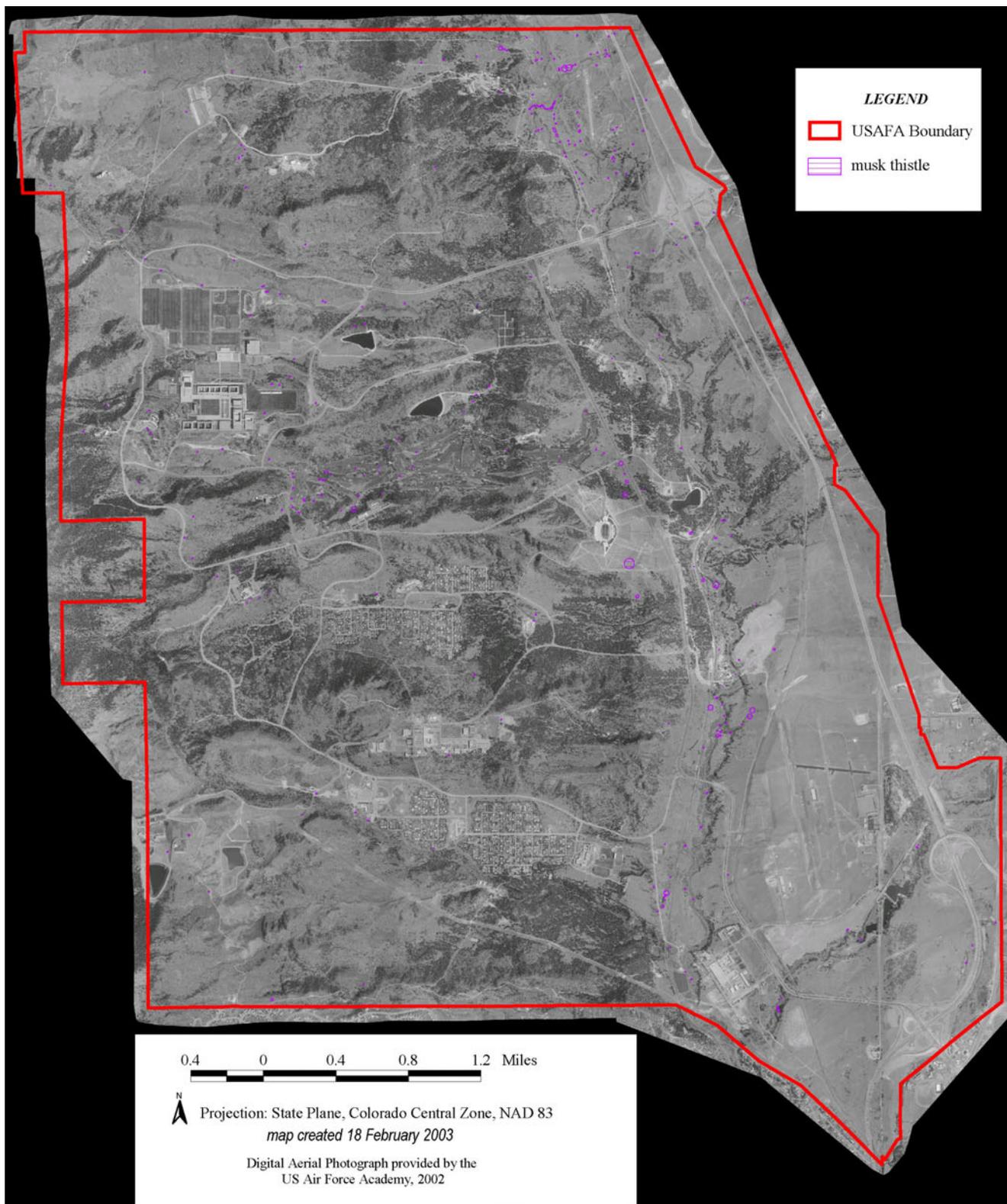
Map 5. Distribution of Russian olive (*Eleagnus angustifolia*) at the U.S. Air Force Academy in 2002.

