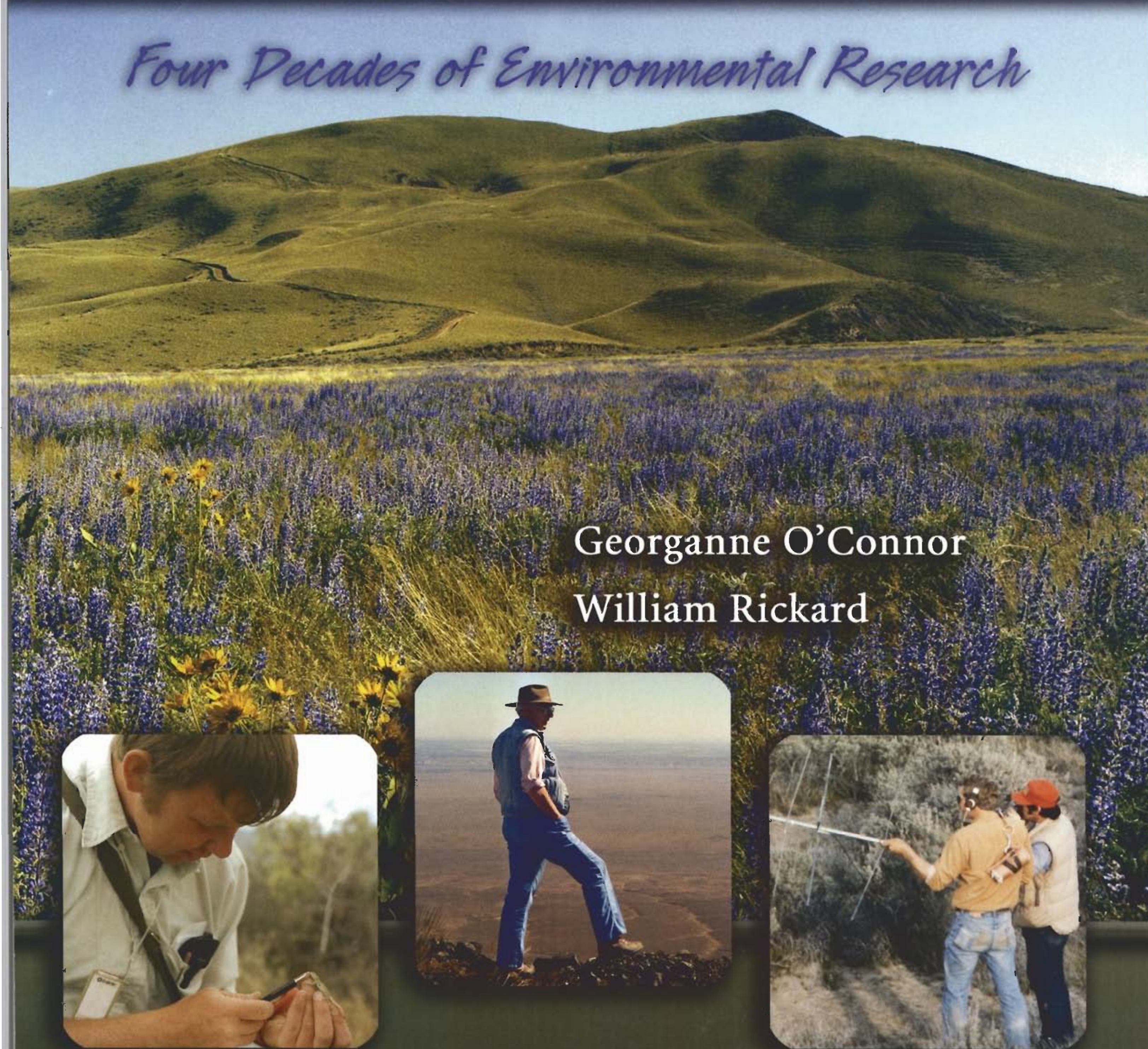
A HISTORY OF THE FITZNER/EBERHARDT

ARID LANDS ECOLOGY RESERVE

Four Decades of Environmental Research



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Pacific Northwest National Laboratory

Operated by Battelle for the U.S. Department of Energy

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A HISTORY OF THE FITZNER/EBERHARDT ARID LANDS ECOLOGY RESERVE

Four Decades of Environmental Research

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Acknowledgments

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PREFACE

When the U.S. Army Corps of Engineers acquired land for its top secret Hanford Engineer Works in 1943 and made the northeast-facing flank of the Rattlesnake Hills a safety zone, they unwittingly created an ecological refuge for native plants and animals. Sagebrush and bunchgrass, vegetation types that once covered large portions of the northwest western United States, thrived in this area.

In 1967, the U.S. Atomic Energy Commission (AEC) set aside and fenced 120 square miles of this land west of newly constructed state Highway 240 and called it the Arid Lands Ecology (ALE) Reserve. In addition to maintaining its status as a safety zone, the Reserve's specific purposes were ecological research and education.

For more than 35 years, ALE provided a research area free from human-related land-use pressures such as cultivated agriculture, livestock grazing, and urban development, which are common in other parts of the region.

Why this Book? Why Now?

Pacific Northwest Laboratory (PNL)* managed the ALE Reserve for the U.S. Department of Energy (DOE) from 1967 until 1997 when DOE transferred management of the land to the U.S. Fish and Wildlife Service (USFWS). During that time, PNNL conducted a long-range ecological research program on semi-arid ecosystems for DOE and other clients.

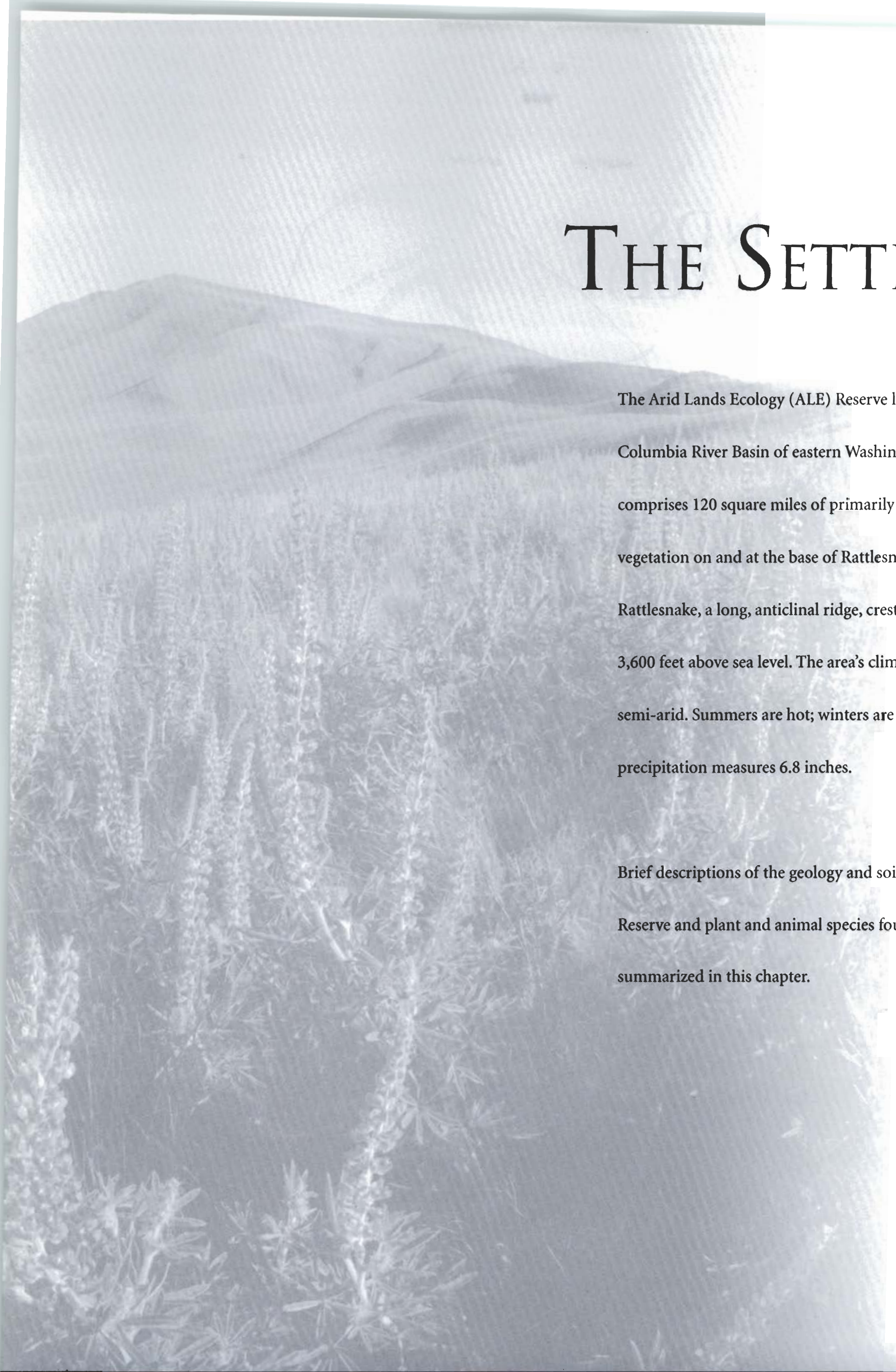
Although researchers have published individual reports, journal articles, and a book about ALE, no one document has yet addressed the need for a description of how it evolved under DOE's stewardship or summarized the breadth of research and education activities conducted on the Reserve.

The purpose of this book is to fill that need. It briefly describes the setting of ALE in Benton County, Washington; outlines historical land uses of the Reserve; describes its establishment and designations; and provides examples of the types of research and education projects conducted over four decades. A comprehensive bibliography also is provided.

As ownership of ALE is legally transferred from DOE to the USFWS, this document also serves as a record of how DOE, as a federal land manager, has preserved the ecological integrity of a unique and diminishing ecosystem.

The story of ALE would not be complete without first-hand descriptions of the Reserve from scientists and others involved in the land's long-term stewardship. An oral historian interviewed several of these individuals as part of the development of this book. Their memories of ALE and research they conducted there pepper the book. Their careers, their stories, are ALE's story too. ■

* In 1995, Pacific Northwest Laboratory (PNL) changed its name to Pacific Northwest National Laboratory (PNNL).

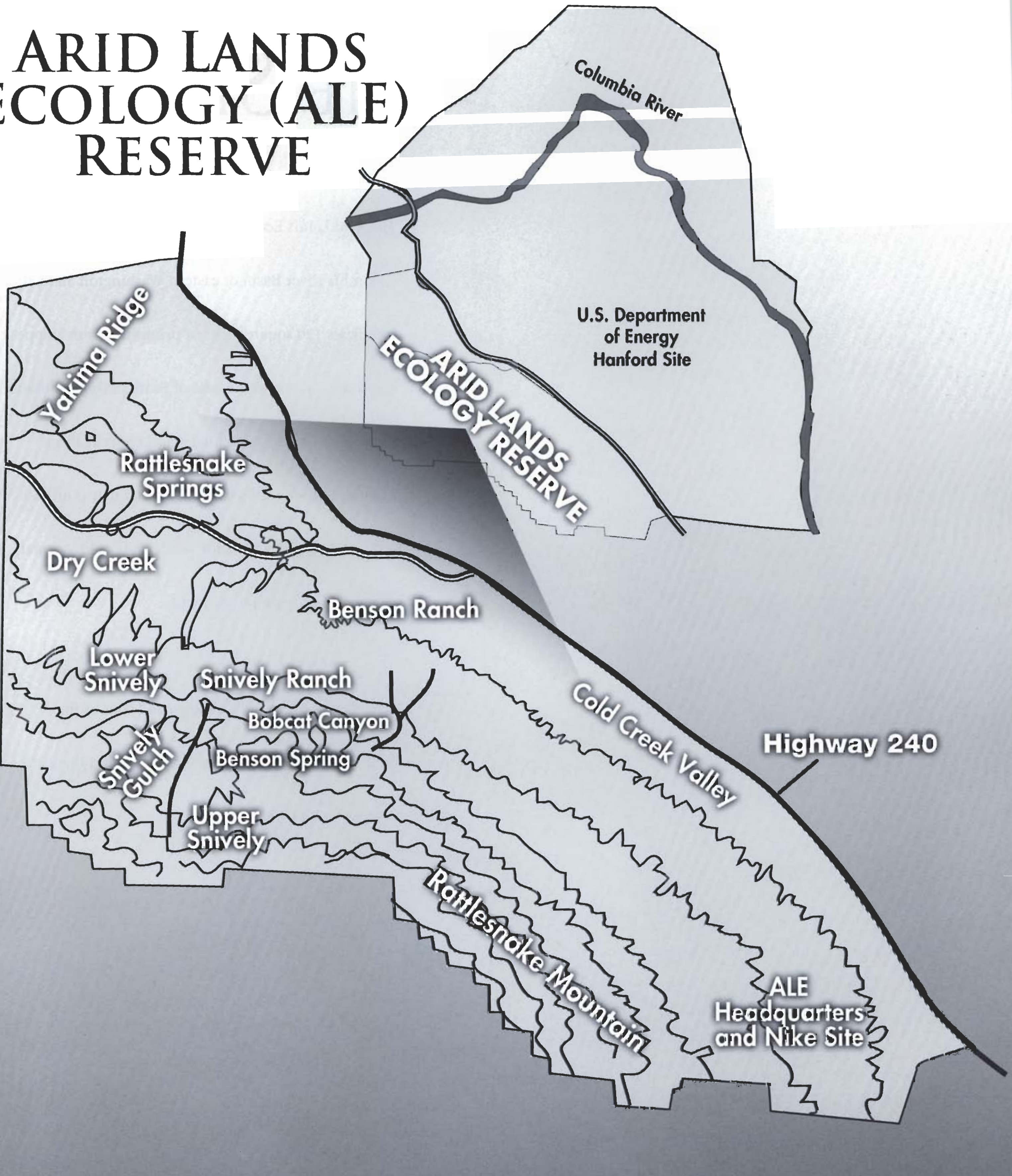


The Setting

The Arid Lands Ecology (ALE) Reserve lies in the Columbia River Basin of eastern Washington State. It comprises 120 square miles of primarily shrub-steppe vegetation on and at the base of Rattlesnake Mountain. Rattlesnake, a long, anticlinal ridge, crests at about 3,600 feet above sea level. The area's climate is arid to semi-arid. Summers are hot; winters are cold. Annual precipitation measures 6.8 inches.

Brief descriptions of the geology and soils of the Reserve and plant and animal species found there are summarized in this chapter.

ARID LANDS ECOLOGY (ALE) RESERVE





Geology and Soils

The geologic history of the Columbia Basin began about 17 million years ago when layers of molten lava began flooding across Washington, Oregon, and Idaho, creating what is now one of the largest continental volcanic provinces. Cataclysmic glacial floods millions of years later cut through the basalt layers. Rattlesnake Mountain is basaltic bedrock that has faulted and been folded upward. The Columbia Basin forms part of the Columbia Intermontane Province.

A number of different soil types occur on ALE. They vary according to elevation. On the lower and middle slopes of Rattlesnake Mountain, soils consist primarily of Warden and Ritzville silt loams. Stony silt loams, such as Kiona and Lickskillet, occur on the upper slopes. The plains along the base of the mountain contain sandy soils such as Hezel sand, Koehler sand, and Burbank sandy loam.

Vegetation

Plant communities on ALE comprise both shrub-steppe and riparian (streamside) vegetation. Shrub-steppe vegetation is found throughout the Reserve. Riparian communities are limited to narrow bands near water. These communities are briefly described below.

Shrub-Steppe

Under natural conditions, shrub-steppe vegetation includes widely distributed shrubs (sagebrush, rabbitbrush) and perennial bunchgrasses (Sandberg's bluegrass/ bluebunch wheatgrass) as well as annual and perennial forbs (balsamroot, phlox, and fleabane). A mosaic of natural plant communities occurs on ALE.

Pacific Northwest Laboratory (PNL) scientists identified six major shrub-steppe plant communities on ALE, as outlined below. The communities change with elevation, topography, and soils.

- Bitterbrush/sagebrush/Sandberg's bluegrass—This community, which occurs on flat land at the base of Rattlesnake Mountain supports needle-and-thread grass, Indian ricegrass, sand dock, and other species that thrive in sandy soil.
- Big sagebrush/Sandberg's bluegrass—This community, found between 600 and 700 feet, may include Indian ricegrass, needle-and-thread grass, and

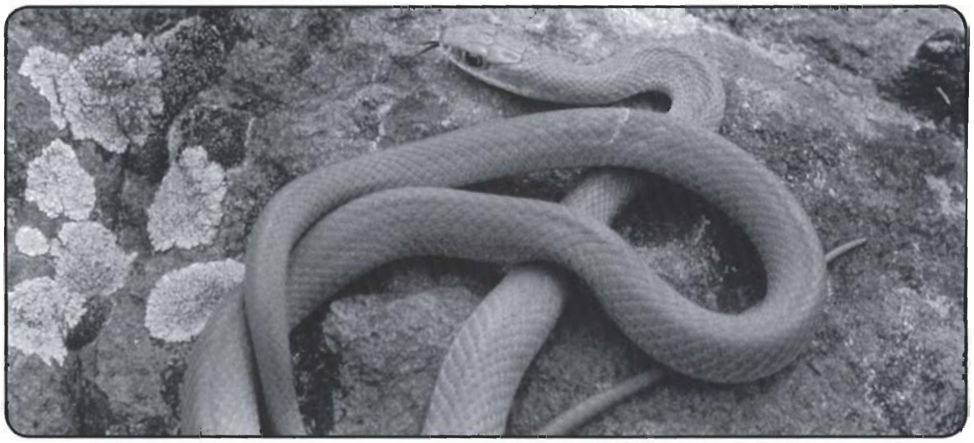
bottlebrush squirrel tail. Forbs include Carey's balsamroot and longleaf phlox. Shrubs such as spiny hopsage, green rabbitbrush, and gray rabbitbrush also may occur at this elevation. This plant community once covered about 32,000 acres of ALE.

- Sagebrush/bluebunch wheatgrass—At about 1,000 feet, big sagebrush is the dominant shrub, and bluebunch wheatgrass the dominant bunchgrass. Other plants found in this habitat include longleaf phlox, fleabane, lupine, and Sandberg's bluegrass.
- Three-tip sagebrush—This habitat occurs at 2,600 feet and above. Three-tip sagebrush as well as bluebunch wheatgrass, Sandberg's bluegrass, and Cusick's bluegrass are found in this community. This community type once covered more than 3,500 acres of ALE.
- Rocky Ridge Crest—At 3,600 feet, the crest of Rattlesnake Mountain, the plant community consists of thymeleaf buckwheat, Sandberg's bluegrass, and woolly pod milkvetch. Hood's phlox, rosy balsamroot, and narrowleaf goldenweed also are found in this habitat.
- Greasewood/saltgrass and spiny hopsage/Sandberg's bluegrass—This habitat is found only in the Dry Creek drainage near Rattlesnake Springs. Greasewood relies on root contact with the subsurface water table to survive summer drought.

In addition to these plant communities, The Nature Conservancy (TNC) of Washington located 26 populations/occurrences of nine rare plant taxa on Yakima Ridge and the north slopes of Rattlesnake Mountain. A newly described variety of milkvetch (*Astragalus conjunctus* var. *rickardii*) has been described from the crest and north slopes of Rattlesnake Mountain. The plant is named for long-time ALE botanist William Rickard, one of the individuals responsible for the establishment of the ALE Reserve and its subsequent status as a Research Natural Area (RNA).

Riparian

Two small permanent springs located on ALE—Rattlesnake Springs and Snively Springs—support riparian plant communities dominated by willow, black cottonwood, chokecherry, and mock orange. Several springs with ephemeral streamflow also are scattered across Rattlesnake Mountain. The riparian areas form narrow corridors along stream banks that provide important nesting habitat for a number of bird species.



Wildlife

ALE is home to a number of animal and bird species. Common small mammals include the Great Basin pocket mouse, coyote, black-tailed jackrabbit, deer mouse, northern grasshopper mouse, sagebrush vole, and Townsend's ground squirrel. Bobcats and badgers also have been seen occasionally. Rocky Mountain elk are the largest mammal species on ALE.

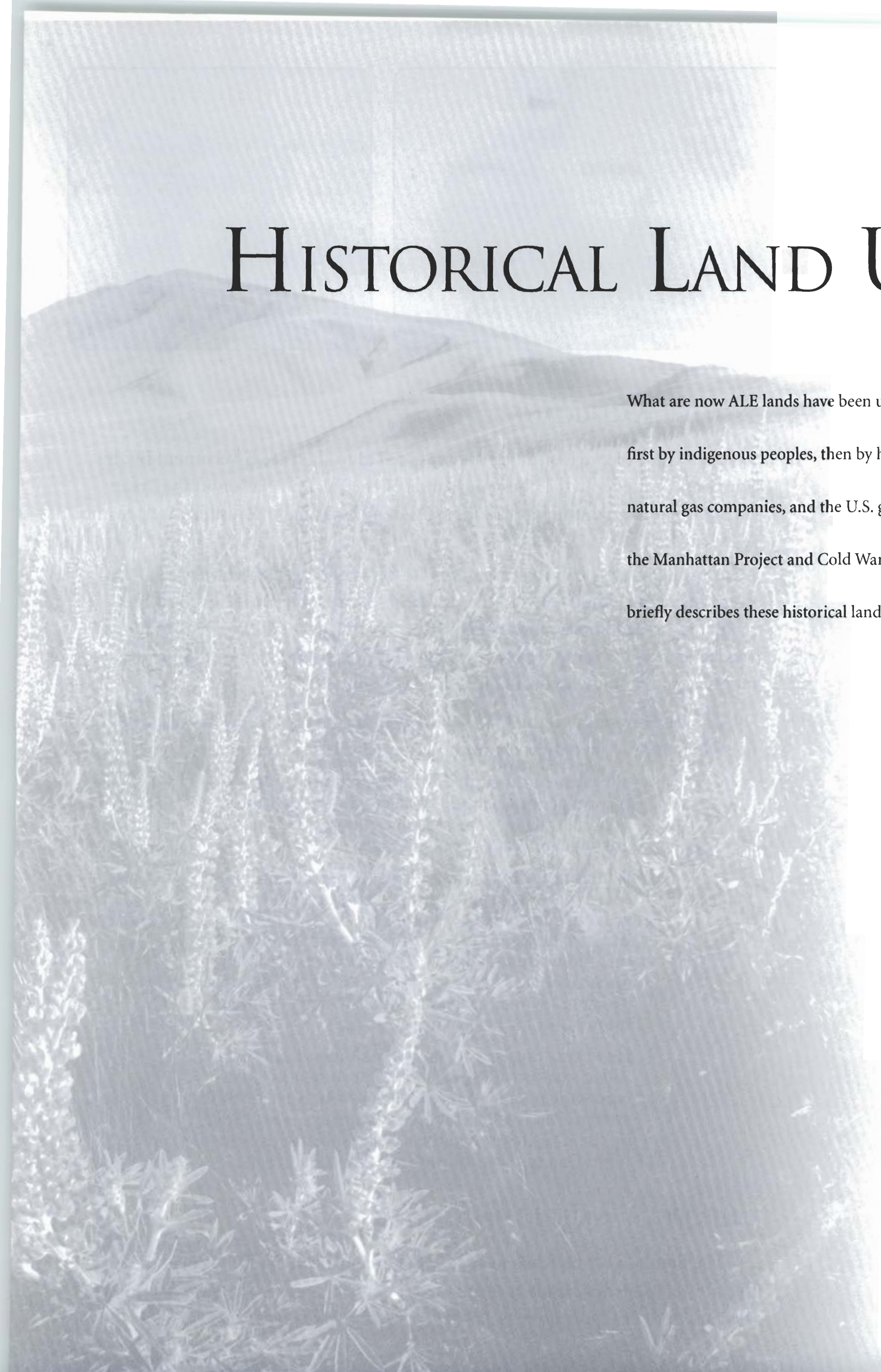
Reptiles known to inhabit the Reserve are the side-blotched lizard and horned lizard. Snakes include the western Rattlesnake, gopher snake, striped whipsnake, desert night snake, and yellow-bellied racer. The Great Basin spadefoot toad also has been reported on ALE.

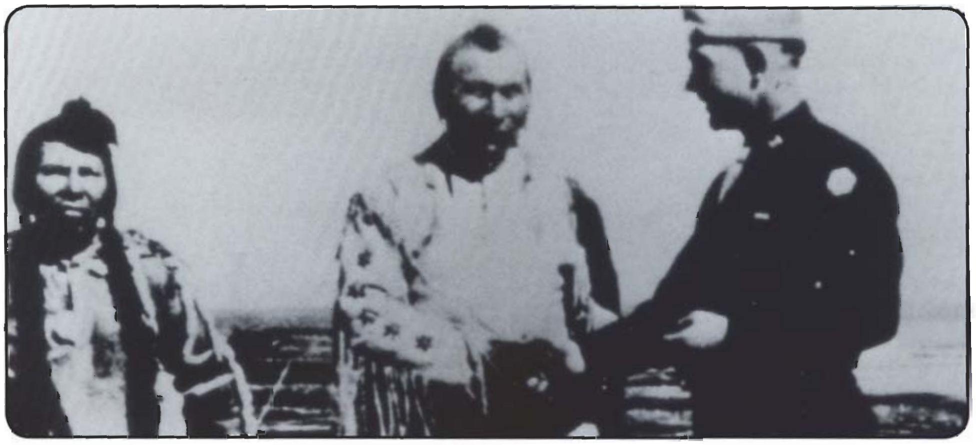
More than 1,500 species of insects have been identified in the lower Columbia Basin, many of which are found on ALE. Forty-six species of moth/butterfly taxa are known to inhabit the Reserve as well as a number of species of darkling beetles and grasshoppers.

The Nature Conservancy of Washington has documented 158 bird species on ALE. Common breeding birds on the Reserve include the western meadowlark, horned lark, vesper sparrow, and Brewer's sparrow. Riparian species include the black-billed magpie, western kingbird, and flicker. The red-tailed hawk, Swainson's hawk, ferruginous hawk, and great horned owl are some of the raptor species that have been found. ■

Historical Land Uses

What are now ALE lands have been used for centuries: first by indigenous peoples, then by homesteaders, natural gas companies, and the U.S. government during the Manhattan Project and Cold War. This chapter briefly describes these historical land uses.



Native Americans

The ALE Reserve is situated on lands ceded to the U.S. government by the Fourteen Confederated Tribes and Bands of the Yakama Nation in the Treaty of 1855. The Wanapum people did not sign a treaty, but also used what became ALE lands.

Although native cultures' use of the Reserve is not fully documented, researchers know that Native American peoples gathered plants for food and medicine, grazed horses, and used ALE for hunting grounds. Portions of the area also served as camping grounds, burial grounds, and sacred sites to conduct religious ceremonies, according to tribal representatives.

In a 1995 proposal to the U.S. Department of Energy (DOE) to acquire ALE, the Yakamas described their connection to the Reserve as follows:

> Since time immemorial, this area has provided the indigenous peoples of the region with lithic materials, wild game, seasonal roots and berries, grazing land, and burial grounds.
>
> Rattlesnake Mountain is also a sacred site and holds special significance to the Yakama people. The great religious leader, Smohalla, is known to have gone to the Ridge as a young man searching for direction. After fasting and abstaining from water for several days, he received a vision in which he was presented with a song and rituals which became the foundation for his teachings.
>
> However, long before Smohalla's time, Rattlesnake Ridge was considered a sacred location and a place where the people went to seek visions. Ancient trail systems intersect at Rattlesnake Springs. These trails tie the ALE Reserve to the known subsistence and migration patterns of the ancestral inhabitants.

European-American Settlers

The first Euro-Americans to settle what are now ALE lands began arriving in the late 1800s. Renee Hinds and Lee Rogers described how these early settlers saw the land in their report *Ecological Perspectives of Land Use History*:

> At the Horn, a place where the Yakima River makes a sharp bend at the point of a mountain, they turned north and camped at a place later known as the E.F. Benson ranch just below Rattlesnake Springs.... It was a desolate region. It is today. There are miles and miles of sagebrush inhabited only by coyotes and rattlesnakes, while eagles sail far up in the blue.

The authors credit August Eastland, who wrote *History of Benton and Franklin Counties and Other Interviews*, with this quote.

Homesteading

Euro-American settlers homesteaded ALE between the 1890s and 1940. The Snively, Benson, and Porter-Hartman families established the earliest homesteads. Homesteaders built houses with whatever wood was available in areas near reliable water sources such as Snively Springs and Rattlesnake Springs. Two ranch families (Benson Ranch and Hodges Ranch) drilled deep wells for water. Homesteaders raised sheep, cattle, and hogs and planted gardens. Some settlers tried dryland farming. But because of the arid climate, these efforts often failed, and the homesteads were abandoned.

Dryland crops such as wheat, rye, and barley (used for winter livestock feed) apparently were successful at fields high in the Rattlesnake Hills. In areas where irrigation water was available, crops such as alfalfa were grown. These sites included lower Snively field, where water was obtained from Snively Springs, and Benson Ranch, where the Benson's piped water from Rattlesnake Springs. Former residents of Benson Ranch indicated this irrigation supplied all their water.

Very little information is available on early homesteaders. However, in 2000, PNNL archaeologist Mona Wright worked with seven teachers from the Kennewick, Finley, Kiona-Benton, and Columbia school districts to prepare a paper on the Snively Ranch. These researchers visited Snively Canyon where a house foundation remains, and reviewed historic documents, photographs, and county property records to glean a better image of the Snively family.

Wright and her colleagues determined that Henry J. Snively, a lawyer and politician hailing from West Virginia, played a prominent role in local and state governmental affairs and served as legal council in Yakima for many years. They discovered that the former Snively Ranch was one of several ranches owned and

operated by the Snively family during the first half of the twentieth century, and that the ranch was not the primary family residence.

Two single wooden structures remained at the source of Snively Springs. The main house burned in 1957, and a nearby bunkhouse in 1981. The single remaining foundation and basement at Snively Springs is thought to have been either a springhouse or small single-story home. Snively's son Harry managed the ranch until the Hanford Engineer Works took over the holdings in 1943. Harley Sweany, a long-time Benton City resident and PNL research technician, assisted in the last wheat harvest at Snively field. The Snively Canyon and Rattlesnake Springs areas are now considered archaeological districts. They were named to the National Register of Historic Places in 1976.

Grazing

Ranchers used ALE lands as winter pasture (November to January), mostly for sheep. Hinds and Rogers noted that former sheep ranchers estimated that 9,000 to 15,000 sheep wintergrazed on ALE between 1880 and 1940. They said the area was ideal for grazing sheep because of its mild winter weather and abundance of winterfat, a protein-rich forage shrub. Some spring grazing occurred on ALE in the Cold Creek Valley. Sheep grazing declined as settlers fenced the land, eliminating large open areas of rangeland.

Natural Gas Production

In the early 1900s, a gas field on the north side of Rattlesnake Mountain produced natural gas for the local towns of Toppenish, Prosser, Grandview, Sunnyside, Satus, Granger, and Mabton. According to geologists, the old Rattlesnake Hills Gas Field is actually a small hill located 1 mile north of Rattlesnake Mountain. The hill is what geologists call an anticline, a fold in the earth's crust that pushes it up like an arch. Natural gas was found trapped under the arch.

The Conservative Land Investment Company first discovered natural gas in the Rattlesnake Hills in 1913 while drilling a water well. The natural gas was not developed for commercial use, however, until 1929. Flow was estimated at 70,000 to 500,000 cubic feet per day at 5.5 to 7 pounds per square inch pressure. According to the DOE Richland Operations Office (DOE-RL), 25 wells were


dug in the 1930s. The wells were given such names as West Coast #1, Northwest Natural Gas #2, and Walla Walla #3. Well depths ranged from 700 to 1,200 feet. It was believed that most gas had been removed when production operations terminated in the early 1940s.

Reportedly, seven families lived near the gas field while it operated. They acted as caretakers of the facility. The DOE-RL reported in 1993 that domestic and drilling artifacts still existed at some gas well sites. These artifacts included various types of glass containers, dinnerware, cans, and tower components.

"The Rattlesnake gas field played an important role in the history of oil and gas exploration in the Columbia Basin," according to geologists Steve Reidel, Kevin Lindsey, and Karl Fecht, who published *Field Trip Guide to the Hanford Site* in 1992.

Hanford Engineer Works: Buffer Zone

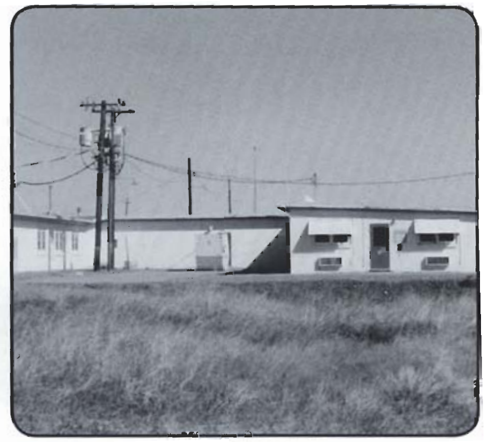
In 1943, the U.S. Army Corps of Engineers acquired the 120 square miles that make up the ALE Reserve as part of the total 640 square miles needed for the Manhattan Project. The federal government, using the authority of the War Powers Act, offered area residents compensation and ordered them to leave the area. The Hanford Engineer Works was then constructed.

"Through the initial build-up of Hanford, and subsequent build-ups during the Cold War, the ALE Reserve lands were never used to house plutonium production facilities, and neither raw materials for its manufacture nor any final products were ever stored there," DOE noted in a 1995 report. ALE land was used largely as a buffer zone. In its status as a buffer zone, "the landscape has been subject to relatively few human-induced disturbances except occasional unsolicited livestock grazing," the *ALE Management Plan* notes.

Nike Missile Site

In response to heightened Cold War tensions and the escalating international nuclear arms race, the U.S. Army developed Nike Ajax missile defense systems. They located four Nike installations (batteries) on the Hanford Site: three on the Wahluke Slope and one (H-52) on ALE. These facilities were part of the Army's Camp Hanford, which was established in North Richland in 1950 to provide air defense of Hanford.





All four Nike "batteries" consisted of a control center, launch area, and associated barracks and administration building. "Each Nike missile site had two launch sites, two underground missile storage magazines, 20 Ajax missiles, and eight launchers," Hanford historian Dave Harvey said in *History of the Plutonium Production Facilities at the Hanford Site Historic District*. On ALE, the control center was located on the crest of Rattlesnake Mountain. The launch areas were located at about 1,200 feet, at what eventually became ALE headquarters. Barracks were located in both areas.

The Nike missiles were deactivated between 1958 and 1960. Of the four installations built on the Hanford Site, only the ALE launch and radar control site remain relatively intact, Harvey noted. ■

Interview with David G. Rice

Archaeology

My first opportunity to visit Project ALE lands was in summer 1968 when I was tasked by the National Park Service to conduct an archaeological reconnaissance of Hanford Site lands away from the Columbia River for the Atomic Energy Commission. My escort was Randall E. Brown, Battelle geologist. We concentrated our field efforts in two locations where artifacts and lithic debitage had been previously noted by Hanford Site biological and geological staff.

Snively Basin and Ranch

The ranch was a pre-Hanford Site feature dating from the 1920s. It consisted of two main building structures and some minor fences and corrals. These were in large part intact, but very run down. I observed prehistoric lithic debris in the soil exposed around the buildings. Mr. Brown pointed out a rock outcropping in the east canyon wall across from the ranch that contained metamorphosed pumicite that resembled obsidian or ignimbrite. This may have been a local stone source for making small lithic tools in prehistory. Similar lithic material had been observed on Locke Island during the survey for the Ben Franklin Dam reservoir during the fall of 1967.

As we walked past lower Snively Springs and out of the mouth of Snively Gulch, facing more to the north, small concentrations of flakes and late-period projectile points were found in two locations and recorded as sites. On the flat to the north, the area had been cleared and leveled as a landing strip for small aircraft.

It appeared to me that the locality was important in prehistory because Rattlesnake Creek was a water source surrounded by arid lands, protected by Snively Gulch from the wind. It provided a gateway to resources in the Rattlesnake Hills to the south and west, and was close to Rattlesnake Springs to the northeast. I thought that enough sediment filled the floor of lower Snively Basin and Snively Gulch to preserve archaeological materials from many time periods if one had the opportunity to do some testing.

Rattlesnake Springs

Large plants of greasewood and sage surrounded the area of Rattlesnake Springs. Within the springs, a multitude of small water plants and shrubs abounded. At the springs, the water was about 25 feet below the top of the surrounding banks. The banks exposed a double-banded layer of volcanic pumicite. Mr. Brown had attributed this layer to Glacier Peak at about 12,000 years ago, and he pointed out that it was deposited in water. (I believe that more recent studies have identified the double-banded ash as belonging to Mt. St. Helens and Glacier Peak dating between 11,250 and 12,000 years ago).

Lithic material in the form of cryptocrystalline chunks, flakes, and spalls were scattered all along the top of the spring, particularly on the north side. Numerous pieces of basalt fire-modified rock from prehistoric camp fires was also observed there. It was clear to me that the site had much potential for temporary occupations ranging from historic times into Early Period prehistory.

Rattlesnake Mountain

On a separate occasion during the summer of 1968, Norm Fuller, AEC Director of Real Estate Division, suggested that I should examine a spring located a short ways down the northeastern side of the summit of Rattlesnake Mountain. He said the Army built a paved road leading down to the spring in order to construct a pumping station. He said that many artifacts had been reportedly found there by AEC security staff.

On my own I was able to visit this spring. It had been heavily disturbed by the Army construction, but contained definite evidence of sporadic prehistoric visitation. I personally noted flakes of obsidian, cryptocrystalline rock types, opal, and petrified wood. There was also the preserved remains of freshwater mussel shell in the still intact midden deposit.

Later in the summer of 1968, Francis J. McHale, AEC Director of Security, told me that 1920s Hanford-White Bluffs town pioneers used to see a seasonal vegetative change on the side of Rattlesnake Mountain at this spring where Indian travelers tethered their horses. Harry Anderson, Security Division, told me you could see this vegetative patch from the Hanford townsite.

