Table 3.3 Observed annual mean 24-hour PM_{10} values (μg/m³) from three counties near the Savannah River Site

County	1995	1996	1997	1998	1999	2000
Aiken, SC	19	19	21	23	21	21
Barnwell, SC	16	17	19	19	19	23
Richmond, GA	NA[a]	24	26	28	24	23

Source: U.S. Environmental Protection Agency 2001a.
[a] NA = Not available

While official $PM_{2.5}$ monitoring data for South Carolina are not available, unpublished data indicate that emissions at rural sites exceed the annual $PM_{2.5}$ concentration standard of 15 μg/m³ from April to September each year. The possibility that $PM_{2.5}$ standards might be exceeded near the forest-urban interface could restrict burning in the future. In contrast, PM_{10} concentrations seldom approached half of the annual mean standard of 50 μg/m³ (table 3.3).

Ecological Restoration

Christopher D. Barton, John I. Blake, and Donald W. Imm

The long history of human settlement, agriculture, and industry at the Savannah River Site (SRS) has created extensive opportunities for ecological restoration. Two hundred years of farming, drainage, dam construction, stream channeling, fire protection, subsistence hunting and fishing, exotic animal and plant introduction, and selective timber harvesting have caused major changes in the SRS landscape (table 3.4). These activities degraded the native plant and animal communities by removing species for commercial use (e.g., longleaf pine, white oaks; see appendix for scientific names of plants) or subsistence needs (e.g., white-tailed deer, wild turkey [*Meleagris gallopavo*]; see table 4.24 for scientific names of mammals). Tillage eliminated native vegetation locally, and exotics (e.g., kudzu, hogs, and cattle) competed with or damaged native species. Activities also altered natural hydrologic and wildfire regimes essential to the maintenance of native communities. Baseline surveys of the flora and fauna at SRS in the 1950s provide a measure of the degree of human impact (e.g., Batson and Kelley 1953; Freeman 1954; Freeman 1955).

Since the establishment of SRS, certain activities have also directly or indirectly affected native plant and animal communities. Industrial operations, such as the discharge of thermal effluent to streams (Halverson et al. 1997) and construction of facilities (Mayer and Wike 1997), caused contamination and habitat loss. The planting of non-native slash pine on old fields, harvesting of older trees in remnant forests, and site preparation for planting altered vegetation composition.

Management activities that contributed to ecological restoration of the SRS occurred regularly during the first several decades of the Site's operation. These include planting and seeding of longleaf pine, initiation of prescribed burning, draining of impoundment areas, reintroduction of the eastern wild turkey, and restoration of red-cockaded woodpecker habitat. The single most important restoration activity was probably the establishment of the buffer zone (unoccupied by human residents) to isolate the SRS facilities (Baker and Chesser 2000). This action allowed some native species to recover without further intervention (Beavers et al. 1973; Jenkins and Provost 1964). Those species included the American alligator, white-tailed deer, beaver, bobcat, and many reptiles and amphibians (see chapter 4). Similarly, certain silvicultural activities such as planting, harvesting, and burning have accelerated natural plant succession and expansion of native savanna plants (Smith 2000) and increased the abundance of important wildlife food plants (McCarty et al. 2002). In addition, protection of unique communities for research allowed recovery of local populations of aquatic species (Davis and Janecek 1997).

Current Ecological Restoration Strategies and Activities

Restoration efforts have expanded in the last decade as knowledge of presettlement conditions (Frost 1997), current community distributions (chapter 4), and restoration techniques have increased. In general, the goal of ecological restoration at SRS is to restore native species, their habitats, and key environmental processes while retaining the integrity of the Site's missions.

Hardwoods

Early survey plats show a dominance of pine, but white oaks (e.g., *Quercus alba, Q. stellata, Q. michauxii*) were a common hardwood species two hundred years ago (Frost 1997), occupying the most fertile soils. These hardwood forests represent the preferred habitat for many wildlife species

Table 3.4 General ecological impacts from post-European settlement in the Central Savannah River Area and strategies for ecological restoration

Post-European settlement activity	General ecological impacts	Examples specific to SRS	Restoration strategies
Selective harvesting of commercial pines and hardwoods	Loss of tree species and critical habitat for dependent species	Longleaf pine, white oaks, bald cypress, swamp tupelo	Replant or regenerate species on appropriate sites
Forest fire prevention, limiting the spread of natural fires	Dominance of woody shrubs and trees, loss of grass and herbaceous plants	Loss of savanna herbs and grasses on remnant sites and associated animals	Thin stands and establish regular burning regimes during winter and summer
Subsistence hunting, fishing, and predator control	Loss of or reductions in major vertebrate species	Bison, black bear, red wolf, cougar, sturgeon, gopher tortoise	Regulate hunting and fishing and selectively reintroduce species
Introduction of exotic plants and animals not native to SRS	Competition with and predation on natives, and destruction of rare plants	Feral hogs, dogs, fire ants, kudzu	Direct control of non-natives where problems are localized
Farming activities involving intensive tillage, chemicals	Local destruction of vegetation, stream sedimentation	Tillage impacted 75% of SRS, with widespread use of arsenic, nitrogen, phosphorus fertilizer	Revegetate old fields and bare areas, stabilize streamside areas
Drainage and farming of seasonal wetlands such as Carolina bays	Loss of seasonal wetland-dependent species of plants and animals	Most wet depression meadows farmed, >50% drained by ditching	Restore hydrology, reintroduce selected native wetland vegetation
Construction of mill dams, impoundments, and channeling streams	Altered stream structure and associated fish, plants, and invertebrates	Probably >20 small dams and ponds on streams at SRS in 1951	Break down water-holding structures to reestablish natural flow
Isolations and reductions in size of native vegetation areas	Fragmentation of the communities, limiting dispersal and densities	Farming estimated to directly impact 75% of SRS, about 60% forested in 1951	Reestablish native vegetation and large blocks of specific types

