RATTLE FIRE COMPLEX
EMERGENCY STABILIZATION AND REHABILITATION
FINAL MONITORING REPORT

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The Rattle Fire Complex started on June 20, 2002 from multiple lightning strikes and resulted in a total of 94,519 acres of burned landscape. The Rattle Fire Complex includes the Diamond Creek Fire (88,347 acres) and the Black Canyon Fire (6,172 acres) (BAER Plan, 2002). Fire suppression costs through July, 2002 for the complex exceeded $11 million (BAER plan p.13).

An Interagency Burned Area Emergency Response (BAER) team prepared a plan for emergency stabilization and rehabilitation (ES&R) efforts outlining recommended treatments and follow-up monitoring for the entire Rattle Fire Complex. Initial cost estimates for ES&R work on BLM lands totaled over $6.5 million. All but two of the BAER plan recommendations for the BLM managed lands were implemented as recommended or amended. Final ES&R costs completed on BLM administered lands total over $3.9 million.

Combined, over 50,000 acres of BLM lands were affected by fire resulting in over 44,000 black acres in the Rattle Fire Complex. The BLM lands within the Diamond Creek Fire, outlined by the Diamond and Cottonwood watershed perimeters, form the area of interest of this project. Rehabilitation actions on the Diamond Creek and Cottonwood Creek watershed portions of the Diamond Creek Fire were managed by the BLM Moab Field Office. This report covers monitoring of these stabilization and rehabilitation treatments.

Rehabilitation treatments completed in the Diamond Creek and Cottonwood Creek watersheds include: 1) general aerial seeding, 2) second seeding with ballistic and mycorrhizal coatings, 3) hydro-mulch application to valley bottoms, 4) stabilization work on ten low water crossings and 5) dredging irrigation ponds for sediment retention. Several monitoring programs were conducted including: 1) monitoring of seeding effectiveness, 2) monitoring of overall vegetative recovery, and 3) monitoring of watershed treatment effectiveness.

Monitoring results show that the seeding treatments were partially successful in meeting the rehabilitation goals but unsuccessful in stabilizing the watershed within the 3 year monitoring window. The effectiveness of seeding treatments was hampered in the 2003 growing season by persistent drought conditions; however the seeding treatments were effective in establishing a strong and vigorous perennial grass component by 2005. The seeded forb component was only successful in the uplands while the seeded shrub component was unsuccessful. The hydro-mulch appeared to have no effect on ecological goals. The road treatments all failed within several months, due to large flooding events.

Stream channels remain highly unstable despite the partial success of the seeding treatments. High rates of erosion, gullying and sedimentation are occurring both in the larger perennial channels and in the smaller ephemeral channels and upland rills. Access to the burned area remains severely hampered due to washed out road crossings. A downstream ranch access and irrigation ditch system continues to suffer from flooding and excessive sedimentation.

I. INTRODUCTION

A. FIRE STATISTICS

The Rattle Fire Complex (RFC) started on June 20, 2002 from multiple lightning strikes and resulted in 94,519 acres of burned landscape (Rattle Fire Complex BAER Plan, 2002). The RFC includes the Diamond Creek Fire (88,347 acres) and the Black Canyon Fire (6,172 acres) (Maps 1 & 2, Appendix A). The RFC is located in the Book Cliffs northeast of the town of Thompson, Utah and approximately 6 miles east of the Uintah and Ouray Indian Reservation. The RFC includes the following jurisdictions:

- BLM – Moab Field Office
- BIA – Uintah and Ouray Agency
- State of Utah – School Institutional Trust Lands Administration
- State of Utah – Division of Wildlife Resources
- Private

The Diamond Creek Fire burned portions of Willow Creek, Cottonwood Creek and Diamond Creek watersheds. Within the Diamond Creek and Cottonwood Creek watersheds over 36,881 acres burned, with 31,688 acres under BLM management. A majority (82%) of the burned acres in these watersheds had high to moderate burn severity (Map 5, Appendix A). The area with the highest burn severity was within the headwaters of Diamond Creek (Maps 6 & 7, Appendix A). Valley bottoms were also particularly hit hard (Photo 1.1).

Photo 1.1: "Most of the bottomlands … had high vegetation mortality and high burn severity." (BAER plan, p. vi)

B. PRE-FIRE CONDITIONS

The RFC is regionally located within the Utah portion of the Colorado Plateau physiographic province on the Tavaputs Plateau (Map 3, Appendix A). The Tavaputs Plateau spans much of eastern Utah and western Colorado. The plateau is made from Cretaceaous and Tertiary period deposits (USDA Forest Service, McNab et al. 1994). A geomorphological examination shows that these deposits rise gradually southward and upward from the center of the Uinta Basin. The plateau continues to rise until it reaches elevations between 8,000 and 10,000 feet and monolithic erosional cliffs (USDA Forest Service, McNab et al. 1994). The Book Cliffs form the southwestern and southern terminus of the Tavaputs plateau and mark the transition into the valleys of Carbon, Emery, and Grand counties. The Book Cliffs begin near Helper, Utah located in Carbon County and initially extend eastward making a smooth arc southward toward to Green River, Utah. The cliffs change direction at Green River extending eastward, paralleling I-70, eventually arcing northeast toward Colorado.

The Diamond Creek and Cottonwood Creek portions of the Diamond Creek Fire are located in the Book Cliffs province of the Colorado Plateau (Map 3, Appendix A). Diamond Creek and Cottonwood Creek flow south out of the Book Cliffs to the Colorado River. Elevations in Diamond Creek and Cottonwood Creek watersheds range from 5000 feet to almost 9500 feet. High and extremely steep slopes, sometimes in excess of 80%, dominate the terrain. Canyon bottoms are relatively narrow and flat and made up of loose unconsolidated alluvial and colonial sediments. According to the Central Grand County Soil Survey, 93% of the burned area soils (over 42,000 acres) have severe hazard classifications for water erosion (BAER plan, p.128).

Canyon walls are comprised of barren rocky ledges, Pinyon-Juniper or oak-brush covered slopes. Vegetation types present throughout the RFC prior to the burn include Pinyon-Juniper, Oak-Mountain Mahogany, Sagebrush, Aspen, Douglas Fir, Ponderosa Pine, Spruce-Fir, and Riparian (BAER plan, p.160). See Map 4, Appendix A for the vegetative communities located throughout the RFC.

Photo 1.2: Cottonwood Canyon, 1998

Diamond Creek and Cottonwood Creek have perennial to intermittent stream flows. There are several springs in the upper tributaries and towards the headwaters, and a larger spring in Diamond Canyon called Oak Springs.

Pre-fire access was limited to a single road in each canyon, with 8-10 low water fords or crossings in each canyon. One stream crossing was along a beaver dam. The Cottonwood Creek road ended several miles downstream of the fire perimeter. Vehicle access was limited to occasional ATV use. The Diamond Creek road extended several miles into the burned area, although several stream crossings were annually troublesome in the spring and summer. Historically, the Grand County Road Dept. had maintained these roads systems through grading activities several times a year, providing access for hunters and ranchers.