I was never successful in having enough time to determine just where this feature was located or which plants were responsible for the sighting on the mountain. Also, I was never able to visit the spring at the toe of the slope, where I suspect there is another prehistoric site.

Rattlesnake Mountain Lower Northeast Slope

During the Hanford Site Cleanup Program in 1976-1978, I followed J.A. Jones Company cleanup crews along the 1,200 foot road. We visited gas well sites and three related personnel housing sites dating from the late 1920s-1930s. The structures were dilapidated, consisting only of a few walls and foundations. There were intact dumps with household historic material. I observed a Troy firebrick at one of the gas wells.

Cold Creek Valley North of Rattlesnake Springs

In 1985-1986, I conducted archaeological surveys of drill hole pads and water trenches for the Basalt Waste Isolation Project. Some of these extended onto ALE lands in the Cold Creek Valley between Rattlesnake Springs and the 200 West Area. The valley had just had an extensive grass fire, so the entire ground surface was exposed (but blackened).

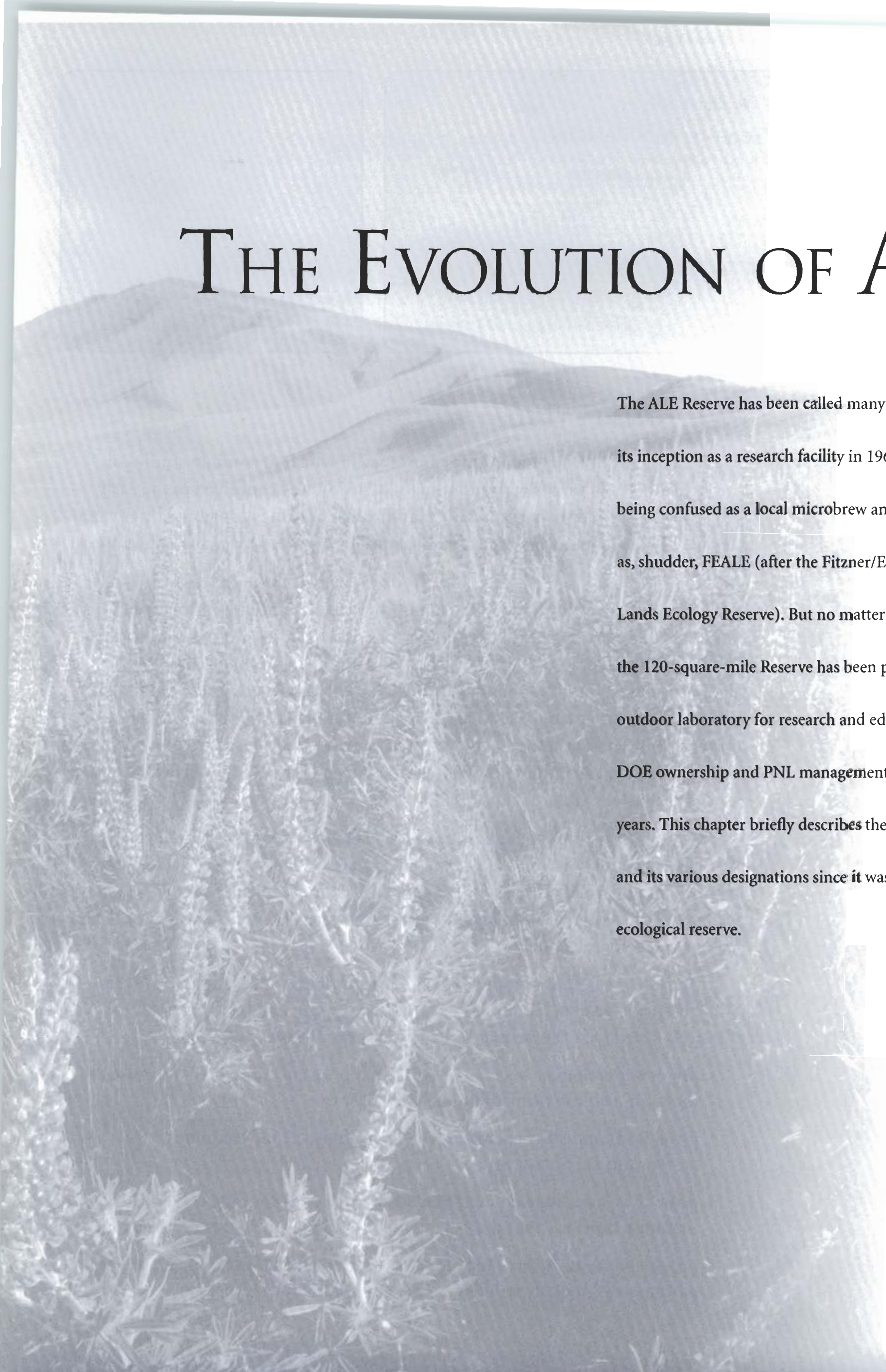
It was possible to see several places where seasonal water from Cold Creek gushed to the surface. No archaeological sites or isolated finds were identified. However, I have since felt that seasonal freshets along Cold Creek served many a prehistoric campsite, and that evidence for small campsites will eventually turn up when there is some erosion. The surface burn exposed what appeared to me as one of the old White Bluffs wagon road beds leading from the 200 West Area to Rattlesnake Springs. I reported on this to Rockwell Hanford as an historical feature.

Former Nike Missile Site

In 1990-1991, as part of the Corps of Engineers Formerly Used Defense Sites Program, I compared surviving buildings and structures comprising the former Nike site at Hanford with original as-built drawings. The site is significant as the best preserved Cold War Era Nike installation at the Hanford Site. This preservation is in no small part related to the reuse of the facility as the Ecology Reserve Headquarters.

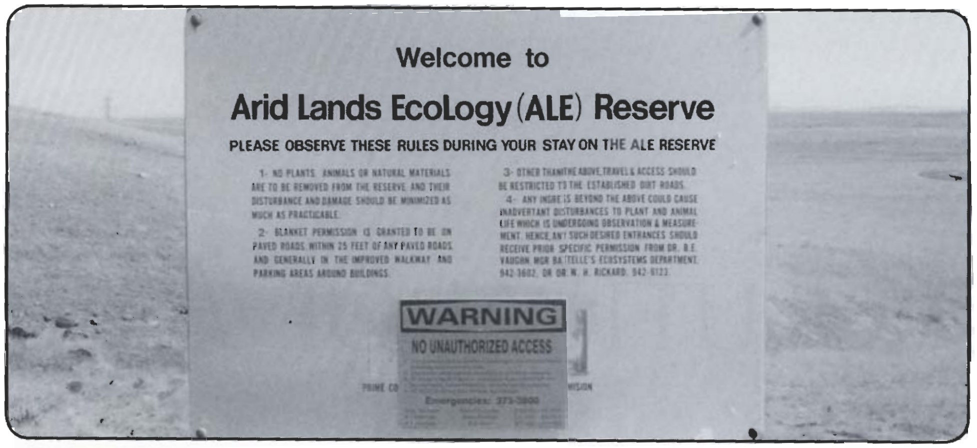
I hope this gives some impression of the level of investigation and findings as a result of my various site visits on Project ALE lands.

—DAVID G. RICE is a senior archaeologist with the U.S. Army Engineer District, Seattle. This "interview" was received as a memorandum from Rice to Darby Stapp, manager of the Hanford Cultural Resource Laboratory (February 2003).



The Evolution of ALE

The ALE Reserve has been called many things since its inception as a research facility in 1967, including being confused as a local microbrew and referred to as, shudder, FEALE (after the Fitzner/Eberhardt Arid Lands Ecology Reserve). But no matter what its title, the 120-square-mile Reserve has been preserved as an outdoor laboratory for research and education under DOE ownership and PNL management for more than 30 years. This chapter briefly describes the creation of ALE and its various designations since it was established as an ecological reserve.



ALE Reserve (1967)

The concept of a large, outdoor laboratory in which to conduct studies of native plants and animals without human intrusion was conceived in the early 1960s. Botanists and managers of the Hanford Laboratories (operated by General Electric [GE] Company) and AEC managers all recognized the value of Hanford lands as an ecological oasis.

Because the Hanford Site had been off limits to the public for decades, it contained large areas of native habitat in pristine or near-pristine condition. The landscape that contained the largest areas of near-pristine habitat was the Rattlesnake Hills and portions of the adjacent Dry Creek and Cold Creek valleys. This land encompassed large patches of native plants and associated animals, soil types, and topography representative of the shrub-steppe ecosystem that covered much of the semi-arid northwestern United States before Euro-American settlement.

In an effort to conserve this land, in 1962 the AEC began to fence the area west of Highway 240 to the crest of the Rattlesnake Hills to exclude trespassing livestock and off-road vehicles. In 1967, by AEC administrative order, this area was designated the Arid Lands Ecology Reserve and "permanently" set aside for desert ecology research and education.

In July 1973, PNL researcher Tom O'Farrell published an article on "Project ALE" in *Pacific Search*, a regional natural history journal. In the article, O'Farrell noted that the primary purposes of the Reserve were to:

- preserve portions of vegetation types that once covered a great expanse of the semi-arid interior Columbia River Basin
- provide an undisturbed system where ecologists could examine environmental questions
- provide an area large enough that ecologists could conduct controlled manipulations without destroying the integrity of the natural system
- provide field study areas for the scientific and education community, particularly graduate students in the environmental sciences.

Former ALE researcher William Rickard said ALE was created with the help of Dr. Rexford Daubenmire (professor of botany and plant ecology, Washington State University), Dr. John Wolfe (chief, Ecological Research Division, AEC Headquarters), Mr. Herbert M. Parker (manager, Hanford Laboratories, GE), Dr. William Rickard (biological scientist, Hanford Laboratories), Mike Tiernan (program manager, AEC, Richland Field Office), and others.

"The vision and determination of these people brought to our area an important research facility that has, for four decades, enabled scientists and students to study a relatively undisturbed shrub-steppe ecosystem," Rickard said.

Rattlesnake Hills RNA (1971)

Four years after ALE was created, it was designated the Rattlesnake Hills RNA as part of a five-agency federal cooperative agreement under the Natural Area Preserves Act. Research Natural Areas were created to assist in preserving the natural diversity of Washington and Oregon. They represent examples of important regional terrestrial and aquatic ecosystems. More than 100 RNAs exist in the Pacific Northwest.

The purposes of an RNA are to:

- preserve examples of all significant natural ecosystems for comparison with those influenced by man
- provide education and research areas for ecological and environmental studies
- preserve gene pools of typical and endangered plants and animals.

Federal agencies who administer RNAs in the Northwest include the U.S. Forest Service, National Park Service, U.S. Bureau of Land Management (BLM), USFWS, and DOE.

In a 1994 letter from the U.S. Forest Service's Pacific Northwest Research Station to Janet Anderson, Special Assistant to the Secretary of Energy, Hermann Gucinski described the value of ALE as an RNA as follows:

ALE is a critical area as it is one of the only remaining examples of a naturally functioning shrub-steppe ecosystem found in Washington. It is also the biggest remaining example of the generic shrub-steppe ecosystem found in the United States. Its large size is of importance.... It is quite unusual to have an area available for long-term environmental monitoring and research that permits addressing factors that operate at a landscape scale.

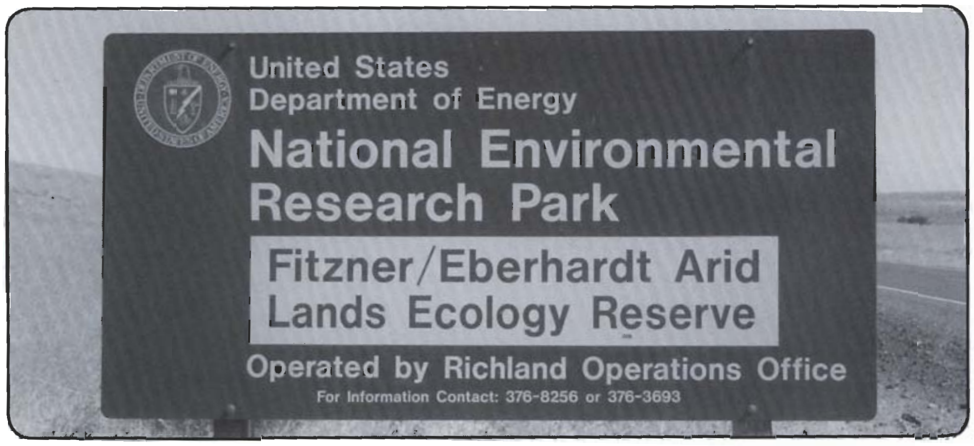
Over the years a substantial body of inventory and monitoring data has been collected at the ALE site. Though this body of knowledge has value in and of itself, its real value lies in its ability to describe a baseline which then serves as a basis to detect and follow changes in environmental trends. These kinds of data represent a considerable financial and temporal investment....

The value of this site is enhanced because over the years ALE has also developed a strong research program, in concert with the inventory and monitoring efforts. The personnel and infrastructure that are currently in place provide an historical context and institutional memory that has great value.

National Environmental Research Park (NERP) (1977)

Ten years after ALE became a Reserve, the DOE dedicated portions of the Hanford Site, including ALE, as a NERP. The Hanford NERP was one of seven DOE established across the nation in six major ecoregions covering more than half of the United States. The other NERPs were located at the Idaho National Engineering Laboratory (Idaho), Fermilab (Illinois), Oak Ridge (Tennessee), Savannah River (South Carolina), Los Alamos (New Mexico), and the Nevada Test Site (Nevada).

The NERP concept was an outgrowth of the National Environmental Policy Act (NEPA) of 1969, the Energy Reorganization Act of 1974, and the public's desire, at the time, to protect the environment. The idea also was consistent with a 1969 Federal Council for Science and Technology policy statement that



encouraged national laboratories to make their unique research and training facilities available to a broader spectrum of the scientific community.

The mission of the NERPs was to conduct research and education activities that would:

- develop methods for assessing and documenting the environmental consequences of ongoing and proposed energy development
- explore methods for eliminating or minimizing predicted adverse effects of various energy and weapons activities on the environment
- train people in ecological and environmental sciences
- use the parks for educating the public on environmental and ecological issues.

The ALE Reserve was a segregated portion of the Hanford NERP dedicated to long-term preservation of pristine vegetation. Only nondestructive modulation experiments could be conducted at ALE (i.e., those that did not irreversibly alter the landscape, such as controlled grazing or modifying precipitation by controlled overhead sprinkling).

In an internal report, DOE said the research parks were important because they provided secure settings for scientists to conduct research on a broad range of subjects, such as plant succession, biomass production, environmental behavior of radionuclides, and the cost and effectiveness of rehabilitation of disturbed lands.

DOE also said the parks provided rich environments for training researchers and introducing the public to ecological sciences. In addition, because the parks were associated with the extensive laboratory facilities of DOE national laboratories, a stable infrastructure and cadre of environmental scientists were available as resources for visiting researchers and the public.

The DOE considered ALE the most valued portion of the Hanford NERP because, as an environmental research area for four decades, it created a wealth of scientific baseline data invaluable for assessing environmental change.

The ALE portion of the NERP also supported DOE's long-term environmental quality mission. Applied research conducted there supported environmental restoration and operations through such studies as the following:


- evapotranspiration at the field lysimeter facility in support of unsaturated flow modeling for the Hanford Site
- animal burrowing characteristics to support biointrusion-resistant barrier design of low-level waste internment facilities
- groundwater recharge
- seismic studies to provide data support and structural design criteria for Hanford facilities, which supported public and worker safety.

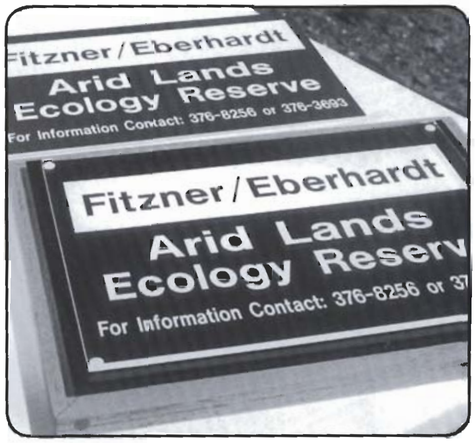
Fitzner/Eberhardt Arid Lands Ecology Reserve (1993)

An act of Congress renamed ALE in 1993. Public Law 103-60, Title 11, Section 1177, signed into law November 30, 1993, states, "The Hanford Arid Lands Ecology Reserve in Richland Washington, is redesignated as the Fitzner/Eberhardt Arid Lands Ecology Reserve."

The new name honors Richard E. Fitzner and Lester E. Eberhardt, two PNL research scientists who died June 3, 1992, in a plane crash while studying wildlife near Yakima, Washington. As career wildlife biologists, Dick and Les contributed to wildlife studies on ALE and the larger Hanford Site. Fitzner studied reptile and amphibian populations and Hanford's raptors, especially bald eagles, ferruginous hawks, and Swainson's hawks. He also studied bats, Canada geese, and small mammals. Fitzner joined PNL in 1970 and earned a Ph.D. on the life history of the Swainson's hawk in southeastern Washington.

Eberhardt earned his doctorate studying the ecological behavior of juvenile Canada geese on the Hanford Reach of the Columbia River. He also studied deer and elk and was an expert on using radiotelemetry. Eberhardt and students conducted many of the studies of the Rattlesnake Hills elk herd. He joined the laboratory in 1978.

Wildlife studies conducted by Fitzner and Eberhardt contributed important scientific information to the understanding of how animal species live in semi-arid habitats. Both scientists were known locally for extensive interactions with the Tri-Cities campus of Washington State University and their support of university



and pre-university education programs at PNL. They left a legacy of well-trained students and knowledge that served as a basis for continuing efforts.

The 53rd Washington State Legislature initiated the original drive to rename the Reserve for these scientists. In March 1993, the Legislature passed House Joint Memorial 4007 (by unanimous vote) petitioning President William Clinton, the Congress, and Secretary of Energy Hazel O'Leary to name ALE the "Fitzner and Eberhardt Arid Lands Ecology Reserve."

State Representative Lane Bray (of Richland) worked with Senator Patty Murray and Congressman Jay Inslee to ensure House Joint Memorial 4007 was federally enacted as an amendment to the Fiscal Year 1994 Defense Authorization Bill.

The September 13, 1993, *Congressional Record* notes Representative Inslee's support for this measure: "In recognition of their highest contributions made to the scientific community, I ask that the Congress honor the achievements of Dr. Fitzner and Dr. Eberhardt with passage of this amendment," Inslee said.

Management Transfer of ALE (1993-1997)

In 1993, with the change in mission at Hanford from plutonium production to environmental cleanup, DOE-RL began the process of releasing clean tracts of land "potentially excess to DOE mission needs" for other uses. ALE was one such tract of land.

In accordance with federal laws regarding management and disposal of federal property, the General Services Administration notified other federal agencies of the availability of the property. In response, in spring 1995, the BLM and the Yakama Nation submitted proposals to take over the land.

In May of that year, Washington Governor Mike Lowry and U.S. Secretary of Energy Hazel O'Leary jointly sponsored a facilitated meeting in Richland to discuss future uses and management options for the Reserve. The BLM and Yakama Nation made presentations on their proposals at the meeting.

Proposals from Benton County, Washington, and the Alliance for the Advancement of Science through Astronomy also were discussed. Members of the audience were given an opportunity to provide oral and/or written comments. Of

the 26 persons who spoke, nearly all supported the continued preservation of ecosystems on ALE by maintaining it as a research and/or educational facility.

Secretary O'Leary reviewed all the proposals submitted, and in August 1996, announced that DOE would remain in control of ALE. In a letter to the Yakama Nation O'Leary said, "A change in ownership would result in unacceptable cost to the Department in meeting standards imposed as a result of a change in the site boundary."

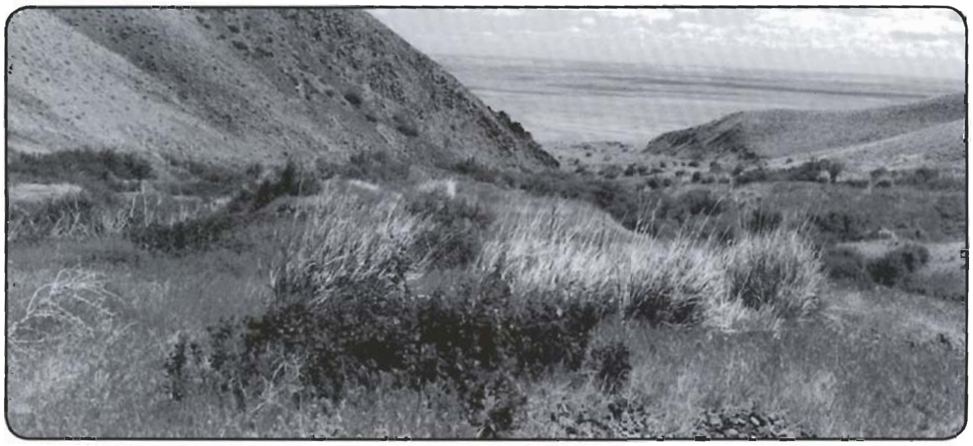
O'Leary also said that "...the Department intends to enter into an agreement with the U.S. Fish and Wildlife Service to manage the area to protect its natural resources and cultural values, while allowing increased access for appropriate activities."

A year later, on August 27, 1997, U.S. Secretary of Energy Federico F. Peña signed an agreement with the USFWS to operate ALE. Under terms of the agreement, DOE remained the owner of the Reserve, "...but the Fish and Wildlife Service will supervise it." Also under the agreement, the USFWS was to prepare a comprehensive management plan for the Reserve.

"It was an accident of history that preserved the Reserve since we needed it as a buffer to ensure secrecy for the weapons work being done at Hanford," Peña said. "It's our responsibility to ensure that the Reserve will remain a source of joy and wonderment for future generations."

The DOE-RL's primary objective in entering into the agreement was to ensure ALE was managed as a safety and security buffer for ongoing Hanford missions. The USFWS' main objective was to ensure ALE was operated and managed for the protection and preservation of native shrub-steppe habitat and associated wildlife species. Common objectives included ensuring that:

- the integrity of ALE as an intact resource was maintained
- ALE was managed as a resource to be used by Native American peoples for religious and cultural purposes
- access to ALE was available for the educational, scientific, and recreational benefit of the public to the extent access was consistent with other objectives.



HANFORD REACH NATIONAL MONUMENT (2000)

Less than three years after transferring management responsibility of ALE to the USFWS, ALE lands became part of the newly created Hanford Reach National Monument. President William Clinton established the Monument under the American Antiquities Act on June 9, 2000. Vice President Al Gore made the announcement from the shores of the Columbia River in Richland that day. "These lands are among America's treasures, and we owe it to future generations to preserve them," Gore said.

Presidential Proclamation 7319 set forth direction for the USFWS to manage the monument in coordination with DOE. The USFWS divided the 195,000-acre Monument into five administrative units. ■

Four Decades of Environmental Research

Research mimics the times.

William H. Rickard

This chapter summarizes environmental research conducted on the ALE Reserve over four decades (1960s-1990s). Although DOE and its predecessors—the AEC and Energy Research Development Administration (ERDA)—have sponsored environmental monitoring programs on what is now ALE since 1944, arid land ecological research didn't begin until the 1960s.

At that time, the AEC's Division of Biology and Medicine in Washington, D.C., provided funding for studies to understand how the shrub-steppe ecosystem (or what was then called desert steppe) functioned. As part of the DOE work, researchers investigated plant, animal, and desert stream ecology; microclimatology; and soils/soil-water dynamics. Quantitative ecological investigations also were conducted.



Types of Research Conducted

Plant Ecology

Early botanical investigations documented species composition, distribution, and abundance of plant communities. Other studies identified abiotic factors controlling primary production and the influence of plant communities on animal abundance.

Researchers explored how arid land biota responded to natural and human-induced stresses and addressed such questions as the response of shrub-steppe plants to burning and extreme weather; rate of self recovery of abandoned farm land; uptake of radionuclides and stable mineral elements from soil by rangeland plants; response of rangeland plants to persistent livestock grazing; and the distribution and relative abundance of rare, threatened, and endangered species.

Animal Ecology

Research on animal ecology focused on investigations of small mammal population structure, function, and abundance; irradiation studies; studies of the main insect groups of arid lands, particularly ground-dwelling beetles; and baseline surveys of bird abundance. Later studies investigated animal responses to natural and human-induced changes in the rangeland environment. This work was closely integrated with plant ecology studies.

Desert Stream Ecology

Aquatic studies at ALE investigated the physical, chemical, and biological characteristics of Rattlesnake Springs, primary productivity, and invertebrate populations. At the time the work began, little was known about the function of cold desert springs and streams. This pioneering research was conducted largely by Colbert E. Cushing and his graduate students.

Microclimatology/Micrometeorology

The purposes of microclimatological investigations were to identify and describe microclimates within ALE and test for statistically valid correlations of temperature and precipitation at ALE with those made at the Hanford Meteorology Station. These studies supported investigations of plant phenology, evapotranspiration, and other interactions between the atmosphere and living organisms. This research

combined the work of ecologists and Hanford meteorologists, creating a combined expertise that was generally not available elsewhere.

Soils/Soil-Water Dynamics

The purpose of early soil studies was to classify and map the distribution of soils. Then investigators looked at the role of soil microbes in the flow of energy and cycling of mineral nutrients within the arid land ecosystem; the influence of soil temperature and moisture on soil respiration rate and the role of mineral weathering processes; and correlations between soil properties and the distribution of plant communities. Soil-water dynamics research focused on studies of the basic mechanisms that control ecosystem functions. Researchers investigated how arid land ecosystems use water, carbon, and nitrogen. They also looked at energy balance and the interrelationships between internal dynamics, microbial ecology, and plant growth.

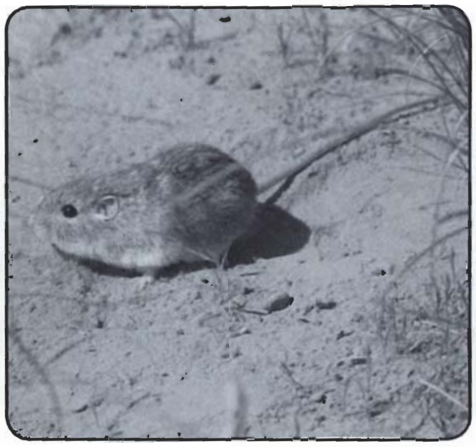
Quantitative Ecology

All ALE research projects contributed to the quantitative and modeling capability. Work in this area included developing a quantitative sampling methodology for field studies, including sample survey designs and census methods; developing a quantitative rationale for the study of basic productivity in ecosystems; and synthesizing field data into mathematical models with predictive capabilities.

Other

In addition to ecological work, other studies were conducted on ALE related to surface and groundwater hydrology, geology and paleoecology, cultural resources, gravitational physics (at the Gravitational Physics Laboratory), and space sciences (at the Space Science Laboratory and Rattlesnake Mountain Observatory). These investigations are not described here.

Instead, the following sections provide examples, by decade, of ecological studies conducted on ALE. Representative sample research descriptions were selected from annual reports to the AEC/ERDA/DOE, which were edited for many years by Burton Vaughan and Raymond Wildung. The level of detail provided for each example is based on the level of detail provided in these reports. For more information on these studies, see the Bibliography. ■


1960s: Ecological Research Beginnings

Early field studies at ALE were designed to test the combined effects of ionizing radiation and other environmental stresses on field populations of plants and animals. These studies initially were conducted by scientists and technicians employed by GE, which operated the Hanford Laboratories for the AEC from 1947 through 1964. The first ecology studies on land that is now a part of ALE began in the early 1960s. Research began with aquatic studies conducted at Rattlesnake Springs, as described in personal interviews with William Rickard and Colbert Cushing at the end of this chapter.

1965—Worldwide Fallout

Battelle's management of the AEC's research and development activities at PNL began in 1965. The studies were concerned with the effects of releases of radionuclides to air, soil, and water. That year, "arid land ecology studies" was cited as a priority research area in the annual report. Two ecological studies were conducted at ALE in 1965, both conducted by W.H. Rickard, the sole terrestrial ecologist. These studies are briefly described below.

- ***Cesium-137 in Winter and Summer Annuals of a Desert Steppe Environment (W.H. Rickard)***

  Purpose: To determine if common annual rangeland plants of arid and semi-arid regions could be used as biological indicators of yearly or subyearly deposition of cesium-137 present in worldwide fallout. Previous studies had used crop plants grown in experimentally contaminated soil in laboratory conditions to measure root uptake of various radionuclides.

  Method: The concentration of cesium-137 in cheatgrass, a winter annual, and Russian thistle, a summer annual, growing on the same quadrants located in an abandoned field were analyzed to determine the concentrations of radioactive cesium inside or on the surfaces of plant stems or leaves.

  Conclusions: Annual rangeland plants could be used as an indicator of the yearly or subyearly accumulations of cesium-137 and provide estimates of the amount of cesium likely to be ingested by herbivorous mammals and birds.

- ***Year-to-Year Changes in Darkling Beetle Abundance (W.H. Rickard)***

  Purpose: To estimate the number of adult autumn emergent darkling beetles in a representative sagebrush-grass habitat at Rattlesnake Springs and determine year-to-year changes in abundance related to environmental variables such as weather and primary productivity.

  Method: Pitfall trapping was conducted in the fall of 1963, 1964, and 1965.

  Conclusion: A 3-year decline in the darkling beetle population was observed. The investigator concluded that the decline may have been related to a concurrent decline in the yield of herbaceous plants. Later studies in this same habitat into the 1990s showed that beetle populations never regained the same abundance as in the 1960s.

1966 —Project ALE

Environmental studies focused on radioactive materials bioaccumulation and basic ecology in 1966. The annual report to the AEC for that year noted that, "…at year end prospects appeared excellent for the establishment of a large segment of the Hanford Reservation as a long-term ecology study area. This is known as Project ALE, signifying Arid Land Ecology, a representative segment of shrub-steppe habitat, one of the most extensive ecosystems in the United States." Two ecological studies conducted in 1966 are described below.

- ***Effects of Radiation on Native Rodents (T.P. O'Farrell and G.E. Cosgrove)***

  Purpose: To investigate the responses of small mammals to acute ionizing radiation. The study sought to determine $LD_{50/30}$ values for mammals native to the Hanford Reservation. These values were needed to plan field studies designed to test the combined effects of radiation and environmental stresses on natural populations of indigenous species.

  Method: A total of 180 Great Basin pocket mice and 90 deer mice were captured on ALE and irradiated with a 10,000-Ci cobalt-60 source. All deer mice and 90 pocket mice were irradiated at a dose rate of approximately 590 rads/minute. The remaining pocket mice were irradiated at about 90 rads/minute. Weights were taken at four different times postirradiation. Dead animals were weighed, necropsied, and fixed in formaldehyde. Tissue samples were prepared for histological examination.



Conclusions: Great Basin pocket mice were less resistant to acute ionizing radiation than deer mice. Secondary effects of radiation included prolonged testicular atrophy in deer mice and extensive loss of hair and loss of muscle tone in the cheek pockets of Great Basin pocket mice. The authors concluded that these effects could be important mortality factors under natural conditions. Loss of hair would immediately upset a part of the hygro-thermo regulatory capabilities that are important to survival of desert species. Loss of control over pockets needed to transport seeds would force pocket mice to rely on available underground caches of seeds or spend more time aboveground eating seeds as they are found, thus exposing the species to greater predation.

- ***Altitudinal Distribution of Eleodes hispilabris on the Hanford Reservation (W.H. Rickard)***

  Purpose: To determine the relative abundance and seasonal distribution of the ground-dwelling darkling beetle *Eleodes hispilabris* at different elevations ranging between 500 and 3,100 feet on the slopes of Rattlesnake Mountain.

  Method: Abundance was determined by weekly catches of beetles from pitfall traps at eight sites along an elevational transect from the basal plain to near the crest of Rattlesnake Mountain.

  Conclusions: *E. hispilabris* was much more abundant at lower elevations than at higher elevations. The period of seasonal activity of adult beetles at the highest elevation was only 15 weeks compared with 30 weeks at lower elevations. Microclimate appeared to be an important factor in regulating seasonal activity of *E. hispilabris*.

1967—Designation of the Arid Lands Ecology Reserve

Four studies of animal life on the ALE and five related to physiology of rangeland plants were reported for 1967. "Research in plant physiology was stimulated by the establishment … of the Arid Lands Ecology Reserve, a 120-square-mile area of the Hanford Reservation that will be fenced to exclude stray livestock and permanently set aside for studies of desert ecology," noted the annual report for that year. Brief descriptions of some studies conducted in 1967 follow.

- ***Psychrometric Determination of Water Potential of Desert Plants (J.J.C. Hsieh)***

  Purpose: To determine the leaf water potential of some common desert plants.

  Method: The water potentials of sagebrush, greasewood, rabbitbrush, and saltgrass were measured using a thermocouple psychrometer. Values for diurnal and seasonal changes were obtained.

  Conclusion: The water energy status of desert plants could be inferred from thermocouple psychrometer measurements.

- ***The Influence of Summer Wildfire on Ground-Dwelling Beetles (W. H. Rickard)***

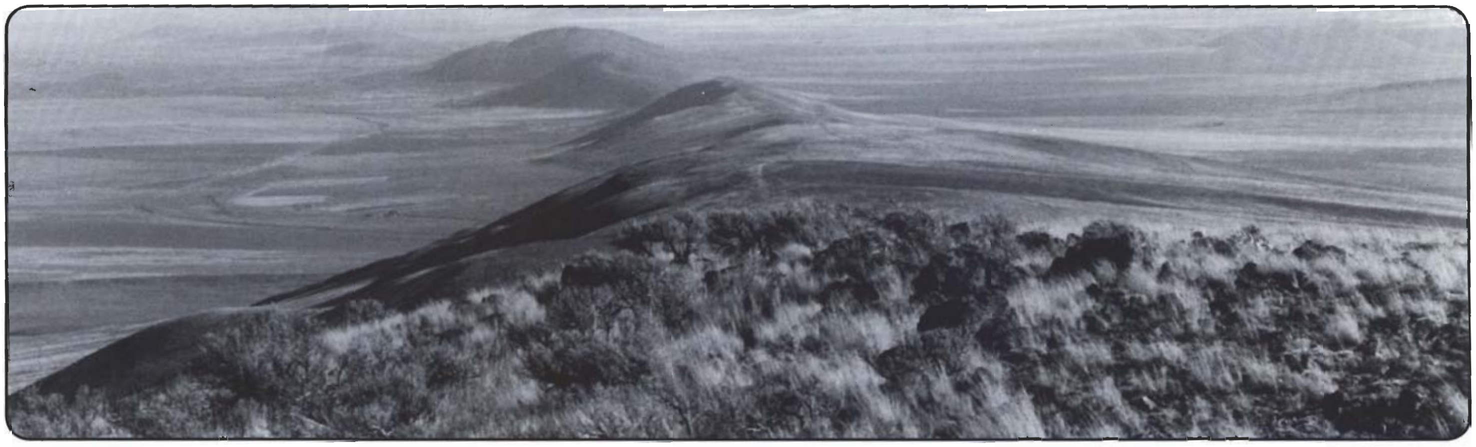
  Purpose: To explore the impact of fire on populations of ground-dwelling beetles in steppe vegetation. Fire was sometimes used in management of desert steppe lands to economically eradicate shrubs and stimulate the growth of livestock forage plants. The impact of fire damage on animals was seldom considered.

  Method: Four species of ground-dwelling beetles were trapped in recently burned and adjacent unburned sagebrush-grass communities.

  Conclusions: The total number of beetles caught in burned and unburned areas was similar. Populations of ground-dwelling beetles typical of a desert steppe community were not adversely affected by burning that destroyed sagebrush shrubs. Fires were not effective in killing adult beetles because they are not active on the soil surface, and larvae are buried in the soil. Wildfire is not effective in reducing the long-term food supply because grass roots are not destroyed by fire.

1968—A Master Plan for Ecological Research

In 1968, PNL submitted a research master plan to the AEC for ecological research. The plan's foreword noted, "Opportunities for environmental scientists to serve mankind have never been greater than now. These professions especially have a vital role in conserving those resources on which man is dependent for his sustenance and fulfillment of life."



The purpose of the plan was to correlate future research in terrestrial and fresh water ecology with the goals and missions of the AEC's Division of Biology and Medicine. Former ALE researcher Larry Cadwell said about the plan, "One can see the multiple influences of the time in the plan. They are based on 1) the need for basic ecological study, 2) the International Biological Program work, which was just beginning but clearly had an influence on this plan, 3) the need (for the ecological work) to support the AEC mission and Hanford operations, and finally, 4) an early recognition of the need for scientifically based data and information to support sound land management." The plan proposed an Arid Lands Ecology Program, centered on the ALE Reserve. Program objectives were to

- characterize the biogeosphere of a classic, minimally disturbed arid steppe environment and understand the basic exchange processes involved in the near steady state and natural dynamic operation of simple systems. (At the time, it was assumed a complete bioenvironmental characterization of the Reserve could be made in 5 years.)
- apply a carefully controlled and supervised systems-oriented approach in the science of ecology through the interdisciplinary research contributions of many investigators.
- provide basic insight, by the efficient handling of environmental data, and predictive capability, by the development of mathematical simulations, to assess the response of a simple ecosystem to various man-induced changes.
- achieve a quantitative basis for determining the biological costs involved in introducing radioactive and other pollutants, including herbicides and pesticides, into an undisturbed terrestrial environment.
- establish a scientific basis for future enlightened management of arid lands resources—particularly toward the increased sustenance of man.
- provide a unique opportunity for the education of systems-oriented, quantitative ecologists and other environmental scientists to enhance the nation's "human" resources in the field of resource management.

Also in 1968, ALE was selected by the International Biological Program (IBP), a National Science Foundation project, as a site for desert biome studies. A long-term study of ALE microclimates began that year. Some research projects conducted in 1968 follow.

- ***Soil Fungi and Perennial Grass Roots (J.D. Davis and W.H. Rickard)***

  Purpose: To determine the association of fungal species with five perennial grasses in the Rattlesnake Hills.

