Lesquerella pruinosa Greene (Pagosa bladderpod): A Technical Conservation Assessment

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COVER PHOTO CREDIT

Lesquerella pruinosa (Pagosa bladderpod). Photograph by author.

SUMMARY OF KEY COMPONENTS FOR CONSERVATION OF *LESQUERELLA PRUINOSA*

Status

Lesquerella pruinosa Greene (Pagosa bladderpod) is currently known from 21 occurrences in Archuleta and Hinsdale counties in southwestern Colorado and from one newly discovered occurrence in northern Rio Arriba County, New Mexico. It is narrowly endemic to outcrops of the Mancos Shale Formation in the vicinity of Pagosa Springs, Colorado and adjacent New Mexico. The total population of *L. pruinosa*, based on estimates from element occurrence records, is between 5,209 and 20,619 individuals; however, additional plants are unaccounted for in occurrences where population size estimates were not made. NatureServe ranks this species as globally imperiled (G2), and the Colorado Natural Heritage Program ranks it as imperiled in the state (S2). Region 2 of the USDA Forest Service lists *L. pruinosa* as a sensitive species, and it is included on the Bureau of Land Management Sensitive Species List for Colorado. It is not listed as threatened or endangered under the Federal Endangered Species Act (U.S.C. 1531-1536, 1538-1540), nor is it a candidate for listing.

Primary Threats

There are several threats to the persistence of *Lesquerella pruinosa* in Region 2. In approximate order of decreasing priority, threats to *L. pruinosa* include residential and commercial development, off-road vehicle recreation, other recreational activities, energy resource development, exotic species invasion, use of herbicides and pesticides for weed management and range improvement, effects of small population size, grazing, prairie dog herbivory, fire, global climate change, and pollution.

Primary Conservation Elements, Management Implications and Considerations

Nine or possibly 10 of the 21 occurrences are located, at least in part, on federal lands, with six or possibly seven on the San Juan National Forest. One occurrence is in the O'Neal Hill Botanical Special Interest Area of the San Juan National Forest, and portions of this occurrence are included in a conservation easement and the Ant Hill State Natural Area. Most occurrences (14 or possibly 15 of 21) are found at least in part on private land where they are threatened primarily by residential and commercial development. Archuleta County is one of the fastest growing counties in the United States, and future land use plans drafted by Archuleta County do not include adequate provisions for the protection of *Lesquerella pruinosa*.

Designation of additional protected areas to prevent development of *Lesquerella pruinosa* habitat is needed to ensure the long-term viability of this species. Pursuing conservation easements on private properties where *L. pruinosa* is found or other protective land status changes would help to ensure the viability of occurrences on private land. Because *L. pruinosa* typically occurs in small patches, protection of relatively small areas would probably be highly successful in conserving this species and preventing eventual listing under the Endangered Species Act.

Several occurrences of *Lesquerella pruinosa* appear to be small enough to be susceptible to inbreeding depression. Inventories and monitoring are a high priority for *L. pruinosa*. Research is needed to investigate the population biology and autecology of the species so that conservation efforts on its behalf can be most effective.

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INTRODUCTION

This assessment is one of many being produced to support the Species Conservation Project for the Rocky Mountain Region (Region 2) of the USDA Forest Service (USFS). *Lesquerella pruinosa* is the focus of an assessment because it has been designated a sensitive species in Region 2 (USDA Forest Service 2003). Within the National Forest System, a sensitive species is a plant or animal whose population viability is identified as a concern by a Regional Forester because of significant current or predicted downward trends in abundance or significant current or predicted downward trends in habitat capability that would reduce its distribution (FSM 2670.5(19)). A sensitive species may require special management, so knowledge of its biology and ecology is critical. This assessment addresses the biology of *L. pruinosa* throughout its range in Region 2. This introduction outlines the goal and scope of the assessment and describes the process used in its production.

Goal of Assessment

Species assessments produced as part of the Species Conservation Project are designed to provide forest managers, research biologists, and the public with a thorough discussion of the biology, ecology, conservation status, and management of certain species based on available scientific knowledge. The assessment goals limit the scope of the work to critical summaries of scientific knowledge, discussion of broad implications of that knowledge, and outlines of information needs. The assessment does not seek to develop specific management recommendations. Instead, it provides the ecological background upon which management must be based and focuses on the consequences of changes in the environment that result from management (i.e., management implications). Furthermore, it cites management recommendations proposed elsewhere and examines the success of those recommendations that have been implemented.

Scope of Assessment

The assessment examines the biology, ecology, conservation, and management of *Lesquerella pruinosa* with specific reference to the geographic and ecological characteristics of Region 2. Similarly, this assessment is concerned with reproductive behavior, population dynamics, and other characteristics of *L. pruinosa* in the context of the current environment rather than under historical conditions. The evolutionary environment of the species is considered in conducting the synthesis, but placed in a current context.

In producing the assessment, refereed literature, non-refereed publications, research reports, and data accumulated by resource management agencies and other investigators were reviewed. Because basic research has not been conducted on many facets of the biology of *Lesquerella pruinosa*, literature on its congeners was used to make inferences in many cases. The refereed and non-refereed literature on the genus *Lesquerella* and its included species is somewhat more extensive and includes other endemic or rare species. Although some, or even a majority, of the literature on members of *Lesquerella* genus may originate from field investigations outside of Region 2, this document places that literature in the ecological and social contexts of the central Rocky Mountains. All known publications on *L. pruinosa* are referenced in this assessment, and many of the experts on this species were consulted during its synthesis. All available specimens of *L. pruinosa* were viewed to verify occurrences and incorporate specimen label data. Specimens were searched for at COLO (University of Colorado Herbarium), CS (CSU Herbarium), RM (Rocky Mountain Herbarium), KHD (Kalmbach Herbarium, Denver Botanic Gardens), SJNM (San Juan College Herbarium), CC (Carter Herbarium), GREE (University of Northern Colorado Herbarium), NMCR (New Mexico State University Range Science Herbarium), and UNM (University of New Mexico Herbarium). The assessment emphasizes refereed literature because this is the accepted standard in science. Non-refereed publications or reports were regarded with greater skepticism, but they were used in the assessment because there is very little refereed literature that specifically treats *L. pruinosa*. Unpublished data (e.g., Natural Heritage Program records, reports to state and federal agencies, specimen labels) were important in estimating the geographic distribution of this species, but these data required special attention because of the diversity of persons and methods used in collection.

Treatment of Uncertainty in Assessment

Science represents a rigorous, systematic approach to obtaining knowledge. Competing ideas regarding how the world works are measured against observations. However, because our descriptions of the world are always incomplete and our observations are limited, science focuses on approaches for dealing with uncertainty. A commonly accepted approach to

science is based on a progression of critical experiments to develop strong inference (Platt 1964). However, it is difficult to conduct experiments that produce clean results in the ecological sciences. Often, observations, inference, good thinking, and models must be relied on to guide our understanding of ecological relations. Confronting uncertainty then is not prescriptive. In this assessment, the strength of evidence for particular ideas is noted, and alternative explanations are described when appropriate.

Treatment of This Document as a Web Publication

To facilitate the use of species assessments in the Species Conservation Project, they will be published on the Region 2 World Wide Web site. Placing documents on the Web makes them available to agency biologists and the public more rapidly than publishing them as reports. More importantly, it facilitates revision of the assessments, which will be accomplished based on guidelines established by Region 2.

Peer Review of This Document

Assessments developed for the Species Conservation Project have been peer reviewed before release on the Web. This assessment was reviewed through a process administered by the Center for Plant Conservation, employing two recognized experts on this or related taxa. Peer review was designed to improve the quality of communication and to increase the rigor of the assessment.

MANAGEMENT STATUS AND NATURAL HISTORY

Management Status

Lesquerella pruinosa is included on the Region 2 sensitive species list (USDA Forest Service Region 2 2003), which affords some protection to the species on National Forest System land. *Lesquerella pruinosa* was first given Region 2 sensitive status in 1993 (USDA Forest Service 1993). The status of *L. pruinosa* in Region 2 was reconsidered in 2003 with the revision of the Region 2 sensitive species list. It was determined that *L. pruinosa* warrants sensitive species status due to declining habitat quantity and quality as a result of recreational impacts, road improvements, invasive species encroachment, weed control, residential development, and oil and gas development (Houston and Sidle 2002).

According to Redders et al. (2001), species are designated as sensitive by the Regional Forester when they meet one or more of the following criteria:

1) the species is declining in numbers or occurrences, and evidence indicates that it could be proposed for federal listing as threatened or endangered under the Endangered Species Act if action is not taken to reverse or stop the downward trend

2) the species' habitat is declining, and continued loss could result in population declines that lead to federal listing as threatened or endangered under the Endangered Species Act if action is not taken to reverse or stop the decline

3) the species' population or habitat is stable but limited.

Numbers one and two both apply to *L. pruinosa*.

Because *Lesquerella pruinosa* is designated sensitive in Region 2, the USFS is required to consider this species in order to maintain its habitat and occurrences (see Forest Service Manual 2670). Issues regarding sensitive species must be addressed in all environmental assessments within suitable habitat. The collection of sensitive species is prohibited without a permit (see Forest Service Manual 2670). The USFS can modify allotment management plans and projects or contracts to give consideration to *L. pruinosa* on a discretionary basis. Biological assessments and evaluations are conducted when applications for permits for various land uses are considered, and impacts to sensitive species can be mitigated.

Lesquerella pruinosa is also included on the Bureau of Land Management (BLM) Sensitive Species List for Colorado (Bureau of Land Management 2000).

The current global NatureServe rank for *Lesquerella pruinosa* is G2 (NatureServe Explorer 2004). The global (G) rank is based on the status of a taxon throughout its range. A rank of G2 is ascribed to taxa that are imperiled globally because of rarity (6 to 20 occurrences) or because of other factors contributing to its imperilment. In Colorado, *L. pruinosa* is given a state rank of S2 (Colorado Natural Heritage Program 2004). The state (S) rank is based on the status of a taxon in an individual state, using the same criteria as those used to determine the Global rank. Due to the

single known occurrence, *L. pruinosa* warrants a state rank of S1 in New Mexico, but it is currently not ranked (SNR; Tonne 2002).

Lesquerella pruinosa was proposed as Endangered in 1975 and again in 1976 (Anderson 1988a, Redders et al. 2001). In September 1985, the U.S. Fish and Wildlife Service placed it on the Category 2 list (C2) (U.S. Fish and Wildlife Service 1985, Anderson 1988a, O'Kane 1988). The C2 designation was used to list taxa for which current information suggested that endangered or threatened status was warranted but insufficient information was available to support listing. O'Kane (1988) noted that known threats and its limited distribution qualified it as a threatened species, but more fieldwork was needed to make a determination. The C2 designation was eliminated in 1996, and *L. pruinosa* is no longer under consideration for listing as threatened or endangered.

Ten species of *Lesquerella* are listed as Threatened or Endangered under the federal Endangered Species Act, or are candidates for listing (U.S. Fish and Wildlife Service 1999, U.S. Fish and Wildlife Service 2004a). One species, *L. filiformis*, was recently downlisted from Endangered to Threatened status (U.S. Fish and Wildlife Service 2003).

In 1988, the Colorado Natural Areas Program placed *Lesquerella pruinosa* on the Colorado Plant Species of Special Concern list (Anderson 1988a), and it is now tracked by the Colorado Natural Heritage Program. Part of the largest known occurrence of this species is within the Ant Hill State Natural Area (Colorado Natural Areas Program 2003).

Lesquerella pruinosa is a State Species of Concern in New Mexico. As such, it should be protected from the effects of land uses when possible because it is a unique and limited component of the regional flora (Tonne 2002).

Existing Regulatory Mechanisms, Management Plans, and Conservation Strategies

A conservation strategy has been written for *Lesquerella pruinosa* (Redders et al. 2001) to identify conservation goals and measures necessary to preserve the species and its habitat and to provide guidance in complying with sensitive species directives; it is intended to provide management direction for a ten-year period (1999-2009). The conservation strategy includes a discussion of the biology, threats, and beneficial management actions for *L. pruinosa*. Portions of this strategy will be incorporated into the revision of the San Juan National Forest Plan (Redders et al. 2001) and are included in this assessment where relevant.

One occurrence of *Lesquerella pruinosa* on the San Juan National Forest benefits from special land status designation. The O'Neal Hill Botanical Special Interest Area (SIA) was established with the goal of protecting *L. pruinosa* at this site. The SIA was designated by the USFS in 1993 after it was acquired from The Nature Conservancy in 1992. To acquire this area, the USFS purchased 2,200 acres of the Piedra Ranch with monies appropriated by Congress from the Land and Water Conservation Fund, and another 660 acres were donated to the USFS by The Nature Conservancy (Rouse 1992, Redders et al. 2001).

The O'Neal Hill Botanical SIA is designated within the 10C Management Prescription in the Forest Plan, which emphasizes the protection and maintenance of *Lesquerella pruinosa* and its habitat. Beneficial actions relevant to *L. pruinosa* that are mandated under this management prescription are reviewed in the Beneficial management actions section. The following description of the SIA is paraphrased from Redders et al. (2001). The 437-acre SIA is in the East Fork Piedra Allotment of the San Juan National Forest, and is divided into three separate, contiguous units. Unit A is approximately 138 acres and includes steep shale hill slopes. Unit B is approximately 269 acres and includes gentle shale hill slopes. Unit C is approximately 30 acres and includes gently sloping plains. Livestock grazing is prohibited in Units A and B, but it is allowed in Unit C as long as a monitoring study set up in 1999 shows that grazing does not adversely affect the population and habitat of *L. pruinosa*. Unit C was first grazed in 1999. Grazing continued in Unit C through 2001, but it was stopped in 2002 to minimize impacts to a wetland mitigation project adjacent to the monitoring plots (Brinton personal communication 2006).

While SIAs can be effective conservation tools, managers have limited options for protecting these sites. For example, withdrawing grazing leases can be difficult. If there is a mineral estate, withdrawing the minerals from exploitation must be coordinated through the BLM and may require congressional approval (Austin personal communication 2004).

Parts of the occurrence at O'Neal Hill Botanical SIA (EO #10) that are not on National Forest System land are in locations with special land status designation. One suboccurrence is within the Ant Hill State Natural

Area (Colorado Natural Areas Program 2003). Another is on the Lynd Property, a 340-acre portion of the Piedra Ranch that contains excellent *Lesquerella pruinosa* habitat (Neely 1990, Rouse 1992). The Lynd Property was sold to a private party and a conservation easement donated to The Nature Conservancy, which ensures that the land is managed for the conservation of *L. pruinosa* (Rouse 1992, Redders et al. 2001).

Including the O'Neal Botanical SIA, nine (possibly ten) occurrences of *Lesquerella pruinosa* are located at least in part on federal land, with six (possibly seven) on the San Juan National Forest. Three occurrences are located on land managed by the BLM (San Juan Field Office). Fourteen (possibly 15) occurrences are partly or entirely on private land. One occurrence is on the Southern Ute Reservation. **Table 1** is a summary of land ownership of *L. pruinosa* occurrences, and **Table 2** describes the land ownership of specific occurrences.

Anderson (1988a) offers management recommendations for *Lesquerella pruinosa*, which are discussed in relevant sections of this assessment. General guidelines for the management of threatened, endangered, and sensitive species appear in Austin et al. (1999). The Nature Conservancy includes *L. pruinosa* as a conservation target in the Southern Rocky Mountain Ecoregion (Neely et al. 2001, Schulz et al. 2004). Fourteen occurrences were selected for conservation actions in the Pagosa Springs area in The Nature Conservancy's Southern Rocky Mountain Ecoregion Plan, with a goal of protecting all occurrences. The Archuleta County Community Plan (Archuleta County 1999) does not include any provisions for the conservation of *L. pruinosa*.

The Colorado Natural Heritage Program designates Potential Conservation Areas (PCAs), which are ecologically sensitive areas where land use practices need to be carefully planned and managed to ensure that they are compatible with protection of natural heritage resources and sensitive species within them (Colorado Natural Heritage Program Site Committee 2002). A primary purpose of PCAs is to support land use planning. *Lesquerella pruinosa* is present in six PCAs: Ant Hill, Stollsteimer Creek North, Mill Creek at Pagosa Springs, Taylor Canyon at San Juan River, Turkey Mountain, and Chromo (**Appendix**; Colorado Natural Heritage Program 2004). PCA status does not confer any regulatory protection of the site, nor does it automatically exclude any activity. PCA boundaries are based primarily on factors relating to ecological systems, and represent the best professional estimate of the primary area supporting the long-term survival of the targeted species or plant associations. The Colorado Natural Heritage Program has given the San Juan National Forest (Lyon and Denslow 2002) and Archuleta County (Sovell et al. 2003) PCA boundaries to facilitate awareness of this species and its habitat among planners and land managers.

Adequacy of current laws and regulations

Existing legal protections that apply to *Lesquerella pruinosa* pertain only to occurrences residing on land administered by the USFS and the BLM. However, 14 (or possibly 15) of the 21 known occurrences occur at least partly on private lands, and there are no federal or state laws protecting this species on private lands.

Although *Lesquerella pruinosa* has benefited from efforts to protect it from human impacts, current protection will be insufficient to prevent decline of this rare species. Under development scenarios planned for Archuleta County, it is likely that some occurrences on private land will be affected or extirpated. The rapidly growing human population (particularly in the Pagosa

Table 1. Land ownership status of the 21 occurrences of *Lesquerella pruinosa*. Because some occurrences have multiple owners, the total is less than the sum of the rows in the table. Where land ownership is uncertain, numbers are included in parentheses. See Table 2 for ownership of specific occurrences.

Land Ownership Status	Number of Occurrences	Subtotals
USDA Forest Service (San Juan National Forest)	6 (1)	
O'Neal Hill Botanical Special Interest Area		1
Bureau of Land Management	3	
Bureau of Indian Affairs (Southern Ute Tribe)	2	
Private	14 (1)	
State Natural Area	1	
TOTAL	21	

Table 2. Summary information for the known occurrences of *Lesquerella pruinosa*.

Source ID[1]	County	Location	Owner / Manager	Date last observed	EO rank[2]	Size (acres)	Abundance	Elevation (ft.)	Habitat
1	Archuleta	Pagosa Springs	Private	07-Jun-1994	C	14	31	7,280	Mancos Shale slope. Aspect: South. Soil: Adobe (clay). Dry, south-facing slope. Tree cover: 0%. Shrub cover: 0%. Forb cover: 10%. Graminoid cover: 15%. Moss/lichen cover: 0%. Bare ground: 75%.
2	Archuleta	Turkey Mountain	USDA Forest Service (USFS) San Juan National Forest, Private	20-May-2004	B	587	1,000 to 10,000	7,400-7,800	Flat shale meadows and shallow slopes, openings in ponderosa pine forest. Rolling, bare gray clay hills. Mancos Shale hills with *Pinus ponderosa* and *Mahonia repens*. Also on steep bank of road cut. Aspect: variable. Slope: 10-35 degrees. Light exposure: open to partial shade. Topographic position: midslope. Moisture: dry. Soil: gray clay loam derived from Mancos Shale.
4	Archuleta	Dyke	Bureau of Land Management (BLM) San Juan Field Office, Private	25-Jun-1993	B	23	60 or more	6,900	This area is an excellent example of Mancos Shale communities; *Ipomopsis polyantha* is present; Douglas fir on cooler slopes in the area; *Juniperus osteosperma* / *Quercus gambelii* community on lower slopes. In clay soil on south exposure. However, *Lesquerella pruinosa* occurs only on undisturbed portions of the site. Aspect: south, east, and west. Soil: Clay with shale alluvium. Geologic substrate: Mancos Shale and sandstone. *Melilotus officinalis* present. Disturbed, some off-road vehicle activity and selective logging. Sale of land by the Bureau of Land Management may lead to development.
5	Archuleta	East Pagosa	Private	12-May-2004	C	8	70	7,280-7,360	On Mancos Shale. Aspect: North. Light: open. Topographic position: crest and upper slope. Moisture: dry. Soil: gray clay-loam. Surface littered with loose shale fragments. Open meadow. Close to a popular trail. Highly disturbed; power line and access road above site, 4-wheel and motorcycle trails almost everywhere; precipitous cutbank just below, hanging above store buildings.
6	Archuleta	Museum Road	Private	04-Jun-1985	C	Not reported	40	7,200	Mancos Shale. Aspect: West. Soil: gray loam. Growing on a road cut. Seedlings present.

Table 2 (cont.).

Source ID[1]	County	Location	Owner / Manager	Date last observed	EO rank[2]	Size (acres)	Abundance	Elevation (ft.)	Habitat
8	Archuleta	Taylor Canyon	Bureau of Indian Affairs Southern Ute Tribe, Private	04-Jun-1985	C	Not reported	70	7,150	Mancos Shale. Aspect: East. Soil: gray clay. Slope: 0-35%. Many seedlings present.
9	Archuleta	Stollsteimer Creek	BLM San Juan Field Office	1987	D	Not reported	2	6,890	Geologic substrate: Mancos Shale. Aspect: West. Soil: clay. Slope: 15-30%.
10	Archuleta, Hinsdale	O'Neal Hill	USFS San Juan National Forest O'Neal Hill Botanical Special Interest Area, Private (including conservation easement held by The Nature Conservancy), Ant Hill State Natural Area	08-Jun-2005	A (?)	1,427	~6,500 in 2001, less than 100 in 2003	7,760-8,800	This area contains many suboccurrences. *Lesquerella pruinosa* is found on steep slopes, clay knobs, ridges, on barrens surrounded by montane grasslands, and with Gambel oak (*Quercus gambelii*) and ponderosa pine (*Pinus ponderosa*) on upper slopes. Also found on grassy slopes with Arizona fescue (*Festuca arizonica*) and other grasses. Soils are derived from Mancos Shale. The substrate is gray and platy, and highly erodible with deep gullies. Human uses of the area include light grazing and logging (historic). Portions of the area may also have been used to grow hay. Disturbance has resulted from infrastructure including a pipeline and roads.
11	Archuleta	Chromo	Private	04-Jun-1989	B	Not reported	900	7,500	In barren areas of Mancos Shale along the sides of a dry gully above irrigated pastures, also above a mountain meadow. Area is heavily grazed in summer through October by cattle and horses. Pines were logged historically at this site. Plants occur on steep side slopes and on barrens and on an old roadbed.
12	Archuleta	Stollsteimer Creek	BLM San Juan Field Office	1991	E	Not reported	"small population"	7,700	Scattered down a drainage.
13	Archuleta	Hot Springs	Private	11-Jun-1994	C	Not reported	10	7,120	Mancos Shale slope. Tree cover: 0%. Forb cover: 20%. Moss/lichen cover: 0%. Sl shrub cover: 0%. Graminoid cover: 5%. Bare ground: 75%. With *Ipomopsis polyantha* and *Townsendia rothrockii*.

Table 2 (cont.).

Source ID[1]	County	Location	Owner / Manager	Date last observed	EO rank[2]	Size (acres)	Abundance	Elevation (ft.)	Habitat
14	Archuleta	Aspenglow	Private	10-May-1994	C	Not reported	~25	7,570	Mancos Shale slope with *Pinus ponderosa* and *Quercus gambelii*. Tree cover: 20%. Forb cover: 10%. Moss/lichen cover: 0%. Shrub cover: 20%. Graminoid cover: 0%. Bare ground: 50%.
16	Archuleta	Nichols Draw	USFS San Juan National Forest, Private	17-Jul-2003	B	13	Hundreds	8,240-8,360	Mancos Shale ridges. Tree cover: 0%. Shrub cover: 5%. Forb cover: 40%. Graminoid cover: 25%. Moss/lichen cover: less than 5%. Bare ground: 35-60%. Aspect: South-southeast. Light exposure: open. Moisture: dry. Evidence of threats and disturbance: light grazing by cattle and elk. Does not appear to be having an effect on the occurrence.
17	Archuleta	Pordonia Point	Bureau of Indian Affairs Southern Ute Tribe	29-May-1996	B	5	~100	7,240-7,440	Growing on barren Mancos Shale between clumps of Gambel oak. Tree cover: 10%. Forb cover: 5%. Moss/lichen cover: 1%. Shrub cover: 20%. Graminoid cover: 5%. Bare ground: greater than 50%; patchy. Topographic position: midslope. Moisture: dry. A D4 Cat, ATVs, and numerous trucks drove over the area on April 8 and 23 on the way to a prescribed burn. *Lesquerella pruinosa* did not seem to be impacted.
18	Archuleta	Trujillo Road	Private, County Road Right-of-way	04-May-2002	C	1.9	11	7,060	Road cut in Mancos Shale. Little other vegetation. Probably vulnerable to road improvements.
19	Archuleta	Chromo	Private	29-May-2002	B	8	Over 100	7,400-7,480	Sides of dry wash above river; clay soils from Mancos Shale. Cattle graze in this area but probably do not use the barren areas of the gully.
20	Archuleta	Chris Mountain	USFS San Juan National Forest	22-May-2003	B	~200	~2,000	7,100-7,700	Rolling uplands on Mancos Shale with ponderosa pine and Gambel oak. Aspect: S/SW. Slope: variable. Slope shape: concave. Shrub cover: less than 60%. Tree cover less than 30%. Light exposure: partial shade. Plants along road threatened by road and ditch maintenance; some groups of plants may be threatened by off road vehicle disturbance.

