Riparian and Upland Restoration at the U.S. Department of Energy Rocky Flats, Colorado, Site - 12360

Jody K. Nelson*
*S.M. Stoller Corporation, Contractor to the U.S. Department of Energy Office of Legacy Management, Westminster, Colorado 80021

ABSTRACT

Remedial investigation and cleanup at the Rocky Flats, Colorado, Site was completed in 2005. Uplands, riparian, and wetland habitat were disturbed during cleanup and closure activities and required extensive revegetation. Unavoidable disturbances to habitat of the Preble's meadow jumping mouse (a federally listed species) and wetlands required consultation with regulatory agencies and mitigation. Mitigation wetlands were constructed in two drainages, and a third developed naturally where a soil borrow area intercepted the groundwater table. During the 50-plus years of site operations, 12 ponds were constructed in three drainages to manage and retain runoff and sewage treatment plant discharges prior to release off site. A batch-release protocol has been used for the past several decades at the terminal ponds, which has affected the riparian communities downstream. To return the hydrologic regime to a more natural flow-through system similar to the pre-industrial-use conditions, seven interior dams (of 12) have been breached, and the remaining five dams are scheduled for breaching between 2011 and 2020. At the breached dams, the former open water areas have transformed to emergent wetlands, and the stream reaches have returned to a flow-through system. Riparian and wetland vegetation has established very well. The valves of the terminal ponds were opened in fall 2011 to begin flow-through operations and provide water to the downstream plant communities while allowing reestablishment of vegetation in the former pond bottoms prior to breaching. A number of challenges and issues were addressed during the revegetation effort. These included reaching an agreement on revegetation goals, addressing poor substrate quality and soil compaction problems, using soil amendments and topsoil, selecting seeds, determining the timing and location of revegetation projects relative to continuing closure activities, weed control, erosion control, revegetation project field oversight, and contractual limitations. A variety of ecological restoration techniques were conducted at the site to meet these challenges. These efforts have resulted in vegetation becoming well established in most locations.

INTRODUCTION

The U.S. Department of Energy's (DOE's) Rocky Flats Site is located between Boulder and Golden, Colorado, along the Front Range of the Rocky Mountains approximately 26 km (16 miles) northwest of downtown Denver. The site was established in 1951 to manufacture nuclear weapons components for the nation's nuclear weapons program. During the height of operations, over 6000 employees worked at the site, which included over 162 hectares (400 acres) of industrial development (Figure 1).

Figure 1. Aerial photograph of Rocky Flats (2001), looking toward the northwest.

Weapons production halted in 1992, and the site's mission changed to include environmental investigations, cleanup, and site closure. In October 2005, DOE and its contractor completed an accelerated 10-year, $7 billion cleanup of chemical and radiological contamination left from nearly 50 years of production. The cleanup required the decommissioning, decontamination, demolition, and removal of more than 800 structures; removal of more than 500,000 m^3 (650,000 yd^3) of low-level radioactive waste; and remediation of more than 360 potentially contaminated environmental sites. As a result of cleanup operations, approximately 263 hectares (650 acres) of disturbed land required revegetation.

ECOLOGICAL SETTING

At an elevation of approximately 1830 m (6000 ft), the site contains a unique ecotonal mixture of mountain and prairie plant species resulting from the topography of the area and its proximity to the mountain front. Native plant communities at the site include the xeric tallgrass prairie, mesic mixed-grass prairie, shrublands, wetlands, and Great Plains riparian woodland communities. The spatial distribution of the plant communities is largely determined by the hydrology and soil types at the site. The xeric tallgrass prairie is present on the pediment tops (upper flat surfaces extending from the mountain front) and ridge tops, primarily on the western side of the site, although smaller pockets occur on the eastern side. The pediment tops are underlain by the Flatirons very cobbly, sandy-loam soil type, which has developed from the Rocky Flats Alluvium.