  Method: Ten soil samples were taken at various elevations on Rattlesnake Mountain. Samples were analyzed in the laboratory using soil dilution and immersion techniques.

  Conclusions: Distinctive soil fungal populations existed associated with each perennial grass species.

- ***Chemical Characterization of the Arid Soil Organic Fraction (R.E. Wildung)***

  Purpose: To determine the role of arid soil in the flow of energy and cyclization of nutrients within the arid land ecosystem, specifically to elucidate the elemental composition and acidic properties of plant lignins and soil humic acids isolated from plant-soil associations over a range of altitudinal regimes within the arid environment.

  Method: Representative soils were characterized as to pH, content of organic carbon, sand, silt, clay, cation exchange capacity (CEC), and microbial activity.

  Conclusions: Elemental composition and CEC of the arid soil humic acids were similar to analogous isolates from the humid regions, but changes in chemical properties of arid soil humic acids appeared to reflect differences in the quantities and properties of lignins present in dominant vegetation types and in decomposition processes over the altitudinal gradient.

- ***A Climatological Survey of Temperature-Precipitation-Vegetation Relations on the ALE Reserve (W.T. Hinds and J.M. Thorp)***

  Purpose: To measure microclimatic variation on ALE and determine the interrelationship between function in native plant communities and the atmospheric environment.

  Method: A network of 26 long-term microclimatological stations was established. Where not restricted by topography, stations were selected on five elevational transects to provide data in or near major ecological study plots or areas of similar vegetation. Basic microclimatological measurements at these stations included monthly precipitation and monthly maximum and minimum temperature at 0.3 meters aboveground. Only temperature data were collected in 1968.

  Conclusions: A definite and repeated air temperature pattern became increasingly important. Local topography modified this generalization, especially near the crest of the Rattlesnake Hills. Highest temperatures consistently occurred at Upper Cold Creek and Benson Ranch. Higher elevations showed an increase in species numbers, and in places, the existence of species known to require more mesic moisture relations than existed at lower elevations. Both the amount and efficiency of precipitation increased with altitude.

1969—Characterizing the Arid Environment

By the end of the decade, an Ecosystems Department had been established at PNL that employed 46 staff members (plus 20 other contributors and consultants). Studies on ALE had grown from one to 28. The annual report editors noted, "On the Arid Lands Ecology (ALE) Reserve, nearly all major components of the ecosystem have been identified. Characterization of the so-called abiotic components (micrometeorology, soil chemistry, and surface water hydrology) is now established." A few sample studies from 1969 are described below.

- ***Soil Properties Related to the Local Distribution of Plant Communities (K.R. Price and R.D. Harr)***

  Purpose: To determine possible relationships and correlations between soil properties and plant community distribution.

  Method: Soil samples were collected in the vicinity of Rattlesnake Springs from 28 selected piezometer corings. The number of samples per site ranged from 8 to 54 and reflected the relative distances from ground surface to the surface of the water table.

  Conclusions: The greasewood/saltgrass community was associated with much higher levels of total salts than contiguous sagebrush/cheatgrass communities. Community types with sagebrush present seemed to tolerate sulfate salts. However, where low pH and high SO_4:Cl ratios characterized surface soils, shrubs were replaced by herbs.

- ***Distribution and Abundance of Small Mammals on Rattlesnake Mountain (ALE Reserve) (E.B. Kritzman, T.P. O'Farrell, and J.D. Hedlund)***

  Purpose: To quantify the distribution and abundance of deer mice and pocket mice on ALE as a function of altitude and season.

  Method: Relative population sizes were determined by live trapping on 1.5-acre quadrants on Rattlesnake Mountain.

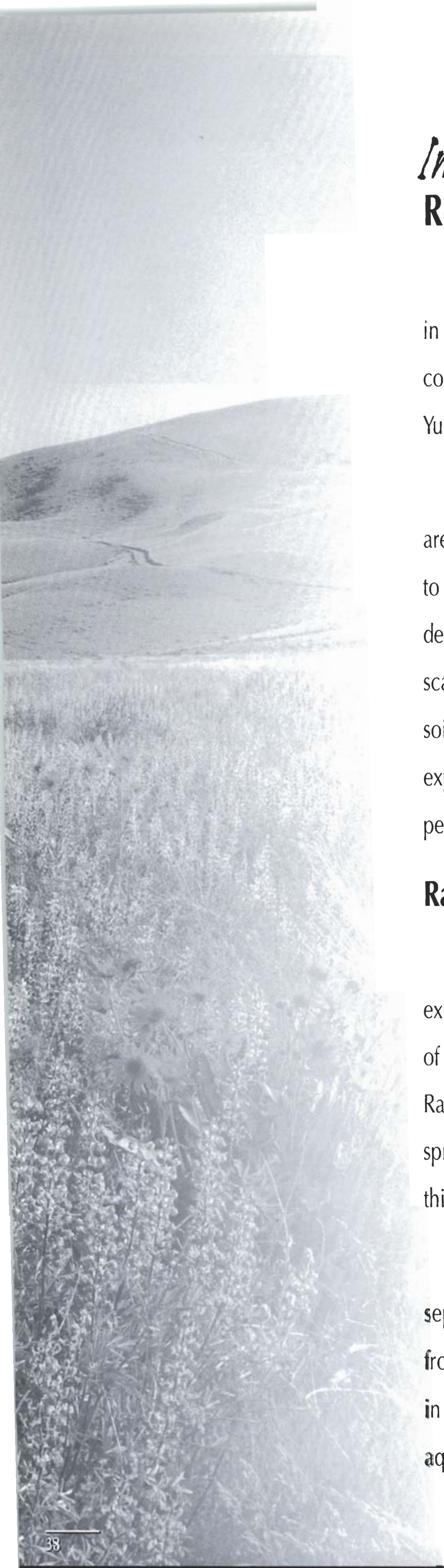
  Conclusions: All populations increased during spring, summer, and fall. Pocket mice were not captured during the winter, and the duration of their hibernation may have been related to altitude. In general, deer mice numbers were directly proportional to increasing elevation, whereas pocket mice were inversely related.

- ***Productivity of Rattlesnake Springs (C.E. Cushing and E.G. Wolf)***

  Purpose: To determine the primary productivity and energy balance of Rattlesnake Springs.

  Method: Concurrent investigations measured the primary and secondary productivity of the upper 1/3 mile of the Rattlesnake Springs stream system. Measurements for organic matter input-output were taken at three stations; two stations provided observation points for downstream biological and chemical changes, and one station was used to determine the effects of a large pool on the stream system.

  Conclusions: Upstream-downstream changes and seasonal changes occurred in water temperature, dissolved oxygen, and chlorophyll. However, other factors, such as alkalinity, total dissolved solids, and various nutrients showed very little seasonal or upstream-downstream variation. ■



Interview with William H. Rickard

Research Beginnings at Rattlesnake Springs

I came to Hanford in September 1960 from New Mexico Highlands University in Las Vegas, New Mexico. I had been studying the recovery of Mojave Desert plant communities exposed to heat and blast from aboveground nuclear explosions in Yucca and Frenchmen Flats at the Nevada Test Site near Mercury, Nevada.

The "Ecology Group" was located in the 146FR building in the 100 F reactor area. Most ecological research at the time was centered on reactor effluent releases to the Columbia River. Much of the terrestrial research was directed toward determining the distribution of worldwide radioactive fallout on regional landscape scales in the Pacific Northwest and Arctic Alaska. Laboratory work on plants and soil contamination centered on determining the uptake of radionuclides from experimentally contaminated soil with emphasis on crop plants as food sources for people and livestock.

Rattlesnake Springs

There was a special need for a small stream that could be used to perform experimental additions of different kinds of radionuclides and to follow the pathways of uptake by biota. A suitable place was the small, permanent stream known as Rattlesnake Springs, located in the Dry Creek drainage on what is now ALE. The springs flowed along the surface for about 1 mile before soaking into the ground. At this time, there were only a few trees along the stream.

A 20- x 40-foot metal building was erected near the stream, a water well and septic system were installed, and electrical power was brought to the building from the 200 West Area. Jared Davis and Dr. John Wolfe were the prime movers in the creation of this field laboratory. Dr. Colbert Cushing was the principal aquatic biologist.

There were a couple of things that needed to be done to make the site suitable for aquatic research. The biggest problem was stray cattle from neighboring ranches. Historically, cattle had watered at Rattlesnake Springs, and the area had been heavily overgrazed. Cattle tended to congregate at the springs because it was one of the few places where water was available year 'round.

In 1961, two dams were built across the stream, and several small ponds were excavated. An 800-acre piece of land surrounding the stream was fenced with a five-strand barbed wire fence to keep cattle away from the stream.

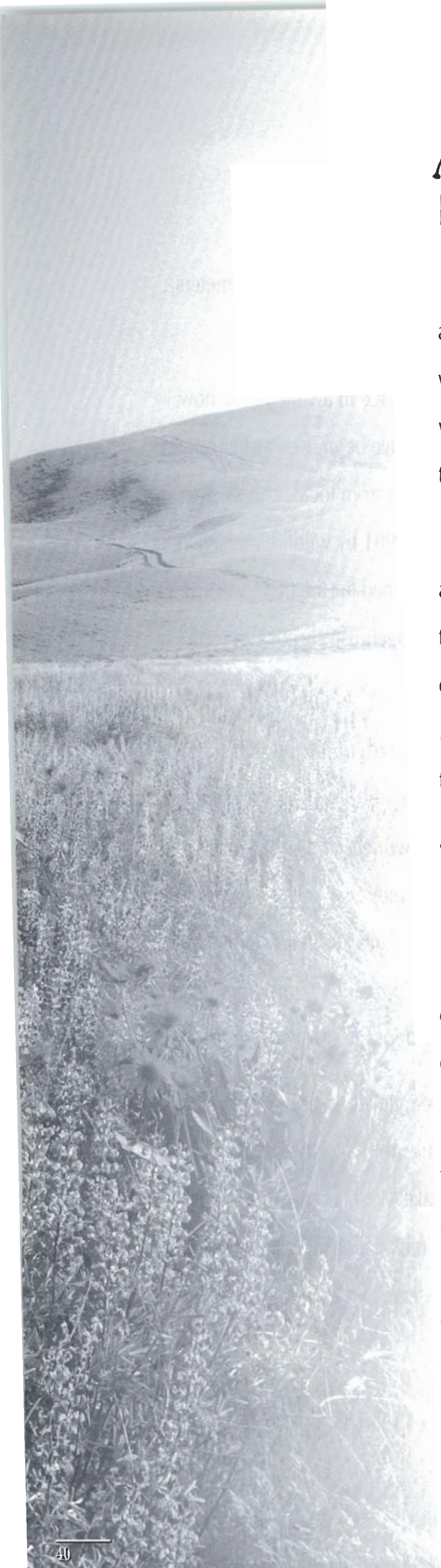
The first winter following dam construction, a massive flood swept down Dry Creek and washed out both dams. Administrators of the Hanford Laboratories (operated then by General Electric) decided that the stream was not suitable for research with radioisotopes.

In the early 1960s, studies at Rattlesnake Springs was limited to the 800 fenced acres. Here, two permanent vegetation study plots were established, one in a sagebrush community and the other in a greasewood community. Each 30- x 30-meter plot was permanently marked at 5-meter intervals around the plot perimeters with steel fence posts.

I used to go back every once in awhile to see how they were doing. The plots have been used as field study plots by students and teachers from local schools. The greasewood plot burned in 1981 by wildfire and again in 2000. The sagebrush plot burned for the first time in 2000. None of the sagebrush shrubs survived the burning.

The most important studies conducted at these plots were gravimetric measurements of soil water accretion (input from rainfall and snowmelt) and soil water depletion (water loss by evapotranspiration) made in the sagebrush and greasewood communities. Measurements of sodium, potassium, calcium, and magnesium uptake by greasewood and spiny hopsage shrubs were made.

In 1967, a 120-square-mile area west of Highway 240 was fenced to exclude cattle from DOE property. The area included parts of Rattlesnake Mountain, Yakima Ridge, and the Dry Creek and Cold Creek drainage ways. It was called the Arid Lands Ecology Reserve and appeared on the new maps of the Hanford Site.



Interview with Colbert E. Cushing
Rattlesnake Springs Aquatic Laboratory

I arrived at Hanford in November 1961. They had just completed the laboratory out at Rattlesnake Springs with the idea of doing quite a bit of radioecology work out there, which actually never materialized to the degree we had planned. But in the early '60s, we started studying the basic chemical and physical characteristics of Rattlesnake Springs, taking periodic water samples, physical measurements , temperature, and things like that.

Rattlesnake Springs was my favorite place on ALE. If you walked up from the lab a quarter mile or so it goes into a fairly deep canyon, and I used to like walking down there. You could stroll along the stream; it was very nice, but the floods and the ecological changes taking place have made it now so it's like hacking your way through a jungle. But in the '60s, when you could walk up in that canyon, it would be 110 degrees up on top of the edge, and it'd be nice and cool down there along the stream. I used to like that.

'70s

In the late '60s and early '70s, a man named Dr. Ed Wolfe came to me to do Ph.D. research at Rattlesnake Springs. He was from the University of Idaho and spent over a year studying the primary productivity of Rattlesnake Springs and developing energy budgets up and down the stream.

In the '70s, there was also some descriptive work done on the algae. A man by the name of Ed Lippert from Portland State University spent about a year with me as a postdoc, sampling the algae in several places in Rattlesnake and Snively Springs. He was an algal-taxonomist, and he documented and photographed all the species of algae that had occurred in the waters. A master's student by the name of Dale McCullough from Idaho State University did his graduate work on the bioenergetics of insects using Rattlesnake Springs and the laboratory there. This was a study determining cycling of carbon and uptake of the various elements using radionuclides and radioactive tracers. Dale's work was very good.

Also during the '70s, Dr. Jim Barnes, a professor of Brigham Young University, and I did a study on the processing of leaf detritus by the insects in Rattlesnake Springs. This was not a real long and detailed study, but we wanted to compare the processing rates of leaf detritus in Rattlesnake with another stream down near Provo.

'80s

Some significant things happened during the '80s: a high school student who worked with me for a summer did a real nice job of studying the food habits of a small mayfly nymph at Rattlesnake Springs. His name was Ryan Rader, and he did an excellent job of looking at the food habits and the gut contents of these little insects. During this time, Bill Rickard and I published a small paper that we still laugh about. It sort of documents the recovery of streamside vegetation at Rattlesnake Springs following the removal of the cattle. The article had two photos, a before and after, and that was more than the text of the article!

Then, the best piece of work that was done in the '80s was by a student named Bill Gaines from Central Washington University who came down to do his master's research with me. Bill sampled and studied the trophic structure and secondary production of all the insects in Rattlesnake and Snively Springs. It's a very tedious research process involving collecting and measuring every insect. It takes a lot of dedication to do this kind of work, and Bill did an excellent job. Also during the '80s, I did a study of the contribution of allochthonous detritus. That's a fancy word for organic matter from outside the stream. We looked at how much was contributed to Snively Springs; we put traps out to determine how much fell in the stream and how much was blowing into the stream.

'90s

Only one major study was done in the '90s. A man named Lynn Mize did his Ph.D. research at Snively Springs and Douglas Creek up toward Wenatchee. He measured the stable carbon isotopes in aquatic insects and their food and materials to determine the main source of energy to stream insects. Was it the vegetation and the algae growing in the stream or was it the organic matter that came in from outside the stream?

The aquatic work we did at Rattlesnake and Snively on ALE was very unique because very little has been done on cold desert spring streams. In fact, a lot of the studies we did there are still quoted. It is a cold desert spring as opposed to the hot desert springs of the Mojave and Sonoran deserts. The studies were unique in that there just isn't that much research done in cold desert spring stream systems. They still form one of the basic collections of research done on these kinds of habitats.

Interview with Burton Vaughan

ALE Management

I came to Battelle in 1969 to manage the Environmental Sciences Department and retired in 1990. For 25 years, we conducted the newly funded Arid Land Ecology program as a substantial DOE-Headquarters funded program, along with add-ons here and there from other participating agencies. What we accomplished in that time was a methodology for substantiating the dynamics of the shrub-steppe ecosystem.

When I came to the Lab, the Arid Land Ecology Reserve had just been set aside as a formal site for the new DOE program. Drs. Rickard, Eberhardt, O'Farell, Hinds, and others were key project leaders who helped found the ALE program. The vegetation and wildlife portions of the ALE program had a head start before I got there, arising out of the environmental radiological monitoring program, but from 1969 on, we re-oriented these programs to focus on ecological relationships and instituted new portions involving soil, soil microbial, insect, and the micrometeorology affecting vegetational dynamics. The micrometeorology network gave us detailed information for the next decade and a half.

For many years we also hosted a part of the National Science Foundation's International Biological (IBP) Program, which looked at grassland ecosystem recoverability following human intervention. The combination of these ancillary programs along with DOE's ALE research program constituted what was probably the longest funded study of a grasslands ecosystem that had been supported anywhere in the United States. What we know about ALE is generally useful for eastern Washington and Oregon and for western Idaho and even parts south such as the Owens Valley in California, and parts of Arizona. The book, *Shrub-Steppe*, is the best way to locate the extensive literature resulting from these efforts.

Another important type of research we did at ALE was soil science, which had to do with soil types and mobilization of bound materials from the soil. It was conducted by Ray Wildung and others. Dr. Wildung's program on the mobilization of soil elements continues to be a very dynamic area, for which he is nationally eminent. The DOE gold medal was awarded for his research on the mobilization elements, and scientists around the United States.

Another part of the program focused on the theoretical science of environmental monitoring. Dr. Richard Gilbert in the Statistics Department had substantial credentials in this area. He worked with Dr. Lee Eberhardt, a statistician on our staff, who was a permanent member of a National Academy of Sciences panel and distinguished in this area. Eberhardt developed unique methods for determining wildlife densities, wildlife penetration into new areas, and field sampling statistics, which were important in environmental monitoring.

Currently, many of the former ALE staff teach in various capacities at WSU-TC, including me. Dr. Bill Rickard is still taking students out to the Arid Lands Ecology Reserve; Dr. Janelle Downs is doing the same, I'm sure. Janelle did some particularly valuable work involving sagebrush. It was more theoretically oriented but very important to some of the classes I teach, like evolutionary biology.

National Environmental Research Park

In 1977, when ALE became a NERP, I testified in Washington before the Subcommittee on Science and Technology in the U.S. House of Representatives. The subcommittee was interested in learning more about federal efforts to create a coordinated network of research sites, including the International Biosphere Reserves, the federal Research Natural Areas systems, and DOE's NERP sites. Subcommittee chairman, George Brown, hoped the hearings would help raise the consciousness of people regarding the significance of what we were doing.

The NERP included ALE as well as everything on the Hanford flats that did not include the industrial areas. As a result of the NERP designation, we had quite a number of people from outside agencies who used ALE. About 100 Ph.D. dissertations have been published out of the research done on the Reserve. PNL also had several programs for bringing in users from the schools. This was all very carefully controlled. If you're running an environmental reserve you can't have people running around willy nilly. It was particularly important because of fires. It was fairly easy to inadvertently start a fire.

I would recommend we continue to maintain ALE for research and education. The word research implies that you go back and search again. It's part of keeping the information alive. I see things that appear to be repetitive from time to time because people don't know the literature. There may not always be people like me around to remind them there is literature on the ALE site.

1970s: Environmental Modulation

The 1970s were the "heyday" of research on ALE. In addition to basic research, ecological studies focused on modulations of natural ecosystems. Researchers investigated changes that resulted from modifications of the environment due to wildfire, irrigation, grazing, and herbicidal applications. Many of these studies started under the auspices of the National Science Foundation's IBP, which provided major funding for ALE research.

Types of ecological research also began to broaden during the 1970s because of growing public interest in the environment and concerns about the deterioration of air and water quality and use of agricultural pesticides.

In response to these concerns Congress had passed several new laws, including the Clean Air Act of 1970; the Clean Water Act of 1972; NEPA; amendments to the Federal Insecticide, Fungicide, and Rodenticide Act; the Toxic Substances Control Act of 1976; laws aimed at protecting wetlands; and the Endangered Species Act of 1973. These laws, particularly the Endangered Species Act, profoundly influenced the use and management of federal and non-federal lands.

1970—International Biological Program

Grassland biome studies were initiated in 1970 as part of IBP. The overall purpose of the program was to examine the productivity of the grasslands of North America and determine the effects of grazing on the grasslands biome. Many studies at ALE were aimed at determining system response to perturbations. The results were intended to support modeling of ecosystem function and the interrelationship of natural system components. The buzz words of the time were "systems ecology," according to former ALE researcher Larry Cadwell.

Research that year also continued on small mammals, hydrologic cycling, and precipitation patterns on ALE. Geological studies continued to show the uniqueness of the Reserve.

Some samples of work conducted in 1970 follow.

- ***Estimation of Plant Biomass in Old Fields (R.O. Gilbert, W.H. Rickard, and J.F. Cline)***

  Purpose: To estimate living and dead plant biomass at three elevations on the ALE Reserve.

  Method: Estimates were made on abandoned fields at Benson Ranch (600 feet), Lower Snively (1,000 feet), and upper Snively (1,700 feet) at approximately 2-week intervals on five harvest days beginning in March 1970. At each location, two 20- x 50-meter replicates were chosen and each divided into five equal strata of 10 x 20 meters. Each plot was harvested by collecting all aboveground living and dead material within the plot. For each harvest day, averages and standard errors were computed and expressed in grams per square meter for standing-dead litter, fallen litter, living aboveground biomass by species, and total living aboveground biomass.

  Conclusions: Biomass in grams per square meter increased throughout the spring growing season at all three elevations. Biomass production started later in the spring at Upper Snively but continued to increase after growth was complete at Lower Snively and Benson Ranch.

- ***Evaporation from Bare and Vegetated Lysimeters at Different Elevations (W.T. Hinds)***

  Purpose: To determine moisture use of bare soil and cheatgrass at two elevations on ALE.

  Method: Thirty-three small weighing lysimeters (21 cheatgrass, 12 bare) were installed in old fields at two elevations. Lysimeters were weighed weekly or semiweekly, allowing estimation of evaporation and transpiration between weighings.

  Conclusions: The data indicated that the lower elevation provided a more efficient environment for moisture usage by cheatgrass than did the higher elevation, partially offsetting the advantages of the higher precipitation totals measured at higher elevations.

- ***Stream Characteristics at Rattlesnake Springs (R.D. Harr)***

  Purpose: To compare relative elevations of water in Rattlesnake Springs. The information was used in conjunction with known elevations of groundwater and reference points to show the relationship between groundwater and streamflow.

  Method: Numerous holes were augured at short distances from the stream throughout the 700 meters of its length.

  Conclusions: Streamflow originated in the 350-meter reach where Dry Creek channel was lower than the perched water table. Below this reach the stream channel was higher than the surrounding water table, which indicated outflow from the stream to the groundwater.

1971—Research Natural Area

In 1971, ALE became the Rattlesnake Hills RNA. Ecosystems Department manager Burton Vaughn noted in the annual report that year that, "Time has led to appropriate growth and change in the original [ecological] research programs, but it is a tribute to our sponsors' foresight that broad-based ecological effort has continued. Without this continuity, we would not have had a base of scientists sufficiently informed to provide assistance in assessing the environmental impact of our developing high-energy technology."

Studies of the distribution and abundance of small mammals on Rattlesnake Mountain continued in 1971 as did investigations of the reproductive behavior of the northern grasshopper mouse. As part of IBP studies, researchers investigated the effects of grazing on small mammal populations.

Terrestrial plant studies focused on describing vegetation of the grassland biome study site, collecting native plants specimens for the herbarium, and conducting sampling surveys of annuals growing on abandoned cultivated fields. Soil studies continued to determine soil moisture, mineral elements, soil nitrogen, and water usage.

Additional studies were conducted to determine the influence of soil temperature and moisture, grazing, irrigation, and herbicide application on the respiration rate of soils on ALE.

Brief descriptions of some studies conducted in 1971 follow.

- ***Flora of the ALE Reserve (J. O'Farrell)***

  Purpose: To collect indigenous plant species, prepare the plants as reference herbarium species, and catalog them.

  Method: Twenty-five collection trips were made to various locations in April. Visits continued into October. An attempt was made to visit major habitats, particularly those on the altitudinal gradient several times during the growing season to ensure most species would be collected.

  Conclusions: A total of 170 different plant species were collected, identified, and mounted, including 17 shrubs, 24 grasses, and 129 forbs. Photographs were made to document the habitat, growth form, and colors of the species.

- ***Watershed Characteristics of the Snively Basin (K.R. Price)***

  Purpose: To characterize the surface hydrology of the Snively Basin.

  Method: Precipitation, streamflow, and soil moisture were measured to define the source, residence pattern, and outflow of water from the basin.

  Conclusions: The data (and carbon-14 dating) indicated that the perennial streamflow from the Snively Basin was not of watershed origin, but from springs producing ancient water trapped between layers of basalt that underlie the region.

- ***Influence of Environmental Factors on Arid Soil Respiration Rate— I. Temperature and Moisture (R.E. Wildung and R.L. Schmidt)***

  Purpose: To determine the influence of soil temperature and moisture on soil respiration rate.

  Method: Twelve locations were randomly selected from four strata in an undisturbed (18-hectare) field plot located on a Ritzville silt loam soil on ALE. Vessels that could be sealed to form a canopy over the soil surface were inserted to a soil depth of 19 centimeters. Carbon dioxide evolution from soil was measured for 24-hour periods from April to September.

  Conclusions: Results emphasized the strong dependence of higher plants and the soil microflora on moisture in arid regions and suggested that carbon flow through unperturbed arid ecosystems during spring, summer, and fall was limited largely by inadequate soil moisture.

1972—Terrestrial Ecology

By 1972, the number of staff members in the Ecosystems Department had grown so much the terrestrial ecology group moved to offices at ALE Headquarters on the Reserve. That year, the annual report said "...considerable technical development took place related to ecosystems modeling in the ALE and Grasslands Biome programs and determination of rates of biogeochemical cycling." Grasslands ecology studies were directed at learning the structure and functioning of native grasslands; measuring the productivity of pristine vegetation associations, and describing the impact of large animal herbivory on the ecosystems. Information also was collected that year on climatology, micrometeorology, aquatic ecology, soil chemistry, plant herbage dynamics, animal population dynamics, and rates of decomposition and mineral cycling on grazed and undisturbed sites. Field investigations were conducted to determine the influence of grazing and other environmental parameters on carbon flow through the soil.

Descriptions of some studies conducted in 1972 are provided below.

- ***Taxonomy of Rattlesnake Springs (B.E. Lippert and C.E.Cushing)***

  Purpose: To collect and identify algae from Rattlesnake Springs and other aquatic sites on ALE. This work was initiated in April 1972 as part of a systematic sampling program.

  Method: Twelve sites were sampled on Rattlesnake Springs and five were sampled at various springs on the Reserve. Intensive sampling was carried out through August 1972 and continued on a reduced level during fall and winter months.

  Conclusion: Ninety species were identified in five phylums: Chlorophyta, Euglenophyta, Chrysophyta, and Cyanophyta. A complete catalog, including sampling locations, species lists, and microphotographs and taxonomic characteristics of each species was completed. Preserved specimens in various forms (liquid, cleared, prepared slides, and dried) were made available for study.

- ***Impact of Cattle Grazing on Shrub-Steppe Vegetation (W.H. Rickard, R.O. Gilbert, and J.F. Cline)***

  Purpose: To assess the impact of controlled cattle grazing on a near pristine stand of shrub-steppe vegetation.

Method: Cattle were first introduced to replicate 9-hectare pastures in spring 1971. Fifteen head of Hereford steers grazed for 58 days in 1971. The cattle grazed for 41 days in 1972.

Conclusions: Results indicated that cattle had eaten or destroyed, by trampling, about 32 grams per square meter of the total annual herbage yield of perennial grasses. This amounted to about 70 percent of the herbage yield.

Continued spring grazing was expected to result in the demise of Cusick's bluegrass and slender hawksbeard in the grazed pastures. The removal of leaf area by grazing was expected to result in a conservation of stored soil-water resulting in increased growth of unpalatable plants, especially sagebrush. The breaking up of the soil crust was expected to favor the invasion of alien winter annuals, especially cheatgrass.

- ***Insect-Plant Association (L.E. Rogers and N.E. Woodly)***

Purpose: To determine the seasonal history of shrub-inhabiting insects and develop a procedure for more intensive population sampling of these species

Method: Insects (and spiders) were collected from major shrubs (sagebrush, greasewood, winterfat, hospage) by sweep net sampling.

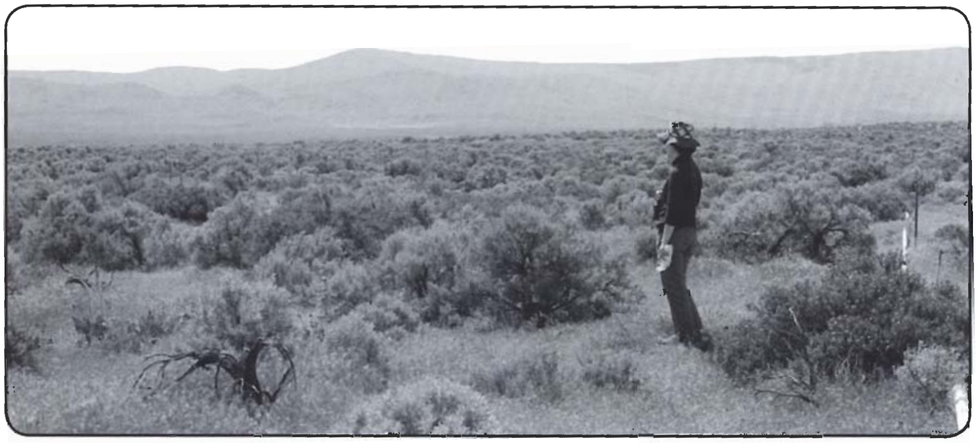
Conclusions: Insect abundance seemed to follow the same pattern, irrespective of shrubs sampled. Numbers were low in April, rapidly increased to a maximum in May or June, then declined. The greatest number of insects were collected from greasewood. The occurrence of insects on big sagebrush were of particular interest because sagebrush was the dominant plant on ALE. In addition, few other animals included sagebrush in their diets, thereby enhancing the role of insects in energy and nutrient cycling within the sagebrush community.

- ***A Simple Lysimeter Technique for Comparison of Water Use and Herbage Yield in an Annual Grassland Community (W.T. Hinds)***

Purpose: To compare water use and herbage yield in an annual grassland community using small lysimeters.

Method: Small lysimeters were constructed from 5-inch-diameter pipes closed with a Lucite bottom implaced in 6-inch-diameter pipes for sleeving. The lysimeters were situated in two abandoned fields, one at 600 feet and one at 1,700 feet. Water use by cheatgrass at the two locations was measured. Field and lysimeter productivities and water loss at the 1,700-foot elevation were compared.

Conclusions: Three of the four density-elevation treatments lost less water than was lost from unvegetated lysimeters. The observed field water loss, and the observed field herbage yields were close, on average, to those from the lysimeter measurements, suggesting that plant growth in the lysimeter faithfully emulated the field environment.



1973—Computer-Retrievable Data

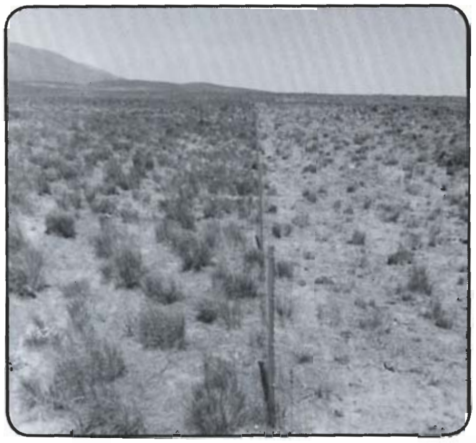
An extensive body of data was assembled in the terrestrial ecology programs in 1973. Efforts were made to make all data computer-retrievable, and preliminary modeling schemes were tested. Plant ecology research that year ranged from collecting vascular plants for herbarium specimens to estimating herbage yields in native and alien plant communities. Grassland ecology studies focused on collecting plant, animal, and abiotic data and integrating them to provide a complete picture concerning the impact of cattle grazing on a shrub-steppe ecosystem. Investigations also were conducted to determine the influence of grazing and other environmental parameters on carbon flow through soil. Mammal population dynamics studies were broadened, and new studies were initiated on the ecology and population dynamics of rangeland insects. Soils investigations were directed toward understanding the role of arid soils in carbon and nutrient cycling as influenced by environmental perturbations. Some studies conducted in 1973 are described below.

- ***Mineral Weathering Processes (R.E. Wildung, R.C. Routson, and T.R. Garland)***

  Purpose: To estimate the role of mineral weathering in the mineral budget for the ALE Reserve. To do this, it was necessary to identify soil mineral assemblages and determine the rate and sequence of weathering actions.

  Method: The elemental compositions of rainwater and three perennial springs emanating from the northeast-facing slope of Rattlesnake Mountain were measured at seven time intervals to estimate the seasonal range in effects of soil biogeochemical processes on mineral budgets in the watersheds.

  Conclusions: The composition of spring water did not differ significantly with location over the 3-year monitoring period. Waters were classified as calcium bicarbonate types. Comparing the composition of the spring waters with rainwater sampled in 1973, it was evident that percolation through soil resulted in higher water pH and increased concentrations of all ions analyzed except potassium, iron, and aluminum. The latter elements were reduced in concentration. Information obtained from this study in conjunction with soil mineralogical analyses and a material balance being developed was expected to provide the first estimates of the role of mineral weathering in the mineral budget for ALE.



- ***Nematode Abundance in the Shrub-Steppe (J. Smolik and L.E. Rogers)***

  Purpose: To ascertain the role of nematodes in the shrub-steppe ecosystem.

  Method: Soil samples were collected during a period representing the approximate time of peak plant standing crop values. Six samples were selected from grazed and ungrazed treatment areas to evaluate nematode abundance under pristine and managed conditions.

  Conclusions: On the basis of preliminary sampling, the authors postulated that nematodes would be found to constitute a significant portion of the belowground invertebrate biomass in the shrub-steppe ecosystem.

- ***Sagebrush Leaf Water Potentials in Grazed and Ungrazed Grasslands (W.T. Hinds and B. Klepper)***

  Purpose: To determine whether the removal of a substantial fraction of the transpiring surfaces of the grasses, by grazing, would improve soil-water relations for sagebrush.

  Method: Leaf water potentials of sagebrush twigs were estimated by pressure chamber readings during spring and summer in grazed and ungrazed experimental pastures on ALE.

  Conclusions: No difference in soil-water relations was detected between grazing treatments, but clear evidence of the seasonal pattern of sagebrush and soil-water relations was obtained.

1974—Applied Ecology

By 1974, the AEC annual report noted that major efforts at characterization had been completed, extensive quantitative data were stored in computer-retrievable format, and statistical evaluations were in process. Those data and the experience gained over the previous 6 years were relevant to problems encountered in revegetation and economical restoration of lands likely to be strip-mined for coal and as practical applications for management of waste burial grounds.

New information obtained during the 1973-1974 growing season concerned the response of steppe region biota to environmental stresses such as wildfire, cattle grazing, and an above-average year of precipitation. Animal ecology

efforts shifted in 1974 from small mammals to other major fauna of the Reserve, including insects, birds, and reptiles. Precipitation data obtained from the network of climatological stations on ALE were analyzed for similarities of precipitation regimes and related to precipitation events at the Hanford Meteorological Station.

Some studies conducted in 1974 are briefly described below.

- ***Manipulation of Herbaceous Ground Cover by Irrigation and Selective Herbicide Applications (J.F. Cline and D.W. Uresk)***

  Purpose: To determine the effects of irrigation and herbicide selection on herbaceous ground cover.

  Method: Three 5.75-hectare study areas were established in a sagebrush/cheatgrass community located near Rattlesnake Springs. One site was irrigated with an automated overhead sprinkling system to simulate a year of high precipitation. A selective herbicide was applied to the second plot to kill cheatgrass. The third site remained as control with no manipulation.

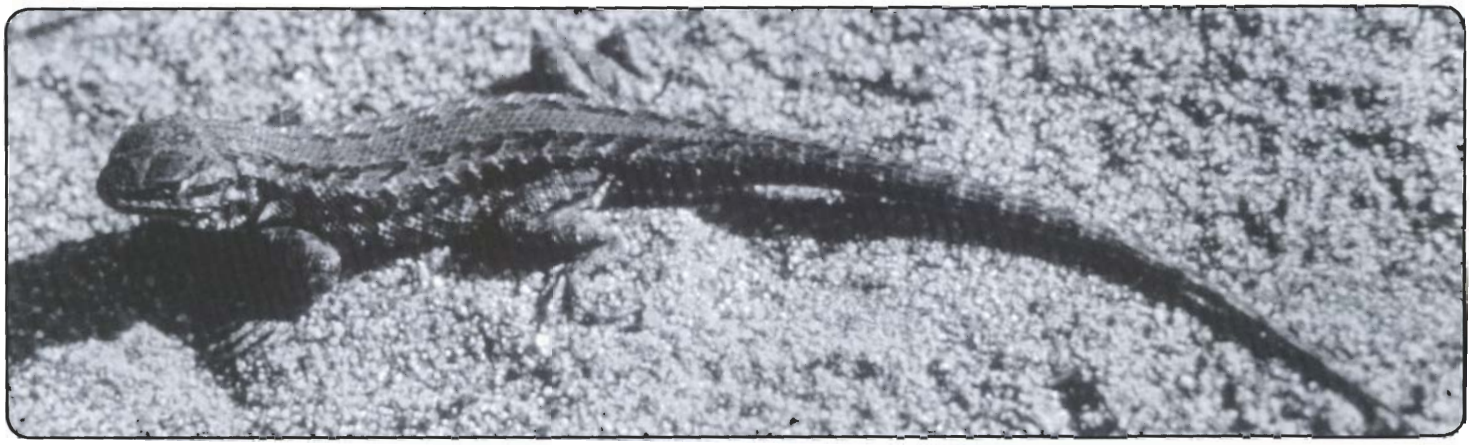
  Conclusions: Irrigation increased ground cover by cheatgrass from 38 percent in control plots to 71 percent in the irrigated plots. The herbaceous groundcover among control, herbicide, and irrigated plots was significantly different. The authors concluded that the herbicide treatment did not reduce forb cover, and that the reduced forb cover in the irrigated plots may have been due to the intensive competition from the cheatgrass.

