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Beginnings of Range Management: An Anthology of the Sampson-Ellison Photo Plots (1913 to 2003) and a Short History of the Great Basin Experiment Station

David A. Prevedel
E. Durant McArthur
Curtis M. Johnson

Abstract

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High-elevation watersheds on the Wasatch Plateau in central Utah were severely overgrazed in the late 1800s, resulting in catastrophic flooding and mudflows through adjacent communities. Affected citizens petitioned the Federal government to establish a Forest Reserve (1902), and the Manti National Forest was established by the Transfer Act of 1905. The Great Basin Station, a forerunner of the Intermountain Forest and Range Experiment Station, was created in 1911 within this area to study the influence of rangeland vegetation on erosion and floods.

This publication contains a collection of 12 recurring sets of photographs that started in 1913 on these depleted high-elevation rangelands. The sites were rephotographed in the 1940s, 1972, 1990, and 2003. It is also a tribute to two men who pioneered the science of range management—Arthur W. Sampson and Lincoln Ellison. As Directors of the Experiment Station, they initiated and maintained the early photo sites and study plots. It was with these photograph records and study plots that many of the interpretations and guidelines for the management of high-elevation watersheds were developed.

After 90 years, plant community changes on these high-elevation watersheds has led to a vegetation composition significantly different than the original condition. New plant communities have reached thresholds where yearly vegetative composition appears to be climate driven. Many of the higher elevation areas remain in unsatisfactory watershed health with active erosion.

Keywords: rangeland photos, repeat photography, secondary succession, watershed health, high elevation watersheds, tall forb, Great Basin Experiment Station, Arthur Sampson, Lincoln Ellison

Cover Photo: Sheep grazing on Wagon Road Ridge, 2004
(photo by Curt Johnson)

The Authors

David A. Prevedel is Geographic Information Systems (GIS) and Remote Sensing Program Coordinator for the Intermountain Region of the USDA Forest Service in Ogden, UT. He holds a B.S. degree in range science from Utah State University. He was Range Conservationist on the Ferron Ranger District, Manti-LaSal National Forest, 1971 to 1976.

E. Durant McArthur is Project Leader and Research Geneticist, Shrub Sciences Laboratory, and Scientist-in-Charge, Great Basin Experimental Range, USDA Forest Service, Rocky Mountain Research Station, Provo, UT. He holds an A.S. degree from Dixie College and B.S., M.S., and Ph.D. degrees from the University of Utah.

Curtis M. Johnson is Regional Rangeland Ecosystem Specialist for the Intermountain Region of the USDA Forest Service in Ogden, UT. He holds a B.S. degree in forest management from Humboldt State University and an M.S. degree in watershed management from the University of Arizona.

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Overview

This publication contains a collection of a recurring set of photographs with interpretations that started in the early 1900s on depleted high-elevation rangeland, but more so it is a tribute to two men who pioneered the science of range management: Arthur W. Sampson and Lincoln Ellison. It was they who initiated the photos, and it was with these photographs and associated study plots that many of the interpretations and guidelines for the management of high-elevation watersheds were developed. These were to have worldwide application. This document also contains a history of the Great Basin Experiment Station (Intermountain Forest and Range Experiment Station) (appendix D).

Arthur Sampson was born in Oakland, NE, in 1884. He developed an early interest in the outdoors and pursued it in his study of botany and plant ecology at the University of Nebraska where he received a B.S. degree in 1906 and an M.A. degree in 1907. He then accepted a position as Plant Ecologist with the USDA Forest Service. In the next few years, his application of the research method to forest land management problems resulted in clear and convincing evidence of the undesirable effects of improper grazing and led to many land management recommendations that are used today. He was the first Director (1912 to 1922) of the Great Basin Experiment Station in Utah. In addition, during this time he did graduate work, first at Johns Hopkins University and later at George Washington University where he received a Ph.D. degree in 1917.

He began teaching at the University of California in 1922. In 1923 he was promoted to Associate Professor, in 1936 to Professor, and upon retirement in 1951 he was granted emeritus status. He wrote four textbooks on range management as well as many research publications that have had far-reaching influence. Of perhaps greater importance was the painstaking care that he took in his teaching. It challenged and inspired everyone who was exposed to his courses. No one has exerted a more profound influence on the field of range management. The focus of Professor Sampson's research was on the ecology of Western ranges. He died in 1967 (Parker and others 1967; University of California 1968).

Lincoln Ellison was Forest Ecologist and Lead Researcher at the Great Basin Experiment Station from 1938 to 1945. He was part of a succession of pioneering scientists working on Western ecology at the Station, which was also an essential training ground for several generations of ecologists. He was born in 1908 in Portland, OR, and attended the University of California at Los Angeles from 1926 to 1931 (B.A. degree 1931). He then attended the University of Minnesota (M.S. degree 1938 and Ph.D. degree 1948). His undergraduate major was botany. Graduate studies were also botany, with minors in geology and biometry. Ellison transferred to the Forest Service in Ogden, UT, in 1945 and was in charge of grazing research, and in 1953 he was appointed Division Chief of Range Research (Norman 2004).

Ellison has been cited as one of the most influential individuals in the creation of a high level of awareness about erosion tragedies on National Forest Lands (Moir 1989).

Ellison accomplished essential research studies on the relationship between soil and vegetation, and he felt that reverence for the ecological balance was an economic, aesthetic, and ethical obligation. He served as President of the Utah Academy of Sciences, Arts and Letters in 1955. During his career, Lincoln Ellison published many research documents on the ecology and management of high mountain watersheds. He is still cited in sources as diverse as Soviet Soil Science and in studies on the ecology of the steppes of Inner Mongolia. After observing and working on the depleted rangelands of central Utah, he wrote:

> Survival rests not only on sound management: sound management itself rests on moral values. If we ignore or despise our environment, it will destroy us. If we reverently strive to understand our environment and our place in it, if we develop an attitude of respect and love for it, we have laid the groundwork for survival (Norman 2002).

Lincoln Ellison died in a snow avalanche in 1958 at the Snow Basin ski area.

The Great Basin Experiment Station has served as a training ground and working site for numerous scientists in addition to Arthur Sampson and Lincoln Ellison. For additional information on these people and their accomplishments, see Antrei (1982), Keck (1972), McArthur (1992), and appendix D.

The **Great Basin Experimental Range** provided a variety of conditions for observation and study. In its early days, a twisting, rutted 12-mile dirt road ran from Ephraim, UT, past the Experiment Station Headquarters, and to the skyline of the Wasatch Plateau. On this route, elevation rose 5,600 ft through nine life zones and associated biotic communities. These zones and communities were so close together and easily accessible that they provided great diversity in plant species, soils, and climate, and thus gave the opportunity for convenient, efficient study of a wide variety of ecologically oriented problems of wild land management. Visitors from all over the world came to the Station to study its work for application to their circumstances.

Work on the Experimental Range was possible because of a small community of Forest Service houses where the researchers and their families, as well as visitors, could live near the experimental plots and enclosures they studied. The Headquarters site is still owned by the Forest Service, but is operated by Snow College in Ephraim as an Environmental Education Center (Norman 2003). Appendix D is a more detailed history of the Great Basin Experiment Station.

The Rocky Mountain Research Station holds the data from the Great Basin Experiment Station. This data ranges from precise quadrat to broad rangeland inventories. This large historical record contains an extensive photo file, and tabular data at many scales. Climatic data exists back to 1926.

Dr. Richard A. Gill at Washington State University, Pullman, is working on the recovery and analysis of the Great Basin Experimental Range datasets. He is archiving nearly 50 years of historical plant community and soils data from the Wasatch Plateau (Gill 2003). He and his graduate students are continuing research work on the effect of grazing on soil organic matter formation and belowground respiration.

Introduction: The Beginnings of Range Management

Lying on the north to south uplifted backbone of central Utah is a high montane area known as the Wasatch Plateau. To the west are the Sanpete Valley and the Mormon settlements of Mayfield, Manti, Ephraim, Spring City, and Mt. Pleasant. On the east, in its rain shadow, are Castle Valley and the San Rafael Swell with the communities of Emery, Ferron, Castle Dale, Orangeville, and Huntington. As each canyon from the Plateau flows east or west, it opens to farms and towns, each nourished by the streams that originate as snow in the highlands. It was here in the late 1880s that ignorance of man's environment contributed to overgrazing and erosion, which resulted in floods and mudslides that ravaged some of these communities (Geary 1992).

Following the establishment of the Manti National Forest in 1905, the Great Basin Station, a forerunner of the Intermountain Forest and Range Experiment Station, was created in 1911. Here the first studies of the influence of range vegetation on erosion and floods were made. These studies first clearly demonstrated that herbaceous vegetation, and not forest cover alone, had a profound effect on the infiltration and yield of water from torrential storms. The studies showed that the abundance and character of apparently insignificant grasses and forbs high on the watershed could mean the difference between the normal streamflow of clear, usable water, and abnormal, disastrous mud-rock floods. This led to a great deal of additional research in the fields of hydrology, climatology, ecology, agronomy, and forestry, oriented primarily toward rehabilitating depleted vegetation and stabilizing eroding soil (Ellison 1954).

One of the few long-term studies outside of the central grassland regions was initiated by Arthur Sampson of the Experiment Station in 1913. This census continued when Lincoln Ellison became Director of the Experiment Station in 1938. The permanent plots cover a span of 45 years, and the plots were maintained in areas where climate was continually monitored (Gill 2003). Names such as Arthur Sampson and Lincoln Ellison, who were in charge of the Station, were to later become synonymous with the new science of range management.

In his landmark monograph "Subalpine Vegetation of the Wasatch Plateau," Lincoln Ellison (1954) described the scientists involved and how, through the Intermountain Forest and Range Experiment Station, they first clearly demonstrated that herbaceous vegetation, and not forest cover alone, had a profound effect on the infiltration and yield of water from torrential storms. Early on, researchers found that effective soil protection against accelerated erosion was more important in the subalpine zone than forage production, and this protection was probably more closely correlated with cover, both of vegetation and litter, than it was with total weight of associated vegetation. Ellison further stated that the watershed conditions were attributable in large part to our ignorance of soil-plant cover relations, our unconscious assumption that the present vegetation is normal, and the confusion in the literature and in the minds of land managers between primary succession involving soil development on the one hand and secondary succession and accelerated soil erosion on the other (Ellison 1954).

For clarification, ecologists of today interpret secondary succession as not defining degradation or a loss of soil condition, but as a mechanism for gradual improvement.

Origin of Photographs

Part of the early range studies on watershed protection were a series of photographs and plots monitoring changes in vegetation and soil conditions, starting in 1913. Figures 1 and 2 are location maps.

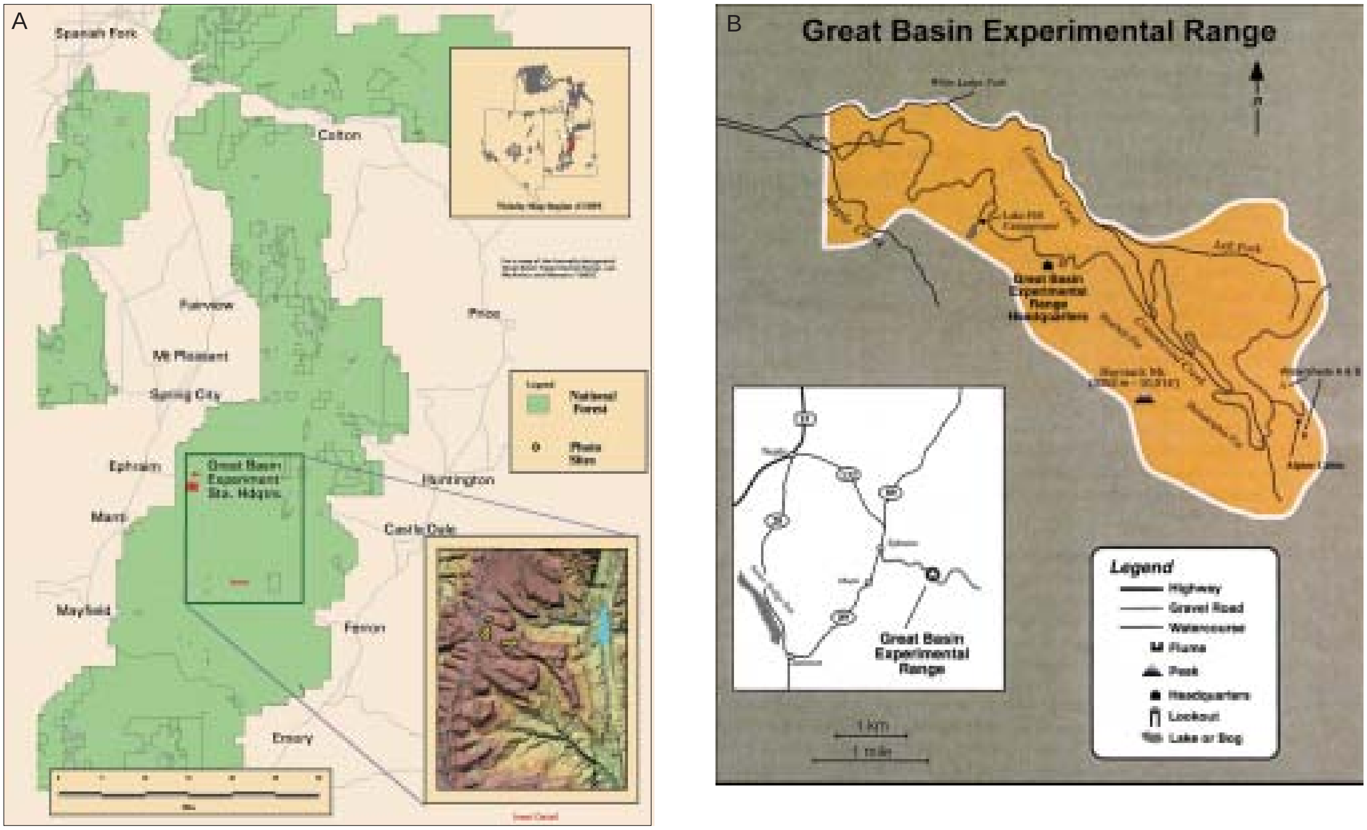

Figure 1—(A) The photograhic points lie within the historic Great Basin Experiment Station's informal boundary (box). (B) the formally designated Great Basin Experimental Range is smaller (McArthur and Monsen 1996).

Twelve repetitive photograph sites are colocated on what were some of the 52 permanent square-meter quadrats used for studying changes in cover and plant community composition for the Great Basin Experiment Station. Thirty-five of the plots were established mostly by A. W. Sampson and his associates between 1913 and 1916. Seventeen were established in 1925 or later. These photographs have been helpful in corroborating evidence of change from permanent plots and quadrats and in preserving a record of the character of denuded soil surfaces (Ellison 1954). Lincoln Ellison rephotographed the same areas from 1938 to 1947.

In 1972, as part of the area administration for the Manti-LaSal National Forest, reprints of what could be found of the early photographs from selected quadrat sites were acquired from the Forest Service Archives in Washington, DC. They were then field located and rephotographed by Dave Prevedel during that summer.

Subsequently, in 1990 and 2003, the sites were again rephotographed by Dave Prevedel and Curt Johnson. Because the latter photographs were for administrative use and not research, no ground sampling or measurements were made. Only the notes referenced with each photo were recorded. Current existing vegetation species on protected areas and the photo plots are listed in appendix B for comparison. We have been careful to rephotograph the sites on approximately the same dates as the earlier photographs. Tall forb types, in addition to phenological and seasonal climatic responses, experience significant change after the first frosts when a good deal of the plant material is reduced to ground litter. When reviewing the literature over 90 years of research and publication, and in personal communications, we found that in addition to taxonomical changes, ecological terminology had changed. Terms such as invader, introduced, bunchgrass, climax, and so forth, have been modified in their application and meaning. We have attempted to clarify these facts and statements where indicated.

The paper emulsion photographs from 1913 through 1990 were scanned with a Microtec Scan Maker 98XL scanner at 600 dpi in TIF and JPG formats. They were then enhanced in contrast with Adobe Photoshop. The 2003 photographs were taken with a 4 Mega Pixel digital camera at 300 dpi in JPG format. Global Positioning System (GPS) location readings of the photo sites were also taken at that time.

Photo documentation over the 1913 to 2003 period was accomplished by the following range scientists:

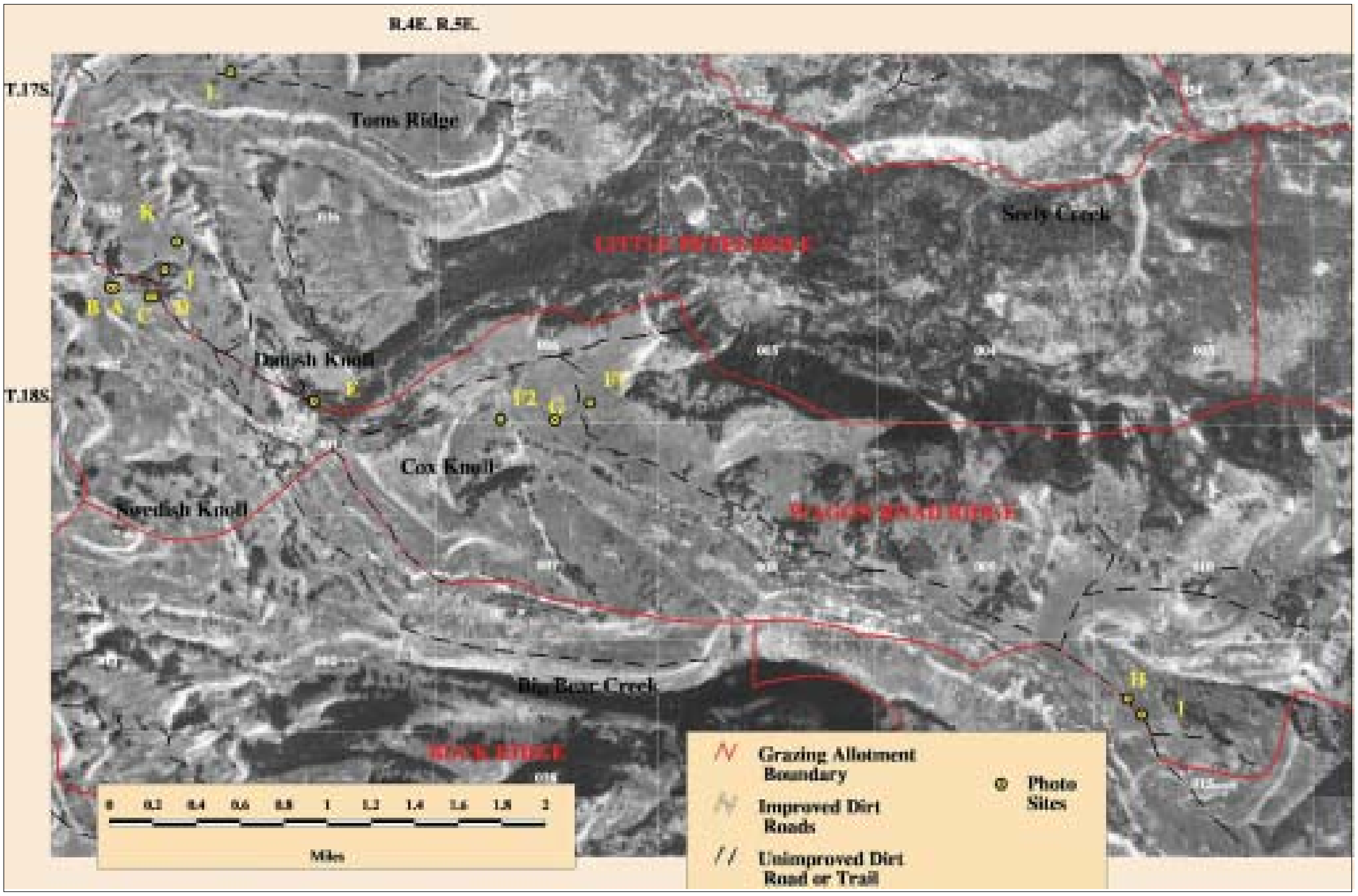

Figure 2—Photographic points: detail of location on the Wasatch Plateau.