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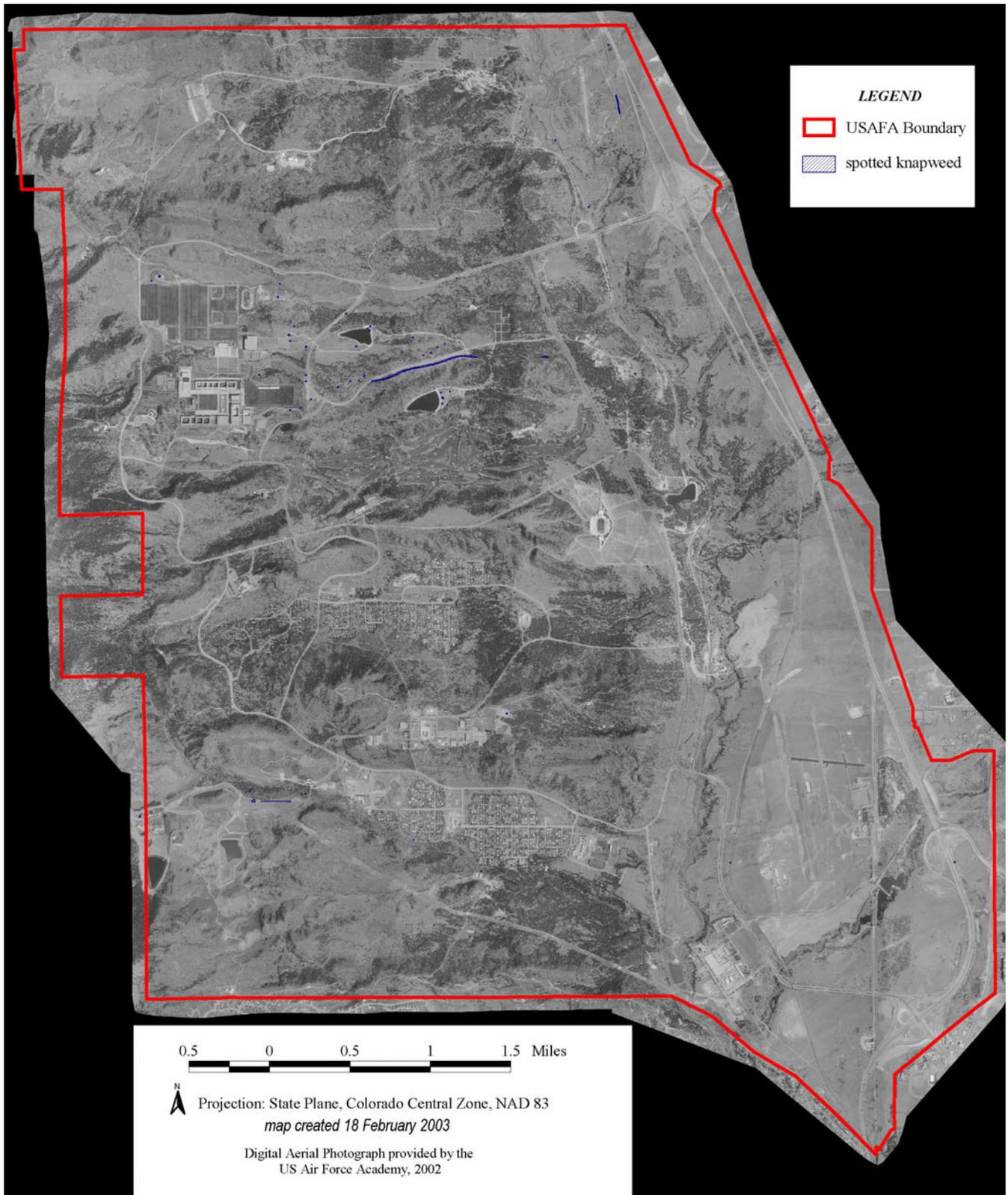
Map 6. Distribution of Fuller's teasel (*Dipsacus fullonum*) at the U.S. Air Force Academy in 2002.

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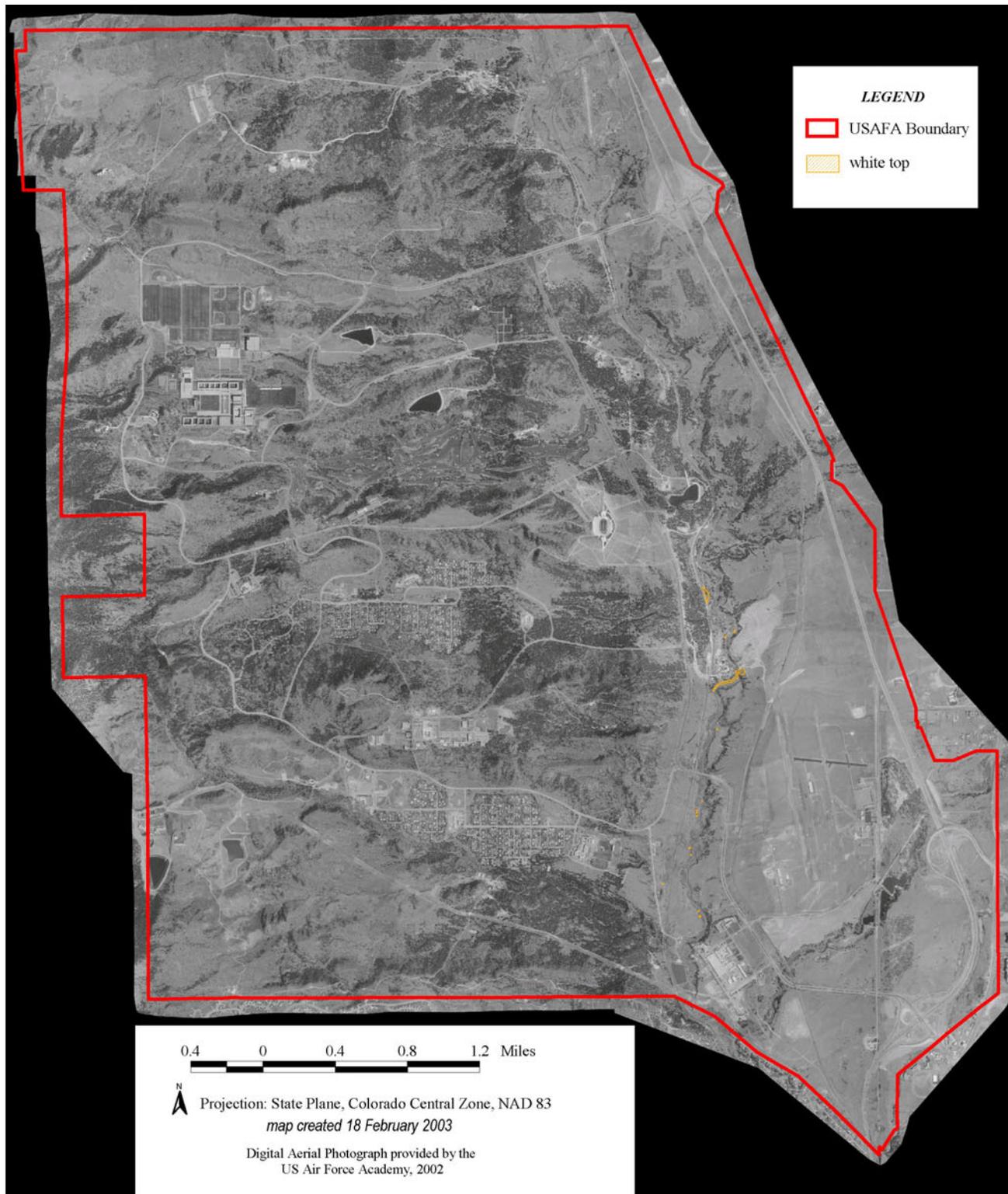
Map 7. Distribution of musk thistle (*Carduus nutans*) at the U.S. Air Force Academy in 2002.