Table 2 (concluded).

Source ID[1]	County	Location	Owner / Manager	Date last observed	EO rank[2]	Size (acres)	Abundance	Elevation (ft.)	Habitat
21	Hinsdale	Williams Creek	USFS San Juan National Forest	10-May-2004	B	0.6	~500	8,190	Open, exposed slope of Mancos Shale. Moisture: dry. Tree cover: less than 20%. Shrub cover: less than 40%. Forb cover: 15%. Bare ground: 75%. Aspect: South-southwest. Slope: 40%. No threats evident.
O'Kane 4539	Hinsdale	Oakbrush Ridge	USFS San Juan National Forest	15-May-1999	E	Not reported	Not reported	7,900	Grassy foot slope of Mancos Shale hills topped with *Pinus ponderosa*.
O'Kane and Heil 4822b, ISTC	Rio Arriba	Eagle Point	Private	06-Jun-2000	E	Not reported	Not reported	7,585	Rolling low hills of sage and grassland. Clay of Mancos Shale.
Seed Sample at NCGRP	Archuleta	Chromo	Possibly USFS San Juan National Forest and/or Private	Unknown	E	Not reported	Not reported	7,930	Not reported.

[1]Source ID is Colorado Natural Heritage Program element occurrence number unless otherwise noted.

[2]Element Occurrence rank key: A – excellent estimated viability; B – good estimated viability; C – fair estimated viability; E – not evaluated (based on element occurrence rank specifications on file at the Colorado Natural Heritage Program).

Springs area) will likely increase the impacts to public lands in Archuleta County, which will result in habitat degradation within occurrences of *L. pruinosa*. Habitat fragmentation between known occurrences may also result in edge effects and reduced geneflow, potentially leading to inbreeding depression. While existing laws and regulations may prevent the extinction of *L. pruinosa*, they appear inadequate to prevent population decline, local extirpation, and loss of heterozygosity. Existing protected areas may not provide sufficient habitat to maintain its viability if *L. pruinosa* depends on a metapopulation structure for its persistence.

Adequacy of current enforcement of laws and regulations

There have been no known cases in which an occurrence of *Lesquerella pruinosa* was extirpated due to human activities or the failure to enforce any existing regulations. However, this does not necessarily indicate that current regulations or their enforcement are adequate for its protection. Human impacts, including residential development, have probably diminished the distribution and abundance of this species.

Enforcement of existing restrictions of off-road vehicle use on USFS and BLM land is very difficult. Users frequently pull down barriers and breach fences to gain access to off-limits areas (Brekke personal communication 2004). Federal agencies lack sufficient resources to patrol the areas they manage.

Biology and Ecology

Classification and description

Lesquerella pruinosa Greene (Pagosa springs bladderpod) is a member of the Brassicaceae (Cruciferae) family. Members of the Brassicaceae are found on all continents except Antarctica (Rollins 1993). It is a large family that includes approximately 3,350 species worldwide (Al-Shehbaz 1984), with new taxa continuing to be recognized (Rollins 1993). North America is an important center of diversification for this family, with 778 recognized species (Rollins 1993). However, the major center of diversity for the family is southwestern Asia and the Mediterranean (Heywood 1993, Rollins 1993). Unlike some other families, the boundaries between many genera of the Brassicaceae (including *Lesquerella*) are often poorly defined. This suggests that the Brassicaceae are a relatively recently evolved family since wide gaps exist between the genera of more ancient families (Rollins 1982). There are many narrowly endemic genera and species within the Brassicaceae (Heywood 1993).

The family Brassicaceae is in the class Magnoliopsida (dicots), subclass Dilleniidae, order Capparales (Mabberley 1997, USDA Natural Resources Conservation Service 2004). The Brassicaceae is closely related to the Capparaceae. Recent cladistic analysis has shown that the Brassicaceae is a monophyletic group nested within the paraphyletic Capparaceae. It has been proposed to lump the Brassicaceae within the Capparaceae (Judd et al. 1994; see the Preface to Mabberley (1997) for an interesting discussion of this issue). It was noted by O'Kane and Al-Shehbaz (2003) that "future work in the family will certainly yield further taxonomic alignments since there is rampant morphological convergence, and because previous taxonomy in the family has relied heavily on fruit morphology (e.g., Rollins 1993, Al-Shehbaz 1984) to the exclusion of floral features."

Rollins (1993) includes 95 *Lesquerella* taxa in North America, but several new species have been described since his treatment (Rollins 1995, Rollins et al. 1995, Anderson et al. 1997, O'Kane 1999). Kartesz (1999) reports 74 species and 25 subspecies and varieties of *Lesquerella* in North America. Weber and Wittmann (2000) list 14 species of *Lesquerella* from Colorado.

A close affinity between the genera *Lesquerella* and *Physaria* was first noted by Payson (1921), and later by Rollins (1939) and other researchers. The morphological characters used by Rollins (1993) to distinguish these genera are those of the fruit, but many workers have noted that there is a continuum of variation in diagnostic characters between these genera and that it is impossible to draw a natural line of demarcation between them (Al-Shehbaz and O'Kane 2002). The similarity between these genera, and the vague boundary between them, is discussed in Al-Shehbaz and O'Kane (2002). Mulligan (1968) moved four species from *Lesquerella* to *Physaria*. Recent taxonomic research on these genera shows that *Physaria* as narrowly circumscribed is polyphyletic, having arisen more than once within *Lesquerella*, and that *Lesquerella* is paraphyletic (Al-Shehbaz and O'Kane 2002). From these data, it is now clear that recognition of *Physaria*, as it has been historically circumscribed, is no longer supported. Because *Physaria* (Gray 1849) was described before *Lesquerella* (Watson 1888), Al-Shehbaz and O'Kane (2002) transferred 91 names (including 75 at the species rank) from *Lesquerella*

to *Physaria*; they did attempt, however, to conserve the name *Lesquerella* (O'Kane et al. 1999). The taxa remaining in *Lesquerella* were segregated into a new genus *Paysonia* (O'Kane et al. 1999, O'Kane and Al-Shehbaz 2002). This new treatment is likely to become widely recognized. For example, it will be followed in the forthcoming volume of the *Flora of North America* that will include the Brassicaceae, in which *L. pruinosa* will be treated as *P. pruinosa* (Greene) Al-Shehbaz and O'Kane. However, the name *L. pruinosa* as recognized by Kartesz (1999) and the PLANTS Integrated Taxonomic Information System databases (USDA Natural Resources Conservation Service 2004) is adhered to in this assessment.

O'Kane and Al-Shehbaz (2003) included *Lesquerella pruinosa* in their phylogenetic analysis of the genus *Arabidopsis*. Based on a strict consensus tree, *L. pruinosa* was most closely related to *Physaria acutifolia* and *P. didymocarpa*. However, this study did not focus on the genus *Lesquerella*, so these taxa are not necessarily its closest relatives.

History of knowledge

Charles Fuller Baker first collected *Lesquerella pruinosa* on July 21, 1899 in the vicinity of Pagosa Springs during a trip to southwestern Colorado (Greene 1901). The specimen was sent to Edward Lee Greene who described it as *L. pruinosa* in 1901 (Greene 1901). Baker's type specimen (Baker s.n.) is housed at the University of Notre Dame Herbarium (Rollins and Shaw 1973), along with Greene's specimens (Ewan and Ewan 1981). Baker did not make a practice of numbering his specimens (Ewan and Ewan 1981). On the same trip, Baker also collected the type specimen for *Ipomopsis polyantha*, another narrowly endemic species sympatric with *L. pruinosa* (Anderson 1988b, Anderson 2004).

Rydberg did not include *Lesquerella pruinosa* in *Flora of Colorado* (Rydberg 1906) or in *Flora of the Rocky Mountains and Adjacent Plains* (1922). Coulter and Nelson (1909) included *L. pruinosa* doubtfully (indicated by a question mark) within *L. engelmannii*, along with *L. ovata* and *L. ovalifolia*. *Lesquerella pruinosa* was treated as a full species in Payson's monograph of the genus (Payson 1921), and its taxonomic validity has not been disputed since. Work on the genus *Lesquerella* was begun by Reed Rollins early in his career, with a discussion of the genus and description of new taxa (Rollins 1939), which eventually led to a second monograph of the genus in North America (Rollins and Shaw 1973). *Lesquerella pruinosa* is included in the latter reference.

Before the 1970s, *Lesquerella pruinosa* was known only from the type locality (Pagosa Springs) and from Ant Hill, approximately 10 miles north of Pagosa Springs (Anderson 1988a). The passage of the Endangered Species Act led to raised interest and awareness of *L. pruinosa* because it was twice proposed for listing in the 1970s. Inventories for *L. pruinosa* were conducted in the 1970s and 1980s to assess its status (reviewed in Anderson 1988a). The first inventory was conducted in 1977 by Barry Johnston of the USFS, who found the Turkey Mountain/Catchpole Creek occurrence on the San Juan National Forest. In 1985, inventories by Johnston, Steve O'Kane, and John Anderson led to the discovery of the Taylor Canyon occurrences, and an inventory by Clair Button of the BLM led to the discovery of the Dyke occurrence. In 1988, John Anderson relocated and mapped the Ant Hill/Gordon Creek occurrence and discovered the Chromo occurrence (Anderson 1988a).

In 1985, Bonnie Jakubos, a student at Fort Lewis College, selected five sites (EOs #2, 4, and 8 in **Table 2**) to investigate the relationships between the density of *Lesquerella pruinosa* and biotic and abiotic environmental factors. She used multiple regressions to look for correlations between density and cover, slope, topographic position, and geologic substrate. The results of her study are incorporated into this assessment. There were no statistically significant correlations between qualitative habitat data and *L. pruinosa* density, which is partly attributable to the small sample size.

In the 1990s and 2000s, surveys by Sara Brinton of the San Juan National Forest, Peggy Lyon of the Colorado Natural Heritage Program, Steve O'Kane from the University of Northern Iowa, and Ken Heil from San Juan College led to the discovery of several new occurrences, extending the known range north into Hinsdale County, Colorado and south into Rio Arriba County, New Mexico (Heil and Allred 2000). A long-term trend study was installed in 1999 within the O'Neal Hill Botanical SIA (Lyon 2001).

Non-technical description

Lesquerella pruinosa derives one of its common names, "frosted bladderpod," and its scientific name from the very short, dense hairs that cover the leaves and stems to give the plant a frosted appearance (Colorado Native Plant Society 1997). Rollins and Shaw (1973)

and Rouse (1992) provide an overview of useful diagnostic characteristics paraphrased here. The stems of *L. pruinosa* are 10 to 20 cm long, may be decumbent or erect, and arise out of a simple or woody caudex that is often supported by a stout taproot. The basal leaves are 4 to 8 cm long with suborbicular or obovate blades that can be entire to sinuate or shallowly-toothed. The cauline leaves are 0.8 to 2.3 cm long, obovate to rhombic, and can be entire or shallowly-toothed. The flowers are small and yellow with spatulate petals that are expanded at the base (**Figure 1**). The fruiting inflorescences are dense and elongated (**Figure 2**). The pedicels are 8 to 11 mm long and sigmoid (**Figure 3**, **Figure 4**). The siliques are 6 to 9 mm long, sessile or substipitate, and globose to ellipsoid. The seeds are not winged or margined.

Figure 1. *Lesquerella pruinosa* in flower. Photograph by Bob Clearwater, provided by Sara Brinton, used with permission of the photographer.

Figure 2. *Lesquerella pruinosa* in late flower and early fruit at Chromo. Photograph provided by Peggy Lyon, used with permission.

Figure 3. The fruit of *Lesquerella pruinosa*. Note the sigmoid pedicels characteristic of this species and its close relative *L. pinetorum*. Photograph by Bill Jennings (from Colorado Native Plant Society 1997, used with permission).

The close relationship between *Lesquerella pruinosa* and *L. pinetorum* has been noted by many authors (Payson 1921, Rollins and Shaw 1973, Anderson 1988a). Payson (1921) wrote that *L. pruinosa* is "most closely related to *L. pinetorum* and marks a decided advance in specialization as well as a considerable step in the northward progression of this line of development. It is definitely separated from *pinetorum* by its conspicuous rosette and broad-bladed radical leaves. *Lesquerella pruinosa* and *L. pinetorum* are the only perennials that have sigmoid pedicels, glabrous pods, and stellae with branched rays." Payson (1921) refers to these two species collectively as the "pinetorum group." Rollins and Shaw (1973) elaborated further on the relationship between *L. pruinosa* and *L. pinetorum*: "*Lesquerella pruinosa* is most closely related to *L. pinetorum* of New Mexico and Arizona, which it resembles in habit, in the large basal leaves, and in the elongated infructescenses of large glabrous siliques borne on sigmoid pedicels. *Lesquerella pruinosa* is distinguished from *pinetorum* by the small foliar trichomes and the broad basal leaves which narrow very abruptly to a slender petiole and in being only sparsely pubescent on the upper leaf surface." *Lesquerella pruinosa* usually has two to four ovules per fruit whereas *L. pinetorum* in New Mexico usually has twice as many.

Lesquerella pinetorum ranges through Arizona and southern and central New Mexico and does not overlap with the range of *L. pruinosa* (Rollins and Shaw 1973). The nearest occurrences of *L. pinetorum* to *L. pruinosa* are located approximately 200 miles to the south in the Sandia Mountains above Albuquerque in Santa Fe and Sandoval counties (Martin and Hutchins 1980, Anderson 1988a). Both species are found in similar habitats (Rouse 1992). The relationship of *L. pruinosa* with *L. pinetorum* "provides evidence for the northward migration of a southwestern floristic element as far as the base of the San Juan Mountains in southern Colorado and, hence, for warmer climatic conditions at some period in the past" (Anderson 1988a).

Lesquerella pruinosa is not likely to be confused with other species in the same habitat (Spackman et al. 1997, Tonne 2002). It is readily distinguished from two other members of the genus in southwestern Colorado (Anderson 1988a). Its rhombic (oval) basal leaves distinguish it from *L. fendleri*, which has linear basal leaves and occurs in the Four Corners region approximately 100 miles west of Pagosa Springs (Anderson 1988a). *Lesquerella rectipes* occurs in western Archuleta County and has stellate-pubescent fruits, unlike those of *L. pruinosa*, which are glabrous (Anderson 1988a).

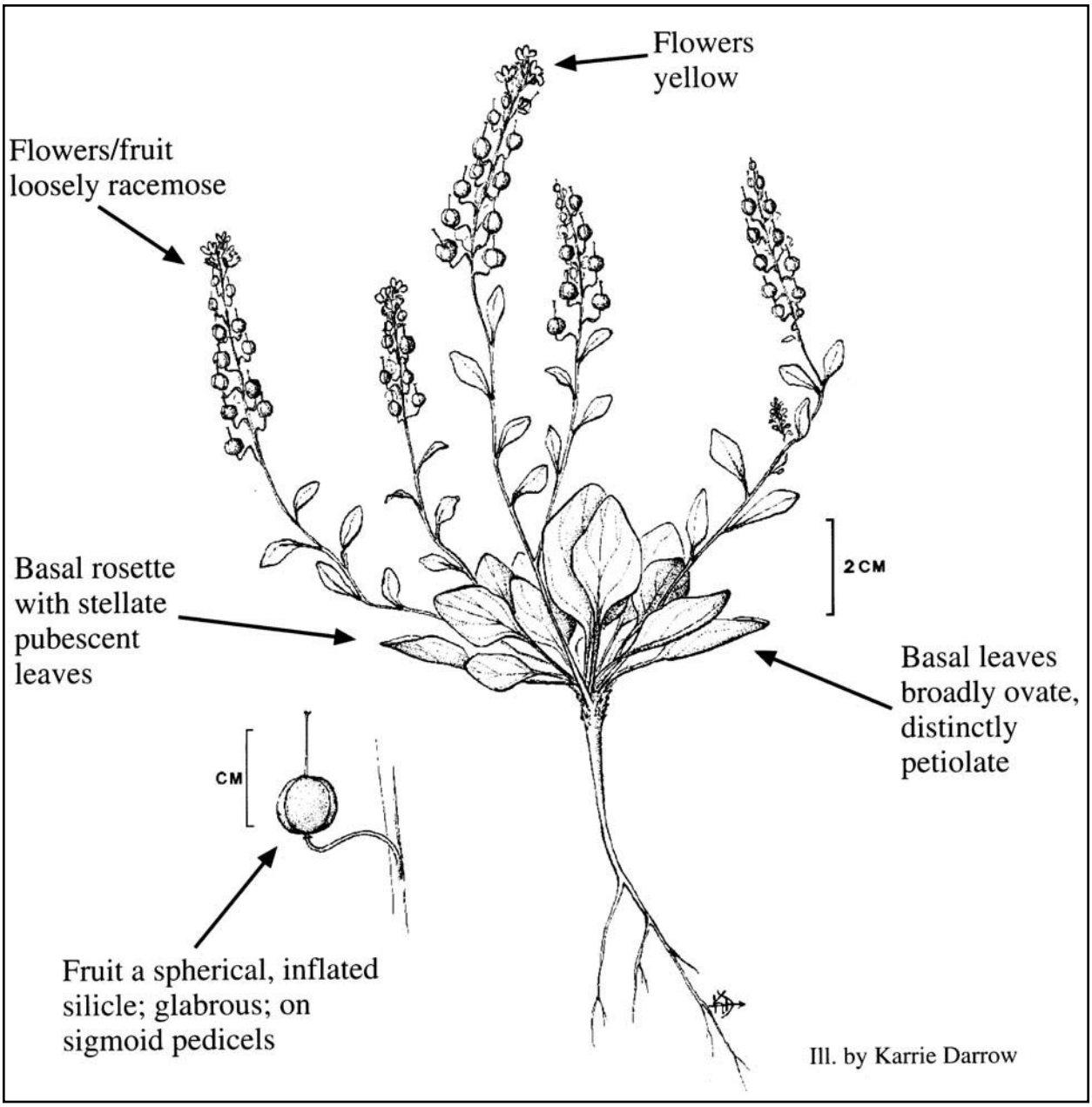

Figure 4. *Lesquerella pruinosa*. Illustration by Karrie Darrow, from Spackman et al. (1997), used with permission.

Technical description

The following technical description of *Lesquerella pruinosa* is taken from Rollins (1993):

> "Perennial, densely pubescent; caudex simple or branched, covered with old leaf bases; trichomes sessile or substipitate, small, smooth to finely granular, 4- to 7-rayed, rays forked or bifurcate, fused toward their bases; stems decumbent or erect, simple, to 2 dm high; basal leaves petiolate, 4-8 cm long, blades suborbicular or obovate to rhombic, entire to sinuate or shallowly dentate, abruptly narrowed to a slender petiole; cauline leaves obovate to rhombic, entire to shallowly toothed, the lower ones petiolate, those above sessile, 0.8-2.3 cm long; inflorescences dense; petals yellow, ca. 9 mm long; fruiting pedicels stout, sigmoid and horizontal to slightly curved and ascending, 8-11 mm long; siliques 6-9 mm long, sessile to substipitate, subglobose or ellipsoid, valves inflated and rather thin, glabrous on exterior and interior; styles 3.5-7 mm long; ovules 2-4

(6) per locule; seeds somewhat flattened, neither margined nor winged."

Published descriptions, keys, and photographs

Several descriptions of *Lesquerella pruinosa* are available. Greene's original description from 1901 is good but less precise than those of later authors. Payson (1921), Rollins and Shaw (1973), and Rollins (1993) offer excellent detailed descriptions of *L. pruinosa*. A brief description appears in Harrington (1954), and Rickett (1973) gives a very brief description but no photograph. *Lesquerella pruinosa* was not included in Rydberg (1906) or Rydberg (1922). Spackman et al. (1997) is an excellent resource that provides an illustration of *L. pruinosa* (**Figure 4**), a range map, photographs of plants and habitat, and notes on diagnostic characteristics. Ecology Consultants Inc. (1978) also includes an illustration. Tonne (2002) includes the description from Rollins and Shaw (1973) and a range map for the distribution of *L. pruinosa* in New Mexico. Good photographs of a plant and a close-up of the fruits appear in Colorado Native Plant Society (1997). A scanning electron micrograph of the trichomes of *L. pruinosa* is included in Rollins (1993). Genetic sequence data for *L. pruinosa* are available on the internet (National Center for Biotechnology Information 2004). Weber and Wittmann (2001) offer a useful key to the genus *Lesquerella* in Colorado.

Distribution and abundance

Distribution

Lesquerella pruinosa is distributed in a northwest- to southeast-trending belt along the foothills of the San Juan Mountains in Archuleta and Hinsdale counties, Colorado and Rio Arriba County, New Mexico (**Figure 5**, **Figure 6**). This area is drained by the San Juan River and some of its tributaries, including the Piedra River, Stollsteimer Creek, Rito Blanco, and Navajo River (Anderson 1988a). The town of Pagosa Springs, Colorado lies at the center of the species' distribution. Within its 42 by 13.25 mile range, *L. pruinosa* is restricted to outcrops of Mancos Shale (**Figure 7**). The greatest distance between any two occurrences is between Turkey Mountain and Chromo, where occurrences are separated by approximately 9 miles; most occurrences are separated by 1 to 5 miles.

The total area occupied by *Lesquerella pruinosa*, based on element occurrence data, is 2,296 acres (Colorado Natural Heritage Program 2004). However, ten records do not report occupied area. The size of occurrences of *L. pruinosa* ranges from 2/3 of an acre (EO #21) to approximately 1,427 acres (EO #10). *Lesquerella pruinosa* has a patchy distribution and is usually found in colonies of one to 10 acres (Anderson 1988a) or 20 acres (Redders et al. 2001, based on observations by Alan Carpenter).

Lesquerella pruinosa is found on federal lands managed by the USFS (San Juan National Forest) and the BLM. It is also found on private land and on the Southern Ute Reservation (**Table 1**, **Table 2**). Six (possibly seven) occurrences are known from National Forest System land on the San Juan National Forest, including the two largest known occurrences at O'Neal Hill Botanical SIA (EO #10) and Turkey Mountain (EO #2). Redders et al. (2001) reported nine occurrences from the San Juan National Forest, with three within the O'Neal Hill Botanical SIA and the area protected by the Piedra Tract Management Plan; these three are considered a single occurrence by the Colorado Natural Heritage Program since they are all within 1 mile of each other. Because there are no data on migration and rates of gene flow between the occupied areas, the Colorado Natural Heritage Program (2004) arbitrarily defines occurrences of *L. pruinosa* as occupied areas separated by at least 1 mile.

There have been many surveys targeting *Lesquerella pruinosa* (e.g., Johnston 1977, Johnston and Lucas 1978, Weiss 1980, O'Kane 1985, Anderson 1988a, Lyon and Denslow 2002, Sovell et al. 2003), and they continue to yield new occurrences and additional occupied area within known occurrences. However, a great deal of potential Mancos Shale habitat remains to be searched. Scattered areas of apparently suitable habitat extend in a band south of Chromo for 25 miles along Highway 84 as far as Chama, New Mexico (Anderson 1988a, Redders 2001). Sivinski (personal communication 2004) has searched accessible areas on private and state lands around Chama without finding *L. pruinosa*. It is possible that the occurrence in Rio Arriba County marks the southern limit of the species (Sivinski personal communication 2004). Limited access to private land has made it difficult to search all areas within the known distribution of *L. pruinosa* (Anderson 1988a, Sivinski personal communication 2004).

Through its close affinity with *Lesquerella pinetorum*, *L. pruinosa* adds to the biological diversity of the San Juan Mountain foothills by contributing a southwestern floristic element (Anderson 1988a). *Lesquerella pruinosa* is also important as an example of a pioneer species adapted to harsh clay soils (Anderson 1988a).