  The authors also noted that the crowding out of forbs such as Russian thistle by cheatgrass was an important consideration for management of waste burial grounds because forbs generally are more efficient accumulators of radioactive nuclides from soils than grasses and also generally have a taproot that reaches deeper into the soil profile and, therefore, have a greater potential for growing into buried waste zones.

- ***Bird Use of Riparian Vegetation (R.E. Fitzner and J.T. Rotenberry)***

  Purpose: To document species abundance in a riparian community in Snively Gulch.

  Method: Five site visits were made to Snively Gulch from June through August to record number and species of birds observed.



Conclusions: Thirty-five bird species were recorded (including 14 sage grouse, which are no longer present anywhere in the lower Columbia Basin). The authors noted that these data were of interest because they represented bird populations remote from agricultural disturbances, urban residential activity, and industrial operations.

- ***Primary Productivity in a Perennial Grass Community After Wildfire (Ecosystems Department Staff)***

Purpose: To measure primary productivity in a perennial grass community a year after the summer 1973 wildfire.

Method: Live aboveground biomass of large perennial bunchgrasses (bluebunch wheatgrass, Cusick's bluegrass, and Thurber's needlegrass) were compared in adjacent burned and control sites.

Conclusions: The yield of perennial grasses, primarily bluebunch wheatgrass, dramatically increased the year following burning. Data collected from this study indicated that burning was a stimulus to growth of bluebunch wheatgrass, at least during the first season following summer burning. The authors noted that the important observation was that burning removed the stress that was constraining herbage production in bluebunch wheatgrass.

- ***Dietary Analysis of the Side-Blotched Lizard, Uta stansburiana stansburiana, from a Big Sage Community in Southeastern Washington (J.K. Sheldon and L.E. Rogers)***

Purpose: To analyze the feeding habits of the side-blotched lizard to determine the position of the species in the food web in a big sagebrush community.

Method: Thirteen adult lizards were collected. Upon capture, the adults were immediately killed and injected with 95 percent ETOH to stop all digestive processes. Stomachs were later removed and contents examined.

Conclusions: Stomach contents revealed a broad selectivity of food types, indicating an opportunistic type of feeding behavior. Three groups of non-insect arthropods were encountered. Of these, red mites and spiders appeared to occupy an important position in the overall diet. Insects representing 8 orders in 17 identified families comprised the remainder of the diet.

1975— Microclimates

In January 1975, research and development programs of the AEC became part of the newly formed ERDA. Data summarizations and analyses were the focal point of ecological micrometeorology/climatology studies. A long-term study of microclimates also was published that year. Studies related to the IBP continued. Extensive studies of small mammal populations conducted in past years were summarized for open literature publication. The annual report for that year noted that the methodology and techniques developed under the animal ecology program at ALE were vital to new Hanford Site-related studies focused on the radioecology of waste management zones. Brief descriptions of some investigations conducted in 1975 follow.

- ***Plant Phenology (R.H. Sauer)***

  Purpose: To investigate the relationships between plant development (phenology) and weather.

  Method: The 10 plots set up in 1974 were expanded and searched to include more species. One-hundred-forty-nine individually flagged plants, composed of 26 species, were scored weekly for nine phenophases. Data were aggregated to show the duration of growth and reproductive and flowering periods.

  Conclusions: The 1973-1974 growing season had unusually heavy rainfall while the 1974-1975 growing season had an unusually cold spring. These contrasts in weather could be seen in the rate of development and length of growth period. Two new species were identified (sulfur lupine and tall willowherb). These species were not abundant on ALE before 1974-1975. The unusually high rainfall of 1973-1974 and cool spring of 1974-1975 permitted these species to become more prominent.

- ***Scorpions, Beetles, and Lizards (N. Gower and L.E. Rogers)***

  Purpose: To assess the relative abundance and seasonal changes in population of the fall-occurring scorpion (*Vejovis boreus*), beetle (*Philolithus densicollis*), and lizard (*Uta stansburiana*) populations.

  Method: Seven study sites were selected as representative of the ALE Reserve. Species were collected using pitfall trapping. Scorpions were removed and preserved. Lizards and beetles were counted and released.



Conclusions: *V. boreus* was the only scorpion trapped and was probably the only species present. It was most abundant at low elevations. Pitfall trapping appeared to be an effective method of monitoring population changes in scorpions. Lizards and beetles also were trapped in greater numbers at lower elevations. The lack of trapping success at higher elevations probably reflected lower population numbers due to the lower air and soil temperatures at these locations.

- ***Dynamics of Biomass and Crown Estimates of Agropyron spicatum and Poa sandbergii, and Forbs (D.W. Uresk, J.F. Cline, W. H. Rickard, V.D. Charles, L.F. Nelson, M.A. Combs, C.A. Lee, and L.E. Rendall)***

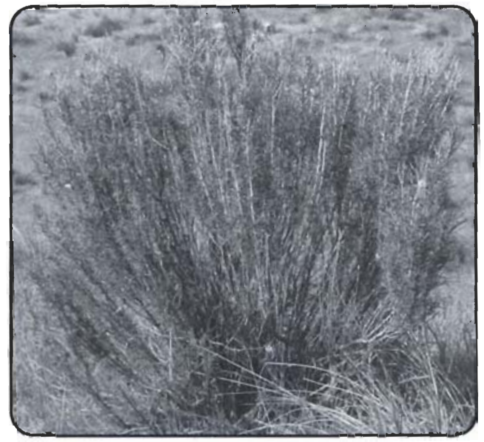
Purpose: To examine the dynamics of plants in a pristine stand of shrub-steppe vegetation when subjected to burning, 2 years of consecutive grazing, and following 1 year and 2 years of recovery from grazing.

Method: Plant sampling of bluebunch wheatgrass, Sandberg's bluegrass, and forbs was conducted every 3 weeks during the growing season and once during pre- and post-seasons. Data were collected from 1971 to 1974. Plant samples were divided into live, dead, and crown material. All crown material was ashed and expressed as ash-free weights.

Conclusions: Peak biomass estimates for bluebunch wheatgrass were lower on the grazed pastures. Burning had a beneficial effect on bluebunch wheatgrass the following season. Peak biomass estimates for Sandberg's bluegrass were approximately the same on grazed and ungrazed pastures from 1971 to 1973. In 1974, a significant increase in biomass occurred on the grazed, recovery, and burn pastures.

The authors concluded that this may have been the result of forbs increasing that were not selected by cattle. Forbs showed a reduction in peak biomass when first subjected to grazing; however, after several years, forbs increased due to grazing. Burning appeared to have a larger impact on the forbs than grazing when the pastures were allowed to recover.

This type of extensive data were useful in providing insight into the productivity in a shrub-steppe community with biological stress and different climatic conditions.



- ***Microclimates of the ALE Reserve (W.T. Hinds, J.M. Thorp, J.T. Rotenberry)***

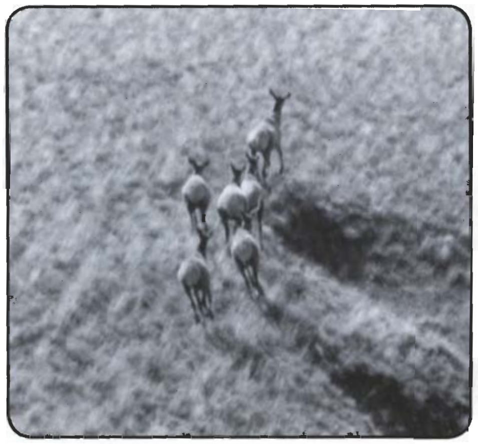
  Purpose: To identify the degree of similarity or dissimilarity between microclimates on the ALE Reserve. This investigation began in 1968.

  Method: Correlation coefficients from the network of meteorological stations on ALE (and the Hanford Meteorological Tower) were calculated for monthly maximum temperature and monthly precipitation. A cluster analysis was performed to average the influence of maximum and minimum temperature and precipitation.

  Conclusions: Three major groups of microclimates occurred on ALE and the adjacent plain: the Meteorological Tower, low elevation valley stations, and all others on the Reserve (sloping terrain). The large group of stations on the slopes of the Rattlesnake Hills contained several subgroups of stations differentiated on the basis of slope and elevation. One low elevation subgroup along the Yakima River lay across contour lines, whereas all other groups lay along terrain contours, indicating that at that region, something other than elevation was important. Comparisons of similarities and differences among the 26 stations illustrated where microclimates appeared to be similar and could provide information to explain vegetation differences or similarities over the landscape.

1976—Environmental Impact and Land Restoration

Ecological research studies in 1976 were tied, primarily, to applied projects that dealt with environmental impact and land restoration. It was expected that information for this research would have wide use and applicability to all kinds of energy technologies expected to be centered in the shrub-steppe region. At the time, three standard types of ecological investigations were being developed: 1) biotic characterization, including descriptions of major habitats and endangered or threatened species; 2) performance of native plant species, including determination of growth habits, nutrient requirements, and productivity; and 3) mineral cycling, including the estimation of availability and behavior of airborne deposits to green plants. The first studies of the Rocky Mountain elk herd in the Rattlesnake Hills also was reported that year. The first animals were observed in 1972.



- ***An Authentic Record of Elk in the Shrub-Steppe Region of Washington (W.H. Rickard and L.E. Rogers)***

  Purpose: To document the establishment of a Rocky Mountain Elk herd on the ALE Reserve.

  Method: Routine aerial surveillance of the ALE Reserve was conducted beginning in autumn 1974.

  Conclusions: Aerial surveillance revealed the presence of a group of about 14 elk using the Reserve in 1974. Elk were observed year 'round in the Rattlesnake Hills.

  It was suspected that elk calves were dropped in spring 1975, but young calves were not actually seen by researchers. In autumn 1975, much rutting activity was observed. In June 1976, two cows, each with a newborn calf, were observed on the ALE Reserve.

- ***Airborne Contaminants and Accumulation by Plants (W.H. Rickard and L.E. Rogers)***

  Purpose: To document the behavior of individual clumps of bluebunch wheatgrass as accumulation sites for airborne cesium-137 (a radioactive constituent of worldwide fallout from nuclear testing).

  Method: Samples of bluebunch wheatgrass were collected in an experimental sagebrush-bluebunch wheatgrass pasture on ALE. Radiochemical analyses of the samples were conducted.

  Conclusions: Results showed that the highest levels of radiocesium were clearly associated with grass crowns. The youngest (uppermost) grass parts were associated with the lowest levels of radiocesium. Data also indicated that grass clumps could collect airborne debris in dust on aerial parts and direct those materials to the crown tissues.

  Individual clumps of bluebunch wheatgrass acted as points of fallout accumulation. The accumulation concentrated in the crown tissues and suggested that small invertebrate organisms living and reproducing in the crown environment were exposed to slightly higher doses of cesium-137 than those organisms living in or on the adjacent open soil.

- ***Cattle Diets and Selectivity of Plants (W.H. Rickard and L.E. Rogers)***

  Purpose: To determine the botanical composition of diets of steers that grazed on sagebrush-bluebunch wheatgrass pastures. (Information on cattle diets and selectivity was needed for land rehabilitation practices following surface mining.)

  Method: Sampling for plant biomass consisted of clipping 16 one-half-square-meter circular plots at 3-week intervals throughout the spring growing season. Ten samples of cattle feces were collected over a 20-day period biweekly during the grazing seasons.

  Conclusions: Botanical composition of steer diets showed that bunchgrasses (Cusick's bluegrass, Thurber's needlegrass, Sandberg's bluegrass, and bluebunch wheatgrass) were the major food items, followed in importance by forbs and shrubs. The authors noted that by seeding the most palatable and preferred plants, livestock production could be increased.

1977—National Environmental Research Park

In October 1977 ERDA became the DOE. Ecological research was funded by DOE's Office of Health and Environmental Research (OHER). That year, the entire Hanford Site, including ALE, was dedicated a NERP. The purpose of a NERP was to promote the use of DOE lands for ecological research of national and regional interest funded by sources other than DOE. In response, three National Science Foundation studies were funded that year to look at plant demography on ALE, the ecophysiology of rodents, and the ecology of shrub-steppe birds. These studies added to the growing ecological database for the ALE Reserve and provided a carefully protected research location for field research by offsite investigators.

Investigators noted in the annual report that the designation of the Hanford Site as a NERP was "...expected to accelerate the orderly accumulation of ecological information concerning the shrub-steppe ecosystem in North America and make it one of the scientifically best known arid land areas in the United States." Investigators W.H. Rickard, J.D. Hedlund, and R.E. Fitzner published an article on the Rattlesnake Hills elk herd in *Science* that year.

A few sample projects for 1977 follow.


- ***Primary Productivity: Response to the 1977 Drought (W.H. Rickard)***

  Purpose: To measure primary productivity of three plant communities during a growing season characterized by unusually low precipitation.

  Method: Productivity was measured by hand clipping live parts of herbaceous plants (cheatgrass and bunchgrass) at peak yield at three study sites (upper Snively, lower Snively, ALE Headquarters).

  Conclusions: Productivity at the three study sites was the lowest measured in 10 years of records. During the 1977 growing season, average herbage production for cheatgrass at upper Snively field was 66 ± 11 g/m^2 dry weight; for lower Snively field it was 9 ± 3 g/m^2 dry weight; and for bunchgrass it was 9 ± 3 g/m^2 dry weight.

- ***Mineral Content of Steppe-Shrub Litter: Baseline Values (W.H. Rickard)***

  Purpose: To collect baseline values of mineral content in shrub-steppe litter. (In 1977, it was expected that coal-fired steam-electric power stations or nuclear power stations would be built in low population areas of the shrub-steppe region. Operating cooling towers and coal-fired stations were expected to add to the mineral content of steppe shrubs through direct foliar retention and soil buildup over a period of years. So baseline data were needed before the plants were operational so that any increases in mineral content related to airborne effluents of the facilities could be determined.)

  Method: Freshly fallen litter from greasewood, hopsage, rabbitbrush, bitterbrush, and sagebrush were collected. Chemical analyses of the litter were conducted.

  Conclusions: Data showed that greasewood litter was high in sodium; hopsage litter was high in potassium and magnesium; bitterbrush litter was high in calcium, magnesium, and sulfur; and sagebrush litter was high in iron and zinc.

- ***Avifauna of an Isolated Streamside Plant Community (W.H. Rickard)***

  Purpose: To document bird use in an isolated spring-brook habitat virtually free from the presence of a resident human population.

  Method: Thirty surveys were conducted over 2 years in Snively Canyon.

Conclusions: A total of 3, 298 individuals of 81 species were recorded over 2 years, including 15 individual sage grouse during two separate counts. Of the 81 species, 34 were "accidental" or of irregular occurrence within the canyon even though a few were abundant in the surrounding shrub-steppe. Nineteen of the remaining 47 were considered dominant. Each contributed at 1 percent (33) of the total number of individuals seen. The dominants were considered diagnostic of the two major seasonal assemblages of birds: spring/summer breeders and fall/winter/spring migrants.

1978—Dissertation Projects

The 1978 annual report noted that "...well over 30 dissertation projects have been sponsored by PNL consistent with NERP objectives." Dissertation topics in 1978 were related to the ecology and behavior of the long-billed curlew and the ecology of shrub-steppe birds. Terrestrial ecology studies in 1978 continued to focus on determining important plant and animal species of ALE and their responses to landscape perturbations such as fire, grazing, and weather, and to more static features of the landscape such as topography and soil. Studies were conducted to evaluate the ecological success of self-established biotic communities on severely disturbed habitats. (The process of self-revegetation of disturbed ground is termed ecological succession.) Dietary habits of animals were studied to establish meaningful food webs and material transfers between ecological trophic levels. The network of 26 weather stations on ALE was maintained. Data on precipitation, air temperatures, and soil temperatures were collected and made available electronically. Some samples of research conducted in 1978 follow.

- ***Bats of the ALE Reserve (R.E. Fitzner)***

  Purpose: To examine the temporal and spatial distribution and habitat preferences of bats inhabiting riparian habitats on the ALE Reserve.

  Method: Bats were collected at Snively Gulch and Rattlesnake Springs using mist nets in July and August. Specimens were mounted and kept in the collection at ALE Headquarters.

  Conclusions: Three species of bats were collected. The western pipistrelle was the most frequently captured. None of the location or date records for the species captured were unusual for Washington. The specimens provided authentic records of bats on ALE.

- ***Self-Revegetation of Replowed Cheatgrass Communities: Short-Term Aspects (L.E. Rogers and R.H. Sauer)***

Purpose: To examine plant productivity on ground replowed after a 30-year occupancy by cheatgrass.

Method: Two long-abandoned agricultural fields were selected for study: the upper field was located at approximately 1,700 feet, the lower field about 3 miles away at 1,000 feet. Both fields had similar soils. Two macroplots were staked in each field. Two subplots were plowed in late autumn 1974; the remainder of each macroplot was left unplowed and served as a control. Comparative data on phytomass were taken in 1976 and 1977. Plant material was harvested in March, April, and May.

Conclusions: The replowed plots in 1976 yielded almost three times more live phytomass than the control plots. This suggested that productivity was enhanced by plowing and the burying of accumulated dead plant parts, which then decomposed, making nutrients available for plant uptake. The 1977 drought had a more deleterious impact on productivity in replowed plots than on the control plots. Cheatgrass dominated both upper and lower fields. Percent botanical composition did not differ appreciably, except for tansy mustard, which was noticeably higher in the lower field. Plant yields in the lower field were much lower in 1977 than in 1976. This was attributed to drought. The drought harmed replowed plots more than the control plots. During 1976, the control plots were almost twice as productive as the plowed plots. These findings suggested that the dead plant material (mulch) was probably more important as a soil-water conservation measure than as a nutrient source.

- ***Ground Squirrel Food Habits (L.E. Rogers)***

Purpose: To characterize the diets of ground squirrels. (This work was conducted as part of a larger study that looked at diets of major consumers. The information was important in understanding food webs because consumption serves as a control point for all materials entering the pathways. Food habit analysis also is a useful tool in understanding how consumer populations partition the available food supply.)

Method: Fecal pellets from 72 ground squirrels were examined microscopically.

Conclusions: A total of 15 plant taxa were identified. The most commonly occurring food items were bluegrass (probably Sandberg's bluegrass), tansy mustard, and lupine. The habitat occurrence frequency of these three heavily foraged species was 15 percent, 14 percent, and 1 percent, respectively, indicating the ground squirrels were probably actively searching them out.

1979—Ecosystem Function

By the end of the decade, ALE still supported some long-term basic ecological studies needed to understand how ecosystems functioned under natural and human-induced stresses. Major study topics included the impact of plowing, cattle grazing, and wildfire; revegetation of steep slopes; leaffall monitoring of desert shrubs for ecological trends; endangered species; biotic transport (food webs) analysis; plant phenology (climatic associations); population studies of shrub-steppe biota (birds, mammals, insects); and wildlife use of seral plant communities.

Some studies conducted in 1979 are described below.

- ***Wildlife Utilization of Disturbed Plant Communities (L.E. Rogers, R.E. Fitzner, and K.A. Gano)***

  Purpose: To evaluate sampling techniques and provide a database to ascertain what changes in plant communities as a result of siting of energy-related facilities in the shrub-steppe would mean to resident wildlife.

  Method: The study compared vegetation, ground-dwelling beetles, small mammals, birds, and large mammals on two each adjacent replicated plots of native bunchgrass and cheatgrass community types.

  Conclusions: Vegetation—Phytomass, cover data, and phenological descriptive data collected during the 1979 growing season established the duration of foliar growth and seed production as important in identifying potential food source supplies for wildlife throughout the year. Ground-Dwelling Beetles—Some beetles, such as *Eleodes novoverrucula*, *Amara* sp. and *Harpalus* sp. clearly appeared to prefer the cheatgrass habitat. Others, such as *Eleodes granulata*, were only common in the native area. Small Mammals—Seven small mammal species were captured during four trapping sessions. Birds—Seven species of birds occurred in the invaded fields, while 19 inhabited the pristine areas. Large Mammals—Coyotes, mule deer, elk, and porcupines were recorded in the cheatgrass and native plots.

- ***Primary Productivity of Dryland Grass Communities: A 10-Year Summary (W.H. Rickard)***

  Purpose: To assess primary productivity of dryland grass communities.

  Method: Measurements of aboveground primary productivity were made in three grass communities at different elevations over a 10-year period.

  Conclusions: Self-established cheatgrass communities were more productive, on average, than the native grass community. The lower elevation cheatgrass community was more productive than any of the 10 native grassland sites studied in the IBP Grassland Biome network. Annual productivity of the cheatgrass communities was also more variable than the native grass community. Cheatgrass communities were more productive than the native communities probably because cheatgrass was more effective in exploiting shallow soil water. "It is clear that native perennial bunchgrass communities in the shrub-steppe are an ever-diminishing and perhaps irreplaceable living resource," the authors said.

- ***Response of Shrubs to Severe Drought, Measured by Litterfall Collection (W.H. Rickard and J.L. Warren)***

  Purpose: To measure the effects of drought on shrub productivity.

  Method: Shrub litterfall in sagebrush, greasewood, hopsage, and bitterbrush communities was collected monthly in the growing seasons before, during, and after the 1977 drought. Shrubs were located at four elevations. Short lengths of PVC pipe were used to collect litterfall. One collector was placed under the canopy spread of each shrub and emptied of its contents monthly. Rain gauges, read monthly, were maintained at three sites.

  Conclusions: Growth of shrubs was very limited in the drought year of 1977 at all sites except the high-elevation sagebrush site. Hopsage failed to produce leaves in 1977. However, growth for all species was restored in 1978 when precipitation was more normal. ■

Interview with Ray Wildung
Soil Science at ALE

My scientific contributions to ALE started in 1967 as a soil scientist/biogeochemist. At the time, ecological research on the Hanford Site was conducted under the auspices of the Atomic Energy Commission. As an arm of Congress, the AEC had financial clout and strong advocates for radiation ecology. It was understood that in order to define the effects of radiation, it was also necessary to establish basic ecological principles, such as how terrestrial and aquatic systems behaved in the absence of radiation. Therefore, in addition to core financial support, there was considerable flexibility in the type of ecological research that could be undertaken.

I was able to bring backgrounds in soil chemistry and (the first) microbiology to the Hanford Site. I was interested in how geochemistry and microbiology operated together to control nutrient fluxes and pollutant form and transport...an area of research that has since grown tremendously and has been dubbed biogeochemistry. The research that we began at Hanford in those early days has also grown with the addition of great people like John Zachara, Jim Fredrickson, Harvey Bolton, Dom Cataldo, Tom Garland, Shu-Mei Li, and Fred Brockman and served as a basis for interdisciplinary capability that helped justify PNNL's Environmental Molecular Sciences Laboratory and implement DOE's Subsurface Science and Genome to Life Programs.

When I first arrived at Hanford, I was shocked at what a large land area (120 square miles) had been set aside and preserved for research. The arid shrub-steppe system that was set aside represents vast land areas throughout the world that play a very important role in global processes. The other thing that impressed me about ALE was that, despite first impressions, there is a tremendous difference in the soils (and microbial populations), plants, and fauna as you go up the altitudinal gradient from the basal plains (500-foot elevation) to the top of Rattlesnake Mountain (over 3000 feet) with distinct ecotones reflecting differences in temperature and precipitation and soil forming processes. The Reserve even has perennial springs and streams with defined watersheds. ALE, therefore, offered a diverse set of conditions influencing biogeochemical processes and the opportunity to separate and define the effects of key variables...heaven to any soil scientist. If continuity of funding had been available, I probably would have spent the rest of my life studying these processes at ALE, but AEC and its successor agencies had evolving missions and our research evolved and changed with those missions.

Biogeochemistry

Part of my first year at Hanford was spent mapping soils on the ALE Reserve and correlating them with two previous maps that had included the Hanford Site. The next few years were devoted to research to understand the fundamentals of how carbon flows through the soil system, how it changes with the temperature and moisture gradient and man's perturbations such as livestock grazing, irrigation, and herbicide treatment, and how carbon flow influences the weathering and availability of nutrients available for plants.

This effort ultimately led to new studies for the National Institute of Environmental Health Sciences and ERDA/DOE on the relationships between microbial processes and radionuclide and metal form in soils and uptake by plants and animals. We also began to characterize the pond sediments at Rattlesnake Springs and this served as an entrée into aquatic chemistry and one of the first PNNL non-AEC (1831) research programs (for the EPA) studying phosphorus release from lake sediments and the relationships to eutrophication processes. Thus, our earlier studies on ALE served as a springboard for research on pollutant behavior in both terrestrial and aquatic systems.

The bottom line of our research at ALE was that we found that 90 percent of the energy and carbon flow through the system occurs in the first 30 centimeters of the soil profile during periods of about 2 weeks in the spring and 2 weeks in the fall when temperature and moisture are optimum. That was an extremely important finding with respect to how these systems function and respond to perturbations such as global climate change.

Also, we found that plant respiration and microbial decomposition were forming carbon dioxide and carbonic acid that subsequently drove mineral weathering processes (including the solubilization of plant nutrients). Tom Garland, Ron Schmidt, and I spent many pleasant days on ALE measuring soil carbon fluxes under different conditions and observing first hand that arid systems are alive and breathing and full of interesting flora and fauna.

Our mineral weathering studies were conducted largely in a closed watershed near

the top of Rattlesnake Mountain (one of my favorite places) where we were able to look at the quantity and composition of rainwater coming into the system, the water going out in spring flow, back calculate the mineral dissolution (thanks to Ron Routson), and show that the key factor that drove mineral weathering was carbon dioxide produced by plant respiration and microbial decomposition processes. It was a very important process for biogeochemical cycling on the ALE Reserve and has major implications for DOE's current interest in carbon sequestration, as carbon dioxide is conserved in the system.

I'm really proud of the studies we conducted on ALE. I believe we were on the forefront of science at the time, and as a result of what we learned at ALE, made some sound contributions in other fields. The fundamental, interdisciplinary approaches we developed on ALE proved extremely valuable when DOE's priorities shifted to radionuclide fallout, synfuels, oil shale, and ground disposal of wastes at defense nuclear facilities.

As DOE missions changed, we have been able to provide new insights into biogeochemical processes important in governing the behavior and effects of pollutants, establish the existence of an incredible subsurface biosphere with implications for the evolution of life on earth and extraterrestrial systems, and demonstrate how to use microbial processes for subsurface cleanup and synthesis of new pharmaceuticals for nuclear imaging.

Baselines

In my view one of the most important contributions of the ALE Reserve has been (and should continue to be) the ability to study natural processes over time with minimal intervention by man. In this respect, history IS important because biogeochemical and ecological changes generally occur gradually under natural conditions. You need to be able to separate out the effects of man's perturbations from the effects of, say, seasonal and annual differences in temperatures and moisture. You can have a drought one year and think the world is coming to an end, then the next year it'll be flourishing out there.

So you need to preserve, protect, and study ecosystems to develop an understanding of how seasonal, annual, and decade-long cycles occur in order to help establish an overall baseline and determine whether there are, indeed, real effects of man-induced phenomena such as acid rain or global climate change.

I hope the new management of ALE will continue to promote it as a site for fundamental research to address these issues. Mathematical models are great tools for guiding research and synthesizing research results but they must be based on (and there is no substitute for) real data acquired properly in the field.

Education

There has always been a strong educational component to studies at ALE because the PNNL research staff wanted it that way. Almost every scientist working on ALE has reached out to the educational community, bringing in students and faculty for collaborative research and study. Secondary, undergraduate, and graduate students have come not just from the region but also from all over the nation and world to study here. I remember when I was manager of the Environmental Sciences Department, we had something like 150 different interactions with students and faculty in one year—many of them working in the field at ALE. Burton Vaughan was a strong advocate of educational outreach and helped pave the way through innovative outreach programs throughout his career as a manager at PNNL.

Then there was the outreach by PNNL staff that were teaching at local universities and using the ALE site for hands-on learning. And there were lectures at various universities, service clubs, and primary and secondary schools throughout the region.

It has been a major advantage for us to have interactions with the educational community, facilitating our access to new ideas, allowing us to participate in the training of the next generation of scientists, and helping provide a balanced perspective on environmental stewardship for people who will later become involved in all aspects of our society.

Even if you just looked at it from a strictly parochial standpoint, it is the best public relations effort you can ever conduct as a national laboratory. We have so many people who come back to visit now who have spent time working here at the Laboratory and who have become senior scientists and/or contributors to society all over the world. In my view, every effort needs to be made to continue to exploit ALE as an incredible and unique educational resource.

Interview with John Thorp
Meteorology and Climatology

I came to work at Hanford in 1951 as a meteorologist for the General Electric Co. and worked for my first 16 years as the A-shift weather forecaster at the Hanford Meteorology Station (HMS) located at the 200 West area. The Met Station was manned 24 hours a day, 7 days a week by four forecasters, each working a rotating shift schedule.

Our primary responsibilities were: 1) to issue a 24-hour general weather forecast for the Hanford area twice each day, and 2) on each of the three daily shifts to issue to plants generating stack releases, an 8-hour "production" forecast of wind speed, wind direction, and stability factor. We also issued special forecasts to the electrical distribution operators if thunderstorms or high winds were expected during the shift. The forecaster also made hourly observations of wind speed and direction, clouds, atmospheric pressure, precipitation, temperature, and relative humidity.

At that time, computer technology and satellite images of weather phenomena were things of the future, and the base for our forecast came from charts on which the forecaster had hand-plotted weather information from each reporting station in the northwest U.S. and southwest Canada. This information was taken from a teletype printout. Once plotted, the weather charts were then analyzed by the forecaster to help determine his forecasts.

In 1966 I transferred into the research division of Atmospheric Sciences. I had mixed feelings about such a change as I enjoyed forecasting and had no training in meteorological research. Weather forecasting is one kind of work you never take home with you. One makes his forecast, and whether it turns out to be correct or not, there are no second chances and you start the next day with a "clean slate." One doesn't do that with any other kind of work at Hanford that I know of. I was urged to at least try the research position as one of my main tasks would be to accompany research teams to different parts of the country and provide specific forecasts for their field experiments. I was also told that if after a year I wanted to return to shift forecaster I would have that option.

They were things about the research position I didn't like, but in retrospect, it was probably the better way to go. My new position still kept me mostly involved with synoptic meteorology and climatology dealing with actual and real time weather processes. Most experimental research studies I was involved with were designed to measure washout of atmospheric pollutants by rain or snow, and a major part of my job was trying to determine when and if precipitation would occur at the experimental site area.

ALE Research

I believe Dr. W. Ted Hinds was the person primarily responsible for the idea of doing research on the microclimatology of the newly designated Arid Lands Ecology Reserve. When his proposal was funded he asked me to join him on this venture. Together, in 1967 and 1968, we set out a 26-station microclimatological network to measure precipitation and maximum and minimum temperatures on the Reserve. We set up five elevational transects, each went from roughly the elevation of Highway 240 (160 meters) to the crest of Rattlesnake Mountain at about 1080 meters. These transects made use of existing roads to avoid disturbing plant life as much as possible. The crest of Rattlesnake Mountain has probably the most fragile plant life within the Reserve and we were very careful to pick crest sites and routes to them that avoided as much as possible treading on even lichens and moss.

The easternmost transect, named "Blacktop" followed the blacktop road that leads to the astronomical observatory at the eastern end of the mountain crest. Its trend was mostly along the direction of the crest instead of at right angles to the crest as did the other transects. A few miles to its west we set up the "Winterfat" transect, named for a low native shrub (*Euorotia lanata*). Because of the scarcity of roads on this transect we had only three stations. Next came the "Central" transect, also limited by lack of roads; however, on this one, we chose three of the five sites at the top of the mountain, one just down from the crest on the southwest, one on the crest, and a third down 100 feet or so on the northeast slope of the mountain where there is a spring. Next was the "Benson" transect, which had a road, though dirt, that ran from the old Benson Ranch site at 189 meters to 939 meters at the northwest end of the crest of Rattlesnake Mountain. We were able to set out eight sites on this transect, which gave us a good elevational distribution of measurements. The fifth and last transect to the west was "Snively" with four sites between 204 meters and

533 meters, terminating in an old wheat field above the Snively ranch house of pre-Hanford days.

Initially, our sites measured maximum and minimum temperatures, and we attempted to make observations once a week. Normally, climatological measurements are made hourly or daily, but we had neither time, funds of manpower to make this 92-mile trip, much of it on rough dirt roads or "tracks" on even a weekly basis so we soon changed our schedule to monthly. Even then there were times in winter when mud or snow, or in summer when deep dust pockets rendered portions of our route inaccessible by vehicle. One perhaps does not think of dust as being an obstacle on back roads, but late in a hot, dry summer the very fine grained soil on roads in the western end of the Reserve often developed dust "pockets" that would be axle deep and impassible even with our 4-wheel drive vehicle. We just did the best we could when roads were bad, sometimes adding considerable mileage to reach a site from another direction.

Our plan was to make the complete run in one day on or near the first of each month. Some runs still stand out in my memory. One such trip was made on February 1, 1979. Six to eight inches of powder snow had fallen during the last days of January and temperatures were near to below zero Fahrenheit during the period. Wayne Stone (a member of our Department who had lived near the gas wells low on Rattlesnake Mountain before the days of the Hanford project) had accompanied me as we visited most of the ALE sites on January 31. We had not been able to get to the Anderson Field site at the top of the Benson Transect because of deep snow on the steep road. It was not really imperative that we get the data from that one station, but the snow conditions were so tempting that on the following day I took my cross-country skis and drove to Whitstran, then up ranch roads on the gentle southwest slope of Rattlesnake Mountain to the Ice Ranch about a mile below the crest. Mr. Ice gave me permission to leave my vehicle there, and then using blue wax (for cold snow) I skied about a mile uphill across his fields to the crest, then down a quarter mile or so to the site.

Other vivid memories of those days include instances on the crest of Rattlesnake Mountain when the wind was so strong that one could not open the door on the windward side of the truck. Fierce winds are not infrequent on the crest; in one case a number of years ago a recording anemometer was blown away by a final recorded gust of 150 mph. More gentle memories include the massive blooming sprees of hip-high velvet lupine in 1975 and 1984 along most of the length of the mountain below 350 meters. There were acres of dense blooms making areas of lavender color visible from miles away.

The wildflower fields near the Anderson Rim site were usually spectacular in April and May.

During the comfortable months of spring and autumn I frequently had passengers with me who wished to have a close up view of ALE in addition to the expansive view from the summit. Rare encounters with rattlesnakes would briefly stimulate the heart rate. Other animals that we occasionally saw on our route were rabbits, badgers, deer, coyotes, sometimes even a stray cow from ranches on the south side of the mountain. Before the termination of our 10-year study a few elk had strayed onto the Reserve.

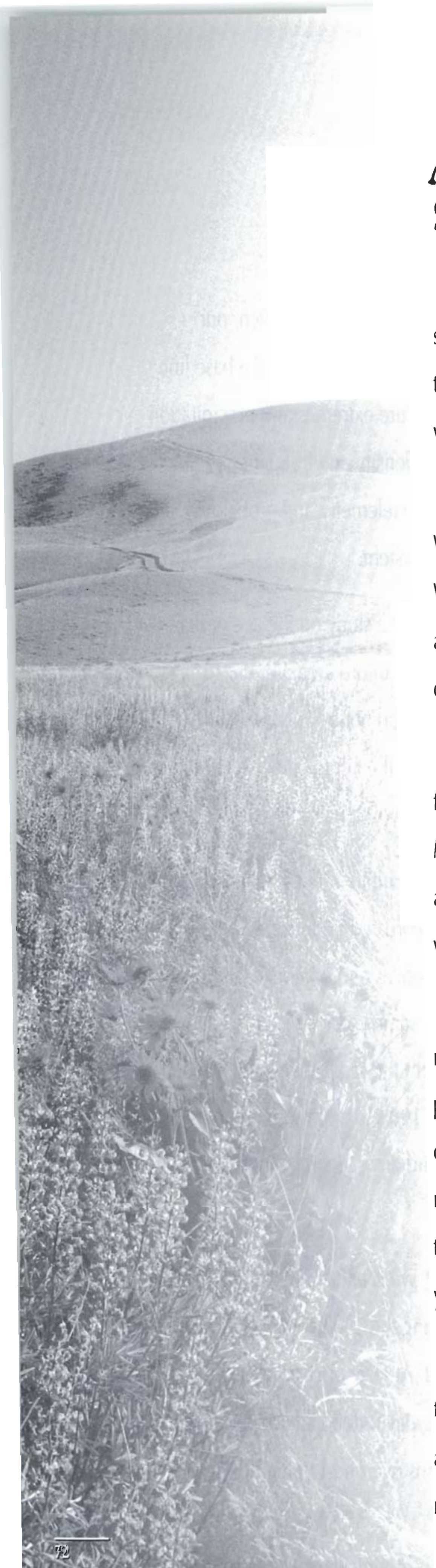
The main purpose of our project was to characterize the microclimate of the Reserve. The elevational distribution of types of vegetation very obviously shows differences resulting from soil type and precipitation variation. Our measurements over 10 years gave us a basic monthly precipitation and maximum/minimum temperature distribution for ALE, and we published a report in 1977 of our findings. The average bio-year (October through May) precipitation is a major factor in plant growth. This bio-year precipitation ranged from 16 centimeters in the Cold Creek Valley that parallels Highway 240, to 24 centimeters on the northeast slope just below the crest of Rattlesnake Mountain.

Compared to most climatological research, our program was rather primitive, but it provided a base line of information on temperature extremes and precipitation for the Reserve. A greater density and frequency of observations would require telemetry and probable damage to the fragile ecosystem.

Ted Hinds and I also did a study on the age of Big Sagebrush growing on the Hanford area. We chose specimens from areas that had not been burned over for many years and counted the annual growth rings in sections taken from the base of these old shrubs.