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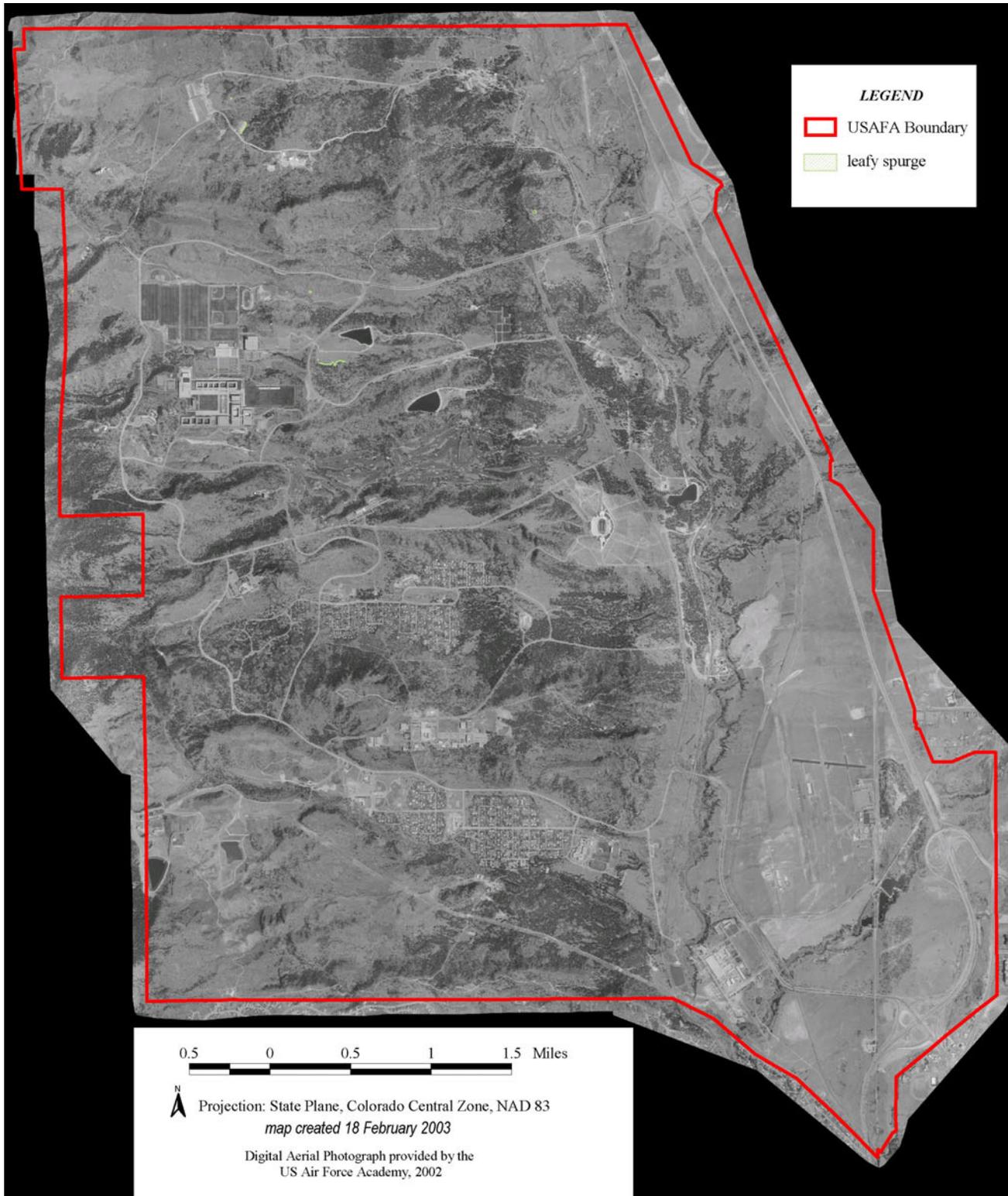
Map 8. Distribution of spotted knapweed (*Acosta maculosa*) at the U.S. Air Force Academy in 2002.

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Map 9. Distribution of hoary cress (*Cardaria draba*) at the U.S. Air Force Academy in 2002.

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Map 10. Distribution of leafy spurge (*Tithymalus esula*) at the U.S. Air Force Academy in 2002.

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RARE PLANT OBSERVATIONS

Ten species of rare plants have been documented from the Academy and Farish. All of the rare plant occurrences documented at the Academy and Farish are included in Appendix 4 of this document. Observations were made of two rare plant species during this study. One previously known population of Rocky Mountain cinquefoil (*Potentilla ambigens*) (G3 S1S2) was revisited, and two previously unknown subpopulations were discovered at the Academy in 2002. The Monument Creek element occurrence of *P. ambigens* was estimated to include approximately 360 plants and the new Aardvark occurrence included 25 individuals. The other newly discovered cinquefoil population includes approximately 40 individuals. Additionally, several scattered individuals were found throughout the general area. Most of the population appears healthy with no immediate threats. However, the Aardvark subpopulation is experiencing ongoing disturbance from trucks being driven through the population to remove trees for transplantation. A T-post fence or other enclosure could be installed to redirect truck traffic around this population without inconveniencing tree crews. All occurrences of *P. ambigens* might be threatened in the future by knapweed, which is common along roadsides in some portions of the Academy.

A population of Rocky Mountain gay feather (*Liatris ligulistylis*) (G5? S1S2) previously unknown at the Academy was discovered at Lehman Run. This population was estimated to include around 100 plants and appears healthy and undisturbed. It may be threatened in the future by Canada thistle, which is present extensively throughout the wetland, although not in abundance within the population of *L. ligulistylis*.