C. WEATHER STATISTICS

At the time of the fire, the area was experiencing a regional drought which began in 1998. "The 12 month period ending in August 2002 was the driest in recorded history throughout the Southwest" (Merriam Powell, 2003). Tree ring research suggests it may have been the driest period in 1400 years (USGS, 2003). As a result, soil moisture and fuel moisture levels were at record low conditions.

In summer 2003, when the initial stabilization and rehabilitation treatments began, rainfall amounts were approximately 60% of normal. Most precipitation came during scattered summer thunderstorms, with low storm intensity and duration. During July, 2003 there was no measurable rainfall at 5 of the 6 raincans located within the fire perimeter.

Although the regional drought continued into 2004, precipitation levels returned to normal in August, 2004. Storm intensity, duration and extent increased. Because of the extended nature of the drought, soil moisture levels continued to be low throughout 2004.

Historically normal rainfall amounts and storm intensities continued through the summer of 2005. At this time, soil moisture conditions began a return to more normal levels.

II. FIRE EVALUATION AND RECOMMENDATIONS

A. BAER PLAN

The BLM and BIA requested the help of a National Interagency Burned Area Emergency Response (BAER) Team to address potential effects of the fire and fire suppression impacts on the Diamond Creek and Black Canyon Fires. The BAER team arrived in Moab and quickly completed a comprehensive Emergency Stabilization and Rehabilitation Plan (BAER plan, 2002).

Values at risk identified by agency resource specialists and confirmed by the BAER team included: Watershed, Vegetation, Forestry, Wildlife, Cultural, and Wilderness Study Areas. The BAER plan identified the following rehabilitation objectives:

- Locate and stabilize severely burned slopes which pose a direct threat to human life, property or critically important cultural and natural resources.
- Recommend post-fire rehabilitation prescriptions which prevent irreversible loss of natural and cultural resources.
- As practical and necessary, restore conditions to areas disturbed by fire suppression actions.
- Conduct immediate post-burn reconnaissance for fire suppression related impacts to threatened and endangered (T&E) species, and cultural sites.
- Provide long-term monitoring recommendations intended to ensure the success of rehabilitation efforts.

B. BAER PLAN RECOMMENDATIONS

1. Treatment Recommendations

The BAER Plan made 23 specific recommendations for post-fire treatments, described as specifications. Pertinent rehabilitation specifications include:

1) Aerial seeding (specification #22)
2) Seeding and mulching in valley bottoms (specification #12)
3) Armor low water ford and road crossings (specification #15)
4) Maintain existing ponds to control ashflow (specification #23)
5) Engineering design for sediment control facilities (specification #14)
6) Energy dissipators (specification #17)

2. Monitoring Recommendations

The BAER plan recommended monitoring for seeding effectiveness, vegetative recovery and watershed treatment effectiveness. Specific monitoring recommendations included:

1) Specification #13 involves monitoring for watershed conditions. This monitoring includes water quality sampling and sediment movement and channel dimension surveys to determine if BAER treatments are successful at reducing fire effects.
2) Specification #19 is monitoring of seeding effectiveness. This monitoring would determine the success of revegetation efforts on acres identified as having less than 60% slopes and moderate to high burn severity.

3) Specification #20 refers to monitoring of vegetative recovery. This monitoring would help determine if management objectives are being met and to identify any future seeding needs to restore ecological processes.

C. TREATMENTS IMPLEMENTED

The Bureau of Indian Affairs was very active with ES&R actions in the Black Canyon Fire area, and the State of Utah managed ES&R actions on the northern portion of the Diamond Creek Fire. The BLM Moab Field Office managed ES&R actions in the southern portion of the Diamond Creek Fire. Table 2.1 provides a summary of treatments implemented by the BLM Moab Field Office over the course of the project. Specific treatment details are described below.

Treatment	Fiscal Year	Units
2002 Accomplishments		
Stock Pond Cleanout	2002	1 each
2003 Accomplishments		
Aerial Seeding	2003	26,444 ac
Armor Low Water Crossings	2003	10 each
Mycorrhiza Seed Treatments	2003	60,000 lbs
Watershed Monitoring	2003	101,000 ac
Vegetative Monitoring	2003	5 plots
2004 Accomplishments		
Vegetative Monitoring (remote sensing USU agreement)	2004	82,462 ac
Watershed Monitoring	2004	40,000 ac
Vegetative Monitoring	2004	26,444
Aerial Seed and Mulch Implementation	2004	2,050 ac
2005 Accomplishments		
USU Agreement Modification (acquire aircraft imagery)	2005	N/A
Stock Pond Cleanout	2005	1 each
Watershed Monitoring	2005	40,000 ac
Vegetative Monitoring	2005	18,982 ac
Noxious Weed Monitoring and Control	2005	50 ac

Table 2.1: Rattle Fire Complex Stabilization and Rehabilitation Treatments

1. General Aerial Seeding (specification #22)

In order to stabilize the watersheds and slow the invasion of cheatgrass, the BAER Team recommended treating areas of moderate to high burn severity occurring on slopes less than 60%. An aerial seed treatment was applied to upland and bottomland areas on BLM lands within the Cottonwood and Diamond watersheds in the fall of 2002. The 26,444 acre treatment consisted of 196,000 pounds of seed composed of 7 species of native grasses, forbs, and shrubs.

2. Seed and Mulch Valley Bottoms (specification # 12)

The BAER plan recommended seed and straw mulch be applied by ATVs with small blowers. The proposed cost exceeded $3.7 million. This recommendation was not approved for funding as submitted by the BAER plan.

An amended proposal was submitted by the BLM Moab Field Office in the fall of 2002, which was approved for funding. This treatment involved aerially seeding 1400 acres of canyon bottoms. The seed mix included 12 species of native grasses, forbs, and shrubs that were treated with a ballistics coating to minimize drift and increase penetration into the soil. The initial 7,990 pounds of untreated seed became 53,868 pounds after the ballistics coating was added. In addition, a mycorrhizal seed coating was applied to six selected species in an attempt to give the seeded species a competitive advantage over cheatgrass and increase the soil stabilization potential by increasing plant establishment.

A hydro-mulch treatment was aerially applied on 650 acres immediately after the seeding (Photo 2.1). The mulch treatment was applied in an attempt to stabilize the soil and seed on site thus minimizing the loss of seed from erosion or predation. The mulch was also intended to increase the surface organic layer. The treatment consisted of 1,170,000 pounds of thermo-mechanically refined virgin wood fiber mulch with 117,000 pounds of guar tackifier.