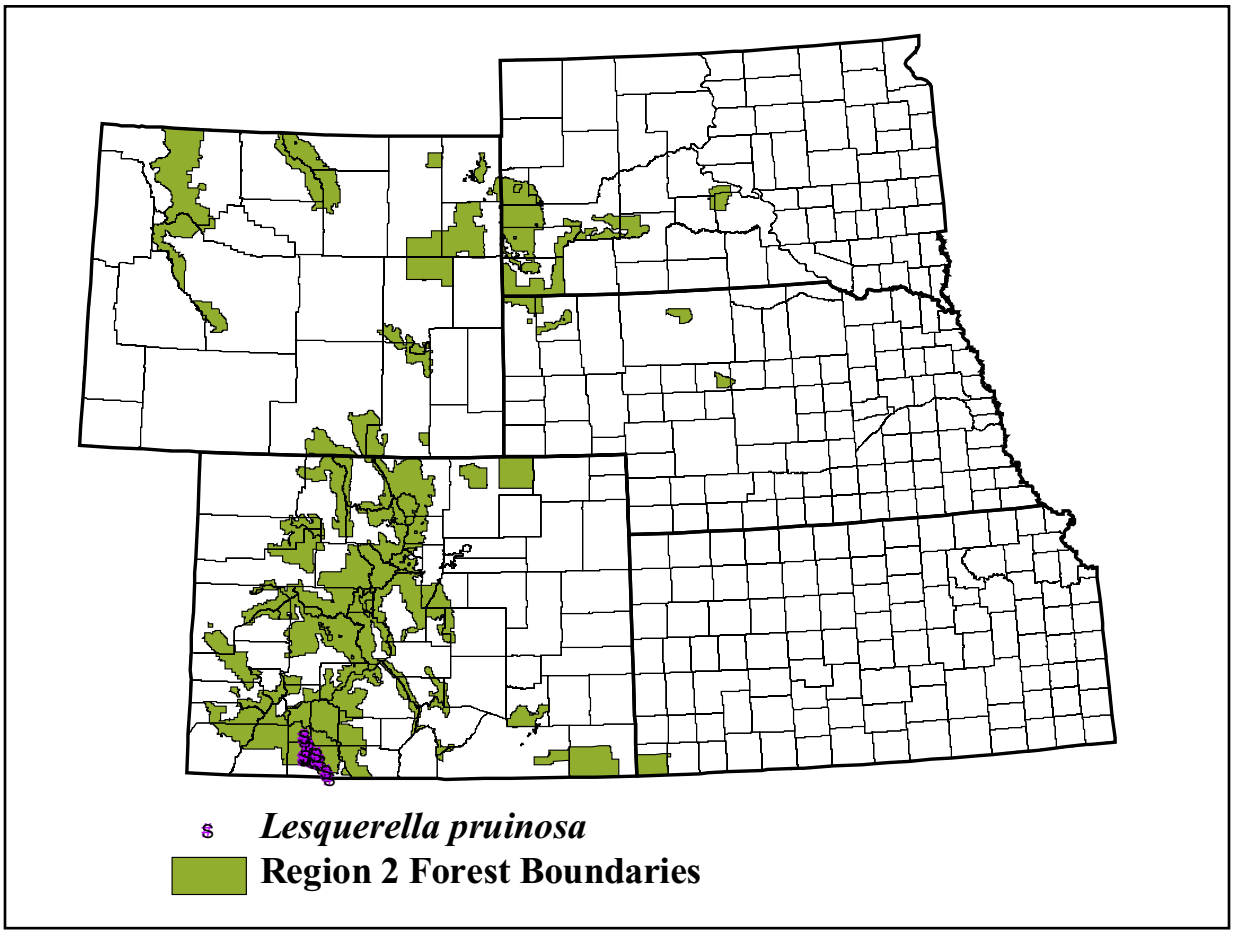

Figure 5. The global distribution of *Lesquerella pruinosa*, including the states of USDA Forest Service Region 2.

Species of *Lesquerella* are native to the arid parts of western North America. Most species are found in areas adjacent to the Rocky Mountains from Canada to the southern extremity of the Mexican Plateau, with at least three species native to South America. Like *L. pruinosa*, they are often found on calcareous soils (Payson 1921, Rollins and Shaw 1973).

Abundance

Reported population estimates of individual occurrences range from 2 to 10,000 individuals (**Table 2**; Colorado Natural Heritage Program 2004). The three largest known occurrences are on National Forest System land at Turkey Mountain (EO #2), Chris Mountain (EO #20), and O'Neal Hill Botanical SIA (EO #10). The occurrence at O'Neal Hill Botanical SIA (EO #10) was estimated to contain 6,500 individuals in 2001 and represents a significant fraction of the total population of the species. However, population numbers at this site vary greatly between years; Lyon (personal communication 2004) reported only 100 plants within the O'Neal Hill Botanical SIA in 2003 following a record drought. Population estimates at Turkey Mountain (EO #2) also range widely, from 1,000 to 10,000 plants. Only one non-USFS occurrence (EO #11 at Chromo) contains more than approximately 100 plants.

An estimate of the total population of *Lesquerella pruinosa* based on element occurrence data ranges between 5,209 and 20,619 individuals (Colorado Natural Heritage Program 2004). Redders et al. (2001) estimated a total of 15,500 individuals based on observations by Sara Brinton in 1999. However, observations at O'Neal Hill Botanical SIA (EO #10) suggest that drought or other factors reduced the population in 2002 and 2003. All but approximately 1,488 individuals have been documented from National Forest System land.

Population trend

Anthropogenic disturbance and gradual loss of habitat since European settlement of the Pagosa Springs area 120 years ago have probably caused a steady population decline of *Lesquerella pruinosa*.

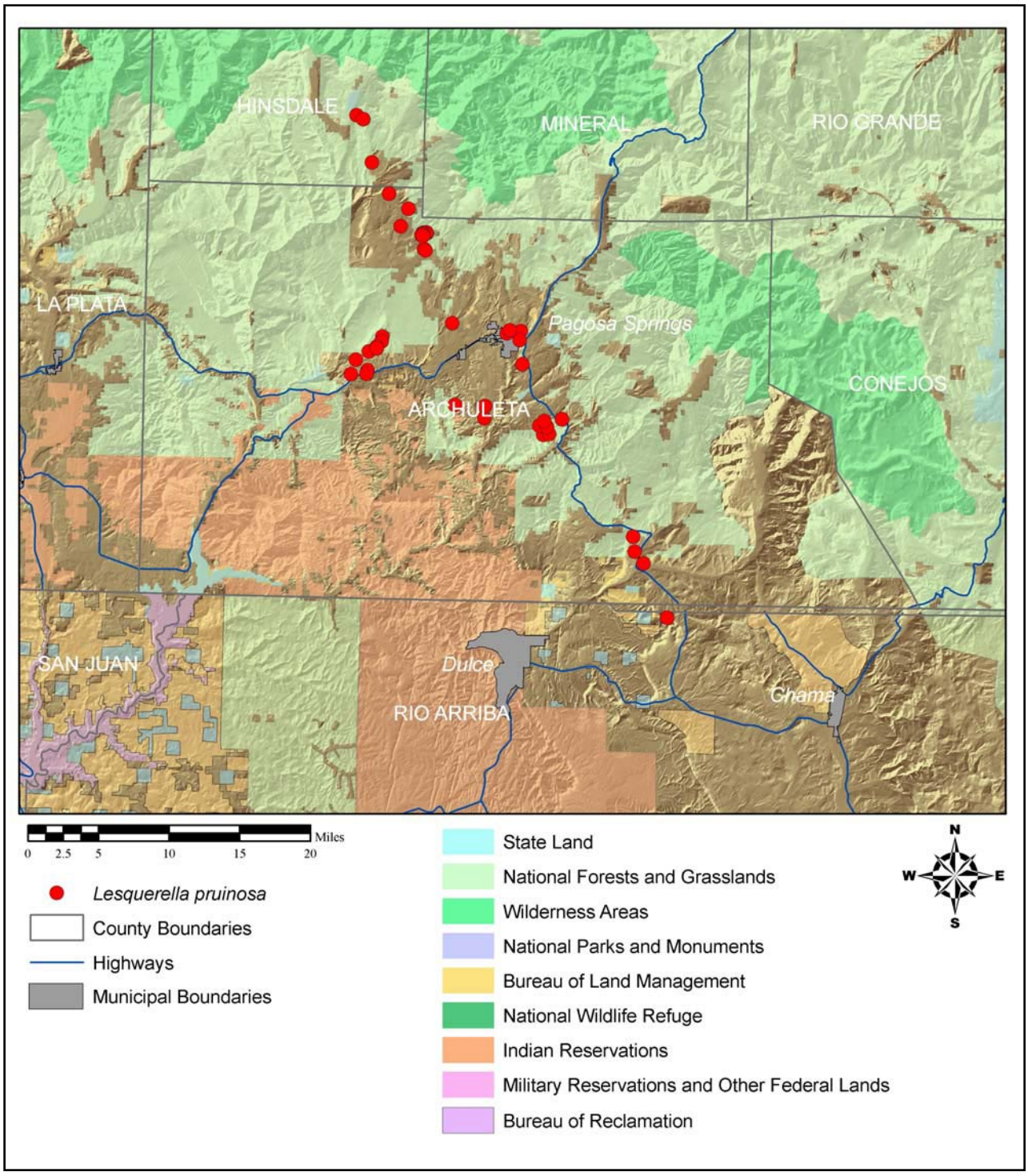

Figure 6. Known distribution of *Lesquerella pruinosa*, showing relationship of occurrences to county boundaries, physiographic features, municipalities, roads, and land ownership.

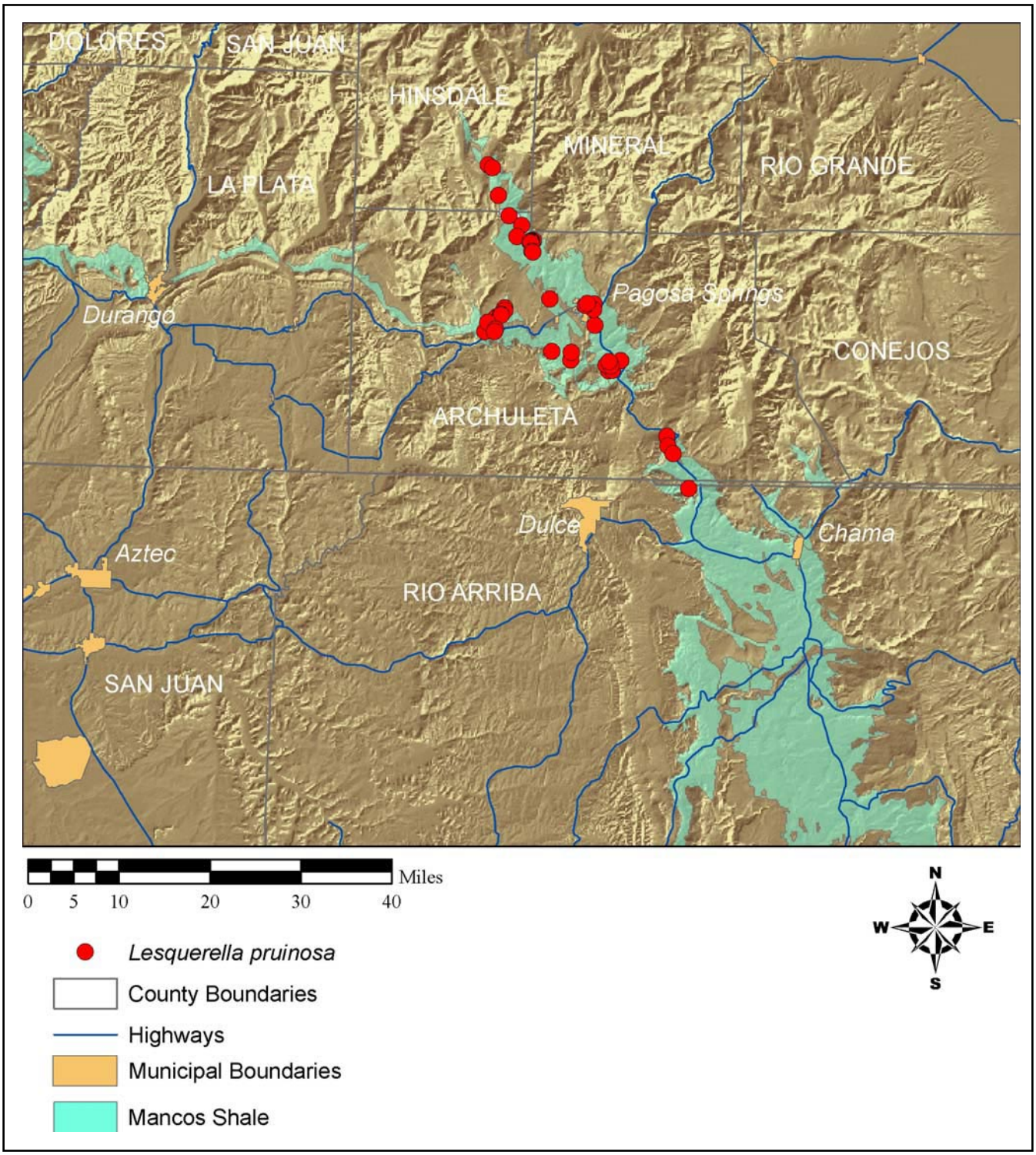

Figure 7. The known distribution of *Lesquerella pruinosa* relative to outcrops of Mancos Formation shale.

Because Pagosa Springs is built on potential habitat and occurrences are known from within the city limits, it is likely that population declines and habitat loss were greatest in this area due to concentrated human activities (Anderson 1988a). Declining habitat quantity and quality on federal and private land are likely to result in continued downward trends for *L. pruinosa* range-wide (Redders 2001, Lyon personal communication 2004).

Observations of the O'Neal Hill Botanical SIA suggest that the abundance of *Lesquerella pruinosa* may vary from year to year. Initial monitoring in 1999 and 2001 suggested that the population was stable (Redders 2001). However, abundance declined precipitously in 2002 and remained low in 2003 (Sovell et al. 2003, Colorado Natural Heritage Program 2004, Lyon personal communication 2004). Monitoring was not conducted in 2002 through 2004 because there were few if any plants present within the plots. In 2005, the population appeared to rebound somewhat, but there were only 45 individuals in the ten monitoring transects as opposed to 272 in 2001 (Brinton personal communication 2005). Gunnison's prairie dog (*Cynomys gunnisoni*) populations increased simultaneously with the decline of *L. pruinosa*, but it is not known if there is a causal relationship between the two species. It was speculated that the decline of *L. pruinosa* was due to drought, but on nearby private property under a similar management regime, plants remained fairly common in 2002 and 2003 (Lyon personal communication 2004). Brinton (1997) noted that *L. pruinosa* had appeared to be unaffected by a 1996 drought. Additional investigation and monitoring are needed to determine the causes of population decline at O'Neal Hill Botanical SIA.

Habitat

General habitat description

Published accounts of the habitat of *Lesquerella pruinosa* include "Mancos slate or shale, meadows, and gentle slopes" (Rollins 1993), "in fine-textured soils derived from Mancos Shale" (O'Kane 1988), "on dry soils" (Rollins and Shaw 1973), and "narrowly endemic on clay-shale" (Weber and Wittmann 2001).

Lesquerella pruinosa is limited to soils derived from the Upper Cretaceous Mancos Shale Formation (Jakubos 1985, Anderson 1988a, Redders 2001, Redders et al. 2001, Tonne 2002, Colorado Natural Heritage Program 2004). Most reports note the highest densities of *L. pruinosa* on exposed, gray clay barrens within montane grasslands or with small hills and ridges above them (Anderson 1988a, Rouse 1992, Tonne 2002). Smaller occurrences are found in open ponderosa pine (*Pinus ponderosa*) stands and Gambel oak (*Quercus gambelii*) communities; numbers of plants apparently decrease under a forest canopy. *Lesquerella pruinosa* can be associated with Douglas-fir (*Pseudotsuga menziesii*) and Engelmann spruce (*Picea engelmannii*) communities at the upper limits of its range (Anderson 1988a, Tonne 2002). Colorado Native Plant Society (1997) noted that *L. pruinosa* does best in shaded areas where organic debris mixes with the clays to form a soil about 6 inches deep over shale bedrock. However, this is contradictory to most reports and element occurrence records, which typically report *L. pruinosa* in barren soils where organic content is probably low. *Lesquerella pruinosa* will not tolerate dense shade such as in the center of Gambel oak clones (Jakubos 1985, Colorado Native Plant Society 1997). **Table 2** provides habitat summaries for all known occurrences of *L. pruinosa*.

Element occurrence records indicate that *Lesquerella pruinosa* is concentrated between 6,890 and 8,800 ft. (**Table 2**), with an average elevation of 7,500 ft. (Colorado Natural Heritage Program 2004). Rollins and Shaw (1973) and Rollins (1993) report *L. pruinosa* from as low as 6,500 ft., but there are no element occurrence data confirming this. All other reports (Anderson 1988a, O'Kane 1988, Rouse 1992, Austin et al. 1999, Tonne 2002) document it between 6,810 and 6,890 ft.

Lesquerella pruinosa has been reported from all aspects and slopes (Anderson 1988a). Jakubos (1985) found no correlation between density and aspect, which is consistent with other observations of the species (Johnston 1977, Johnston and Lucas 1978, Weiss 1980, O'Kane 1985). However, Jakubos (1985) did observe strong consistency between density of *L. pruinosa* and slope at all five sites. The highest densities of *L. pruinosa* were observed on slopes of approximately 15 percent.

Disturbance

Many reports suggest that *Lesquerella pruinosa* has an affinity for disturbed sites. Mancos Shale soils are easily eroded and are thus chronically disturbed (Naumann 1988), particularly on slopes where *L. pruinosa* is most often found. At Chromo, most *L. pruinosa* grows in barren areas along the sides of a dry gully where rapid erosion is taking place (**Figure 8**), but it is also found above the gullies in more heavily vegetated areas (**Figure 9**; Sovell et al. 2003, Lyon personal communication 2004).

Figure 8. *Lesquerella pruinosa* habitat at Chromo. Photograph by Peggy Lyon, used with permission.

Lesquerella pruinosa has generally been observed to do best in disturbed, open-canopied environments, including openings in ponderosa pine forest, and it is primarily associated with grasslands and shale barrens in very early to early seral stages (Redders 2001, Lyon personal communication 2004). It is likely that chronic natural disturbance and soil chemistry conspire to arrest succession, maintaining vegetation in early seral stages at many locations inhabited by *L. pruinosa*. Plant community succession is likely to proceed to shrublands, woodlands, or ponderosa pine if soils are stabilized, or as noted in the Geology and soil section, if additional sand is present in the soil that improves the aeration and facilitates water infiltration. Anderson (1988a) noted that *L. pruinosa* may act as a pioneer species in colonizing outcrops of Mancos Shale, but it appears to persist and become part of the climax community. At the O'Neal Hill Botanical SIA, *L. pruinosa* is found in relatively lush montane grasslands (**Figure 10**, **Figure 11**). The Community ecology section has more information on the vegetation associated with *L. pruinosa*.

Lesquerella pruinosa also occupies anthropogenically disturbed sites, especially roadsides (**Figure 12**; Lyon personal communication 2004). At these locations, *L. pruinosa* takes advantage of the lack of competitors through its ability to colonize bare shale soils. It is unlikely that these sites offer any security to *L. pruinosa* since they are not managed for the species' conservation. For example, routine road maintenance includes applying herbicides to weeds, mowing, and grading, all of which could kill *L. pruinosa*. As the human population grows in the Pagosa Springs area, it is likely that roads will be widened and/or paved, both of which could affect roadside occurrences. Brinton (personal communication 2004) noted that at Pordonia Point (EO #17), *L. pruinosa* did not appear to have incurred any lasting effects from all-terrain vehicles, a tractor, and numerous trucks that drove through the occurrence in 1996 on the way to a prescribed burn. Johnston (1985) observed population recovery in an area near Pagosa Springs (EO #1) that was excavated for development seven to eight years previously. The tolerance threshold of *L. pruinosa* to impacts of this sort is not known. Regarding *Eriogonum lewisii*, another shale endemic in Nevada, Morefield (1996) wrote, "Almost never has a rare plant species been observed to continue spreading onto disturbances farther outside its rare habitat type, or to persist where disturbance is severe and continuous. If rare species had the biologic

Figure 9. *Lesquerella pruinosa* habitat at Chromo. Photograph by Peggy Lyon, used with permission.

and ecologic characteristics of invasive weeds, they would not now be rare."

Climate

From 1906 to 1998, annual rainfall reported in Pagosa Springs averaged 20.21 inches per year (Western Regional Climate Center 2003). It is relatively dry in the spring and early summer months (May and June) when *Lesquerella pruinosa* is most actively growing, but precipitation increases in July and August with the onset of the monsoon. During this same period, average maximum temperatures for May, June, and July are 68, 78, and 83 ºF respectively (Western Regional Climate Center 2003). Nighttime freezing temperatures occur frequently before June, and have a 30 percent chance of occurring in early July as well. Anderson (1988a) reports a growing season of 100 days in five of 10 years, from June 9 to September 18. However, *L. pruinosa* is clearly tolerant of periodic frost since it is actively growing in May. Jakubos (1985) speculated that climate does not limit the distribution of *L. pruinosa* because there is very little macroclimatic variation throughout its range. However, she also speculated that higher summer temperature extremes recorded in the Durango area may limit its western extent.

Vegetation

Lesquerella pruinosa occurs in the Temperate Steppe Division of the Dry Domain in the Ecoregion classification of Bailey (1995). Within the Temperate Steppe Division, it is found on the margins of the Colorado Plateau Semidesert Province and the Southern Rocky Mountain Steppe-Open Woodland-Coniferous Forest-Alpine Meadow Province.

The highest densities of *Lesquerella pruinosa* tend to be in open clay barrens surrounded by montane grasslands (Anderson 1988a). Smaller occurrences are found in open ponderosa pine stands and Gambel oak communities, with the numbers apparently decreasing when plants become part of the forest understory (Anderson 1988a). In association with the ponderosa pine and Gambel oak communities, *L. pruinosa* acts as a climax species, whereas it tends to be a pioneer species on raw shale (Anderson 1988a). Near its upper elevational limit, *L. pruinosa* occurs with Douglas-fir and Engelmann spruce (Anderson 1988a, Austin et al. 1999).

Lesquerella pruinosa has been documented from five ecological systems (after Rondeau 2001 and Comer

Figure 10. The very grassy habitat of *Lesquerella pruinosa* at O'Neal Hill Botanical Special Interest Area, where monitoring occurred in 1999 and 2001. Photo by Peggy Lyon, used with permission.

Figure 11. Typical vegetation and physiography of the Piedra Valley, with barren slopes and hills scattered among montane grasslands, Gambel oak, and ponderosa pine woodlands. *Lesquerella pruinosa* is most common on the more barren areas. Photograph provided by Peggy Lyon, used with permission.

Figure 12. A roadside site where *Lesquerella pruinosa* is found on the road shoulder and road cut. Photograph provided by Carol Dawson, used with permission.

et al. 2003). These are Gambel Oak- Mixed Montane Shrubland, Southern Rocky Mountain Montane Grassland, Ponderosa Pine Woodland, Ponderosa Pine Savanna, and Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland.

The vegetation of the Pagosa Springs area has been greatly modified by conversion to pastures, logging, road construction, and the growth of the town. Much of the area in and around Pagosa Springs was historically a ponderosa pine forest with an understory of Gambel oak (Sovell et al. 2003). The remaining natural vegetation in the area is relatively dense compared to many locations on Mancos Shale (Colorado Native Plant Society 1997, Anderson personal communication 2003).

Geology and soil

Lesquerella pruinosa has very high fidelity to Mancos Shale substrates and has invariably been reported from soils derived from this formation. This is well illustrated by comparing its distribution to that of Mancos Shale within its range (**Figure 7**). At Taylor Canyon (EO #8), *L. pruinosa* is located in areas mapped as Dakota sandstone, but small alluvial deposits derived from Mancos Shale are found in the area where *L. pruinosa* occurs (Sovell et al. 2003, Colorado Natural Heritage Program 2004). In southwestern Colorado and northwestern New Mexico, Mancos shale is exposed around the rim of the Archuleta uplift, forming an arc extending from the Durango area east through Archuleta County and south into Rio Arriba County, with an extension reaching north into Hinsdale County.

The Mancos Shale was deposited in the late (upper) Cretaceous period in a shallow inland sea. It is stratigraphically located above the Dakota sandstone and below the basal members of the Mesa Verde Group (Weimer 1960). Mancos Shale is heterogeneous throughout its distribution, varying from a fine, hard, blocky structure to thin, flaky, friable layers (Potter et al. 1985a). It contains interbedded sandstone and bentonitic layers.

Mancos Shale weathers into a fine clay soil that is characteristically heavy and gray in color (Anderson 1988a, Redders et al. 2001). Soils on which *Lesquerella pruinosa* is found vary in color from gray to black (Johnston 1977) and are typically moderately well-drained to well-drained (Redders et al. 2001). They may be shallow on slopes where shale bedrock occurs at a depth of about 4 to 6 inches, allowing plants to insert their long taproots into cracks in the shale (Johnston 1977, Redders et al. 2001).