The wetland at Lehman Run where *L. ligulistylis* grows is unlike any other at the Academy, being characterized by *Salix* sp. and *Pentaphylloides floribunda* as shrub dominants, with extensive *Juncus* sp. and *Carex* spp. in the herbaceous layer. The amount of comparatively unaltered wetland remaining is not great, so careful management of what remains can help retain a valuable element of biodiversity at the Academy. Monitoring and control of Canada thistle at Lehman Run is likely to benefit *L. ligulistylis* if management efforts are used that minimize impacts to *L. ligulistylis*. Herbicides, if used, should be hand applied to individual thistle ramets. Timing of application to maximize impact while minimizing the risk of exposing *L. ligulistylis* to herbicide will be important. Application on windy or potentially rainy days is probably ill-advised.

Please see Appendix 4 for Colorado Natural Heritage Program Element Occurrence Records for these occurrences.

RECOMMENDATIONS

Careful management of weeds in the vicinity of rare plant and animal occurrences will help to ensure that populations of these elements of biodiversity are not compromised. Widespread use of herbicides on the Academy has the potential to negatively impact populations of the federally listed Preble's Meadow Jumping Mouse (*Zapus hudsonius*

preblei). Application in the riparian habitat for this species may have negative impacts on mouse populations. Management of noxious weeds is included among the tasks needed to maximize the extent, quality, and connectivity of Preble's Meadow Jumping Mouse habitat (Grunau *et al.* 1999). Russian olive and knapweed (probably diffuse knapweed) are specifically mentioned in the management plan for Preble's Meadow Jumping Mouse. See the recommendations offered in the Rare Plant Observations section of this document for specific recommendations regarding herbicide handling and application to weed populations in the vicinity of rare plant occurrences.

Efforts to eradicate weeds that are currently uncommon on the Academy will offer large rewards for a relatively small cost. A concerted effort to eradicate tamarisk, St. Johnswort, and Scotch thistle is likely to preempt costly future weed management on the Academy. Aggressive management of hoary cress is also likely to prevent a more serious infestation in the riparian areas in the future.

Students and volunteers are a potential workforce for weed management activities. They can be particularly effective in the management of non-clonal species that can be killed by hand pulling such as diffuse knapweed, spotted knapweed, musk thistle, and Scotch thistle. The thistles can be easily killed using a shovel to sever the plant from the root just below ground-level. However, it will be important to train volunteers and students to distinguish native thistles such as the wavyleaf thistle (*Cirsium undulatum*) from non-native species. Volunteers and students could also assist with the eradication of Russian olive from the Academy. Small Russian olive trees can be effectively removed using a weed wrench. Again, teaching crews to distinguish Russian olive from silverberry (*Shepherdia argentea*), its native look-alike, will be necessary to prevent impacts to this desirable and uncommon species.

ACKNOWLEDGEMENTS

This project was made possible through the assistance and expertise of many people. Our primary contact for the project, Brian Mihlbachler, provided unflagging support throughout all phases of the project. His initiative provided the impetus to start the project, and his broad knowledge of weed infestations throughout the Academy and Farish gave the project a solid foothold. His time spent orienting field crews and checking in with field botanists was extremely valuable. Jim McDermott, Steve Wallace, and Greg Speights also provided crucial logistical support and advice. Gerry Shisler and Albert Lioen provided imaging and other information needed to support the mapping component of the project. Thanks also to the U.S. Air Force Academy Security Forces for accommodating the needs of this project.

Dr. Gerald Michels provided helpful advice on noxious weed infestations at the Academy. Dr. Tass Kelso provided access to the Carter Herbarium for specimen verification and familiarization with the plants of the Academy and Farish. Dr. Alan Carpenter provided advice on the use of mobile devices for weed mapping. Rob Billerbeck and Bill Cheatum provided insights regarding weed species of Colorado and integrated data from this project into the Colorado Weed Mapping Program.

Several CNHP and CSU staff provided crucial assistance. Drew Redfield provided critical computer hardware and software support, particularly during the implementation of the project. Susan Spackman Panjabi assisted with hiring and project oversight. Jill Handwerk provided information on rare plant occurrences and incorporated new occurrences into the CNHP database. Jane Nusbaum and Barbara Brayfield provided crucial financial oversight. Ron wishes to thank his field assistant, Obie for his contributions to the project. Thanks also to Susan Spackman Panjabi for her careful review of the report.

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APPENDIX 1. THE NATURAL HERITAGE RANKING SYSTEM

Information is gathered by CNHP on Colorado's plants, animals, and plant communities. Each of these species and plant communities is considered an **element of natural diversity**, or simply an **element**. Each element is assigned a rank that indicates its relative degree of imperilment on a five-point scale (e.g., 1 = extremely rare/imperiled, 5 = abundant/secure). The primary criterion for ranking elements is the number of occurrences, i.e., the number of known distinct localities or populations. This factor is weighted more heavily because an element found in one place is more imperiled than something found in twenty-one places. Also of importance are the size of the geographic range, the number of individuals, trends in both population and distribution, identifiable threats, and the number of already protected occurrences.

Element imperilment ranks are assigned both in terms of the element's degree of imperilment within Colorado (its State or S-rank) and the element's imperilment over its entire range (its Global or G-rank). Taken together, these two ranks give an instant picture of the degree of imperilment of an element. For example, the lynx, which is thought to be secure in northern North America but is known from less than 5 current locations in Colorado, is ranked G5S1. The Rocky Mountain Columbine which is known only from Colorado, from about 30 locations, is ranked a G3S3. Further, a tiger beetle that is only known from one location in the world at the Great Sand Dunes National Park is ranked G1S1. CNHP actively collects, maps, and electronically processes specific occurrence information for elements considered extremely imperiled to vulnerable (S1 - S3). Those with a ranking of S3S4 are "watchlisted," meaning that specific occurrence data are collected and periodically analyzed to determine whether more active tracking is warranted. A complete description of each of the Natural Heritage ranks is provided in Table 1.