The xeric tallgrass prairie community dominates this soil type and is characterized by native graminoid species such as big bluestem (*Andropogon gerardii*), little bluestem (*Andropogon scoparius*), needle and thread (*Stipa comata*), mountain muhly (*Muhlenbergia montana*), and forbs such as Porter's aster (*Aster porteri*) and blazing star (*Liatrus punctata*).

The mesic mixed grassland community dominates the hillsides at the site. Denver-Kutch-Midway clay loams form the complex of soil types on the hillsides where species such as western wheatgrass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), side oats grama (*Bouteloua curtipendula*), green needle grass (*Stipa viridula*), and Kentucky bluegrass (*Poa pratensis*) are common. At locations where more moisture is available, particularly on the hillsides and in the drainage bottoms, shrubland communities, wetlands, and Great Plains riparian woodland communities predominate. The underlying geology influences the locations of the more hydric communities at the site. Where the Rocky Flats Alluvium meets the underlying bedrock, groundwater seeps form on the hillsides, and large hillside seep wetlands occur at these locations. These wetlands are dominated by various species of sedges (*Carex* sp.), rushes (*Juncus* sp.), cattails (*Typha* sp.), and various forb species. On the hillsides above the seep lines and wetlands, shrublands grow in long narrow bands. The shrublands are dominated by chokecherry (*Prunus virginiana*), hawthorn (*Crataegus erythropoda*), and American plum (*Prunus americana*). In the valley bottoms along the intermittent streams, plains cottonwood (*Populus deltoides*), peach leaf willow (*Salix amygdaloides*), coyote willow (*Salix exigua*), and wild indigo (*Amorpha fruticosa*) predominate.

REGULATORY ISSUES

Cleanup and closure operations at several locations at the site addressed two regulatory issues related to revegetation: Preble's meadow jumping mouse (*Zapus hudsonius preblei*) and wetland issues. The Preble's mouse, a federally listed threatened species under the Endangered Species Act, lives in the drainages (riparian areas) at the site. Disturbances to Preble's mouse habitat had to be addressed through a consultation process with the U.S. Fish and Wildlife Service (USFWS) prior to the start of work. A Programmatic Biological Assessment and separate, project-specific Biological Assessments were prepared and submitted to the USFWS to address the potential impacts to the Preble's mouse habitat resulting from cleanup and ongoing operations at the site. The Biological Assessments addressed mitigation and reestablishment of Preble's mouse habitat at disturbed areas and provided general revegetation guidance, monitoring requirements, and success criteria.

Discussions and consultation with the U.S. Environmental Protection Agency and the U.S. Army Corps of Engineers were conducted to address disturbances to wetlands. Nationwide and individual Section 404 permits were used to address wetland issues and mitigation. A wetland mitigation monitoring and management plan was also written to assist with the mitigation activities.

GOALS

In general, the primary goal of the revegetation efforts at Rocky Flats was to reestablish vegetation on the disturbed areas to prevent soil erosion and help meet surface water quality standards at the site. However, additional goals are to:

- Reestablish more-natural stream flows in the reconfigured channels and drainages, and reestablish the associated riparian, wetland, and upland habitat.
- Reestablish plant communities using dominant native species found on the surrounding undisturbed landscape.

- Reestablish Preble's mouse riparian habitat in mitigation areas to offset disturbances and losses from cleanup activities.
- Reestablish and create new wetlands as mitigation to offset disturbances and losses from cleanup activities.