Photograph date	Photographer
1913 to 1922	Arthur W. Sampson and Associates
1932	Associates of the Great Basin Experiment Station, C. L. Forsling, Director
1938 to 1947	Lincoln Ellison
1972, 1990, 2003	David A. Prevedel
1990, 2003	Curtis M. Johnson

The Wasatch Plateau: Physical Characteristics

Excellent characterizations of the Wasatch Plateau are included in Ellison's 1954 monograph. To maintain clarity and continuity, scientific plant names used by Ellison are maintained in their old nomenclature system. Cross reference to current nomenclature for these plants is included in appendix A (USDA Plants Database 2004). Following are brief excerpts from his monograph, with supplemental information noted by annotations, to help set the character of the landscape.

Terrain and Geology

The photograph sites all are located above 10,000 ft elevation on the top of an area known as the Wasatch Plateau. The greater part of this top is level or rolling. Most of it is easily accessible to domestic livestock and has been heavily grazed. Lying on conspicuous white Flagstaff limestone, the parent material is of Eocene origin that forms a cap several hundred feet thick. Its origin was a large fresh water lake in what is now central Utah. During the Pleistocene period, the area was entirely covered with glaciers, and there are many cirques forming the head basins. In some years, certain snowbanks persist all summer long (refer to figure 3 for a topographic cross section).

Soils

Soil parent material is limestone and shale. Accordingly, the soils are mostly clays and clay loams that are light brown in color. Today, horizons are poorly developed and difficult to define due to the amount of soil lost to erosion. White limestone fragments predominate in much of the area. Organic matter content appears to be low due to the amount of accelerated erosion that has taken place. Soil moisture-

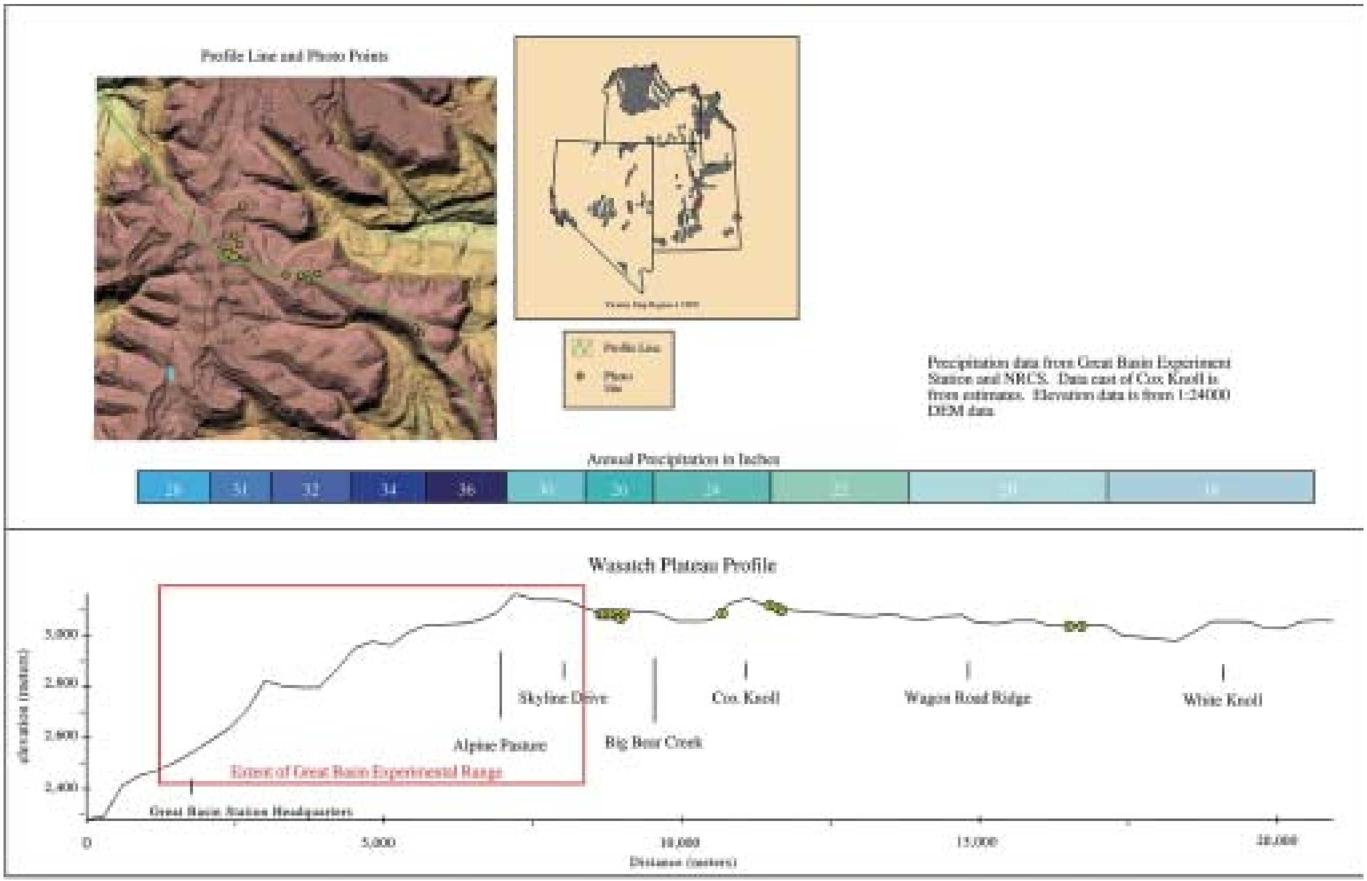

Figure 3—Terrain profile and precipitation, Wasatch Plateau, Utah.

holding capacity is also low because of the loss to erosion. As early as 1916, Sampson reported that evaporation in the subalpine zone of the Wasatch Plateau was about the same as in the much warmer oak brush zone approximately 2,500 ft lower. The retarding effect of lower temperatures at these higher elevations is evidently offset by a much greater wind movement in the subalpine zone. This is undoubtedly compounded by the lack of a persistent vegetative ground cover. The authors' observations of pristine tall forbs sites indicate that poorly defined and developed "A" horizons may be a characteristic of this type.

The photo sites are clustered on four land types that vary in precipitation, soils, and topology (fig. 4):

1. Upper Big Bear Creek Basin Land Type (Photo Sites A, B, C, and D)—This area is characterized as being on the side slopes of a large cirque basin with slopes varying from 10 to 40 degrees. Soils are deep with A and B horizons almost totally absent due to historical erosion. Some accelerated erosion and head cutting is still occurring today. Precipitation varies from 26 to 30 inches annually. Large rock fragments are exposed when erosion removes soil down to near bedrock. Lying close to the top of the Plateau, it contains little conifer vegetation, and the open aspect probably was favorable to historically supporting one of the tall forb associations.

2. Cox's Knoll Highlands Land Type (Photo Sites E, F, and G)—This area is in the estimated 22- to 24-inch annual precipitation zone. It lies approximately 2 miles east of Skyline Drive. Soils are shallow with poorly defined horizons and have numerous rock fragments. Sheet erosion is occurring on some limited areas. Terrain at the location of the photos is basically flat. Cox's Knoll is a prominent "knob" left by glaciation and has a long history of sheep concentration and bedding. A snowbank area exists on the east side, which is the site of one of the photos. Historically, vegetation on this area was mixed. Conifer on the northern aspects is subalpine fir with aspen on the more favorable aspects. Cox's Knoll was probably a grass-forb site with Kings fescue (*Leucopoa kingii*) dominant along with alpine blue grasses. Snowbank areas most likely supported tall forbs dominated by tall larkspur.

3. Wagon Road Ridge Land Type (Photo Sites H and I)—Wagon Road Ridge is a long predominant plateau extending east of the main crest of the skyline. The photo sites are about 5 miles from this top. Slopes are flat and the precipitation much lower (estimated 20 inches or less annually). Soils are very shallow with numerous rock fragments. Perennial winds constantly dry out the soil. Historically, vegetation on this site was a grass-shrub mixture dense enough to support ground fires as evidenced by the numerous fires scars on trees in the area. Aspen and *Ribes* (red currant) may have also been prominent.

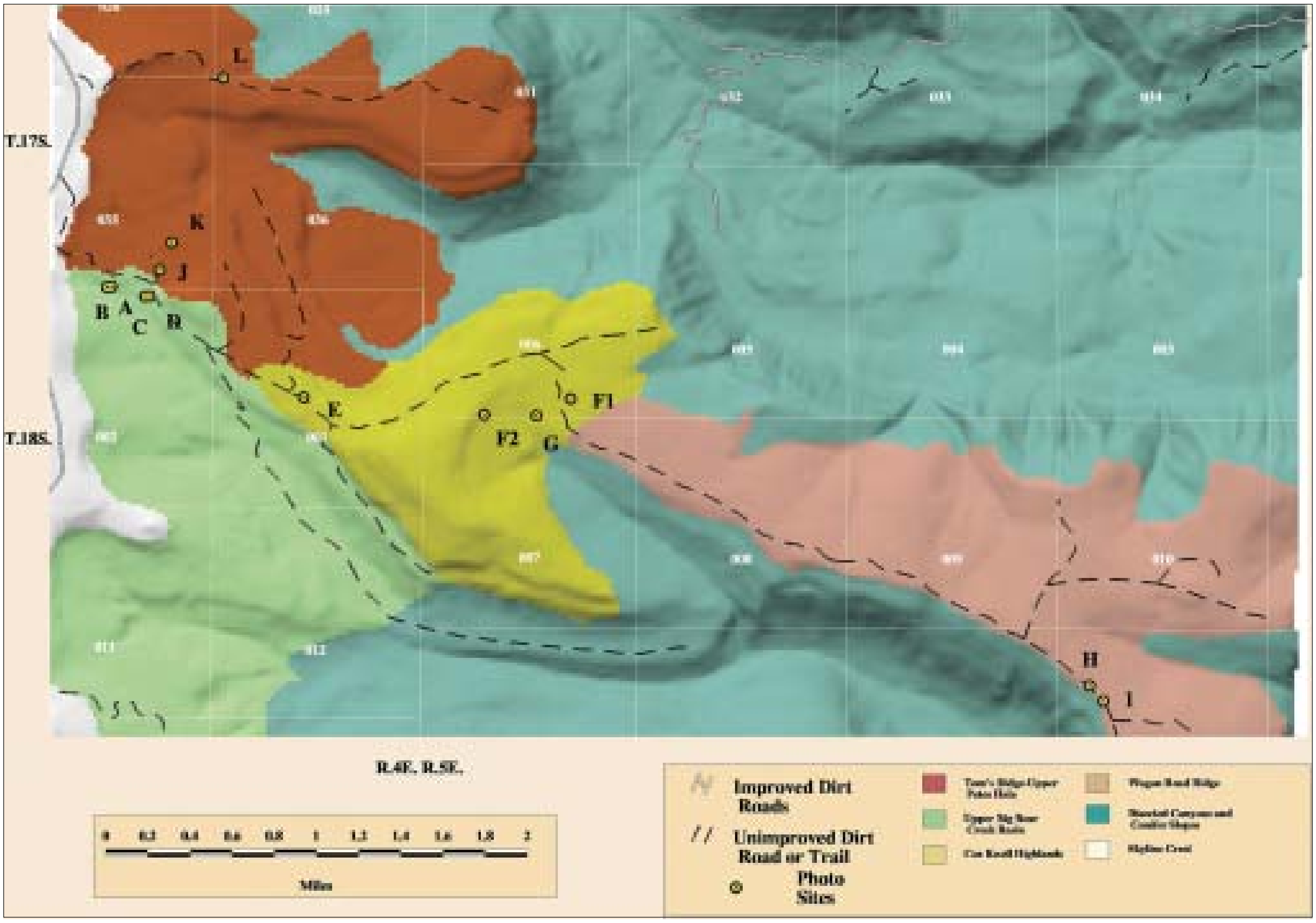

Figure 4—Land types associated with photo sites, detail of location.

Limber pine is reestablishing on the area probably as a result of the lack of wildfire.

4. Tom's Ridge: Upper Pete's Hole Land Type (Photo Sites J, K, and L)—This area lies immediately east of Skyline Drive and, like the Big Bear Creek Land Type, consists of cirque basins from past glaciation. However, the photo sites lie on flat terraces that may have been intermittent fluvial swamps or wet areas as the glaciers melted. Soils are moderately deep and fine textured. Few rock fragments exist in the profiles. Some sheet erosion and rilling occur today. Pocket gophers seem to favor this area, as they are present almost everywhere. Precipitation is in the 26- to 30-inch annual range. Historical vegetation was probably an upland tall forb association

Existing Vegetation

Vegetation descriptions are confined to the subalpine zone. Herbaceous communities are more extensive in this subalpine zone than other communities dominated by trees or shrubs. Composition of the herbaceous cover varies greatly from place to place. Large areas are dominated by grasses, predominantly *Stipa lettermanii*, *Agropyron trachycaulum*, *Trisetum spicatum*, and *Hordeum nodosum*. Other areas are dominated by forbs—*Artemesia discolor*, *Taraxacum officinale*, *Achillea lanulosa*, *Penstemon rydbergii*, *Geranium richardsonii*, and others. Still other major plant associations occur on disturbed areas as a result of local microclimatic conditions.

Lewis (1993) summarized:

> Historically high grazing pressure during the latter half of the last century and extending into the early portion of this century drastically changed the soil and vegetation conditions on the Wasatch Plateau. In general, vegetative ground cover was reduced and species composition was changed from an original tall forb-dominated setting to lower statured forb, grass, and shrub species.

The existing herbaceous communities should be considered as interim or opportunistic because of the past history of grazing use. The original vegetation has been altered for so long that nobody can remember what it once was like. Accounts of pristine vegetation of the subalpine zone of the Wasatch Plateau are lacking. The only evidence of the original character of vegetation of the subalpine zone is based primarily on areas that have escaped grazing or that have been grazed relatively lightly, and on changes that have taken place on areas that have been protected. Lincoln Ellison is believed to have first referenced the vegetation in the subalpine zone as being tall forb. Lewis (1993) stated that the tall forb type in this portion of its range originally occurred on relatively deep, fertile soils with approximately 35 inches of annual precipitation and above 8,500 ft elevation. Other sections of the Plateau at lower elevations that receive lower amounts of precipitation due to specific weather patterns and rain shadow influences had other plant community types. Many of the plant species from these more xeric types moved into the tall forb setting during the heavy grazing years.

Small patches of Engelmann spruce (*Picea engelmannii*) and alpine fir (*Abies lasiocarpa*) dot the rolling terrain of the higher parts of the subalpine zone, and these trees form dense forests on steep northerly exposures. During the late 1990s, spruce budworm severely infested these stands and resulted in almost 100 percent mortality in some areas.

Aspen (*Populus tremuloides*), the prevalent species of the montane forest below the subalpine zone, extends into the subalpine zone in small stands, most commonly on southern exposures. Limber pine (*Pinus flexilis*) is common on steep, rocky, southern exposures. One of the most common shrubs is *Ribes montigenum*. In some areas, low shrubs such as yellow rabbitbrush (*Chrysothamnus viscidiflorus*) dominate.

Climate

Records from the Great Basin Experiment Station indicate there are about 60 to 80 frost-free days per year near the photograph sites. The highest summer temperature to be expected is about 75 degrees. Precipitation exceeds 30 inches annually, about two-thirds occurring as snow. Summer precipitation varies significantly from year to year, and may be a driving force in shaping the dominant vegetation in any given year. The prevailing wind is westerly, in summer usually from slightly south of west. The air in the subalpine zone is seldom still. Daily average wind speeds in the summer average between 2.75 and 8.5 miles per hour (Price and Evans 1938). Wind is responsible for forming great drifts of snow behind patches of coniferous timber and enormous cornices on the eastern rim of the Plateau. These also leave their impression on the vegetation (fig. 5 and 6).

Area Grazing and Management (Administrative) History

We will probably never know how much grazing use was made of the Wasatch Plateau. Sheep numbers in the Utah territory were low prior to 1880, but increased explosively after that (fig. 7). By 1885 the territory supported 1 million head, and by 1890, about 1.5 million. By the turn of the 20th century sheep numbers reach 3.8 million (Hindley and others 2000).

Most of the residents in communities adjacent to the Plateau were of Scandinavian decent whose parents had fled poverty and religious prosecution in Europe, and in many instances, pushed handcarts across the American plains to settle these lands. They had virtually no prior experience with the low capabilities and regenerative powers of desert and semiarid mountain lands. Most at first assumed that spontaneous natural processes would restore the land (Hall 2001).

Just before the turn of the 20th century, sheep populations grazing the entire Wasatch Plateau peaked at somewhere between 800,000 and 1 million head (USDA-FS Manti-LaSal NF 1994). The sheepmen were not all local residents. Many of them were transients who would bring their flocks from Colorado (and with the advent of railroads in Sanpete Valley, from Oregon), follow the snow up the flanks of the Plateau in spring, graze northward along the subalpine zone during summer, and ship their sheep from Colton, UT, in the fall. Close herding and excessive trailing were only two of the destructive practices of early grazers. Still another element in range deterioration was the unwieldy size of herds. In 1880, herds might consist of from 2,000 to 3,000 sheep exclusive of lambs. Unrestricted overgrazing prompted one observer to write that between 1888 and 1905, "The Wasatch Range, from Thistle to Salina, was a vast dust bed." Old Sanpete residents tell of being able to count the herds of sheep on the mountain by the dust clouds they could see from the valley (Ellison 1954).