(chapter 4). Although the approximate area and distribution of hardwood stands is similar to that of pre-European settlement (Frost 1997), human activities have drastically altered the composition. Colonial settlers preferred oaks for barrels, furniture, and fuelwood. As a result, oaks declined to the point that they are no longer dominant in most hardwood stands on SRS. Certain red oak (e.g., *Q. falcata*) and hickory (e.g., *Carya pallida*) species sustained less dramatic reductions.

Hardwood stands currently occur along stream corridors, near the Savannah River swamp on nontillable soils, and on sandhill soils too poor to farm. Upland stands often occur in small isolated remnants that escaped fire, in fencerows, and in stringers leading from stream corridors through the uplands. The current management objective is to maintain the existing percentage of land area in hardwood, mixed pine-hardwood, and bottomland swamp forest stands. Some area reduction within the primary red-cockaded woodpecker recovery zone (see chapter 1) may be offset by increases in the other zones through conversion of old-field pine to mixed hardwood-pine on mesic or wet soils. Restoration goals are to improve the quality of the species mixture in stands, particularly increasing white and red oaks, dogwood, holly, and other species that are soft fruit–producing.

Experimental planting of various hardwood species in existing hardwood and old-field stands has occurred since the mid-1960s. However, poor stock quality, competition, and inappropriate site selections limited success. Since 1993, the SRS has planted 157 ha (388 ac) of hardwood on moist sites with a mixture of cherrybark oak, swamp chestnut oak, willow oak, green ash, white oak, and sycamore (figure 3.8a). Limited seed and seedling availability is a major constraint to planting more white and red oaks on suitable sites. Methods for restoring hardwoods include harvesting, usually clear-cutting small blocks of either pine or previously high-graded hardwood stands, followed by site preparation, which may include burning and herbicides. Enrichment planting of various oaks and other species is followed by competition release using mechanical cutting or spot treatment with herbicide. Natural regeneration of oaks is often unreliable due to previous removals, irregular acorn crops, and high acorn consumption by animals. The SRS developed a cooperative seed orchard to help supply southern red and white oak seed. Because size and root development of the bare-root stock is critical to long-term survival and growth (Kormanik, Sung, and Kormanik 1994), nursery managers carefully select the stock. Root competition and shading from overstory trees result in poor growth of species planted in the