The task was more difficult than we had anticipated because the trunks of sagebrush, in contrast to tree trunks, have lobes and grooves and other irregularities. The ring thickness for the same year can vary considerably on lobes from the same specimen. We had hoped to find specimens 100 years or more old, but I don't recall that we found any sagebrush more than about 70 years old.

In spite of dust, mud, wind and snow, my memories of about 10 years of visiting the 26 climatological sites on ALE are most pleasant. At least once a month I could leave my office for a long day outdoors to observe the effects of changing seasons over most of the Reserve.



Interview with Ken Gano
Small Mammals and Insects

I hired on at ALE in March 1974 as a temporary technician to go out and help trap small mammals. I worked with John Hedlund and Dave McCullough, who was also temporary. John Hedlund was the lead mouse trapper. He had the program for most wildlife work going on at ALE at that time, which he inherited from Tom O'Farrell.

I trapped small mammals on ALE and all over the Hanford Site for 3 or 4 years. We were doing population dynamics studies and investigating species composition. We trapped in different habitat types, looking at different population attributes associated with habitat. The focus was more basic research than what we end up doing nowadays. There's very little of that kind of work going on now.

In the late '60s/early '70s they did a lot of exposure studies, determining LD50s for plants, small mammals, and other creatures. Those studies were tied to the Manhattan Project, and they were doing them at DOE sites all over the country such as Oak Ridge and Idaho Falls. O'Farrell did a lot of those exposure studies, which were tapering off as I came in.

Most of the work I did was related to looking at either habitat differences or manipulation of habitats. In the '70s, Tom O'Farrell set up 1-hectare mouse-trapping plots out by Rattlesnake Springs that we manipulated. We irrigated one, put herbicide on another, and kept one as a control. The purpose was to look at the effects of the manipulations on the dynamics of the ecosystem. What did irrigation or herbicide do to the plant communities? Mouse populations? We studied the plots for about 3 or 4 years. It was kind of interesting.

Actually that project is how I got started at ALE. It was a pretty intense mouse trapping program. We trapped 300 traps a day, three days a month near that site. We also had the IBP plots, which were two 12 x 12, 144 traps-per-grid plots. It would get repetitive after awhile, but it was interesting to look at the data later and see what was happening. The manipulation plot trapping went year 'round at that time.

Then I ended up getting involved with Lee Rogers doing some insect work, which was another one of my loves. I helped Lee with pit trapping and with characterizing all ant species on ALE. I went around to every habitat I could find collecting ants to characterize all the species. That's probably in the collection down at WSU right now. We ended up with something like 18 different ant species. That was a fun little time.

About '76 or '77, I was taking classes at the graduate center just to learn more about what I was doing, and keep up with where I was going. At one point Lee Rogers said, "...well, geez, you're halfway there, why don't you get a masters?" So I got into the graduate program and got my master's degree. Along the way I took some radiation ecology classes, one from Gene Schreckhise, a health physicist.

Part of the project for that class was to do a study and write up a report dealing with radiation exposure. Gene helped me set up a study design, basically a toxicity test, an LD50 test on harvester ants and radiation exposure. At the time, we had a big gamma cell up at ALE-HQ in one of our laboratories So I thought well OK, let's do this gamma exposure study on harvester ants. So that was my class project. I went out and dug up a couple thousand harvester ants and separated them all out, put them in petrie dishes, and exposed them to levels of gamma all the way from a couple of rad up to 250,000 rad. I counted them every day for about 2 months. It took about 20,000 rad to start to see any decline in the population. I got a journal article out of the study, which was published it in *Environmental Entomology*. That was my first journal article.

As the '70s progressed we did less and less basic research and more applied research for companies like Atlantic Richfield. We did some small mammal population studies on and around waste sites for them.

In the '70s we had a staff of about 26 researchers and technicians working up on ALE. We were down to about six researchers by '85: me, Lee Rogers, Dick Fitzner, Les Eberhardt, Larry Cadwell, and Jack Cline. I think that was about it plus a couple technicians.

Hanford NERP

Late '70s I believe is when they started the National Environmental Research Park, which was a big thing at DOE sites across the country. It was one of the early DOE attempts to "officialize" natural areas they managed as research areas. It was great because it brought in students and faculty from all over the country.

Different graduate students would come in under NORCUS to do research or summer projects. They looked at different things than we were looking at. A couple of students worked on coyotes and birds. John Rotenberry did some work with all the passerine birds at ALE in the early '70s. He worked with sage sparrows, horned larks, and meadowlarks. Another student named Mark Johnson did a diet study on Townsend's ground squirrels, deer mice, and pocket mice. Colleen McShane did her thesis on the effects of burning on bunchgrass.

I remember the wildfires at ALE. They were always traumatic. We had a couple in the late '70s. One time in '81 the fire came right up to the buildings. Of course the big fire in '84 took off probably 70 or 80% of the sagebrush on ALE. That was probably one of the biggest habitat changing events up there. Then the 2000 fire took off all but about 1% of the sagebrush.

Nooks and Crannies

I was at ALE for 11 years pretty as much a field researcher. I got to see probably more nooks and crannies of that area than most people ever will. I have a lot of real fond memories of some neat places up there, little canyons and different springs and even archaeological sites that a lot of people probably at that time didn't know about.

There's a lot of history there, from the old timers who settled the place to the Basque sheepherders and gas field workers. The sheepherders would have these little camps, and every once in awhile we'd find an old stove out in the middle of nowhere way up on some ridge where a sheepherder had camped.

I have several favorite places on ALE: one is a little spring just below the crest of the mountain. If you go down that draw there's another spring that pops up. There's an old cistern there, probably one McWhorter or Anderson built way back before Hanford days. There are a lot of these draws with springs where the ranchers built cisterns to collect water. They'd pipe the water into a watering trough so there would always be open water for the cattle to drink. At one little spring there is a bench (terrace). You're high enough there so you can see the entire Hanford Site. You can see people or animals coming for miles. It's a beautiful place.

Bobcat Canyon is another favorite spot. The water comes out of the ground there and it runs for a hundred yards or so then disappears. There's crayfish in that little spring. I used to wonder how they got there. The whole Snively Basin is neat, too.

I think ALE should continue to be used for research, and I think there should be an open invitation for graduate students to go up there and do arid land research. There's still a ton of studies that can be done up there. There's always questions about how to manage fire better, how to manage the elk herd, and how to revegetate where the elk have trampled the land. Graduate students could explore questions like that in cooperation with Fish & Wildlife.

Anyway, ALE was a good place to work. When things got slow or you needed a break you could step out the door and go for a little walk and you'd be out there in the sagebrush. You didn't have to go very far to get completely away from civilization. It was a fun place to be. Hard to beat. Lots of good people.

1980s: Impacts of Energy Facilities

By 1980, the number, variety, and method of interdisciplinary studies had decreased as funding from DOE Headquarters decreased. Ecological research shifted to the larger Hanford Site and to other regions. Many research topics were linked to specific DOE energy-related programs rather than to basic science.

In general, terrestrial ecology studies focused on long- and short-term impacts of the construction and operation of energy facilities in arid regions and how the impacts could be mitigated. The studies were designed to provide DOE information needed to comply with the intent of federal environmental acts.

Arid lands water balance became an important research topic during that decade, initiated, in part, by a growing interest in selecting waste disposal sites in areas with low rainfall and deep unsaturated soils. The Watershed Research Facility was established to acquire information on microclimate, soil and sediment loss, and nutrient use. Studies continued on wildlife use of perturbed ecosystems and the how arid landscapes responded to a wide range of natural and human-related disturbances. Also in the 1980s, international concern about the greenhouse effect led to initiation of some studies related to global climate change.

Information provided in annual reports for the decade were much less specific than in previous decades, because, at the time, DOE requested general overviews of projects, rather than specific research details. Often, only principal investigators' names were mentioned; thus, the names of other researchers involved in the research may not be reflected in the following descriptions.

1980—Wildlife Use of Revegetated Land

Terrestrial ecology studies conducted as part of the Hanford NERP looked at land use, small mammals, and breeding birds. The NERP studies were conducted in conjunction with similar investigations in other parts of the shrub-steppe region. Counts of pocket mice on ALE were compared with catches in Curlew Valley, Utah. Results of bird censuses in southeastern Washington were compared with similar studies conducted in southeastern and southwestern Idaho. Results of 2-year studies of wildlife use of disturbed plant communities at ALE were reported in detail in 1980.

- ***Wildlife Utilization of Self-Revegetated Old-Field Plant Communities (L.E. Rogers, R.E. Fitzner, K.A. Gano, and J.L. Warren)***

  Purpose: To compare wildlife use of old-field annual grass communities and relatively undisturbed native grass communities.

  Method: Data were gathered over a 2-year period on plant cover and standing crop values, ground-dwelling beetles, birds, and small mammal abundance to test the hypothesis that old-field annual grass communities had not diminished wildlife abundance, total plant cover, or net primary production.

  Conclusions: Vegetation—Self-revegetated old-field plots produced three to four times more litter than did native plots. 1980 was a more productive year for plants than 1979 for all four study plots (two representing native vegetation and two representing old-field vegetation). The increased yield in 1980 may have been partially explained by the dramatic difference in precipitation between the two years.

  Rainfall in the 1979 season totaled 7.33 inches, while 1980 growing season rainfall was 16.14 inches. Also, the 1979 growing season was unusually cold, and snow and ice remained on the ground for a much longer time than in the 1980 season. Native plots were slightly more affected by year-to-year variations in the physical environment than were the old-field plots.

  Mammals—Abundance of pocket mice was equal on old-field and native plots during late fall and winter months, but many times greater on native plots during the summer. Deer mice were only caught in November and March and were most often captured on the native plots. Harvest mice were more often trapped on the old-field plots.

  Birds—Old fields, being relatively monotypic in appearance, promoted less bird species diversity than did the native communities.

  Beetles—Old-field habitats favored some species of ground-dwelling beetles and discriminated against others.

1981—Recovery From Disturbance

In 1981, researchers continued to conduct some basic research studies. They also looked at how and how quickly selected ecosystems recovered from natural and human-induced changes.

Terrestrial ecology studies supported research designed to ensure a strong theoretical basis for decision-making policies, environmental assessments, and resource management decisions. Results of these studies were intended to apply not only to Hanford, but to lands throughout the semi-arid regions of the western United States.

Some studies conducted in 1981 are briefly described below.

- ***Effects of Fire and Clipping on Bluebunch Wheatgrass (M.C. McShane and R.H. Sauer)***

  Purpose: To compare the effect of wildfire or grazing on the growth of bluebunch wheatgrass.

  Method: Study plants were burned or clipped individually or as part of a 1-meter radius circle to simulate differences caused by competition from surrounding vegetation. Plant response was measured in terms of productivity, leaf lengths, culm lengths, seed head lengths, basal area, and the number of flowering culms.

  Conclusions: Results from this study suggested that burning or light grazing after the plants have cured, would decrease vegetative, but not reproductive, productivity the following season. Heavy grazing, even in late season, would decrease the vigor of a bluebunch wheatgrass range.

- ***Comparison of Small-Mammal Abundance in Shrub-Steppe Communities (R.E. Fitzner, K.A. Gano, and J.L. Warren)***

  Purpose: To determine if differences in abundance or species composition of small mammals persisted between undisturbed native sites and old-field environments. The study also sought to determine the merits of using relative and absolute abundance estimators to assess changes in small mammal populations. Data were collected in 1978, 1979, and 1980.


Method: Four study plots were selected in native and old-field communities. Sherman live traps were used during seven trapping sessions in 1980. Abundance estimates were calculated using the single mark-recapture procedure.

Conclusions: Seven mammal species were caught during 1980 trapping sessions. On the old-field plots, only two trapping sessions yielded enough captures to validate the estimation procedure. The pristine areas logged enough captures to make more accurate estimates. When both areas had sufficient data, the estimate of small mammal abundance in the old fields was slightly higher for June 1979 than for 1978 and equivalent for March 1980.

- ***Birds of Pristine and Old-Field Communities on the ALE Reserve (R.E. Fitzner)***

  Purpose: To determine whether differences in the diversity or density of birds existed between pristine and old-field communities.

  Method: Bird surveys were conducted on paired study areas representing pristine (climax habitats of bluebunch wheatgrass) and old-field (cultivated more than 40 years previously and dominated by cheatgrass) communities.

  Conclusions: Old-field communities did not support as many native bird species as did native bunchgrass habitat. Pristine communities provided food and cover necessary for year-round survival. Variations between diversity and density of bird species between the varied pristine sites indicated that microhabitat differences affected birds.

1982—Detecting Change

One goal of the terrestrial ecology program in 1982 was to find ways of detecting changes in ecosystems while the changes were still small and amenable to technology design or control options. Studies looked at the response of ant colonies to changes in vegetation, the response of plant communities to wildfire, and the response of sagebrush to chemicals added to soil. Researchers also continued to develop measurement techniques capable of detecting slowly paced ecological changes. Investigators determined what kinds of long-term measurements were cost effective and appropriate for several typical western ecosystems. Some studies conducted in 1982 follow.

- ***Response of Ant Colonies to Vegetation Changes (L.E. Rogers and W.H. Rickard)***

  Purpose: To determine if the presence of shrubs enhanced certain plant communities as ant habitat, and relate the results to waste burial site cover design. (Ants are believed to be important in shrub-steppe communities because they provide food for lizards and birds. Also, as ants collect plant seeds as food and store them below ground, a sufficiently large ant population can interfere with broadcast seedlings on shrub-steppe ranges, thereby reducing the establishment of seedlings that eventually produce the preferred wildlife or livestock forages.)

  Method: Colony populations of the ant *Camponotus semitestaceus* were estimated using 2- x 2-meter plots in two separate plant communities—one that supported sagebrush and one that did not.

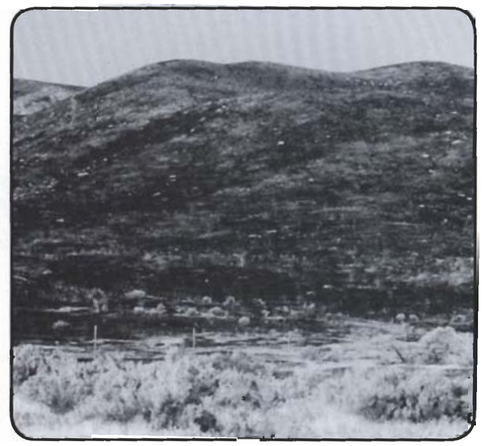
  Conclusions: Results showed that sagebrush plots attracted more ants than the non-sagebrush community. Because ants burrow deeply into the earthen covers overlying shallow burial trenches containing radioactive waste, they can bring soil particles and bits of waste material to the ground surface. The study recommended that by revegetating burial trenches with herbaceous plants instead of shrubs, the attraction of trenches as an ant habitat probably could be reduced.

- ***Response of Plant Communities to Wildfire (W.H. Rickard and L.E. Rogers)***

  Purpose: To test the hypothesis that the 1981 summer wildfire had destroyed cheatgrass seeds and would expose the soil surface to accelerated wind and water erosion.

  Method: Surveys were conducted in two burned study fields on ALE.

  Conclusions: Cheatgrass communities were susceptible to summer wildfires but not permanently damaged. The response of the cheatgrass communities to burning was prompt, and rapid cheatgrass reestablishment prevented accelerated soil erosion without requiring artificial reseeding or fertilization. The findings indicated that annual plants can play important roles in revegetation in semi-arid regions.



- ***Response of Sagebrush to Chemicals Added to the Soil on the Hanford Site (W.H. Rickard)***

  Purpose: To determine whether chemical depositions (from possible coal-fired steam plants) caused significant long-term damage in plants.

  Method: Long-term buildup of boron, copper, manganese, molybdenum, and zinc were simulated in a typical shrub-steppe soil. Chemicals were applied to the ground surface beneath 100 sagebrush plants. After two growing seasons, new-growth sagebrush leaves were picked by hand and chemically analyzed.

  Conclusions: Results showed that only molybdenum was readily taken up by sagebrush leaves. Molybdenum is of concern to livestock growers because elevated concentrations in forage and drinking water can cause disease in cattle.

1983—Responses to Perturbation

Studies conducted on ALE in Fiscal Year 1983 continued to focus on plant and animal responses to natural and human-induced perturbations.

- ***Response of Salt-Tolerant Shrubs to Wildfire (W.H. Rickard)***

  Purpose: To study the recovery of two salt-tolerant shrubs—greasewood and spiny hopsage—after the summer 1981 wildfire. (These plants are important because they provide food for animals and have unusual capacities to cycle minerals to shallow-rooted herbaceous plants.)

  Method: The abundance and shrub canopy cover of these shrubs were estimated using samples from plants growing on a permanently marked study plot established in 1965.

  Conclusions: Burning stimulated sprouting of greasewood, but individual plants were smaller. Canopy cover by greasewood was expected to be restored to pre-burn levels within 3 to 4 years. All spiny hopsage shrubs were killed by fire. Their failure to sprout after burning suggested that hopsage on that plot were growing under less-than-optimal conditions and thus overly sensitive to burn damage. Hopsage was not expected to return for many years, if at all. The study emphasized the value of permanent plots to document changes in species composition in plant communities after environmental disturbance.

- ***Use of Foraging Animal Populations for Biotic Transport Studies (W.H. Rickard)***

  Purpose: To determine if small animals foraged on more kinds of plants than did large animals. This information was needed for biotic transport studies.

  Method: Dietary studies were conducted of animals on the ALE Reserve (darkling beetles, grasshoppers, birds, mice, and cattle).

  Conclusions: Studies indicated that only a few individuals within some populations eat the same food as other individuals. Small animals exhibited more variety in their diets than did large animals. This implied that food chains, contaminant pathways, and biotic transport analysis at the population level may be difficult to interpret and in some cases interpreted incorrectly. Small organisms emerged as important subjects for future biotic transport studies.

1984—Dynamics of Arid Lands

In 1984, a major new research effort at ALE, Dynamics of Arid and Semi-Arid Ecosystems, was initiated to further scientific understanding of globally important ecosystems. Studies did not begin until 1985, but plans for the program included identifying environmental conditions that affected water balance, quantifying the abiotic and biotic factors controlling vegetative production in the shrub-steppe region, and determining the influence of vegetation on estimates of animal abundance between different plant communities. Studies of Rocky Mountain elk in the Rattlesnake Hills continued to be conducted on ALE in 1984, and journal articles were published in the peer-reviewed literature.

- ***Radiotransmitters Facilitate Research on Movement and Abundance of Wildlife (S.M. McCorquodale)***

  Purpose: To investigate the movement, abundance, and population growth of elk on the ALE Reserve (1983 and 1984).

  Method: Elk were fitted with radiotransmitters to monitor activities.

  Conclusions: Studies showed that the Rattlesnake Hills herd was increasing (a total of 55 animals in 1984) and that elk seldom left the Reserve. The rapid increase was attributed to low predation by other animals such as coyotes and to federal regulations that prohibited hunting on the Reserve.

- ***Home Ranges of Elk in an Arid Environment (S.M. McCorquodale, K.J. Raedeke, and R.D. Taber)***

  Purpose: To analyze the home ranges of elk inhabiting ALE.

  Method: Eight adult (4 female, and 4 male) radio-collared elk were relocated 782 times by ground or aerial tracking between January 1983 and September 1984.

  Conclusions: Annual and seasonal home ranges of elk on ALE were approximately 3 to 10 times larger than those reported for elk in forested regions. Distances between consecutive day locations for the ALE population were 2 to 5 times greater than the same distances measured for elk populations inhabiting forested habitats.

1985—Biotic Transport

Arid Lands Ecology researchers studied the effect of stress (as a result of fire) on the water balance of bunchgrass-dominated communities in 1985. Studies reflected analyses of long-term ecological research on native shrubs (sagebrush, bitterbrush, and spiny hopsage) and introduced bunchgrasses (crested wheatgrass). Research also was conducted on biotic transport and plant and animal activities that facilitated the cycling and redistribution of materials such as water, minerals, nutrients, and contaminants. Some studies reported for 1985 are described below.

- ***Influences of Wildfire on Soil Water Dynamics (L.E. Rogers)***

  Purpose: To test the hypothesis that, because soil-water dynamics are intimately affected by plant processes, any perturbations of vegetation of large areas would affect the water balance of that area.

  Method: Three study plots were established (one in a sagebrush-bunchgrass community, one in a bunchgrass community that burned in 1981, and one in a bunchgrass community that burned in 1984). Hydroprobe ports were installed to monitor soil moisture, and portable meteorological stations were placed on each site. Soil moisture data were collected every 2 weeks, meteorological data hourly, and leaf area and biomass by species at the time of peak standing crop.

  Conclusions: Results indicated that changes in leaf area and biomass of a plant community affected water storage within the soil profile.

- ***Long-Term Ecological Research (L.E. Rogers)***

  Purpose: To determine the effects of sodium from dead leaves of greasewood on the soil profile of a plant community.

  Method: Soil samples were collected from greasewood shrubs near Rattlesnake Springs and analyzed.

  Conclusions: Data collected from this study showed that after long periods of time, the presence of a greasewood shrub had a pronounced effect on the water-soluble anions and cations of the soil profile, and that the changes were most evident near the soil surface. Should the shrubs be destroyed, the chemical composition of the soils was expected to become much like that of the adjacent grassy area, because the soluble ions were leached downward into the soil by rainfall percolation. The amount of time required for the soluble inorganic constituents to recover to background concentrations under prevailing climatological conditions had not yet been determined.

- ***Actinide Element Redistribution in Soils (L.L. Cadwell)***

  Purpose: To determine the effects of natural environmental processes (freezing/thawing, weathering, microbial decomposition) and range or agricultural cropping practices (tilling, fertilizing, irrigation) on the uptake of radionuclides by plants and the distribution of the radionuclides in the soil profile over extended periods of time.

  Method: Samples of soil cores were analyzed radiochemically as part of a larger study to examine the uptake and mobility of actinide elements in soil and plant systems. Lysimeters spiked with actinide elements had been maintained for 10 years in field enclosures under conditions that approximated arid land agricultural and range conditions.

  Conclusions: Vertical redistribution of selected actinide elements in the soil column was observed after four growing seasons. Radionuclides were found to have migrated upward and downward in both the irrigated (crops) and nonirrigated (rangeland) lysimeters. Sampling for radionuclide redistribution after an additional five growing seasons revealed no further migration in most soil columns. The originally mobile actinide elements appeared to be bound within the soil column, and in general, were not available for appreciable redistribution.

1986—Watershed Research Facility

During 1986, new research was initiated to provide simultaneous observations of major arid land processes. As part of this effort, the Watershed Research Facility was constructed on ALE. The facility comprised a set of precision-weighing lysimeters to provide information on soil-water dynamics and energy balance parameters; an irrigation system and series of field manipulation plots to study the interrelationships between internal dynamics, microbial ecology, and plant growth parameters; and a series of microwatersheds and rainfall simulators for identifying the influence of biota on near-surface water balance and resulting transport parameters. Some studies conducted in 1986 are described below.

- ***The Effect of Natural Disturbance on Vegetation and Soil Moisture in the Shrub-Steppe (S.O. Link and M.E. Thiede)***

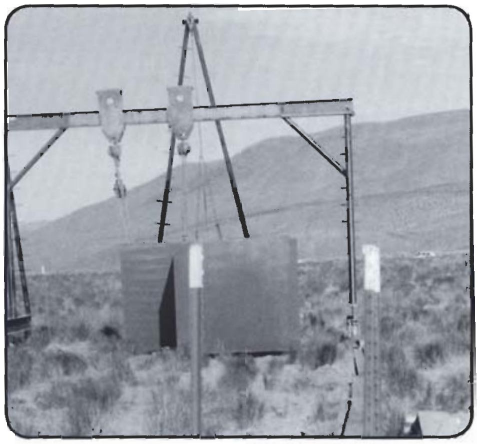
  Purpose: To examine the effects of the 1981 and 1984 wildfires on the relationship between yearly soil-water extraction patterns and plant activity.

  Method: Plant growth was monitored at five research sites beginning in 1984 for green leaf area and biomass. Litter biomass was determined to assess rate of biomass turnover. The sites were different with respect to fire history, plant community composition, and microclimate.

  Conclusions: Leaf area decreased at all sites between April and June because of increasing water stress and genetically controlled phenology. Biomass was not consistently lower in June than it was in April. Litter patterns were not time dependent. After 2 years of study it was apparent that, except for approximately 6 months after the fire, there had been little, if any, difference between annual water storage changes in the profile for the bunchgrass and shrub sites. Apparently, all water precipitated at these sites cycled back to the atmosphere through evapotranspiration.

- ***Biotic Transport Processes in Arid Ecosystems (L.L. Cadwell)***

  Purpose: Studies were initiated in 1986 to measure and model the hydrologic cycle response as it related to plant and animal process in a natural, semiarid environment. Purposes of the 1986 work were to plan and coordinate the research approach; acquire and test the rainfall simulator; conduct initial rainfall simulations; and design, characterize, and install field test plots.



Method: The study site selected near Bobcat Canyon was part of the Watershed Research Facility. Simulated rainfall was applied to study plots to view response and measure transport parameters. Study plots consisted of one plot with native vegetation and one with all vegetation clipped and removed.

Conclusions: Results suggested that surface characteristics in the shrub-steppe influencing runoff were highly variable, could exhibit distinct spatial patterns, and were likely to be the product of dynamic physical/biological interactions. Preliminary results suggested a need to examine spatial variability on a smaller scale to describe the fundamental processes affecting surface-water redistribution in arid landscapes.

- ***Installation of Precision-Weighing Lysimeters for Evapotranspiration Measurements at Hanford's Arid Land Ecology Reserve (G.W. Gee)***

Purpose: To install precision-weighing lysimeters constructed during the year to measure variations in evapotranspiration for distinct plant communities at ALE.

Method: Monolith-type lysimeters were arranged in pairs on a bunchgrass-dominated site and on an adjacent sagebrush site. Each lysimeter weighed about 7 metric tons and consisted of an undisturbed block (monolith) of soil 1.5 meters on a side and 1.7 meters deep. The lysimeters were set on electronic platform scales to record weight changes that represented water loss via evapotranspiration or water gain from precipitation. The data collection system included monitoring instruments and radiotelemetric capability.

Conclusions: During the summer, the lysimeters continuously collected water gain/loss data. After a rainfall of only 0.25 centimeters, weight gain/loss could be clearly seen from the scales, showing the sensitivity of the system to moisture changes.

- ***Fall-Winter Habitat Use by Elk in the Shrub-Steppe of Washington (S.M. McCorquodale)***

Purpose: To analyze seasonal use patterns of Rocky Mountain elk on ALE.

Method: Four adult female elk were immobilized from a helicopter and fitted with radio-collars, ear-tagged, and released. Collared elk were relocated 397 times between October 1, 1985, and March 31, 1986. Attempts were made to sample locations of both bedded and foraging elk.

Conclusions: Collared elk showed activity-dependent habitat selection. Sagebrush/Sandberg's bluegrass areas were preferred by resting or ruminating elk, while Sandberg's bluegrass and cheatgrass areas without sagebrush were preferred for foraging. The authors determined that foraging elk tended to use fewer vegetation types than did bedded elk, indicating the foraging elk were more selective of foraging habitats than bedding habitats.

1987—Satellite Imagery

During Fiscal Year 1987, a high priority was placed on continuing research that provided simultaneous observations of major arid land processes. Much of this effort focused on the Watershed Research Facility.

Research also was initiated to evaluate the use of satellite imagery to measure ecosystem processes in landscapes. The work was sponsored by the National Aeronautics and Space Administration (NASA) and was conducted in conjunction with DOE's remote sensing (Remote Fluvial Experiments [REFLEX]) program.

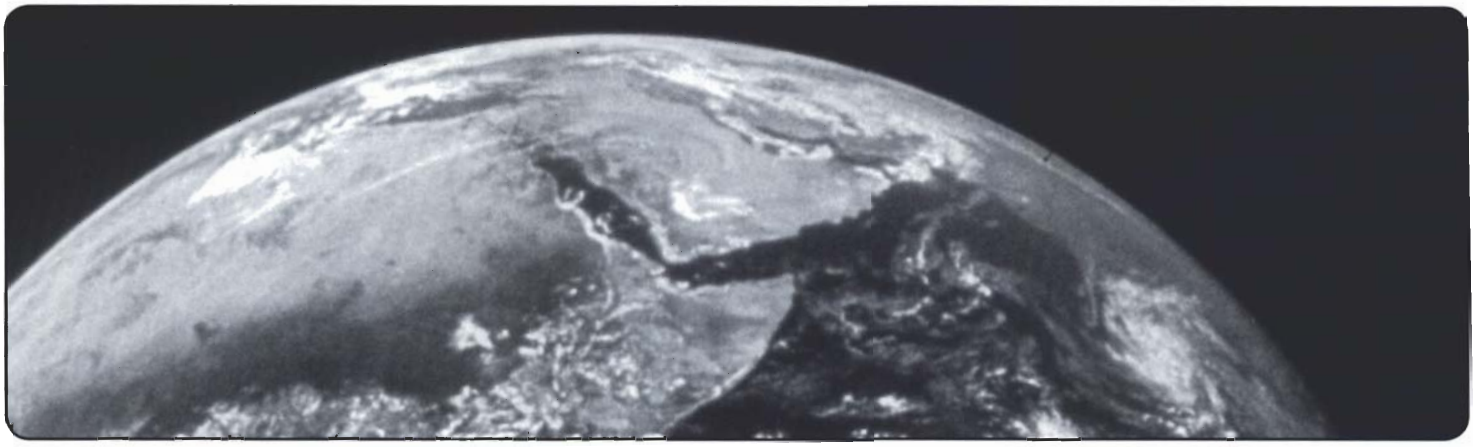
A few examples of work conducted on ALE in 1987 are provided below.

- ***Arid Land Water Balance Studies (G.W. Gee, M.E. Thiede, and S.O. Link)***

  Purpose: To investigate water balance in two plant communities on the ALE Reserve as part of long-term studies to develop sound transpiration models that could be used to describe water loss from various plant communities on the Hanford Site.

  Method: Precision-weighing lysimeters installed in 1986 at bunchgrass and sagebrush plots were monitored to provide data on soil moisture and water use by vegetation for those plant communities.

  Conclusions: The average difference between evapotranspiration at the two sites was about 10 percent, which was considered small in comparison to other methods that have been used to estimate evapotranspiration and other water balance components. Variations in soil profiles may have contributed to differences in water losses observed at the two sites.



- ***Measuring Land Surface Temperatures Using Landsat Thematic Mapper Data (D.E. Gibbons, P.A. Beedlow, and G.E. Wukelic)***

  Purpose: To develop accurate estimates of evapotranspiration over large areas to model watershed processes and assess vegetation stress.

  Method: Data were gathered at specific sites on the ALE Reserve during a Landsat 5 overflight in spring 1986. Data were collected in conjunction with ground-truth temperature data and from published literature.

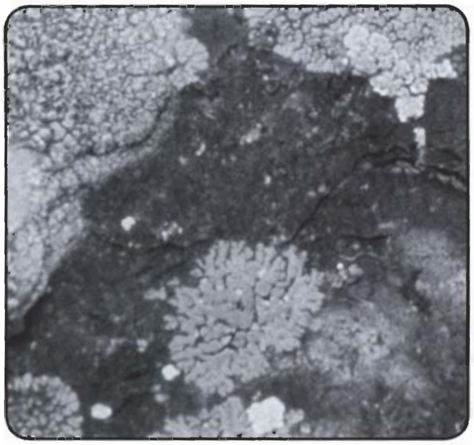
  Conclusions: The research demonstrated the need to calibrate Thematic Mapper data using local radisonde data and cover-specific emissivity values if accurate surface temperature measurements were to be made. When local radiosonde corrections were made in conjunction with cover-specific emissivity, satellite estimates of surface temperature could approximate the actual surface temperature to within 0.5 degrees C.

- ***The Effect of Perturbations to the Water and Nitrogen Cycles in Arid Land Ecosystems (S.O. Link, P.A. Beedlow, and M.E. Thiede)***

  Purpose: To study the response of carbon fixation, evapotranspiration, and mineralization to perturbations that could result from burning fossil fuels. This work was conducted in cooperation with scientists from the Idaho National Engineering Laboratory.

  Method: Two study sites were chosen to represent an undisturbed sagebrush-bunchgrass community and a disturbed old-field community dominated by cheatgrass. At each site, 30 circular plots were randomly chosen. Twelve plots were untreated; 18 plots were treated, six with additional water, six with additional nitrogen, and six with additional water and nitrogen.

  Conclusions: No significant effect was apparent from additional nitrogen on soil-water extraction by plants. Major difference between plots was soil dryness at the end of the growing season. Soil-water content as a function of depth at the sites showed the effect of additional water, although differences between water treatment and control were small. Adding water resulted in higher midday xylem water potential in sagebrush; nitrogen had no such effect. Xylem water potential in bunchgrasses was low in water-treated and control plots. However, water-treated bunchgrasses were greener and more succulent than control plants, implying bunchgrass was capable of activity under great water stress.



1988—Detecting Environmental Change

A high priority was placed in 1988 on initiating research that integrated basic knowledge about major land processes with ecological theory and advanced computational and analytical capabilities. Studies focused on understanding and predicting the response of terrestrial systems to environmental stress. This information was expected to be valuable to DOE and other government agencies by predicting responses to all forms of natural and human-related stress (CO_2 increases, drought, wildfire, waste storage, soil disturbance, and pest outbreaks). Other studies included a Ph.D. study of the ALE coyote population.

- ***Arid Lands Water Balance (G.W. Gee, J.S. Depner, and S.O. Link)***

  Purpose: To test an unsaturated water flow model and assess the use of lysimeter data for predicting water balance of grass and shrub plant communities.

  Method: The UNSAT-H water balance model was tested on data collected from the bunchgrass lysimeters at the Watershed Research Facility for 1 year. Model results were compared with data collected from the lysimeters for the same period.

  Conclusions: The lysimeters appeared to adequately measure the daily water balance during the year and continued to provide data that could be used to calibrate unsaturated water flow and water balance models under semi-arid site conditions.

- ***Spatial Variability in Ecological Factors Influencing Surface Water Distribution in the Shrub-Steppe (R.L. Skaggs and L.L. Cadwell)***

  Purpose: To determine the significance of spatial variability in vegetation and soil properties on hydrologic responses in the shrub-steppe and evaluate the importance of measurement scale on parameter estimation.

  Method: An initial series of infiltrometer studies was conducted at the Watershed Research Facility. Simulated rainfall was applied to 25 subplots containing five replicates each of five cover types: sagebrush, bluebunch wheatgrass, Sandberg's bluegrass, cryptogam, and bare soil. Data collected included rainfall amount, antecedent soil moisture, and surface runoff.

Conclusions: The ratio of runoff to rainfall varied from a low of 0.23 inches per hour for sagebrush to a high of 0.42 inches per hour for bare soil. The low ratio for sagebrush plots reflected the effect of plant roots and organic matter in the soil on effective permeability, soil structure, bulk density, porosity, depression storage, and surface roughness. The bare soil and cryptogam plots had similarly high runoff-to-rain ratios. These treatments had little impact on porosity, soil organic matter, or microrelief. Sandberg's bluegrass and bunchgrass demonstrated the incremental effect of more shallow-rooted plants on infiltration capacity.

- ***Optimal Measurement Scales and Experimental Design for Detecting and Predicting Global Ecosystem Change (J.M. Thomas, V.I. Cullinan, and M.A. Simmons)***

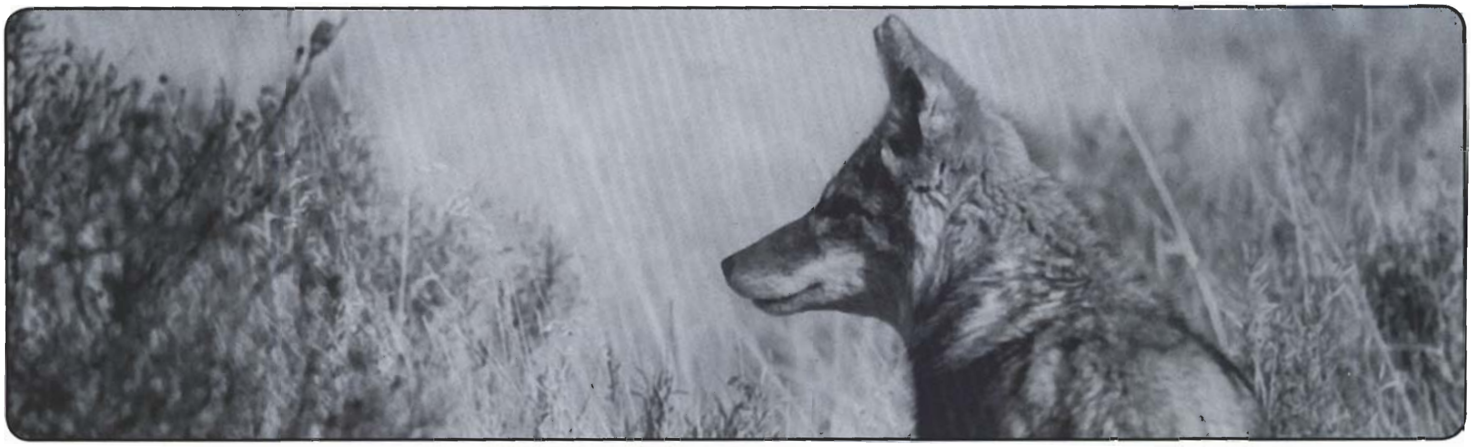
Purpose: To develop a methodology to quantify landscape changes that result from global or regional environmental impacts.

Method: Statistical models that determine ecological scale were extended by using estimates of variability and correlation across a landscape. (The method worked for field data based on 1-meter cover estimates and for Landsat satellite reflectance data contained in 30-square-meter pixels collected from the same site.) To obtain data to test the model, plant cover measurements were made at ALE and the Idaho National Engineering Laboratory.