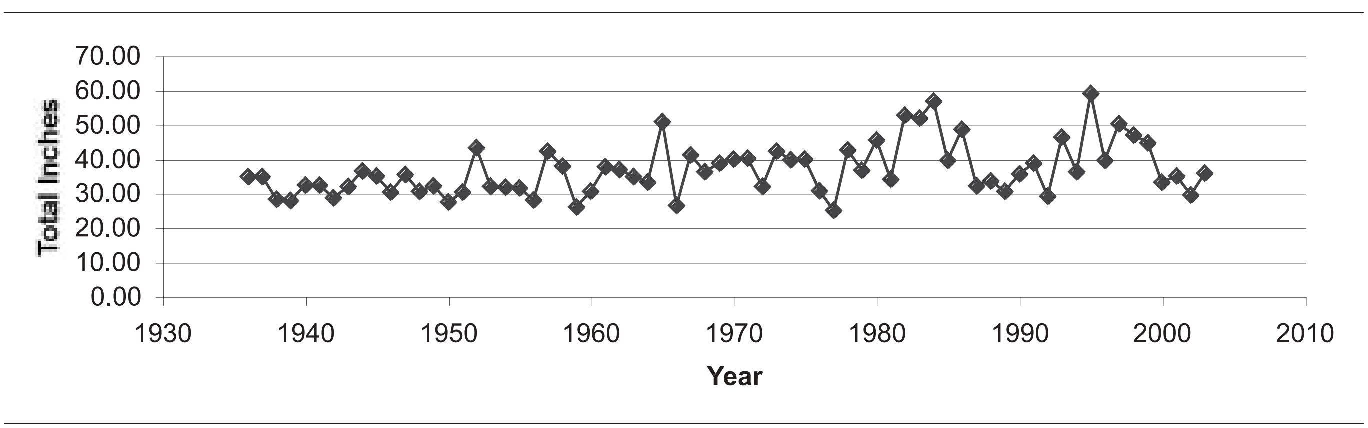

Figure 5—Annual precipitation for the subalpine zone of the Wasatch Plateau, Utah.

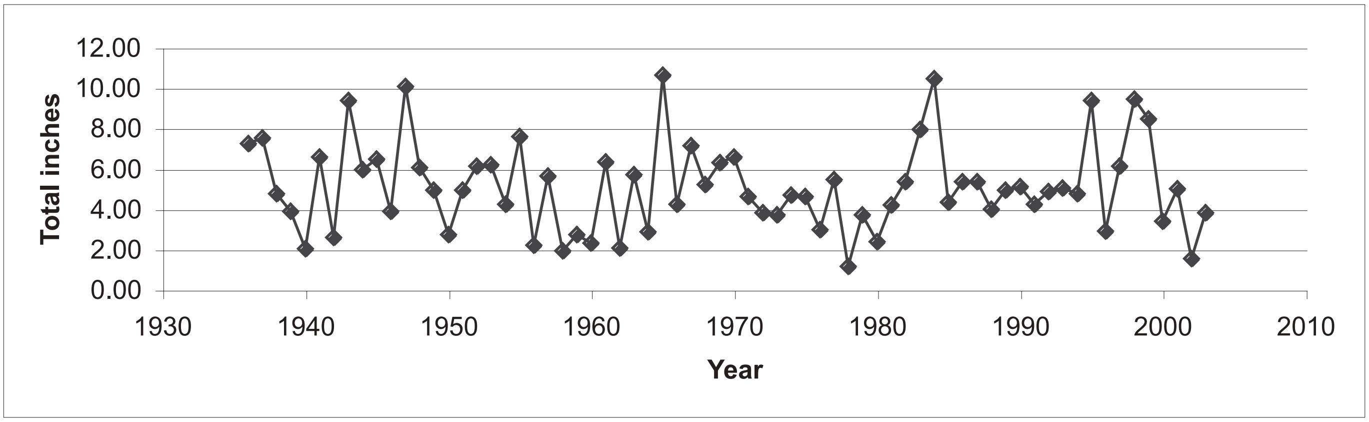

Figure 6—Summer precipitation (June, July, August) for the subalpine zone of the Wasatch Plateau, Utah.

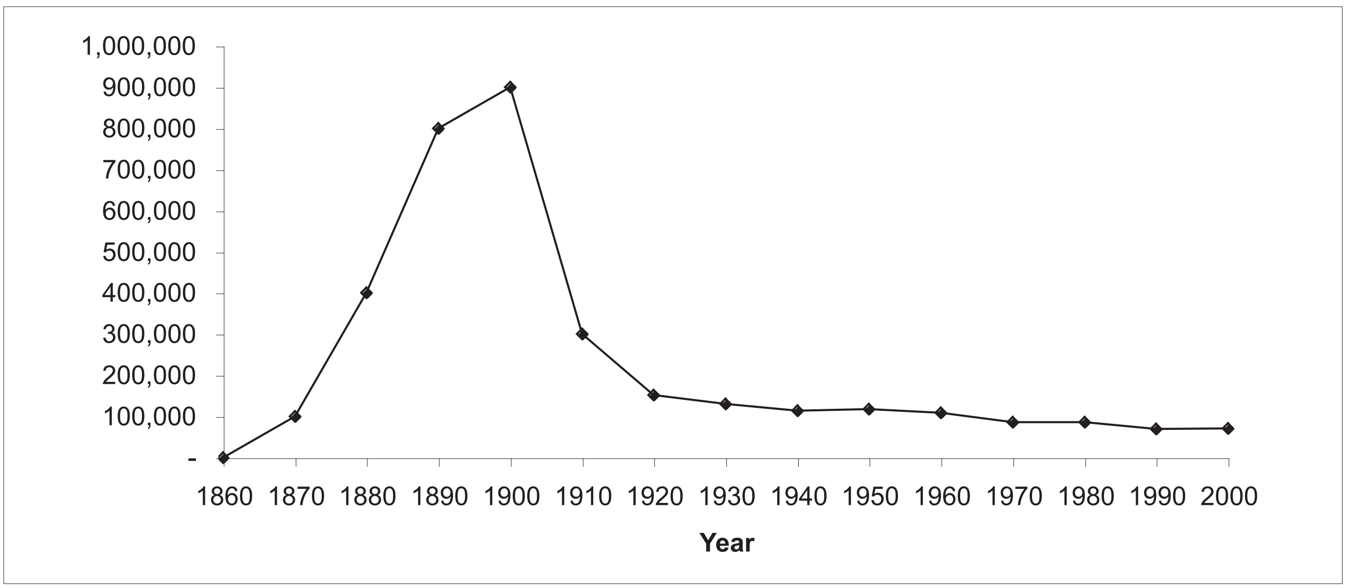

Figure 7—Number of sheep on the Wasatch Plateau.

Grazing rights were determined by "customary use," which meant that if you had grazed your livestock in a particular area in one year you had a presumptive right to put them there again the following year. But if a more aggressive competitor trespassed on "your range," your legal recourses were limited.

Streams that had once run clear became roily throughout the year. Typhoid, spread by contaminated water, was epidemic in Sanpete and Emery Counties during the late years of the nineteenth century. Tensions developed between the stockmen and the residents and water-users in the valleys. Because most of the sheep with their economic benefits belonged to Sanpete County growers, but a greater area of the subalpine range drained into Emery County streams, the most vigorous complaints about stream contamination tended to come from the east side of the mountains. It was common around the turn of the 20th century for Emery County Sheriff's Deputies to arrest sheepherders for "befouling the waters," only to have the charges dismissed by Sanpete County judges. Utah Senator Thomas Kearns, defending the politically powerful woolgrower interests, declared at the height of the controversy (Geary 2003):

> If it be true, and scientific men tell us it is a fact, that water purifies itself within three miles, then it occurs to me that all that is necessary...is to guard the streams against contamination from the distance.

However, it was Sanpete Valley that paid the greatest price for the overgrazing of the Wasatch Plateau through a series of disastrous floods. Sanpete towns were typically established on the banks of creeks, but there is no record of serious flooding during the first three decades of settlement. Then, in August 1889, heavy rains carried mud and boulders from the denuded mountain slopes into the streets and homes of several towns. Between 1889 and 1910, serious floods were reported in Manti and Ephraim and in other canyons on the Sanpete Valley side of the Wasatch Plateau almost every summer. By the end of 1901, the situation in the Sanpete Valley was desperate. Livestock overgrazing was frequently blamed for the disastrous flooding. L. R. Anderson was elected mayor of Manti on a "no more floods" platform.

In 1902, Sanpete Valley citizens petitioned the Federal government to establish a Forest Reserve above Manti (Geary 2003).

Albert Potter, head of the Grazing Division of the U.S. Department of Forestry (later the Forest Service) warned that unless overgrazing was stopped, the watershed above Manti and Ephraim would be irreparably harmed. Potter reported that intensive grazing had ruined the forage over most of Sanpete County's high country, which he found covered with sagebrush or else completely barren. Gifford Pinchot toured the area that summer, remarking that, "It would take the revenue of a city like Chicago to save Manti unless the overgrazing of this canyon is stopped" (Hall 2001).

On May 29, 1903, President Theodore Roosevelt signed the official proclamation creating the Manti Forest Reserve. Jurisdiction of the existing Reserves was transferred to the Department of Agriculture through the 1905 Transfer Act. A few months later, Gifford Pinchot, Chief of the Forest Service, imposed grazing fees and a use-by-permit system. In addition, permits were only issued to local residents; roving bands with no home ranch were excluded. The establishment of the Manti National Forest was not free from conflicts. The initial management plan proposed in 1904 called for a limit of 100,000 sheep and 15,000 cattle and horses, with no sheep permitted on the critical Sanpete Valley watersheds. This proposal met with predictable resistance from wool growers, who requested permits for 400,000 sheep. The number of sheep permitted was successively increased to 125,000, then 175,000, and ultimately 300,000, leading to complaints from Emery County that "The Manti Forest reserve is now a sheep man's preserve and the presumed objects for which it was created are...practically nullified." Forest Supervisor A. W. Jensen, through persistence and persuasion, managed to reduce the sheep permits to 200,000 by 1907 and increased the cattle permits to 28,000, thereby placating the Emery County cattlemen. Over time, grazing permits were restricted to operators who farmed land in valleys adjacent to the forest. Jensen invited the stock raisers themselves to draw the boundaries between grazing districts (allotments).

Supervisor Jensen was a local attorney who moved the Forest Headquarters from Manti to Ephraim to be closer to his law practice. The early forest rangers were also locals who had grown up in the towns and villages at the base of the mountains. In many instances these rangers had herded livestock or worked at sawmills on the mountains. They typically had close relatives, friends, and neighbors in the livestock industry, so it was not always easy for them to enforce the forest rules (Geary 2003).

Between 1904 and 1919, the number of permitted sheep on the Manti Forest was reduced from nearly 300,000 to 140,000 (USDA-FS Manti-LaSal NF 1994).

Arthur Sampson wrote of this time: "The first historically to call the attention of the entire Western management were the public land administrators, of which the United States Forest Service was the pioneer" (Sampson 1954).

In 1911, an area in Ephraim Canyon was selected as the site for a Forest Service Range and Watershed Research Station. First named the Utah Experiment Station, it was subsequently renamed the Great Basin Experiment Station. The Station brought the nation's first true range scientists into the region. The Station became the focal point for studies on range restoration, plant vigor, poisonous plants, revegetation, impacts of grazing on erosion and runoff, artificial seeding, plant nutrition, rodent damage, and silviculture (Keck 1972, USDA-FS Manti-LaSal NF 1994). Extensive seeding trials and reseeding programs started almost immediately.

A 1922 U.S. Forest Service report declared that "range more extensively abused by bad management...probably did not occur" (Hall 2001). Many of the ranches with permitted livestock were adjacent to the National Forest boundary, and livestock were simply turned on and off the forest land. When Mont E. Lewis was Ranger at Castle Dale in the 1940s, actual stocking of cattle in particular was far above permitted numbers. Upon the start of enforcing livestock numbers, the Forest Service had to issue temporary permits to ranchers above the grazing permit numbers so that the local economy would not collapse. The temporary permits were then gradually phased out (Lewis 1976). Sheep numbers were somewhat more controllable because of the "driveway system" of getting the animals to their respective allotments. Here, the number of bands could be observed, but the number of animals in a band was often questionable. Generally, a permitted band consisted of 1,500 adult animals. Some areas of National Forest were designated as "lambing areas," and sheep were permitted onto lower elevation ranges as early as April. As animal husbandry improved after the Great Depression, improvement of breeding stock and genetics took place. Twining of lambs was a common improvement. The weaning weight of lambs increased substantially, and pounds of forage consumed per head increased. The Wasatch Plateau was known for producing market "fat" lambs of 100 to 110 pounds by late August.

It was no easy matter to restore the damaged watershed lands. The Civilian Conservation Corps did some important work on the Forest during the 1930s, constructing roads, ponds, and stock fences. Later still, heavy equipment was used to terrace the steep south-facing slopes of the west side drainages such as Spring City Canyon.

By the 1950s most grazing permits for sheep on high-elevation ranges were from early July to October. However, bands often stayed into November or when snow forced them off. Administrative recourse by Forest Service Rangers was often rebuffed by political connections. In 1954 Ellison stated,

> In some places the subalpine zone is being drastically overgrazed at the present time. Wide spread accelerated soil erosion continues, despite the fact that in may places vegetation has improved materially and erosion has been slowed.

Broad areas of the Wasatch Plateau were plowed and seeded by the Manti National Forest at this time, primarily with smooth brome on the higher elevations and crested wheatgrass at the lower elevations.

By the mid 1960s, the Forest Service was making a concerted effort to manage grazing use. Rangeland analysis was initiated, which included measuring plant species composition and production. The Wasatch Plateau was unique in that grazing allotments up until this time included common use areas on mid-elevation ranges where both sheep and cattle used the same area. Common use was eliminated and the division between sheep and cattle range fenced. As a result, most sheep allotments were confined to the higher elevations. The allocation of acreage in each allotment was based on plant species composition and air-dried forage weight.

In the early 1970s, sheep numbers were still over-allocated. As a result, additional reductions were made.

Mechanical treatments were also successful in the restoration of rangeland. Beginning in 1955 with the passage of the Public 566 Small Watersheds Act, critical areas were contour trenched and seeded. Major work was accomplished in the late 1960s and early 1970s in the Cottonwood Creek Drainage for the Joe's Valley Reservoir site and the Ferron Creek Drainage for the Mill Site Reservoir Project. Some critical areas were fenced and closed to grazing on high-elevation sheep ranges.

Today, the photograph areas lie on two sheep allotments with the following permitted numbers (refer to fig. 2): (1) Wagon Road Ridge sheep and goats: 1,000 ewes with lambs, July 8 to September 27; (2) Little Pete's Hole sheep and goats: 1,080 ewes with lambs, July 15 to September 30.

Grazing systems are basically a multi-time-over-use system that has been in place for decades. Currently, about 71,000 sheep are permitted to graze on the entire Wasatch Plateau, or what was the former Manti National Forest.

Undoubtedly, the majority of the area of the Wasatch Plateau has improved in range condition, particularly on lower and mid-elevation ranges. Disastrous flooding ceased after 1950. However, portions of high-elevation sites where sheep grazing is still permitted and where, concurrently, some of the photo points exist, remain in less than satisfactory rangeland health.

Sampson-Ellison Ecological Interpretations

When Arthur Sampson first arrived at the Experiment Station in 1912, rangelands in the subalpine zone were almost entirely denuded. Since 1907, the Forest Service had sponsored Arthur Sampson's research on range revegetation in Oregon's Wallowa Mountains. He was a student of Frederic Clements and the American school of dynamic ecology and the ecological climax state. Sampson believed that groups of plants developed through several stages to reach a stable climax condition. Reestablishing the Plateau as it once was, therefore, meant reestablishing the climax. Sampson found himself facing the dilemma of trying to re-create the climax without really knowing what the climax looked like. He had hoped to resolve the dilemma by monitoring samples of developing vegetation until they reached a stable state, and adopted the "quadrat" method developed by Clements for tracing temporal vegetation changes. By periodically measuring the number and density of species in small demarcated plots, he could estimate vegetation trends over much larger areas (Hall 2001; Parker and others 1967).

From 1913 to 1915, Sampson established over 40 quadrats, about one-third of which excluded grazing. He found that most fenced quadrats showed yearly increases in species numbers and vegetation density, but unfenced, grazed quadrats showed decreases in both. Sampson declared in 1918 that the Wasatch Plateau's range is "virtually in no higher state of productivity than in 1912." Further, he also discovered that his data did not reveal the climax: "The vegetation composition in both fenced and unfenced quadrats had not yet stabilized during the course of his experiments" (Hall 2001).

What species did increase in his studies led him to write in 1919 that "the wheat grasses (*Agropyron*) broadly considered, constitute the climax herbaceous cover. In the vegetation sub climax type, the timber species, of course, constitute the true climax." There are indications that Sampson had something besides essentially pure wheatgrass in mind as the climax. He further wrote,

> The bunch wheatgrass type...supports a considerable variety of weeds and other plants, both of deep and of shallow rooted characteristics. Plants other than grasses usually occupy the soil space between the tufts. The non-grasses occur in varying density, depending chiefly upon the available soil water content. Precipitation percolates deeply on the rather exposed soils of the bunchgrass areas, and as a consequence both deep-rooted and shallow-rooted species, chiefly other than grasses, are commonly found on bunch wheatgrass areas (Ellison 1954).

This observation is not unlike Ellison's where he later postulated that the grassland-dominated communities in the subalpine zone were the result of selective grazing by sheep.

Marc Hall (2001) in an essay, "Repairing Mountains: Restoration, Ecology, and Wilderness in Twentieth-Century Utah," uses the Great Basin Station, with particular emphasis on the contributions of Sampson and Ellison, to make the case that restorationists made progress in finding better ways to live on the land. Hall (2001) concludes his essay by acknowledging that the technical successes were accomplished despite the daunting and continuing challenges of restoring and recovering subalpine, semiarid landscapes. He furthermore concludes that the motivation to act on these problems, despite their difficulty, is a worthy legacy of Sampson, Ellison, and their colleagues. Some direct quotes from Hall's (2001) essay demonstrate the challenges faced by these pioneering ecologists.

> Even before Sampson's arrival in Utah, Manti Forest rangers had begun to revegetate sections of the Wasatch Plateau. In addition to trees, they planted grasses, most of which were forage species that had never

grown in these mountains. At the top of the plateau in 1909, rangers sowed seeds of timothy, Hungarian brome grass, Kentucky bluegrass, orchard grass, meadow oats, Alsyke clover, and redtop. Not being adapted to western mountains, only a small portion of the brome and orchard grass germinated at all. With Sampson's arrival, he built on the experiences of the Manti Forest rangers and on his Oregon work. In the station's first annual report, he wrote that in all previous years he and other range managers had failed to establish a single exotic forage plant anywhere. The only species he found to consistently survive and reproduce in these extreme environments were the ones already growing there. Sampson and his associates focused on finding better ways to collect, germinate, and propagate forage species that could already be found in Western United States mountains.