RIPARIAN AND WETLAND HABITAT REESTABLISHMENT—PREBLE'S MOUSE HABITAT AND WETLAND MITIGATION

As cleanup and closure activities removed buildings and other infrastructure at the site, final land configuration achieved an approximation of the original stream drainages that were present before the site's industrial development. This provided the basic foundation for riparian and wetland reestablishment and also provided opportunities for both Preble's mouse and wetland mitigation. Because the Preble's mouse lives primarily in riparian areas, Preble's mouse mitigation areas were designed to restore or create riparian and wetland vegetation similar to that found along the undisturbed streams and the surrounding upland grasslands at the site. Mitigation wetlands were constructed in two different drainages where the stream gradient was almost flat, and a third developed naturally where a soil borrow area intercepted the groundwater table. Additional wetlands established naturally and through seeding where new seeps expressed on reconfigured hillsides. Wetland mitigation areas were seeded with native wetland species of sedges, rushes, bulrushes, and grasses. In most cases they also had erosion matting placed over the top of the seed to hold the seed in place. To accelerate the establishment of the woody components of the wetland and riparian plant communities, coyote willow, peach-leaf willow, and plains cottonwood stakes or bareroot stock were installed along their perimeters. Stakes were cut from the native species on site. Reestablishment of the plant communities in the mitigation areas for the Preble's mouse and wetlands have done very well and met success criteria at many locations to date. Many of the issues regarding upland revegetation were not as problematic where hydrology was not an issue.

Water balance modeling was conducted to determine potential reductions in stream flows resulting from the loss of imported water and loss of impervious surfaces at the site. Losses to off-site surface water discharges in Walnut Creek were reduced an estimated 78 to 96 percent in wet and dry years, respectively, after site closure [1]. During the 50-plus years of site operations, 12 ponds were constructed in three drainages to manage and retain runoff and sewage treatment plant discharges prior to release off site. A batch-release protocol has been used for the past several decades at the terminal ponds, which has affected the riparian communities downstream. The 8 to 10 annual batch releases from the ponds, typical prior to site closure, were reduced to 1 or 2 annual releases after closure. The unnatural series of ponds along the streams, combined with the fact that the outlet structures on some of the interior ponds were not operational, did not provide for good aquatic resource functions and services in the drainages. To return the hydrologic regime to a more natural flow-through system that approximates the pre-industrial-use conditions and to reestablish more continuous riparian habitat, 7 of the 12 interior dams have been breached. Breaching has also eliminated the ongoing monitoring and maintenance requirements at the dams. The remaining five dams are scheduled for breaching between 2011 and 2020; two are scheduled to be breached during the 2011–2012 winter. At the breached dams, the stream reaches have returned to a flow-through system, and the former open water areas have transformed to emergent wetlands with some shrubland development along the wetland margins. Although the final three terminal ponds are not scheduled to be breached until 2018 to 2020, the valves of the terminal ponds were opened in fall 2011 to begin flow-through operations. The purpose is to provide water to enhance the downstream riparian corridor functions and to allow for the reestablishment of vegetation around the now-exposed pond margins prior to breaching.

UPLAND AND GENERAL REVEGETATION ISSUES AND SOLUTIONS

Numerous factors can affect whether a revegetation project will succeed. Factors such as the choice of a seed mix best suited to the conditions are controllable; other factors—such as climate—are not. Often, decisions are not based on ecological or biological considerations; Instead, economics, site policies, and project management influence how restoration must proceed. Many of these factors affected decisions regarding revegetation efforts at Rocky Flats. The following issues and concerns were addressed during planning and implementation of revegetation activities.

- Revegetation versus true restoration
  - Seed—local genotype versus commercially available
  - Seed mixes
- Seedbed preparation
  - Poor substrate conditions
  - Soil compaction
  - Soil amendments
  - Use of topsoil
  - Isolated, project-by-project revegetation versus larger-scale, regional site revegetation
- Seeding and planting
  - Broadcast versus drilling
  - Timing of revegetation efforts
  - Irrigation
- Management
  - Weed control
  - Erosion control
- Project management and oversight
- Contractual issues