Soils derived from the Mancos Shale are included within the Winifred series (Bauer 1981). Pagosa-Winifred soils are deep, moderately well-drained or well-drained, and fine textured. The pH of Winifred soils is circumneutral to slightly alkaline (6.6 to 8.4) (Collins

1995) and probably well buffered. The alkalinity of these soils may be related to the lack of duff due to low plant cover (Johnston 1977). This contrasts with soils in the Pagosa area derived from other (non-shale) rocks that tend to be somewhat acidic (5.1 to 6.0) (Collins 1995). It is possible that *Lesquerella pruinosa* is a calciphile that will take up toxic levels of phosphorus in slightly acidic soils as described by Musick (1976) for creosote bush (*Larrea divaricata*). Soil map units and descriptions from Bauer (1981) noted by Anderson (1988a) are included in **Table 3**.

Potter et al. (1985a) described Mancos Shale soils from the area near Mancos, Colorado that also apply to *Lesquerella pruinosa*. Vegetation is more mesic where there is a sandstone cap over Mancos Shale or sandstone fragments are mixed into the soil, due to improved water filtration and aeration. Soils are apparently non-alkaline, low in sulfates, and low in sodium concentration in these sites. Areas with a sandstone mantle are more likely to support oak brush, pinyon-juniper, and ponderosa pine vegetation. Vegetation is typically better developed on upper slopes, where the fraction of sand in the soil is greater, than on toe slopes, where the soil is often heavy due to deposition of clay particles from higher upslope (Potter et al. 1985a). Colorado Native Plant Society (1997, p. 24) noted the comparative lushness of vegetation on Mancos Shale in the vicinity of Pagosa Springs relative to other locations, where it "does not weather completely into a gray mush, but retains small rock fragments. Here, shrubs such as rabbitbrush (*Chrysothamnus* sp.) not usually found on heavy clays can survive."

Jakubos (1985) observed that *Lesquerella pruinosa* was consistently found at the "foot of sideslopes," suggesting that it is well adapted to the difficult conditions of these sites. Although pH was not measured, she speculated that the soil pH of these sites might be most amenable to the growth of *L. pruinosa*, based on observations of Potter et al. (1985a) and Potter et al. (1985b). Heavy clay soils such as those on which *L. pruinosa* is found are poorly oxygenated, which restricts the metabolic capacity of the underground portion of the plant. Water is also tightly bound to clay particles, which restricts the availability of water to plants in these soils (Naumann 1988).

Fire

Occurrences of *Lesquerella pruinosa* fall within the montane zone where ponderosa pine is the most common forest tree. *Lesquerella pruinosa* has been frequently reported in close proximity to this species, and their elevation limits correspond closely (Rondeau 2001). Ponderosa pine forests are susceptible to fire, and ground fires have a short return interval. Fires may have occurred every eight to 15 years in the ponderosa pine woodlands and savannas of the Southern Rocky Mountains below 8,000 ft. (Mehl 1992, Harrington and Sackett 1992 as cited in Rondeau 2001). Fire may play a role in the maintenance of suitable habitat for *L. pruinosa* at some locations.

Land use and history

Much of the occupied habitat for *Lesquerella pruinosa* has been modified by human activities and management. The habitat for *L. pruinosa* is traditionally used as rangeland (Anderson 1988a). However, human impacts to the habitat of *L. pruinosa* have been most intense in the vicinity of Pagosa Springs, where habitat has been destroyed or severely altered by residential development and road construction.

Pagosa Springs is named after a cluster of hot springs south of the San Juan River. "Pagosah" is reputedly a Ute word for "healing waters" (Pagosa

Table 3. Soil map units and descriptions reported at occurrences of *Lesquerella pruinosa (*from Bauer 1981 and Anderson 1988a).

Soil Unit	Slope (%)	Description
Carracas Loam	4 to 25	Occurs on slopes and badlands
Carracas Loam	25 to 65	A residuum derived from interbedded shale and sandstone on mesas and sides of canyons and cuestas
Corta Silt Loam	25 to 65	Material derived from interbedded shale and sandstone on mesas
Hunchback Clay Loam	4 to 15	A fine to textured colluvium from mixed rock sources; Badlands and steep deeply dissected areas of barren exposed shale
Work Silty Loam	3 to 12	Alluvium weathered from shale and sandstone
Winifred Clay	4 to 25	Residuum derived from black or dark gay shale on rolling hilly areas
Yawdim Clay	3 to 25	Residuum and local alluvium on shale

Springs Chamber of Commerce 2003). The hot springs at Pagosa were used by the Utes before settlement of the area. In 1877, a toll road was constructed through the current town site, and lots were sold. In 1878, Fort Lewis was constructed to control the Utes, and municipal boundaries were established for the town of Pagosa Springs. The town site included one square mile surrounding the hot springs. Cattle ranching began early in the history of the town and continues today. In 1880, Fort Lewis was moved to Hesperus, but in 1881 the railroad reached the town and stimulated growth. A sawmill was built near the present day junction of Highways 160 and 84, and the area was logged (Larason 2003). Some logging undoubtedly occurred within the habitat for *Lesquerella pruinosa*, but the extent is unknown (Anderson 1988a). There is no known detailed documentation of the pre-settlement vegetation of the area other than the brief notes at each section corner made by the surveyors for the Public Lands Survey during the late 19th and early 20th centuries.

Pagosa Springs is developing rapidly as a popular tourist destination and location for second homes. The population in 1997 was 1,767, but the projected population for 2020 is more than 9,000. Between July 1, 1999 and November 30, 2000, 724 residential building permits were issued in Archuleta County, with 456 (63 percent) in the Pagosa area. Of the projected population of 9,000, 6,700 people are expected to reside in areas outside the current town boundaries (Archuleta County 1999).

Potential habitat

Potential habitat for *Lesquerella pruinosa* is limited to Mancos Shale outcrops (Redders 2001). Locations where discoveries of other occurrences of *L. pruinosa* are likely have been noted, based on their geology and physiography, by Anderson (1988a), Clifford (personal communication 2004), and Sivinski (personal communication 2004). Most recent discoveries have been found near known occurrences, suggesting, as noted by Redders et al. (2001), that public and private lands in the vicinity of the known occurrences are most likely to harbor additional suboccurrences. Anderson (1988a) noted that potential habitat exists on private land along the San Juan River south of Pagosa Springs. Potential habitat extends south of Chromo into Chama, New Mexico where soil conditions are similar to those within *L. pruinosa* occurrences (Anderson 1988a). Mancos Shale is highly variable (Potter et al. 1985a); its character changes further south in New Mexico, where it may not be suitable habitat for *L. pruinosa* (Clifford personal communication 2004, Sivinski personal communication 2004). Most places where occurrences may occur in New Mexico are on private land.

Reproductive biology and autecology

Life history and strategy

In the Competitive/Stress-Tolerant/Ruderal (CSR) model of Grime (2001), characteristics of *Lesquerella pruinosa* most closely approximate those of stress-tolerant species. Stress-tolerant attributes of *L. pruinosa* include adaptations to xeric conditions, tolerance of aberrant edaphic conditions, long lifespan, and low reproductive output. *Lesquerella pruinosa* has limited resources in its difficult habitat and probably grows slowly, as is typical of a stress-tolerator. The short, compact growth form and stout taproot exhibited by *L. pruinosa* are excellent adaptations to inherently unstable environments that can enhance survival (Naumann 1988), and they are also typical of stress-tolerators in the CSR model (Grime 2001). Because it allocates relatively little biomass to the production of its relatively large propagules, *L. pruinosa* has a life history pattern that is best classified as *K*-selected (using the classification scheme of MacArthur and Wilson 1967).

Disturbance may play a role in creating conditions suitable for the reproduction of *Lesquerella pruinosa*. It appears to be a poor competitor, but well-adapted to the edaphic conditions of Mancos Shale (Redders 2001, Lyon personal communication 2004) where soils are deficient in nutrients, often high in sodium, poorly aerated, and chronically disturbed by erosion. *Lesquerella pruinosa* is not found in dense turf and is less evident near creeks where soils are relatively moist and well-vegetated (Rouse 1992). This is strongly suggestive of a life history strategy in which *L. pruinosa* avoids competition through adaptations that allow it to persist where other, more competitive species cannot.

While the periodicity and intensity of disturbance to which *Lesquerella pruinosa* responds favorably have not been investigated, some general observations exist. Monitoring data are needed to determine what levels and types of disturbance might benefit this species, and which are detrimental. Natural chronic disturbance from erosion may be appropriate for *L. pruinosa*. However, Rouse (1992) noted that *L. pruinosa* appears to require intermediate levels of periodic disturbance to sustain open habitat. Redders et al. (2001) wrote that *L. pruinosa* "does best in disturbed, open canopied environments (grasslands, shale barrens), which are primarily associated with very early and early-seral

stages of the vegetation types found within the Mancos Shale habitat." Disturbance from the activities of animals may also affect *L. pruinosa*. Beneficial effects may include competitive release and disturbance that creates colonization sites for *L. pruinosa*. Negative effects may include trampling, enhanced erosion, and competition from noxious weeds.

Lesquerella pruinosa is found in anthropogenically modified sites, including road cuts. While this species is apparently capable of colonizing these sites where they pass through its habitat, the overall impacts of such developments are negative. A road passing through an occurrence pre-empts a significant portion of its habitat, acts as a corridor for the introduction of invasive species, introduces unnatural disturbance, creates a potential barrier to pollinators and dispersers, and alters hydrology and other ecological processes. These impacts are likely to be considerable but may not become apparent for many years.

Reproduction

There have been no studies of the reproductive biology of *Lesquerella pruinosa*, but studies of other species of *Lesquerella* and other members of the Brassicaceae permit a degree of inference. Members of *Lesquerella* are primarily self-incompatible and out-crossing (Rollins 1983, Anderson 1988a). Varying degrees of self-compatibility and self-incompatibility are found among members of the Brassicaceae (Rollins and Shaw 1973, Rollins 1993). Most members of the Brassicaceae possess a sporophytic multiple allele incompatibility system that encourages outcrossing (Bateman 1955). In this system, studied extensively in the Brassicaceae, pollen grains will not germinate on the stigma if either of the two alleles from the parent plant is present (Kimball 2002). *Lesquerella fendleri*, another western perennial species, is self-incompatible (Cabin et al. 1997).

Members of *Lesquerella* typically do not reproduce vegetatively, and it appears that *L. pruinosa* reproduces primarily or entirely by seed. One plant collected in 1977 (and deposited at the Pagosa District Herbarium) was branched below the surface (Johnston 1997). While *L. pruinosa* individuals usually appear discrete, occasional subterranean branching may introduce some error into population counts and estimates.

Chromosome numbers among members of the Brassicaceae vary widely. There are some cases where the haploid chromosome number even varies between populations of the same species (Rollins 1993). Polyploidy is also common within the family. Haploid chromosome numbers of members of *Lesquerella* vary between 5 and 30 (Rollins and Shaw 1973). The chromosome number and ploidy of *L. pruinosa* have not been determined. Its close relative *L. pinetorum* is diploid, with a haploid chromosome number of 5 (Rollins and Rüdenberg 1971, Rollins and Shaw 1973).

Pollination ecology

There has been no investigation of the pollinators, pollination ecology, or floral biology of *Lesquerella pruinosa*. In general, members of the Brassicaceae have unspecialized flowers and tend to be pollinated by generalists (Mabberley 1997). Bees and flies are the most common visitors to members of the genus *Lesquerella* (Rollins and Shaw 1973). *Lesquerella fendleri* depends on insect vectors, to which it offers nectar and pollen rewards, for its pollination (Mitchell 1997a). Bees and beeflies are known to pollinate *L. fendleri* (Mitchell and Marshall 1998), and honeybees (*Apis mellifera*) have been used as pollination vectors in agricultural research on *L. fendleri* (Dierig et al. 2003). *Thelypodium howellii* ssp. *spectabilis* (Brassicaceae) is pollinated by insects including bumblebees (*Bombus* spp.) (U.S. Fish and Wildlife Service 2002). Thrips are frequently observed on and in the flowers of some Brassicaceae (Davis et al. 1998).

The pollination rate of *Lesquerella fendleri* was found to be strongly density-dependent (Mitchell 1997b). Among individuals separated by less than one meter, pollen loads and seed set were significantly greater than among plants separated by greater distances. Mitchell and Marshall (1998) observed evidence of non-random mating in *L. fendleri*. Some pollen donors sired more than 71 percent of seeds on some maternal plants, probably due to pollinator behavior and postpollination processes. Considering the reproductive biology of this and other members of Brassicaceae such as *Brassica kaber* (Kunin 1993), it might be expected that low-density populations of *L. pruinosa* will incur difficulties in seed set.

Phenology

Lesquerella pruinosa begins to flower by mid-May and continues to flower through August; fruiting occurs from June through August (Anderson 1988a, Rouse 1992, Austin et al. 1999). Fruiting phenology appears to depend on elevation (Rouse 1992). Anderson (1988a) observed *L. pruinosa* in flower and early fruit at higher elevations in the first week of June 1985 and 1988, when lower elevation colonies were

already in full fruit at that time. Flowering continues through June (Rollins and Shaw 1973) and August. An individual near Pagosa Springs was observed to still have a few flowers during the last week of August 1988 (Anderson 1988a).

Lyon (personal communication 2004) observed a flush of seedlings following the onset of monsoon rains in late August and continuing into September, 2001 at the O'Neal Hill Botanical SIA (EO #10). There is probably a high attrition rate of seedlings over the winter since relatively few were observed in spring (Lyon 2001). *Lesquerella pruinosa* behaves like a winter annual in this regard, as do at least two of its congeners. *Lesquerella filiformis*, a winter annual, over-winters as a basal rosette and flowers and fruits in the following spring (Center for Plant Conservation 2004). Germination occurs in late winter to early spring in *L. fendleri*, but a second flush of germination may also occur following suitable rains in the fall (Evans and Cabin 1995). In wet monsoon years, *L. pruinosa* has been observed to bloom in the fall (King personal communication 2005); for example, the cover photograph was taken on September 16, 2005.

Safe sites

Elberling (2000) reported that desiccation cracks contain disproportionately high numbers of seeds, seedlings, and adults of *Lesquerella arctica*. Although the habitats inhabited by *L. arctica* are very different from those of *L. pruinosa*, it is possible that desiccation cracks in shale-derived soils could offer refuge to the seeds of *L. pruinosa* as well. Germination of *L. fendleri* is higher under high soil moisture than under low soil moisture conditions. The presence of light had the strongest effect on germination of *L. fendleri* (Hyatt et al. 1999). Lyon (personal communication 2004) noticed congregations of seedlings of *L. pruinosa* near prairie dog burrows and on the sides of gullies in August and September 2001 at the O'Neal Hill Botanical SIA (EO #10).

Fertility and fecundity

There has been no formal investigation of seed fertility or fecundity in *Lesquerella pruinosa*. Informal observations suggest that seed production does not appear to be a factor limiting the abundance or reproductive rate of *L. pruinosa* (Anderson 1988a, Redders 2001). Investigations of other taxa may offer insight into what abiotic environmental variables affect seed set and fecundity. The timing and amount of water availability were shown to affect growth and fecundity in *L. fendleri* (Hunsaker et al. 1998). A relationship between salinity and seed yield of *L. fendleri*, with yield decreasing as salinity increased, was also observed (Grieve et al. 1997) and was used in selecting potential salt-tolerant cultivars (Dierig et al. 2003). Adamsen et al. (2003) investigated effects of nitrogen fertilization on seed yield in *L. fendleri* and observed significantly higher flower production and seed yield with fertilization.

Dispersal mechanisms

Many observations report a clumped (non-random) distribution pattern of *Lesquerella pruinosa* (Jakubos 1985, Anderson 1988a, Lyon 2001, Redders et al. 2001). Most seedlings appear to occur near parent plants, so limited dispersal may be partially responsible for the clumped distribution.

There has been no investigation of dispersal vectors for the seeds of *Lesquerella pruinosa*. In members of *Lesquerella*, the valves of the siliques dehisce and fall away prior to seed dispersal, leaving the seeds to be dispersed independently of one another, probably by wind and water (Rollins 1983). However, there appear to be no specialized adaptations to aid in the dispersal in *L. pruinosa* (Anderson 1988a). The low stature of the plant suggests that wind is limited as a dispersal agent. Most seeds of *L. fendleri* remain within 1 m of the parent plant (Cabin 1996). At Pagosa Springs (EO #1), entire inflorescences containing ripened fruits had broken off and were found lower down the slope (Johnston 1997). The inflorescences had not been eaten, but they may have been broken by browsing herbivores. Dispersal of seeds and fruits may occasionally occur in this way.

Cryptic phases

Seed dormancy in higher plants is a means of avoiding unfavorable environmental conditions by arresting growth and development (Evans and Cabin 1995). Seeds of various *Lesquerella* species (but not *L. pruinosa*) have been studied due to their economic value or in efforts to recover populations. At least three species of *Lesquerella* have been shown to have annual dormancy-nondormancy cycles, suggesting that *L. pruinosa* may as well. Seeds with annual dormancy-nondormancy cycles are dormant at some times of the year but not others. Studies of *L. fendleri* reported temporal variation in the dormancy of seeds stored in the field and in the laboratory, suggesting that the dormancy cycle may be regulated by environmental factors (Hyatt et al. 1999). *Lesquerella lyrata* and *L.*

lescurii, two rare winter annuals from the southeastern United States, have been shown to have an annual dormancy-nondormancy cycle (Baskin and Baskin 1992, Baskin and Baskin 2000). Seeds of *L. lyrata* were kept in an unheated greenhouse for 10 years and remained viable (Baskin and Baskin 2000). All three species form persistent seed banks. As annuals, a long-lived seed bank enables *L. lyrata* and *L. lescurii* to persist without producing seeds every year. A seed bank also can exist for at least one year in *L. fendleri* and enhances the possibility of spreading germination through time (Hyatt et al. 1999). Puppala and Fowler (2002) investigated seed pretreatments of water with gibberellic acid and potassium nitrate as possible means of improving dark germination in *L. fendleri*. They reported that soaking seeds in plain water for 4 hours, followed by complete drying, was sufficient to deactivate the light requirement for breaking dormancy in *L. fendleri* seeds.

Monitoring data from the O'Neal Hill Botanical SIA (EO #10) suggest that mature *Lesquerella pruinosa* individuals may exhibit prolonged dormancy (Lyon 2001). However, individual plants were not marked in this study, so it was not determined whether some plants not seen in 2002 were dead or merely dormant.

Phenotypic plasticity

There is considerable variation in plant size in *Lesquerella pruinosa*, which is probably correlated with the age of individuals. There is no evidence to suggest ecotypic variation in *L. pruinosa*. *Lesquerella pulchella* has considerable variation along elevation gradient, where high elevation variants have flowers that are both larger and more numerous (Rollins 1995).

Mycorrhizal relationships

Arbuscular mycorrhizal (AM) fungi belong to a group of nondescript soil fungi (Glomales) that are difficult to identify because they seldom sporulate (Fernando and Currah 1996). They are the most abundant type of soil fungi (Harley 1991) and infect up to 90 percent of all angiosperms (Law 1985). Unlike most land plants, members of the Brassicaceae do not typically form mycorrhizal symbioses (Barbour et al. 1987) and have demonstrated decreased fitness in the presence of AM fungi (Lewis 1985, Read 1999). *Sisymbrium altissimum*, an annual Eurasian weed in the Brassicaceae, is not a host plant for AM fungi (Fontenla et al. 1999). There apparently have been no assays of *Lesquerella* species for mycorrhizal symbioses.

Hybridization

Cases of sympatry among species of *Lesquerella* are uncommon in western North America, where a single taxon typically occurs at a given site (Rollins and Shaw 1973). This is true of all sites where *L. pruinosa* has been observed. Rollins and Shaw (1973) also note that no cases of undoubted interspecific hybridization have been observed in the Rocky Mountain region or intermontane basins of the western United States. The lack of sympatry among western *Lesquerella* species probably contributes to the infrequency of hybridization events in this genus. Three cases of natural hybridization in *Lesquerella* are known in North America, and numerous artificial hybrids that show a high degree of fertility have been induced (Rollins and Shaw 1973, Rollins and Solbrig 1973). Rollins and Solbrig (1973) did not attempt to create artificial hybrids using *L. pruinosa*. Under highly controlled laboratory conditions, *L. fendleri* was crossed with Brassica napus to create a fertile hybrid (Skarzhinskaya et al. 1996, Schroder-Pontoppidan et al. 1999).

Demography

Several occurrences of *Lesquerella pruinosa* appear to be small enough to be susceptible to inbreeding depression. Among occurrences where abundance was reported, nine report fewer than 100 individuals, and a tenth is reportedly "small" (**Table 2**). One occurrence consisted of only two individuals at the time it was observed. A minimum viable population size has not been determined for *L. pruinosa*. The U.S. Fish and Wildlife Service (2004b) suggested a minimum viable population size of 2,000 plants for *L. thamnophila*, based on Pavlik (1996). Only three occurrences of *L. pruinosa* have a documented population that large, one of which appears to have declined precipitously since 2001. The small size of many occurrences of *L. pruinosa* and its dependence on outcrossing makes inbreeding depression, loss of genetic diversity, genetic drift that overrides natural selection, and fragmentation important issues for the conservation of the species. Effective population sizes of 50 to 500 individuals are believed to be required to avoid inbreeding depression, and larger populations (N_e = 500-5,000 individuals) are required to maintain evolutionary potential (Soulé 1980).

Little is known about the population genetics of *Lesquerella pruinosa*. There has been much research on the population genetics of its relative, *L. fendleri*; the literature is discussed in this assessment where relevant.

The degree of connectedness among *L. pruinosa* occurrences is not known, but current knowledge of its distribution suggests that outlying occurrences may be genetically isolated (Anderson 1988a). Known occurrences are separated by 1 to 9 miles (**Figure 6**). The degree to which geneflow is occurring between occurrences is not known. Studies of allele frequencies in different population centers could clarify the degree of connectivity and identify those occurrences that are crucial to preserving the maximum genetic diversity of the species.

Mitchell (1997a) investigated the effects of pollen load on seed set in *Lesquerella fendleri*. Some plants achieved nearly full seed set at 50 grains per flower while others could have produced more seeds with more pollen. However, most plants naturally had 120 grains per flower or more, so seed production should rarely be limited by pollen in large populations. The results of this study suggest the possibility that small populations of *L. fendleri* may not get enough pollen per flower for maximum seed set. Mitchell (1997b) observed that pollen load does not appear to affect progeny vigor, so pollen limitation appears likely to result primarily in decreased seed set.

Spatial autocorrelation between individuals had measurable effects on reproductive success of *Lesquerella fendleri* (Roll et al. 1997). Individual reproductive success in *L. fendleri* was shown to increase with the density of conspecifics within 1 m. However, variation in the density of conspecifics 1 to 3 m away had no effect on reproductive success. It appears that processes occurring at fine scales (<1 m) have important effects on reproduction (Roll et al. 1997). The authors suggest that increased pollinator visitation is the most likely cause of these effects and may vary among pollinators.

Research conducted on *Lesquerella fendleri* investigated the theory that seed dormancy can affect the evolution of post-germination traits not directly associated with dormancy and germination. Work by Evans and Cabin (1995) on *L. fendleri* provided the first empirical evidence supporting this theory. Subsequent work showed that seedlings represent a nonrandom genetic subset of the underlying seed bank (Cabin 1996) and that germination timing and environment can significantly affect the genetic structure of emerging plant populations in *L. fendleri* (Cabin at al. 1997). Cabin et al. (1998) compared the genetic structure of soil seeds and surface plants of *L. fendleri*. Soil seeds and surface plants showed significantly different allele frequencies. Seeds germinate in the spring, but often there is a second flush of germination late in the growing season of *L. fendleri* (Hyatt et al. 1999). If flowering is related to germination date, then the population may be subdivided into subpopulations that overlap spatially but experience constricted geneflow. Cyclic germination may also facilitate the differentiation of subpopulations (Hyatt et al. 1999). Populations of *L. fendleri* with different dormancy characteristics appear to act as genetically distinct metapopulations within a single occurrence, which may serve to increase fitness in their variable environment and to decrease intraspecific competition (Hyatt and Evans 1998, Hyatt et al. 1999).

It is not known if a metapopulation structure such as that described above for *Lesquerella fendleri* exists in *L. pruinosa*. *Lesquerella pruinosa* seedlings have been observed in spring and in late summer and fall (Lyon 2001, Redders et al. 2001, Lyon personal communication 2004), suggesting the possibility that physically intermingled but genetically distinct populations as described by Hyatt et al. (1999) could exist in *L. pruinosa*. This is an intriguing concept that merits further investigation.