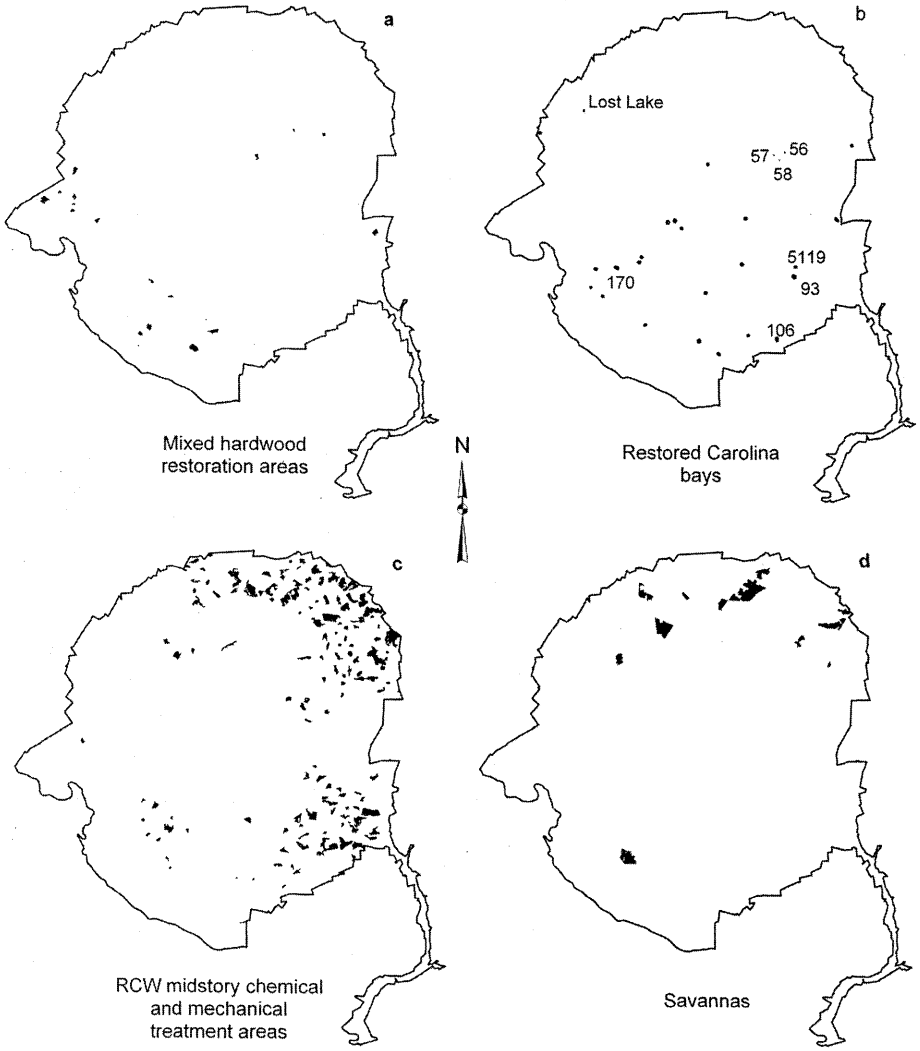

Figure 3.8. Locations of restoration projects on the Savannah River Site: (a) mixed hardwood stands restored since 1993; (b) Carolina bays with restoration activity since 1989 (bays not labeled are the nineteen bays in the mitigation bank); (c) red-cockaded woodpecker habitat restored since 1983 by midstory removal and prescribed burning; and (d) sites selected for establishment of savanna plant populations in old-field pine stands. RCW = red-cockaded woodpecker (U.S. Forest Service, unpublished data).

understory (R. H. Jones, Virginia Polytechnic Institute, unpublished data), so planting in newly cleared areas free of competition is preferable.

Bottomlands and Riparian Zones: Pen Branch

The SRS has a "no net loss" wetlands policy and a wetlands banking program to mitigate potential loss of wetlands on the site. Several wetland mitigation projects involving the creation, restoration, or enhancement of wetlands have been performed on SRS (Irwin et al. 1997). The Pen Branch restoration, required for the continued operation of K Reactor (U.S. Department of Energy 1991), exemplifies the mitigation process at SRS. The Savannah River swamp is a 3,020-ha (7,462-ac) forested wetland on the floodplain of the Savannah River at the SRS (see figure 2.4). Historically the swamp consisted of approximately 50 percent bald cypress–water tupelo stands, 40 percent mixed bottomland hardwood stands, and 10 percent shrub, marsh, and open water (Nelson, Dulohery et al. 2000). Major impacts to the swamp hydrology and vegetation occurred with the completion of nuclear production reactors in the early 1950s. Water was pumped from the Savannah River through secondary heat exchangers of the reactors and discharged into tributary streams that flowed into the swamp. From 1954 to 1988, SRS discharged high-temperature effluents in excess of 65° C (149°F) into one of the tributaries, Pen Branch, at rates often twenty to forty times greater than normal flow. The sustained increases in water volume resulted in overflow of the stream banks, erosion of the original stream corridor, and deposition of a deep silt layer at the confluence of Pen Branch and the river floodplain. The nearly continuous flooding of the swamp, the thermal load of the water, and the heavy silting resulted in complete mortality of the original vegetation in the Pen Branch corridor and in large areas of the river floodplain (figure 3.9).

Once SRS reduced the pumping, natural reestablishment of early successional species like cattail, bulrush, buttonbush, pokeweed, blackberry, and black willow occurred in the affected areas. However, few volunteer seedlings of bottomland hardwoods or bald cypress were evident. Therefore, a mitigation action plan was formulated to guide the restoration of the degraded Pen Branch wetlands. The successful completion of the mitigation entails three strategies: (1) the rehabilitation of the Pen Branch corridor and delta by natural succession, (2) the reforestation of the corridor and delta by planting, and (3) the compensatory mitigation of other

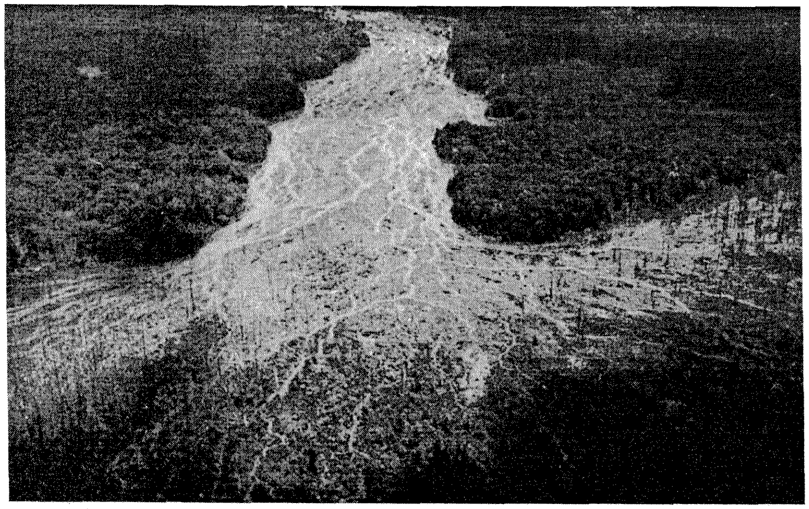

Figure 3.9. Aerial view of the Pen Branch corridor and delta on the Savannah River Site during reactor operations (U.S. Forest Service files).

impacted areas on the SRS pending evaluation of the success of the first two approaches.