A revegetation plan was developed to assist project managers with revegetation efforts at the site. During the development of the revegetation plan, stakeholders raised the question of whether the revegetation efforts were going to be a revegetation project or a restoration project (i.e., reestablishment of a native prairie like the undisturbed surrounding grasslands?). During discussions it became apparent that a true restoration project was not a realistic goal for several reasons, such as (1) no true restoration of a native prairie has ever been demonstrated anywhere, so the goal would be impractical, (2) seed is not available for many of the species found on the surrounding native prairies, (3) such an effort would require decades, at a minimum, and (4) there was no such requirement in the contract between DOE and the operating contractor, and imposing such a requirement would prove problematic. As a result, the term and concept of revegetation was settled on, and the goal would be to establish a native perennial cover of vegetation using the dominant native graminoid species found on the surrounding prairies along with a few early successional native species. Seed mixes were developed based on the dominant plant species present in the native plant communities at the site. Different seed mixes were developed for use based on the topographic position, soil type, and hydrologic conditions of the revegetation location. Upland seed mixes that were developed for the more xeric, rocky pediment/ridge-top areas differed from those developed for the finer-textured soils on the hillsides. Separate seed mixes were developed for riparian and wetland areas.

Another issue raised by stakeholders was whether local genotypes of the dominant graminoid species would be used in the seed mixes. It is generally held that species that have evolved locally or regionally in an area are best suited to the local or regional environmental conditions. The problem is that local genotypes are rarely available commercially or in the volumes needed for a project the size of Rocky Flats (approximately 263 hectares [650 acres]). The discussion concerning the use of local genotypic seed was finally dismissed because there would not be enough time to collect and grow out the quantities of graminoid seed needed for the project, and the cost would be prohibitive. Instead, commercially available native seed was used.

Out of this discussion, however, came an idea to have volunteers collect local genotypic seed, which could then be interseeded into the revegetation areas. This would also help to increase the species diversity of the revegetation areas, since many of the native species common on the native grasslands are not available commercially. It would also help move the revegetation areas toward the goal of some of the stakeholders who wanted more of a true "restoration" of the grassland areas. Since site closure, the Jefferson County Nature Association, a volunteer group, has conducted volunteer seed collection events to collect native seeds of different species on surrounding lands and provide them to DOE for use in the revegetation areas. The group also received a grant with Natural Resource Damage monies to assist with the collection efforts. Several volunteer seed-picking opportunities are held each year, and the seed collected has been used on site at various locations. Initially, forb seed was not desirable in the volunteer collected seed (nor is it in the revegetation seed mixes) because the herbicide applications typically used during the first few years after seeding to promote graminoid establishment kills most of the forbs. However, now that the grasses have become well established at most locations, the interseeding of forbs is desirable to increase diversity. Several forb "nursery" areas have been established across the site where chemical weed control is restricted, and once established, the forb species will be able to spread from these locations.

Past revegetation efforts at the site, often decades old, used nonnative graminoid species such as smooth brome (*Bromus inermis*), intermediate wheatgrass (*Agropyron intermedium*), crested wheatgrass (*Agropyron cristatum*), and other similar species. However, because these species are nonnative, often aggressive, and often outcompete native species, it was determined that these species would not be allowed in the seed mixes.

Seedbed preparation is an important component to a successful revegetation effort. Early in the planning it was recognized that the soil conditions left after site closure could be problematic for good vegetation establishment. The former Industrial Area was essentially a developed city with hundreds of buildings, roads, parking areas, utility infrastructure, and other disturbances that had completely removed or altered the original soils. Where roads and parking lots had been located, only roadbase was left after the asphalt or concrete was stripped off. At other locations, gravel parking areas were left with the gravel on them. The soils at these locations were often highly compacted from years of vehicle traffic. Where the native Rocky Flats Alluvium was present, ripping of this rocky, cobbly soil often left large rocks across much of the surface. Fill material was brought in from both on-site and off-site sources to bury infrastructure that would remain in place. Fill materials were also used for covers on two landfills at the site. Most of the material placed on the landfill covers and at other locations was subsurface material that was excavated and placed on the surface as a growing medium. These materials were often rocky or clayey and not best suited as a seedbed.