Conclusions: The scale where similar processes no longer influenced percentage cover was between 300 and 400 meters, depending on the location and plant species measured. The optimal transect segment length was about 100 meters. Results implied that long-term ecological monitoring or monitoring to detect global change needed to consider the size and spacing of sampling units over landscapes. If ground truth for satellite-based measures could be obtained, then Landsat methodology could offer an inexpensive satellite-based means to assess global change.

- ***Antler Characteristics in a Colonizing Elk Population (S.M. McCorquodale, L.E. Eberhardt, and G.A. Sargeant)***

Purpose: To investigate age-specific antler characteristics of Rocky Mountain elk occupying the ALE Reserve.



Method: Measurements and/or weights were obtained from cast antlers, from the antlers of hunter-killed elk, natural mortalities, and from the antlers of elk immobilized for research purposes.

Conclusions: Antler growth patterns indicated rapid growth relative to other elk populations, particularly in younger age classes. Age-specific antler weights and length parameters were above average relative to other populations and increased through the oldest age class studied (9 years). Rapid and substantial antler growth in this population corresponded with high reproductive and survival rates and rapid numerical growth of the herd.

- ***Sociodemography of an Unexploited Coyote Population (R.L. Crabtree)***

  Purpose: To estimate socio-demographic parameters of a natural, unexploited coyote population.

  Method: Adult coyotes were categorized by social class based on physical characteristics, space use, site fidelity, movement patterns, and social interactions with other coyotes.

  Conclusions: Coyotes exhibited a high degree of spatial structuring according to well-defined social classes and subclasses. Territorial social groups contained an older age alpha pair and an average of 1.4 young adult associates. Loners or non-territorial individuals comprised 33 percent of the spring population with two social classes: solitary residents (with older and younger subclasses) and nomads. The average range of social group members, solitary residents, and nomads was 14.5, 54, and 220 square kilometers. Territories were contiguous, non-overlapping, and uniform in size.

1989—Remote Sensing

Three ongoing project areas in Fiscal Year 1989 that formed the core of ecological research at ALE included landscape ecological studies, arid lands water-balance studies, and microcosm-level gas exchange studies. Global change-related effects as well as hazardous waste disposal activities in arid areas had drawn increased attention to the water status and movement of contaminants in the vadose zone.

- ***Landscape Ecological Studies: Quantitative Remote Sensing of Ecological Processes-Evapotranspiration (D.E. Gibbons, S.O. Link, B.A. LeBaron, and R.R. Kirkham)***

  Purpose: To determine the effects of the plant community on evapotranspiration.

  Method: A bunchgrass (burned) and sagebrush-bunchgrass (unburned) community at the same elevation were monitored using neutron-probes, weighing lysimeters, and Bowen ratio/energy balance micrometeorological stations.

  Conclusions: The three methods showed good agreement with evapotranspiration rates. Data indicated that evapotranspiration rates between the two communities were similar, but that the weighing lysimeters may have lost water earlier in the spring than did the surrounding plant communities.

- ***Arid Lands Water Balance (M.D. Campbell and G.W. Gee)***

  Purpose: To document the interrelations of the elements of water budget (precipitation, evapotranspiration, water storage, drainage, and runoff). Data collected from the study were to be used to validate unsaturated water flow models for arid sites.

  Method: Natural precipitation, evapotranspiration, drainage, and storage were measured at the four weighing lysimeters installed on ALE in 1986. Two lysimeters were located at a bunchgrass site, and two were located at a sagebrush-bunchgrass site.

  Conclusions: There was no drainage from any of the lysimeters. Thus, the precipitation was partitioned into evapotranspiration and storage. There appeared to have been little difference between the water budgets from the four lysimeters. Only the degree of depletion of soil moisture appeared to have been different, with the grass removing water slightly faster and to a slightly greater degree than the grass-shrub combination. The grass-shrub combination slightly favored water storage.



- ***Thermoregulation in Wild Elk Inhabiting the Hanford Site in Southeastern Washington (S.E. Petron)***

  Purpose: To determine the extent of diurnal body temperature cycling in elk and if seasonal differences in these cycles existed.

  Method: Five wild elk (2 females, 3 males) were monitored using a radio-telemetry technique.

  Conclusions: The overall average body temperature was 38.4° C in summer and in winter. However, the average diurnal temperature variation was 1.1±-0.1 (SE) degrees C in summer and 0.6 ± (SE) in winter. ■

Interview with Lee Rogers
Insect Ecology

My primary area of interest is invertebrate ecology, insect ecology, specifically. I was hired in 1972 to implement the insect ecology studies on ALE as part of the International Biological Program. My background is really pretty broad in ecology, and that is one reason I was so excited to come to work on ALE where the bird, mammal, and plant studies were so integrated.

I conducted a lot of population-level insect studies initially. We were trying to understand why insect populations vary so much in terms of size, density, and distribution. A lot of our work in the early years was doing pitfall trap studies. We had traps scattered all over the countryside and we were comparing insect abundance in relation to meteorological conditions and other biotic changes.

Since insects are one of the major contributors to consumer biomass, we initially were interested in how the insect community was structured and how that structure changed in response to perturbations such as wildfire, cattle grazing, drought, or soil disturbance. Later, those studies evolved into dietary analysis/energy flow questions where we were trying to determine how materials are transported through the environment.

I was very fortunate to have been also involved in some of the small mammal population studies and some of the bird dietary studies, specifically burrowing owls. Dick Fitzner and I worked for a number of years studying the dietary habits of burrowing owls.

In 1984 there was a large wildfire on ALE, where part of the site burned, and part didn't. This event provided an opportunity to determine how the ecosystem was going to recover and how it functioned in response to fire. At that point we started focusing on a large-scale integrated watershed studies that involved a lot of different disciplines.

Many of the questions we were exploring had to do with water balance, particularly how wildfire changed the water balance of the system. Some studies involved installing these huge lysimeters in the ground. They weighed about 8 tons, and they were undisturbed soil blocks. We installed one lysimeter in a burned area and one in an unburned area so we could really look at the effects of burning. Those studies went on for a number of years and were very useful.

After that, we started getting involved in larger landscape-level studies, particularly looking at the use of satellite information: Landsat Thematic Mapper data. One thing we wanted to look at was being able to model water balance on a landscape level. As ecologists, we always tended to work in sample sizes of 1 square meter or half a square meter, and there we were dealing with the large scale, kilometers or square kilometers. It turned out we eventually were able to put together a model predicting evapotranspiration over all ALE. These studies involved linking ecology, hydrology, and remote sensing disciplines, a first in science. The biota had a tremendous influence on water balance.

So there's a lot of very interesting data out there. Unfortunately we never were able to integrate all the information (from populations to landscapes). DOE started getting out of the ecology business about that time. So there were fewer and fewer follow-up studies and little funding for data integration. Historically, the old Atomic Energy Commission was one of the primary sponsors of ecological studies. They really developed ecosystem-level studies. But as things evolved, DOE decided it was best to put their money elsewhere, and they started getting out of ecology. So we weren't able to bring a lot of those studies to conclusion, which I regret, but that's the way it goes.

Unique Opportunities

We had a really unique opportunity on ALE to go out and study a system that was probably as close to pristine condition as you're going to find, to see how shrub-steppe systems function naturally without a lot of overlying influence by humans. And we did a pretty good job.

It's hard to find any place like that in the world anymore, but if you can get that kind of baseline data, then you can start understanding or have a better understanding of how various human-related perturbations are affecting what you're seeing in terms of environmental response. We looked at a lot of different kinds of human-related perturbations like cattle grazing and the influence of past agricultural practices. We also looked at the effects of fire on the ecosystem.

When I first came here in '72, we received large chunks of money for major plant and animal ecology studies. This enabled us to go out and investigate things we found interesting. You'd see some interesting event or behavior, and you'd want to know now why is that going on, and you could look at it. Probably in the '80s funding started changing, and it became more and more competitive. You had to write specific proposals for specific aspects of research, which means you had less opportunity to take advantage of these opportunistic things you'd see out there.

And the way things worked in the government, once you start down that path of becoming more and more specific in your research objectives, the trend continues. And also the trend of decreasing funding over the years continued. So then we started branching out and doing more and more work for other government agencies, especially the Department of Defense. But all that work was really based on our understanding of the basic ecology that was developed at ALE.

I find myself thinking occasionally about my years at ALE, things such as doing the intensive insect and plant studies with Bill Rickard and Dan Uresk. I remember working with Dick Fitzner where we went up Snively Canyon, stayed all night netting bats. Sometimes we did light trapping at night or conducted some spotlighting surveys of jackrabbits at night. Those were some very enjoyable times.

Interview with Larry Cadwell
Radiation Ecology and Wildlife Monitoring

It was January 1978 when I started work here. My background is in ecology, radiation ecology. At that time, there was quite a lot of radiation-related ecological work going on, funded by the Department of Energy.

One project I worked on at ALE had to do with looking at the uptake of radionuclides from plants. Gene Schreckhise and I believe Ted Hinds were the first to set that up. Gene took it over from Ted, and I ultimately wound up managing it. The objective was to grow crops in what we called lysimeters, which were PVC tubes that were about 6 inches in diameter and 3 feet deep. Soil was placed in the tubes, a preparation of soil was mixed with the radioactive transuranic element (uranium, thorium, plutonium, americium, or neptunium) was added in a certain configuration, and then plants were grown in them. The plants were common agricultural plants: alfalfa, peas, and barley. I think cheatgrass was also a treatment. The objective was to determine the transfer of those elements from soil to plant. The crops were harvested, and samples were analyzed. Today, you would probably never be able to set up an outdoor experiment like that using those materials.

Wildlife Monitoring

Toward the mid-'80s DOE-HQ's interest in nuclear work at ALE decreased. So the four or five projects that had funded ecological and nuclear work basically dropped away. Then the NERP funding decreased, and DOE HQ's funding basically tapered off to the point it was almost non-existent. We went from being funded primarily from DOE-HQ to more local DOE-RL funding. The DOE-RL programs had different objectives. It wasn't basic ecological research or nuclear research like HQ had supported.

Some work that was ongoing in the late '80s and early '90s was managed by Dick Fitzner and Les Eberhardt. Dick was doing a lot of the general ecology, wildlife kind of

studies. I remember one night shortly after I came here, I went out to Snively Canyon with Dick to set up mist nets to trap bats he was studying. We slept face up in the back of a pickup truck and watched the satellites go over.

Les Eberhardt had a project for DOE associated with our Public Safety and Resource Protection Program. It was called the Wildlife Monitoring Project. After the 1992 plane crash when Dick and Les were killed, I assumed responsibility for the project.

The most significant portion of wildlife monitoring conducted on ALE had to do with tracking the behavior and growth of the Rocky Mountain elk population. The population was continuing to grow so we monitored the herd to help DOE deal with impacts as elk started to move off ALE onto private land.

From a scientific standpoint we were most interested in the population ecology of the herd because of its exponential growth. Populations can grow exponentially when you introduce them to an unlimited resource, and that's effectively what we had at ALE: a few animals and 126 square miles. There are very few occurrences in ecology where wild animals, elk in particular, can be studied like that. With the treeless environment and use of radiotransmitters we could track the animals very well, which allowed us to collect good verifiable data on the numbers of animals and the number of calves produced each year.

Some of our studies led to journal publications that actually compared this growth to the theoretical maximum population growth. The rate of reproduction of those animals was pretty phenomenal compared to normal elk populations at other locations. Les really had an interest in following and understanding the growth of that population.

At least two graduate students worked on elk studies: Scott McCorquodale and Ted Heilman. Ted's major professor, Bob Garrott (from the University of Wisconsin at Madison, then Montana State University), also participated in elk studies on ALE.

Weighing Lysimeters

Rainfall simulator and lysimeter studies were conducted on ALE in the late '80s. These were large weighing lysimeters, large meaning they were 5- by 5-foot square. The lysimeters were paired, and there were two pairs, one in the shrub-grass vegetation at the base of Bobcat Canyon and the other in a burned area with no shrubs. I remember putting in those lysimeters the summer of '86. It was really hot out there. Melvin Campbell, who worked for Glendon Gee, also worked on installing the lysimeters. They are still out there today and, for a lot of years, have collected useful data on transpiration. I don't think too many people realize how much work done on ALE—like the lysimeter studies—supported DOE's waste management mission.

Stewardship and Research

DOE has had a long history at ALE and has been extremely visionary in seeing a value and a need for research areas. I think one thing that's been clearly demonstrated is that you can have a naturally preserved area and conduct research there. We conducted research for more than 30 years on ALE, and yet, it is one of the highest quality shrub-steppe habitats in existence.

I guess one of the most important things for people to understand about ALE is that it's a valued resource, particularly if we look at the loss of shrub-steppe habitat in Washington. ALE will become more and more important because it's going to be one of the few places available for study. I hope we don't lose that availability because of management practices that change it from a preserved area with research capabilities to simply a preserved area with limited access for research.

1990s—Global Climate Change

In the 1990s, growing concern over the potential for human activities to significantly alter the Earth's climate resulted in development of a global climate change research program in the United States. Reportedly, every major division of the federal government, including DOE, supported the program. Dollars for global change research trickled down to the Hanford Site, which resulted in some new environmental studies at ALE directed at guiding government policy for global change.

In general, in the early 1990s, PNL conducted basic scientific studies of fundamental mechanisms at ALE that control ecosystem functioning. These investigations focused on developing more accurate predictions of how ecological, hydrologic, biogeochemical, and atmospheric processes interacted to influence long-term changes and how spatial scales influenced environmental responses in arid and semi-arid environments.

The scale of ALE investigations changed during the decade from the ecosystem level to landscape-size areas. The ability to predict the consequences of global climate change requires that processes be modeled at landscape scale. Understanding landscape scales was necessary not only for the global climate change work, but also for DOE's environmental restoration activities.

By the mid-1990s, most funding from the Office of Health and Environmental Research at DOE headquarters for ecological research at ALE had dried up. However, DOE-RL continued to support the ecosystem monitoring as part its Public Safety and Resource Protection Program. Investigations of rare plants and the Rattlesnake Hills elk herd were conducted as part of the project. In the 1990s, project biologists documented substantial growth of the Rattlesnake Hills elk herd, as well as its increased use of private properties, extensive movements across Highway 240 to the Hanford 200 Areas. In addition, photographs of elk trails and ground-based measurements indicated significant impacts to the natural resources on ALE.

A major new development in ecological studies occurred in 1992 when DOE signed a memorandum of understanding with TNC of Washington to conduct a biodiversity inventory and analysis of the Hanford Site, including ALE. The goal of the inventory was to identify and map occurrences of native plant communities, rare plant populations, and important animal taxa over large areas. The DOE awarded TNC a grant to conduct the inventory in 1994. TNC also contributed privately raised funds to support the work. TNC conducted surveys in 1994, 1995, and 1997. PNNL researchers assisted the Conservancy in these efforts, merging PNNL's long-term research data collected on ALE with data from TNC. These efforts provided DOE with information useful for making resource management and land-use decisions.

Some studies conducted from 1990 until 1997—when DOE transferred management of ALE to the USFWS as part of its efforts to shrink the size of the Hanford Site—are described below.

1990—Fundamental Mechanisms

In 1990, researchers examined the dynamics of soil nutrients, water, gas flux across interfaces, and energy to understand how stress influenced the efficiency with which an ecosystem processed its essential resources. Quantitative remote sensing techniques also were developed to estimate fundamental ecological properties over landscape-size areas.

Some examples of 1990 research investigations are described below.

- ***Vegetation as a Controlling Influence in Shrub-Steppe Water Balance (L.L. Cadwell, M.D. Campbell, and R.L. Skaggs)***

  Purpose: To examine the role of vegetation in partitioning of precipitation into runoff and infiltration.

  Method: Data were collected until FY 1989 during field studies at the Watershed Research Facility. Five predominant shrub-steppe cover types were tested (sagebrush, bunchgrass, Sandberg's bluegrass, cyrptogamic crusts, and bare soil).

  Conclusions: Results showed that among the five cover types, sagebrush had a significantly greater ability to induce infiltration, whereas cryptogamic crust and bare soil areas resulted in much greater runoff and less infiltration. Grasses produced an intermediate partitioning of rainfall into infiltration and runoff. Data suggested that under high-intensity rainfall, the shrub-steppe land surface behaved like a mosaic of "stones," "sponges," and areas of intermediate infiltration with the sagebrush "sponges" providing a stabilizing influence that minimized runoff. Sagebrush appeared to have a self-serving ability to enhance its own water supply. If extrapolated to larger landscape units, the results suggested that reduction of sagebrush in the shrub-steppe plant community would alter the water balance in favor of runoff when high-intensity rainfall occurred. Conversely, runoff would occur at lower rainfall intensities in the absence of sagebrush.

- ***Effects of Soil Water Deficit and Plant Age on Plant Water Uptake (J.L. Downs, S.O. Link, and R.A. Black)***

  Purpose: To examine the relationship between decreasing soil water content and hydraulic resistance and the relationship between increasing plant age and hydraulic resistance for cheatgrass grown in field soils.

  Method: Hydraulic resistance of cheatgrass was determined on a whole-plant basis under varying soil-water conditions and increasing plant age. Resistance was estimated by determining the relationship between water flux through the plant and the corresponding hydrostatic pressure required to raise the xylem pressure potential in the shoot to zero. The water flux or transpiration rate was measured using a small chamber gas exchange system by exposing the plant to differing levels of light.

  Conclusions: Determinations of the relationship between the flux and balancing pressure for a number of replicate plants indicated changes in the apparent hydraulic resistance with plant age and soil-water deficit. Older plants had higher resistance to water transport than did younger plants, and plants growing in drier soils had higher resistances than those growing in soils maintained at high soil-water potentials. The relationship between water flux and pressure differential was linear for most plants. The estimated values of hydraulic resistance varied among individual plants of the same age but increased significantly 6 weeks after germination. Soil-water status affected hydraulic resistance to a lesser degree than did plant age.

- ***The Effect of Fire on Nitrous Oxide Flux from Bromus tectorum Dominated Old Fields (L. Schwarz, S.O. Link, J.M. Klopatek, H. Bolton, Jr., B.D. McVeety, and L.E. Rogers)***

  Purpose: To determine how arid ecosystems process water, carbon, and nitrogen, particularly the efflux of nitrous oxide (N_2O). (Nitrous oxide is a radiatively important biogenic trace gas that has received attention as a significant factor in global climate change.) This study was conducted jointly with researchers from Arizona State University.

  Method: A gas chromatography procedure using static chambers was developed to measure the flux of N_2O from cheatgrass-dominated old fields. The effect of fire on the rate of efflux was determined as a function of

time since rewetting. Intact soil cores were extracted from the field in June. Replicate cores were assigned to the control group and to the burn group (burned and burned with feces).

Conclusions: Results suggested that the ecosystem was patchy with respect to N_2O flux. Most of the ecosystem was limited in nutrients, thus limiting the potential of soil microorganisms to evolve N_2O as evidenced by control microcosms. Small patches exhibited significantly higher rates of N_2O flux associated with feces deposition. Burning can significantly increase the flux of N_2O in the ecosystem.

1991—Ecosystem Function

ALE researchers continued to perform basic scientific studies of fundamental mechanisms that control ecosystem functioning in 1991. Investigators also continued to monitor the Rattlesnake Hills elk herd.

- ***Natural Runoff in the Shrub-Steppe: Implications for Groundwater Recharge (L.L. Cadwell, G.W. Gee, and V.D. Parks)***

  Purpose: To measure the quantities of runoff occurring on undisturbed silt loam soils on ALE. (Natural runoff in the Hanford shrub-steppe has the potential to concentrate surface water and contribute to local groundwater recharge.)

  Method: Observations on natural runoff were made by measuring runoff volumes collected in large catchment vessels directly below each of 12 study plots located within the native sagebrush-bunchgrass community.

  Conclusions: Research demonstrated that significant runoff occurs in the shrub-steppe and that the combination of factors present during the winter (including the opportunity for moisture to accumulate as snowpack, frozen soil, and rapid warming) provided the potential for the greatest runoff. Data demonstrated considerable potential for localized recharge, particularly near the base of slopes and within drainages.

  Data further suggested that loss of natural vegetative cover greatly enhanced the potential for runoff and recharge. Results provided clear implications for management of the large, sloped land areas adjacent to Hanford waste management areas.


- ***Net Radiation and Relationship Among Surface Temperature, Normalized Difference Vegetation Index, and Elevation on the Arid Lands Ecology Reserve (S.O. Link, G.M. Petrie, L.G. McWethy, R.R. Kirkham, and L.E. Rogers)***

  Purpose: To investigate the possibilities of predicting evapotranspiration on a landscape scale in natural ecosystems.

  Method: Evapotranspiration was predicted using empirical models based on ground-based and Landsat Thematic Mapper satellite data.

  Conclusions: Strong linear relationships existed among surface temperature, the normalized difference vegetation index (NDVI), and elevation. Surface temperature decreased with increasing elevation and with increasing values of NDVI.

  The decrease in surface temperature with increased elevation was expected with the associated decreased air temperature. The decrease in surface temperature with increasing NDVI was associated with increased green vegetation.

  More green vegetation causes the surface to be cooler because less warm bare ground contributed to the observed surface temperature, and green vegetation is cool because of the evaporation of water (transpiration).

- ***The Effects of Nitrogen and Water on Bromus tectorum Biomass in the Field (S.O. Link, J.L. Downs, M.E. Thiede, and H. Bolton, Jr.)***

  Purpose: To determine which factor, water or nitrogen, was the stronger predictor of shoot biomass of *Bromus tectorum*.

  Method: Experimental design consisted of six levels of water, six levels of nitrogen, and five replicate plots for a total of 180 experimental units. Plants were harvested from the plots and analyzed in the laboratory.

  Conclusions: Results of this experiment indicated that nitrogen and water at natural levels were both severely limiting to *B. tectorum* shoot biomass production. Both water and nitrogen are significant predictors of shoot biomass production.


1992—Sensitive and Critical Habitats

In 1992, PNL continued to examine the dynamics of soil nutrients, water, gas flux across interfaces, and energy. PNL scientists investigated nitrogen and water dynamics in a shrub-steppe ecosystem. They also explored non-methane hydrocarbons (NMHCs) and their role in soil chemistry and atmospheric pollution. A team of researchers compiled the best available information on sensitive and critical habitats and plants and animals of importance.

In addition, staff developed a database program capable of archiving, retrieving, and manipulating the data collected over nearly 30 years of shrub-steppe research on ALE. Although data initially were collected to answer specific research questions, computerizing the datasets made the information available to answer broader environmental questions relating to the maintenance of species, environmental restoration, and land management. The database program was used to assist the Washington State Department of Wildlife and DOE-RL in making land-use decisions.

- ***Changes in Hydraulic Resistance of Bromus Tectorum Under Enhanced Nitrogen and Water Conditions (J.L. Downs and S.O. Link)***

  Purpose: To investigate resistances to water uptake and transport for *Bromus tectorum.*

  Method: Transpiration and shoot xylem potential were measured on plants growing in old-field communities. Twenty circular plots were located in the old field. Treatments were randomly assigned: five each for a control (no water or nitrogen), additional nitrogen, additional water, and additional water plus nitrogen. Minirhizotrons and neutron probe access ports were installed in each plot.

  Conclusions: Results indicated that plants receiving additional nitrogen were either better able to access soil-water or better able to transport water from the soil to the root. Comparison of the neutron probe soil moisture profiles for the water and nitrogen-plus-water treatments indicated that plants in the nitrogen-plus-water plot were able to extract more moisture from the profile.

- ***A Survey of Volatile Organic Compounds Emitted from Shrub-Steppe Vegetation (M.D. Wessel, S.O. Link, and R.G. Kelsey)***

  Purpose: To determine what volatile NMHCs are emitted by dominant plants found on ALE. A researcher from the U.S. Department of Agriculture, Forest Service, assisted in this study.

  Method: Samples of big sagebrush, hopsage, tumblemustard, rabbitbrush, bluebunch wheatgrass, and cheatgrass were collected, weighed, and analyzed using gas chromatography equipped with a mass spectroscopic detector.

  Conclusions: Four of the six species analyzed produced significant quantities of NMHCs. No detectable NMHCs were found in the two grass species analyzed. Researchers theorized that it was possible that NMHCs emitted from vegetation were actually strong greenhouse gases.

- ***Data Management for the Arid Lands Ecology Reserve and the Environmental Research Park, Hanford Site (S.L. Thorsten and M.A. Simmons)***

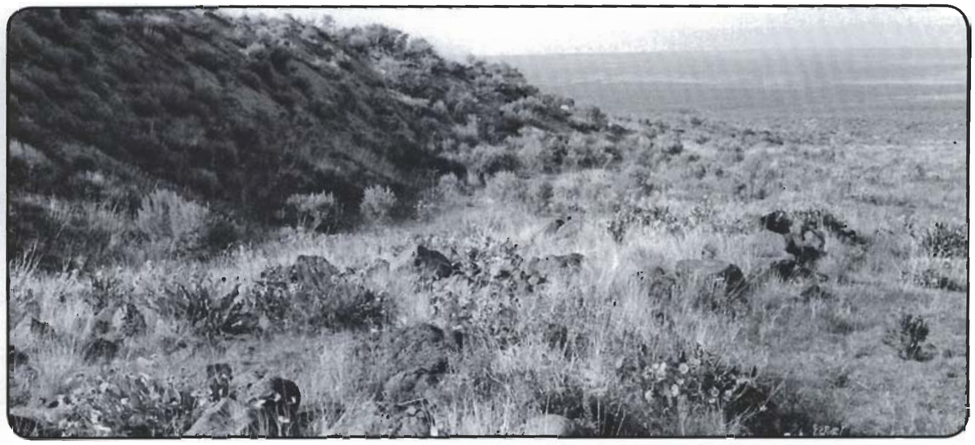
  Purpose: To develop a database program capable of archiving, retrieving, and manipulating data collected for ALE and the Hanford NERP.

  Method: The Ecological Data Manager (EDM) program was created on the Apple Macintosh using software transportable across platforms.

  Conclusions: The main EDM program provided access to raw data by individual record. The Study Site file provided locations of study sites and pertinent topographical features, as well as general information on the history, climate, geography, flora, and fauna. Studies that incorporated Geographic Information System (GIS) technology could store their visual identification records and other relevant photographic information in the files.

- ***Habitat Types on the Hanford Site: Wildlife and Plant Species of Concern (J.L. Downs, W.H. Rickard, C.A. Brandt, L.L. Cadwell, C.E. Cushing, D.R. Geist, R.M. Mazaika, D.A. Neitzel, L.E. Rogers, M.R. Sackschewsky, and J.J. Nugent)***

  Purpose: To compile and publish information on sensitive and critical habitats on the Hanford Site, including ALE.



Method: PNL researchers worked with Westinghouse Hanford Company to compile the information, which was collected from basic research programs, monitoring programs, and educational endeavors.

Conclusions: A report on sensitive habitats (areas known to be used by threatened, endangered, or sensitive plant or animal species) was produced. The report described and provided maps for six primary habitats according to vegetation and topography (basalt outcrops, scarps, and screes; riparian streams and springs; shrub-steppe on slopes; sand dunes and blowouts; abandoned fields/disturbed areas; and shrub-steppe on the Columbia River Plain).

1993—Threatened and Endangered Species

Research funded by OHER, which supported long-term terrestrial studies, ended in 1993. Work described in the annual report was directed toward understanding terrestrial systems as a basis for managing the resource and addressing environmental problems such as global change. Studies conducted as part of the Public Safety and Resource Protection Program related to monitoring and reporting trends in wildlife populations; conducting, recording, and mapping populations of threatened, endangered, and sensitive plant and animal species; and cooperating with Washington State and federal and private agencies to help ensure protection afforded by law to native species and their habitats.

- ***Remnant Resource Islands in a Burned Shrub-Steppe Site (J.J. Halvorson, H. Bolton, Jr., and J.L. Smith)***

  Purpose: To detect remnant or "ghost" resource islands in the shrub-steppe environment. Resource islands are zones of comparatively high concentrations of nutrients such as carbon and nitrogen. They are known to exist for several soil parameters under individual big sagebrush shrubs. An investigator from the U.S. Department of Agriculture, Agricultural Research Service participated in this study.

  Method: Burned and unburned stands of sagebrush separated by an unpaved road were selected. In the unburned site, surface soil samples were collected from directly beneath and near 10 mature sagebrush along four transects. On the burned site, samples were collected similarly, except transects originated from 10 burned sagebrush stumps. Each sample was analyzed for biological and chemical properties.

Conclusions: Resource islands were observed under living sagebrush for all soil properties. Overall, samples from the unburned site contained significantly more total nitrogen, total inorganic nitrogen, and soil microbial carbon. These sites had significantly higher electrical conductivity, a higher rate of soil microbial respiration, and higher anaerobic carbon and nitrogen mineralization. The burned site samples also respired more carbon per unit biomass. It was concluded that resource islands at the ALE sites were not self-perpetuating, but are closely coupled to the influence of a living plant. The authors suggested that the recognition of ghost islands may be important for determining the ecological or environmental consequences of the removal of sagebrush or for understanding the scale of variability of soil properties on sites that have been denuded by fire or cutting.

- ***Habitat on Hanford (J.L. Downs, J.J. Nugent, and L.L. Cadwell)***

Purpose: To develop a detailed map delineating the extent of existing big sagebrush habitat and other native vegetation associations on the Site. The map was designed to aid in managing particular wildlife species of concern and in identifying sensitive and critical habitat areas.

Method: Maps of vegetation associations across the entire Hanford Site, including ALE, were traced from medium-altitude, color aerial photography flown in 1987 and 1991. Original tracings were overlain and registered on U.S. Geological Survey (USGS) 7.5-minute topographic maps. The data were digitized for use in GIS classifications of land use/vegetation were verified through field observations in as many areas as possible. Data were collected through a cooperative effort with the Washington Department of Wildlife and Department of Ecology.

Conclusions: The map created as a result of this effort included 13 vegetation/land-use cover types. Nine of these occurred on ALE. The map layer resided in the Geographical Resources Analysis Support System (GRASS) on the GIS and could be used in conjunction with the biological database system EDM.

- ***Sage Grouse Surveys (J.L. Downs and R. Mazaika)***

Purpose: To conduct surveys for sage grouse. (Sage grouse previously had been reported as residents of ALE. The species was listed as a federal candidate 2 species and a state candidate species at that time.)

Method: Sagebrush habitat on slopes across the Hanford Site and historical lek locations were surveyed. Surveys were conducted during predawn and sunrise hours at known lek sites. Pedestrian surveys of likely sagebrush habitat areas were conducted by walking transects through remaining sagebrush habitat and visually searching for signs of sage grouse such as droppings or roosting sites.

Conclusions: No sage grouse were sighted during the 1993 surveys of lek sites or the pedestrian survey of likely habitat areas. Inclement weather affected the timing and completion of the surveys and may have contributed to a lack of success in finding sage grouse. Also, although much of the likely sagebrush habitat was investigated, many areas of ALE are relatively remote and not easily accessed.

1994—Biodiversity Inventory

Ecological studies funded in 1994 as part of DOE-RL's Public Safety and Resource Protection Program included a population census and contraceptive studies of Rocky Mountain elk, and surveys of plant species of concern, conducted in cooperation with TNC. TNC also began its biodiversity inventory in 1994.

- ***Growth of an Isolated Elk Herd (L.E. Eberhardt, L.L. Eberhardt, B.L. Tiller, and L.L. Cadwell)***

Purpose: To document the growth of an isolated elk population over nearly 20 years.

Method: Elk population trend data were secured from approximately weekly counts made during aerial patrols of the ALE Reserve (from 1975 to 1981), from a telemetry study begun in 1982, and from herd composition data collected from 1982 to 1984.

Conclusions: Nearly 20 years of population trend data yielded an overall rate of increase of 20 percent per year. A high (0.98) annual survival was calculated. An initially high calf-cow ratio was reduced in later years of the study, but causes could not be determined. The reproductive and survival data indicated a maximum rate of increase of 24 percent per year. The data were used to show that a feasible maximum sustainable rate for elk may be as high as 28 percent.

- ***Biodiversity Inventory and Analysis of the Hanford Site: Rare Plant Botany (K. Beck and F. Caplow [The Nature Conservancy of Washington])***

  Purpose: To conduct a survey on ALE (and in other areas of the Hanford Site) that appeared to have the greatest potential for supporting rare plant taxa.

  Method: Rare plant surveys were conducted at four levels: reconnaissance (walkthrough), light (widely spaced transects), moderate (numerous transects and higher intensity surveys), and complete (closely spaced transects and close searching in areas with rare plant populations or in habitat with a high potential for having them). The surveys took place periodically from March through August. All rare plant occurrences were fully documented and mapped on 7.5-minute USGS quadrangle maps with a GPS.

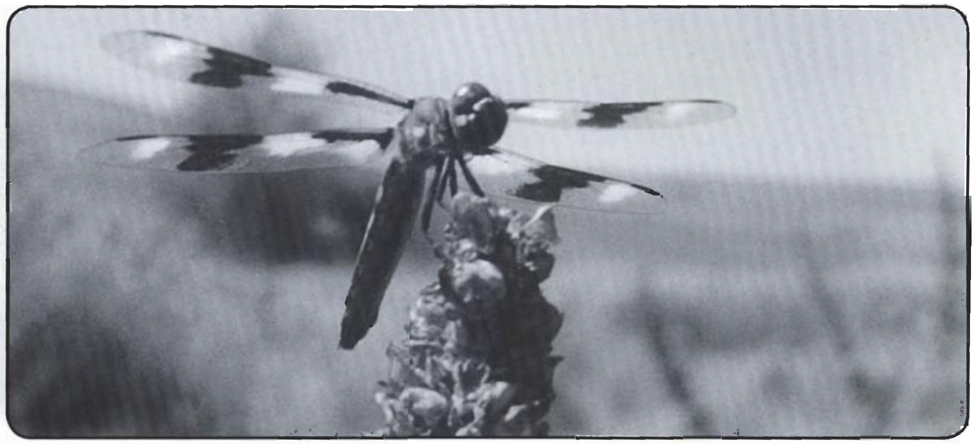
  Conclusions: Fifteen new populations of rare plants were found on ALE, eight of which were listed as state sensitive species, five as threatened species, one as a sensitive species, and one as a state Monitor Group 1 species. Most populations were located on the lower flanks of Rattlesnake Mountain or Yakima Ridge. Species included Piper's daisy, Columbia milkvetch, desert evening primrose, and Snake River cryptantha.

- ***Biodiversity Inventory and Analysis of the Hanford Site: Entomology (J.R. Dillman, P.A. Ensor, D.L. Strenge, and R.S. Zack [The Nature Conservancy of Washington])***

  Purpose: To conduct a large-scale biodiversity study of insects on ALE.

  Method: Several permanent sites were established and surveyed weekly to biweekly from March through December. Sites were located at Rattlesnake Springs, Lower Snively Springs, Snively Ranch, a dirt access road off of the 1,200-foot road, the radiotelescope site on Rattlesnake Ridge, the area around ALE headquarters, and the well site near the top of Rattlesnake Ridge.

  Conclusions: The survey revealed several insect species new to science, many rare species, and many recorded from Washington State or Benton County for the first time. Nearly 20,000 specimens were collected, 500 of which had been identified by the time the 1994 annual report was written. Identified species included 2 centipedes, 1 earwig, 1 praying mantid, 60 butterflies and moths, 90 leafhoppers and relatives, 65 true bugs, 72 bees and wasps, 103 beetles, and 126 true flies.



1995—Biodiversity Inventory

The Nature Conservancy of Washington's biodiversity inventory and analysis of the Hanford Site, including ALE, continued to provide DOE-RL with a comprehensive account of the species and ecosystems present on the Site. In 1995, bird, insect, and amphibian/reptile surveys were conducted on ALE. Also in 1995, Wildlife Resource Monitoring Project biologists monitored the Rattlesnake Hills elk herd. More than 300 elk were recorded on ALE that year before the offsite hunting season began. During the 1995 hunting season, 20 elk (17 bulls and 3 cows) were known to have been harvested from adjacent private lands.

Examples of some biodiversity inventory work conducted by TNC in 1995 are provided below.

- ***Biodiversity Inventory and Analysis of the Hanford Site: Ornithology (P. Bartley, T. Greager, D.N. Rolph, and A.M. Stepniewski [The Nature Conservancy of Washington])***

  Purpose: To conduct a bird census of the Hanford Site, including ALE.

  Method: Bird censuses were conducted using a combination of general transect surveys and point counts between late March 1994 to mid-November 1995. Eighty surveys were conducted on ALE along three routes. Point counts were made between May 1 and June 21. Thirty-two point count stations were established on ALE. The stations were visited once each in 1994 and 1995.

  Conclusions: Sixteen bird species of special concern were observed on ALE, including great blue heron, golden eagle, Swainson's hawk, ferruginous hawk, prairie falcon, Says phoebe, gray flycatcher, willow flycatcher, long-billed curlew, burrowing owl, Lewis' woodpecker, western bluebird, sage thrasher, loggerhead shrike, grasshopper sparrow, and sage sparrow.

- ***Biodiversity Inventory and Analysis of the Hanford Site: Lepidoptera (J.R. Dillman, P.A. Ensor, D.L. Strenge, and R.S. Zack [The Nature Conservancy of Washington])***

  Purpose: To conduct an inventory of Lepidoptera, the order of insects containing butterflies and moths.

Method: Surveys were conducted on ALE in 1994 and 1995.

Conclusions: ALE supported the greatest diversity of Lepidoptera found at the Hanford Site. Forty-six butterfly taxa were identified within ALE boundaries. Nine of those species were found only at ALE. Three uncommon species (Nevada skipper, Washington hairstreak, and Veazie's checkerspot) were found on Rattlesnake Ridge. Twenty-seven additional species were recorded on or near the ridge crest. One-hundred-seven moth taxa collected at ALE were identified.

- ***Biodiversity Inventory and Analysis of the Hanford Site: Herpetology (L.A. Hallock [The Nature Conservancy of Washington])***

  Purpose: To conduct an inventory of amphibian and reptile species on the Hanford Site (including ALE).