From 1993 to 1995, the SRS planted approximately 75 percent of the affected Pen Branch floodplain area in bottomland hardwood tree species, keeping the remaining area (25 percent) unplanted for experimental purposes (figure 3.10). Three restoration approaches were formulated to address the differing conditions of the impacted floodplain. Approximately 8,700 seedlings were planted in the lower corridor (15 ha, or 37 ac) without any site preparation, and the delta (12 ha, or 30 ac) was planted after herbicide application in the absence of burning (figure 3.11). The upper corridor (24 ha, or 60 ac) was planted after the application of herbicide and a prescribed burn. Herbicide application and prescribed burning were performed to control a dense black willow overstory and to clear brush and vines from the planting area. Tree species included in the plantings were overcup oak, swamp chestnut oak, nuttall oak, willow oak, cherrybark oak, water hickory, persimmon, green ash, sycamore, swamp black gum, water tupelo, and bald cypress (Dulohery et al. 1995). While the stream structure and aquatic communities were not manipulated, the trees were expected to alter light, temperature, and organic debris (logs, leaf litter) in the stream favorably for fish and invertebrates. In

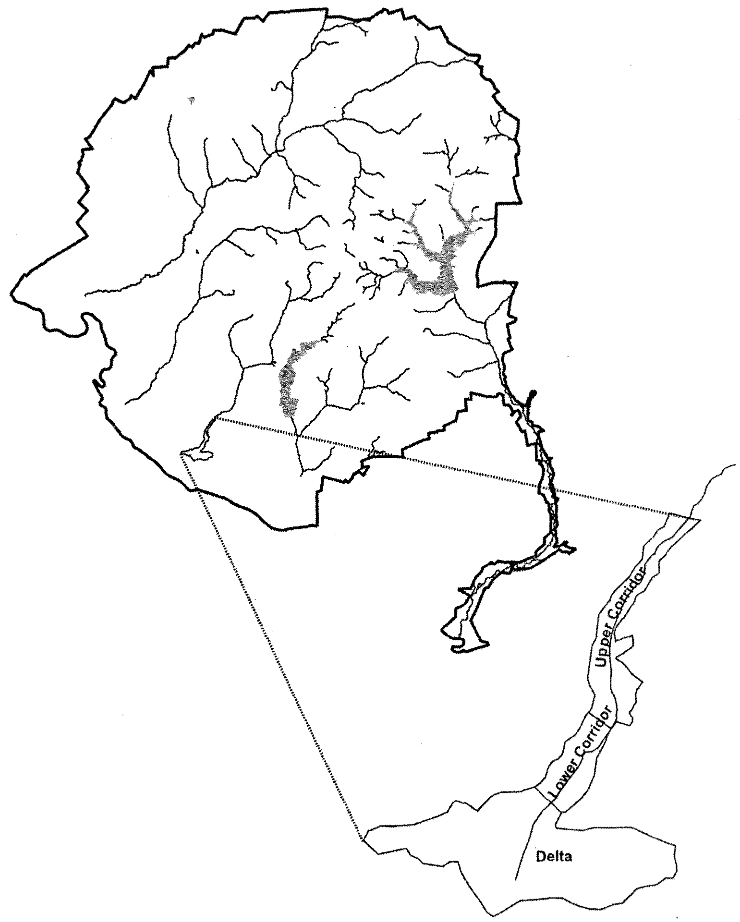

Figure 3.10. Degraded wetland areas of the Pen Branch corridor and delta on the Savannah River Site that were impacted by thermal releases from reactors and later restored as part of the mitigation effort.

addition, several areas of open water in the delta were left unplanted with cypress or tupelo to benefit wading birds, waterfowl, and alligators.

The SRS developed an extensive research program to examine the restoration ecology of the Pen Branch system. A special edition of *Ecological Engineering* (Nelson, Kolka et al. 2000) outlines many of these studies. Tree seedling studies indicated that many site preparation techniques (burning, herbicides, thinning) did not significantly impact early growth or survival (Dulohery, Kolka, and McKevlin 2000). However, tree shelters

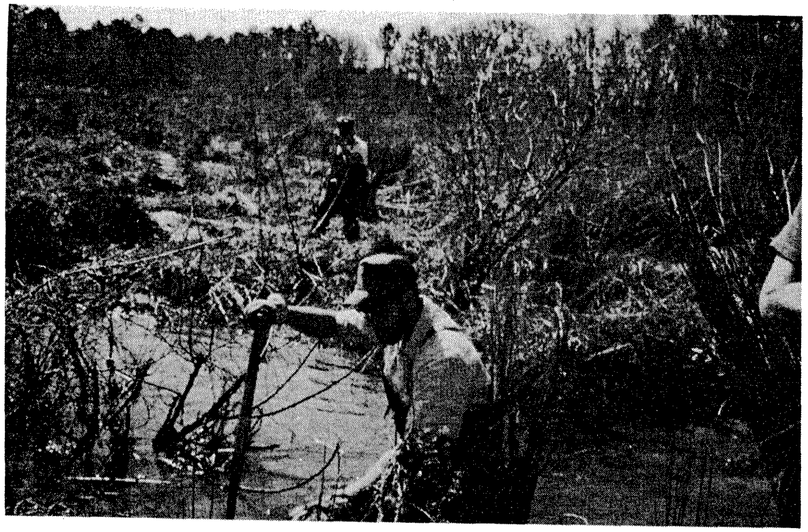

Figure 3.11. Planting trees in the Pen Branch corridor on the Savannah River Site, 1993 (U.S. Forest Service files).