The lifespan of *Lesquerella pruinosa* has not been determined. Most species of *Lesquerella* are perennials, and some develop a considerable amount of woody tissue in their caudices (Payson 1921). Based on field observations that noted the presence of old rosettes on the plants, *L. pruinosa* appears to be a somewhat long-lived perennial (Anderson 1988a). It can probably live at least 10 years (Lyon personal communication 2004). **Figure 13** is a life cycle graph of *L. pruinosa* modeled after Caswell (2001).

No Population Viability Analysis (PVA) has been performed for *Lesquerella pruinosa*. Apparently there has never been a PVA of any member of the genus *Lesquerella* or other members of the Brassicaceae (U.S. Fish and Wildlife Service 1999, U.S. Fish and Wildlife Service 2004a) from which inferences could be drawn for this report. Monitoring and preliminary quantitative assessment of population viability have been conducted for at least four federally listed taxa in the Brassicaceae: *Arabis serotina* (shale barren rockcress) (U.S. Fish and Wildlife Service 1991), *L. filiformis* (limestoneglade bladderpod) (U.S. Fish and Wildlife Service 1988), *Thelypodium howellii* ssp. *spectabilis* (Howell's thelypody) (U.S. Fish and Wildlife Service 2002), and *T. stenopetalum* (slenderpetal thelypody) (U.S. Fish and Wildlife Service 1997). Conducting a minimum viable population study is among the recovery steps cited for the federally listed species *Lepidium barnebyanum* (Barneby's pepperweed) (U.S. Fish and Wildlife

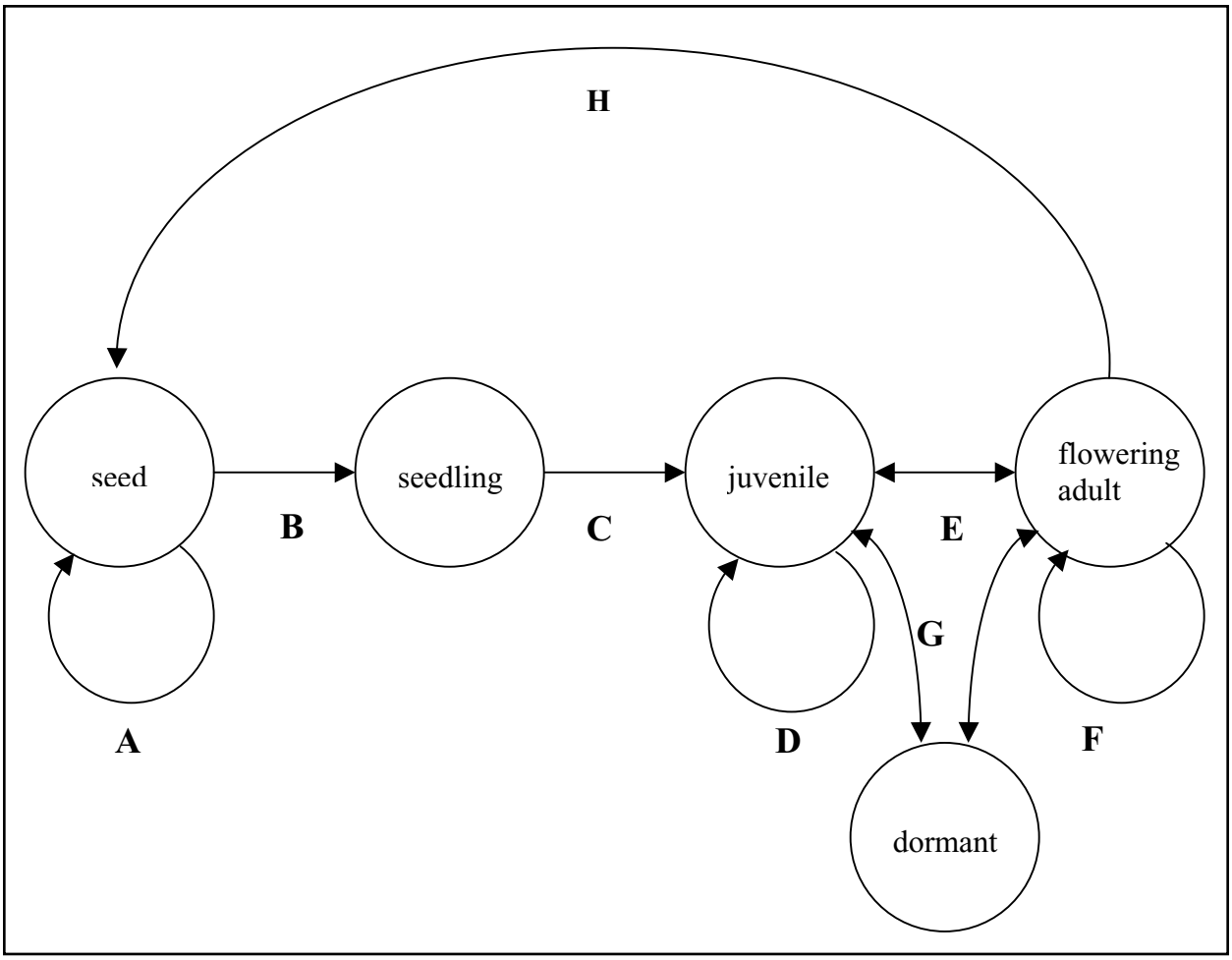

Figure 13. Hypothetical life cycle graph (after Caswell 2001) for *Lesquerella pruinosa*. Much of this is somewhat speculative because there has been no demographic monitoring where individuals were tracked through their life history stages. The value of A is not known, although the existence of seed banks has been confirmed in other species of *Lesquerella* (Baskin and Baskin 1992, Hyatt et al. 1999, Baskin and Baskin 2000). The duration of the juvenile stage is not known, but plants may be capable of remaining in the juvenile stage for multiple years (D). *Lesquerella pruinosa* is clearly a polycarpic perennial (F). Given a probable slow growth rate and the large size of some individuals, plants probably survive for ten or more years as flowering adults (F) (Anderson 1988a, Lyon personal communication 2004). Observations by Lyon (personal communication 2004) suggest that *L. pruinosa* may be capable of prolonged dormancy (G). However, this is highly speculative and further research is needed. Fecundity has not been measured (H), but *L. pruinosa* reportedly produces copious quantities of seed (Anderson 1988a).

Service 1993). Identifying critical life history stages that contribute most to population or metapopulation dynamics is crucial to developing recovery strategies for rare plants (Schemske et al. 1994). These stages have not been identified for *Lesquerella pruinosa*.

Lesquerella pruinosa has been noted to be strongly clumped within occurrences (Lyon personal communication 2004). Factors that are thought to influence the spatial distribution of other *Lesquerella* species at a local scale include microhabitat characteristics, the distribution pattern of suitable germination sites for seeds, natural disturbance patterns, seed dispersal mechanisms, interaction with other vegetation, and topographical heterogeneity (Cabin and Marshall 2000, Cabin et al. 2000, Elberling 2000, Fertig 2000, Beatty et al. 2003).

Community ecology

There has been only one formal study of the community ecology and interspecific relationships

of *Lesquerella pruinosa*. The available information regarding community ecology of *L. pruinosa* is otherwise limited to surveys, herbarium specimens, observations, and inference from Geographic Information System (GIS) data layers. Much effort has been devoted to field studies of this species, which provide a basic understanding of its distribution and habitat. Understanding of the interactions of *L. pruinosa* with other species remains poor.

Jakubos (1985) conducted the only formal investigation of the community ecology of *Lesquerella pruinosa* completed to date. She used multivariate analyses to conduct a limited investigation of the relationship between plant density and biotic and abiotic habitat variables. The results of this study were inconclusive due to problems with small sample size; no statistically significant relationships were observed. Nonetheless, the results provide some insight into the ecology of *L. pruinosa* and are reviewed here. Jakubos (1985) noted that dominant and subdominant species varied widely among sites, as did associated species at each site. Jakubos noted further study is needed on the effect of forb and grass cover on *L. pruinosa* density. *Lesquerella pruinosa* tends to grow near the edge of the clones of Gambel oak, but not within clones. This suggests that Gambel oak may outcompete *L. pruinosa* and prevent it from inhabiting some sites where oak cover is high. Except for a negative correlation between centers of Gambel oak clones, there does not appear to be any consistent association between *L. pruinosa* and any other species. Leaf litter did not appear to inhibit the growth of *L. pruinosa*, especially at Taylor Canyon (EO #8) where approximately one-third of the individuals observed were growing in oak leaf litter. Density of *L. pruinosa* at sites with leaf litter appeared equal to density at sites where soil was not covered by litter. There were no correlations with vegetative cover, except for weak and insignificant correlations with forb and grass cover. Correlations were not found between other environmental factors and plant density. This study compared density among five occupied sites; no unoccupied sites were sampled.

Associated vegetation

The vegetation throughout the range of *Lesquerella pruinosa* is a complex and heterogeneous mosaic of grasslands, shrublands, woodlands, and ponderosa pine forest. There do not appear to be any particularly strong affinities of *L. pruinosa* for any one vegetation type (Jakubos 1985). *Lesquerella pruinosa* is often found on open shale slopes in oakbrush communities and, less frequently, in open stands of ponderosa pine (O'Kane 1988). Anderson (1988a) noted that density is highest in disclimax open clay barrens within montane grasslands that do not become forested, with decreasing density as plants become part of the forest understory. *Lesquerella pruinosa* is most often associated with montane grasslands of the *Festuca arizonica* (Arizona fescue) series (Anderson 1988a, Redders et al. 2001). Smaller occurrences are found in open ponderosa pine forests and Gambel oak-dominated shrublands. *Lesquerella pruinosa* has been documented in forests dominated by Douglas-fir at the upper limits of its range (Anderson 1988a). Plant species commonly associated with *L. pruinosa* include *F. arizonica* (Arizona fescue), *Astragalus lonchocarpus* (rushy milkvetch), *Symphoricarpos oreophilus* (mountain snowberry), *Carex inops* ssp. *heliophila* (sun sedge), *Rosa woodsii* (Woods' rose), and *Townsendia glabella* (Gray's townsend daisy). **Table 4** is a list of all associated species that have been documented with *L. pruinosa*. **Appendix** contains summaries of PCAs that include *L. pruinosa*, and these summaries include descriptions of the vegetation.

In the area around Pagosa Springs (within the Mill Creek at Pagosa Springs PCA), natural vegetation is predominantly ponderosa pine forest with Gambel oak in the understory. However, much of the natural vegetation has been removed with the development of the area. *Lesquerella pruinosa* habitat and populations are highly fragmented and vulnerable to extirpation (Sovell et al. 2003). In the Dyke area (within the Stollsteimer Creek North PCA), *L. pruinosa* is associated with sparse to moderately dense vegetation, including *Juniperus scopulorum* (Rocky Mountain juniper) and shrubs. At the O'Neal Hill Botanical SIA, *L. pruinosa* is found on Mancos shale barrens, but it also occurs in more heavily vegetated areas where grasses (including *Festuca arizonica*) and forbs are dominant (**Figure 10**, **Figure 11**; Lyon personal communication 2004).

Lesquerella pruinosa has been documented from five ecological systems as defined by Rondeau (2001): Gambel Oak- Mixed Montane Shrubland, Southern Rocky Mountain Montane Grassland, Ponderosa Pine Woodland, Ponderosa Pine Savanna, and Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland.

Gambel Oak- Mixed Montane Shrubland is most commonly found on dry foothills and lower mountain slopes, often situated above pinyon-juniper woodlands. In many occurrences, the canopy is dominated by *Quercus gambelii* (Gambel oak) although *Amelanchier* spp. (serviceberry), *Cercocarpus montanus* (mountain

Table 4. Associated species documented with *Lesquerella pruinosa*.

Life Form	Rare / Exotic	Common Associate	Scientific Name	Life Form	Rare / Exotic	Common Associate	Scientific Name
Forb			*Achillea lanulosa*	Forb			*Smilacina stellata*
Forb			*Allium cernuum*	Forb	E		*Taraxacum officinale*
Forb			*Allium* sp.	Forb			*Tetraneuris ivesiana*
Forb			*Apocynum* sp.	Forb			*Thalictrum* sp.
Forb			*Artemisia frigida*	Forb	R	X	*Townsendia glabella*
Forb			*Artemisia ludoviciana*	Forb	R		*Townsendia rothrockii*
Forb			*Astragalus bisulcatus*	Forb			*Townsendia* sp.
Forb		X	*Astragalus lonchocarpus*	Forb	E		*Tragopogon dubius*
Forb	R		*Astragalus missouriensis* var. *humistratus*	Forb		X	*Vicia americana*
Forb			*Astragalus pattersonii*	Forb			*Viola nuttallii*
Forb			*Astragalus racemosus*	Forb			*Viola* sp.
Forb			*Astragalus* sp.	Forb		X	*Wyethia arizonica*
Forb			*Boechera* sp.	Forb			*Yucca harrimaniae*
Forb			*Castilleja* sp.	Graminoid			*Bouteloua gracilis*
Forb			*Chaenactis* sp.	Graminoid		X	*Carex heliophila*
Forb			*Clematis hirsutissima*	Graminoid			*Elymus elymoides*
Forb		X	*Comandra umbellata*	Graminoid		X	*Festuca arizonica*
Forb			*Draba* sp.	Graminoid			*Hilaria jamesii*
Forb			*Erigeron compositus*	Graminoid			*Koeleria macrantha*
Forb			*Erigeron divergens*	Graminoid		X	*Muhlenbergia montana*
Forb		X	*Erigeron flagellaris*	Graminoid			*Oryzopsis hymenoides*
Forb		X	*Eriogonum alatum*	Graminoid	E		*Phleum pratense*
Forb			*Eriogonum* sp.	Graminoid	E		*Poa pratensis*
Forb			*Euphorbia* sp.	Graminoid			*Stipa* sp.
Forb			*Geranium* sp.	Shrub			*Amelanchier utahensis*
Forb			*Gilia* sp.	Shrub			*Berberis fendleri*
Forb			*Helenium autumnale*	Shrub			*Ceanothus fendleri*
Forb			*Heterotheca* sp.	Shrub			*Chrysothamnus* sp.
Forb			*Heterotheca villosa*	Shrub			*Crataegus* sp.
Forb			*Hymenopappus filifolius*	Shrub			*Eriogonum lonchophyllum*
Forb			*Hymenopappus newberryi*	Shrub			*Forestiera pubescens*
Forb			*Ipomopsis aggregata*	Shrub		X	*Mahonia repens*
Forb	R		*Ipomopsis polyantha*	Shrub			*Paxistima myrsinites*
Forb			*Linum lewisii*	Shrub			*Prunus virginiana*
Forb			*Lithospermum incisum*	Shrub			*Purshia tridentata*
Forb			*Lupinus argenteus*	Shrub			*Rhus trilobata*
Forb	E		*Melilotus officinalis*	Shrub			*Ribes* sp.
Forb			*Packera neomexicana*	Shrub			*Rosa* sp.
Forb			*Packera streptanthifolia*	Shrub		X	*Rosa woodsii*
Forb			*Penstemon crandallii* ssp. *glabrescens*	Shrub		X	*Symphoricarpos oreophilus*

Table 4 (concluded).

Life Form	Rare / Exotic	Common Associate	Scientific Name	Life Form	Rare / Exotic	Common Associate	Scientific Name
Forb		X	*Penstemon linarioides*	Tree		X	*Juniperus osteosperma*
Forb			*Penstemon* sp.	Tree			*Juniperus scopulorum*
Forb			*Penstemon strictus*	Tree			*Picea engelmannii*
Forb	R		*Penstemon teucrioides*	Tree			*Pinus edulis*
Forb		X	*Potentilla hippiana*	Tree			*Pinus flexilis*
Forb			*Pseudocymopterus montana*	Tree		X	*Pinus ponderosa*
Forb			*Senecio neomexicanus*	Tree			*Pseudotsuga menziesii*
Forb			*Senecio* sp.	Tree		X	*Quercus gambelii*
Forb			*Senecio werneriifolia*				

mahogany), *Symphoricarpos* spp. (snowberry) and other shrubs may also be co-dominant (Rondeau 2001).

Southern Rocky Mountain Montane Grasslands occur in well-drained sites that are typically maintained by periodic fire (Rondeau 2001). They may be mixed with patches of woody vegetation including *Populus tremuloides* (quaking aspen) and *Pinus ponderosa* (ponderosa pine), as seen throughout the range of *Lesquerella pruinosa*. They are typically dominated by various species of bunchgrasses, including Arizona fescue and *Muhlenbergia montana* (mountain muhly).

Forests dominated by *Pinus ponderosa* fall into two ecological systems as defined by Rondeau (2001): Ponderosa Pine Woodland and Ponderosa Pine Savannas. These systems separate grasslands or shrublands at low elevations and more mesic coniferous forests at higher elevations, and are typically found in warm, dry, exposed sites. The systems are dominated by ponderosa pine and normally have a shrubby understory. Fire plays an important role in the maintenance of both systems (see the Fire section for details). Because they occur at lower elevations, contain valuable timber resources, are relatively accessible to livestock, and are attractive locations for low-density residential development, these systems have been heavily impacted and degraded by human use.

Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodlands of the Piedra Valley and surrounding area are dominated by Douglas-fir. When growing in association with *Pinus ponderosa*, *P. contorta* (lodgepole pine) and *Populus tremuloides* (quaking aspen), *Pseudotsuga menziesii* (Douglas-fir) often becomes the dominant species if succession is not interrupted by major disturbances such as fire. Older trees are resistant to fire, but young trees are easily killed. Douglas-fir can reproduce under its own canopy, often resulting in mature stands where different age classes are represented. Old stands in Colorado generally reach 400 years, but some are known to have reached 700 years (Mehl 1992 as cited in Rondeau 2001).

Lesquerella pruinosa occurs with other rare plants at several locations. At Turkey Mountain (EO #2), it occurs with *Astragalus missouriensis* var. *humistratus*, *Phlox caryophylla*, and *Townsendia glabella*. Near Pagosa Springs (EO #1 and #13) and Dyke (EO #4), it is found with *Ipomopsis polyantha* (Pagosa skyrocket), a very rare species known only from three locations in the Pagosa Springs area (Anderson 2004). It is also found with *T. rothrockii* (Rothrock's townsend daisy) at one location near Pagosa Springs (EO #13).

Much of the habitat of *Lesquerella pruinosa* has been subjected to extensive modification and intensive land use practices for at least 120 years. The natural vegetation and associated species for *L. pruinosa* have been disrupted or removed at many locations, particularly in the vicinity of Pagosa Springs. Montane grasslands throughout Colorado have been grazed for more than 100 years, and in some areas have been overgrazed (Rondeau 2001).

It is likely that *Lesquerella pruinosa* avoids competition through its unique adaptations to disturbance and poor soils, as is seen commonly in rare plants in western North America (Morefield 1996). However, it also appears to tolerate more productive soils. The Life history and strategy section includes a discussion of the role of disturbance in the reproduction of *L. pruinosa*.

Herbivory

Consumption of *Lesquerella pruinosa* by native ungulates or domestic livestock has not been observed directly, but grazing does occur throughout its range (Redders et al. 2001, Brinton personal communication 2004, Lyon personal communication 2004). *Lesquerella pruinosa* is known from four grazing allotments on USFS land (Pagosa Allotment, East Fork Piedra Allotment, Divide Park Allotment, and Eightmile Mesa Allotment; Redders et al. 2001); all of these allotments are currently active (Brinton personal communication 2004). Grazing is allowed on Unit C of the O'Neal Hill Botanical SIA, but has not occurred since 2002 (Brinton personal communication 2004) BLM and private lands where *L. pruinosa* occurs are also grazed (Johnston 1985, Colorado Natural Heritage Program 2004).

The effects of grazing on *Lesquerella pruinosa* are not known, but current speculation is that they are minor. This may be due in part to the low palatability of the species (Rouse 1992). Members of the genus *Lesquerella* may cause digestive tract irritation when grazed (Burrows and Tyrl 2000). Cattle have been grazing the Lynd property (EO #10) at Piedra Valley for decades with no apparent effect on the *L. pruinosa* growing there. At least some *L. pruinosa* occurrences experience heavy use by elk during the winter (Rouse 1992). Johnston (1985) observed healthy, uneaten plants on private land where cattle use was heavy. Because *L. pruinosa* is found primarily on barren sites, cattle and native ungulates probably favor more productive sites.

The effects of disturbance caused by grazing in *Lesquerella pruinosa* habitat are not known. Grazing by ungulates (i.e., livestock, deer, elk) may be integral in reducing vegetation cover and exposing bare soil necessary for *L. pruinosa* recruitment (Rouse 1992, Schulz 1997, Redders et al. 2001). Johnston (1985) speculated that low-growing *L. pruinosa* is resistant to trampling; however, the effects of trampling by cattle and elk have not been measured (Rouse 1992). While these observations suggest that disturbance may play a natural role in the autecology of *L. pruinosa*, the threshold at which disturbances become detrimental is unknown. Trailing by livestock and native ungulates passing though occupied habitat to reach range that is more productive has the potential to affect portions of occurrences.

Gunnison's prairie dogs (*Cynomys gunnisoni*) are present in or near at least 12 occurrences of *Lesquerella pruinosa* (Sovell et al. 2003, Lyon personal communication 2004). In 2003, they were present at Taylor Canyon at San Juan River PCA, Mill Creek at Pagosa Springs PCA, and Stollsteimer Creek North PCA (**Appendix**). The largest prairie dog colonies on National Forest System land near occurrences of *L. pruinosa* are in the vicinity of the O'Neal Hill Botanical SIA (Lyon personal communication 2004). As with grazing ungulates, there is no direct evidence that prairie dogs utilize *L. pruinosa* for forage. Redders et al. (2001) suggest that soil disturbance caused by grazing ungulates and prairie dogs may help to create and maintain colonization sites for *L. pruinosa*. However, the precipitous decline observed at the O'Neal Botanical SIA in 2002 was accompanied by a large increase in the local population of Gunnison's prairie dogs. It is not known if there is a causal relationship between these two factors or if they vary independently of one another. *Lesquerella pruinosa* was absent in areas in 2002 where there are no prairie dogs (Lyon personal communication 2004). More research is needed to determine the impacts, if any, of prairie dogs on *L. pruinosa*.

Parasites and disease

Lesquerella pruinosa does not appear to be susceptible to disease or predation (Redders 2001), and there have been no observations of parasites or disease on *L. pruinosa* (Anderson 1988a). There are two reports of damage to plants that apparently resulted from insects. One plant at Pagosa Springs (EO #1) had been chewed by an insect around the margins of the leaves (Johnston 1997). At Turkey Mountain (EO #2), some plants were missing pods, with only the pedicel remaining (Johnston 1997).

CONSERVATION

Threats

Several threats to the persistence of *Lesquerella pruinosa* have been documented and reviewed extensively by Redders (2001), Redders et al. (2001), and in less detail by others (Anderson 1988a, O'Kane 1988, Rouse 1992, Sovell et al. 2003). Additional threats are included here, as well as information to support or qualify the threats listed in Redders et al. (2001).

Activities that result in habitat destruction on private, state, and county land are the greatest threats to *Lesquerella pruinosa* (Rouse 1992, Redders et al. 2001). In approximate decreasing order of priority based on Redders et al. (2001), specific threats to *L. pruinosa* include residential and commercial development, off-road vehicle recreation, other recreational activities,

energy resource development, exotic species invasion, use of herbicides and pesticides for weed management and range improvement, effects of small population size, grazing, prairie dog herbivory, fire, global climate change, pollution and overutilization. These threats and the hierarchy ascribed to them are speculative, and more complete information on the biology and ecology of this species may reveal other threats. The magnitude of each threat varies greatly across the range of *L. pruinosa*. Threats to particular occurrences are discussed here and in the Evidence of populations in Region 2 at risk section. Assessment of threats to this species will be an important component of ongoing inventory and monitoring studies.

Redders (2001) summarized the threats to *Lesquerella pruinosa*:

> "Residential growth and development on private land on Mancos Shale is destroying essential habitat for this species. Archuleta County is one of the fastest growing counties in the state. Residential growth and development increases demand for recreational opportunities on both private and federal lands, which poses a threat to the habitat of this species mainly from hiking and off-road vehicles (ATVs), motorcycles, and mountain bikes. Plant competition from exotic and native plant species on federal and private land is a threat since these plants directly compete with *L. pruinosa* for space, sunlight, water, and nutrients. As the abundance and distribution of other plant species increases, colonization sites (bare soil) decrease, and a more closed canopy reduces the direct sunlight that *L. pruinosa* prefers. Since this species is often found along roads, that part of its habitat (private and federal lands) could be disturbed by road improvements, weed control, and vehicle traffic. Oil and gas development on private land and federal lands is also a threat to this species and its habitat."