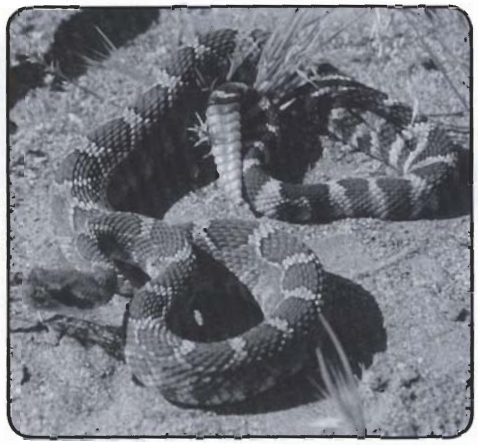
  Method: Surveys were conducted periodically from March to October. Eighty-three days were spent in the field. Methods used included visual encounter surveys, road sampling, cover boards, drift fence arrays, pitfall traps, call sampling, aquatic funnel traps, and seines.

  Conclusions: One amphibian (Great Basin spadefoot toad) and five reptile species (short-horned lizards, side-blotched lizards, racer, gopher snake, and western rattlesnake) were found on the ALE Reserve.

1996—Permanent Monitoring Plots

Ecosystem monitoring work under PNNL's Public Safety and Resource Protection Program continued in Fiscal Year 1996. Studies of Rocky Mountain elk focused on the growth of the herd and increasing damage to natural plant communities on ALE and to crops on adjacent private property. Permanent monitoring plots for flora and fauna also were established on the Hanford Site, including ALE, to improve measurement of natural and human-caused change and evaluate ecosystem health.

A draft biological resources management plan also was published in 1996. The purpose of the plan was to provide a framework for ensuring appropriate biological resource goals, objectives, and tools were in place to make DOE-RL an effective steward of Hanford lands and to implement an ecosystem management approach for biological resources on the Site. Biological inventories also were conducted by TNC in 1996.


- ***Establishment/Sampling of Permanent Monitoring Plots (L.L. Cadwell, J.L. Downs, and M.A. Simmons)***

  Purpose: To improve biological resource monitoring.

  Method: Thirty permanent plots were established in selected habitat types across the Hanford Site to collect baseline information. Plot locations were determined based on the condition of the sampling area, sensitivity of the habitat type to land-use change, and amount of prior information available for the sampling area. Vegetation surveys were conducted on these 20-hectare plots during spring and summer to provide biodiversity and monitoring information. Vascular plants were sampled along transects in each plot, and the percentage of the ground covered with biotic crust (lichens, mosses, and algae) also was estimated. Percent canopy cover and species abundance were analyzed.

  Conclusions: Total plant canopy cover found on the 30 plots ranged from 56 to 92 percent, with alien species cover ranging from 3 to 58 percent. Estimates of biotic crust cover ranged from 3 to 60 percent. Total cover (vascular plants and biotic crust) ranged from 66 to 143 percent (total canopy cover can be more than 100 percent). Plots with the greatest number of species were located at elevations above 2,000 feet. High species diversity also was found in areas with mature shrub inventory. Plots in areas that had been impacted by wildfire, in general, had slightly fewer species.

- ***Development of a Biological Resources Management Plan (J.A. Hall and L.L. Cadwell)***

  Purpose: To develop a comprehensive plan for managing the overall health of the entire Hanford ecosystem.

  Method: To write and distribute a draft plan that would provide DOE-RL and its contractors a consistent approach to protect biological resources and monitor, assess, and mitigate impacts to them from site development and environmental cleanup and restoration activities.

  Conclusions: A multi-hundred-page plan was written, produced, and distributed to interested parties. The plan described the Site's biological resources by management levels of concern; outlined DOE-RL's roles and responsibilities; described impact assessments, mitigation and restoration; and provided details on biological resource inventory and monitoring, landscape management, and data management.

1997—U.S. Fish and Wildlife Service Management

In 1997, DOE-RL transferred management of ALE from PNNL to the USFWS under a renewable land-use permit. Management transfer was part of DOE's plan to dispose of property it no longer needed, thereby shrinking the size of the Hanford Site. The permit granted the USFWS use of ALE "...for the purpose of operation...as a Research Natural Area." Although the USFWS gained management responsibility for the land, PNNL continued to monitor the Rattlesnake Hills elk herd.

The Nature Conservancy also continued its biodiversity inventories in 1997 (and on a limited scale in 1998). Information collected by TNC, along with existing data from PNNL's Ecosystem Management Project, provided information to support DOE's land-use planning process and data on which to base responsible biological resource stewardship and management actions.

- ***Biodiversity Inventory and Analysis of the Hanford Site: Birds (P. Bartley, T. Greager, B. LaFramboise, N. LaFramboise, D. Rolph, and A.M. Stepniewski [The Nature Conservancy of Washington])***

  Purpose: To conduct bird inventories of ALE and other areas of the Hanford Site.

  Method: Bird censuses used a combination of point counts, walking transects, and driving transects. The census period extended from March to December. Information on geographic distribution and habitat association also were obtained.

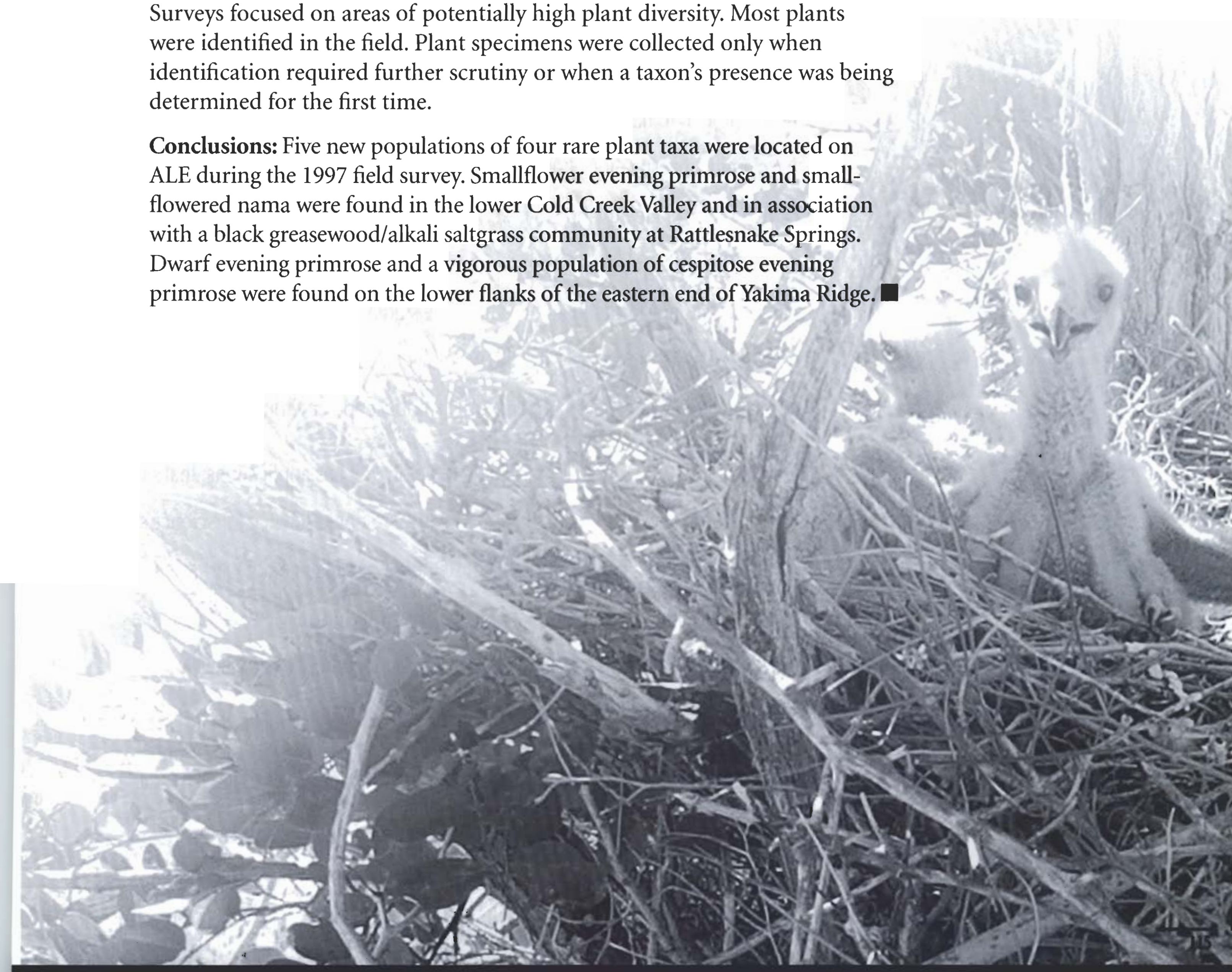
  Conclusions: The 1997 bird surveys documented a total of 121 species. More than twice the number of species unique to a particular area were observed on Central Hanford as compared with ALE. On ALE, several species of conservation concern primarily used big sagebrush-dominated habitats: loggerhead shrike, sage sparrow, and sage thrasher. Lark sparrow and white-crowned sparrow also were observed using big sagebrush habitats. Vesper sparrow and grasshopper sparrow frequently inhabited three-tip sagebrush/bluebunch wheatgrass habitat. Long-billed curlews were observed most frequently in cheatgrass fields that border State Highway 240. Golden eagle, prairie falcon, and western bluebird were observed along the crest of Rattlesnake Mountain.

- ***Biodiversity Inventory and Analysis of the Hanford Site: Rare Plants (K. Beck and F. Caplow [The Nature Conservancy of Washington])***

  Purpose: To conduct rare plant inventories on ALE and other parts of the Hanford Site.

  Method: Field surveys were conducted by foot from April to August. Surveys focused on areas of potentially high plant diversity. Most plants were identified in the field. Plant specimens were collected only when identification required further scrutiny or when a taxon's presence was being determined for the first time.

  Conclusions: Five new populations of four rare plant taxa were located on ALE during the 1997 field survey. Smallflower evening primrose and small-flowered nama were found in the lower Cold Creek Valley and in association with a black greasewood/alkali saltgrass community at Rattlesnake Springs. Dwarf evening primrose and a vigorous population of cespitose evening primrose were found on the lower flanks of the eastern end of Yakima Ridge. ■



Interview with Janelle Downs
Botany and Community Education

I grew up in Franklin County, basically seeing Rattlesnake Mountain on the horizon from the time I was very small. I came to work at ALE originally in 1980 on a summer internship when I was just a green recruit right out of college. It has been an important facility for me in terms of accomplishing my educational goals. Both my master's degree and my Ph.D. were based on projects done using ALE facilities. My favorite places are the top of Bobcat Canyon, upper Snively Springs, the west end of the summit of Rattlesnake Ridge, and the dry creek bed above Rattlesnake Springs. They're all beautiful places and unique because of their lack of disturbance over the last 50 years.

During the first decade I worked on the Arid Lands Ecology Reserve we were fortunate enough to have funding from DOE-HQ and be involved in a number of very basic scientific investigations. Over the years I worked on several programs funded by DOE's Office of Health and Environmental Research. One was the Dynamics of Arid Lands in which we used ALE as an outdoor laboratory to look at basic ecosystem processes in an undisturbed natural setting. We studied cycling of both nitrogen and carbon—very basic processes—and the water cycle, using the natural landscape to quantify how those processes happened in a shrub-steppe environment.

Much of the basic research that's been done on ALE has applications; that's the function of basic research. Many times we hear we're doing science for science's sake, and that's sort of an oxymoron because there is no science done for science's sake. We build on those blocks of knowledge, and if we don't have access to areas like ALE to further our understanding of ecosystem function, we can't develop adequate land management plans.

In the second decade, I was involved with research programs that gave DOE the kinds of answers it needed for environmental restoration. One project was the Hanford Barriers Program in which we used study sites on ALE as analogs for ecosystems on Hanford that would undergo environmental restoration. We helped collect baseline or historical matching data that could be used for models and help predict how systems that developed on Hanford barriers would perform over long time periods.

I've also been involved in what used to be the Ecosystem Monitoring Program where, again, we looked to ALE and its resident flora and fauna as baseline information for comparison against flora and fauna on Hanford's Central Plateau. We still do have some long-term monitoring plots on ALE we would like to maintain access to as a comparison dataset for what's going on at Hanford. These plots help us explain changes in population trends and in numbers and differences between habitats. They help us better understand the implications and potential impacts of Hanford operations on the system as a whole. Even as recently as the past few weeks we have been looking at how the vegetation and microbiotic crust on ALE has recovered on several long-term monitoring plots.

ALE has functioned not only as an incredible laboratory for research to understand basic research problems like ecosystem function, but also the life history and physiological conditions of numerous wildlife and their importance to both Washington State and the Pacific Northwest as shrub-steppe habitat declines. It has served as a baseline for a number of different kinds of studies, including, in the mid-1990s, a Washington Department of Wildlife study on habitat fragmentation effects on sage sparrows, a state candidate species. ALE was an important place for the agency to access because the shrub habitat, at that point, hadn't suffered the fragmentation you might find in more agriculturally oriented parts of Benton or Franklin counties. So ALE also has been an important baseline for state and regional questions.

Education

One of my jobs while I was working out of the ALE headquarters building was to coordinate the activities and resources needed for undergraduate and graduate students who worked over semesters or seasons. At times we would have 10 to 12 students vying to see who could get to the truck first to get to the field to do their research. A number of graduate studies looked at the deer and elk populations on ALE and Hanford. Some of the most interesting work investigated the physiological adaptations deer and elk undergo to withstand the extreme temperatures found in the shrub-steppe. What we found was that elk may be better suited to withstand extreme summer temperatures than deer, which was sort of contrary to the belief that elk are really a forest animal. Graduate students also studied coyote territory and the nesting behavior of ferruginous hawks, a state sensitive species.

A wealth of research projects have made use of the ALE Reserve. Work has been done to better understand the water-balance and photosynthetic properties of sagebrush— because it's a ubiquitous dominant plant across much of the West, and we need to understand how it works because, lo and behold, a number of wildlife species depend on sagebrush for survival. Studies also have been conducted on microbiotic crust, how it functions in the landscape, recovers after fire, and its functions in terms of nitrogen fixation and erosion protection.

Besides graduate and undergraduate research activities on ALE, one of the more enjoyable things that I've been involved in over the past decade has been teacher and secondary student education concerning the landscapes that they live in. This was accomplished through a number of different programs such as Science ALIVE, the Teacher Research Associates (TRAC) program, and now the Partnership for Arid Land Stewardship (PALS). We have been able to hold workshops and develop programs for educating educators, and I think there's been some incredibly powerful teaming. A number of different people at the lab have put a great deal of effort and volunteer time into science education programs.

One thing I can't say enough about is how important and rewarding it is to work with teachers in the shrub-steppe landscape. The ability to take people into that landscape—away from the road and all the distractions—and have them appreciate it and begin to know what it's composed of is incredible, whether it's the teachers, a field ecology class from WSU-Tri-Cities, or a public tour.

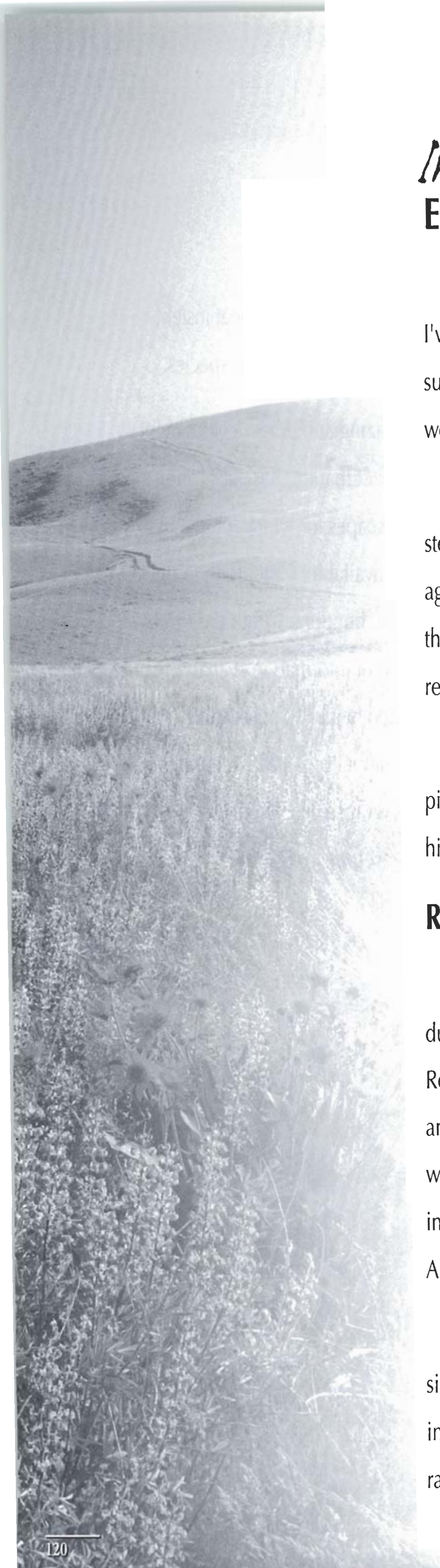
I don't know how many people have said to me "I will never look at sagebrush the same way again," or "I never knew how many plants and animals were here." For a number of people in the community, just that opportunity to get out and walk through the shrub-steppe, get down and touch the ground or the cryptogamic crust has been a life-changing event.

Research Natural Area

I think it's important for the public to realize that the community and the nation as a whole need places like ALE , designated Research Natural Areas, in which research and education are encouraged. The community needs to recognize the importance of understanding some of the last natural ecosystems we have, not just a list of what's out there, not just a map, but an actual understanding of the function of that system so we can apply that knowledge either to restore other ecosystems or understand how we can better manage the remaining shrub-steppe in our state, the region, and the West.

The reason ALE exists as it does today is because there wasn't a lot of management going on. Management, for the most part, consisted of making sure things were left in a natural state. We didn't manage to replant; we didn't manage to develop new ways to protect one species over another. The entire area was protected, and the most important thing was that it was protected from human intervention. From that standpoint the landscape was allowed to heal on its own, and we've learned a lot from that process. For example, we had an opportunity to look at the conditions of old fields—abandoned farms that were not disturbed for over 50 years. That gave us great insight as to the resilience and recovery rates for native species.

ALE's protection from grazing and other development make it unique, as does the fact that it's, basically, one of the few shrub-steppe landscapes for which long-term research information is available. Other long-term ecological research sites exist, but none within the shrub-steppe ecoregion. The wealth of information available from ALE and expertise gained by our scientists over four decades puts us in a position to consult with other researchers and collaborate on research. These things have made ALE a valuable resource for DOE.



Interview with Brett Tiller
Elk Monitoring and Research

I have been a wildlife research scientist with the Laboratory since June 1990. I've been engaged in biological monitoring programs and research that were done to support DOE management goals for the Arid Lands Ecology Reserve. Primarily, my work involves mammals and birds.

When PNNL conducted work for DOE at ALE, part of our charter was stewardship of those lands. Several federal directives require that government agencies have sound biological management plans to preserve federal lands and their biological resources. A big part of PNL's charter was to describe the ecological resources on ALE and summarize their "value."

For many years, we were almost a pseudo-management agency for DOE on that piece of land. Because it was not contaminated and not developed, ALE had really high value, biologically resource speaking.

Rattlesnake Hills Elk Herd

Since the 1970s, the ALE Reserve has turned into somewhat of a refuge for elk during the hunting season, but some animals were reported to be straying off the Reserve onto adjacent farmlands. Management objectives were to try to harvest animals out of these areas. The Washington State agency that technically manages wildlife populations in the state counted on us to provide them with solid technical information that would allow them to decide whether there were too many elk on ALE and whether adjacent landowner crop damage claims were legitimate.

Questions were raised about whether the rapidly increasing elk population had significant impacts on the vegetation and if the foraging and trampling impacts were in excess of what the ALE land could sustain. In response to these questions, we used radio-collared animals to track movements on and off the Hanford Site.

We also closely monitored the rate of population increase and demographics of the elk herd. For a time, elk were a novelty in the Columbia Basin. People wanted to see elk increase to the point where they were in sufficient numbers so they could be legally hunted on adjacent private lands. That created more interest. People wanted to hear how many elk were out there, and what the harvest allotment was going to be. Again, we were in a position to provide DOE with solid data. This information benefited the wildlife management agencies as well.

As we monitored herds and plotted their rates of increase, I tried to examine factors that were affecting the increasing elk population. It was apparent that shooting adults on private lands was removing a portion of the herd every year, but this source of mortality wasn't as large as the number of animals being born each year. The number of calves varied greatly from year to year.

Because of the relatively low harvest, a large proportion of old cows would build up in the herd. Older cows would only recruit a young every other year while younger cows, three to eight years of age, would recruit a young every year.

So, what if all of a sudden you have this buildup of relatively old animals and the recruitment drops? Then some massive harvest occurs: say, for example, the big fire when all the animals were forced to live on private lands, and a large proportion of the herd got harvested, wiping out a large percentage of the old females, leaving quite a few young females. The recruitment rate starts increasing again. This pattern creates drastic changes in growth. The herd was about 30 animals in the early '70s and increased to 800 animals or more in the 1990s.

The breeding season behaviors of the Rattlesnake herd, I hear, are unlike those of herds anywhere else in that for the male elk, it's "all or none." The male has a harem of females, and because there's no place for the herds to hide from the other male aggressors or challengers, you continually find these massive battles going on among the bull elk. One bull battles hundreds of other bulls sometimes to contend for the harem. Watching one bull take on five bulls at once and watching them all scatter is pretty interesting, pretty amazing really. No other place in the country has such a vast open terrain that supports elk.

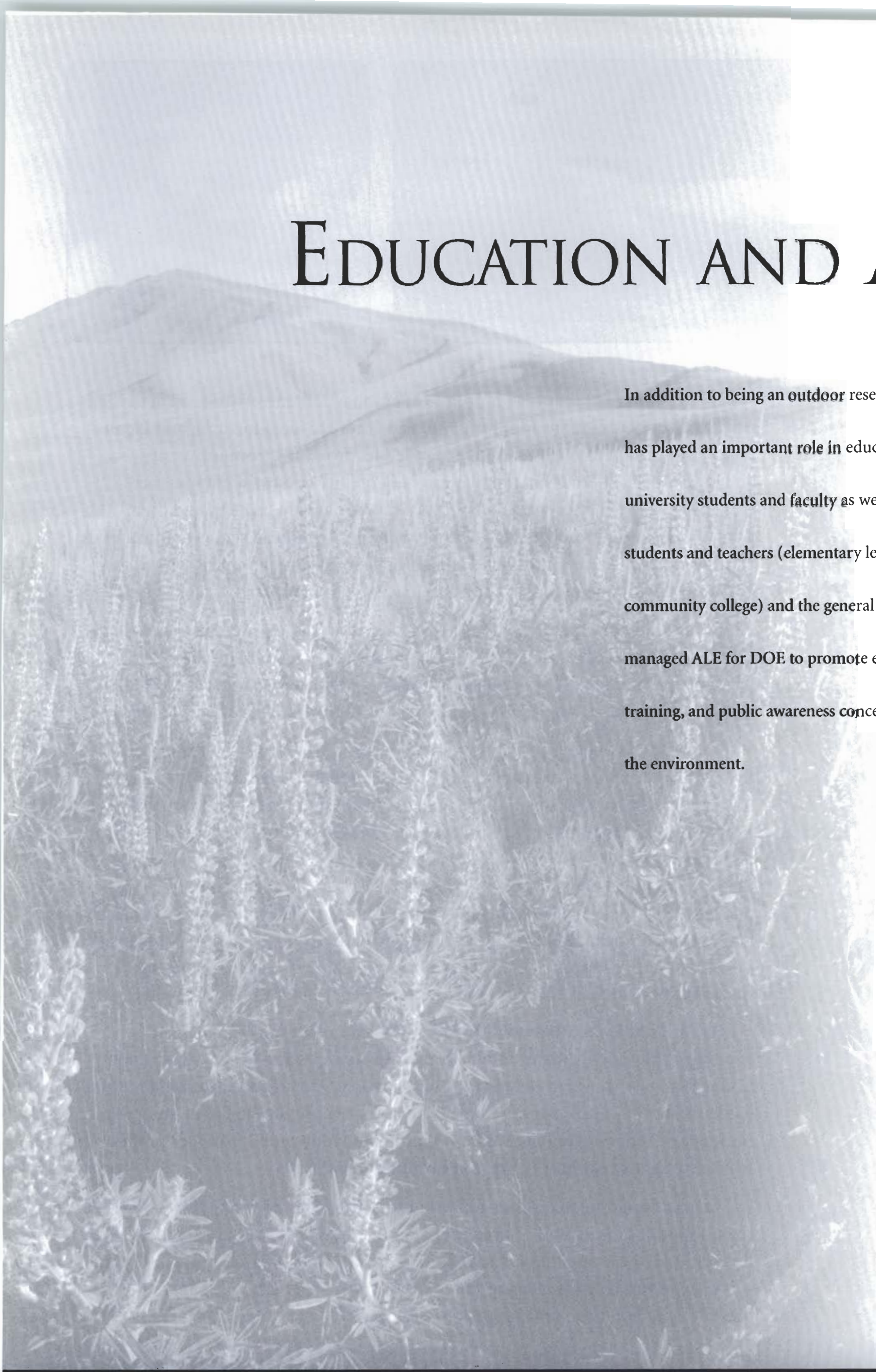
Education

I actually took my field ecology course in graduate school from Bill Rickard. ALE was our study site. Since I got my degree I have been engaged in a large number of science education activities related to ALE, ranging from middle school students all the way through teachers. We would go out there and conduct small-scale animal

and plant studies to show their associations and how we could quantify and demonstrate differences between habitats. I also was involved in a public education program through WSU (the Arid Lands Field Institute) where PNNL scientists acted as tour leaders for elk, and other activities. Basically since 1990, I've been fully engaged every summer doing some education activities out there. It was fun, but you committed a lot of your own time.

ALE's natural features show its uniqueness. I think people ought to be able to see the place, so they can appreciate it more. So far, few people ever really get a chance to see ALE, so they don't understand the value of it. The public hears about it, and hears that it's valuable, but when they drive by on Highway 240, it looks like a big old field of cheatgrass and other weeds. That's about all they can see from the road. You've got to see it yourself. Partial access to ALE would be great for the general public, not just for certain groups who are crazy about the birds and the bees, but everybody. I also think ALE should be kept open for research. The data are important not just for particular agencies, but to science in general.

My role at ALE has been simply as a provider of sound scientific information. I'm quite happy as that messenger.



EDUCATION AND ALE

In addition to being an outdoor research laboratory, ALE has played an important role in educating hundreds of university students and faculty as well as pre-university students and teachers (elementary level through community college) and the general public. The PNL managed ALE for DOE to promote education, teacher training, and public awareness concerning ecology and the environment.

In the early years, education programs emphasized university-level activities, providing undergraduate appointments and graduate, postdoctoral, and faculty fellowships. In the late 1980s, PNL expanded its programs from university activities to reflect DOE's national efforts to enhance pre-university science education. The Lab increased its emphasis on elementary, middle, and high school student and teacher activities; partnerships with local schools, universities, state agencies, science centers, and education associations; and programs that encouraged women and minorities to participate in mathematics and science.

Many students and teachers who participated in these programs were assigned tasks by staff researchers conducting ecologically oriented research projects. Others participated in intensive short-term workshops to increase content knowledge, skills, and understanding about science and ecological studies of arid lands.

University fellowship programs for students and faculty also increased in the 1980s and 1990s, as did partnerships with regional and national colleges and universities. Both university and pre-university programs were administered first by the Northwest Organization for Colleges and Universities for Science (NORCUS) and later by Associated Western Universities, Inc. (AWU) in conjunction with the Education Programs Office at PNL. Over the years, university programs were managed by such individuals as Burt Vaughan and Eric Leber. Program specialists have included Michelle Nichols, Curtis Nettles, and Mona Bauman. Pre-university programs were managed by Irene Hays and then Jeff Estes. Science education specialists have included Royace Aikin, Karen Wieda, and Kathy Feaster Alley.

As ALE researcher Ray Wildung noted, "I remember one year we had something like 150 different interactions with students and faculty. It was not unusual to have different people in various phases of education from high school students all the way to postdoctoral appointees working in the field. There were undergraduate and graduate students coming to study under different programs from throughout not just the region but the nation."

In addition to formal education programs, there has been an effort to educate the public about arid land ecology since soon after ALE was established. In 1970, for example, the annual report to AEC noted that "considerable effort has been made to permit conservation-oriented groups to gain a better understanding of the AEC's long interest and support of ecology."

The following sections describe university programs, pre-university programs, and efforts to communicate the role of arid land ecology to the public. The descriptions cover education activities from the 1960s until summer 1997, when the USFWS assumed management of ALE.

University Programs

Over the years, opportunities for ecological research and education attracted student and faculty researchers from colleges and universities all across the country. The Laboratory provided transportation, laboratory and office space, equipment, and specialized mentoring to assist students with their research. These studies added to ALE's ecological database.

Where possible, the number of students/faculty in a given year and their research topics are described below, based on information provided in PNL's annual reports to AEC/ERDA/DOE. The annual reports cite hundreds of students at all levels as working on research projects at ALE. However, only a few records exist that detail the number of participants or specific kinds of investigations conducted. For this reason, the information provided is sketchy. For many years, university students and faculty were listed, if at all, only as names on organization charts.

1960s

Graduate research studies were conducted on ALE even before it was named a Reserve in 1967, and education was made one of its primary missions. For example, T.P. O'Farrell, a postdoctoral student from Oak Ridge, Tennessee, conducted small mammal studies on what would become ALE in 1965 and 1966. O'Farrell stayed on as a staff scientist and later managed the Terrestrial Ecology Section of the Ecosystems Department.

In 1968, the NORCUS program was established at the Joint Center for Graduate Studies (now Washington State University-Tri-Cities). The purpose of the program was to provide direct experience for students and faculty in research and development at the Laboratory and stimulate new ideas for solving problems in research and development. The program supported undergraduate, graduate, and faculty appointments.

In 1968 and 1969, F.L. Rose worked on postdoctoral studies of cold desert streams at Rattlesnake Springs. Also in 1969, E.G. Wolf conducted Ph.D. research at Rattlesnake Springs. His research focused on primary productivity. Other graduate students who worked on ALE in the 1960s included R.N. Mack, who conducted studies of mineral cycling in sagebrush that year, and K.R. Price, who investigated the root distribution of sagebrush.

1970s

In the 1970s, the number of students and faculty working on the Reserve increased. In addition to DOE-funded research, ALE provided a study site for a National Science Foundation investigation of shrub-steppe birds conducted by Oregon State University and for studies of plants and rodents by investigators from Washington State University and the University of Washington. Students and faculty known to have conducted ALE research in the 1970s, and their work, if known, are listed below. The list may be incomplete.

1970—Two graduate students continued their studies in 1970:

- *Primary Productivity of Rattlesnake Springs (E.G. Wolf)*
- *Mineral Cycling in Sagebrush (R.N. Mack)*

1971-1972—One graduate student conducted studies in 1971 and 1972:

- *Small Mammal Studies (R.K. Schreiber)*

1973—One graduate student conducted ecological studies on ALE in 1973:

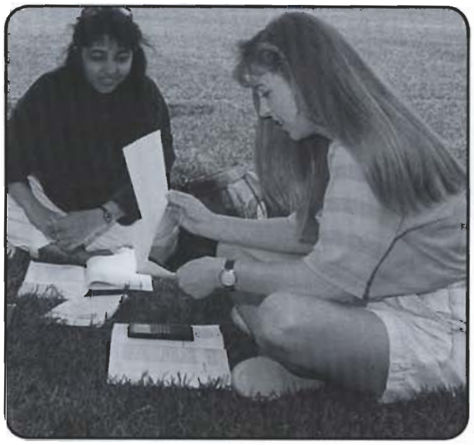
- *ALE Bird Studies (J.T. Rotenberry)*

1974—Three graduate students conducted ALE research in 1974:

- *Dietary Analysis of the Side-Blotched Lizard (J.K. Sheldon)*
- *Movement Patterns of Coyotes as Determined by Radio-Tracking (J.T. Springer)*
- *Bird Use of Riparian Vegetation (J.T. Rotenberry)*

1975—In 1975, five students were involved with ecological projects:

- *Raptor Ecology Studies (R.E. Fitzner)*
- *Movement Patterns of Coyotes as Determined by Radio-Tracking (J.T. Springer)*
- *Scorpions, Beetles, and Lizards (N. Gower)*



- *Coyote Food Habits on the Hanford Reservation (P.F. Stoel)*
- *Bioenergetics of Stream Insects (Dale McCullough)*

1976—Three graduate students and one faculty member from Oregon State University performed studies at ALE as part of a National Science Foundation project in 1976:

- *Shrub-Steppe Birds (J. Wiens, faculty; J. Rotenberry, R. Mason, and R. Pietruszka)*

1977—Three university researchers were granted access to the ALE Reserve for ecological studies in 1977:

- *Plant Demography (R.N. Mack, Washington State University)*
- *Ecophysiology of Rodents (G.J. Kenagy, University of Washington)*
- *Ecology of Shrub-Steppe Birds (J.A. Wiens, Oregon State University)*

1978—J. T. Rotenberry, Oregon State University, completed a dissertation in 1978 titled *Ecological Relationships among Shrub-Steppe Birds: Competition or Opportunism in a Variable Environment*. Three university faculty researchers continued to use the Reserve that year for studies begun in 1977, as listed below:

- *Plant Demography (R.N. Mack, Washington State University)*
- *Ecophysiology of Rodents (G.J. Kenagy, University of Washington)*
- *Ecology of Shrub-Steppe Birds (J.A. Wiens, Oregon State University)*

1979—Two visiting research scientists continued to use ALE as field study sites (Kenagy and Mack). Four graduate students and two faculty appointees also conducted ecological investigations on the Reserve. Some of these students and their studies are listed below:

- *Effect of Fire on Bluebunch Wheatgrass (M.C. McShane, Washington State University)*
- *Ecological Distribution of Rosy Balsamroot (M.A. Parkhurst, Joint Center for Graduate Study)*
- *Radioisotopes to Determine Plant Root Distribution and Biomass (P. Bookman, Washington State University)*
- *Taxonomy of Bottlebrush Squirreltail in Relation to Numerical Taxonomy (R. Newsome, Beloit University)*

Also in 1979, ALE researchers conducted a cooperative study of the Rattlesnake Hills elk herd with the Washington State Game Department as a result of concern over the elk possibly damaging farms and ranches neighboring ALE.

1980s

By the mid-1980s, the annual report to DOE noted that environmental sciences projects at ALE and the Hanford NERP had sponsored more than 70 master's theses and doctoral dissertation studies by joint arrangement with universities in 25 states. In 1985 alone, 129 assignments were reported that allowed students and faculty from all parts of the United States to participate in research projects. "It is noteworthy that many individuals continue to publish collaboratively with PNL many years after their initial contacts," the 1985 report said.

The University Programs Office at PNL reported that from 1985 to 1989, approximately 33 undergraduate students, 64 graduate students, and 22 university faculty participated in university programs that were associated with ALE. These numbers primarily represent participants who were provided appointments to the Laboratory through AWU NW and might not include all students or faculty. Lists of some students and faculty, and their research projects, if available, follow. This information was excerpted from PNL annual reports to DOE concerning ecological sciences.

1980—The annual report for 1980 noted that two students had completed research projects for advanced degrees in botany and wildlife management and that two university professors continued to use field facilities at ALE to pursue ecological studies supported by the National Science Foundation.

1981—One NORCUS graduate fellow participated in terrestrial ecology research in 1981 for an advanced degree in zoology:

- *Habitat Requirements of the Marsh Hawk (P.A. Thompson, Washington State University)*

1982—The 1982 annual report noted that "...about 300 university and college personnel have used the NERP site since the Arid Lands Ecology Reserve was established. Sixty dissertations at the master's and doctoral levels have been co-sponsored by PNL, and well over 100 college and university faculty members have participated in these PNL programs." No mention was made of specific research projects or individuals.


1983—The 1983 description of university interactions was the same as for 1982. No additional information was provided.

1984—In 1984, the annual report noted that two university faculty researchers had access to the ALE site. The studies were funded by Washington State University and the National Science Foundation. The investigations concerned the response of native plants to ash fall from Mt. St. Helens and the response of soil-dwelling algae to wildfire. In addition, three students reportedly completed requirements for master of science degrees and graduated in 1984. At that time, five students representing Pacific Northwest universities were reported working onsite. Some studies conducted by graduate students that year are listed below:

- *Movement and Abundance of Elk on ALE Using Radiotransmitters (S.M. McCorquodale)*
- *Ecological Study of Coyote Populations (R. Crabtree)*
- *Chemical Resource Allocations in Populations of Blue-Flowering Lupine (M. Hasey)*
- *Secondary Production of Insects (W.L. Gaines)*

Also in 1984, eight Ecology Group staff members were listed as affiliate faculty members at the Joint Center for Graduate Study in Richland.

1985—According to the 1985 annual report, ALE and the overall NERP had provided a doorway for university participants interested in environmental research at the Hanford Site since 1968. "Several hundred faculty and students have participated in research under this program, profiting by their access to the facilities of PNL and contributing to the many DOE research projects in environmental sciences," the report said. University Programs Office records showed that six graduate students and two faculty members potentially worked on projects associated with ALE in 1985.

1986—Overall laboratory support to universities significantly increased in 1986. This included direct support via subcontracts and indirect support to NORCUS for stipends to allow student and faculty participation at PNL. Several new collaborative relationships were developed under a Collaborative Agreement between PNL and Washington State University. Nineteen dissertation studies on ecological topics reportedly were in progress that summer, including research on elk and coyote populations.

In addition to PNL hosting faculty from other universities, Ecology staff members held affiliate or adjunct appointments at a number of universities and contributed to the universities' education programs directly through the Tri-Cities University Center (TUC) in Richland. The annual report noted that approximately two-thirds of the TUC teaching staff were scientists and engineers from PNL, including 14 senior staff members from Earth and Environmental Sciences.

1987—Two students completed doctoral dissertations and graduated in 1987; another student completed a master's thesis. Five other graduate students were working onsite researching coyotes and plant populations. The annual report said that future graduate research would be encouraged in the general field of arid land studies with special emphasis on developing a detailed understanding of the response of arid ecosystems to human-induced disturbances, in line with DOE-funded research at the time.