and root pruning were effective silvicultural techniques that enhanced survivability in areas prone to stress from herbivory and competition (Conner, Inabinette, and Brantley 2000). A 1997 survey showed that water tupelo, green ash, sycamore, and persimmon had the highest survival in the upper corridor, while bald cypress survived best in the wetter lower corridor and river delta areas (Kolka et al. 1998). Although species abundance and, in some cases, diversity are higher in the Pen Branch floodplain than in the reference systems (table 3.5), the composition of plant and animal communities and key energy sources such as soil carbon and nutrients indicate that the Pen Branch floodplain remains an immature, early successional system but is moving toward recovery (Giese et al. 2000; Wigginton, Lockaby, and Trettin 2000).

Pen Branch is currently functioning as a viable early successional wetland. Kolka et al. (2000, 2002) used measurements of hydrology, soils, vegetation, carbon and nutrient cycling, and animal communities to predict wetland function in response to the restoration. As a consequence, SRS wetland restoration research will serve as a template for future wetland restorations on site and elsewhere.

Table 3.5 Species richness, calculated as either total number of species observed or average number, for taxa in Pen Branch compared with disturbed post-thermal (20–30 years) and late successional forested reference sites at the Savannah River Site

	Pen Branch (unplanted)	Pen Branch (planted)	Fourmile Branch and Steel Creek (post-thermal)	Meyers Branch and Tinker Creek (reference)
Total vegetation[a]	81	79	68	63
Herbaceous species[a]	2.35	2.86	2.23	2.96
Macroinvertebrate orders[b]	22.4	NA	NA	17.6
Herpetofaunal species[c]	44.4	44.2	NA	NA
Avian species[d]	8.2	9.7	16.3	19.1
Fish species[e]	21	18	15	12.5

[a] Giese et al. 2000.
[b] Lakly and McArthur 2000.
[c] Bowers et al. 2000.
[d] Buffington et al. 1997.
[e] Paller et al. 2000.

Carolina Bays

The SRS has several hundred Carolina bays or baylike depression wetlands, ranging from small (less than 0.1 ha or 0.25 ac) ephemeral bays to large (larger than 50 ha or 124 ac) bays that retain water for most of the year (chapter 2; Schalles et al. 1989). They serve as habitat for a wide range of rare plants and many vertebrates. The adjacent uplands also provide nesting sites for turtles and birds, as well as niches for facultative wetland plants. Although bays share some common plant and animal associates, the variability in composition between bays with similar soil, hydrology, and geomorphic conditions suggests that periodic rainfall, fire, and chance colonization also influence the observed flora and fauna (Greenberg and Tanner 2004). Predicting the restored structure and composition of the dominant vegetation of a disturbed bay is difficult, even using current topographic, soil, and hydroperiod conditions (De Steven and Toner 1997). In a specific restored bay, predicting the species of vertebrates and invertebrates, particularly rare or sensitive species, is even more difficult.

Initial estimates by Kirkman et al. (1996), based on 1951 aerial photography, indicated that approximately two thirds of these isolated wetlands and nearly all of the associated uplands had been altered by human

Figure 3.12. A drainage ditch from a Carolina bay on the Savannah River Site. The bay is visible as the canopy opening in the background (U.S. Forest Service files).

activities such as draining (figure 3.12), farming, harvesting, and restriction of fire. However, beaver dams and other natural processes have closed the drainage ditches in some bays and natural recolonization has occurred without human intervention. Thus, the need for restoration is limited to those sites where the level of disturbance is such that recovery will not occur by natural processes alone. To identify sites effectively altered by drainage activities, SRS scientists recently considered information from geographic information databases, published reports, and field visits (table 3.6), in addition to the 1951 aerial photography (Kirkman et al. 1996). They determined that 195 (57 percent) of the 343 depression wetlands on SRS are not effectively drained. Nineteen bays were destroyed by construction activities in the early decades of Site operations. Of the remaining 129 bays, 4 were restored in the early 1990s, 16 are currently being restored, and another 3 are scheduled for restoration in 2006–2007. Field visits have yet to confirm the status of 92 bays with ditches evident in 1951.