Regarding disturbance, Redders et al. (2001) added:

> "Ground disturbance associated with mining, road and trail construction, pipelines, stock ponds, horse pastures, road maintenance, and ditch work may directly destroy *L. pruinosa* individuals and habitat, and may cause soil compaction and changes to the hydrologic regime which could be detrimental to the species."

The sections below are expanded discussions of threats identified by Redders.

Influence of management activities or natural disturbances on individuals and habitat quality

Residential and commercial development

Residential and commercial land development in the Pagosa Springs area is occurring at a rapid rate (**Figure 14**) and is the greatest threat to *Lesquerella pruinosa*, which occurs on some of the land being developed. The development of Pagosa Springs has been stimulated by its proximity to ski areas, which has resulted in expansion of the airport and construction of second homes (Anderson 1988a, O'Kane 1988). The construction of houses, buildings, barns, parking lots, and pastures destroys both *L. pruinosa* individuals and their habitat (Redders et al. 2001). Occurrences near Pagosa Springs are threatened by high-density residential and commercial development (where land is entirely under private ownership or along the State Highway 84 right-of-way); outlying occurrences are threatened by second home and mountain cabin development (Anderson 1988a, Sovell et al. 2003). Extensive low-density development has been observed at Chromo, Turkey Mountain, and throughout the Pagosa Springs area in the vicinity of occurrences of *L. pruinosa* (Sovell et al. 2003). Low and medium-density development such as that planned for much of the entire global range of *L. pruinosa* (**Figure 15**) fragments areas of natural habitat (Knight et al. 2002).

The construction of roads and trails through its habitat also threatens *Lesquerella pruinosa*. While plants at Taylor Canyon and elsewhere have been observed to colonize road cuts (**Figure 12**), these habitats are not likely to support occurrences of *L. pruinosa* over the long term without conscious effort to manage for them. The proliferation of roads and disturbance from construction are likely to encourage the spread of weeds into habitat for *L. pruinosa*. Right-of-way management practices such as grading and weed spraying are likely to be harmful to *L. pruinosa*.

Commercial development threatens occurrences of *Lesquerella pruinosa* in the vicinity of Pagosa Springs. Several large retailers are interested in constructing "big box" (greater than 100,000 square feet) retail outlets to serve the Pagosa Springs area within occupied and potential habitat for *L. pruinosa*. A location near the intersection of Highways 84 and 160 is under consideration for this type of development, as are other sites in Archuleta County (**Figure 14**).

Figure 14. The intersection of Highway 160 and Highway 84, east of Pagosa Springs. Residential and commercial development is intensifying in this vicinity, where four occurrences of *Lesquerella pruinosa* (EOs #1, 5, 6, and 13) are located. Other threats at this site include weed invasion, right-of-way management, utility maintenance and installation, and off-road vehicle use. Photograph by Al Pfister, provided by Ellen Mayo, used with permission.

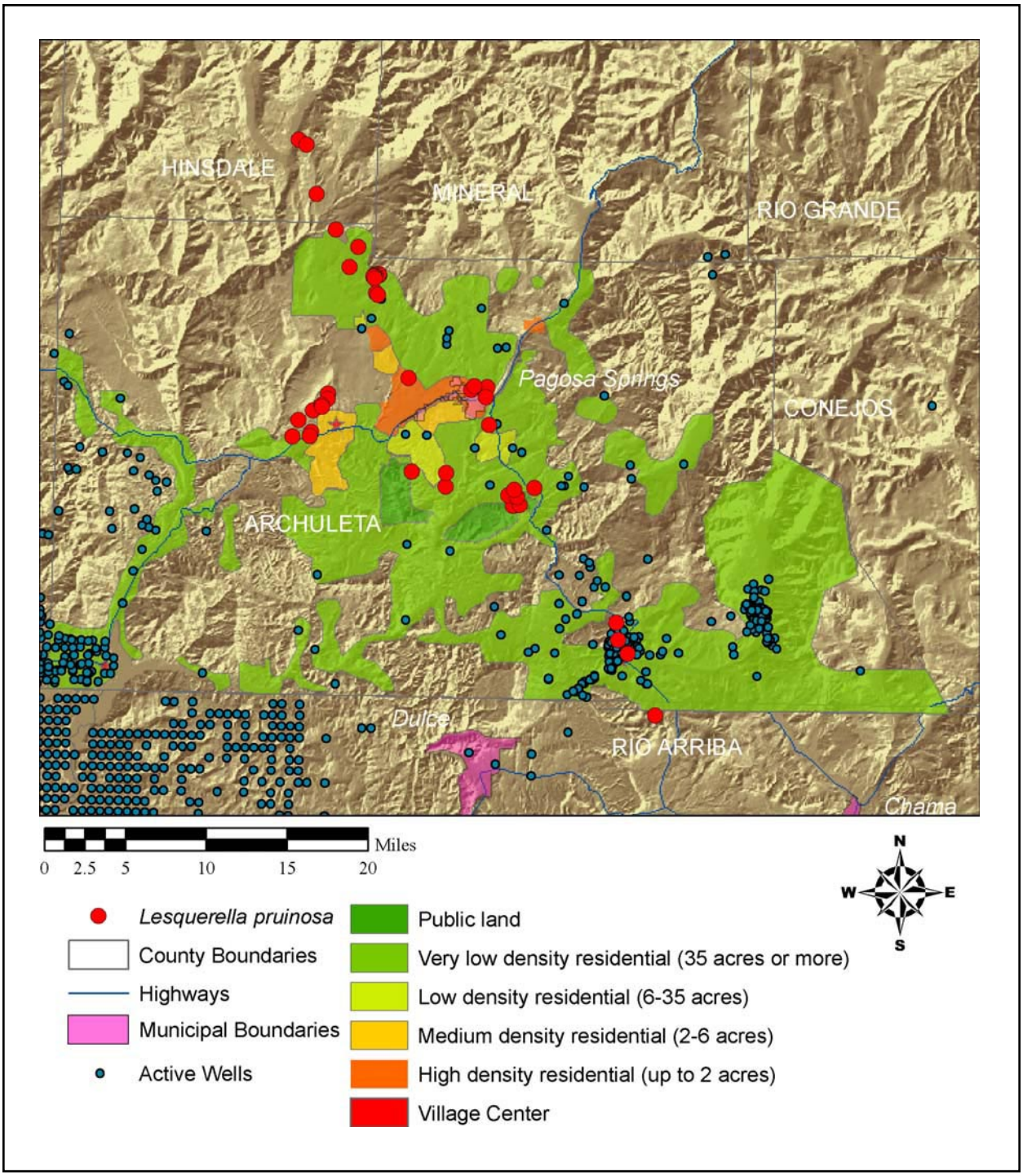

Figure 15. Threats to *Lesquerella pruinosa* resulting from future land use in Archuleta County and energy resource development in the San Juan Basin. Future land use is from Archuleta County 1999 (updated in 2001), provided by the City of Pagosa Springs. Public lands are generalized in this map; see Figure 6 for current land ownership status. Active gas well locations are from NMEMNRD 2004 and Colorado Oil and Gas Conservation Commission 2004.

Off-road vehicle recreation and other recreation

The proximity of *Lesquerella pruinosa* habitats to a large and rapidly growing human population increases the threat from inappropriate recreational use of its habitat. Off-road vehicle use is a common and growing threat to rare plants and to biodiversity in general, and both legal and illegal off-road use of public lands have increased in recent years (Bureau of Land Management 2001). All known occurrences of *L. pruinosa* are threatened to some extent by off-road vehicle use, and the intensity of this use will certainly increase as human populations increase in the vicinity of Pagosa Springs. Barren areas in which this species is found are frequently exploited by users of all-terrain vehicles (ATVs), four-wheel drive trucks, motorcycles, and mountain bikes for off-road vehicle recreation because of their challenging slopes and the lack of interference from vegetation (Lyon and Denslow 2001).

Recreation impacts are intense at East Pagosa (EO #5) and have also been documented at Pagosa Springs (EO #1). At Pordonia Point (EO #17), *Lesquerella pruinosa* appeared resilient to the impacts of vehicles passing through the area on their way to a prescribed burn for a short period. While this suggests that *L. pruinosa* is tolerant of episodic disturbance, the nature of this disturbance is unlike the chronic disturbance regime imposed by frequent off-road vehicle traffic. Consistent ATV, motorcycle, and mountain bikes traffic could adversely impact *L. pruinosa* occurrences due to trampling, uprooting, and soil compaction (Johnston 1997). Direct impacts to plants were reported at East Pagosa (EO #5), where several dead plants were observed in a motorcycle track. Some recreation sites are on private land adjacent to National Forest System land, and *L. pruinosa* occurrences on these federal lands could be affected if trespass use were to occur (Redders et al. 2001). There is potential for non-motorized recreation to affect *L. pruinosa*, but no impacts none have been documented to date.

Energy development

There are currently approximately 300 active natural gas wells within the range of *Lesquerella pruinosa* (**Figure 15**; Colorado Oil and Gas Conservation Commission 2004). The greatest concentration of active wells is on private land near Chromo, where there are approximately 100 wells. Interest in energy exploration and development of this area continues (Jones 2003). Well pad and service road construction disturb and fragment habitat, and may kill plants. The proliferation of roads also encourages the spread of weeds and may lead to habitat degradation and damage to individual plants due to increased off-road vehicle use. There has been some oil and gas exploration at Turkey Mountain on National Forest System land (Johnston 1985, Anderson 1988a), which reportedly had limited impacts to *L. pruinosa* since additional roads were not needed within its habitat (Johnston 1985). An existing access road at Turkey Mountain passes through a colony of 40 plants; changes to this road (e.g., grading, widening) have the potential to impact more individuals (Johnston 1985).

A draft environmental impact statement has been written to address a proposal to install approximately 300 natural gas wells in the northern San Juan Basin, which includes a portion of southwestern Archuleta County (Bureau of Land Management and USDA Forest Service 2004). Because there is no Mancos Shale or known occurrence of *Lesquerella pruinosa* within the proposed project area, it appears that it will not directly impact *L. pruinosa*.

Effects of herbicide and pesticide use

Use of herbicides and pesticides for weed control and range management also threatens *Lesquerella pruinosa* (Redders et al. 2001) as these chemicals are likely to kill *L. pruinosa* individuals or the insect pollinators on which this species depends (Redders et al. 2001). Spraying of roadside weeds could decimate portions of occurrences of *L. pruinosa* along Highway 84 and at many locations including the O'Neal Hill Botanical SIA, Pagosa Springs, Turkey Mountain, and Taylor Canyon (Sovell et al. 2003). The USFS has used herbicides at the O'Neal Hill Botanical SIA to manage Canada thistle and yellow toadflax (Colorado Natural Heritage Program 2004).

Effects of small population size

Stochastic processes (random events) represent a threat to small occurrences of *Lesquerella pruinosa*. Based on information available at the time, Rouse (1992) stated that occurrences of *L. pruinosa* were not small enough to suffer ill effects from inbreeding depression. However, more recent information suggests that most occurrences of *L. pruinosa* are small enough to be of questionable viability (Colorado Natural Heritage Program 2004). Based on the minimum viable population size estimate of 2,000 individuals determined for *L. thamnophila*, all but two or three occurrences of *L. pruinosa* are of questionable long-

term viability. It is not known if the small size of many *L. pruinosa* occurrences is due to natural processes or the result of human impacts.

Grazing

All grazing allotments administered by federal agencies on which *Lesquerella pruinosa* occurs are active (Brinton personal communication 2004). While the magnitude of the threat to this species from grazing is unclear, most authors (most notably Redders et al. 2001) consider the threats arising from livestock grazing to be minor compared to other threats.

Many variables affect the degree to which a particular occurrence is susceptible to impacts from grazing. Cattle probably do not use the steep Mancos Shale slopes where *Lesquerella pruinosa* is most often found. However, occurrences of *L. pruinosa* may once have extended into areas currently being grazed. Because it appears that *L. pruinosa* is grazed minimally, if at all, (Rouse 1992) and is probably not particularly palatable to ungulates (Rouse 1992, Burrows and Tyrl 2001), grazing threatens *L. pruinosa* primarily through soil disturbance caused by hoof action, which may result in increased erosion, trampling, trailing, soil compaction, uprooting, and weed invasion (Anderson 1988a, Rouse 1992, Redders et al. 2001). Disturbance by ungulates (e.g., livestock, deer, and elk) has been noted at Chromo (EO #11), Pagosa Springs (EO #1), and O'Neal Hill (EO #10) (Colorado Natural Heritage Program 2004).

Livestock trailing can result in significant impacts on shale barrens (Neely 1990). Anderson (1988a) noted that "intense livestock concentrations in small pastures around water sources with subsequent heavy trailing have resulted in pulverization of the fine textured soil the plants grow on and destruction of portions of their habitat at Chromo and Gordon Creek [near O'Neal Hill]."

Elk heavily utilize some areas within the range of *Lesquerella pruinosa*. Heavy trampling by elk was reported at Pagosa Springs (EO #1) (Colorado Natural Heritage Program 2004). The Piedra Valley, where most *L. pruinosa* occurrences occur, is a migration route for elk traveling between winter and summer ranges. In low-snowfall winters, elk use the south slopes of O'Neal Hill, and this could result in significant trampling of *L. pruinosa* individuals if elk populations increase over time (Redders et al. 2001). Although this species has evolved under a natural grazing regime imposed by elk, elk populations are currently at historically high levels and may be placing unprecedented grazing pressure on *L. pruinosa*.

Horse grazing on ranchettes is a significant threat to *Lesquerella pruinosa* that is likely to increase as residential development proceeds in Archuleta County (Anderson 1988a, Rouse 1992). Small parcels where horses are kept are typically overgrazed.

Prairie dogs occur in *Lesquerella pruinosa* habitat, particularly on the drier slopes in the Piedra Tract area (Neely 1990). Redders et al. (2001) noted that although there is no indication that prairie dogs graze *L. pruinosa* plants, they may become a threat if the prairie dog colony increases dramatically in size. Redders et al. (2001) considered the risk of this threat to be low, but this was prior to the large increase in the prairie dog population at O'Neal Hill in 2002 and 2003 during which *L. pruinosa* declined in some areas (Lyon personal communication 2004). Because there is no information available on whether there is a causal link between these observations, the threat from prairie dogs remains uncertain.

Fire

Periodic fire has historically been an important natural ecosystem process in the ponderosa pine-dominated forests and savannas of the Pagosa Springs area. It is not known whether fire historically played a significant role in creating or maintaining *Lesquerella pruinosa* habitat and occurrences or how fire affects *L. pruinosa* individuals. Fire is not likely to carry well through most *L. pruinosa* habitat, suggesting that a relatively small portion of the total population has the potential to be affected by fire (Redders et al. 2001). However, fire may be important in metapopulation dynamics if fire opens dense forest to create habitat for *L. pruinosa*.

Global climate change

Global climate change appears in this assessment as a low priority threat since its impacts are somewhat speculative and beyond the ability of local land managers to mitigate. However, it is likely that global climate change will have major impacts on *Lesquerella pruinosa*. It has been widely hypothesized that the climate envelope in which many rare and geographically restricted species reside will no longer coincide with critical habitat variables (such as soil type) under global warming scenarios. This will create highly stressful conditions for these species and will likely lead to extinction in many cases (Schwartz 1992). *Lesquerella*

pruinosa cannot easily move further north or to higher elevations to compensate for warmer temperatures since it is already found at the northern end of the extent of Mancos Shale in the area (**Figure 7**). Thus global warming may create untenable conditions throughout the species' range.

Projections based on current atmospheric CO_2 trends suggest that average temperatures will increase while precipitation will decrease in Colorado (Manabe and Wetherald 1986). Other models predict that a larger proportion of annual precipitation will come during winter as snowfall (e.g., Giorgi et al. 1998), possibly leading to drier conditions during the growing season. This will have significant effects on nutrient cycling, vapor pressure gradients, and a suite of other environmental variables. Temperature increase could cause vegetation zones to climb 350 feet in elevation for every degree F of warming (U.S. Environmental Protection Agency 1997). The potential consequences of this scenario to *Lesquerella pruinosa* are difficult to predict; it is likely that its habitats would remain barren as vegetation zones shifted, but the community composition might be expected to change with unpredictable consequences.

Pollution

Increased nitrogen loading has been observed in plant communities worldwide (Schwartz and Brigham 2003). Nitrogen enrichment experiments show universally that nitrogen is limited (Gross et al. 2000). This is likely to cause a few species to increase in abundance while many others decline (Schwartz and Brigham 2003). Relatively low levels of nitrogen enrichment are advantageous to some species but deleterious to others, making it difficult to predict species- and community-level responses.

Interaction of the species with exotic species

Regarding the threat of invasive species to *Lesquerella pruinosa*, Redders et al. (2001) wrote: "Plant competition from exotic and native plant species is a major threat since these plants directly compete with *L. pruinosa* for space, sunlight, water, and nutrients. As the abundance and distribution of other plant species increases, colonization sites (bare soil) decrease, and a more closed canopy reduces the direct sunlight that *L. pruinosa* prefers. Exotic species of concern known to occur in and around *L. pruinosa* occurrences and habitat include smooth brome (*Bromus inermis*), Russian thistle (*Salsola kali*), yellow sweetclover (*Melilotus officinalis*), yellow toadflax (*Linaria vulgaris*), musk thistle (*Carduus nutans*), and Canada thistle (*Cirsium arvense*)." Other exotic species that have been noted in association with *L. pruinosa* include cheatgrass (*B. tectorum*), redstem storks'-bill (*Erodium cicutarium*), horehound (*Marrubium vulgare*), yellow salsify (*Tragopogon dubius*), Kentucky bluegrass (*Poa pratensis*), and dandelion (*Taraxacum officinalis*) (Sovell et al. 2003, Colorado Natural Heritage Program 2004). Potter et al. (1985b) observed Russian thistle (*S. kali*) in plots on slopes of Mancos Shale at Austin, Colorado (in Delta County), and it has been observed at the O'Neal Hill Botanical SIA (Neely 1990). Exotic species observed in Potential Conservation Areas are included in **Appendix**.

Melilotus is a Eurasian genus that is widely naturalized in North America (Mabberley 1997). Yellow sweetclover has invaded occurrences of *Astragalus ripleyi*, a rare Colorado and New Mexico endemic in the San Luis Valley, where it apparently results in decreased density of *A. ripleyi* (Colorado Natural Heritage Program 2004). It has spread into naturally disturbed areas in the O'Neal Hill Botanical SIA (**Figure 16**; Neely 1990, Lyon personal communication 2004) (**Figure 16**), and is a frequent invader on clay and shale barrens in Colorado. It has also been observed at Turkey Mountain (Sovell et al. 2003). The behavior of yellow sweetclover on the Mancos Shale around Pagosa Springs should be watched.

Cheatgrass is documented with *Lesquerella pruinosa* and in Archuleta County (University of Colorado Herbarium 2003) and represents a potential threat. This species aggressively invades native plant habitat, and its spread has been well documented throughout the Intermountain West (Young and Blank 1995), where it has outcompeted perennial understory species in pinyon-juniper woodlands and thus caused an increase in erosion (West and Young 2000). As a winter annual, cheatgrass may compete with the seedlings of *L. pruinosa* by preemptively utilizing water and nutrients. Efforts to manage cheatgrass often employ early season burning, but this practice may injure *L. pruinosa* as well. The dramatic changes invoked by cheatgrass on the fire ecology of woodland ecosystems are also a cause for concern if it becomes widespread in the woodland and forest habitats of *L. pruinosa*. Invasion of its habitat by cheatgrass is among the principal threats to the federally listed *L. filiformis* (U.S. Fish and Wildlife Service 1988).

Yellow starthistle (*Centaurea solstitialis*) is present on Colorado's western slope (Dillon 1999), although not in the vicinity of the range of *Lesquerella*

Figure 16. Invasion of *Lesquerella pruinosa* habitat by yellow sweetclover (*Melilotus officinalis*; yellow flowers in the bottom of the wash) at O'Neal Hill Botanical Special Interest Area. Photograph by Peggy Lyon, used with permission.

pruinosa. It poses a very real threat to *L. pruinosa* and many other native plant species if efforts to contain it fail. This species has a wide ecological amplitude and the potential to spread widely in Colorado. It currently infests 10 million acres in California (Colorado Weed Management Association 2002).

Other exotic species of concern for *Lesquerella pruinosa* include halogeton (*Halogeton glomeratus*), Russian knapweed (*Acroptilon repens*), and medusa head rye (*Taeniatherum caput-medusae*). While these species have not yet been documented with *L. pruinosa*, they are aggressive species that have invaded large areas of native plant habitat throughout the Intermountain West.

Over-utilization

As one of the first plant families to be recognized, members of the Brassicaceae have a long history of human use (Rollins 1993). Members of this family include some of our most familiar food crops and seasonings (Heywood 1993) and have numerous medicinal applications (Texas A&M Bioinformatics Working Group 2002). However, there are very few New World Brassicaceae for which there is any culinary use (Rollins 1993), and no such uses are reported for *Lesquerella pruinosa* or its close relatives.

Most interest in members of the genus *Lesquerella* has centered on their potential as oil seed crops. Members of this genus have been found to contain hydroxy fatty acids that have similar properties to castor oil (U.S. Department of Agriculture 1991). Hydroxy fatty acids in castor oil are ricinoleic acid and sebacic acid. These are listed as strategic and critical materials by the Department of Defense due to their importance as ingredients in the manufacture of resins, waxes, nylons, plastics, corrosion inhibitors, cosmetics, and coatings. They are also used in grease formulations for high-performance military and industrial equipment. Currently all castor bean derivatives are imported. *Lesquerella* species contain lesquerolic, densipolic, and auricolic acids, which are similar to the ricinoleic and sebacic acids found in castor oil. The concentration of these acids varies among species of *Lesquerella*. Apparently the concentration of these acids has not been measured in *L. pruinosa*, and there has been no investigation of the virtues of *L. pruinosa* for production of hydroxy fatty acids or other potential agronomic applications. However, recognition of the potential value of *L. pruinosa* as a source of alleles

for enhancing crop yields is increasing (United States of America 1996). Grieve et al. (2001) investigated the potential of *L. fendleri* as a phytoremediator of selenium-contaminated soils, for which *L. pruinosa* may also have potential.

Conservation of *Lesquerella* species is important due to their commercial potential, and alleles present in *L. pruinosa* may prove valuable in the development of cultivars. Because of their enormous agronomic potential, there has been considerable effort since the mid-1980's to develop members of the genus as a new crop. Although these efforts have focused on *L. fendleri*, which is native to the southwestern United States, other species of *Lesquerella* are also being investigated (Ploschuk et al. 2001, Ploschuk et al. 2003). Pigments in the oil are difficult to remove, and this adds to processing costs and creates a barrier to its commercialization (Wood and McGraw 1999). Hybridizing *L. fendleri* with other *Lesquerella* species is improving its potential as a crop (Wood and McGraw 1999). However, there is nothing presently to suggest that research on members of *Lesquerella* poses a threat to *L. pruinosa*, even if *L. pruinosa* becomes an eventual target of such research.

Lesquerella pruinosa is included in a database of potential rock garden plants (Slaby 2004), and while collection of wild plants or seed for commercial sale could affect this species, there is little reason to suspect that over-utilization of this species for commercial purposes poses a significant threat at this time. Care should be taken by collectors not to remove plants from occurrences with fewer than 50 individuals (Wagner 1991, Pavlovic et al. 1992).

Conservation Status of Lesquerella pruinosa in Region 2

Is distribution or abundance declining in all or part of its range in Region 2?

At this time, there are insufficient data available to assess the range-wide population trend for *Lesquerella pruinosa*, but there is significant evidence that the quantity and quality of habitat for this species as declined in the past 100 years. Available information suggests that at least part of the occurrence at the O'Neal Hill Botanical SIA declined significantly between 2001 and 2003, but again there are no quantitative data to support this observation.

Do habitats vary in their capacity to support this species?

There appears to be considerable variation in the capacity of habitats to support *Lesquerella pruinosa*. The key habitat variable for this species is clearly geologic substrate, since it has never been found in sites where soils are not derived from Mancos Shale. However, the species occupies only a small part of the total area of Mancos Shale outcrops. Brinton and others with the San Juan National Forest surveyed three apparently suitable sites in 2003 and 2004 for *L. pruinosa* and failed to find it (Brinton 2004). It is possible that there remain some habitat characteristics that have not yet been identified that determine the suitability of habitats for *L. pruinosa*. It is also possible that the surveyed locations have not yet been colonized by *L. pruinosa*.