This single rank system works readily for all species except those that are migratory. Those animals that migrate may spend only a portion of their life cycles within the state. In these cases, it is necessary to distinguish between breeding, non-breeding, and resident species. As noted in Table 1, ranks followed by a "B", e.g., S1B, indicate that the rank applies only to the status of breeding occurrences. Similarly, ranks followed by an "N", e.g., S4N, refer to non-breeding status, typically during migration and winter. Elements without this notation are believed to be year-round residents within the state.

Table 1. Definition of Colorado Natural Heritage Imperilment Ranks.

Global imperilment ranks are based on the range-wide status of a species. State imperilment ranks are based on the status of a species in an individual state. State and Global ranks are denoted, respectively, with an "S" or a "G" followed by a character. **These ranks should not be**

G/S1 Critically imperiled globally/state because of rarity (5 or fewer occurrences in the world/state; or very few remaining individuals), or because of some factor of its biology making it especially vulnerable to extinction.

G/S2 Imperiled globally/state because of rarity (6 to 20 occurrences), or because of other factors demonstrably making it very vulnerable to extinction throughout its range.

G/S3 Vulnerable through its range or found locally in a restricted range (21 to 100 occurrences).

G/S4 Apparently secure globally/state, though it might be quite rare in parts of its range, especially at the periphery.

G/S5 Demonstrably secure globally, though it may be quite rare in parts of its range, especially at the periphery.

GX Presumed extinct.

G#? Indicates uncertainty about an assigned global rank.

G/SU Unable to assign rank due to lack of available information.

GQ Indicates uncertainty about taxonomic status.

G/SH Historically known, but not verified for an extended period, usually.

G#T# Trinomial rank (T) is used for subspecies or varieties. These taxa are ranked on the same criteria as G1-G5.

S#B Refers to the breeding season imperilment of elements that are not permanent residents.

S#N Refers to the non-breeding season imperilment of elements that are not permanent residents. Where no consistent location can be discerned for migrants or non-breeding populations, a rank of SZN is used.

SZ Migrant whose occurrences are too irregular, transitory, and/or dispersed to be reliably identified, mapped, and protected.

SA Accidental in the state.

SR Reported to occur in the state, but unverified.

S? Unranked. Some evidence that species may be imperiled, but awaiting formal rarity ranking.

Notes: Where two numbers appear in a state or global rank (e.g., S2S3), the actual rank of the element falls between the two numbers.

APPENDIX 2: SUMMARY OF U.S. AIR FORCE ACADEMY WEED DATA

File Structure

Each geographic file is provided in ArcView shapefile (.shp) format and Arc/Info export (.e00) format so these data can be readily used in ArcView, Arc/Info or ArcGIS. All files are projected to the State Plane Coordinate System, Colorado central zone, North American Datum of 1983 (map units are feet). FGDC (Federal Geographic Data Committee) compliant metadata are provided as ASCII text files and are named the same as the geographic files with a .met file extension. Be sure to review the metadata for more detailed information and for definitions of each item in the attribute tables.

Because the data include links (aka hotlinks) to images of specific weed infestations and areas, the file structure on the local drive of the user's computer must be the same as the file structure on the CD so ArcView can use a predefined filepath to find and pull up the images. Copy the folder "noxiousweeds2002" to the root of your hard drive or a network drive (the actual drive letter, e.g. c:\, d:\, etc. does not matter). All subfolders (GrossArea, MapError, Photos, and RawData) must remain nested under the noxiousweeds2002 folder. Note that hotlinking information is only provided in the ArcView shapefiles. An ArcView project (noxiousweeds2002.apr) is also included.

Explanation of Weed Data

There are three types of data included on the CD: "raw" data, "gross area" data and "mapping error" data. In each file the data are presented in a different way as described below and in Figures 1-3. Each file type lends itself best to a particular use, so it is important to select the appropriate file for each application. Potential uses for each file are listed in the descriptions below. Naming conventions were applied to each of the file types, and were used consistently throughout the project (Table 1).

Table 1. Summary of the file types used for weed data at the U.S. Air Force Academy in 2002.

File Type	File Name
Raw Data <i>Data in these files are not buffered and appear as they were initially mapped in the field (points, lines or polygons).</i>	weeds_pt.shp, weeds_pt.e00, weeds_ln.shp, weeds_ln.e00, weeds_ply.shp, weeds_ply.e00, rareplants.shp, rareplants.e00
Gross Area <i>This file includes the radii and buffer widths ascribed in the field. All features are polygons and reflect the actual size of the infestations.</i>	weeds_ga.shp, weeds_ga.e00
Mapping Error <i>This file includes the radii and buffer widths plus an additional 20m buffer to account for the potential inaccuracy of the GPS.</i>	weeds_me.shp, weeds_me.e00

Description of Each File Type

Raw Data

These files maintain the original, edited data in separate point, line, and polygon shapefiles. Because some occurrences in the “other” category do not have an area associated with them (e.g. weed species that were not among those sought in the survey, but mapped nonetheless), they appear only in these files. The photos are hotlinked to these files since they represent the complete weed flora mapped in this project. Rare plants are also included as points. Because the point and line features have no area, they must remain in separate shapefiles, as follows:

Folder: RawData

Geographic Files:

Weed Points: weeds_pt.shp or weeds_pt.e00

Weed Lines: weeds_ln.shp or weeds_ln.e00

Weed Polygons: weeds_ply.shp or weeds_ply.e00

Rare Plant Points: rareplants.shp or rareplants.e00

Gross Area

The shapes included in this file reflect the estimated size of each weed infestation. All point, line, and polygon features are combined into one file here and buffered by the area observed in the field. Thus, all features in this file have an area and are represented as polygons. Points (Figure 1) are represented as a circle with the radius that was ascribed in the field. Lines (Figure 2) are represented as an elongated polygon that includes the buffer width and topological direction ascribed in the field. Lines also have “flat” ends to prevent overestimating the size of the infestation. Features that were mapped as polygons (Figure 3) in the field are not changed in this file and appear as they were mapped and edited by the field technician (i.e. no buffers).