Prior to the initiation of restoration, the influence of residual overstory trees, burning, and soil disturbance on vegetation in bays was unknown. In December of 1989, three intact bays (Bays 56, 57, 58) were experi-

Table 3.6 Level of disturbance to surface hydrology by drainage ditches in isolated depression wetlands at the Savannah River Site in 2002

Status of hydrological disturbance	Number	Percent
No ditch present in 1951[a]	124	36.2
Ditch present in 1951, but no drainage[b]	71	20.7
Ditch present in 1951, drainage confirmed[c]	14	4.1
Ditch present in 1951, restored[d]	23	6.7
Ditch destroyed[e]	19	5.5
Ditch present in 1951, drainage status unknown[f]	92	26.8
Total	343	100

[a] No evidence of drainage appeared in 1951 photograph, though some wetlands were probably farmed.
[b] Ditches were filled through natural processes, or slope of drain was inadequate, for drainage.
[c] Not all wetlands are potential restoration candidates due to proximity to site operations.
[d] Includes four restored in the 1990s (Lost Lake, 170, 5119, and 93), sixteen restored in 2002, and three scheduled for 2006.
[e] Destroyed in the early decades of SRS facility development and operations.
[f] Not field checked to confirm condition.

mentally burned and tilled to test certain hypotheses. Soil tillage stimulated vegetation diversity, recruitment from the seed bank, and rare plant occurrence (Kirkman and Sharitz 1994). Active bay restoration (figure 3.8b) started with Lost Lake in the late 1980s and early 1990s (Halverson et al. 1997). Lost Lake is a bay impacted by the M Area waste retention basin overflow. Though farmers had previously drained Lost Lake, contamination from the basin required the bay to be redrained, the contaminated soil removed, and the area revegetated with native species. The hydrologic restoration was successful, but removal of soil probably had a detrimental effect; after restoration, reptiles have declined adjacent to the bay and non-native cattails have invaded (Halverson et al. 1997). Three drained bays (Bays 106, 170, and 5119) were restored in the early 1990s by harvesting the trees and plugging the ditches. However, for a variety of reasons (e.g., potentially limited seed bank, lack of soil disturbance, drought) few if any wetland plants naturally recolonized the areas, and the ditch plug on Bay 106 failed. In 1994, the drainage ditch of Bay 93 was closed, half of the wetland was harvested, and half of each portion (harvest/nonharvest) was burned. After four years, both harvesting

Table 3.7 Effects of burning, harvesting, and harvesting plus burning on the average herbaceous species richness and percent wetland species occurring in Bay 93 on the Savannah River Site before and after closing the drainage ditch in 1994

	1993		1994		1995		1998	
Treatment	Species richness	Wetland species[a]	Species richness	Wetland species[a]	Species richness	Wetland species[a]	Species richness	Wetland species[a]
Control	1.4	NS[b]	2.3	0	1.2	0	3.8	NS
Burn	1.3	NS	1.3	0	1.0	0	2.1	NS
Harvest	3.0	NS	15.1	45.1	13.1	57.7	5.9	74.8
Harvest and burn	0.4	NS	15.0	42.5	10.7	61.8	4.0	61.1

Source: J. Singer, Savannah River Ecology Laboratory, unpublished data.

[a] Percent obligate and facultative wetland plants.

[b] NS = not sampled.

and harvesting-plus-burning treatments increased wetland plant species richness (table 3.7; Singer 2002).

In the late 1990s, an experimental approach was developed to restore several bays in conjunction with a wetland mitigation banking program. In 1997, SRS established a wetland mitigation bank to compensate for unavoidable wetland losses from future authorized construction and environmental restoration (U.S. Department of Energy 1997). The bank will not only hasten mitigation efforts with respect to regulatory requirements and implementation, but also will provide on-site and fully functional mitigation in advance of impacts. Using information and techniques from previous SRS work (as outlined above), researchers and managers identified nineteen Carolina bays in the nonindustrialized management area of SRS as candidates for restoration (see figure 3.8b). All nineteen bays possessed an active drainage ditch and a vegetation composition characteristic of a disturbed wetland system. Of the nineteen bays, sixteen (totaling approximately 20 ha, or 49 ac) were restored in 2001 by plugging the ditches and altering the vegetation. The remaining three bays serve as nonrestored controls in the interim. Undisturbed bays of similar size were used as reference sites.

Several alternatives for restoring bays and adjacent uplands are being compared in a factorial design. On the SRS, two principal upland habitats commonly occur with Carolina bays: fire-managed, open-canopy pine savannas and relatively unmanaged, unburned, closed-canopy mixed pine-hardwood forests. To gain a better understanding of the relationship between buffer zone management and wetland properties, these two upland management alternatives are being examined as long-term goals. Bay-margin treatments were applied to a 100-m (328-ft) radius, from bay rim into the upland (figure 3.13). With each of these two upland alternatives, the bays were organized such that two wetland vegetation types (herbaceous and forested) were established, thus creating four bay-margin community combinations. Approximately 10 percent of the interior of herbaceous bays was planted with obligate wetland grasses (*Panicum hemitomon* and *Leersia hexandra*). The remaining area was not planted, but natural succession was encouraged through soil scarification. Forested bays were planted throughout their interior with swamp tupelo and bald cypress.