Photo 2.1: Mulching in Diamond Canyon

3. Armor Low Water Fords and Crossings (specification # 15)

The BAER plan recommended installing armored low water fords and armor on road crossing fill. Removing culverts and stabilizing beaver dam crossings were also recommended. Nine crossings were identified in the BAER plan for these treatments.

In April and May of 2003, the BLM Moab Field Office treated 10 low water crossings. Seven crossings in Diamond Canyon were armored and in Cottonwood Creek, two stream crossings were armored and one mud bog adjacent to the stream was treated (Photos 2.2 and 2.3). Each segment had a site-specific design which generally included applying erosion control material, gravel road base and restoring the pre-fire channel configuration.

Photo 2.2: Mud bog adjacent to Cottonwood Creek

Photo 2.3: Low Water Crossing Armoring

4. Maintain Existing Ponds to Retain Ashflows (specification # 23)
This specification called for maintaining two existing ponds to retain ashflows. Accumulated sediment needed to be removed to restore storage capacity of two existing off-channel ponds on Cottonwood Creek located between the burned area and the Colorado River.

A private ranch is located near the confluence of Diamond and Cottonwood Creeks. Less than one mile downstream of the confluence is an earthen diversion structure where most of the flow from Cottonwood Creek is diverted. This diversion ditch feeds two irrigation ponds. The upper pond was inundated with sediment and ash during the first post-fire storms. The lower pond was not connected to the ditch at the time of flooding and therefore was not affected.

In September, 2002 the upper pond was cleaned out by pushing the dirt to the side. The diversion continued to feed the pond and filled a second time with sediment. The pond was cleaned out again in fall of 2004 by pushing the dirt to the side.

D. TREATMENTS NOT IMPLEMENTED

1. Engineering Design of Sediment Control Structures (specification #14)
This specification called for an engineering design of sediment control structures in the Diamond Creek and Cottonwood Creek watersheds. "Opportunities exist for storing sediment in off-channel sediment storage facilities by reconstructing incised channels in selected order 3-6 streams in the mid and upper elevations of the Diamond, Cottonwood watersheds and constructing sediment traps in the lower Cottonwood Creek watershed" (BAER plan, p.75).

This action was not funded as part of the initial rehabilitation effort and the BLM Moab Field Office did not pursue this recommendation any further. This treatment would have entailed significant construction within a majority of the valley bottoms, both within the burned area and for miles downstream.

2. Energy Dissipators (specification #17)
This specification recommended energy dissipators to slow overland flow and promote sediment deposition onto the floodplain (BAER plan, p. 87). Dissipator structures made of biodegradable sandbags would divert flood flows onto flat terraces and floodplains. This would reduce streamflow velocity, promote sediment and debris deposition, and reduce potential for gullying. Suitable sites for dissipators were identified on floodplains and terraces along Diamond Canyon near Oak Springs.

This action was also not funded as part of the initial rehabilitation effort and the BLM Moab Field Office did not pursue this recommendation any further. The sites identified by the BAER team for dissipater structures were located in both Flume Canyon and Spruce Canyon Wilderness Study Areas (WSAs).

E. MONITORING

1. Vegetative Effectiveness Monitoring
In order to fulfill the ES&R monitoring mandate, this project monitored ES&R treatment effectiveness and the overall rehabilitation of vegetation. The majority of the ES&R treatment expense has been applied to the bottomland areas. Consequently, the bottomland treatment areas were considered a priority for ground monitoring and were monitored quantitatively. The upland treatments were less expensive and for the most part inaccessible and therefore were qualitatively ground monitored. The entire burned area within both Diamond and Cottonwood watersheds were monitored using Quickbird multispectral and panchromatic imagery.

2. Watershed Monitoring
In order to better understand how effective BAER treatments were at reducing fire effects on the watershed, watershed conditions were monitored. Specification #13 in the BAER plan describes a watershed monitoring program that addresses the needs of both the Black Ridge Fire and the Diamond Creek Fire. This project involved the southern portion of the Diamond Creek Fire comprised of the Diamond and Cottonwood Creek watersheds.

Watershed monitoring was initiated within a month of fire control and continued for 3 years. Monitoring techniques included collection of climate data, stream channel cross section surveys, water quality sampling and repeat photography.

F. COST SUMMARY

Emergency stabilization and rehabilitation costs for the implemented treatments, labor and other operational costs for the RFC are summarized in Table 2.2. Although funding allocation began in fiscal year 2002, implementation of most of the treatments did not begin until fiscal year 2003. Other costs, such as the costs associated with the completion of this report were not funded through the ES&R program since they have gone beyond the scope of the three year life cycle for ES&R funding and therefore are not represented in this table.

Fiscal Year	Subactivity	Subactivity Name	Category	Net Spent
FY2002				
2002	2822	Emergency Stabilization	Contracts/Services	$27,294
2002	2822	Emergency Stabilization	Supplies/Materials	$22,550
2002	2822	Emergency Stabilization	Labor	$27,884
2002	2822	Emergency Stabilization	Misc Operational	$1,441
Subtotal:				**$79,169**
FY2003				
2003	2822	Emergency Stabilization	Contracts/Services	$1,894,818
2003	2822	Emergency Stabilization	Supplies/Materials	$1,450,725
2003	2822	Emergency Stabilization	Labor	$182,828
2003	2822	Emergency Stabilization	Equipment	$6,335
2003	2822	Emergency Stabilization	Misc Operational	$19,600
Subtotal:				**$3,554,306**
FY2004				
2004	2822	Emergency Stabilization	Contracts/Services	$14,006
2004	2822 & 2881	Emergency Stabilization & Rehabilitation	Supplies/Materials	$4,288
2004	2822 & 2881	Emergency Stabilization & Rehabilitation	Labor	$153,472
2004	2822	Emergency Stabilization	Equipment	$4,835
2004	2822 & 2881	Emergency Stabilization & Rehabilitation	Misc Operational	$10,452
Subtotal:				**$187,052**
FY2005				
2005	2822	Emergency Stabilization	Contracts/Services	$20,513
2005	2822	Emergency Stabilization	Supplies/Materials	$1,215
2005	2822 & 2881	Emergency Stabilization & Rehabilitation	Labor	$83,072
2005	2822	Emergency Stabilization	Equipment	$851
2005	2822 & 2881	Emergency Stabilization & Rehabilitation	Misc Operational	$2,801
Subtotal:				**$108,452**
Total Rehab Costs:				**$3,928,979**

Table 2.2: Rattle Fire Complex ES&R Costs

III. VEGETATIVE MONITORING REPORT

A. DESCRIPTION OF ECOLOGICAL MODEL


Photo 3.1: Remnant decadent sagebrush.