But in 1913, most all of the 1,130 attempted plantings, consisting of sprouts and stems collected from local willow, aspen, and mountain elder, died within a few months. The next spring, Sampson planted ten times this number, along with seeds of local gooseberry, alpine currant, and two wheat grasses. Discouragingly, very few survived, with only the wheat grasses showing some success. After two seasons of poor results with locally found species, Sampson expanded his search for species to other nearby national forests. From Idaho, Payette Forest Rangers sent him seeds of two alpine grasses that were favorites of local sheep. Sawtooth Forest rangers sent him several ounces of wild carrot seeds. From California, Trinity Forest rangers provided him with seeds of a local clover. But all of these seeds showed poor abilities to germinate and propagate in Ephraim Canyon, even in plots that had been fenced to exclude cows and sheep.

With these problem areas in mind, Sampson even sought help from the USDA's Bureau of Plant Industry. He made plans to test species that had been collected in Australia, Transvall, and the Mediterranean. In 1915, the bureau sent Sampson several strains of alfalfa that it had developed from Russian stocks. These also failed. An important though subtle point is that while he had begun to plant native vegetation, he was not planting native vegetation as it existed in the past. The natives he planted were usually limited to forage plants useful to cattle and sheep. So while Sampson hoped to revegetate the Wasatch Plateau more like nature ordinarily revegetated it, he still sought to improve the land to a condition that was better than the original. As it became more obvious that his improvements would not work on the plateau, Sampson set his goal on reestablishing what used to grow there.

During its first decade, the condition of the herbaceous subalpine uplands of the Wasatch Plateau was the main concern of the Great Basin Experiment Station, and Sampson and other early researchers at the Station were in the forefront of interpreting this scenario. Three landmark publications were released during this period (as cited in Ellison 1954): Reynolds (1911) described the effects of grazing in producing floods; Sampson and Weyl (1918) studied the effects of grazing on erosion; and Sampson (1919) studied secondary succession in relation to range management.

Further quoting from Hall (2001):

Sampson's experiments therefore indicated that historical—not ecological—research should give the best information about what to plant on the plateau. After Sampson left Utah in 1922 to become a professor at Berkeley, one of the main research pursuits at the Great Basin Station was to determine the plateau's historic vegetation so that it might be restored.

Lincoln Ellison, who became Sampson's fourth successor, carried out the most comprehensive vegetation history of the Wasatch Plateau, before or since. Beginning in 1938, and for the next fifteen years, Ellison sought to reveal once and for all the state of the plateau's flora before it had been altered by livestock. But Ellison soon discovered that not much had been recorded about the early plant cover. Local sheep herders and retired forest rangers provided Ellison with the best historical information. From his 1943 interview with seventy-four-year-old sheep herder, James Jensen, Ellison corroborated his own hunches and scattered clues that broad leafed plants (or "forbs"), rather than grasses, originally covered much of the rolling alpine lands. During the summer of 1942, he had searched neighboring mountain ranges by horse and foot for pristine, relic sites to get a better idea of pre-grazing vegetation. In 1954 Ellison published his accumulated findings about the plateau's pre-grazing flora. But he also concluded that even if he could determine what once grew there, such plants would probably no longer survive and reproduce anyway. Ellison had come to think that the real problem lay in soil loss, not in species choice. He was to write that an overgrazed area may appear to be recovering and may occasionally produce as much as before. But its soil has not recovered, nor is there much prospect that its soils will ever recover. The presence of tall grass is a false indicator of range recovery; such vegetation did not reflect true restoration. Ellison emphasized that while past land use had done damage, only future land use might retain what was left. After spending his career searching for ways to restore the range, Ellison concluded that the alpine meadows above Ephraim and Manti could never be completely restored. Only ethical land use could prevent further degradation.

Today, Ellison and his studies on the Wasatch Plateau have been continually cited as the authority on what is known as the "tall forb" plant community. This type extends from the southern Wasatch Range in Utah northward into Montana. It is characterized by a large array of luxuriant, rather tall (16 to 48 inches [0.4 to 1.2 m]) mesic forbs (fig. 8). In the climax condition, many species are present without any species dominating (Murray and Mayland 1994).

According to Ellison (1954), natural areas, relic forbs and grasses in the shelter of shrubs, observation of range under different degrees of use, and trends in secondary succession following the elimination of grazing all indicate an original vegetation of more mesic character than prevails today. Rather than a singe dominant species over any extensive area, the original upland-herb association appears to have been a mixture of many species of tall, rather succulent forbs, grasses, and sedges. The following species were probably among the most prominent:

Mertensia leonardii	*Bromus carinatus*
Agropyron trachycaulum	*Bromus anomalus*
Valeriana occidentalis	*Carex festivella*
Osmorhiza occidentalis	*Carex hoodii*
Heracleum lanatum	*Carex raynoldsii*
Angelica pinnata	*Aquilegia coerulea*
Polemonium foliosissimum	*Castelleja sulphurea*
Erigeron speciosus	*Castelleja leonardii*

The majority of these species are characteristic of rather moist sites and are especially relished by sheep. Compared with them as a group, vegetation of most of the upland-herb association as it exists under grazing today (1954) is relatively xeric, with the following dominants: *Stipa lettermanii*, *Taraxacum officinale, Artemisia discolor, Madia glomerata, Penstemon rydbergii, and Geranium richardsonii*. It is noted that *Madia glomerata* and *Chrysothamnus vicidiflorus* are absent from relic or protected spots, and that *Stipa lettermanii, Artemisia discolor*, and *Helenium hoopesii*, which are also often abundant on more heavily grazed range, occur only sporadically (Ellison 1954).

Ellison did question whether the limitations of the small natural areas and occurrence in the shelter of shrubs of the same mesic species were representative of the upland-herb

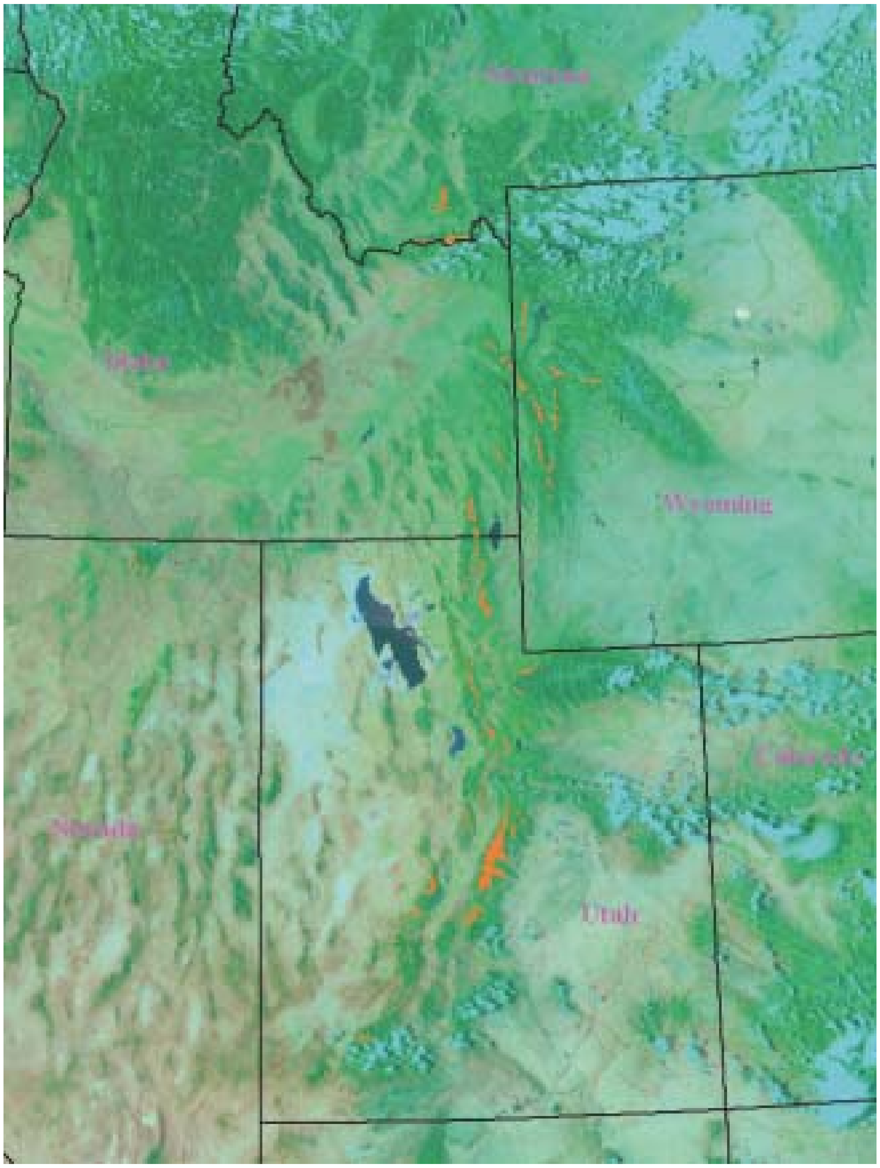

Figure 8—TYROS AVHRR satellite image showing approximate location of tall forb types within the Intermountain area (red) (data compiled from Murray and Mayland 1994; Rosiere 2003; Winward 1998; personal observations; and spectrial reflectance.

association as a whole. He concluded that the pristine vegetation must have been more mesic than the vegetation prevailing on the existing grazed range.

Currently, Robert M. Thompson, Range Conservationist on the Manti-LaSal National Forest, recognizes at least four tall forb community types on the Wasatch Plateau. This is important to note because we feel that Great Basin Experiment Station baseline sites of Watersheds A and B, the protected alpine pasture (all on the west side of Wasatch Plateau), and the photograph sites (east side of Wasatch Plateau) may not be in the same plant associations. In fact, documentation provided by the Rocky Mountain Research Station indicates that the photograph sites are in different precipitation and climatic zones (fig. 3).

In the next section we will view the photographic record over 90 years and see how well Sampson's and Ellison's interpretations and predictions unfolded. The photographs are not analytical data, but can provide insight for observations and possible conclusions. Our interpretations follow the photograph section.

Before viewing the photographs, the reader should be aware that Ellison based many of his hypotheses on historical experience and observation. Four main conclusions may be extracted from his 1954 monograph on vegetation of the subalpine zone of the Wasatch Plateau:

1. The induced drier microclimate restricts mesic species.

Citing from the monograph: "The restricted occurrence of the mesic species today has an important implication. This is that one result of over grazing is a trend toward an increasing xeric environment. Removal of herbage by overgrazing exposes the soil to wind and sun, and consequent loss of the normal litter cover has the same effect. Accelerated soil erosion usually follows, intensifying the induced drought in several ways, from speeding up the loss of cover to causing rainfall that would normally augment the soil moisture supply to be lost as superficial runoff. Under such conditions species that are adapted to a dry environment are found over those that require more moisture, and a tendency toward xerophytism results.

Possible drier microclimate ranks equally with selective grazing and trampling disturbances of the soil in explaining the changes that have occurred since the white man's livestock began to graze."

2. Grasslands may be the result of selective sheep grazing.

Citation: "The grass dominated communities on sheep range are primarily a result of selective grazing. Speaking very broadly, grasses are less palatable to sheep than forbs, and under heavy utilization by sheep year after year, forbs are handicapped and grasses favored. Hence over time forbs tend to disappear and grasses come to dominate the stand. *Achillea lanulosa*, *Artemisia discolor*, *Erigeron ursinus*, and *Penstemon rydbergia*, are codominants in some of these grass-dominated communities, partly because they are only slightly or moderately palatable to sheep no doubt but also because their rhizomatous growth habit enables them to store food reserves out of reach of grazing animals, and to make rapid regrowth after having been grazed, if moisture and warmth allow. *Taraxacum officinale*, which does not have rhizomes, is also a common codominant of grasses in these communities. The disadvantage of a relatively high palatability in its case appears to be offset by phenological and morphological adaptations for it flourishes under heavy grazing by sheep and cattle."

Note that grazing also removed desirable grass species as well as the desirable forbs. The resulting grassland species may not have been significant in the composition of the original vegetation.

3. *Artemisia discolor* and *Penstemon rydbergii* are invasives introduced by sheep.

Citation: "*Artemisia discolor* occurred in 1913 principally on ridges, the areas from which soil is most severely eroded by sheep in grazing, bedding, and trailing. The extensions of area between 1913 and 1936 were also on ridges and on south-facing slopes in herbaceous types for the most part, readily denuded by overgrazing. The fact that this *Artemisia* is absent from large areas in the subalpine zone also bears upon the problem of its origin and spread. Furthermore, all the natural areas but one is free of it. The evidence for invasion of ephemeral communities by rhizomatous species like *Artemisia discolor* and *Penstemon rydbergii* exists. It happens that these two species are extraordinarily persistent under heavy grazing and on terrain where erosion is rapid. With their rhizomatous growth form they would have persisted, had they been present, while bunchgrasses and tap rooted forbs were being eliminated by extreme overgrazing. If they had been part of the original vegetation, they should be well distributed today, having held their ground while other members of the upland-herb association were being destroyed. Because they are obviously invading extensive areas dominated by ephemerals, however, one is led to doubt whether either of them was part of the original mixed upland herb association or at any rate a very common part of it.

Because *Artemisia discolor* is so commonly found on erosion-pavement areas in the central part of the subalpine zone, it might be supposed at first sight to be one of the pioneers in normal succession. However, from the foregoing lines of evidence, together with the fact that *Artemisia* is present on few talus slopes, and on these only in places where the seed may have easily have been washed in from above, it seems clear that this species has been introduced." Note that *Artemisia discolor* is now treated as *A. michauxiana* or *A. ludoviciana* var. *incompta* (Conquist 1994; Welsh and others 2003). The Wasatch Plateau material is best placed as *A. ludoviciana* var. *incompta*. Also, *A. ludoviciana* var. *incompta* and *Penstemon rydbergii* are treated as native in current systematic treatments (Conquist 1994; Welsh and others 2003). We recognize that they may have expanded, but our belief is that *Artemisia discolor* and *Penstemon rydbergii* were not introduced to this region.

4. Accelerated erosion may continue independently of vegetation composition.

Citation: "Very great increases in vegetation have occurred in many parts of the subalpine zone during the last 40 years (1954), but changes in vegetation on permanent quadrats during the past decade or two suggest that this upward trend has ceased. It appears, therefore, that management practices which succeed in raising the range from the lowest stage in secondary succession may still not be adequate for continuing improvement.

The fact is also clearly evident that loss of soil by accelerated erosion acquires a momentum that is increasingly difficult for vegetation to stop unaided. Accelerated erosion modifies the site very greatly and the conditions accompanying it have a great deal to do with the kind of vegetation that succeeds in becoming established. Because of the difficulty that plants have in getting established on some eroded slopes, the soil may continue to erode long after overgrazing is removed.

It is often difficult to distinguish between trends that result from current grazing and trends set in motion by grazing, or by other factors, in the distant past. This is one of the major problems in judging range condition and trend.

There is abundant evidence to show that accelerated erosion can go on independently of vegetation composition; one must also consider its amount as an adequacy of protective cover. Where plants and litter between them cover less than 50 to 75 percent of the surface in the subalpine zone of the Wasatch Plateau, accelerated erosion is usually manifest."

Interpretation of the Photo Record

Site A: Head of Big Bear Creek Looking East at Danish Knoll

Figure 9—**Site A, August 25, 1921**—View of three of the early enclosures established by the Intermountain Forest and Range Experiment Station. Transmountain water ditch is in the foreground. Note the denuded aspect of the landscape, particularly along the drainages. Large gullies and rills are apparent. Photo site C is at the enclosure on the upper left of this picture. Danish Knoll is in left middle.

Figure 10—**Site A, August 22, 1941**—Note the increase in ground cover. Grasses appear to be establishing, and the large gullies and rills are more stable. The major drainage bottoms and immediate side slopes still appear bare. The water in the ditch is from melting snowbanks.

Figure 11—**Site A, August 1972**—Ground cover has continued to increase. Note that slender wheatgrass (*Agropyron*) and Letterman's needlegrass (*Stipa*) now dominate the aspect. It is easy to see Sampson's and Ellison's interpretations that grasslands were either part of the climax vegetation or increased with sheep grazing.

Figure 12—**Site A, August 30, 1990**—Note the increase of herbaceous sagebrush. Grasses are still apparent, but have decreased. It is important to note that Ellison stated this was not an early successional stage, but an opportunistic species. The main drainage into Bear Creek on the right has stabilized significantly.

Figure 13—**Site A, September 4, 2003**—Herbaceous sage still dominates the foreground, but note the site now contains a mixture of taller forbs (*Viguiera multiflora*) and *shrubs* (*Sambucus racemosa*). Grasses are dominant on the flatter aspects. Note the landscape is taking on a mixture of many vegetation species. Ground cover is still lacking on slopes in the middle of the picture. These oblique photographs are somewhat deceptive in that they overrepresent the amount of ground cover. Note the water in the transmountain ditch. Irrigation water is captured on the east side of the Wasatch Plateau divide and transported back to the west side for irrigation purposes by means of tunnels.

Site B: Head of Big Bear Creek Looking West

Figure 14—**Site B, August 19, 1943**—Ellison's caption reads: "An ephemeral community on an eroding slope in which perennials are invading – elevation 10,000 ft." Note the amount of bare soil on this site even after the Manti National Forest had been created 40 years before.

Figure 15—**Site B, August 29, 1948**—Lincoln Ellison retook this photo in 1948. Caption: "Note grasses have invaded the gullies along the sheep trail on the contour, also spread of *Artemisia discolor* in immediate foreground. Grasses are pedestalled, and it is doubtful whether they can invade fast enough under present grazing pressure to control erosion on this slope" (/s/ L. Ellison).

Figure 16—**Site B, August 1972**—Grass species dominate the site. The main drainage channel is still barren, with the occurrence of herbaceous sage in this channel bottom.

Figure 17—**Site B, August 30, 1990**—Grasses have decreased and herbaceous sagebrush dominates the site. Note the lateral spreading of the sage through its rhizomatous growth form. The drainage channel still seems to be actively eroding as witnessed by the rock and erosion pavement in the bottom. Soil loss seems to be several inches relative to the drainage bottom since the last photograph. This substantiates Ellison's projection that erosion in drainage bottoms would continue on these sites even with the establishment of vegetation.

Figure 18—**Site B, September 4, 2003**—Note the reestablishment of grasses in the drainage channel. Erosion and overland flow of soils seems to have decreased. Herbaceous sage is now codominant with grasses, having lost its spreading clump growth form. Dr. Richard Gill (personal communication) reports that this breakup of a rhizomatous growth form is consistent with other rhizomatous species during drought.