Vulnerability due to life history and ecology

Lesquerella pruinosa has a narrow tolerance of edaphic conditions that limits it to very specific soil types derived locally from a specific geologic stratum (i.e., Mancos Shale outcrops). Given the proximity of these outcrops to a large growing human populace, the rate of their development, their fragility, and their suitability for off-road vehicle use, the habitat specificity of *L. pruinosa* leaves it extremely vulnerable to extirpation. Exotic plant species place *L. pruinosa* occurrences at risk through competition for space, sunlight, water, and nutrients. Increased cover results in greater competition for limited resources; a more closed canopy reduces the direct sunlight preferred by *L. pruinosa* (Redders 2001). Less bare ground may also impact recruitment. As an obligate outcrosser, *L. pruinosa* is vulnerable to changes in the abundance of insects that pollinate it. Collins (1995) demonstrated that human disturbance regimes and reduction in plant biodiversity reduced pollinator species richness, so the cumulative effects of these impacts may combine to put *L. pruinosa* at further risk. Fragmentation also affects the movement of pollinators. *Lesquerella pruinosa* habitat is susceptible to impacts from anthropogenic disturbance, such as off-road vehicle use, and to disturbance that might enhance erosion, including heavy livestock grazing.

Evidence of populations in Region 2 at risk

Ongoing residential growth and development of private land on Mancos Shale outcrops are destroying essential habitat for this species (Redders 2001).

Archuleta County is one of the fastest growing counties in the United States, with a population increase of 85 percent between 1990 and 2000 (U.S. Census Bureau 2003). Development plans for Archuleta County affect almost the entire global range of *Lesquerella pruinosa*, but these plans include no provisions to ensure the species' long-term viability. Land use plans developed by Archuleta County are documented in the Archuleta County Community Plan (Archuleta County 1999). In this plan, most areas inhabited by *L. pruinosa* are planned for very low density residential (35 acre or more), low density residential (3 to 35 acres), and medium density residential (2 to 5 acres) development (**Figure 15**). A "village center" is planned for the Dyke Area near EO #4. This was evidently not intentional; the participating parties were not aware of the species during the development of the plan, and there was apparently no public input regarding this species (J. Miller personal communication 2003). Two projects conducted by the Colorado Natural Heritage Program (Lyon and Denslow 2002, Sovell et al. 2003) provided data to Archuleta County regarding *L. pruinosa* that could be incorporated into any plan revisions.

Nine (or possibly ten) occurrences of *Lesquerella pruinosa* are on public land where they benefit from sensitive species status and decreased exposure to development. A conservation easement protects a portion of one occurrence (EO #10) on private land. Much of the area around Mill Creek and Pagosa Springs has already been subdivided, making conservation action difficult in this area.

Human impacts have been documented at many sites, and some occurrences have been severely impacted. The East Pagosa occurrence (EO #5) is highly disturbed, with a power line and access road above the site, four-wheel drive and motorcycle trails almost everywhere adjacent to plants, with a precipitous cut bank just below, hanging above store buildings. Occurrences in the vicinity of Pagosa Springs are fragmented by residential development (Anderson 1988a). Residential growth increases demand for recreational opportunities on both private and federal lands, which intensifies the pressure on *Lesquerella pruinosa* from hiking and off-road vehicle use by ATVs, motorcycles, and mountain bikes. Roadside occurrences (EO #s 2, 4, 5, 6, 10, 11, 18, and 20) are susceptible to impacts resulting from road improvements, weed control, and vehicle traffic (Redders 2001).

Management activities that could occur on National Forest System land in the vicinity of *Lesquerella pruinosa* occurrences include timber sales, prescribed burns, off-road vehicle use, and the construction and maintenance of pipelines, ditches, power lines, and roads. (Redders et al. 2001). At Turkey Mountain (EO #2), plants along roads are threatened by road maintenance or modifications (Sovell et al. 2003). Because of its sensitive species status, any projects of this sort will require the completion of a Biological Evaluation to describe the direct, indirect, and cumulative effects of these activities on the species and its habitat (Redders et al. 2001).

Management activities on private, state, and county lands, where portions of 15 (or possibly 16) of the 21 known occurrences of *Lesquerella pruinosa* occur, include livestock grazing, home building, road construction, road maintenance, and weed spraying. The portion of the occurrence on the Lynd Property (EO #10) is protected from direct impacts from residential development under a conservation easement held by The Nature Conservancy (Redders et al. 2001).

Many occurrences of *Lesquerella pruinosa* are found in sites that are maintained by an anthropogenic disturbance regime. While *L. pruinosa* appears to tolerate disturbance, it has not been shown that human disturbance is a reliable medium to ensure the long-term viability of this species. It is likely that with increased urbanization of the sites where *L. pruinosa* is currently found, these areas will no longer be managed as they are now, and *L. pruinosa* might be extirpated by those management practices.

Management of Lesquerella pruinosa in Region 2

Implications and potential conservation elements

There is no documentation of the effects of historic, ongoing, or proposed management activities on the abundance or distribution of *Lesquerella pruinosa*. The autecology of the species is unknown, and cause-effect relationships between *L. pruinosa* density and natural processes (i.e., prairie dog population, drought) or human-mediated changes to the environment (i.e., livestock grazing) are poorly understood. Threats cited in this assessment are based either on observations or on known management plans or trends. Where possible, inferences are made in this assessment based on relatives of *L. pruinosa* and ecological studies on Mancos Shale, to deduce the probable impacts of ongoing and likely future environmental changes on *L. pruinosa*.

Conservation goals of the San Juan National Forest are intended to provide long-term protection for *Lesquerella pruinosa* and its habitat in order to preserve the species and to maintain its viability. They are also intended to prevent its listing as threatened or endangered under the Endangered Species Act, and to provide protective measures that could ultimately lead to its removal from the Region 2 Forest Service Sensitive Species List (Redders et al. 2001). Management actions that are likely to benefit *L. pruinosa* on USFS land are discussed in detail in the Beneficial management actions section of this document.

It is likely that a thoughtful assessment of current management practices on lands occupied by *Lesquerella pruinosa* would identify opportunities for change that would be inexpensive and have minimal impacts on the livelihood and routines of local residents, ranchers, managers, permittees, and recreationists while conferring substantial benefits to *L. pruinosa*. See the Tools and practices section for potential beneficial management actions for *L. pruinosa*.

Tools and practices

Species and habitat inventory

Species inventory remains a high priority for *Lesquerella pruinosa*. Because much energy has been spent searching for this species, discoveries of occurrences continue. Areas with the highest likelihood of new occurrences are those with Mancos Shale-derived substrates in the vicinity of known occurrences. Many of these areas remain to be searched because of the difficulties in obtaining permission to visit private land. When willing landowners are identified, the opportunity should be taken to search for the species on their property. *Lesquerella pruinosa* is generally easy to identify and can be identified in flower, fruit, and vegetative stages. It tends to grow in open habitats, which makes it easy to find. However, the best time for inventory is mid-May to mid-June when the plant is flowering and most conspicuous. When in fruit, the dark gray-green color of the plants blends into the gray soil, making them more difficult to find (Anderson 1988a).

It is possible that occurrences beyond the known range of *Lesquerella pruinosa* await discovery. Outcrops of Mancos Shale extending from Pagosa Springs west to Durango and south into Rio Arriba County, New Mexico (**Figure 7**), particularly along Highway 84 to Chama (Anderson 1988a), are all worthy of inventory.

Aerial photography, topographic maps, soil maps, and geology maps can be used to refine search areas. The use of these resources to refine survey efforts is most effective for species for which there is knowledge of its substrate and habitat specificity such as *Lesquerella pruinosa*, and from which distribution patterns and potential search areas can be deduced.

Searches for *Lesquerella pruinosa* could be aided by the use of deductive and inductive species distribution modeling techniques. Species distribution modeling is an effective means of determining the extent of suitable habitat on National Forest System land. Classification and Regression Tree (CART) modeling (Breiman et al. 1984) is an inductive technique well suited to modeling the potential distribution of *L. pruinosa*, given readily available categorical data on geology, vegetation, and other habitat variables. CART has been used to model the distribution of sensitive plant species in Wyoming (e.g. Fertig and Thurston 2003). Combining this technique with other inductive techniques such as envelope models (DOMAIN, BIOCLIM, MaxEnt) could help to refine a potential distribution map further by adding inference on the likelihood of the presence of *L. pruinosa* (Thuiller et al. 2003, Beauvais et al. 2004). Techniques for predicting species distributions are reviewed extensively by Scott et al. (2002).

Population monitoring

In 1992, Alan Carpenter of The Nature Conservancy established monitoring plots on the Lynd Property adjacent to the O'Neal Hill Botanical SIA. Plants were marked and basic demographic data (i.e., size of individuals, life history stage) were gathered (Colorado Natural Heritage Program 2004). However, these plots were never revisited.

In 1999, the USFS established population trend monitoring plots at the O'Neal Hill Botanical SIA; these were resampled by Peggy Lyon and Sara Brinton in 2001 and 2005 (Lyon 2001, Brinton personal communication 2004, Lyon personal communication 2004, Brinton personal communication 2006). The plots were visited in 2002 through 2004 but not sampled. Density classes (30+ plants, 1 to 30 plants, or none) were used to establish the baseline population in 1999, but this method was not sensitive enough to detect a change of 10 percent over ten years (Lyon 2001). The methodology was revised in 2001, after which a census of all plants was taken in each sample unit (20m x 20 cm belt transect).

Some problems with the monitoring plots at the O'Neal Hill Botanical SIA were reported by Lyon (2001, personal communication 2004). The belt transects often did not pass through any plants because of the scattered, clumped distribution pattern of *Lesquerella pruinosa*. It appears that the sampling design or intensity resulted in sampling errors (Elzinga et al. 1998, p. 64). In a highly clumped distribution such as that of *L. pruinosa*, the choice, size, and method of placement of the sampling unit are very important. Long, narrow quadrats (belt transects) can be an effective method of measuring density for population monitoring, but it is possible that a wider quadrat or more quadrats are needed to avoid sampling errors at the O'Neal Hill Botanical SIA. Considerations for determining appropriate sampling intensity for population monitoring are discussed by Elzinga et al. (1998, chapter 7).

Rouse (1992) discussed monitoring *Lesquerella pruinosa* using a demographic approach in which individual plants are marked and tracked. Data are gathered for each marked plant in each monitoring visit. Ideally, this would include a measure of size, life history stage, fecundity (i.e., the number of fruits or some other measure of reproductive output), and mortality. Recruitment within each quadrat can be quantified by counting seedlings. To reduce the chance of missing seedlings, a quadrat frame subdivided with tight string can help observers to search each quadrat systematically and objectively. Elzinga et al. (1998) offers additional suggestions regarding this method. Seed viability and longevity can be estimated using small buried bags containing known numbers of live seeds that are collected and tested periodically using tetrazolium chloride and germination trials on subsets of each bag. Suitable methods for monitoring pollinators, which are a critical autecological factor for *L. pruinosa*, are discussed in Kearns and Inouye (1993).

Data from demographic studies can provide insight into the rates at which plants change from seeds to seedlings to juveniles to reproductive individuals and would allow transition probabilities to be determined. They would also yield insight into the longevity, fecundity, seed bank dynamics, annual growth rate, and recruitment rate of *Lesquerella pruinosa*, and they would permit the use of modeling in which critical life history stages, minimum viable population size, and probability of long-term persistence could be determined. Demographic monitoring of *L. prostrata* was done using belt transects allowed for the quantification of numbers of individuals in four age classes: seedlings, which included non-reproductive rosettes with two to four leaves; vegetative, which included non-flowering rosettes with five or more basal leaves; reproductive, which included plants in flower or fruit; and dead (Fertig 2000).

Simpler and less labor-intensive approaches to monitoring can provide insight into overall population trends. Individual plants can be counted within permanent or temporary plots, and a tally can be kept of the numbers of plants in each life history stage without marking individuals. Only baseline data are available from this study at present. Adding this component to the existing monitoring at O'Neal Hill Botanical SIA would require little additional effort.

Because of the fragile nature of *Lesquerella pruinosa*'s habitat and its susceptibility to pulverization at many locations, careful consideration must be given to the development of monitoring protocols that minimize impacts. Anderson (1988a) recommended periodic site visits every 2 to 3 years using plotless methods, with annual visits to the sites around Pagosa Springs where development may be occurring. A few sites, such as the O'Neal Hill Botanical SIA, are on relatively flat, well-vegetated terrain that is tolerant of occasional foot traffic.

Site selection is an important consideration in developing a monitoring program. Adding other locations under different management regimes will provide information useful to the management of *Lesquerella pruinosa*. Additional monitoring sites in the vicinity of Pagosa Springs are needed to determine if these occurrences are still viable under current levels of disturbance. Monitoring occurrences near Chromo and Turkey Mountain, with continued monitoring of occurrences at Pagosa Springs and O'Neal Hill Botanical SIA, would provide data from sites representing much of the range of *L. pruinosa* and include a range of land use practices. It will be important to define *a priori* the changes that the sampling regime intends to detect and the management actions that will follow from the results (Schemske et al. 1994, Elzinga et al. 1998).

Elzinga et al. (1998) recommends several methods of monumentation, depending on the site physiography and frequency of human visitation to the site. This is an important consideration that will reap long-term benefits if done properly at the outset of a monitoring program. Wooden stakes were used initially to mark the locations of transects at O'Neal Hill Botanical SIA in 1999, but when the plots were revisited in 2001 most of the stakes were lying on the ground (Lyon personal communication 2004). The transect locations were remarked with rebar in early summer of 2001 at one end, but inaccuracies

in plot placement resulted from using a compass to lay the tape along the transect. In late summer of 2001, the transects were revisited to mark the other end of the transect, allowing field crews to simply stretch the tape between the two rebar markers.

Adding a photo point component to population monitoring following the recommendations offered in Elzinga et al. (1998) could facilitate the tracking of individuals and add valuable qualitative information. A handbook on photo point monitoring (Hall 2002) is available and provides detailed instructions on establishing photo points and photo plots. Photo monitoring sites must be selected carefully, and a sufficient number of sites should be selected if the data are intended to detect population trends.

At present, the priorities lie in gathering data on the distribution and abundance for *Lesquerella pruinosa*. Gathering abundance data can be done rapidly and requires only a small amount of additional time and effort at each occurrence (Elzinga et al. 1998). Simple presence/absence monitoring is not recommended for *L. pruinosa*.

Habitat monitoring

Habitat monitoring should be conducted concurrently with population monitoring. Documenting habitat attributes, disturbance regime, and associated species during all population monitoring efforts will augment our present understanding of its habitat requirements and management needs. If carefully selected environmental variables are quantified during monitoring activities, they may help to explain observations of population change. Habitat monitoring of known occurrences will alert managers to new impacts such as weed infestations and damage from human disturbance or grazing. Making note of signs of degradation from overgrazing may help managers to minimize impacts by implementing changes in the grazing regime. Change in environmental variables might not cause observable demographic repercussions for several years, so resampling the chosen variables may help to identify underlying causes of population trends.

Estimating the cover and/or abundance of associated species could facilitate the investigation of interspecific relationships through ordination or other statistical techniques. In very sparsely vegetated plots this can be difficult, but it can be done accurately using appropriate cover classes or subdivided quadrat frames. Understanding the environmental constraints acting on *Lesquerella pruinosa* would enable beneficial management of this species. Gathering data on edaphic characteristics (e.g., moisture, texture, and soil chemistry, particularly pH, if possible) from the permanent plots described above would permit the canonical analysis of species-environment relationships. These data would facilitate hypothesis generation for further studies of the ecology of this species. Gathering data from unoccupied but hypothetically suitable sites is also very useful in establishing the autecological requirements of a species (Wilken personal communication 2003). This approach has been used productively for other rare species, and it often reveals critical ecological variables that would otherwise have been missed. Comparing soil chemistry between occupied and unoccupied habitat could help to refine the definition of potential habitat if soil chemistry controls the distribution of *L. pruinosa*.

Observer bias can be a significant problem with habitat monitoring (Elzinga et al. 1998) unless field crews are carefully trained in accurate and consistent techniques of estimating plant cover. Habitat monitoring is usually better at identifying new impacts than at tracking changes in existing impacts. For estimating weed infestation sizes, using broad size classes helps to reduce the effects of observer bias. To assess trampling impacts, using photographs of impacts to train field crews will help them to consistently rate the severity of the impact.

Beneficial management actions

The most effective beneficial management actions for *Lesquerella pruinosa* are those that protect occurrences from residential and commercial development. Redders et al. (2001) included land acquisition among the list of beneficial actions for the USFS to consider in managing *L. pruinosa*. Actions of this sort are needed soon, before occurrences are lost and higher property values preclude purchase by public lands agencies.

Conservation easements, fee purchase, and other land trust activities are useful conservation tools for protecting occurrences on private land (Anderson 1988a, Lyon and Denslow 2002, Sovell et al. 2003). Acquisition of conservation easements is cited in the Archuleta County Community Plan as a tool for maintaining the "desired future condition" of the county (Archuleta County 1999). Voter-approved mil levies and other funding sources such as Great Outdoor Colorado (GOCO) are suggested in the plan to achieve purchase of easements and open space. There are opportunities for counties or other entities to purchase the development

rights to parcels that support occurrences of *Lesquerella pruinosa*. Purchasing conservation easements even on small properties may confer significant benefits to the conservation of this species, given its high degree of imperilment (Rouse 1992, Sovell et al. 2003). Only three occurrences are 200 acres or larger (**Table 2**), and most are less than 50 acres (Colorado Natural Heritage Program 2004). Numerous occurrences could be protected, with the addition of a modest buffer at a relatively small cost.

Traditional ranching activities are likely to favor the long-term persistence of this species (Sovell et al. 2003). Recovery actions for the federally listed plant *Lesquerella pallida* include working with landowners to develop and implement management to protect the species (Diamond and Orzell 1992). Acquiring land and developing landowner contacts and beneficial management actions contributed to the downlisting of *L. filiformis* from Endangered to Threatened (US Fish and Wildlife Service 2003).

Redders et al. (2001) describe short- and long-term conservation measures in an extensive review of beneficial management actions for *Lesquerella pruinosa*. These are included here, with information obtained from other sources as cited.

- Implement Standards and Guidelines and General Direction for the O'Neal Hill Botanical SIA (Management Area Prescription 10C), outlined in the San Juan National Forest Land and Resource Management Plan. Through the Forest Plan revision process, review and update this information, if necessary, and develop additional Standards and Guidelines, General Direction, and Mitigation Measures specific to the management of *Lesquerella pruinosa* and its habitat. Amend revised Forest Plan as needed, if proposed changes are supported by research or monitoring information.

- Identify and map potential habitat for *Lesquerella pruinosa*. Inventory land to determine the extent and distribution of the species. Coordinate mapping and inventories with The Nature Conservancy and others to identify populations and habitat on non-federal lands. Inventory potential habitat in New Mexico to determine if current land uses pose a threat to this plant (Tonne 2002).

- Gather site-specific information on *Lesquerella pruinosa* populations to better describe and understand habitat characteristics and the long-term adaptive capacity of the species.

- Develop and implement monitoring plans to establish baseline data, to evaluate *Lesquerella pruinosa* population and habitat trends, to evaluate reproduction and survival requirements, and to evaluate the effects of management activities on the species and its habitat. Add monitoring sites to provide more complete data on the rangewide status of *L. pruinosa*; Chromo and Turkey Mountain, as well as other locations, offer suitable sites for expansion of the monitoring program. Monitor habitat to track weed invasion and impacts to occurrences resulting from weeds and to prioritize weed management efforts (Sovell et al. 2003). Add a component to the existing monitoring protocol in which individuals are marked and tracked to provide valuable data on demographic variables that remain unknown for *L. pruinosa* including lifespan, transition probabilities, and whether it is capable of prolonged dormancy.

- Develop an augmentation plan for populations whose existence appears threatened; this may include increasing the number or size of *Lesquerella pruinosa* populations by seeding or transplanting individuals, or by improving habitat. To maintain or establish population sizes of 2000 individuals or more is among the recovery goals of *L. thamnophila* (U.S. Fish and Wildlife Service 2004b). Guidance for risk assessment of *L. pruinosa* appears in Austin et al. (1999).

- Collect seed from *Lesquerella pruinosa* populations representing the variability of the habitat for cryogenic storage. Maintain stores of the seed of *L. pruinosa* in case restoration should become necessary, similar to recovery recommendations for *L. pallida* (Diamond and Orzell 1992).

- Increase public and USFS awareness and support for *Lesquerella pruinosa* and its habitat. Conduct meetings, workshops, and field trips that showcase the species

and provide education about it. Develop volunteer protection and inventory programs. Create stewardship opportunities similar to The Nature Conservancy's Registry Program, in which private landowners are informed about the rare plants on their land and asked to sign an agreement to protect and monitor the population.

- Coordinate conservation efforts with The Nature Conservancy, the Colorado Natural Heritage Program, USFS, state and county governments, and private landowners.

- Identify funding and personnel necessary to implement the conservation measures and monitoring identified in this conservation strategy.

Conservation measures pertaining specifically to threats as listed by Redders et al. (2001), with details added where possible, include:

- Monitor current and future residential and commercial development in and around known populations and potential habitat, and determine impacts of development.

- Conduct Biological Evaluations for proposed projects that could impact populations or habitat.

- Use travel restrictions, signs, and fencing to reduce recreation impacts on populations and habitat.

- Avoid activities that facilitate the invasion of noxious weeds and other non-native invasive plants.

- Eliminate or control noxious weeds and other non-native invasive plant species.

- Minimize or reduce plant competition and shading from native and non-native species.

- Protect populations from herbicides, road maintenance, and constructions projects. Communicate with appropriate county, state, and USFS road maintenance crews. Educate private landowners on herbicides and their effect on the species. Attach a stipulation to permits for oil and gas exploration at Turkey Mountain to not allow changes to the alignment, surface elevation, and alignment of the access road (Johnston 1985).

- Prohibit pesticides and other insect control methods near populations.

- Monitor effects of livestock grazing, and adjust management if necessary.

- Keep prairie dog populations in check. Monitor when necessary.

- Prohibit fire impacts (e.g., direct burning, suppression activities, post-fire reclamation) in populations or habitat.

- Identify *Lesquerella pruinosa* populations on non-federal lands that need protection, and look for opportunities to acquire those lands or to protect them with conservation easements. Retain federal lands with populations or suitable habitat of *L. pruinosa*, unless non-federal land status will benefit the species.

Long Term Conservation Measures for *Lesquerella pruinosa* listed by Redders et al. (2001) include:

- Avoid population isolation and habitat fragmentation. Identify pathways for pollinator outcrossing and seed dispersal between populations, and try to protect them to ensure that populations are linked and natural gene flow can occur.

- Identify natural disturbances (both historic and current) or environmental factors that maintain, enhance, or restore populations or habitat of *Lesquerella pruinosa*. Reintroduce, if necessary and if possible, the historic disturbances (i.e., grazing, fire, erosion) with appropriate frequency. Develop manipulations methods needed to maintain, enhance, or restore populations and habitat if historic disturbances cannot be reintroduced.

- Identify and implement research questions and projects to increase our understanding of *Lesquerella pruinosa* and its habitat; these are included in the Information Needs section.

Management Prescription 10C describes the management of Botanical SIAs. The provisions of

this management prescription are summarized below. At the O'Neal Hill Botanical SIA, livestock grazing is prohibited in Units A and B, and allowed in Unit C as long as it does not adversely affect the biological resources the Botanical SIA is intended to protect.

- Prohibit range improvement activities; salting grounds, drift fences, and water developments will be located in adjacent areas to draw livestock away from the Botanical SIA.

- Control noxious weeds by mechanical methods only. Allow use of herbicides in adjacent areas if they will not impact the Botanical SIA.

- Prohibit tree cutting and removal.

- Pursue mineral withdrawal of the Botanical SIA. If a withdrawal is not made, supervise activities of claimants to insure minimum impact to *Lesquerella pruinosa.*

- Prohibit surface occupancy for mineral leasing within the Botanical SIA; subsurface activity will be allowed only if it does not adversely affect *Lesquerella pruinosa* populations and habitat. Discourage or prohibit any public use that contributes to impairment of *L. pruinosa* populations and habitat (e.g., camping). Monitor snow machine use and take appropriate action if damage is perceived.

- Permit and encourage use by scientists and educators through consideration of special use applications.

- Prohibit construction of developed recreation sites.

- Prohibit any direct habitat manipulation.

Seed banking

Four samples of *Lesquerella pruinosa* seeds are currently in storage at the National Center for Genetic Resource Preservation (A. Miller personal communication 2003). These samples were collected at Chromo (1018 seeds), Turkey Mountain (EO #2, 100 seeds), and the Ant Hill (EO #10, two samples totaling 1209 seeds). *Lesquerella pruinosa* is not among the National Collection of Endangered Plants maintained by the Center for Plant Conservation (Center for Plant Conservation 2004).