The Diamond and Cottonwood watersheds were historic grazing allotments retired in the mid 90's. Many years of preferential grazing of grasses and forbs by livestock and elk had resulted in bottomlands primarily filled with tall decadent basin big sagebrush, rubber rabbitbrush, and a cheatgrass understory (Photo 3.1). Riparian vegetation included various willows, box elder, cottonwood, and riparian grasses and grasslike species (Photo 3.2). Beaver ponds were present in the riparian zone. Uplands consisted of Pinyon-Juniper, Gambel Oak, Douglas Fir, Aspen, and some Ponderosa Pine communities. Quantitative pre-fire data is generally lacking and this information is compiled from anecdotal information, photographs and site reconnaissance.

The basin big sagebrush and riparian communities in these bottomland areas were almost completely consumed by the moderate to high burn severities of the fire. The remnant beaver ponds and riparian vegetation were scoured away by the intense flash flooding that ensued. These watersheds have become hydrologically unstable due to the prevalence of fire-induced hydrophobic soils and considerable increases in overland flow resulting from the loss of vegetative cover and litter. Stream channels have become deeply incised and floodplains have expanded in some areas causing annual scouring of floodplain vegetation. These extreme hydrologic cutting and filling events appear to be the natural processes responsible for carving the Book Cliffs into their present physiographic condition. Following the fire in 2002, the bottomland areas have been reset to a recently disturbed early seral stage. Primary successional stages are likely to be dominated by grasses and forbs for several years.


Photo 3.2: Pre-fire riparian area.

The ecological model (Figure 3.1) used as a baseline to derive the post-fire ES&R objectives is based on SSURGO soils data (i.e. Soil Survey Geographic Data). The treated bottomland areas are predominately composed of the Flatnose Loamy Bottom ecosite (1,082 acres). The upper reaches of the each drainage, however, transitions into Plite Mountain Loam (90 acres). Several other soil types are present in small amounts. Since the SSURGO Loamy Bottom ecosite dominates the bottomland treatment area it was used in the development of the following ecological model. The loamy bottom ecosite shows a potential absolute vegetative cover of 50% for grasses/grasslikes, 5% for forbs, and 15% for shrubs. The cover potentials of these functional groups were used in the determination of target/threshold objectives presented in the next section. Seeded species are considered surrogate inputs into these functional groups augmenting the potential for natural recovery from existing species (i.e. native species) in order to stabilize the watershed and minimize the invasion of cheatgrass.

B. VEGETATION TREATMENTS

In order to stabilize the watersheds and slow the invasion of *Bromus tectorum*, the BAER Team made recommendations to treat areas of moderate to high burn severity occurring on slopes less than 60%. An aerial seed treatment was applied to upland and bottomland areas on BLM lands within the Cottonwood and Diamond watersheds in fall 2002 (Map 8, Appendix A). The 26,444 acre treatment consisted of 196,000 pounds of seed composed of 7 species of native grasses, forbs, and shrubs and will be termed Treatment 1 hereafter (Table 3.1).

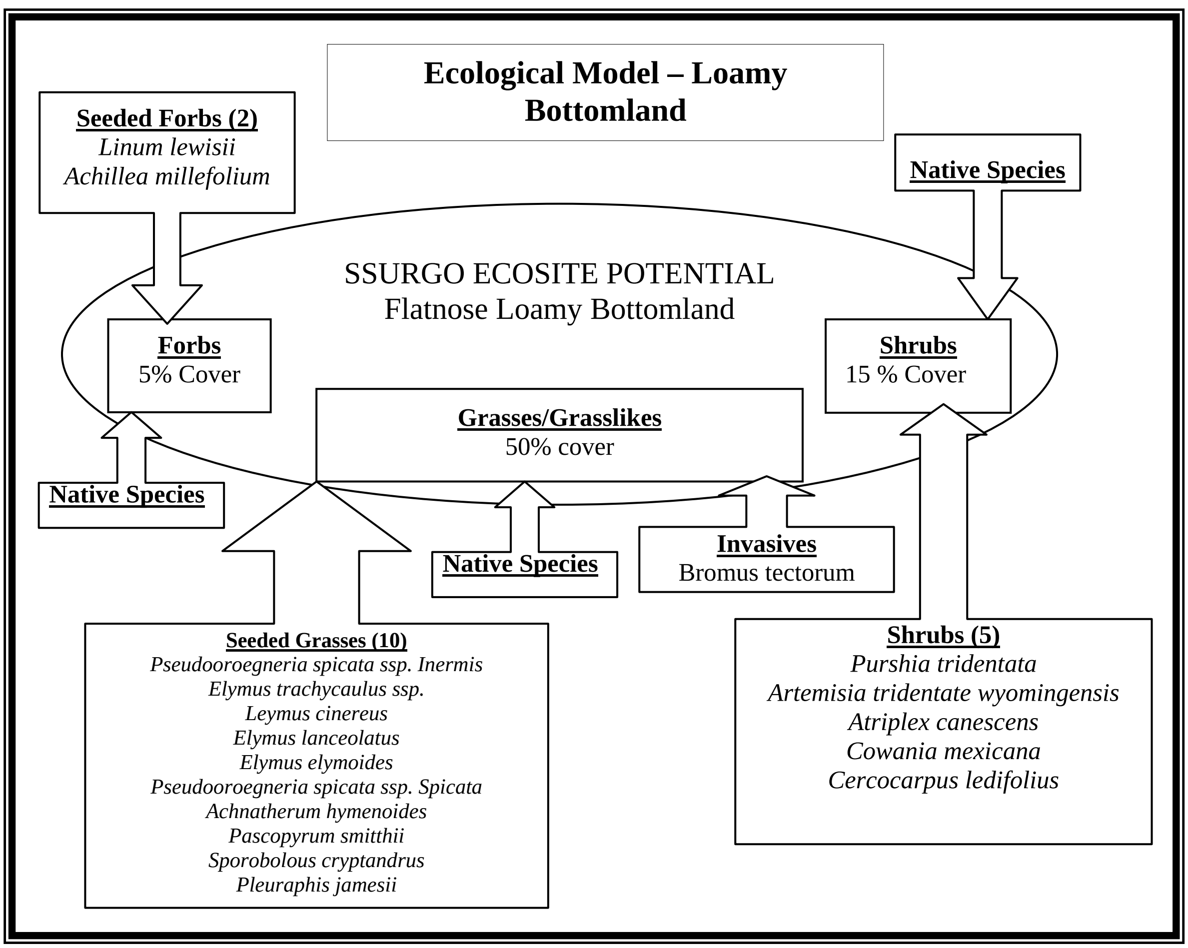


Figure 3.1: Bottomland Ecological Model

A 1,400 acre follow-up aerial seed treatment was applied to bottomland areas of both the Cottonwood and Diamond watersheds in the fall of 2003. The seed mix included 12 species of native grasses, forbs, and shrubs that were treated with a ballistics coating to minimize drift and increase penetration into the soil (Table 3.1). The treatment consisted of 7,990 pounds of seed but this weight increased to 53,868 pounds after the ballistics coating was added. A mycorrhizal seed coating was applied to six selected species (Table 3.1) in an attempt to give the seeded species a competitive advantage over cheatgrass and increase the soil stabilization potential by increasing plant establishment.