Site C: Danish Knoll Enclosure

Figure 19—**Site C, August 3, 1932**—Caption: "The soil is badly eroded and organic matter content is extremely low. Records on this hillside begin in 1916 when the original vegetation had been completely destroyed, and erosion had been so extreme that, except for scattered patches of *Achillea* and *Sambucus*, the soil surface was barren."

Figure 20—**Site C, June 30, 1947**—Caption: "Bunchgrasses are mostly *Agropyron trachycaulum*. A road now runs along the contour above the enclosure and this appears to have acted as a terrace, checking runoff from higher on the slope. Even so, erosion of the lower slope has been marked in this brief period, as alluvial deposits and exposure of rocks in gullies show. Vegetation has increased since 1932, particularly *Agropyron trachycaulum* and *Taraxacum officinale*, but soil erosion has continued rapidly as shown by the exposure of new rocks."

Figure 21—**Site C, August 1972**—Not too much notable change in the last 25 years. Some increases in grass density are apparent.

Figure 22—**Site C, August 30, 1990**—Soil loss continues in the area below the enclosure. Note the increase of exposed rock fragments in the rills. However, the soil is accumulating at the toe of the slope and now is starting to support a more mesic habitat.

Figure 23—**Site C, September 4, 2003**—Note the establishment of ground cover on the lower half of the hillside below the enclosure. The sediment deposited at the bottom of the slope now supports a vigorous community of mesic species that include *Carex* and *Deschampsia caespitosa*; however, a head cut moving up the drainage from the right will bear watching in the future.

Site D: South Side of Danish Knoll Enclosure

Figure 24—**Site D, August 3, 1932**—This photograph was probably taken to monitor the gully that was developing to the side of the mound of grass. Note the amount of raw area. This clump of grass appears to be introduced meadow foxtail.

Figure 25—**Site D, September 31, 1944**—Caption: “Shows general lowering of soil level.” This site appears to be heavily trampled by sheep as they trailed around the end of the enclosure. Large amounts of bare soil are exposed.

Figure 26—**Site D, August 1972**—This photo shows the stabilization of the active gully surfaces and the increase in *Taraxacum officinale.* Grasses are reestablishing and spreading out.

Figure 27—**Site D, August 30, 1990**—Grass and ground cover have been lost. Note the active sheet erosion that is occurring, and a rhizomatous patch of herbaceous sage is trying to establish itself adjacent to the enclosure. The disturbance on this site is probably related to sheep trailing and trampling.

Figure 28—**Site D, September 4, 2003**—Not much change in vegetation, but active rills and small gullies have formed from the overland flow of water. Note the extensive sheet erosion. Disturbance on this site is probably a localized occurrence. The trees on the horizon have been killed by spruce budworm.

Site E: Area Between Danish Knoll and Cox's Knoll on Wagon Ridge Road

Figure 29—Site E, September 15, 1917—Caption: "Heavily overgrazed area. Road can hardly be distinguished from bare soil beside it." Note the mature aspen in the top center of the picture. Other than aspen and conifer, no other vegetation is visible on this site. This was one of the most overgrazed and abused areas on the Wasatch Plateau; it is near an old bed ground and holding area.

Figure 30—**Site E, August 22, 1941**—Caption: "Not so heavily grazed today." Grasses seem to be coming into the site, and ground cover is starting to accumulate.

Figure 31—**Site E, August 1972**—Note the grass dominance on the site. Ground cover has increased along with some herbaceous sage increase. The amount of white rock fragments on the surface indicates soil turnover from frost heaving.

Figure 32—**Site E, August 30, 1990**—Note the further increase in white rock fragments on the surface. This indicates continuing soil dynamics. Grasses and herbaceous sage now codominate the site. Of interest and encouragement is the aspen regeneration coming in under the mature stands. This is probably accountable to the reduced grazing season of sheep use. Aspen suckers are most susceptible to sheep grazing in late September and early October when sheep run out of feed or existing feed becomes very dry (Alma Winward, personal communication).

Figure 33—**Site E, September 4, 2003**—Note the increase in herbaceous sagebrush. Sheet erosion appears to have been reduced or has stabilized. Rock fragments on the surface have increased significantly. The young aspen in the photo have now grown to over 10 ft high, showing that aspen can regenerate itself on the Wasatch Plateau at the 10,000-ft elevation.

Site F: Cox's Knoll Snowbank

Figure 34—**Site F, October 21, 1940 (general view)**—Looking southwest at Cox's Knoll. These high ridges have historically been traditional sheep bed grounds. Caption: "A snow bank area on Wagon Road Ridge, showing progressively severe accelerated erosion, right of center."

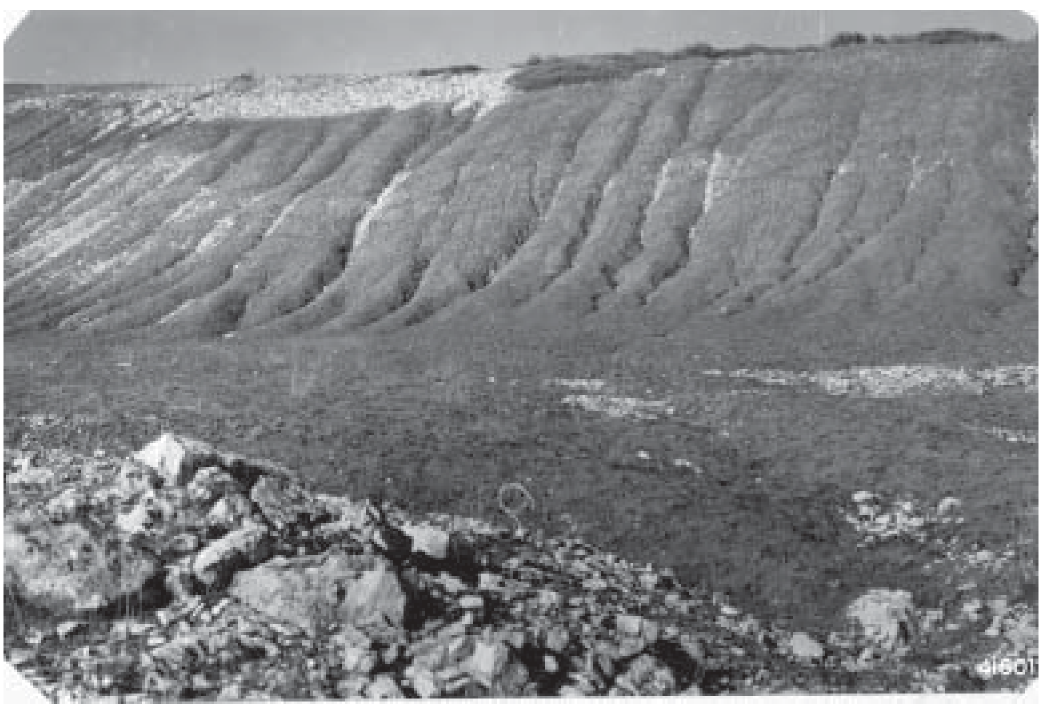

Figure 35—**Site F, October 21, 1940 (Detail)**—Caption from monograph: "Snow bank area on a steep east-facing slope where a snowdrift accumulates each winter. Remnants of *Delphinium barbeyi* indicate that this slope was formerly covered with a tall-forb community, and the depth and character of soil in places indicate that the original cover was luxuriant. The gullies, initially formed by occasional summer storms, are now kept open and enlarged by snowmelt every spring. Dark, slanting lines [across the steep slopes in the center of the photo] are sheep trails."

Figure 36—**Site F, August 1972 (general view)**—Some smoothing out of the snowbank area in background. Note the grassland dominance of the basin. Serviceberry and grass cover have increased in foreground.

Figure 37—**Site F, August 1972 (detail)**—Vegetation is starting to reestablish on peripheral areas of the snowbank, especially top, bottom, and left side of photo. White exposed limestone in 1940 has weathered and decomposed losing its distinctive color, an indication of stabilization. Some of the rills appear to be active. Grass has covered the base area of the bank.

Figure 38—**Site F, August 30, 1990 (general view)**—Note the hedging of the serviceberry (*Symphoricarpus*) in the foreground. Continued grass domination of the basin; however, note the yellow rabbitbrush community coming in from the left side of the photo (north).

Figure 39—**Site F, August 30, 1990 (detail)**—Note the continued cutting of slopes by water as evidenced by exposed white rock fragments. Upper portion of the slope appears to have lost 8 to 9 inches of soil since 1972. Shrubs are trying to establish on the eroded areas.

Figure 40—**Site F, September 4, 2003 (general view)**—The bright green areas under the snowbank in the background are the type site for the tall forb vegetation. Foreground and basin have lost density and ground cover of grass species and may be in transition to a yellow rabbitbrush mixed community. The site contains many remnants of a historic grass community. Sheet erosion seems more prevalent. Photo site "G" is to the far left of this picture and views diagonally across this basin (Robert M. Thompson in photograph).

Figure 41—**Site F, September 4, 2003 (detail)**—This snow bank area has numerous species of vegetation establishing across the steepened face. The rills stabilized only when enough rock was exposed to protect the surface from runoff. Note the large amount of sediment accumulation at the base of the slope and the vegetation established upon it.

Site G: Wagon Road Ridge East of Cox's Knoll

Figure 42—**Site G, September 15, 1917**—View looking north. Although the elevation is 10,000 ft, this site is about 2 1/2 miles east of the crest of the Plateau and therefore outside of the influence of large snowbanks and leeward cirques. Here it appears that the environment has always been drier and more xeric. Exposure to perennial winds is also greater.

Figure 43—**Site G, August 22, 1941**—Caption: "Mat of *Mulenbergia richardsenis* (*M. squarrosa*) tending to exclude other species. Yellowbrush appears to be invading, but very slowly."

Figure 44—**Site G, August 1972**—Mat of *Muhlenbergia* is completely absent. Yellow rabbitbrush and *Stipa* predominate. It appears that more soil is exposed between the perennial plants and some ground cover has been lost.

Figure 45—**Site G, August 30, 1990**—Not much change, although there seems to be more ground cover. A few remnant plants of *Muhlenbergia richardsonis* were found at the camera point on this site.

Figure 46—**Site G, September 4, 2003**—Grasses have decreased, and yellow rabbitbrush seems to be increasing in density. Also, note the increase of the blue-colored *Antennaria rosea*, which has a low mat-forming growth form. Those species currently present indicate an increasingly xeric site. Soils on this site appear to be extremely shallow with the white parent material near the surface. On the Wasatch Plateau, yellow rabbitbrush may be considered a persistent increaser on drier sites (Robert M. Thompson, personal communication).

Site H: Wagon Road Ridge Near White Knoll, Five and One-Half Miles East of the Plateau Crest

Figure 47—**Site H, September 15, 1917**—Caption: "Aspen and grasses in competition for soil moisture. Aspen dying...showing thickened cover (rabbit brush) on heavily grazed sheep range. Note development of erosion pavement." Lincoln Ellison used this site in his monograph as an example of a yellow rabbitbrush community. He postulated that: "the origin of these shrub-dominated communities seems to be the same as the origin of grass-dominated communities: denudation of the original cover and dominance of ephemeral species, followed by invasion of persistent perennials—in this case, low shrubs. As with *Stipa lettermanii*, the increase of *Chrysothamnus* has evidently been helped, not only by the destruction of the original mesophytic herbaceous cover but by a general spread of xeric conditions accompanying overgrazing and accelerated erosion."

Figure 48—**Site H, August 22, 1941**—Caption from Ellison's monograph: "Close observation reveals evidence of active erosion, despite more effective soil protection. Aspen in background is dying out because of sunscald and because root sprouts are annually browsed off to the ground by sheep."

Figure 49—**Site H, August 1972**—Looking north. Site appears to be losing its rabbitbrush domination and progressing into a grass association. Note increase of limber pine in background.

Figure 50—**Site H, August 30, 1990**—This area does not appear to have had significant grazing use in the last few years. Desirable species are increasing. Note the aspen regeneration under the decadent stand.

Figure 51—**Site H, September 4, 2003**—Yellow rabbitbrush is still prevalent; however, it is codominant with grass species. Ground cover may have increased. Note the high lining of the new aspen stems by current sheep grazing. The leeward capture of snow drifts by pioneer species, such as these limber pine, may be critical to the reestablishment of the more mesic species such as aspen on these drier sites. Historically, this site was probably a grassland that was maintained by ground fires.

Site I: Wagon Road Ridge Near White Knoll, 100 Yards East of Photo Site H

Figure 52—**Site I, September 15, 1917**—Caption: "Later stages of succession. Grasses (*Stipa* and *Agropyron*) in foreground, *Ribes* in middle background, and aspen and fir in the far background."

Figure 53—**Site I, August 22, 1941**—Caption: "Many of the dead *Ribes* have disappeared; their stumps can be found. Evidence of hedging indicates that this change is not one of autogenic succession. Note establishment of grasses between yellowbrush."

Figure 54—**Site I, August 1972**—Rabbitbrush appears to be losing its dominance to grass species. No indication is left that *Ribes* once occupied the site. Note the growth of the limber pines during the last 30 years.

Figure 55—**Site I, August 30, 1990**—This site and immediately behind the camera point are in transition. Aspen is going out and grass is increasing. Limber pines are systematically invading the open range type.

Figure 56—**Site I, September 4, 2003**—Yellow rabbitbrush and grasses are codominants. Note the young aspen. The two large limber pines on the left, including the dead one, have large fire scars, indicating that the area frequently burned and the vegetation supported ground fires.

Site J: Looking Northeast From the North Side of Danish Knoll

Figure 57—**Site J, August 22, 1913**—Caption: "Patch of tall larkspur on top of mountain. Other species: yarrow and *Penstemon*." The presence of tall larkspur on this site would indicate it once had mesic conditions to support a tall forb community.

Figure 58—**Site J, August 22, 1941**—Caption: "Yarrow, *Penstemon*, and sweet sage are still important and grasses—*Stipa, Agropyron,* and *Trisetum*—are now conspicuous." Note the disappearance of tall larkspur and the old enclosure as the site becomes more xeric.

Figure 59—**Site J, August 1972**—A heavy infestation of pocket gophers has left the area almost totally denuded of vegetation. This is one of the few localized areas observed on the Wasatch Plateau where pocket gophers caused this significant amount of damage. Ellison stated, "It seems quite clear that the pocket gopher is important as an agent in soil development, in mixing and aerating the soil. He (gophers) is also a potent factor in speeding accelerated erosion." This area was seeded by helicopter in September 1972, but there is no indication that any of the seeding established.

Figure 60—**Site J, August 30, 1990**—Gopher activity has ceased, and several species such as *Artemisia discolor*, *Penstemon rydbergii*, and *Madia glomerata* are invading the site. Some grass (*Bromus carinatus*) appears to be interspersed in the site along with *Helenium hoopsii*.

Figure 61—**Site J, September 4, 2003**—Ground cover is much more prevalent and sheet erosion is not too noticeable. Herbaceous sagebrush is more dominant with *Penstemon* and brome grass continuing as codominants. The lower left corner of the photograph is almost entirely tar weed (*Madia glomerata*). Note the mortality of the conifers caused by spruce budworm. The small patches of red elderberry (*Sambucus racemosa*) are still hanging on.

Site K: One-Half Mile North of Danish Knoll, Looking North Into Little Pete's Hole

Figure 62—**Site K, August 22, 1913**—Caption: "Yarrow range on top of mountain."

Figure 63—**Site K, August 22, 1941**—Caption: "A currant has become established in one corner of the broken-down enclosure. Predominant species: *Penstemon, Taraxacum,* and *Stipa. Achillea* is still important, but no longer predominant."

Figure 64—**Site K, August 1972**—The site appears to have increased in grass species. *Taraxacum* is no longer conspicuous. Continued soil exposure. *Penstemon* and *Stipa* predominate.

Figure 65—**Site K, August 30, 1990**—The current bush that once was in the historical enclosure is barely hanging on. Ground cover has decreased and tar weed has increased on the site.

Figure 66—**Site K, September 4, 2003**—Site is now dominated by *Penstemon* and herbaceous sage. Note the circular colonizing growth pattern. Ground cover has increased. Herbaceous sage and *Pen-stemon* are able to stabilize the site because of their rhizomatous growth system. The single currant bush has been replaced with a red elderberry. Photo site L is on the far ridge above the white limestone cliff.

Figure 67—**Site K, September 4, 2003 (supplemental)**—From previous photo point looking directly west. Active head cutting by melting snow is still occurring on upland slopes with existing grazing use. However, notice that sediment is accumulating in a short distance and being stabilized by grasses.

Site L: Tom's Ridge

Figure 68—**Site L, September 12, 1919**—Site appears to be mostly *Penstemon*.

Figure 69—**Site L, August 13, 1925**—Some evidence of gopher activity as seen from the dirt mounds. *Penstemon* and herbaceous sage predominate.

Figure 70—**Site L, September 19, 1940**—Grasses are now dominant. Note the dirt mounds to the lower left of the photograph.

Figure 71—**Site L, August 1972**—Site has changed from predominantly a grass type to a grass-forb association. *Stipa*, *Penstemon*, and *Achillea* predominate. There is no record of what caused this transition in the interim 32 years.

Figure 72—**Site L, August 30, 1990**—Ground cover appears to have increased along with a mixture of several forb and grass species.

Figure 73—**Site L, September 4, 2003**—This area has continued to improve. Ground cover ranges from 40 to 60 percent with a mixture of forbs and grasses. However, it still cannot be classified as a mesic site. We can see that historically, the site went through many of the same grazing and erosional impacts that the other photograph sites did. Plant species present are similar to other photo sites at this elevation and include *Erigeron speciosus*, *Achillea lanulosa*, *Penstemon rydbergii*, *Artemisia discolor*, *Stipa lettermanii*, *and Lathyrus leucanthus*.

Observations

Although Arthur Sampson and Lincoln Ellison did not have the benefit of almost 90 years of photo records, when viewing the sequence of photographs it is admirable that they were able to interpret many of the ecological and physical processes we see today. Still, Ellison and Sampson would probably be surprised at the prolongation of secondary succession that evolved into stable state and transition ecology we observe today.

It is known that high-elevation ranges are fragile and take a long time to recover, if ever, from extreme past overgrazing and resulting soil loss. They are not simple, easily understood systems. We were not able to quantify one important variable in the recovery of the sites: Is a lack of seed sources one of the reasons many areas are taking so long to recover (Monsen 2004)? It is of note that many species found in protected recovering areas west of the Wasatch Plateau do not yet occur or occur in only a few sites on the east side of the Plateau where the photo sites exist.