Planting was initially successful, and most of the bays exhibited an increased hydroperiod during the first year of recovery compared to the control and reference systems. By 2002, however, all of the study sites, a

b

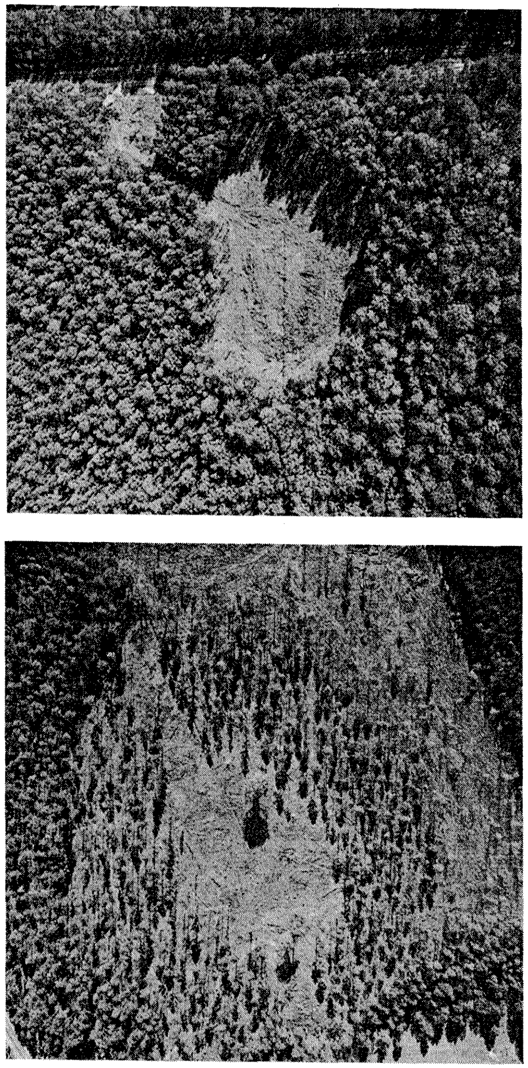

Figure 3.13. Aerial view of restored Carolina bays on the Savannah River Site with (a) a mixed pine-hardwood margin (unthinned) and (b) a pine savanna margin (thinned), 2001 (Westinghouse Savannah River Co.).

including reference wetlands, had dried in response to a severe regional drought. Nevertheless, several species of amphibians, birds, and bats continued to respond positively to the treatments. Monitoring of biotic and abiotic conditions will record progress for five years, 2002–2006, to determine the final net improvement for each wetland.

Savannas

Frost (1997) estimated that fire-maintained savanna communities historically occupied 80 percent of SRS uplands. Grass and herbaceous species originally dominated these communities, which had a pine overstory with scattered fire-tolerant hardwoods (e.g., *Q. incana, Q. stellata, Q. marilandica*). National programs are conserving and restoring these communities for their tremendous species richness of plants, as many as one hundred species per 0.1 ha (0.25 ac; E. W. Kjellmark, P. D. McMillian, and R. K. Peet, University of North Carolina, unpublished data). In addition, savannas provide habitat for several vertebrate species of concern in South Carolina. These include the gopher tortoise (see tables 4.20 and 4.22 for scientific names not given), gopher frog, pine snake, southern hognose snake, Bachman's sparrow, northern bobwhite (*Colinus virginianus*), prairie warbler, and red-cockaded woodpecker. These communities depend on frequent fires to maintain the vegetation complexes. In 1951, many relict savanna plants occurred only along roadsides and in isolated woodlots (W. Batson, University of South Carolina, pers. comm.). Many vertebrate species persisted in clear-cut or heavily thinned stands that simulate the understory vegetation structure of native savannas (Krementz and Christie 1999). In 2001, the Department of Energy approved a plan to restore the gopher tortoise, and approximately one hundred tortoises were reintroduced on SRS (see chapter 4).

Through the 1980s, forestry activities indirectly facilitated restoration and recovery of the savanna communities. The area of longleaf pine more than doubled, and over 12,141 ha (30,000 ac) of scrub oak received stem injection to release seeded or natural longleaf. In 1977, the prescribed burning program was greatly expanded to reduce fuel loading. Managers removed undesirable midstory hardwoods with chemical and mechanical treatments to improve red-cockaded woodpecker habitat (see figure 3.8c). The combined effects of harvesting and burning resulted in favorable conditions for savanna flora and fauna (Harrington and Edwards 1999; Johannsen 1998). In 1991, in systematic surveys of the upland pine forests, botanists identified state- and federally listed plant populations (chapter 5). In 1992, managers integrated red-cockaded woodpecker recovery with restoration of the savanna system as a whole. Research has established the composition of the pre-European landscape and general distribution of fire savannas (Frost 1997); the land-use history at SRS (White and Gaines 2000); and the distribution of savanna plant communities with respect to soil, topography, hydrology, and