A third treatment of hydromulch was also applied to 650 acres of the loamy bottomlands within the Diamond and Cottonwood watersheds in the fall of 2003. The mulch treatment was applied in an attempt to stabilize the soil and seed on site thus minimizing the loss of seed from erosion or predation. The mulch was also intended to decrease the hydrophobicity of the soil by increasing the surface organic layer. The treatment consisted of 1,170,000 pounds of thermo-mechanically refined virgin wood fiber mulch with a 117,000 pounds of guar tackifier.

There are essentially two bottomland treatments that are derived from the overlap of all three treatments:

Treatment 2 (seeding):

- Aerial seeding fall 2002
- Aerial seeding (mycorrhizae) fall 2003

Treatment 3 (seeding and mulch):

- Aerial seeding fall-winter 2002
- Aerial seeding (mycorrhizae) fall 2003
- Mulch fall 2003

COMMON NAME	SCIENTIFIC NAME	2003 Mycorrhizal Coating	Seed 2002 (seeds/sq.ft.)	2002PLS*	Seed 2002 (# viable seeds/sq. ft.)	Seed 2003 (seeds/sq.ft.)	2003PLS*	Seed 2003 (# viable seeds/sq.ft.)	TRT 1 (# viable seeds/sq.ft.)	% TRT 1 (# viable seeds/sq.ft.)	TRT 2&3 (# viable	% TRT 2&3 (# viable seeds/sq.ft.)
Slender Wheatgrass	Elymus trachycaulus ssp. Trachycaulus, var. San Luis	No	8.28	0.9389	7.77	0.00	0.0000	0.00	7.77	28.79%	7.77	11.89%
Western Yarrow	Achillea millefolium	No	7.21	0.9414	6.79	0.00	0.0000	0.00	6.79	25.14%	6.79	10.38%
Thickspike Wheatgrass	Elymus lanceolatus	No	5.35	0.8467	4.53	0.00	0.0000	0.00	4.53	16.77%	4.53	6.93%
Great Basin Wildrye	Leymus cinereus, var. Magnar	Yes	4.51	0.8452	3.81	1.28	0.9000	1.15	3.81	14.12%	4.96	7.59%
Beardless Bluebunch Whe	Pseudoroegneria spicata ssp. Inermis, var. Whitmar	No	4.06	0.8130	3.30	0.00	0.0000	0.00	3.30	12.22%	3.30	5.05%
Lewis Flax	Linum lewisii, var. Appar	Yes	0.76	0.8945	0.68	1.44	0.8572	1.23	0.68	2.52%	1.91	2.93%
Antelope Bitterbrush	Purshia tridentata	No	0.13	0.9229	0.12	0.00	0.0000	0.00	0.12	0.44%	0.12	0.18%
Wyoming Big Sagebrush	Artemiesia tridentata wyomingensis, var. VMS	No	0.00	0.0000	0.00	26.24	0.1277	3.35	0.00	0.00%	3.35	5.13%
Sand Dropseed	Sporobolus cryptandrus	No	0.00	0.0000	0.00	26.06	0.8790	22.91	0.00	0.00%	22.91	35.05%
Bluebunch Wheatgrass	Pseudoroegneria spicata ssp. Spicata, var. Goldar and Seca	Yes	0.00	0.0000	0.00	3.21	0.8620	2.77	0.00	0.00%	2.77	4.23%
Indian Ricegrass	Achnatherum hymenoides var. Nezpar	Yes	0.00	0.0000	0.00	2.77	0.9175	2.54	0.00	0.00%	2.54	3.89%
Western Wheatgrass	Pascopyrum smithii, var. Arriba	Yes	0.00	0.0000	0.00	2.16	0.9018	1.95	0.00	0.00%	1.95	2.98%
Four Wing Saltbush	Atriplex Canescens	No	0.00	0.0000	0.00	0.05	0.3242	0.02	0.00	0.00%	0.02	0.02%
Bottlebrush Squirreltail	Elymus elymoides	Yes	0.00	0.0000	0.00	0.79	0.8771	0.69	0.00	0.00%	0.69	1.06%
Galleta Grass	Pleuraphis jamesii var. Viva	No	0.00	0.0000	0.00	2.31	0.6241	1.44	0.00	0.00%	1.44	2.21%
Curl-leaf Mountain Mahoga	Cercocarpus ledifolius	No	0.00	0.0000	0.00	0.25	0.9074	0.23	0.00	0.00%	0.23	0.35%
Cliffrose	Cowania mexicana	No	0.00	0.0000	0.00	0.11	0.7228	0.08	0.00	0.00%	0.08	0.12%
TOTALS	**TOTALS**	**-NA-**	**30.30**	**-NA-**	**27.00**	**66.67**	**-NA-**	**38.36**	**27.00**	**100.00%**	**65.36**	**100.00%**

Table 3.1: Seed Treatment Details

C. MANAGEMENT OBJECTIVES

The BAER report recommended monitoring for treatment effectiveness and overall vegetative recovery. Management objectives have been defined post-hoc for both categories as none were explicitly defined prior to the application of the treatments. There are several issues associated with the application of the treatments that may either significantly influence or make it difficult to determine treatment effectiveness.

First, the proportion of species in the seed mixes applied to the RFC was determined using pounds of seed as a reference (Table 3.1). This approach makes little sense ecologically because the amount of seeds per pound varies enormously between species. Therefore, in a seed mix the number of pounds of various species may be similar but the actual number of seeds may be highly disproportionate (Figures 3.2 & 3.3). In terms of rehabilitation, number of seeds equates more to the number of potential individuals that may be established than does a weight metric such as pounds of seed. Figures 3.4 and 3.5 show the proportion of seeds in each treatment based on the number of viable seeds derived using PLS values.