Here are some general observations:

- The Wasatch Plateau appears to have long been a mosaic of different plant communities, and not a single community type. Size and distribution of the communities have shifted and been modified by grazing. Even light grazing keeps the communities in the current state. From our observations, we postulate that the subalpine portions of the Wasatch Plateau adjacent to the Sky Line Drive were once one of the tall forb associations or series. The longer ridges running to the east such as Wagon Road Ridge were most likely grass, grass-forb, or grass-shrub dominated. Fire scars on large trees (fig. 74) in this area indicate a pristine vegetation that would support ground fires (Thompson 2004).
- We suspect that moisture and climate-driven environments played a key role in the distribution of the original vegetation mosaics. Appendix B includes species lists from protected tall forb communities on the west side of the Wasatch Plateau. Although not considered fully

Figure 74—Vegetation on Wagon Road Ridge was once dense enough to have supported ground fires, as indicated by these fire scars on limber pines.

recovered, these sites represent an insight on the progression of the communities. Also included are species lists for each of the photo plot sites for comparison.

- *Artemisia discolor (A. ludoviciana* var. *incompta in* current taxonomic terms), *Penstemon rydbergii*, and to some extent *Orthocarpus tolmiei* forb communities are adaptive as opportunists. Other late seral native vegetation does not effectively compete with them on the same site until accelerated erosion stabilizes. Even *Stipa lettermanii* and *Bromus carinatus*, which the authors considered increaser grasses, may be considered in this classification. This assumption is based on the pretext that a seed source does exist for this late seral vegetation. Ellison (1954) postulated: "...we are dealing with secondary succession on accelerated erosion." On the realistic side, we do not believe in calling these species "invaders" as did Ellison. They should probably be called opportunists, increasers, or "saver watershed species" because without their rapid pioneering onto accelerated erosion areas and rhizomatous growth form holding the soil in place, sheet erosion, head cutting, and mudflows on the Wasatch Plateau would have been much more severe. These species may also be favored by climatic and soil conditions such as frost heaving and summer precipitation. Ellison documents the introduction and spreading of these species in his monograph. All photo sites (A through L) indicate this observation. We have also observed that *Artemisia discolor* and *Orthocarpus tolmiei* are dominant species on accelerated erosion areas, and may be used as indicator species to that event. *Penstemon rydbergii* is dominant on deeper soil areas where some sheet erosion is still prevalent or where soils have been disturbed by pocket gophers, frost heaving, and so forth.
- Soil loss continues on some areas as sheet erosion, head cutting, or rills until parent rock material is exposed or until vegetation cover is sufficient to stabilize the area. Ellison postulated this fact and our observations on sites A through F show the same outcome. The increase of rock and rock fragments on the soil surface may also be the result of the turning of the soil and/or cobble sites being pushed up by frost or pocket gophers.
- Sediment will accumulate in lower areas or at the base of erosive slopes. Historically, this sediment just washed down the larger drainages. Mesic plant species have established on these sediment accumulation areas. Here species of *Carex* and other graminoids such as *Deschampsia caespitosa* and *Phleum alpinum* seem to be taking hold (sites B, C, and F). However, these areas are susceptible to head cutting if the drainage areas above have significant overland flow during snowmelt.
- Assessing vegetative trends is extremely difficult on transitional sites. Yearly changes in composition and dominance based on phenology and precipitation (fig. 75) seem to be the rule. Typically, in the summer, increaser forbs dominate, but by fall, cool-season grasses produce seed and dominate after the forbs have become succinct. On drier years, herbaceous sage is a fall dominant, while on moist years, grasses are fall dominates. Fall grass-dominated sites decrease with drought, particularity with lessened summer moisture. Increases in moisture seem to benefit all species due to lessened competition for soil moisture.
- Climate-driven mechanisms may be more important in determining vegetation. In drier microclimates, yellow rabbitbrush increases on the more xeric of these threshold grass sites (sites E through I). The following tabulation illustrates this dynamic between grasses and shrubs in the White Knoll area of Wagon Road Ridge (Thompson 2004):

	Percent composition by weight			
	1983	**1987**	**1998**	**2004**
Grasses	58.0	49.1	58.8	43.7
Forbs	18.1	30.7	24.9	24.9
Shrubs	24.0	20.1	16.1	30.9

Lewis (1993) projected that in the drier portions of the Plateau where needle grass and yellow rabbitbrush exist today, they would most likely continue to maintain their dominance.

- Selective grazing by sheep under current timing, intensity, and duration continues to suppress or eliminate desirable plant species or those species thought to be in the original vegetation. Preliminary work by Gill (2004) shows that soil effects, as a result of grazing and compaction, include (1) lower microbes, (2) lower respiration, and (3) lower production. In addition, the combination of litter removal and soil compaction lowered soil moisture, particularly in late summer. Sheep grazing may also increase the opportunistic grass species due to selective grazing as Ellison (1954) suggested. Lewis (1993) found, with studies conducted in exclosures and in settings where livestock grazing had been considerably reduced, that a gradual shift was taking place back to tall forb-dominated communities. Rhizomatous, somewhat lower statured forb species, such as *Penstemon rydbergii* (fig. 76), *Achillea millefolium*, and *Artemisia ludoviciana* (*michauxiana*) were gradually replaced by luxuriant, often taller species of forbs.
- Aspen will regenerate and reestablish itself in the subalpine zone if protected from sheep grazing (sites E, H, and I).
- From an ecosystem approach, there has been catastrophic mortality in the subalpine fir conifer communities due to spruce budworm along the entire Wasatch Plateau. This insect epidemic is probably a result of fire suppression over the last 100 years.

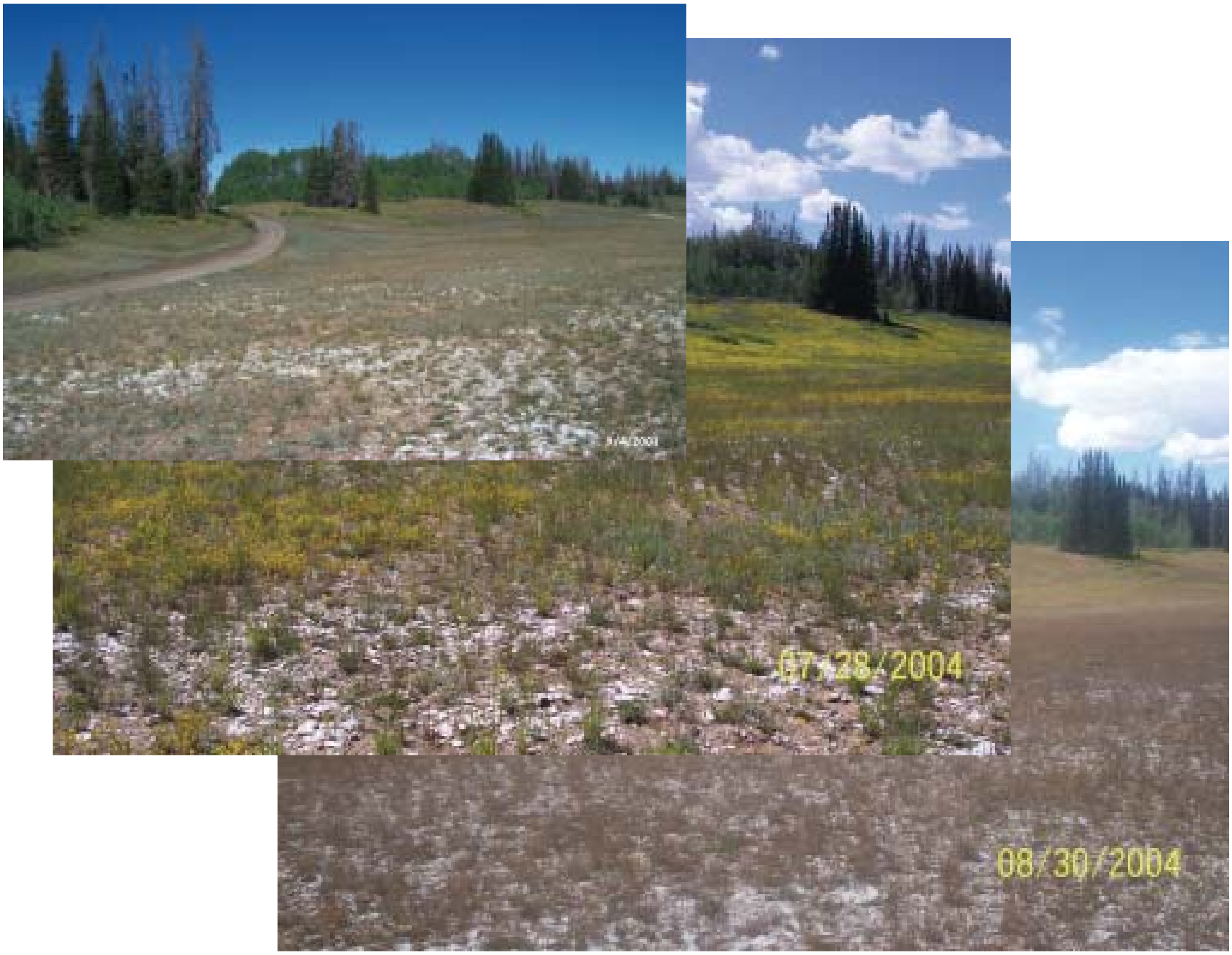

Figure 75—Photos on site E showing change in dominance due to phenology and seasonal precipitation. Left to right: fall 2003 (drought year), herbaceous sage dominant; summer 2004, owl clover and grasses dominant; and fall 2004 (moist year), grasses dominant.

Thus, after nearly 90 years we can see the changes, but do not completely know their cause. And we find ourselves in the same position as Ellison (1954) who wrote 50 years ago:

> The man assigned the management of...rangeland faces problems whose final solutions require years of scientific study, but he is expected to deliver immediate answers that are both correct and practical. With the help of a few ecological principles he must be his own scientist, and by observation ascertain what standards he can use for range in ideal condition, on a variety of sites.

Conclusions

Our current knowledge of plant ecology started with early contributions from such men as Sampson and Ellison, and has continued to progress. We believe we are starting to understand why recovery on the Wasatch Plateau has been so prolonged. Within these complex ecosystems, there are many variables in landscape ecology; climate and livestock management interact and have formed the resulting plant communities. A plant community that has lost most of its topsoil and supports vegetation different from the original community seems to reach various levels that appear to be stable (Moir 1989). This is evident by Ellison's (1954) observations that heavily grazed sites appeared to initially recover rapidly when livestock were removed, but then stabilized and ceased recovering. The west side of the Wasatch Plateau, on areas that have been protected from sheep grazing, have taken nearly 100 years to resemble what was perhaps an original tall forb community, and a good deal of the plant succession toward that community has taken place only in the last 30 years.

With the continuing soil loss on most of these sites, site potential will continue to change and succession will not move toward a new stable state. This recognition and the climate-driven annual and seasonal variation in species composition

Figure 76—*Penstemon rhydbergii* is an opportunistic or increaser species on the Wasatch Plateau.

leads us to shift our emphasis from observing community composition to soil- and hydrology-based indicators (that is, stability, precipitation, moisture-holding capacity, and litter) if we are to effectively evaluate current rangeland condition or health. Monitoring should emphasize soil and hydrologic indicators until the soil is stabilized, then species composition will become a more useful indicator of rangeland health. Initial monitoring of community composition should focus on the ability, or lack thereof, of species to stabilize the soil.

As part of this rangeland health assessment, threshold identification is necessary for recognizing which plant communities can potentially occupy a site. We need to be able to predict how thresholds may respond to restoration and/or management practices. Thresholds can be categorized into two general groups: the first group involves structural or compositional thresholds based on changes in community composition, plant growth, and invasive or increaser species such as yellow rabbitbrush; and the second group involves ecosystem function thresholds based on changes in soil and hydrologic properties, nutrient cycling, and productivity as in the herbaceous sage types (Briske and others 2005).

There are several mechanisms interacting and defining the two groups of thresholds. They are currently taking place on all sites and influence the establishment and growth of respective plant communities (concepts taken from Bowman 2004). The first is the development of the soil. When secondary succession stabilizes a site and erosion ceases, soil development can resume. We see this happening on the Tom's Ridge site. Soil development also includes nitrogen fixation. Some plant species such as legumes support symbiotic bacteria in their roots. The bacteria transform atmospheric nitrogen to a molecular form, usable by living organisms. There are several of these types of plants in stable tall forb communities. It would seem that increaser species (*Penstemon* and herbaceous sage) on secondary succession sites may have lower requirements for nitrogen and other nutrients, or are able to assimilate their own nutrients from other sources. We suspect that some observed conditions are the result of nitrogen depletion. Legumes such as *Vicia americana* and *Lathyrus leucanthus* are two of the early nitrogen-fixing species we have observed on the eroding sites.

The presence of mycorrhizae (mutualistic symbiosis of plants and fungi**)** is another important function in facilitation. Early successional species stimulate the infection of roots of later successional species with mycorrhizal fungi, increasing their ability to take up phosphorus (P). Respiration in the soil through microbial activity and decomposition of organic matter are important soil development processes.

Perhaps most important in soil development is the increase of water-holding capacity. The greater the soil's organic matter, or the finer the soil particles resulting from weathering, and so forth, the more water the soil is able to hold. Loss of water-holding capability and drier microclimate ties into Ellison's (1954) interpretation of why yellow rabbitbrush is so persistent.

There are two ways that one plant species can restrict or inhibit the growth of another commonly observed on the Wasatch front:

1. Alleopathy—A decrease in the germination of seeds and lower survivorship of new plants. This is frequently seen with woody sagebrush and conifer species where shed leaves may contain chemical growth inhibitors or create a highly acid pH in the soil. Tar weed (*Madia glomerata*) and owl clover (*Orthocarpus tolmiei*) fall into this category along with their low palatability to grazing ungulates (site K).

2. Competition—This is usually for soil nutrients, soil moisture, and later for light. We observe this in the round clone growth form of *Artemisia discolor* and *Penstemon rybergii* and their rhizomatous roots. Being able to adapt and grow on soils that are erosive and low in nutrients, and possessing morphological characteristics to out-compete other plant species are distinct advantages.

Disturbances were the causal factor for transitional states on the Wasatch Plateau. The large spatial scale of this disturbance contributes to the low recovery rate. How much of a community is disturbed is critical in determining the response (succession). Large-scale disturbances have a greater effect on climate (exposure to winds, drier soils) and availability of plants (seeds) for colonization. The frequency of disturbance is also important. The turning of the soil and the pushing up of rocks and fragments by frost and freezing (turbation) is probably keeping many of the sites on the Wasatch Plateau in a constantly changing state.

Pocket gophers may be affecting the recovery. Gophers have always inhabited the Wasatch Plateau, and soil castings from these rodents can be observed over broad areas. Ellison (1954) stated that pocket gophers were not a primary cause of accelerated erosion on the Wasatch Plateau; however, we observe their castings on most of the photo sites. During the early 1970s, site "J" had reached an epidemic infestation of this animal, which destroyed even the increaser plant species.

Perhaps paramount in restricting recovery on many sites is today's livestock grazing. Although just a small fraction of what historically caused the greatest impacts, it still has an effect on the environment. Selective grazing and soil compaction undoubtedly have an effect in terms of losses of desired plant species, organic matter, and soil respiration. In addition, the reduction of organic matter by grazing reduces both the availability of nutrients and soil water-holding capacity. It is easy to observe on most of the photo sites that vast amounts of top soil were lost historically, and sheet erosion and in some instances accelerated erosion are ongoing occurrences on some sites today (sites C, D, and F). On more productive sites, there has been an impressive resurgence of young aspen even in the subalpine zone as a result of adjusted livestock use over the last 30 years.

We also suspect some communities are mere chance assemblages of different species with similar environmental preferences. The presence or absence of species, yearly viable seed production, and summer precipitation may play important roles in determining the final outcome of a community. With the amount of soil turning by gophers and frost heaving encountered, chance may play an important role in which vegetation species dominates the next year. Many sites will also change rapidly in dominance and composition based on phenology and seasonal precipitation. These communities of chance may be considered as semidynamic thresholds and should not be confused with preferential or original vegetation on these sites.

Long-term climate change has not been analyzed, although we are aware of a persistent drought over the last 6 years and other periods of drought during the last 100 years. We do not know if global climate change is introducing variables we are not aware of. Some unanswered questions include: Has the amount of summer precipitation changed? Is the reduction of flooding during the last 60 years totally the result of improved watershed health, or is there a change in the pattern of summer high-intensity thunderstorms? These need more study.

Climate-driven plant associations are what we see on many sites today. The rapid change yearly between increaser forb dominance and increaser grass dominance appears to be precipitation driven. Researchers and administrators since Sampson have confused this phenomenon with plant succession. Not until the soils are stabilized and erosion stops will the sites return to natural soil development processes that in turn will lead to a return of historical vegetation types.

Climate may also have been a historical factor in allowing ground fires to burn into the subalpine zone on the extreme eastward side of the Plateau on areas such as Wagon Road Ridge. These would have maintained openings by restricting conifer invasion (primarily limber pine) and provided age class diversity within conifer communities to prevent epidemic insect infestations.

Recommendations

1. Rangeland condition or health evaluation should shift from emphasis of plant community composition to soil and hydrology-based indicators. Research should continue on why stabilization and recovery occur on some sites and not on others. Ongoing monitoring should emphasize soil and hydrologic indicators until the soils are stabilized; then, species composition will become a more useful indicator of

rangeland health. This monitoring of community composition should focus on the ability, or lack thereof, of species to stabilize the soil.

2. The current vegetation on many sites does not have the composition observed historically, nor are soils stable on these sites. Explore if seed sources for native desirable species are available. Identify thresholds that can occupy the same site while recognizing that they are difficult to define and quantify because they represent a complex series of interacting components rather than discrete boundaries in time and space .

3. Broad areas of secondary succession communities that are not producing more vegetation than is needed to prevent unacceptable erosions rates should be deferred from supporting domestic livestock grazing until a stable state forb or grass-forb community is present. Traditionally, these deferred areas have been small localized areas such as snowbanks, gullies, and so forth. Protection at a larger scale is needed to maintain watershed health.

4. Correlation needs to be made between historic summer precipitation and high-intensity thunderstorms, and weather patterns and seasonal precipitation of today.

5. Short-term monitoring should be undertaken to document domestic livestock movement and distribution patterns on the photo site areas. Documentation should include avoidance of recreation use, perennial water sources use including the trans-mountain ditches, and the terrain utilized.