Information Needs

Distribution and abundance

Current knowledge of the distribution of *Lesquerella pruinosa* is sufficient to formulate and implement conservation strategies for this species. However, there remains a need for additional inventories as recent reports of new occurrences suggest that others remain undiscovered. Sites to focus future searches are discussed in the Species and habitat inventory section. Assessing the size of each occurrence of *L. pruinosa*, along with documenting land use and threats, will be important for assessing conservation needs and priorities for this species.

Life cycle, habitat, and population trend

The life cycle of *Lesquerella pruinosa* has not been investigated, and its longevity and the transition probabilities among life history stages are unknown. A rigorous, long-term demographic monitoring program would help to quantify these variables. Developing an elasticity analysis could identify critical life history stages that would help to assess threats to the persistence of *L. pruinosa*.

Although basic descriptive information is available for the habitat of *Lesquerella pruinosa* at most locations, more detailed information is needed. Information on the ecological amplitude of *L. pruinosa* with respect to soil texture, soil moisture, nutrient concentrations, and disturbance would be useful to scientists and land managers, and it is needed to understand species-environment relationships for *L. pruinosa*. Investigating possible spatial autocorrelation with other species may help to determine underlying ecosystem processes. Autecological research is needed to help refine our definition of appropriate habitat and to facilitate effective habitat monitoring and conservation stewardship of this species. Jakubos (1985) observed consistent relationships between slope, topographic position, and geologic substrate with density of *L. pruinosa*, but a more robust investigation of these and other variables is needed. Other questions regarding the habitat of *L. pruinosa* that need to be investigated include the effects of fire on *L. pruinosa* individuals and habitat, and the effects of competition from trees, shrubs, and herbs on *L. pruinosa* occurrences and habitat (Redders et al. 2001).

More information is needed to assess population trend in *Lesquerella pruinosa*. Information on trend is

only available from one location and is not based on quantitative data (see the Population monitoring and Demography sections for details).

Responses to change

The responses of *Lesquerella pruinosa* to habitat change resulting from natural and human-mediated processes are unknown. Understanding the specific responses of *L. pruinosa* to disturbance is important for determining compatible land management practices. This species' resilience to human and natural disturbance has not been studied. The response of *L. pruinosa* to grazing is unknown although some observations suggest that it is avoided by cattle and elk (Rouse 1992). It is unknown if trampling by livestock and wild ungulates (e.g., elk, deer) directly impacts *L. pruinosa*. Similarly, it is unknown if indirect effects of elk or cattle grazing, such as increased soil erosion, soil fertilization or reduction of adjacent vegetation, affect *L. pruinosa* (Rouse 1992). The area inhabited by *L. pruinosa* has been grazed by livestock for decades, suggesting that historic patterns of livestock and wild animal grazing have at least not been highly detrimental. However, it is possible that grazing has modest yet important adverse effects on *L. pruinosa* or that certain grazing management practices are detrimental (Rouse 1992).

The role of disturbance in maintaining good-quality occurrences of *Lesquerella pruinosa* needs to be investigated. *Lesquerella pruinosa* appears to do well under moderate disturbance, but the threshold above which it is negatively impacted by disturbance is not well understood. See the Reproductive biology and ecology section for further discussion of disturbance, and the Community ecology section for a discussion of grazing with respect to *L. pruinosa*.

Some observations suggest that invasion by exotic species has the potential to alter habitats for *Lesquerella pruinosa* in highly detrimental ways. Increased competition for soil resources and light that might follow invasion by exotic species is likely to negatively impact *L. pruinosa*. Monitoring the status of exotic species in the vicinity of known occurrences of *L. pruinosa*, either quantitatively or qualitatively, will help to manage and prevent infestations. See the Interaction of the species with exotic species section for more information on this topic.

Metapopulation dynamics

Research on the population ecology of *Lesquerella pruinosa* has not been done. The importance of metapopulation structure and dynamics to its long-term persistence at local or regional scales is unknown, but some observations suggest that *L. pruinosa* may have a metapopulation structure. Emigration, immigration, and extinction rates are unknown for *L. pruinosa*. Baseline population dynamics and viability must first be assessed. These analyses rely on observable trends in individual occurrences. Observing local extinctions would add to our understanding of the metapopulation structure of *L. pruinosa*. Establishing artificial populations in carefully studied sites is one approach to testing metapopulation theory as it applies to *L. pruinosa*. Even for plants in which metapopulation dynamics can be successfully inferred from regional extinction and colonization data, monitoring of individual occurrences is more likely to provide an accurate assessment of the species (Harrison and Ray 2002).

Demography

At present, only the broadest generalizations can be made regarding the demography of *Lesquerella pruinosa*. Reproductive output, recruitment, and longevity are not known (Rouse 1992, Redders et al. 2001). Although *L. pruinosa* is probably an obligate outcrosser, its pollinators are unknown. Factors necessary for seed germination and seedling survival are also unknown (Redders et al. 2001). Some occurrences appear to be very small, suggesting that they may lack the genetic variability and adaptive capacity needed to ensure their long-term survival. However, there is no information on the genetic status of any occurrences of *L. pruinosa*. Critical life history stages of *L. pruinosa* need to be identified before management can address bottlenecks in its persistence. Much work is needed in the field before local and range-wide persistence can be assessed with demographic modeling techniques.

Short-term demographic studies often provide misleading guidance for conservation purposes, so complementary information, such as historical data and experimental manipulations, should be included whenever possible (Lindborg and Ehrlén 2002). However, the value of demographic data for conservation planning and species management cannot be overstated.

Population trend monitoring methods

Methods are available to begin a monitoring program that would reliably monitor population trend. See the Population monitoring section for details on monitoring protocols and considerations for establishing monitoring sites based on the literature and

existing *Lesquerella pruinosa* monitoring plots at the O'Neal Hill Botanical SIA.

Restoration methods

Some consideration has been given to the restoration of vegetation on Mancos Shale substrates. Potter et al. (1985a, 1985b) noted that restoration of these habitats is more likely to be successful if sandstone is added to the soil to improve aeration, infiltration, drainage, root penetration, and leaching of salts (especially sodium). However, this technique is not likely to improve the suitability of habitat for *Lesquerella pruinosa*, which is adapted to the distinctive edaphic conditions of Mancos Shale-derived soils within its range. Amelioration of Mancos Shale sites will probably result in exclusion of *L. pruinosa* by more competitive species.

Agronomic research on the propagation of *Lesquerella fendleri* is likely to be useful in propagating *L. pruinosa* should the need arise (see the Reproductive biology and autecology and Demography sections). *Lesquerella fendleri* plants grown from seeds that germinated naturally exhibited greater survivorship when transplanted to a desert shrubland site than did plants grown from seeds forced to germinate with gibberellic acid (Cabin et al. 1997).

Research priorities for Region 2

The two highest research priorities for *Lesquerella pruinosa* are inventory and monitoring. Inventories are needed to identify all occurrences of *L. pruinosa* so that conservation efforts can be made on their behalf. Research and monitoring are needed to determine the causes of declining abundance at the O'Neal Hill Botanical SIA, and to understand long-term population trends for the species. Demographic information is needed to support the appropriate management of this species. Monitoring the impacts of various land use practices, especially grazing, is needed. Monitoring is also needed to determine the impacts of weeds and other human and natural processes on *L. pruinosa*.

Inventory and monitoring design will benefit from ecological research on *Lesquerella pruinosa*. A clearer understanding of habitat variables that control the density and distribution of *L. pruinosa* is needed (Redders et al. 2001). Specific biological parameters need to be studied in order to understand the biology and ecology of the species (Rouse 1992). Field studies are needed to document the pollinators of *L. pruinosa*, and possible competitors.

Additional research and data resources

A forthcoming volume of the *Flora of North America* will include a treatment of *Physaria* (into which most members of the genus *Lesquerella* will be included) by Ihsan Al-Shehbaz. It was not available for inclusion in this report. The San Juan National Forest is currently rewriting their Forest Management Plan, which was also not available. Management direction written for *L. pruinosa* that will be incorporated into this plan (Redders et al. 2001), has been incorporated into this assessment.

DEFINITIONS

50/500 rule – A generalized rule stating that isolated populations need a genetically effective population of about 50 individuals for short term persistence, and a genetically effective population of about 500 for long-term survival (Soulé 1980).

Calciphile – A plant that grows best on limestone or in soils with a high percentage of free calcium carbonate (Art 1993).

Cladistics – A classification system that expresses the branching relationships between species through a phylogenetic tree with ancestral forms at the bottom and recently diverged ones at the top (Art 1993).

Competitive/Stress-tolerant/Ruderal (CSR) model – A model developed by J.P. Grime in 1977 in which plants are characterized as Competitive, Stress-tolerant, or Ruderal, based on their allocation of resources; competitive species allocate resources primarily to growth, stress-tolerant species allocate resources primarily to maintenance, and ruderal species allocate resources primarily to reproduction; a suite of other adaptive patterns also characterize species under this model; some species show characteristics of more than one strategy (Barbour et al. 1987).

Conservation Status Rank – The Global (G) Conservation Status (Rank) of a species or ecological community is based on the *range-wide* status of that species or community. The rank is regularly reviewed and updated by experts, and takes into account such factors as number and quality/condition of occurrences, population size, range of distribution, population trends, protection status, and fragility. A subnational (S) rank is determined based on the same criteria applied within a subnation (state or province). The definitions of these ranks, which are not to be interpreted as legal designations, are as follows:

- GX Presumed Extinct - Not located despite intensive searches and virtually no likelihood of rediscovery
- GH Possibly Extinct - Missing; known only from historical occurrences but still some hope of rediscovery
- G1 Critically Imperiled - At high risk of extinction due to extreme rarity (often 5 or fewer occurrences), very steep declines, or other factors.
- G2 Imperiled - At high risk of extinction due to very restricted range, very few populations (often 20 or fewer), steep declines, or other factors.
- G3 Vulnerable - At moderate risk of extinction due to a restricted range, relatively few populations (often 80 or fewer), recent and widespread declines, or other factors.
- G4 Apparently Secure - Uncommon but not rare; some cause for long-term concern due to declines or other factors.
- G5 Secure - Common; widespread and abundant.

Ecotype – The morphological expression of a unique genotype that is adapted to particular habitat attributes (after Allaby 1998).

Monophyletic – Applied to a group of species that share a common ancestry (Allaby 1998).

Paraphyletic Group – A group containing a common ancestor and some, but not all, of its descendents (Judd et al. 2002).

Persistent Seed Bank – Seeds that persist on or in the soil until at least the second germination season following dispersal (Baskin and Baskin 1992).

Polyphyletic Group – A group with two or more ancestors, but not including the true common ancestor of its members (Judd et al. 2002).

Potential Conservation Area – A best estimate of the primary area supporting the long-term survival of targeted species or natural communities; circumscribed for planning purposes only (Colorado Natural Heritage Program Site Committee 2001).

Sympatric – Applied to species whose habitats (ranges) overlap (Allaby 1998).

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APPENDIX

Potential Conservation Areas That Include Lesquerella pruinosa

[1] Biodiversity Significance	[2]Protection & Management Urgency
B1: Outstanding Biodiversity Significance	P2 - Threat/opportunity within 5 years
B2: Very High Biodiversity Significance	P3 - Definable threat/opportunity but not within 5 years
B3: High Biodiversity Significance	P4 - No threat or special opportunity
B4: Moderate Biodiversity Significance	P5 - No action to be taken on this site
B5: General Biodiversity Interest	M2 - Essential within 5 years to prevent loss
	M3 - Needed within 5 years to maintain quality
	M4 - Not needed now; no current threats; may need in future
	M5 - Not needed; no threats anticipated

Occurrence Source ID	PCA Name	County	Size (acres)	Biodiversity Significance[1]	Protection & Management Urgency[2]
EO #10, 16	The Ant Hill	Archuleta/ Hinsdale	5,972	B2	P4 / M2

General description:

The Ant Hill PCA consists of gentle to steep slopes of the Mancos Shale formation. Rare plants are found in somewhat disturbed areas with mixed grasses and forbs. Common associated species include curlyhead goldenweed (*Pyrrocoma crocea*), fringed sage (*Artemisia frigida*), trailing fleabane (*Erigeron flagellaris*), rosy pussytoes (*Antennaria rosea*), hairy golden aster (*Heterotheca villosa*), shrubby cinquefoil (*Pentaphylloides floribunda*), wooly cinquefoil (*Potentilla hippiana*), and baby goldenrod (*Solidago nana*). Upper slopes are dominated by ponderosa pine (*Pinus ponderosa*), Gambel oak (*Quercus gambelii*) and Arizona fescue (*Festuca arizonica*). The PCA includes the O'Neal Hill Botanical Special Interest Area, designated by the USFS for the protection of the Pagosa bladderpod. This area was the site of the largest known population of the plant, and is being monitored for changes in the population size. Although thousands of plants were present in 2001, there were few in 2002 and 2003. Simultaneously, a large increase in the prairie dog colony was noted. It was originally thought that the plants' decline was due to drought. However, other nearby populations of the bladderpod appear to be healthy in 2003. Further investigation and monitoring are critical to determine the causes of the population decline of the Pagosa bladderpod at this site.

The Biodiversity rank is based on an excellent (A rank) and a good (B rank) occurrence of the Pagosa bladderpod (*Lesquerella pruinosa*), a globally imperiled (G2) plant species. Habitat destruction is the biggest threat to *L. pruinosa*, especially considering its limited range. Residential growth and development around the city of Pagosa Springs could threaten nearby populations of the bladderpod. Although the element occurrence rank of the population at O'Neal Hill may have to be revised if the plants fail to recover, the PCA rank would remain the same. The PCA also contains an occurrence of the Pagosa phlox (*Phlox caryophylla*), a plant considered vulnerable (S3) in Colorado, last seen at this location in 1985. There is also an excellent (A rank) occurrence of the Gunnison's prairie dog (*Cynomys gunnisoni*), a species that is globally secure (G5S5). Gunnison's prairie dogs are endemic to the southwestern United States and have a broad distribution within Arizona, Colorado, New Mexico and Utah. Gunnison's prairie dogs are declining throughout their range, although extent of the decline is unknown. Indiscriminate poisoning, habitat conversion, and plague have drastically reduced numbers and range. Plague is probably the greatest threat at this time. Gunnison's prairie dog is a keystone species upon which many other prairie species depend. The Burrowing Owl (*Athene cunicularia*), hawks, and fox and coyote are among those animals that are found in greatest numbers on prairie dog towns.

Occurrence Source ID	PCA Name	County	Size (acres)	Biodiversity Significance[1]	Protection & Management Urgency[2]
EO #4, 9, 12	Stollsteimer Creek North	Archuleta	3,019	B2	P1 / M1

General description:

The PCA comprises disturbed areas along Highway 160 at Dyke, and foothills north of the highway to the National Forest boundary. It is characterized by low hills of Mancos Shale, with sparse to moderately dense vegetation including Rocky Mountain juniper (*Juniperus scopulorum*), skunkbrush (*Rhus trilobata*), rabbitbrush (*Chrysothamnus nauseosus*), chokecherry (*Prunus virginiana*

var. *melanocarpa*), bitter brush (*Purshia tridentata*), Gambel oak (*Quercus gambelii*) and a mixture of native and introduced grasses and forbs, including Indian rice grass (*Oryzopsis hymenoides*), blue grama (*Bouteloua gracilis*) and galleta (*Hilaria jamesii*). Upper slopes have ponderosa pine (*Pinus ponderosa*) and Gambel oak, with Douglas fir (*Pseudotsuga menziesii*) present on cooler sites. The PCA also includes a Gunnison's prairie dog town as well as an irrigated pasture on the south side of the highway.

This PCA includes a good (B rank) occurrence, one of only three known occurrences in the entire world of the critically imperiled (G1) Pagosa gilia (*Ipomopsis polyantha*), both of which are within Archuleta County (see Mill Creek at Pagosa Springs PCA). The B rank is based on the observations made in 2001. However the reduction in the population in 2000 and possible extirpation in 2003 may require that the rank be changed. The site also contains good (B), unranked (E) and poor (D) occurrences of the Pagosa bladderpod (*Lesquerella pruinosa*), a globally imperiled (G2) plant. Habitat destruction is the biggest threat to *L. pruinosa*, especially considering its limited range. Residential growth and development around the city of Pagosa Springs could threaten nearby populations of the bladderpod. There is also a fair (C rank) occurrence of the Gunnison's prairie dog (*Cynomys gunnisoni*), a species that is globally secure (G5S5). Gunnison's prairie dogs are endemic to the southwestern United States and have a broad distribution within Arizona, Colorado, New Mexico and Utah. Gunnison's prairie dogs are declining throughout their range, although extent of the decline is unknown. Indiscriminate poisoning, habitat conversion, and plague have drastically reduced numbers and range. Plague is probably the greatest threat at this time. Gunnison's prairie dog is a keystone species upon which many other prairie species depend. The Burrowing Owl (*Athene cunicularia*, G4), hawks, fox and coyote are among those animals that are found in greatest numbers on prairie dog towns.

Occurrence Source ID	PCA Name	County	Size (acres)	Biodiversity Significance[1]	Protection & Management Urgency[2]
EO #1, 5, 6, 13	Mill Creek at Pagosa Springs	Archuleta	4,734	B1	P1 / M1

General description:
The site encompasses Mancos Shale slopes north and south of Pagosa Springs, on both sides of a major highway, Colorado State Highway 84. The area is primarily residential, with some small businesses and the county fairgrounds located within it. The eastern end of the site is more rural, but rapidly developing. Patches of several rare native plants, including the Pagosa gilia (*Ipomopsis polyantha*), survive in residential areas, pastures, roadsides and vacant lots, but populations are extremely fragmented and vulnerable to extinction. The plants are restricted to soils derived from the Mancos Shale formation that extends in a wide swath from northwest to southeast through the central part of Archuleta County. Natural vegetation of the site is predominantly ponderosa pine forest, with Gambel's oak in the understory. However, much of the natural vegetation has been removed with development of the area.

The site is drawn for two good (B-ranked) occurrences of Pagosa gilia (*Ipomopsis polyantha*), a plant that is critically imperiled (G1/S1) on a global scale. A fair (C-ranked) occurrence of Pagosa bladderpod (*Lesquerella pruinosa*), imperiled (G2/S2) globally, a fair (C-ranked) occurrence of Pagosa phlox (*Phlox caryophylla*), vulnerable (G4/S3) in Colorado, and two unranked (E) occurrences of Townsend's Easter daisy (*Townsendia glabella*), thought to be imperiled globally (G2?/S2?) fall within the site. There is also a good (B-ranked) occurrence of the Gunnison prairie dog (*Cynomys gunnisoni*), a species that is globally secure (G5/S5).

Occurrence Source ID	PCA Name	County	Size (acres)	Biodiversity Significance[1]	Protection & Management Urgency[2]
EO #8, 17, 18	Taylor Canyon at San Juan River	Archuleta	4,392	B2	P1 / M1

General description:
The Taylor Canyon PCA encompasses two tributaries of the San Juan River, Stinking Springs Canyon and Taylor Canyon. The two join the San Juan River just to the south of the PCA boundary. Soils in the PCA are derived from Mancos Shale. Areas mapped as Dakota sandstone have alluvium of Mancos Shale in microsites that support the Pagosa bladderpod. The land is privately owned, within the Southern Ute Reservation, but is accessed by county roads. Vegetation of the site is a mosaic of grasslands, sagebrush (*Artemisia* sp.) and ponderosa pine (*Pinus ponderosa*) forest. San Juan National Forest personnel observed the westernmost occurrence of Pagosa bladderpod in Taylor Canyon in 1996. Approximately 100 individuals were seen in an open area of about five acres. None of the plants were flowering. Associated species included Gambel oak (*Quercus gambelii*), Oregon grape (*Mahonia repens*), ponderosa pine, Indian rice grass (*Oryzopsis hymenoides*) and Rocky Mountain juniper (*Juniperus scopulorum*).

The Taylor Canyon PCA supports a good (B rank) and two fair (C rank) occurrence of Pagosa bladderpod (*Lesquerella pruinosa*), a species that is imperiled (G2) on a global scale. Habitat destruction is the biggest threat to *L. pruinosa*, especially considering

its limited range. Residential growth and development around the city of Pagosa Springs could threaten nearby populations of the bladderpod. There are also four occurrences of Pagosa phlox within the PCA, a species that is secure (G4) globally, but vulnerable (S3) in Colorado. The PCA also contains a good (B rank) occurrence of the Gunnison's prairie dog (*Cynomys gunnisoni*). Indiscriminate poisoning, habitat conversion, and plague have drastically reduced numbers and range. Plague is probably the greatest threat at this time. Gunnison's prairie dog is a keystone species upon which many other prairie species depend. The Burrowing Owl (*Athene cunicularia*, G4), hawks, and fox and coyote are among those animals that are found in greatest numbers on prairie dog towns.

Occurrence Source ID	PCA Name	County	Size (acres)	Biodiversity Significance[1]	Protection & Management Urgency[2]
EO #2	Turkey Mountain	Archuleta	1,979	B2	P3/ M3

General description:
This site includes the gentle slopes of Turkey Mountain, on soils derived from the Mancos Shale formation. Dominant vegetation includes ponderosa pine (*Pinus ponderosa*), Gambel oak (*Quercus gambelii*) and flat meadow openings. Other common species include Oregon grape (*Mahonia repens*), serviceberry (*Amelanchier alnifolia*), orange sneezeweed (*Dugaldia hoopsii*), western wheatgrass (*Pascopyrum smithii*), redroot buckwheat (*Eriogonum racemosum*), yarrow (*Achillea lanulosa*), Louisiana sagewort (*Artemisia ludoviciana*), and yucca (Yucca harrimaniae). Four rare plant species were observed along Eight Mile Mesa Road, which runs through the site, in 2001 and 2002. Pagosa bladderpod (*Lesquerella pruinosa*) and Missouri milkvetch (*Astragalus missouriensis* var. *humistratus*) were growing together in disturbed areas just off an unmapped spur road, while Pagosa phlox (*Phlox caryophylla*) was found on the sparsely vegetated roadside. Townsend's Easter daisy (*Townsendia glabella*) was found on a west-facing hillside, in barren shale areas within the ponderosa pine forest, with hairy golden aster (*Heterotheca villosa*).

This site supports an excellent (A-ranked) occurrence of Townsend's Easter daisy (*Townsendia glabella*), a plant that is globally imperiled (G2/S2); and a good (B-ranked) occurrence of Pagosa bladderpod (*Lesquerella pruinosa*), a globally imperiled (G2/S2) plant. It also contains a good (B-ranked) occurrence of a globally imperiled variety (G5T1/S1) of Missouri milkvetch (*Astragalus missouriensis* var. *humistratus*), and a good (B-ranked) occurrence of Pagosa phlox (*Phlox caryophylla*), which is vulnerable in Colorado (G4/S3). Townsend's Easter daisy is endemic to Montezuma, La Plata and Archuleta counties, Colorado. Most occurrences have no information as to abundance; this occurrence is the largest one known.

Occurrence Source ID	PCA Name	County	Size (acres)	Biodiversity Significance[1]	Protection & Management Urgency[2]
EO #11, 19	Chromo	Archuleta	641	B2	P3/ M4

General description:
This site is located at the junction of the Navajo River and Little Navajo River, at Chromo. It encompasses the alluvial bottomland associated with both rivers, and is edged by foothills and low hills of Mancos Shale. The hilly areas have scattered ponderosa pine (*Pinus ponderosa*) and Gambel's oak (*Quercus gambelii*), interspersed with large areas of grass and shrubland. Pagosa bladderpod (*Lesquerella pruinosa*) was found in the southern part of the site in 2002, growing in barren areas along the sides of a dry gully in Mancos Shale that leads down to irrigated pastures along the Navajo River. Other species found in the area included western wheatgrass (*Pascopyrum smithii*), blue grama (*Bouteloua gracilis*), muttongrass (*Poa fendleriana*), fringed sage (*Artemisia frigida*), low rabbitbrush (*Chrysothamnus viscidiflorus*), and broom snakeweed (*Gutierrezia sarothrae*). The northern population of Pagosa bladderpod, documented in 1989 was noted to be heavily grazed. Logging has occurred historically at this location.

The site contains two good (B-ranked) occurrences of Pagosa bladderpod (*Lesquerella pruinosa*), a species that is imperiled (G2/S2) on a global scale. The Pagosa bladderpod is restricted to soils derived from Mancos Shale. Similar soil conditions exist just south of these sites in New Mexico, and an inventory of these areas is needed. Habitat destruction is the biggest threat to *L. pruinosa*, especially considering its limited range. Residential growth and development around the city of Pagosa Springs could threaten nearby populations. Where cattle trails cross the shale barrens, severe erosion may occur. Horse pastures, associated with second homes and typically severely overgrazed, could present a new threat to the species.