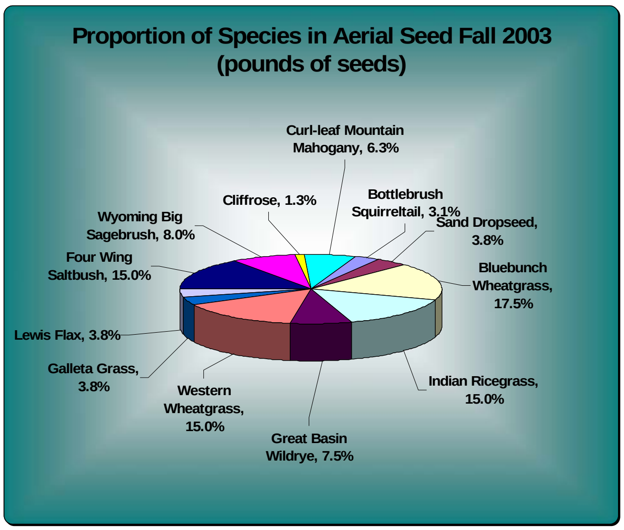


Figure 3.2

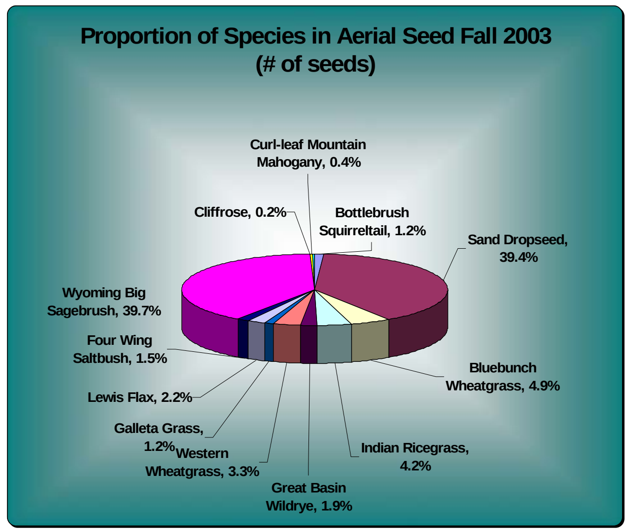


Figure 3.3

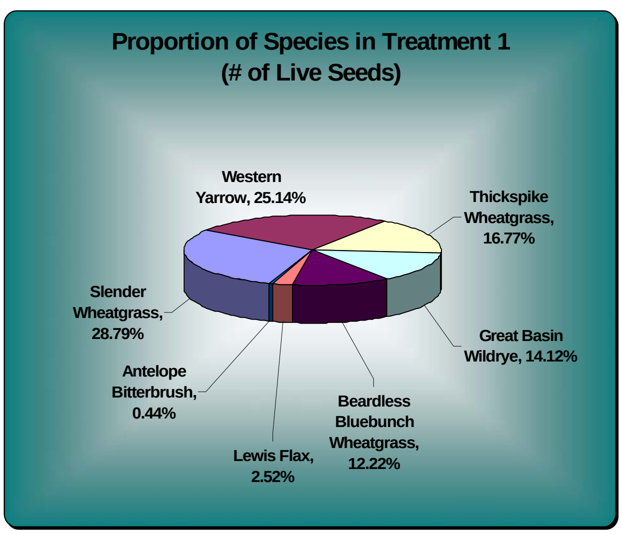


Figure 3.4

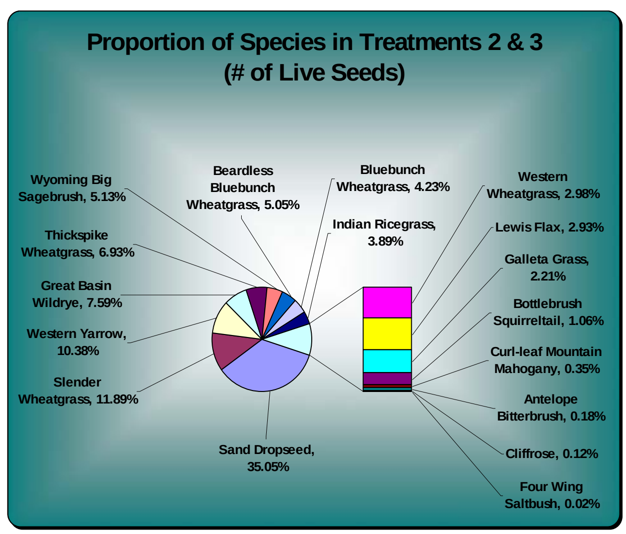


Figure 3.5

Secondly, it is not possible to quantify the effectiveness of the mycorrhizal coating because the mycorrhizal treatment was applied to the entire bottomland. In order to address this question a treatment of the same seed mix without the mycorrhizal coating should have been applied.

Thirdly, no representative untreated control plots were present. Control plots were established in the 2004 pilot study, but several of these control plots had to be located in side canyons and were unexpectedly blown out by overland flooding. The remaining control plots were located on a state tract of land in Cottonwood canyon that was hypothetically left untreated. It showed a relatively high percentage of seeded species some of which were not native to this area in the Book Cliffs indicating that these were not true controls. It is therefore impossible to quantify what would have happened had we not seeded. The lack of good control sites has forced the use of defined target/threshold objectives in the determination of treatment effectiveness.

The objectives have been defined based on the 2004 pilot study, field reconnaissance, SSURGO soils data, SSURGO ecosite descriptions, and ecological intuition. Relative values have been used to normalize for variations in absolute vegetative cover relating to climate variability or other factors. The four target/threshold management objectives are:

1. **Management Cover Objective for Overall Vegetative Recovery**
   Obtain relative vegetative cover values for preferred life forms (native/seeded species) of 20% for grasses, 20% for forbs and 5% shrubs within the study area of the loamy bottomland ecological site within the Diamond/Cottonwood watersheds by 2006.

2. **Management Frequency Objective for Overall Vegetative Recovery**
   Obtain relative frequency values for preferred life forms (native/seeded species) of 30% for grasses, 30% for forbs, and 10% for shrubs by 2006 in the loamy bottomland of the Diamond/Cottonwood Watersheds.

3. **Management Cover Objective for Treatment Effectiveness**
   Limit the relative vegetative cover to 50% for cheatgrass (Bromus tectorum) within the study area of the loamy bottomland ecological site within the Diamond/Cottonwood watersheds by 2006.

4. **Management Frequency Objective for Treatment Effectiveness**
   Obtain relative frequency values for the seeded species of 50% for perennial grasses, 5% for forbs, and 10% for woody sp (ArTr, AtCa, CoMe) with the study area of the loamy bottomland ecological site of the Diamond/Cottonwood Watersheds by 2006.

Aerial cover and frequency data provide a powerful combination of measurable vegetation attributes and can be collected in a relatively short period of time. In this instance, cover is a vertical projection of vegetation from the ground as viewed from above (Elzinga et. al, 1998). Cover values are the most directly related to biomass and will equalize the contribution of plant species to the overall vegetative cover. The methodology for collecting cover data (i.e. line-point intercept) tends to underestimate rare species and species with narrow vertical growth habits (i.e. bunchgrasses). Based on the 2004 pilot study the seeded species are being treated as rare species and therefore frequency data will be collected concurrently with cover data to provide a more powerful assessment of the overall vegetative recovery and treatment effectiveness.