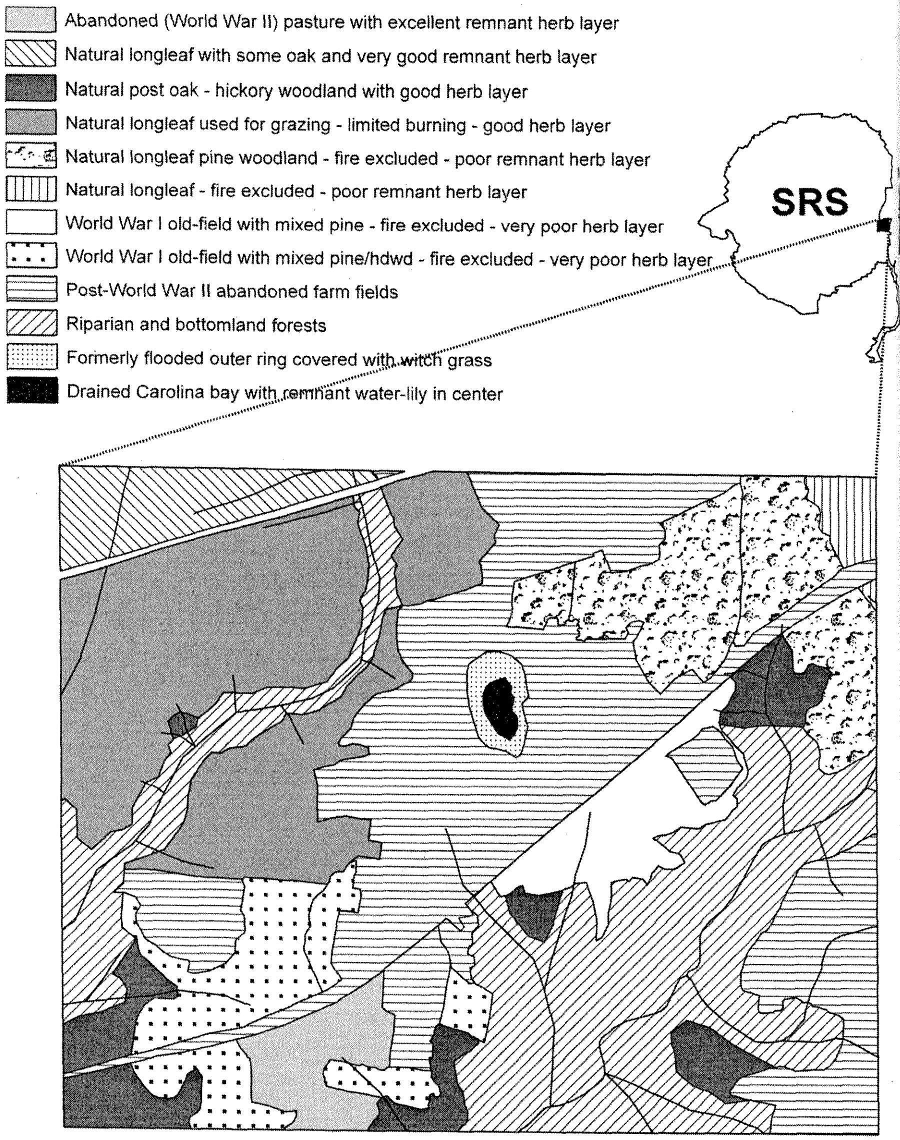

Figure 3.14. Distribution of remnant and degraded savanna plant communities in relation to land-use and fire exclusion history, mapped for potential savanna restoration on a representative section of the Savannah River Site (C. Frost, The Nature Conservancy, unpublished data).

Table 3.8 Savanna grasses, composites, and legumes selected for experimental introduction to old-field pine sites at the Savannah River Site to establish founder populations

Species	Species
Andropogon tenarius	*Galactia macreei*
Anthaenantia villosa	*Lespedeza hirta*
Aristida beyrichiana	*Liatris elegans*
Aristida purpurascens	*Liatris secunda*
Aster concolor	*Liatris tenuifolia*
Aster tortifolius	*Nolina georgiana*
Baptisia lanceolata	*Petalostemum pinnatum*
Baptisia perfoliata	*Pityopsis graminifolia*
Berlandiera pumila	*Polygonella americana*
Carphephorus bellidifolius	*Schizachyrium scoparius*
Chrysopsis gossypina	*Silphium compositum*
Coreopsis major	*Sorghastrum secunda*
Desmodium strictum	*Sporobolus junceus*
Eriogonum tomentosum	*Stylisma patens*
Eupatorium album	*Tephrosia florida*
Eupatorium cuniformis	*Vernonia angustifolia*
Eupatorium curtsii	

landform (Duncan and Peet 1996). The Nature Conservancy has helped map and classify fragments of the remnant savanna communities with respect to their restoration potential (figure 3.14).

Current savanna restoration strategies consist of three components. First, prescribed burning is the key ecological process across the landscape, in conjunction with heavy thinning and midstory control, which stimulates grass and herbaceous species abundance. Second, after removing appropriate mid- and overstory trees, managers burn isolated fragments of intact remnant savanna communities ranging from less than one acre to several acres; this process will increase the abundance and flowering of the understory grass and herbaceous plants already present. Finally, managers and researchers have established local founder populations of rare or uncommon grass and herbaceous species (table 3.8) on old-field pine sites, which have poor seed banks after two hundred years of intensive agricultural use. These populations will ideally recolonize the landscape through dispersal to nearby areas where favorable establishment conditions have been created. Research is evaluating nursery procedures to grow approximately 150,000 individuals of thirty savanna species for experimental transplanting to fourteen old-field pine sites (see figure 3.8d). These sites, which represent a range of fertility and moisture regimes, were heavily thinned and will be burned routinely. The research will assess demography and dispersal ability of each species. These studies will produce an operational plan to establish founder populations of rare and threatened species.