Because of these conditions, a number of options were considered for developing a suitable seedbed. However, ecological considerations were often in conflict with economic or project management objectives. Deep ripping (1 m [3 ft]) would have been very helpful in reducing soil compaction at most revegetation locations. However, site constraints limited ripping depths to 0.3 to 0.6 m (1 to 2 ft) or less because of concerns regarding remaining buried infrastructure. Shallower ripping did help reduce compaction in the upper portion of the seedbed and provided a suitable substrate for seeding and root establishment at many locations.

Because soil conditions varied greatly across the site at revegetation locations, soil amendments and topsoil were considered as additions to improve seedbed conditions. Results of soil tests conducted at several locations indicated that there was no need to add amendments such as compost (organic matter) or fertilizers. These results were applied uniformly across the site, and no amendments or fertilizers were used. The decision was also based on the fact that the cost of amounts needed to revegetate approximately 263 hectares (650 acres) would be prohibitive. At most areas where fill material was placed (building footprints), this approach has proven to be successful, and good stands of vegetation are now established. However, at locations where roadbase and gravel from roads and parking lots were left as a seedbed, vegetation establishment was generally poor. At those locations, compost (90−112 tonnes/ha [40–50 tons/acre]), Biosol (1120 kg/ha [1000 lb/acre]) or Sustane (8-2-4; 616 kg/ha [550 lb/acre]) slow-release fertilizers, and mycorrhizzal inoculant (67 kg/ha [60 lb/acre]) were added and mixed into the soil before a second seeding effort was conducted. The compost, fertilizers, and inoculant were added after site-closure and required additional investment of time and resources to repair what should have been done initially. The addition of these soil amendments resulted in most of these areas meeting success criteria after about 3 years.

Topsoil was added initially after the first few small buildings were removed. The areas were ripped, and topsoil (from off-site) was applied in varying amounts (sometimes up to several centimeters in depth) at these locations and seeded. A critical concern with the use of topsoil is that the seed species present in the topsoil are unknown. Since no topsoil is seed-free, the use of topsoil could result in the introduction of undesirable species and noxious weeds in the revegetation area. This proved to be true at these locations. The nonnative perennial grass species present in the topsoil outcompeted the species in the seed mix and resulted in an undesirable stand of vegetation. At another location, a new noxious weed species (yellow star-thistle; *Centaurea solstitialis*) was introduced to the site. After that experience, topsoil was no longer used for revegetation efforts.

Initial seeding efforts were conducted primarily by broadcasting because the rocky soils at the site made it difficult to effectively drill seed. Areas that were redone with soil amendments were drill seeded.

Revegetation efforts are typically scheduled to occur during the spring and fall planting windows. However, contractual issues, project scheduling, and milestone requirements at the site did not account for this. In order to meet milestones, projects had to be completed (including the revegetation), and to close out project contracts, revegetation activities needed to be conducted as the project was finished—regardless of the time of year. Thus, initially the contractual concerns took precedence over the ecological issues, and projects were allowed to complete revegetation activities at the end of the project.

A problem that developed out of this decision was that many of the smaller revegetation projects that were completed earlier became like small islands in a sea of remaining structures. As closure activities began in surrounding areas, heavy equipment often destroyed these small, completed revegetation areas. Over time, the idea to conduct the revegetation activities in a patchwork fashion (to meet schedules and milestones) was no longer cost effective, as areas were being reseeded multiple times. This approach was finally discontinued, and instead, as small areas were completed, the soils were protected from erosion either by seeding with a temporary seed mix or by applying erosion controls. Final revegetation activities were delayed until larger areas were ready, and revegetation could proceed at all areas. Observations of the areas seeded in and outside the normal planting windows, now 6 to 7 years after seeding, suggest that timing has made little difference in overall abundance of vegetation cover.

Because DOE owns no water rights at Rocky Flats, irrigation of the revegetation areas was not an option. The high cost of importing water and constructing irrigation systems made that approach impractical. Therefore, revegetation efforts have relied on natural precipitation (approximately 33 to 39.4 cm [13 to 15.5 inches] annually). High evapotranspiration rates resulting from high winds and high temperatures also stress vegetation establishment at the site.