Overall vegetative recovery will be monitored using both cover and frequency data as defined in **Management Objectives 1 & 2**. Since the post-fire establishment responses of the multitude of individual species present in the burn are variable, objectives were set based upon the establishment of functional groups (i.e. grasses, forbs, shrubs). Additionally, taxonomic classification of some grass species is difficult because of hybridization forcing them to be lumped into categories by genus. Preferred life forms are non-invasive species that are either native to the area and are establishing naturally or have been seeded by the BLM. They may or may not have significant forage or cover value to wildlife, but do provide some important early seral ecological niche or competition against cheatgrass invasion. A list of preferred species defined for this project can be examined in Appendix C. **Management Objective 1** allows for 55% of the relative vegetative cover to be comprised of undesirable species including cheatgrass. While this objective is not the optimal ecological scenario it is a realistic one based upon the aggressive nature of cheatgrass and its prevalent pre-fire distribution. **Management Objective 2** essentially states that for every 10 frequency quadrats containing vegetation, three should include native/seeded grasses, three should include native/seeded forbs, and one should include native/seeded shrubs. Target/Threshold objectives are intentionally weighted toward the establishment of forbs and grasses because these life forms dominate the early successional stages of the loamy bottomlands. Cover targets are lower than frequency targets as canopy cover may still be fairly low on seedlings and adult plants.

Cover was chosen to assess the spread of *Bromus tectorum* in **Management Objective 3** because frequency values would be extremely high for all but the smallest nested frequency quadrats. High frequency values would neither provide a useful measure of cheatgrass nor provide room to detect change in subsequent years of monitoring.

Frequency will be used in **Management Objective 4** to assess the establishment of seeded species. The seeded species are considered to be rare species based on the 2004 pilot study and the frequency method will provide a better assessment of composition and establishment where cover values would generally be underestimated. The seeded species have been categorized into the functional groups seeded grasses, seeded forbs and seeded shrubs. The treatment may still be successful if functional group targets are achieved but establishment of individual species is low. However, analysis of individual species establishment will also be performed.

D. MONITORING DESIGN

1. Sampling Objective

The sampling objectives were established for cover and frequency methods. The values were determined based upon a 2004 pilot study, field reconnaissance, SSURGO soils data, SSURGO ecosite descriptions, and ecological intuition but are believed to provide a reasonable balance between sample size and sample precision given the high degree of heterogeneity within the RFC.

- **Sampling Objective for Cover**
  I want to be 90% confident that the estimated cover values I obtain are within + or - 20% of the estimated true value.
- **Sampling Objective for Frequency**
  I want to be 90% confident that the estimated frequency values that I obtain are within + or - 20% of the estimated true value.

2. Sampling Design

Monitoring of treatment effectiveness within the RFC incorporates both a landscape and local scale approach. Due to the challenges associated with the vastness, remoteness, and ruggedness of the burn, a time-series of Quickbird satellite imagery is being used to monitor landscape level vegetation patterns across the 2005 growing season through a cooperative agreement with Utah State University (USU). In particular, a fractional cover and vegetation map of the Cottonwood and Diamond watersheds will be developed with special attention to the invasion of cheatgrass. Traditional ground transects are also being used to provide a more detailed look at species composition, frequency and cover within local areas. The combination of the two approaches is believed to provide an effective approach to monitoring RFC treatment effectiveness given current technology.

The entire burn area located within the Diamond and Cottonwood watersheds will be monitored using imagery collected from the Quickbird satellite. Multispectral (2.4 meter spatial resolution) and panchromatic (60 cm spatial resolution) imagery was collected in the cool season and the warm season of 2005. A supervised classification will be performed on the Quickbird imagery to derive a detailed vegetation map within the burn. The thematic layers of the vegetation map will include: Broadleaf Deciduous, Needle-leaf Evergreen, Sagebrush, Cheatgrass, Annual Chenopods, Globemallow and Bare Soil. The invasion of cheatgrass will be of special interest. These thematic groups were selected because they comprise the majority of detectable vegetation within the burn. Additional thematic layers will be added, including patches of seeded vegetation, if detectable patches exist within the burn. A fractional cover map will also be produced using a statistical regression between the Normalized Difference Vegetation Index and Green Fractional Cover estimates measured on the ground. Aerial estimates will be calculated for each landcover type. This portion of the monitoring project will be completed by May 2006 through a cooperative agreement with USU.

Ground sampling in 2005 was confined to the Diamond watershed for logistical and statistical reasons. Access to the Cottonwood and Diamond watersheds is extremely difficult. A rockslide in the 2004/2005 winter blocked road access up Cottonwood canyon.

The remaining area is primarily roadless and motorized travel is restricted under Wilderness Study Area (WSA) status. Existing roads are often seasonally inaccessible during the field season, even by ATV, making helicopter access necessary in some cases. Bottomlands are long and narrow and deeply incised by both ephemeral and perennial waterflow. These access issues are compounded by the large extent of the treatment areas in the Cottonwood and Diamond watersheds and the brief data collection window before the monsoon. It is logistically difficult to obtain adequate sample sizes for rigorous statistical inference or adequate ecological inference when attempting to sample both watersheds. This issue can be addressed by limiting the statistical population of interest to the Diamond watershed. In this monitoring design statistical inference will be limited to the Diamond watershed but ecological inference can be made to Cottonwood watershed. In other words, we will be both qualitatively and quantitatively monitor the Diamond watershed and assume that the levels of vegetative recovery and treatment effectiveness will be similar enough in Cottonwood to base future management decisions upon. Imagery collected over Cottonwood will provide quantitative support and validation for those management decisions.

This broad ecological inference is supported by similarities between the Diamond and Cottonwood watersheds as determined in the 2004 pilot study, site reconnaissance, and background research. The similarities include:

- Similar topographic features
- Similar pre- and post-fire vegetation
- Similar hydrologic characteristics
- Similar soil map unit (Flatnose Loamy Bottomland)
- Same ecological site description with same site potential
- Same treatments

The 9,455 acres of upland treatment in Diamond was ground monitored using qualitative monitoring methods. This was decided because of the challenges of accessing and sampling this acreage on steep and dangerous slopes. Four photopoints were established in Diamond Canyon on accessible slopes of varying aspects. Photos were taken in a panorama at each photo point. A permanent photoplot was established and monumented at each photopoint site. A species composition list indicating presence/absence of all species was collected at each photopoint.

The bottomland treatments were monitored using quantitative methods. Five 130’x 60’ (7,500 square feet) macroplots (Figure 3.6) were established in Treatment 2 and Treatment 3. Eight of the macroplots (i.e. 4 each per treatment) were established at the eight transect locations from the 2004 pilot study. One additional macroplot will be established in each treatment. Ten transects were placed systematically every 12.8 ft with a random start between 0-9 feet. Nested frequency quadrats will be placed at a random start location between (0-5) feet and then every 6 feet for a total of 10 quadrats per transect. Five cover points will be collected for each quadrat for a total of 50 cover points/transect. Total data collection for each macroplot is 10 transects sampled, 100 nested frequency quadrats and 500 total cover points.