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Appendix A: Plant Species Cited

Ellison monograph name	**Current taxonomy name**
Artemesia discolor	*Artemisia michauxiana/A. Ludoviciana* var. *incompta*
Penstemon rydbergii	*Penstemon rydbergii*
Stipa lettermanii	*Achnatherum lettermanii*
Agropyron trachycaulum	*Elymus trachycaulus*
Trisetum spicatum	*Trisetum spicatum*
Hordeum nodosum	*Hordeum brachyantherum*
Taraxacum officinale	*Taraxacum officinale*
Achillea lanulosa	*Achillea millefolium*
Genanium richardsonii	*Geranium richardsonii*
Picea engelmannii	*Picea engelmanii*
Abies lasiocarpa	*Abies lasiocarpa*
Populus tremuloides	*Populus tremuloides*
Pinus flexilis	*Pinus flexilis*
Ribes montigenum	*Ribies montigenum*
Chrysothamnus viscidiflorus	*Chrysothamnus viscidiflorus*
Mertensia leonardii	*Mertensia oblongifolia*
Valeriana occidentalis	*Valeriana occidentalis*
Heracleum lanatum	*Heracleum maximum*
Angelica pinnata	*Angelica pinnata*
Polemonium foliosissimum	*Polemonium foliosissimum*
Erigeron speciosus	*Erigeron speciosus*
Erigeron ursinus	*Erigeron ursinus*
Bromus carinatus	*Bromus marginatus*
Bromus anomalus	*Bromus anomalus*
Carex festivella	*Carex microptera*
Carex hoodii	*Carex hoodii*
Carex raynoldsii	*Carex raynoldsii*
Aquilegia coerulea	*Aquilegia caerulea*
Castilleja sulphurea	*Castilleja sulphurea*
Castilleja leonardi	*Castilleja rhexiifolia*
Madia glomerata	*Madia glomerata*
Helenium hoopesii	*Hymenoxys hoopesii*
Muhlenbergia richardsonis	*Muhlenbergia richardsonis*
Symphoricarpos oreophilus	*Symphoricarpos oreophilus*
Delphinium barbeyi	*Delphinium barbeyi*
Sambucus racemosa	*Sambucus racemosa*
Other plants cited in text	
Deschampsia caespitosa	*Deschampsia caespitosa*
Phleum alpinum	*Phleum alpinum*
Antennaria rosea	*Antennaria rosea*
Viguiera multiflora	*Heliomeris multiflora*
Stipa columbiana	*Achnatherum nelsonii*
Agropyron smithii	*Pascopyrum smithii*
Orthocarpus tolmiei	*Orthocarpus tolmiei*
Lathyrus leucanthus	*Lathrus leucanthus*
Vicia americana	*Vicia americana*

Appendix B: Current Plant Species on Protected Areas and Photo Points

Alpine Cattle Pasture Enclosure, West Side (Protected)

The site is dominated by forbs in both overstory and appearances *with Ligusticum porteri, Geranium viscosissimum, Vicia americana, Erigeron speciosus, and Artemisia ludoviciana* as dominants. The gramonoid component is intermingled with *Elymus trachycaulum*, *Bromus marginatus*, and *Melica bulbosa.* Other important species include *Achnatherum lettermanii*, *Achnatherum nelsonii*, *Lupinus argenteus*, *Heliomeris multiflora*, *Penstemon rydbergii*, *Viola purpurea*, *Aster adscendens*, *Stellaria jamesiana, Thalictrum fendleri, Potentillia gracilis*, *Collomia linearis*, *Osmorhiza occidentalis*, *Castilleja sulphurea*, *Solidago multiradiata*, *Achillea millefolium*, and *Valeriana edulis.*

Elks Knoll RNA, West Side (Protected)

Tall forbs dominate the overstory and appearances. *Geranium viscosissimum*, *Valeriana occidentalis*, *Ligusticum porteri*, *Penstemon rydbergii*, *Aster adscendens*, *Erigeron speciosus*, and *Heliomeris multiflora* are dominant. A good graminoid component is intermingled with *Elymus trachycaulum*, *Melica bulbosa*, and *Bromus marginatus* as dominants. Other plants found on this type are *Carex hoodii*, *Achnatherum lettermanii*, *Carex raynoldsii*, *Carex egglestonii*, *Vicia americana*, *Viola purpurea*, *Agoseris glauca*, *Achillea lanulosa*, *Stellaria jamesiana*, *Ligusticum porteri*, *Thalictrum fendleri*, *Potentilla gracilis*, *Collomia linearis*, *Solidago multiradiata*, *Taraxacum officinale*, *Eriogonum umbellatum*, *Senecio crassulus*, and *Erigeron ursinus*.

Photo Site A

Artemisia michauxiana, *Sambucus racemosa*, *Achnatherum lettermanii*, *Achillea lanulosa*, *Eriogonum umbellatum*, *Koeleria cristata*, *Poa arctica*, *Ribes montigum*, *Potentilla gracilis*, *Antennaria rosa*, and *Heliomeris multiflora*.

Photo Site B

Orthocarpus tolmiei, *Bromus marginatus*, *Achnatherum lettermanii*, and *Artemisia michauxiana*.

Photo Sites C and D

Potentilla gracilis, Poa *artica*, *Achillea lanulosa*, *Taraxacum officinale*, *Koeleria cristata*, *Artemisia michauxiana*, *Vicia americana*, *Eriogonum umbellatum*, *Carex* spp., *Deschampsia caespitosa*, and *Phleum alpinum*.

Photo Site E

Artemisia michauxiana, *Bromus marginatus*, *Orthocarpus tolmiei*, *Achnatherum lettermanii*, *Lathyrus leucanthus*, *Taraxicum officinale*, *Penstemon rydgergii*, *Bromus inermis*, *Sambucus racemosa*, and *Acihillea lanulosa*.

Photo Site F (General)

Leucopoa kingii, *Vicia americana*, *Eriogonum umbellatum*, *Poa pattersonii*, *Elymus trachycaulum*, *Koeleria cristata*, *Achillea lanulosa*, *Taraxacum officinale*, *Poa femdleriana*, *Poa arctica*, *Chrysothamnus vicidiflorus*, *Pascopyrum smithii*, and *Trisetum spicatum*.

Photo Site F (Detail)

Vicia americana, *Bromus marginatus*, *Artemisia michauxiana*, *Taraxacum officinale*, *Rumex crispus*, *Eriogonum umbellatum*, *Oenothera flava*, *and Hordeum brachyantherum*.

Photo Site G

Chrysothamnus vicidiflorus, *Penstemon rydbergia*, *Achillea lanulosa*, *Taraaicum officinale*, *Achnatherum lettermanii*, *Poa arctica*, *Poa fendleriana*, *Artemisia michauxiana*, *Antennaria rosea*, *Koeleria cristata*, *Potentilla gracilis*, and *Achnatherum nelsonii*.

Photo Site H

Chrysothamnus vicidiflorus, *Potentilla gracilis*, *Taraxacum officinale*, *Achillea lanulosa*, *Symphoricarpus oreophyllus*, *Achnatherum lettermanii*, *Elymus trachycaulum*, *Poa arctica*, *Erigeron ursinus*, *Pascopyrum smithii*, *Bromus marginatus*, *Bromus inermus*, *Koeleria cristata*, *Lathyrus leucanthus*, *Achnatherum nelsonii*, *Castilleja* spp., and *Trisetum spicatum*.

Photo Site I

Chrysothamnus vicidiflorus, *Potentilla gracilis*, *Taraxacum officinale*, *Achillea lanulosa*, *Symphoricarpus oreophyllus*, *Achnatherum lettermanii*, *Elymus trachycaulum*, *Poa arctica*, *Erigeron ursinus*, *Pascopyrum smithii*, *Bromus marginatus*, *Bromus inermus*, *Koeleria cristata*, *Lathyrus leucanthus*, and *Trisetum spicatum*.

Photo Sites J and K

Sambucus racemosa, *Phleum alpinum*, *Carex* spp., *Achnatherum lettermanii*, *Bromus marginatus*, *Artemisia michauxiana*, *Helenium hoopsii*, *Madia glomerata*, *Erigeron ursinu*, *Penstemon rydbergii*, and *Taraxacum officinale*.

Photo Site L

Erigeron speciosus, *Achillea lanulosa*, *Penstemon rydbergii*, *Artemisia michauxiana*, *Lathyrus leucanthus*, *Achnatherum lettermanii*, *Orthocarpus tolmiei*, and *Potentilla gracilis*.

Appendix C: GPS Locations for Photo Plots

Site A	Lat: N 39 degrees 17.154 minutes Lon: W 111 degrees 26.370 minutes Lat: 39.285896 N Lon: 111.439470 W
Site B	Lat: N 39 degrees 17.152 minutes Lon: W 111 degrees 26.397 minutes Lat: 39.285868 N Lon: 111.439873 W
Site C	Lat: N 39 degrees 17.115 minutes Lon: W 111 degrees 26.190 minutes Lat: 39.285251 N Lon: 111.436520 W
Site D	Lat: N 39 degrees 17.116 minutes Lon: W 111 degrees 26.164 minutes Lat: 39.285270 N Lon: 111.436083 W
Site E	Lat: N 39 degrees 16.699 minutes Lon: W 111 degrees 25.345 minutes Lat: 39.278320 N Lon: 111.422404 W
Site F1	Lat: N 39 degrees 16.702 minutes Lon: W 111 degrees 23.923 minutes Lat: 39.278313 N Lon: 111.398753 W
Site F2	Lat: N 39 degrees 16.630 minutes Lon: W 111 degrees 24.385 minutes Lat: 39.277178 N Lon: 111.406415 W
Site G	Lat: N 39 degrees 16.629 minutes Lon: W 111 degrees 24.105 minutes Lat: 39.277135 N Lon: 111.401771 W
Site H	Lat: N 39 degrees 15.520 minutes Lon: W 111 degrees 21.146 minutes Lat: 39.258667 N Lon: 111.352667 W
Site I	Lat: N 39 degrees 15.456 minutes Lon: W 111 degrees 21.087 minutes Lat: 39.257604 N Lon: 111.351450W

Site J	Lat N 39 degrees 17.233 minutes Lon: W 111 degrees 26.118 minutes Lat: 39.287076 N Lon: 111.435196 W
Site K	Lat: N 39 degrees 17.338 minutes Lon: W 111 degrees 26.049 minutes Lat: 39.288967N Lon: 111.434150 W
Site L	Lat: N 39 degrees 18.022 minutes Lon: W 111 degrees 25.778 minutes Lat: 39.300351 N Lon: 111.429640 W

Appendix D: History of the Great Basin Station

On the occasion of the 100-year Celebration of the
Manti-La Sal National Forest
Great Basin Environmental Education Center
July 24, 2003

Presented by E. Durant McArthur
Project Leader and Research Geneticist
Shrub Sciences Laboratory, and
Scientist-in-Charge, Great Basin Experimental Range
USDA Forest Service, Rocky Mountain Research Station
Provo, UT

Introduction

It is my pleasure to summarize the history of the Great Basin Station, which is the name I use in this account interchangeably with the Great Basin Experimental Range—its formal current name. Its names and functions have changed with the times since the site was selected in 1911 and research and facility development started in 1912 (Antrei 1982; Keck 1972; McArthur and Monsen 1996). It has been known as the Utah Experiment Station (1912–1918, Great Basin Experiment Station (1918 to 1930), Great Basin Branch Experiment Station (1930 to 1947), Great Basin Research Center (1947 to 1970), and Great Basin Experimental Range (1970 to the present time) (McArthur and others 1999). Since 1997, Snow College in Ephraim, UT, has managed this Headquarters area as the Great Basin Environmental Education Center (GBEEC). In its beginnings research was not clearly separated from other Forest Service functions, although research was clearly the primary purpose of the Great Basin Station. The Station was one of the key elements that coalesced into the Intermountain Forest and Range Experiment Station when the network of nationwide geographical Forest Service Research Stations was established in 1930. Prior to that time it was managed out of the District Office (now Regional Office) in Ogden, UT. The Intermountain Research Station (former Intermountain Forest and Range Experiment Station) Headquarters were in Ogden with the establishment of a separate Forest Service Research branch until that Station was consolidated into the Rocky Mountain Research Station in Fort Collins, CO, in 1997. (Figures 77–88 are not directly referred to in the text. These archival photos are maintained at the Rocky Mountain Research Station's Ogden Service Center.)

Establishment of the Great Basin Station

We are at the historic Headquarters of the Great Basin Station. Research was and is conducted within the Great Basin Experimental Range, which comprises some 4,600 acres in the Ephraim (Cottonwood Creek) Canyon watershed ranging from 6,700 to 10,500 ft elevation. Research from this headquarters, however, was not confined to the Great Basin Experimental Range per se, but expanded out onto other lands in the Manti National Forest (now Manti-La Sal National Forest) and beyond. To quote a technician, Albert Antrei (1936, 1993b) of earlier times (1936):

> My job was to help with the gathering of data in the field for research projects that were to be analyzed during the winter months in Ogden...by scientists in range botany and soil erosion. All of the field work took place on summer range in Ephraim Canyon. Winter range research was conducted at the "Desert Station" about 50 miles from Milford, Utah, and spring-fall range problems were studied at a station north of Dubois, Idaho.

The Station got its start when Arthur Sampson, then 28, and his colleague James T. Jardine (the two had been appointed in 1907 as Forest Service Researchers to study urgent range problems in eastern Oregon) were searching for:

> ...a locality which might somewhat typify extensive range types and climatic conditions. We preferred optimum rather than less favorable conditions for growth; we sought rugged country and a wide range of elevations, with variable soils; and it was especially important to be located where many extensive vegetation types occurred.
>
> Erosion was an extremely serious problem on many recently created National Forests. …Having heard much of the erosion situation in central Utah, we proceeded there; and largely at the urgent suggestion of Supervisor A. W. Jensen, the Manti Forest was among those to be observed (Sampson, personal communication, 1936).

The first buildings constructed (started in 1912 and completed by 1914) were the Director's residence (East House), the laboratory building (museum), the Assistants' residence, and a barn. A greenhouse was soon constructed behind these houses. In the late 1920s a garage and dormitory (the Palmer House) was constructed. In 1933 a new phase of building began with the help of Civilian Conservation Corps (CCC) labor. This phase included the End House (Plummer House) and the South House (dining hall), and by 1936 the Lodge had been built on the site of the former Assistants' residence, which had burned in 1935 (Keck 1972). Tent bases, storage and other out buildings, and a shower house were also constructed to provide for the needs of an active Research Station. Other improvements were also built to facilitate the research studies of the Great Basin Station. These included gauging stations, water catchments basins, grazing exclosures and other fences, and the Alpine Cabin.

Figure 77—Arthur Sampson, circa 1912.

Sampson acknowledged the important role of Supervisor A. W. Jensen not only in the establishment of the Station but the selection of the site: "[Supervisor Jensen] had more to do with location of the Station than any one, indeed more than all other(s)…combined" (Sampson, personal communication). Supervisor Jensen himself described the site selection by a committee that examined several sites in Fairview and Ephraim Canyons. Dr. Sampson was complementary to the thrift and industry of the local builders in the construction of the buildings (Sampson, personal communication, 1936).

The Great Basin Station was selected in 1911 only 8 years after (established 9 years after) the Manti National Forest was established. Parenthetically and interestingly, the appointment of the first forest officers (a Forest Supervisor and Rangers of the Manti, Mayfield, and Emery Districts) was exactly 100 years ago—July 24, 1903 (the Forest was created by President Teddy Roosevelt's decree on May 29, 1903). The two events, establishment of the Manti National Forest and Great Basin Station, were tied together by the condition of the land. L. R. Anderson was elected Mayor of Manti, UT, on the platform "to reduce the flood menace" (Antrei 1982, 1995). Supervisor Jensen stated, "when I was supervisor [1902 to 1911] there was very little grass" (Antrei 1982). The Great Basin Station was established to discover the causes and solutions to the flooding problems as well as other

Figure 78—Arthur Sampson, circa 1930.

rangeland and forest issues. Certainly ecological conditions had changed rapidly on the mountain since the time of settlement. Lauritz Neilsen of Ephraim (born 1875) and James Jensen of Spring City (born 1869) provide first-hand accounts on conditions on the Wasatch Plateau at the time of early grazing activities. Mr. Neilsen, in 1953, at the request of A. Perry Plummer provided a written account of ecological conditions, and Mr. Jensen, in 1946, on a bus ride with Lincoln Ellison which Dr. Ellison recorded as an official file memo (1945) detail the more pristine conditions. Both Dr. Ellison and Mr. Plummer, in turn, were scientists in charge of the Great Basin Station. Mr. Jensen recalled that in 1880, and Mr. Nielsen recalled that in 1885, the vegetation on the Wasatch Plateau was thick and tall and it would obscure sheep and logs. The vegetation in nonforested areas was "weeds" (forbs) and grass. Mr. Neilsen recounts in about 1885 that the road up Ephraim Canyon followed along Cottonwood (Ephraim) Creek up to the place we call "the Hole"—just below the Station. The road crossed back and forth across the creek in a few places. The creek was shallow with clear water and good trout habitat. Both gentlemen recount that there were many large bands of sheep on the mountain. The vast numbers of sheep on the mountain led to conditions such that "looking through the aspen…there was not a green leaf or sprig of any kind as high as the sheep could reach and the ground was absolutely bare. They ate everything that was green" (Antrei 1982) and "...old Sanpete residents, who tell of being able to count the herds of sheep on the mountain by the (columns) of dust clouds they could see from the valley" (Ellison 1954; Reynolds 1911). By the

Figure 79—Manti Flood, 1902.

late 1880s, large floods, driven by summer thunderstorms, started and became increasingly common. A massive flood in Ephraim Canyon in 1889 materially changed canyon access and the character of the creek. These devastating floods scoured and cut channels, caused landslides, destroyed access roads, and carried mud and debris into valley settlements. These conditions led to the loss of much of the topsoil on the Wasatch Plateau—up to 3 ft in many places. Nevertheless, prudent management has led to remarkable recovery over the 100 years of National Forest management, although rebuilding the soils is a process that will take centuries, even millennia, to complete.

Research Programs

Watershed studies were among the first to be undertaken at the Great Basin Station. Director Sampson established two

Figure 80—Wasatch Plateau: building contour trenches with horse and plow during the 1920s.

Figure 81—Arthur Sampson, circa 1930.

Figure 82—Lincoln Elllison, circa 1950.

erosion areas (A and B) in 1912. Studies on vegetation cover, manipulation, and sediment flow have been documented over a 90-year period (Forsling 1931; Meeuwig 1960; Sampson and Weyl 1918; Stevens 2003; Stevens and others 1992; Stewart and Forsling 1931). My colleague Richard Stevens concluded in a recent publication that this long-term study has demonstrated that management practices can stabilize depleted subalpine range through long periods of nonuse or stabilize rapidly with restoration or revegetation techniques (Stevens 2003). The long-term study on the paired watersheds has compared the effectiveness of grasses and forbs for erosion control (grasses establish more quickly), documented the relative effectiveness of various species and litter, and provided information on plant successional trajectories (how plant species interact with one another and their environment over time). Sediment production measured at over 100 cubic ft per acre under various vegetation cover values during the first 40 years of the study have been virtually nil during the last half century (Stevens 2003). Other watershed studies involved infiltrometers and vegetative and mechanical means to reduce gully erosion and control water release in snowbanks (Keck 1972).