This file is probably the most useful of all of those included, since it best reflects the actual observations of weeds in the study area. However, due to the accuracy of the GPS (20m), each infestation may actually be as far as 20 meters in any direction from the feature shown in this file (although CNHP has observed that this particular GPS unit is typically 5-6 meters off). Nonetheless, these data can be used to calculate infested area for all or part of the Academy by species or region, and will be useful for generating maps for spray crews, biocontrol release, or other weed management activities.

Folder: GrossArea

Geographic File: weeds_ga.shp or weeds_ga.e00

Mapping Error

This file includes the radii for point infestations, and the buffers for line infestations. It also includes an additional 20 meter buffer around all features (points, lines, and

polygons). This is portrayed in Figures 1-3 as the largest of the polygons. Features in this file should be thought of as the largest area in which a mapped feature could possibly be found, accounting for the rated accuracy of the GPS unit. Note that lines have “rounded” ends to account for linear uncertainty. Although the GPS unit used has a potential inaccuracy of 20 meters, it is typically far more accurate than this. Inaccuracies of 20 meters were not observed in this study during initial field tests and mapping. The GPS used for the project is probably accurate to within 5 or 6 meters most of the time. Thus, the probability of a feature’s true location being near the outside edge of the mapping error features is quite low, while the probability that its true location is in the center of these features is high. This file will be very useful when searching for an infestation, **as long as the field crews are well aware that features in the Mapping Error file do not represent the size of infestations, but rather where to search for them.** This file should not be used for area calculations, since it includes much area that was not observed to be infested.

Folder: MapError

Geographic File: weeds_me.shp or weeds_me.e00

Completeness Report

The entire Air Force Academy and Farish Outdoor Recreation Area, roughly 19,000 acres, were surveyed for noxious weeds by one person, except for the following locations: 1) the median strip of I-25 was not directly accessed due to the danger posed by highway traffic, although some portions of the median were able to be thoroughly surveyed using binoculars, 2) a recently acquired 20-acre tract associated with Farish Outdoor Recreation Area was not surveyed because staff did not have directions to the property, and 3) the firing range within Jack's Valley was surveyed in its entirety in one day due to military activity, but the quality of the data was likely unaffected. Areas were surveyed during one year only, from June-September, under drought conditions. Previously surveyed rare plant locations were revisited and the field technician was on “high alert” for identifying rare plants in the field, but this is not equivalent to a comprehensive rare plant survey.

Musk Thistle Mapped Feature Type - Point Radius - 6 Meters

FOLDER, SHAPEFILE NAME

Raw Data, weeds_pt.shp

● musk thistle point, as mapped in the field

Gross Area, weeds_ga.shp

○ musk thistle polygon; point buffered by radius

Map Error, weeds_me.shp

■ musk thistle polygon; buffered gross area polygon by 20 meters, the maximum error of the GPS unit.

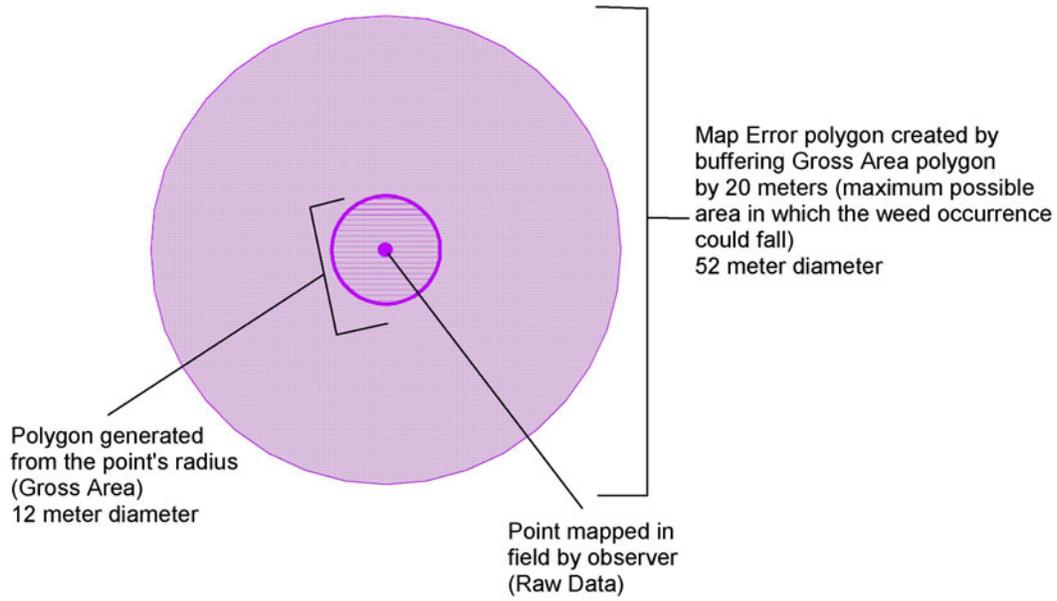


Figure 1. Explanation of the three point feature types included in the final data.

Spotted Knapweed
 Mapped Feature Type - Line
 Buffer Width - 2 meters
 Buffer Direction - Left

FOLDER, SHAPEFILE NAME

Raw Data, weeds_in.shp

 spotted knapweed line, as mapped in the field

Gross Area, weeds_ga.shp

 spotted knapweed polygon; buffered by buffer width and buffer direction

Map Error, weeds_me.shp

 spotted knapweed polygon; buffered gross area polygon by 20 meters, the maximum error of the GPS unit.