1988—Faculty and graduate students conducted a variety of research projects on ALE and the overall NERP in 1988, including the following:

- *Water Relations and Photosynthesis in Big Sagebrush (R.A. Black, Washington State University)*
- *Soil Microbial Ecology (D. Bezdicek, Washington State University)*
- *Arid Land Soils (A. Busacca, Washington State University)*
- *Evapotranspiration (L. Fritchen, University of Washington)*
- *Arid Land Balance (D. Hillel, University of Massachusetts, Amherst)*
- *Geographic Information Systems (W. Smith, Central Washington University)*
- *Ecological Behavior of Coyotes on ALE (F. Knowlton, Utah State University)*
- *Remote Sensing (D. Gibbons, Fort Lewis College, Colorado)*

1989—No graduate, undergraduate, or faculty research at ALE was described in the 1989 annual report. The report did note that PNL researchers were members of graduate and teaching faculty at Washington State University, the University of Washington, and the University of Idaho.

1990s

The early 1990s might well be described as the heyday of education programs at the Laboratory. The University Programs Office reported that from 1990 through 1996, approximately 147 undergraduate, 79 graduate, and


17 postdoctoral students participated in research that potentially involved ALE. Seventy-three faculty members also conducted research during the decade that involved the Reserve.

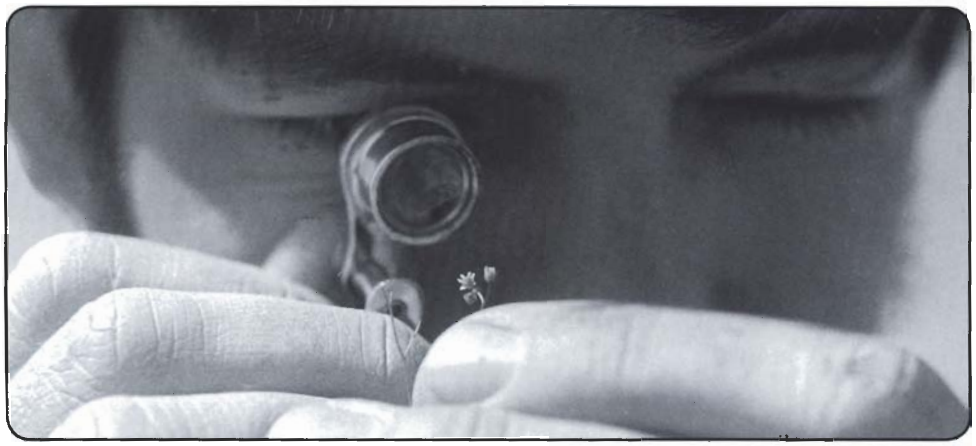
A guide to education programs for 1993-1994 listed seven undergraduate programs, 14 graduate programs, five postdoctoral programs, and six faculty programs as well as numerous minority programs and university partnerships. Some of these programs and participants are described below by year.

1990—University interactions for 1990 included hosting visiting scientists from universities and government agencies. Some studies conducted that year include the following:

- *Effects of Soil Water Deficit and Plant Age on Plant Water Uptake (R.A. Black, Washington State University)*
- *Identifying the Efficiency of Nitrogen Utilization in Semiarid Old-Field Communities (J.L. Smith, U.S. Department of Agriculture [USDA] Agricultural Research Service)*
- *Documenting the Flux of Radiatively Important Biogenic Trace Gases from Shrub-Steppe Communities (J.M. Klopatek and L. Schwarz, Arizona State University)*
- *Stable Carbon Isotope Analyses of Aquatic Insects and their Food Bases in Two Shrub-Steppe Desert Spring-Streams and a Critique of the Method (A.L. Mize)*

1991—The 1991 annual report noted that "PNL has become a leader in developing science education programs for students and faculty at the university and pre-university levels. During 1991, PNL established and strengthened partnerships with major universities and public schools." The Dynamics of Arid Land Ecosystems Project continued to interact extensively with USDA Agricultural Research Service soil scientist J. L. Smith that year. One postdoc (J. Halvorson) and one graduate student (D. Mummey), both from Washington State University, worked with Smith and Laboratory staff.

Also in 1991, the Environmental Management Career Opportunities Research Experience (EMCORE) program began at PNL. Jerry Bromenshenk (faculty research fellow, University of Montana) and five University of Montana undergraduate students participated in the program, teaming with PNL host scientists to explore environmental restoration problems at Hanford.



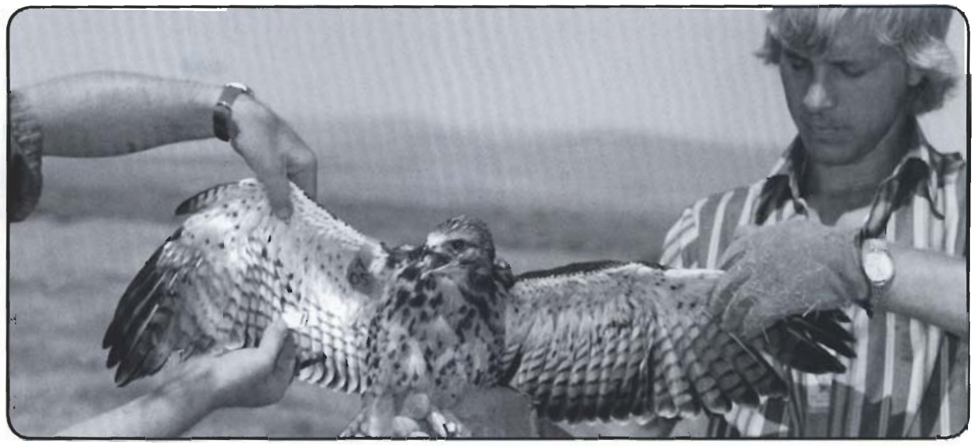
The EMCORE program was designed to expand the number of scientists and engineers qualified to address the nation's environmental problems in the science and technology of environmental restoration and waste management. Undergraduate students participated with a university faculty member in a "team" arrangement. The PNL team's approach was to conduct a group project (learning how to use GIS technology) and individual projects, working with a host scientist. The student/mentor relationship that developed during the initial 10-week summer session continued during the academic year.

1992— In 1992, PNL developed an education initiative, PNL 2000, as part of a statewide effort to implement systemic change in mathematics, science, and technology. As part of PNL 2000, the number of new Laboratory-university partnerships reached a record level. Seven students worked as part of EMCORE. Eight additional students worked in plant and animal ecology. Some ALE-related projects conducted by faculty and students that year include the following:

- *Defining Resource Islands Using Multiple-Variable Statistics (J.L. Smith, USDA; J. Halvorson, and D. Mummey, Washington State University)*
- *Landscape Predictions of Soil Water Dynamics on the ALE Reserve (R. Kremer, University of Montana)*
- *Water Relations of Artemisia tridentata (J. Healy, Washington State University)*
- *Effects of Nitrogen and Water on the Efficiency of Water and Nitrogen Use (D. Jeffries and L. Schwarz, Arizona State University)*

1993—Three students continued to work in the EMCORE projects in 1993. J. L. Smith and his graduate students also continued their work on nitrogen flux and resource islands in the shrub-steppe. Eight other university students participated in university programs related to ALE that year.

1994—Two university faculty members and approximately 16 students worked on environmental sciences projects related to ALE in 1994. Five of these students were participants in the Science and Engineering Research Semester (SERS) program. The program offered college juniors and seniors the chance to participate in research at one of seven DOE laboratories. SERS was the only organized DOE undergraduate program conducted during the academic year, either fall or spring semester.



1995—In 1995, one faculty member and 15 students worked on environmental sciences projects. Two were graduates and 13 were undergraduates. Nine of these students were participants in the SERS program. Students participating in university programs represented universities such as Northwestern State, the University of Central Arkansas, Eastern Michigan University, and Florida A&M University.

1996—Two graduate students from Washington State University, one postdoc from the University of Montana, and seven undergraduate students, participated in university programs related to arid land ecology in 1996. Students represented universities such as Texas A&M, Eastern Kentucky University, Gonzaga University, and Stanford.

1997—In 1997, one faculty member, one graduate student, and six undergraduates participated in university research related to ALE. Two students were participants in the SERS program.

Pre-University Programs

The ALE Reserve provided an important part of environmental education activities for pre-university students and teachers for much of two decades. The ALE management plan included a specific policy for encouraging educational and training opportunities for students and teachers through established programs.

Until the mid-1980s, PNL sponsored only two pre-university programs: Inquiry Into Science (IIS) and the Student Research Apprenticeship Program (SRAP), both targeting high school students. No middle school, elementary school, or teacher programs existed. And there was no central education group within the Laboratory until about 1984, when Irene Hays, among others (chiefly Burt Vaughan in University Programs), enabled by Lab Director Bill Wiley and his education/external relations chief, Jack Bagley, began to create one, as described in the interview at the end of this chapter.

1980s

Although the exact numbers of participants in science education programs related to ALE are not available, the Education Programs Office estimated that more than 100 high school students and 50 teachers participated in ALE-related pre-university education programs in the 1980s.

1980-1986—Strengthening and expanding PNL's relationship with local and area high schools was an objective highlighted in DOE's 1984 Operations Directive to the Laboratory. Former Science Education Center manager Irene D. Hays noted in her 1984 report on the status of education programs at PNL that this goal translated into helping students prepare for future careers; providing opportunities to students, faculty, and school administrators and boards to expand their awareness and understanding of the spectrum of ongoing and future research activities; and providing, as appropriate, faculty and school administrators with consultations on curricula.

"These developments led to PNL's new perspective and renewed commitment to support and assist science education in local and regional educational institutions," Hays said.

Initially, students participated in research-based experiences through IIS. The purpose of IIS was to provide high school seniors who expected to pursue careers in science and engineering an opportunity to work directly with scientists and engineers. Students attended regular classes at their school for one-half day, then worked 4 hours a day, 5 days each week at the Laboratory with a scientist/mentor in a specified research area. This program began in 1973. IIS, now known as the Student Research Internship (SRI), continues today.

Beginning in 1980, high school students from ethnic groups traditionally underrepresented in science and mathematics participated in ALE research through SRAP. Students spent 4 days each week with their mentor/scientist and the fifth day participating in educational enrichment activities provided by the SRAP program. Approximately 12 SRAP students were assigned to ALE research projects in the 1980s. SRAP also continues today. Kathy Feaster Alley manages the program.

"Programs like SRAP and IIS (now SRI) have continued (even in difficult financial times) because of the Lab's interest in workforce development and programs that recruit and retain underrepresented minority students and women into science and engineering," said Jeff Estes, current Science Education Program Office manager.

For the first time, in 1985, the Science Education Center conducted a regional high school student science institute related to environmental topics. The purpose of the institute was to support the education of future scientists, raise the


scientific literacy of the education community, and create a greater understanding of research and development sponsored at the Hanford Site. The first institute included Washington, Oregon, and Idaho students and one teacher from each state. "I was offered $20K by DOE to develop and conduct one of the first of its kind of institutes as a model for what later became the National High School Honors Student Research Institute," Irene Hays said. The program ran from 1989 to 1992.

In 1986, one teacher participating in the national DOE Teacher Research Associates (TRAC) (named REST [Residence in Science and Technology], at the time) worked on a research appointment on ALE. The TRAC program provided summer research appointments for middle and high school science, technology, and mathematics teachers. Some teachers chosen from a national pool were matched with ALE scientists based on their skills, education background, and teaching experience. Teachers received 8-week appointments.

Over the years TRAC teachers have worked on many kinds of research, including insect population and habitat studies, native vegetation habitat management, noxious weed population management, raptor population studies, deer and elk population management, ecological profiling, and environmental restoration and sustainability projects. Science education specialist Royace Aikin has managed this program since 1992 at PNL. When TRAC was discontinued as a national DOE program in the mid-1990s, PNL continued to sustain it with its own funds and funds from the National Science Foundation.

1987—Pre-university programs were mentioned in the PNL annual report to DOE for the first time in 1987. The report noted that ecology staff participated in pre-university education activities by providing 1) instruction and demonstrations in the classroom; 2) student apprenticeships, workshops, and field trips; 3) teacher workshops and cooperative studies; and 4) technical support and assistance to local and regional schools. Specific field study units offered hands-on learning experiences about the plants, wildlife, and environmental processes of the shrub-steppe.

In addition, ecology staff made presentations at more than 25 local schools through the Sharing Science with Schools Program. Topics covered wildlife biology, plant physiology, insect ecology, geology, and meteorology. The purpose



of this program is to stimulate student interest in science and engineering and promote scientific and technological literacy.

1988—In 1988, PNL hosted a 1-week Regional Honors Student Research Institute. Twenty high school students from Washington, Oregon, Montana, Idaho, and Alaska worked with researchers on ALE. The purpose of the DOE-funded program was to introduce high school science students to the scientific method and acquaint them with the technology used to evaluate the environment and resources available to mitigate natural and human disturbances. Several ALE researchers worked with the students and their three local mentor teachers in the field and laboratory.

ALE staff also worked with one SRAP student that year and with two teachers participating in the TRAC program.

In addition, in 1988, ecology research staff made presentations at more than 20 local and regional schools through the Sharing Science with Schools Program. Over the years, as part of this program, researchers have given classroom presentations to audiences ranging from kindergarten students to twelfth grade and at conferences such as Expanding Your Horizons (6-8 grade girls), the Yakima Valley/Tri-Cities Mathematics, Engineering and Science Achievement Career Conference (middle school students), and Young Scientists (Saturday science activities).

1989—During 1989, PNL hosted one of seven national DOE High School Student Honors Research Institutes. Fifty-six students from across the United States and several foreign countries studied arid ecosystems at ALE and marine ecosystems at the Battelle Marine Science Laboratory (MSL) in Sequim, Washington. Participants from Alabama to Wyoming, the United Kingdom, West Germany, and Japan worked with ALE and MSL staff and 10 local teachers to collect data on native plant and animal species. Jeff Estes managed this program at the time.

Also in 1989, two TRAC teachers were assigned to environmental sciences studies. They worked with researchers on vegetation and bird nesting classification studies in sagebrush-bunchgrass communities and assisted in radiotelemetry work. Each teacher participating in the program developed instructional strategies for use in the classroom based on their laboratory experiences.

1990s

The 1990 annual report noted that, "As part of its mission, PNL contributes to strengthening and enhancing science and technology education by building partnerships and developing collaborative programs with elementary and secondary schools, colleges, and universities in the region."

More than 200 students and 100 teachers participated in programs on or related to ALE research during the decade. "The strength of student and teacher programs, developed with the aid of ALE researchers in the '80s and '90s, allowed PNL to submit proposals for funding from the Washington State Office of the Superintendent of Public Instruction and the National Science Foundation when DOE money went away in the late '90s," Jeff Estes said.

1990—Again in 1990, PNL hosted a DOE national High School Student Honors Research Institute. The Institute brought in 60 students from across the United States and several foreign countries to study semi-arid ecosystems in the context of global environmental change. Ten teachers worked with the students and ALE researchers. As part of the program, PNL scientists and science educators began to develop research scenarios that simulated the types of ecological research conducted at ALE, the Hanford NERP, and MSL. These scenarios formed the basis of a problem-solving approach used for later teacher development programs.

Beginning in 1990, and ending in 1996, staff scientists from ALE hosted elementary and middle school teachers participating in the DOE/National Science Foundation-funded National Teacher Enhancement Project (NTEP), known locally as Science Alive. The program was designed to develop teacher leaders who could improve science teaching in classrooms, school buildings, and school districts.

From 1990-1992, 25 teachers (per year) representing multiple school districts in the Yakima Valley and Tri-Cities participated in Science Alive. From 1993-1995, the program worked with 24 teachers from Kennewick, Toppenish, and Yakima. The same 24 teachers participated in the program for three years. In 1996, the program was expanded to include teachers from Pasco and Richland, in addition to the other three districts.

Science Alive targeted schools in the Yakima Valley and Tri-Cities having large numbers of Hispanic, American Indian, and African American students. PNL researchers led teachers through activities designed to help them understand arid land ecosystems. Science education specialist Jeff Estes led this effort.

Five TRAC teachers worked on ALE research. Teachers collected plant, soil, and meteorological data for biobarrier/climate change studies; analyzed a sagebrush/bunchgrass community; and conducted radiotelemetry studies of sage grouse.

Also in 1990, ecology researchers began to work with middle school teachers and students as part of the DOE OPTIONS in Science program. OPTIONS was created as a national effort to get and keep female and minority students in the math/science pipeline. PNL scientists participated in meet-a-scientist sessions at seven middle schools in the Yakima Valley, Tri-Cities, Spokane, and Portland in an effort to interest students in science and technology. A group of scientists also made OPTIONS presentations at middle schools in Seattle. During each year of the OPTIONS program, a terrestrial ecology teacher workshop was held at ALE.

Through OPTIONS, Science Alive, and the Honors Student Research Institutes, PNL scientists and science educators developed a problem-solving approach for teacher development that simulated actual research at ALE. This is how it worked: Program participants

- were given a research problem scenario (such as assessing the impacts on flora and fauna of siting wind turbines in the Rattlesnake Hills or evaluating the effectiveness of a revegetation effort)
- were provided with or gathered background information on the problem
- defined a scope of work
- identified and chose methods and procedures to explore the problem
- practiced needed research skills
- collected, analyzed, and summarized data
- applied new knowledge to the problem scenario
- produced a product (such as a presentation)
- worked with scientists and science educators to design ways to transfer new learning to the classroom.

This approach became the model for conducting professional teacher development programs at PNL.

Also in 1990, researchers continued to make presentations at local, regional, and community schools through the Sharing Science with Schools program.

1991—Two TRAC teachers were assigned to projects in Earth and Environmental Sciences in 1991. Teachers worked with researchers to collect and analyze field and laboratory data on plants, soils, and vegetation in sagebrush-bunchgrass communities; conduct radiotelemetry studies of mule deer and elk; and analyze field data using the GIS.

Environmental scientists also worked on terrestrial ecology projects on ALE with the Science Alive teachers. Teachers learned about habitat diversity, adaptation strategies, population study methods, ecosystem dynamics, remote sensing, and water balance.

Four SRAP students worked with ALE researchers in 1991. In addition, PNL hosted 57 high school students from 49 states and territories and six foreign countries as part of a two-week DOE High School Student Honors Research Institute. Using ALE as a study site, students conducted plant, wildlife, and earth science research activities.

Researchers also made presentations on desert ecosystems at area schools through the Sharing Science with Schools program. They discussed characteristics of the shrub-steppe environment and how wildlife adapt to it.

1992—In 1992, five national TRAC appointees were assigned to earth and environmental sciences. High school teachers assisted researchers in basic and applied research tasks related to plant ecology, revegetation, and plant physiology. ALE researchers also continued to work with middle school students in the OPTIONS program and assisted middle school instructors in teaching science using actual research approaches.

ALE researchers again hosted the DOE High School Student Honors Research Institute. Fifty students from around the world and eight local teachers participated in shrub-steppe plant assessments and habitat enhancement projects. Eight Science Alive teachers also took part in terrestrial ecology activities on ALE.

1993—Three TRAC teachers were assigned to work with ALE-related projects in summer 1993. Teachers gathered field data related to plant ecophysiology and plant population biology. Another 16 teachers from Toppenish and Yakima worked in the field as part of Science Alive. Two SRAP students worked on ecology projects in 1993. Also, a new cohort of Science Alive teachers began investigations on ALE that year.

1994—Sixteen Science Alive teachers from Kennewick and Yakima continued to work on ecology topics related to ALE in 1994. Researchers worked with two SRAP students that summer in projects related to plant and animal ecology. Eight Science Alive teachers worked with staff scientists on ALE.

1995—Science Alive teachers from Kennewick and Toppenish worked with ALE investigators, and two SRAP students worked on ecologically related projects. Researchers also worked with one TRAC teacher that summer.

1996—Three SRAP students and eight Science Alive teachers worked with ALE researchers in 1996.

1997—Building on previous teacher education programs, science educators continued to use ALE in summer 1997, the year the USFWS assumed management of ALE. The primary program was the Partnership for Arid Lands Stewardship (PALS) teacher institute.

The purpose of PALS is to encourage long-term stewardship of arid lands of the Columbia Basin through environmental science education. Staff from PNNL and other partner organizations worked with elementary and middle school teachers to help them understand basic ecology and the function of the shrub-steppe ecosystem. Field work for this program was conducted in arid lands of the Columbia Basin, including ALE. Since 1997, PALS has trained 144 teachers. Each summer program has included some component related to ALE.

The PALS concept was the brainchild of science education specialist Karen Wieda, Jeff Estes, and Jack Bagley. PALS partners have included the Arid Lands Field Institute; Battelle; Columbia Basin College; Educational Service District 123; Eisenhower Professional Development Program, Lower Columbia Basin Audubon Society, PNNL; TNC; DOE; USFWS; Washington State University, Tri-Cities; and the following school districts: Columbia, Finley, Kennewick, Kiona-Benton, Pasco, Richland, and Toppenish.

Models for professional development of teachers—first developed through TRAC, NTEP, and OPTIONS—have served as the basis for the current set of teacher professional development programs such as PALS. "PNNL staff working on ALE helped us develop and refine the fundamental attributes of these professional development programs, which connect academic learning to the world beyond the classroom," Jeff Estes said. "The Ecology Group continues to be a core resource for our environmental education activities."

Public Awareness

The ALE management plan, developed for DOE in 1993, specifically noted that "...publishing information about the natural history of the Hanford Site in the public literature is important and increases community support of Hanford environmental issues." Some examples of these public awareness efforts over the decades follow:

1970—Ecosystems Department scientists met with conservation groups, including representatives of the Audubon Society, the National Wildlife Federation, the Sierra Club, and other major groups. The meetings included tours of ALE and face-to-face discussions with ALE researchers. The Department also produced a "moving picture film" that year called Endless Chain. The film explored the ALE ecosystem. According to the annual report, the film was well received by both technical and public audiences.

1973—Former PNL Ecology Group Manager T. P. O'Farrell published one of the first public interest articles on ALE ("Project ALE: A Natural Desert Community") in 1973 in a regional magazine called *Pacific Search: Journal of Natural Science in the Pacific Northwest.*

1991-1997—Lee Rogers, a former ALE manager, began writing a natural history column in the *Tri-City Herald* in 1991. He continued creating the column until 1997 when Steve Link (PNNL, then Washington State University) took over. The majority of Rogers' articles focused on natural history topics related to work in which he was involved on ALE. The articles were compiled into a booklet called *Shrub-Steppe Seasons: A Natural History of the Mid-Columbia Basin*, which PNNL published in 1995 and again in 1997.

2001—Georganne O'Connor, an Ecology Group writer, and Karen Wieda, science education specialist, developed the book *Northwest Arid Lands: An Introduction to the Columbia Basin Shrub-Steppe* in 2001. It was published by Battelle Press and is distributed by the University of Washington Press. Much of the information provided in the book is based on research conducted on ALE over four decades. The book has been widely distributed throughout the western United States.

In addition to creating print materials, over the years ALE research staff hosted occasional tours of the Reserve by conservation-oriented groups, including the Lower Columbia Basin Audubon Society, TNC, the Washington Native Plant Society, and the Arid Lands Field Institute. These trips were limited in number and in number of participants because of DOE safety and security concerns and the need to protect the natural ecosystem of ALE from human disturbance. ■

Interview with Irene D. Hays
Science Education

I joined Battelle in 1980 after teaching at Richland High and in schools in Idaho and Hawaii. At the time, there were no central focused or formal education programs at Battelle, no entity called "education programs," nothing called the "center for education" or anything like that. There were a few discrete activities going on that could be labeled "education" because they were in partnership with schools or colleges and universities. And then there were some formal employment or recruitment programs housed nominally in the Human Resources Department that had education components. But there was no fire under the process, nobody really claimed education as a worthy or significant program goal.

When I arrived, there were only two pre-college programs in the Lab: Inquiry into Science (IIS) and another high school student program that was a precursor to the current Student Research Apprenticeship Program (SRAP). At that time, the IIS brought in students solely from Richland High School. It was a partnership between Battelle employee Frank Hungate and Jim Harbour, a local teacher. The purpose was to give Jim's top science students an opportunity to get involved in research at Battelle throughout the school year. They were paid primarily by project funds. During that time, students were assigned to laboratories that often related to environmental science or had some connection to work at ALE. Also, some students were assigned to researchers who worked in the field, and these students spent their time on field research.

What is now the SRAP program started in 1979, one year before I arrived at Battelle, and still continues today. I've always been proud that Battelle supports that program because it focuses on students from ethnic groups that are underrepresented in science and technology, such as African American, Native American, Hispanic, and women students.

Funds for SRAP, after the first year, came from the branch of DOE-HQ that still funds education. The head of that funding effort was Harry Young, and then

Rich Stephens took Harry Young's role some years later. Rich is the one who funded the major education programs at DOE Laboratories in my 20 years at Battelle.

Getting Involved

Once I learned of these two education programs, I immediately got involved with them in some way. When I looked around, I saw that nobody was really enthusiastic about education programs, nobody was ready to legitimize education, so I got involved because I cared about it and wanted to do something about growing education programs at Battelle.

Thus began the vision and the pursuit. I would talk to people within Battelle and at DOE, often carrying around in my pocket proposals for programs I tried to sell. Often the listeners just ho-hummed me on my way.

Not that people didn't want to do it, but they didn't understand how it was going to be paid for or the larger benefit to the Laboratory. It was my job to try to promote that, and it became an uphill effort because discretionary money was very tight, as it is now.

Decade of Growth

I became a manager of science education in 1984, if I remember correctly, and I got some direct funding from HQ and support from inside the Lab and outside. We moved into a huge era of growth from 1984 to 1994. DOE-HQ took a larger role with us.

Early on, I developed and designed—pretty much as a single-person organization with a couple of helpers—some focused programs in all areas of pre-college science education. In the mid to late 80s, I was able to hire another education specialist, and then another.

A program for high school teachers was one of the largest programs. It was developed concurrently with efforts at Lawrence Berkeley Laboratory and Argonne. We brought in a few teachers to participate in research beginning in the summers of '83 and '84 under almost bootleg funding.

The early funding came from researchers who needed help in their projects and committed to set aside certain funds that we would use to bring teachers into the Lab. Later, teacher programs became probably the highest priority effort nationally for DOE and several other federal agencies for quite a few years.

At PNL, the program grew from 6 to 50 teachers yearly during that 10-year period. Teachers would spend 8 to 10 weeks in the summer in research at PNL. Eighty percent of their time would be with researchers out on ALE or in laboratories and 20 percent with a cohort of their peers. The teachers developed lessons they could take back to their classrooms based on their research experiences at the Lab.

That early model, which initially was called the REST (Residence in Science and Technology) program, became the TRAC (Teacher Research Associates) program. It still exists today at sites all across the country, under other names. PNL had a large role in establishing the national program. I helped lead the efforts nationally for several years trying to get it legitimized and funded.

I used to joke that my first funding from DOE-HQ was $30,000, and then, as a vision, I moved that decimal point over a few spaces and came up with three million. Then when I got there I moved on, I guess. So there was big growth in the teacher program, but there were other growing programs as well.

We were able to demonstrate that PNL and other labs had something to offer middle school students and elementary school teachers, as well as high school students and teachers.

For a time early on we had a program called Young Scientists. Students would come out to the Lab on Saturdays and go through science stations in the auditorium and around the Site. Probably two-thirds of those stations had to do with research on arid lands and the environment. People like Bill Rickard and many of the researchers who were fathers of the work out on ALE were a part of that program.

Almost every education program had a component that connected to ALE. There was a program called the Honors Student Research Institute, funded by HQ, an environmental science institute. It involved students spending a week or two on ALE and in other ecosystems in Washington State like the saltwater environment at Sequim. One student from every state and about 10 from foreign countries participated. Some years we had as many as 60 kids.

We had beautiful results from that institute. Students kept journals, and some of them would become poetic even about the science they studied. They'd write about the beauty of ALE and what it meant to them to be there.

Those writings illustrate the impact ALE had on students, certainly in terms of their head knowledge but also in terms of their commitment, their heart knowledge about what it means to care for the environment and

know the natural world in a place like ALE. Kids are never the same after those experiences.

I think one thing that made ALE such an appropriate education arena/tool is that the field environment was more accessible to some students than were indoor environmental sciences laboratories. If you were to place some students in an indoor laboratory they would certainly be able to do things, but the environment might not feel as accessible. It might feel foreign to them, and it might discourage them even, in some cases, rather than encourage them to study science.

But almost any young person can find an outdoor environment appealing, more real, you know, than an unknown indoor setting. They can see what they study and touch it; it's all there and accessible. ALE was sometimes the key for students who might have been disenfranchised or disenchanted with science somewhere along the way.

A Larger Purpose

Education programs were instituted as a way to help researchers get some work done and further research projects. But most people at Battelle, in my experience, also have a deep commitment to education. And they want to give something back. Many feel as if they are really making a difference in improving the quality of education in our community and in our country.

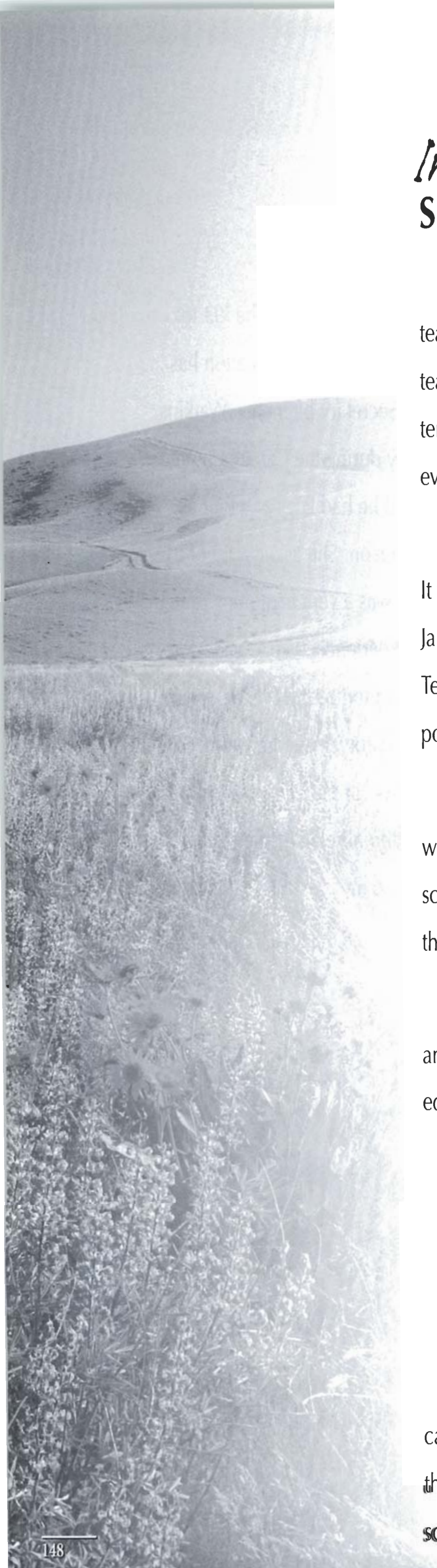
That was the larger purpose for creating programs: to improve the quality of education in this country, and how can you do it any better than working with the teachers of all those students? That role justified the teacher program to a huge extent. When you bring in one teacher you're actually affecting hundreds and hundreds of students. Sometimes even in one school year, a teacher may have 150-200 students a semester. So you can improve the quality of education that was seen at that time to be in deep trouble.

Another reason for education programs that many subscribed to was to get students into what we called the science education pipeline. We wanted to get more students into that pipeline so they might consider careers in science and technology and particularly in environmental science and working with the kinds of pristine environments available at ALE.

We thought that, somehow, by bringing young students into the Laboratory they would be better prepared to make decisions about whether they really wanted to be scientists.

DOE funded several studies to show how many of the university level students actually made it into science careers. So it does appear to work. And we certainly saw evidence that teachers who participated in our programs were revitalized. There was also evidence from some national evaluations we conducted that teachers made really remarkable changes in their classrooms. Those are reasons why education programs were instituted at PNL and elsewhere.

I guess we sort of had a heyday during the 90s. I don't think it's ever been the same in terms of the big rush of enthusiasm and funds for education programs. The programs that exist today were once larger, especially when there was a great deal of funding in the '93 to '94 timeframe. The level of funding for education has a lot to do with who's the Secretary of Energy. Watkins was the Secretary of Energy during the Camelot times. And he was wonderful, and he had Peggy Defour as his right-hand education person. She asked a lot of us but also gave a lot to us. It was a very frustrating time in many ways, but a heady experience. We at PNL were encouraged and enabled to promote our participation in these nationally initiated programs largely due to the vision and commitment of Laboratory Director Bill Wiley and his chief education/external relations person, Jack Bagley, both of whom shared my passion for education.



Interview with Jeff Estes
Science Education

The experiences on ALE were captivating and motivating for students and teachers alike. There was something special about them. I can remember watching teachers on their hands and knees looking at Daubenmire plots where the temperature was well above the comfort zone and being so immersed that they didn't even notice.

But it wasn't just the plants, animals, or geological features that engaged them. It was the PNL researchers. Key people like Dick Fitzner, Les Eberhardt, Bill Rickard, Janelle Downs, Brett Tiller, Bert Cushing, Dennis Dauble, Steve Reidel, Fenton Khan, Ted Poston, Sue Sargeant, Shannon Goodwin, Duane Horton, and others created powerful first-hand learning experiences for students and teachers alike.

Participants in our programs at ALE didn't just read about the environment or watch a video, they experienced it directly and personally with the support of a science expert who helped them to come to more deeply understand and appreciate the land and streams they were learning about.

Teachers used a teaching/learning model that paralleled the way scientists and engineers uncover knowledge and solve problems. Participants in ALE-related education programs took part in learning activities that

- provided a meaningful context
- gave them the chance to explore and discover the ecosystem
- proposed explanations to questions and solutions to problems
- used their newly acquired knowledge both personally and in their classrooms.

Participants in these programs knew immediately how much our scientific staff cared about what they did and how much they wanted participants to experience their passion for the shrub-steppe. The partnership between our scientific staff and our science education staff was particularly powerful and continues to be so even today.

Lasting Memories

I do have some lasting memories about ALE and the people who worked there.

- Colleen McShane and Bill Rickard – Even before I really knew him, Bill was affecting my life and my philosophy of science education. I was a young 4th-grade teacher who had just come to Richland in the fall of 1978. I was beginning a master's program that I would complete in 1982. One requirement was to complete a curriculum project. I'd connected with Colleen somehow, and she had come to my room and helped my kids and me learn about the plants and animals found outside our school yard. At the time, the school (Badger Mountain Elementary) was surrounded by shrub-steppe. One day I asked her if she knew anyone who would be willing to help me with a project on the wildlife communities of the Mid-Columbia. She connected me with Bill, and he helped me develop the curriculum unit I used. It was with great pleasure that I renewed my acquaintance with Bill when I came to work for PNL in 1988.
- Rickard again – He worked with students and teachers, and I begin to notice an unusual ritual. Each group would use small colored tags to mark the variety of shrub species found within a study plot. When the time with Bill came to an end, he gave group members a tag as a souvenir. What was remarkable to me was how much his "students" treasured these souvenirs. There are a variety of ways to judge a person's impact on others. The fact that these mementos were so treasured by his students says a lot about this man.
- Les Eberhardt – Ever been on a goose round-up? I have! I count it among my most blessed memories, as did the 10 or so students in the National High School Student Honors Research Institute. I still remember driving the young geese (couldn't fly yet) up river and "corralling them." I also remember the banding process where Les sat on the ground and stuck the goose's head between his legs while he banded it.
- Dick Fitzner – MSL in the summer. Eagle nest in a tree. A huge mess from the eagle on the ground. Dick Fitzner as happy as could be to dig through the droppings to learn more about the eagle. I knew then he was unique and fascinating.
- Dennis Dauble – Touchet River...fish shocking as part of Honors Student Research Institute...work done for the day, but waiting for Bert Cushing's group to finish aquatic insect collection. I turn and what do I see...fly rod in hand, Dauble is hoping to catch a big trout. I thought...I've got to get a job like this guy.
- Bert Cushing – Touchet again. Insect collection and snorkeling to watch aquatic insects and fish. I had never snorkeled in six inches of water before (or since).
- Janelle Downs – Absolutely remarkable at thinking up "real-life" scenarios that students and teachers could do. This brought a great deal of "context" and meaning to the terrestrial work that was being done. It was also fun to watch Janelle try to manage Bill Rickard, whom we all know cannot really be managed.

ACRONYMS

AEC	U.S. Atomic Energy Commission
ALE	Arid Land Ecology (Reserve)
AWU	Associated Western Universities, Inc.
BLM	U.S. Bureau of Land Management
DOE	U.S. Department of Energy
DOE-RL	DOE-Richland Operations Office
EDM	Ecological Data Manager
EMCORE	Environmental Management Career Opportunities Research Experience
ERDA	Energy Research Development Administration
GE	General Electric Company
GIS	Geographic Information System
IBP	International Biological Program
IIS	Inquiry Into Science
MESA	Math, Engineering, Science Achievement
MSL	Marine Science Laboratory (Battelle)
NEPA	National Environmental Policy Act of 1969
NERP	National Environmental Research Park
NORCUS	Northwest Organization for Colleges and Universities for Science
NTEP	National Teacher Enhancement Project
OHER	Office of Health and Environmental Research (DOE)
PALS	Partnership for Arid Land Stewardship
PNL	Pacific Northwest Laboratory
PNNL	Pacific Northwest National Laboratory (Name changed in 1995 from PNL to PNNL)
REFLEX	Remote Fluvial Experiments (program)
REST	Residence in Science and Technology
RNA	Research Natural Area
SERS	Science and Engineering Research Semester
SRAP	Student Research Apprenticeship Program
SRI	Student Research Internship
TNC	The Nature Conservancy (of Washington)
TRAC	Teacher Research Associates (program)
TUC	Tri-Cities University Center
USDA	U.S. Department of Agriculture
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey

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