The management technique that has proven most beneficial to reestablishing the plant communities at the site has been proactive weed control. This is particularly important in the semiarid environment at Rocky Flats, where plants compete for limited water and nutrients. Although limited mowing and hand control have been used for controlling smaller infestations of undesirable plants, the use of herbicides has been critical in establishing good stands of native grasses at the site. Herbicides are not usually applied during the first growing season because of the potential impacts to establishing grass seedlings. However, prior to the second growing season, selective herbicides are applied to the revegetation areas to reduce the competition from non-graminoid plants (forbs and most noxious weeds). This allows the grasses to utilize the water and nutrients to become established much more quickly than if no weed control was conducted.

A number of administrative controls are also in place to limit the introduction of new weed species at the site. Purchased seed must be certified weed free. Certain species of exotic, nonnative graminoids are not allowed for use at the site. Straw and hay used for mulch or erosion control must be certified weed free. Washing or cleaning of equipment prior to bringing it on site is encouraged but not required.

Installation of erosion controls to protect the seedbed after revegetation and prevent wind and water erosion is essential to success. The appropriate choice of controls is critical to prevent erosion, help establish vegetation, meet storm water run-off requirements, and protect water quality. The U.S. Environmental Protection Agency and the Colorado Department of Public Health and Environment have established stringent water quality standards for the site. Therefore, protecting the soil resources and establishing good stands of vegetation are very important. A variety of erosion control techniques have been used effectively.

Wattles and straw bales have been used extensively on site in place of silt fence. The rocky ground surface and high winds (often more than 130 km/h [80 miles per hour] during winter months) make the use of silt fence impractical. Biodegradable erosion mats with a straw or coconut fiber matrix and permanent turf reinforcement mats have been used successfully. Both types of mats have been used for slope and channel protection; they also help trap moisture and heat and thus provide a good germination bed for the seeded species. The biggest difficulty with the use of erosion mats is penetrating the rocky soils to stake them to the ground. Often, 25-cm (10-inch) nails with washers are used to anchor the mats because the normal 15-cm (6-inch) staples cannot penetrate sufficiently into the ground. The use of crimped straw was used at some locations prior to site closure. However, because of the rocky soils and high winds, most of the straw blew away the first winter and accumulated into downwind ravines and depressions. In places, the straw piled to depths of 60 cm (2 ft) or more, preventing germination of any plants at those locations, often for several years. Crimped straw is no longer used at the site. Among the best erosion control products used were the flexible growth media products such as Flexterra. The product is sprayed on like a hydromulch, provides excellent erosion protection with low maintenance, and acts like a mulch that promotes seed germination and establishment. It has been used successfully on both flat areas (0.34 kg/m^2 [3000 lb/ac]) and slopes (0.39 kg/m^2 [3500 lb/acre]).

Project oversight of the revegetation activities by project managers unfamiliar with revegetation processes instead of revegetation or ecology specialists resulted in several problems. A cookbook approach had been developed in the revegetation plan for project managers to follow. It allowed some flexibility for variations in environmental conditions, substrate differences, applications methods, and project completion schedules. However, more stringent oversight of revegetation activities and the use of hold-points or sign-off steps would have helped prevent some of the problems that had to be dealt with later. Unfortunately, complex project management constraints, overlapping schedules, and resource limitations often prevented that approach.

Greater attention to initial seeding activities could have avoided many reseeding efforts 1 or 2 years later. The revegetation plan allowed for drill or broadcast seeding, but the rocky soils largely prevented the use of a drill seeder at most locations. Therefore, seeding methods varied from hand broadcasting on foot and mechanical broadcasting using mounted or pull-behind seeders, to hand broadcasting out of both sides of 2-seater ATVs while driving. Problems became apparent as vegetation began to establish. At many locations, the seeding operators (often site employees assigned the task of seeding) had not kept track of their movements through the seeding areas. Rows had been missed, and unseeded areas often alternated with seeded areas. As a result, additional reseeding was required in those areas. At some locations, overzealous efforts to avoid soil erosion resulted in erosion controls (straw with flexible growth media sprayed on top to hold it in place) being placed so heavily that it prevented vegetation establishment for several years until the materials had weathered and broken down. At one of the wetland mitigation locations, newly installed willow stakes were pulled out of the ground so that erosion blankets could be installed across the bottom of a created wetland. The stakes were then pushed back through the blanket, tearing off the new roots that had begun to form. These situations could have been largely avoided had project oversight been performed by specialists familiar with the application methods and how the methods would affect the results.