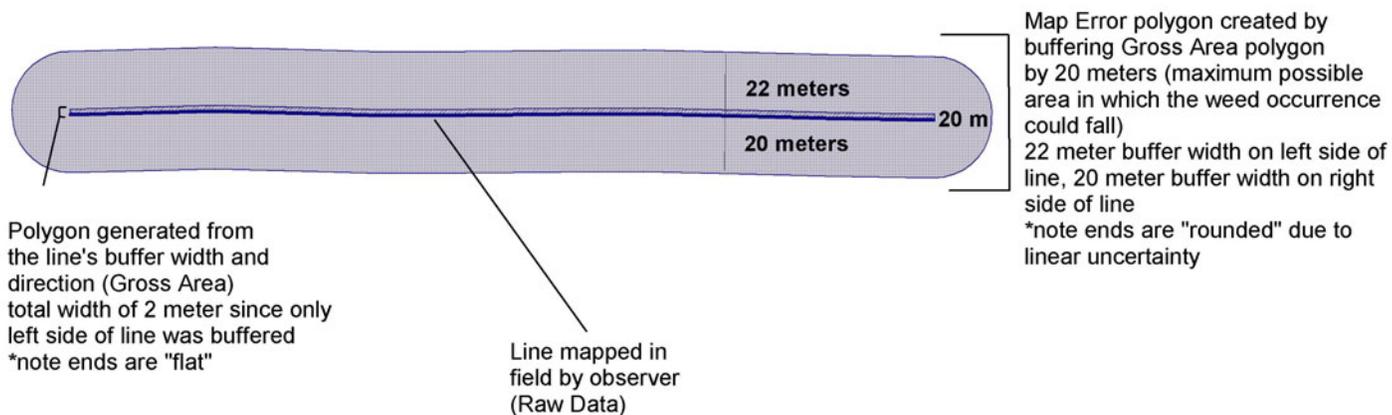


Figure 2. Explanation of the three line feature types included in the final data.

Diffuse Knapweed Mapped Feature Type - Polygon

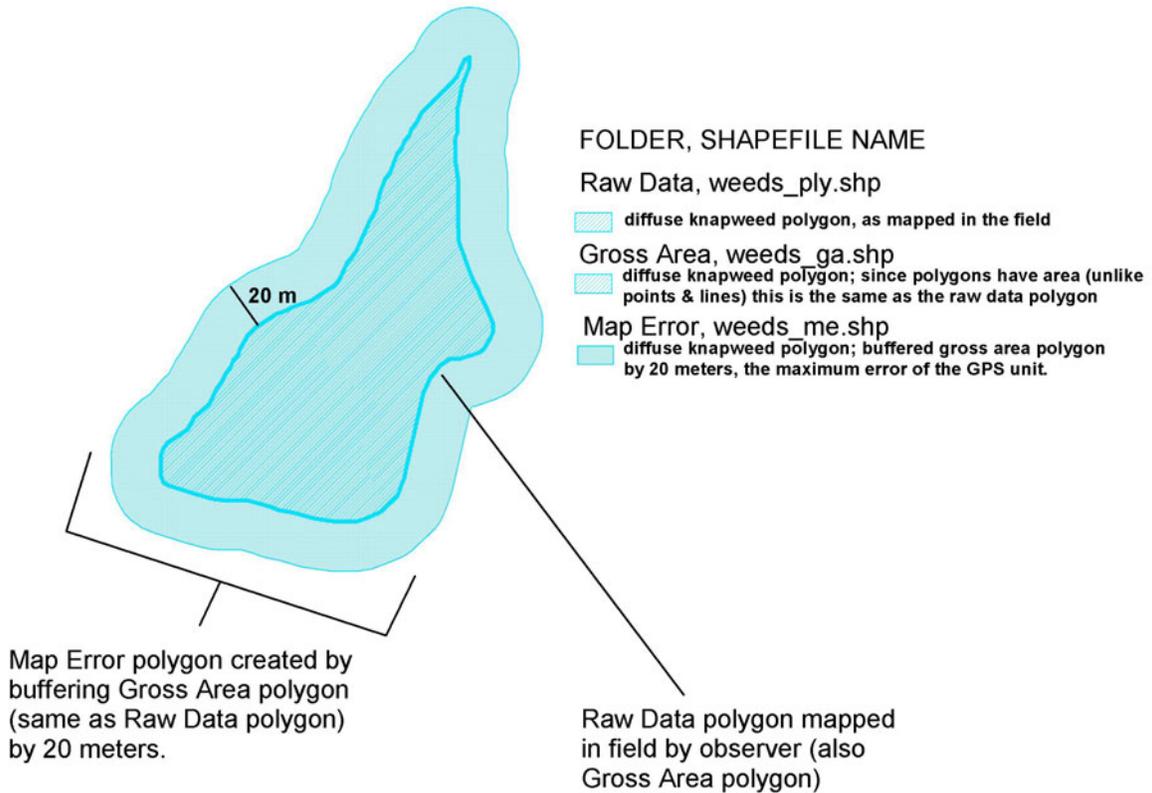


Figure 3. Explanation of the three polygon feature types included in the final data. Note that there is no difference between polygons in weeds_ply.shp and weeds_ga.shp.

APPENDIX 3: INSTRUCTIONS FOR WEED MAPPING

USAFA Weed Mapping Procedures

David G. Anderson

Specifications:

iPAQ operating system: Windows CE

Desktop PC operating system: Windows 2000

ArcPad version: 5.0.1

IN THE MORNING:

Make sure the iPAQ is charged.

Take the iPAQ with you in the field.

Turn it on.

Open ArcPad, and click on “new project...” by pulling down the arrow to the right of the file folder icon

Add files to the project (use the button with the “plus” sign on it.)

- Weeds_ln, weeds_pt, weeds_ply in: SLOT2\AFA\WEEDS
- Image_index in: SLOT2\AFA\JPGS
- The appropriate image in: SLOT2\AFA\JPGS
- Rare plants file if needed in: SLOT2\AFA\RAREPLANTS

Map weeds.