Vegetation composition and dynamics studies conducted at the Great Basin Station and across the Wasatch Plateau have contributed significantly to the body of knowledge for range management and plant ecology. Lincoln Ellison's (1954) superb publication in *Ecological Monographs*, "Subalpine Vegetation of the Wasatch Plateau," is a classical study on the pristine and grazing modified vegetation. He and his colleagues used information on plant succession gained on the Wasatch Plateau to formulate principles for use in management of rangelands. For example, the publications "The Ecological Basis for Judging Condition and Trend on Mountain Range Land" (Ellison 1949) and "Indicators of Condition and Trend on High Range Watersheds in the Intermountain Region" (Ellison and others 1951) provide a basis for a healthy landscape *and* a stable forage resource with proper management. Ellison's basic recommendation is that the land resource is of paramount importance.

Figure 83—Great Basin Experiment Station, 1934.

Shortly after the Great Basin Station was begun, Sampson and his colleagues established vegetation plots and exclosures where grazing effects could be compared under managed and protected conditions (Hall 1997; Keck 1972; Sampson 1919; Tippets and Anderson 1991). These plots have been evaluated over time to monitor succession and are still of use. For example, Dr. Rick Gill of Washington State University is currently conducting research on the impact of sheep grazing on soil organic matter formation and retention, and on belowground respiration under the auspices of a USDA National Research Initiative competitive grant; Dr. Don Breakwell of Brigham Young University is examining the soil microbial community inside and outside of exclosures using DNA profiles analyzed by polymerase chain reaction techniques

An interesting aside is whether grasses or forbs were the dominant pristine herbaceous vegetation. Sampson made a case for grasses, perhaps in part because he was a student of Frederick Clements, a founder and strong proponent of linear vegetation succession. Ellison, however, was convinced that forbs were dominant with an admixture of grasses. When he rode the bus from Salt Lake City to Sanpete County in 1946 with an old timer (the aforementioned James Jensen who remembered "weeds" as the primary herbaceous vegetation), he made it a point to document that conversation and place it in the record (Ellison 1945). Recently Klemmendson and Tiedemann (1994, 1998) reopened that question—the primary herbaceous dominant in the pristine vegetation. No doubt both classes of plants were present. It may be that some conditions favored one class of vegetation as a dominant, and other conditions favored the other one.

The Great Basin Experimental Range, a diverse topography and an environmental gradient, includes several major vegetational types, including mountain herblands, oakbrush, pinyon-juniper, aspen, spruce and fir, and white fir (Keck 1972; McArthur and Monsen 1996). These vegetative types have been differentially modified by ecological conditions and management during the time since the land has been managed (Walker and others 1996). For example, the aspen type has been reduced by about one-half. Oak and mountain brush are also increasing, but sagebrush is decreasing. Seeded exotic, aggressive understory plants, particularly intermediate wheatgrass and smooth brome, were seeded to control erosion and provide forage. They have been so competitive as to exclude native plant recruitment, including that of sagebrush (Monsen and McArthur 1995; Walker and others 1996).

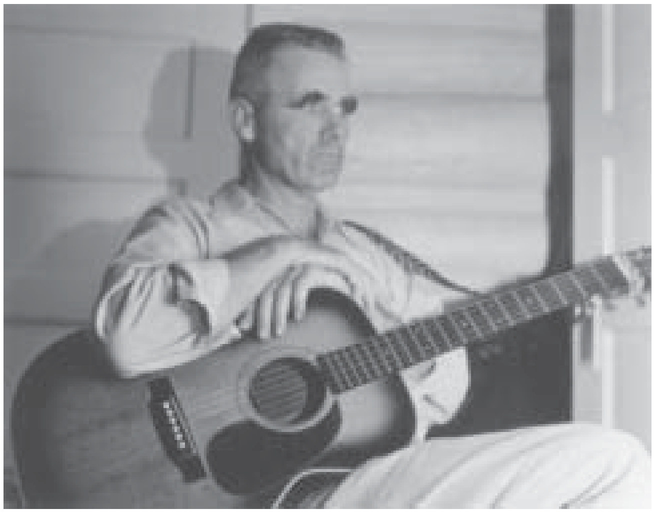

Figure 84—Lincoln Ellison.

Figure 85—Ellison family at the Great Basin Experiment Station, circa 1946.

Plant adaptation for revegetation and restoration of depleted and damaged rangeland and wildlands was started in 1912 by Director Sampson (Hall 1997; Keck 1972). This work has continued until the present not only on the Great Basin Experimental Range but also at many other sites. The greatest impetus to this work was given by A. Perry Plummer, who directed work at the Station from 1947 to 1977, and was involved there from the late 1930s until his death in 1991 (McArthur 1992). Mr. Plummer was a champion of restoring damaged wildlands (Plummer 1977; Plummer and others 1968).

A multitude of testing sites are located on the Great Basin Experimental Range from Major's Flat at the Forest Boundary to the top of the Plateau at the Alpine Cattle Pasture and at many other sites in Utah and beyond. This work was given a major impetus by a cooperative venture begun in 1954 by the Intermountain Forest and Range Experiment Station of the Forest Service (now the Rocky Mountain Research Station) and the Utah Department of Fish and Game (now the Utah Division of Wildlife Resources of the Utah Department of Natural Resources) to restore damaged big game habitats. Mr. Plummer directed that combined effort for many years. The cooperation continues to this day with the Rocky Mountain Research Station effort directed from the Shrub Sciences Laboratory in Provo (but with a presence at the Great Basin Experimental Range), and the Division of Wildlife Resources effort headquartered in Ephraim's Great Basin Research Center. Hundreds of species and populations of grasses, shrubs, and forbs have been tested and dozens of strains have been provided for increase and production for wildland rehabilitation and restoration including several named cultivar varieties. A culmination of this work led to the classical publication "Restoring Big Game Range in Utah" by Plummer and others (1968). This work on plant materials and techniques for rehabilitation of disturbed wildlands has been widely used and has been updated and expanded by several of Mr. Plummer's protegees from the two agencies ("Restoring Western Ranges and Wildlands"—Monsen and others 2004). This combined effort has stimulated interaction and cooperation between a score or more of scientists from both agencies. The current direction of the work is to emphasize native plants for restoration of fire ravaged lands. This effort has also been responsible, in large measure, for the growth of a native seed industry in the Intermountain West. There are several successful wildland seed companies in Sanpete County. In fact, Sanpete County is a Westwide leader in the wildland seed collection and marketing industry.

Plant phenology, vigor, and nutrition studies were also initiated by Director Sampson (Sampson and Malmsten 1926). In these studies plant growth was correlated with season, climate, and other environmental variables including clipping and grazing. These pioneering studies were among the first practical plant physiological studies geared to assay productivity of range plants in natural settings. They were made possible

Figure 86—Great Basin Experiment Station, 1952.

by the diversity of plant species and habits on the Great Basin Experimental Range. Price and Evans (1937) described the climate of the Wasatch Plateau; McCarty (1938) and McCarty and Price (1942) documented carbohydrate and growth characteristics of range plants. This quantitative work was performed in the laboratory building (now the museum) across the lawn from us. What a nice place to work in a laboratory!

Silvicultural studies never rose to the level of those on herbaceous plants, but some interesting work has occurred. An effort was made to grow ponderosa pine and other conifers in the oakbrush zone (Baker 1925a,b; Baker and Korstian 1931). Some remnant trees remain on the Great Basin Experimental Range as a result of those studies that were regarded as unsuccessful because of the pattern of summer precipitation and a soil substrate of heavy calcareous, fine-grained soils. Pioneering studies on the phenology, growth, form, root systems, climate, moisture, and soil requirements of aspen in a western setting were first done by Fredrick Baker (1925a). Followup work on aspen ecology has continued, including

Figure 87—Wasatch Plateau—watershed contouring, circa 1950.

additional work on Baker's plots (Harniss and Harper 1982; Keck 1972; McArthur and others 1999). The aspen system is in decline because of its lack of renewal by fire and other disturbances (Bartos and Campbell 1998). Currently, Stan Kitchen of the Shrub Sciences Laboratory is studying the long-term fire history of the Great Basin Experimental Range. Renewal of aspen stands is a Forest Service management priority.

Other research on the Great Basin Experimental Range was conducted and continues, for example, autecology of *Orthocarpus*, mineral cycling of various plant communities, the effect of gophers on plant succession, and roadside beautification and stabilization. I hope my examples have shown some of the depth and breadth of the research at the Great Basin Station. The Rocky Mountain Research Station, the Manti-La Sal National Forest, and Snow College's Great Basin Experimental Experiment Center continue to support research here.

Education and Training

The Great Basin Station has been a site important in the training of resource personnel. Great Basin Station Director Lincoln Ellison (Keck 1972) once remarked, in 1939, that the Great Basin may be regarded as one of two cradles of range research in this country. The other is the Jornada Range Reserve in New Mexico. It is said that almost everybody in range research has, at one time or another, worked on the Jornada, and almost the same may be said of the Great Basin. Some of these researchers received national and international recognition:

- The founding director, Arthur Sampson, became an Eminent Professor at the University of California, Berkeley, and is considered one of the founders of the formal discipline of range management—he established the first range management curriculum (at the University of California). He authored four ground-breaking and widely used text books (Sampson 1923, 1924, 1928, 1951) on range management, forage plants, and animal husbandry that were published by the New York publishing house, John Wiley and Sons. He received both the American Forestry Association's Conservation Award and the Ecological Society of America's Eminent Ecologist Award.
- Early workers Fredrick Baker and Clarence Korstian became Deans and Administrators at the Forestry schools at the University of California, Berkeley, and Duke University, respectively, and received many honors. Another early worker, W. R. Chapline, became the Chief of Range Research for the Forest Service in Washington, DC, and endowed two prestigious awards presented annually by the Society for Range Management. The second Director, C. L. Forsling, became the Director of Research for the Forest Service in Washington, DC.

Figure 88—Great Basin Experiment Station—employees and families, circa 1952.

- Director Raymond Price became a Staff Officer for research in the Washington Office of the Forest Service and subsequently a long-time Director of both the Southwest and Rocky Mountain Forest and Range Experiment Stations.
- Director Lincoln Ellison was the Lead Rangeland Research Administrator for the Intermountain Forest and Range Experiment Station when his life was cut prematurely short in an avalanche at Snow Basin in 1958. He was a highly respected research leader. Dr. James Blaisdell (1989), himself a prominent rangeland researcher and administrator wrote:

> I have fond memories of Lincoln Ellison—a gentleman, scholar, and friend…I remember his keeping a group of us out in a downpour on the Great Basin Experimental Range so that we could observe the mechanics of runoff and erosion. I recall his thorough review of manuscripts (and how) he would pause and reach for his thesaurus so that we could discuss the precise usage of keywords…. Linc Ellison was a range ecologist par excellent—many years ahead of his time in ecological reasoning and applications to range management. Many are the occasions when I have wished for his sage counsel.

  Another retired Forest Service research Range Scientist, Ralph Holmgren, recently told me how, as a young scientist, he learned from Dr. Ellison. He remembers being enraptured as Lincoln explained his discovery of how tender young plants germinated under an insulating layer of snow to get a jump on the growing season.
- Project Leader A. Perry Plummer (the terminology of administration of the Station changed) was a wonderful teacher with far-ranging impact. He knew the Great Basin Experimental Range like the back of his hand. The roadside plantings that you witnessed coming up the road are his legacy. He is a mentor to my generation, including my colleagues Steve Monsen and Richard Stevens who are here today. His work on rangeland revegetation in the Great Basin Experimental Range and elsewhere were instrumental in the establishment of the Shrub Sciences Laboratory in Provo. It was at a site at the mouth of Ephraim Canyon that the then Deputy Chief for Research of the Forest Service, V. L. Harper, after listening to Mr. Plummer's presentation and viewing some field experiments concluded "we ought to amend…the research program to include a new laboratory at Provo featuring shrub research…" (McArthur 1992). He was honored for his work by national awards from both the U.S. Department of Agriculture and from professional societies.
- Our current generation of researchers associated with the Great Basin Experimental Range has had substantive impacts on research and land management programs and policy through their research and application efforts. This work has been recognized by national awards, wide-ranging consultation, and visits by scientists from around the world.
- The Great Basin Station has been a training ground not only for those I just mentioned but also for many who have visited for various periods of time. There have been numerous field days, conferences, and workshops held here, including many of national importance. I mention a few:
  - Ecological Society of America Range Research Conference, August 1931.
  - New Building Rededication Field Day, August 1936.
  - Servicewide Range Research Seminar for the Forest Service, July 1939.
  - Society for Range Management Summer Meeting and Great Basin Experimental Range 60th Anniversary Celebration, July 1972.
  - Great Basin Environmental Education Center Ribbon Cutting Ceremony, August 1993.
  - Tenth Wildland Shrub Symposium: Shrubland Ecotones, August 1998.
  - Many others including the Utah Section, Society for Range Management Youth Camps, and Utah Educational Association Teacher Training. The tradition continues, and is expanded by the present use of the Headquarters complex—The Great Basin Environmental Education Center of Snow College.

Life at the Station

I conclude my presentation with some insights and vignettes of life at the Station. This beautiful complex has been host to a lot of living. My family and I recall the pleasant summer of 1975 when we lived in the East House while we were in transition from a work assignment from the Great Basin Station and Ephraim to the Shrub Sciences Laboratory and Provo. For the most part we, especially my young family, lived here in isolation. But in earlier years, especially the decades from the teens through the fifties, scientists, technicians, and families filled the compound and forest with life and excitement. My insights into those times are drawn mainly from conversations with members of the Plummer, Ellison, and Hansen families, and from writings of Albert Antrei (1982, 1993b, 1995) and Liane Ellison Norman (in review).

Now would be an appropriate time to mention those who, in addition to the science staff, have kept the Station beautiful and in operational form. I know that Walt Mann and George Gruschow out of the Ogden Station Headquarters made things happen. Paul Hansen was a Technician at the Great Basin Station for 47 years! Imagine all the work and love he put into the Station. Lincoln Ellison said of Paul, "a jewel—he runs the place and I take the credit" (Norman, in review). Gary Jorgensen has been a technician assigned to work at the Great Basin Experimental Range, among other duties, for 35 years. He has been up and down the canyon road literally thousands of times, taking fences up and down, as well as performing multitudinous duties here. Shake his hand if you get a chance. Thanks Gary. Now the GBEEC staff, supervised first by Steve Peterson but for several years by Dave Lanier, has restored and lovingly cared for the Center—my thanks go to them. District Ranger Tom Shore of the Sanpete Ranger District and his staff as well as many from the Manti-La Sal Supervisors Office have also worked hard and long for the good of GBEEC. I give my thanks to all. It became difficult for our Forest Service Research organization to properly fund and maintain the Headquarters complex that became the GBEEC. We are happy to partner with Snow College, the Manti-La Sal National Forest, and the community in a successful GBEEC, and to foster continuing inhouse and cooperative research on the Great Basin Experimental Range.

I return to the life at the Station in bygone days. Let me quote Albert Antrei (1993a) regarding Director Sampson:

> Sampson was a familiar figure in both Sanpete and Sevier Valleys, racing horses at county fairs. Local recollections of him have been generally friendly, and it has been said, the ladies in Ephraim were not unaware of him. Socially, again it has been said, he was in tune with Victorian concepts of the polished gentleman. Nor was he above playing teacher to the farmers. He taught local pea growers, for instance, the value of pea silage as cattle feed. Until he demonstrated it the farmers of Sanpete were accustomed to dispose of the ill-smelling stuff as quickly as possible.

Again, Antrei (1993b) on his personal experiences:

> It was on June 1 [1936] when I descended from that bus in Ephraim, and it was on a Sunday. As the bus departed, I stood alone on the corner of Main and Center Streets occupied by the D. W. Anderson Drug Company. …Before looking for the hotel, which was just around the corner, I looked up at snowladen Haystack Mountain, where the Great Basin Branch Experiment Station of the Forest Service was located. ….Between June 1 and about October 1, I went to town with other station technicians. ...I was making $125 per month, and every Saturday afternoon (we worked until noon) I went to town for a little R & R, to last until the station truck left for the station again usually around midnight. There was a movie theater in Ephraim and on Saturday nights an open-air dancing pavilion. I was not interested in church on Sunday, so on Sunday I remained at the foot of Haystack Mountain, either reminiscent or nursing a headache. Religion did not bother me, and I did not bother it. I drank a little, which in Utah is the same as drinking a whole lot, and I smoked a pipe; moderately, I thought. But here again, in Utah one curl of smoke means a forest fire. This seemed to bother the girls of Ephraim. Eventually, I quit the drinking, and if I desired, I could go months and months without a smoke, which for me was usually no more than an after-dinner thing. The weed never wound me up.

And from Antrei (1993a):

> The Station's young men were all inept at cooking and bottle-washing, and to take care of such chores, as well as to perform the art of a little mothering-at-large, in 1936 there was Annie Bartholomew to advise the field technicians on matters of social conduct and who the girls were in Ephraim. More complete rundowns of such social weight were also available from the State's road grader, Lew Christensen.

Lastly, from Liane Ellison Norman (in review):

> The Station houses were sturdy and pleasant. All had furnaces, electricity, hot and cold running water and wood stoves. None was equipped with a refrigerator; coolers, which connected kitchens with the out of doors, provided the only storage of perishables. …the Station kept a cow for milk, cream, and butter, which provided a succession of adventures. Grocery orders were phoned down to Ephraim's one general store. Whoever went down to Ephraim brought groceries, mail and library books up the 15 miles of winding, rutted road. By—1945 there were six Ellisons, three Hansens (two more to come), and six Plummers (three more to come). Many visitors brought their families. Though apparently isolated, the station seemed—at least to us children—a hive of sociability. …evening activities …brought the Station men and families together in a community during the short summers. There were lively games of tennis, horse-shoes, checkers, chess and charades; evenings spent singing around fireplace or piano; tall tales and shop talk. ….Liane (Ellison) and …Nathalie (Hansen) adopted and hand raised (a fawn—"Billy Deer")….Mrs. Bartholomew insisted that he (Billie Deer) shed tears (when he was taken to the state game preserve). The Station was an extraordinary place to grow up. It was safe and stunningly beautiful….(we) came to the Station every summer…up from Ephraim…across the cattle guard…to the place where scrub oak stunningly gave way to aspen…delicious with clean white trunks and shivering leaves….We developed large repertories of imaginative play…. The women of the Station—our mothers and the cook in the Lodge, where single men and visitors stayed—developed a cooperative social life which allowed the scientists—all of them men at the time—to make systematic observations of the plots on the Wasatch Plateau…The importance of headquarters was that it allowed the scientists to live with their families close to their field work.

Concluding Word

The Great Basin Station has a distinguished history, has provided meaningful research results, has been a meaningful training ground for natural resource professionals, and has been a place of vibrant human life and interactions. It continues to serve as a focal point for natural resource study, training, and education. It is a beautiful place. It is my pleasure to have been and continue to be a part of its continuing saga.

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