With respect to the regulatory issues (i.e., Preble's mouse and wetlands), some of the greatest challenges in dealing with project management involved (1) educating project managers about the issues, (2) incorporating the appropriate time frames needed to get permits and approvals into project work schedule to prevent delays later on, (3) receiving final project designs for submittal to the regulators for approval (on some projects the design was constantly changing), and (4) keeping the project scope in accordance with specific requirements of the permits and approvals once the projects began. Early involvement of the regulatory agency staff in design meetings helped to address certain issues early in the process and helped educate project management of specific regulatory requirements.

Finally, the importance of including revegetation information and language in the contractual agreements for future DOE site closure operations should not be underestimated. Closure contracts between DOE and contractors where revegetation is required should specifically address the issues of soil quality, soil compaction, removal of road base/gravel (and not just the asphalt and concrete above it), application of soil amendments, seeding, erosion controls, and other site-specific issues. Additionally, more stringent oversight of pre-closure revegetation activities with hold-points or sign-off steps throughout the revegetation process could help eliminate problems that do not show up until a few years later. In planning for post-closure maintenance, additional reseeding and revegetation efforts and continued erosion control maintenance and installations should also be considered in budgeting for out-years, since not all initial efforts will succeed. Experience at Rocky Flats has shown that if the closure contract does not adequately address revegetation issues, more intensive revegetation efforts will need to be planned and budgeted for several years after closure.

LESSONS LEARNED

Some of the lessons learned during the revegetation activities conducted at Rocky Flats are listed below:

- Meet with stakeholders to identify revegetation goals early in the process. Is the goal revegetation or restoration? Which plant species will be used, and which will be excluded? Will local genotypic seed or commercially available seed be used?
- Identify soil conditions and compaction issues up front. Conduct soil testing to identify areas that will need soil amendments.
- Do not leave roadbase/gravel as a seedbed. These areas will not grow a good stand of vegetation. Establishing favorable soil conditions up front can result in large cost savings after closure by not having to remobilize equipment and pay for additional revegetation costs in the future.
- Educate project managers and involve regulators (e.g., USFWS, U.S. Army Corps of Engineers) early in the planning stages to address regulatory issues and schedule issues.
- Revegetation and erosion control field oversight should be conducted by knowledgeable revegetation and ecology specialists who have practical experience in revegetation and erosion control planning, installation, and implementation.
- Use hold-points or sign-off steps during fieldwork to ensure that tasks are performed according to specifications.
- DOE site closure contracts should include revegetation language and specifics. Items to address should include goals of revegetation, seedbed preparation issues (soil conditions, soil testing, use of soil amendments, soil compaction), seed selection, use of appropriate equipment to do the work, weed control, erosion control, monitoring, success criteria, and reseeding for failed efforts.

The revegetation efforts have yielded many lessons learned, and although the projects did not always follow a textbook approach, in general the vegetation establishment has been very good across most of the site. Figure 2 shows an aerial view of the site in June 2011. Figure 3 and Figure 4 show additional before-and-after photos of two locations.

REFERENCES

K-H. (2002). Site-Wide Water Balance Model Report for the Rocky Flats Environmental Technology Site. Kaiser-Hill Company, LLC, Golden, CO. May 2002.

Figure 2. Aerial photograph of Rocky Flats in 2011.