WHILE IN THE FIELD:

- Stop editing a shapefile often by going into layers (the stack of paper) and clicking off the checkbox with a pencil icon over it. This will save the file. To continue editing, click the checkbox back on.
- If Arcpad is hanging up or behaving strangely, close files (if you can) and then click on the blue toolbar (on the bottom of the screen when in ArcPad) and go to Settings→ System tab at the bottom of the screen→Memory→Running Programs tab at the bottom of the screen→ stop all programs button.
- Then go back into ArcPad and start over.
- If the above procedure fails to make things run correctly, soft reset the iPAQ by closing all files first, then pushing the stylus into the hole on the bottom right of the device. Wait a few moments- the iPAQ will make a bell chime sound as it reboots. Let the today screen fully come up and then try running arcpad again.
- If a weed or rare plant shapefile appears to be corrupted and unrepairable, stop using that file. Amy or Dave can help you try to save any data that is in that file. On the iPAQ I copied the empty rare plant and weed shapefiles to SLOT2\AFA\EMPTY_FILES. To use one of these, use the iPAQ’s file explorer to make a copy of the file and rename it as “weeds_ln2.shp” or something like that, then copy it to SLOT2\AFA\WEEDS (or RAREPLANTS if a rare plant file). Call us if you need help with this procedure.

WHEN YOU GET BACK FROM THE FIELD FOR LUNCH:

Put the iPAQ in its cradle.

Make sure that active sync starts and that the device synchronizes, and allow that process to finish.

Start file explorer

- Right Click on the “Start” button in the lower left hand corner of the computer screen- select “Explore”
- On the left side of the explorer window, single click on “Mobile Device”
- Double click on “My Pocket PC” on the right side of the explorer window
- Double click on folders in the following order to get to the weed files edited during this day: SLOT2\AFA\WEEDS\
- Copy the files (all files labeled weeds_in, weeds_ply, weeds_pt) by selecting them and then right clicking on the mouse, then hit copy.
- Paste the files in E:\AFA\WEEDS\UNEDITED (replace any existing files in this folder, UNLESS you have not packed and edited them yet).

WHEN YOU GET BACK FROM THE FIELD IN THE EVENING:

Follow the above procedure for when you get back from the field for lunch. If all went well, replace the files you had backed up at lunch.

Start ArcPad on the Desktop Computer

- Go to tools → pack shapefile
- Choose shapefile to pack: go to E:\AFA\WEEDS\UNEDITED and select a file. WRITE DOWN the name of this file.
- Choose packed shapefile: go to E:\AFA\WEEDS\PACKED and name the file as follows if the date is July 15:
 - weeds_in.shp will be renamed as: weeds_in7_15p
 - weeds_ply.shp will be renamed as: weeds_ply7_15p
 - weeds_pt.shp will be renamed as: weeds_pt7_15p
- Use the name of the file you wrote down in the step above to recall what file you are working with so you can rename it appropriately. Repeat the pack shapefile process until all files are packed.

Start ArcView 3.2 by clicking on the desktop icon

- Select file → open project
- Go to E:\ (at bottom of the window), AFA\ and select the project in the window to the left titled AFA.APR.
- In the APR window, click on views on the left side, then select the view you want to view the weed files in (this window is called something like “weeds, rare plants, etc”)
- Click on add theme (the plus button)
- Select all 3 weed files in E:\AFA\WEEDS\PACKED

- They will appear in the top of the view- click on the checkbox to turn them on. You may need to click on the image under them- scroll down on the left hand side bar in the view to see all of the images and click on the checkbox in the one you need.

To edit and clean up a shapefile:

- Highlight the theme
- Go to Theme→ start editing
- Note dotted line around the check box of that theme
- Select a feature in the theme to edit by using the black arrow (select tool).
- Turn on the hollow arrow (Vertex Edit) and begin moving and deleting vertices as needed.
- When finished with that theme, go to Theme→stop editing
- Edit other files as necessary

When finished with edits:

Close Arcview (save project)

Open file explorer

- Go to E:\AFA\WEEDS\PACKED
- Select all files from that day that you just edited
- Copy (right click)
- Paste them in E:\AFA\WEEDS\FINAL
- Rename each file with an identical name, but with an "f" instead of a "p" at the end.
- DONE!

BEFORE YOU GO TO BED:

Make sure the iPAQ is charged.

Copy new empty files onto the iPAQ to be edited the next day.

- Empty files are in: E:\AFA\EMPTY_FILES
- DON'T EVER DELETE ANYTHING FROM THE EMPTY_FILES FOLDER. You'll copy the files out of this daily to the iPAQ, and use them to make each day's new weed (and rare plant) shapefiles.
- These can be copied directly from E:\ to the iPAQ.
- Paste the empty weed files in: MOBILE_DEVICE\MY_POCKET_PC\SLOT_2\AFA\WEEDS (replace existing files UNLESS these have not yet been copied onto the desktop computer for some reason)
- Paste the empty rare plant files in: MOBILE_DEVICE\MY_POCKET_PC\SLOT_2\AFA\RAREPLANTS

FILE TRANSFER PROCEDURES (for sending data to the CNHP office once per week)

Start Netzero

- Double click on the Netzero icon on the desktop
- Enter Username
- Click on “connect”

On desktop, double click WSFTP icon.

- Click “ok” on session properties window that pops up
- Select files (E:\AFA\WEEDS\FINAL or other files) to send (use shift while clicking to select several at once)
- Click the right pointing arrow at center of the window to transfer files to AFAFTP site.
- Click on exit at the lower right corner of the window.
- DONE!

BURNING A DATA CD (For backing up data once a week or so)

Click on Start (lower left corner of screen) → programs → B’s Recorder Gold

- Select DATA CD in the wizard that pops up.
- Click on the launch explorer button
- Drag files from E:\AFA\WEEDS\FINAL (or other files) to the box in the wizard.
- Follow the instructions- click next to continue through the wizard- default settings should be fine
- Label the CD appropriately on the printed side (the side that faces up when you put it in the computer) with a sharpie
- DONE!

FOR TECHNICAL HELP:

Amy Lavender: lavender@lamar.colostate.edu 970-491-2847

Dave Anderson: dgander@lamar.colostate.edu 970-491-5857(w), 970-484-0774(h)

APPENDIX 4: NEW AND UPDATED ELEMENT OCCURRENCE RECORDS

Appendix 4 is not available

Please contact the Colorado Natural Heritage Program for information.