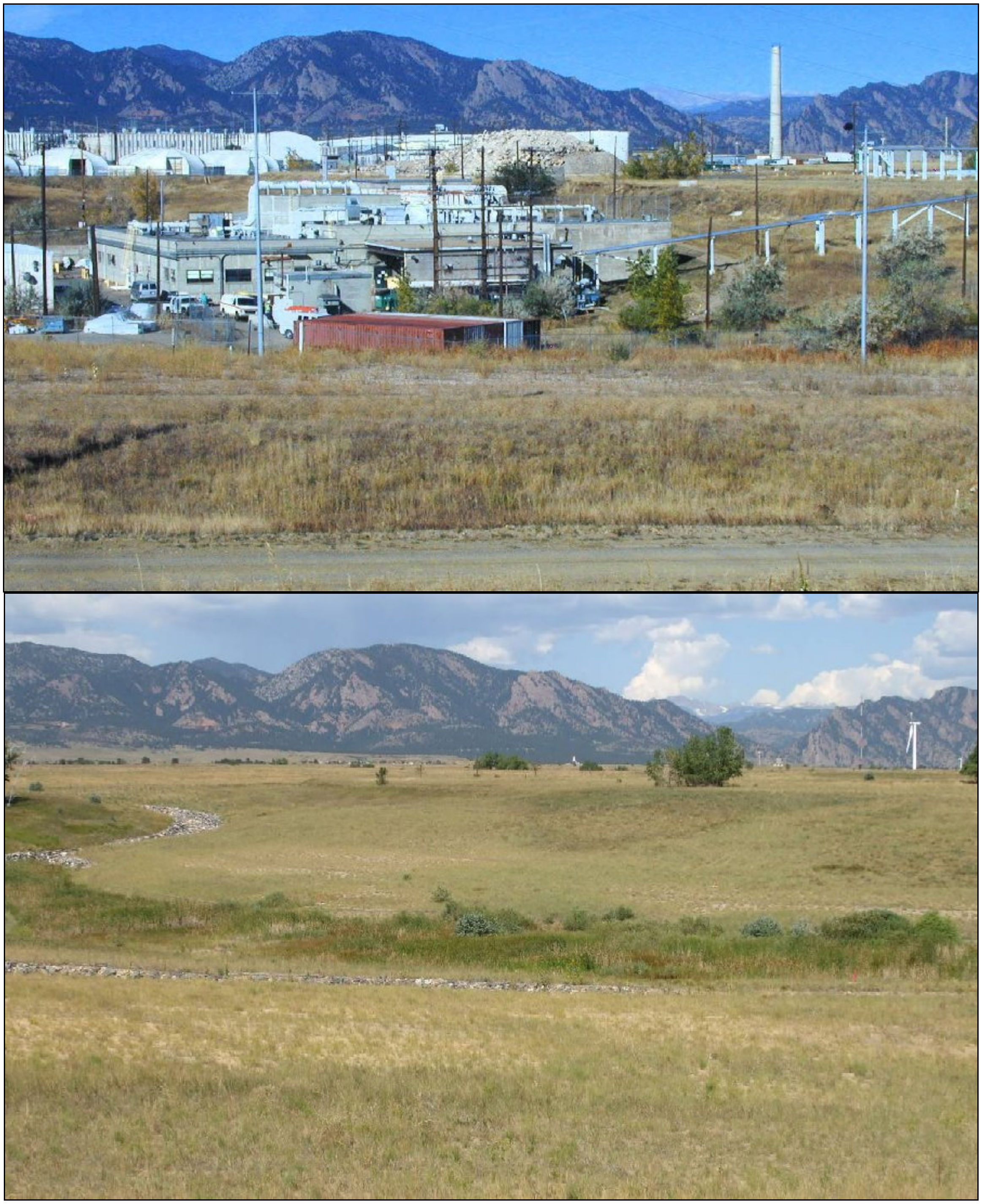

Figure 3. B991 area revegetation and wetland mitigation areas in 2003 and 2011.

Figure 4. 700 area revegetation and wetland mitigation areas in 2003 and 2011.