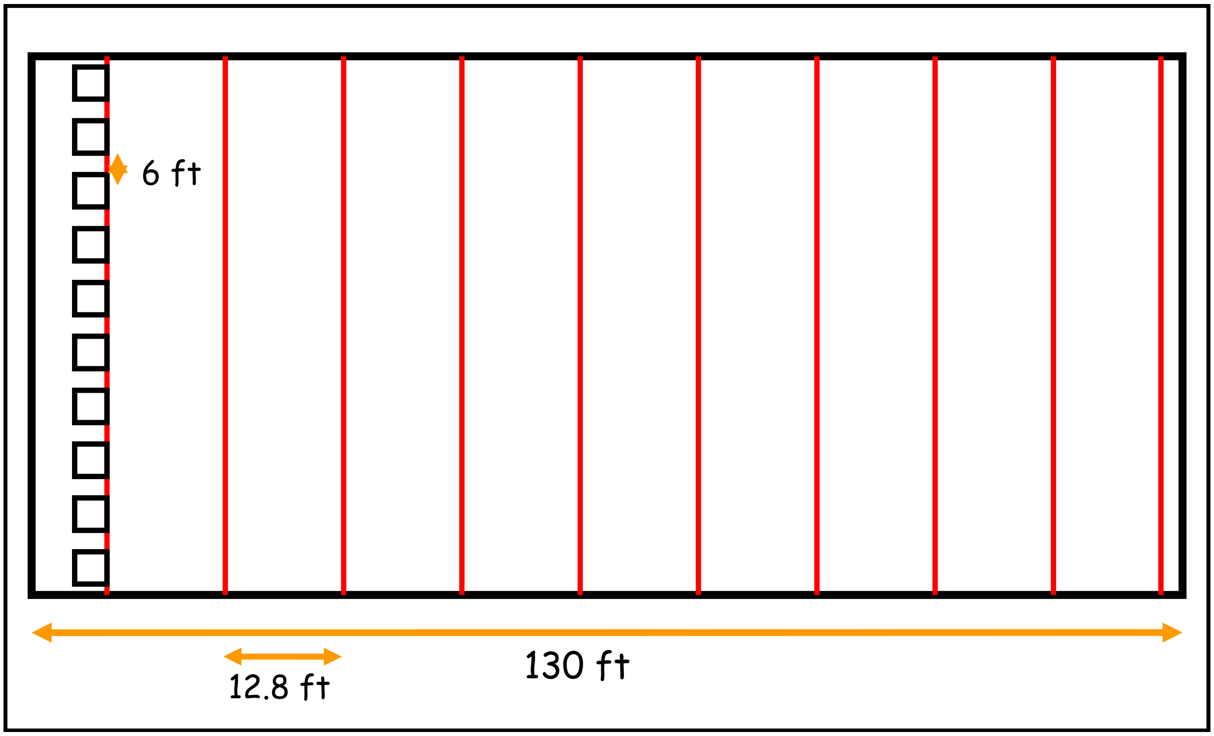


Figure 3.6. Macroplot Design

3. Field Measurement Protocols

Photopoints, photoplots, and base transects were monumented using 2' rebar and GPS locations collected using a Trimble GeoXT. GPS coordinates were differentially corrected and exported as shapefiles. Sampling locations were not located in stands of *Quercus gambelii* or on the floodplains subjected to seasonal scouring. A nested frequency sampling frame containing 3"x 3", 6"x 6", 12"x 12" and 24"x 24" quadrats was used. Plants were considered inside the quadrat if more than 50% is rooted within that quadrat. The ends of the sampling frame where sharpened into tines which were the used like pin flags to collect cover points. Only top canopy hits were collected. A sample datasheet is located in Appendix C.

4. Timing of Monitoring

The pilot study monitoring occurred between May 27, 2004 and July 22, 2004. Monitoring in 2005 occurred between July 1 and August 25. The possibility exists for further monitoring if interest and funding is identified.

5. Intended Data Analysis Approach

Summary statistics will be calculated on the frequency and cover data. Simple means, proportions, standard deviations, standard errors, and confidence intervals will be calculated. Individual macroplots will be compared against the target/threshold objectives to determine the patchiness of treatment effectiveness and overall vegetative recovery. The macroplots will then be averaged together by treatment effectiveness and vegetative recovery determined for the whole. A T-test will be used to test for statistically significant differences between Treatment 2 and Treatment 3 with respect to treatment effectiveness and overall vegetative recovery.

E. SUMMARY OF RESULTS

1. 2004 Ground Monitoring Pilot Study

The 2004 pilot study included 22 individual 50-meter line-point intercept transects read for cover & composition. Thirteen transects were established in the Diamond watershed and nine were established in the Cottonwood watershed. There were four control plots in both Diamond and Cottonwood canyons (i.e. 8 total; Table 3.2). These data were collected between May 27 and July 22 on the 22 permanently installed 50 meter transects (Figure 3.7). These transects were read once using a systematic (1/2 m intervals) line-point intercept method. Measured response variables were plant composition and cover. A portable 10-point angled (~15 º) laser point bar was used in place of a pin flag for intercept measurements. Repeat photography was initiated at each transect. Digital photos were taken looking down (i.e. point A) and back from the end of each transect (i.e. point B). Three photos were taken in orthogonal directions from point A (Appendix B).

Treatment	Diamond	Cottonwood
No-Treatment	*4 transects*	*4 transects*
Mulch (TRT 2)	*4 transects*	*2 transects*
No Mulch (TRT 3)	*4 transects*	*2 transects*
Non-Mycorrhizal Upland Seeding (TRT 1)	*1 transect*	*1 transect*

Table 3.2

Collecting FY2004 transect cover data within the RFC was time-consuming and logistically difficult due to monsoon rains, flash flooding, intense lightening storms and blown-out roads. As a result, cover data collection in FY2004 occurred over a 7 week period on the cusp of the cool/warm season which appears to have had a significant effect on the cover values. The mulch transect data (TRT 3) was collected early in the growing season when cover values from seedlings were very low. Conversely, the no-mulch (TRT 2) and control transects were read later in the season when cover values were more static but had been influenced by increased growth. A statistically significant difference between treatments and controls is an artifact of the timing of the sampling and not the treatments themselves (Figure 3.7).

The control plots established in the 2004 pilot study are not considered good controls. Several of these control plots were located in side canyons out of necessity but were subsequently blown out by monsoonal overland flooding. The remaining control plots were located on a state tract of land in Cottonwood canyon that was hypothetically left untreated. It showed a relatively high percentage of seeded species, some of which were not native to this area in the Book Cliffs indicating that these control areas were being influenced by the treatments. As a result, the 2004 pilot study was not used to determine treatment effectiveness or overall vegetative recovery. However, these data exhibit the same general trends that are evident in the 2005 data which provides additional validation for the conclusions. In particular, the cover of seeded grasses is higher and the cover of cheatgrass is lower in the no-mulch treatment. The FY2004 pilot study was used as an important exercise to determine the limitations of the sampling method and provide insight used to revise the monitoring plan for FY2005.

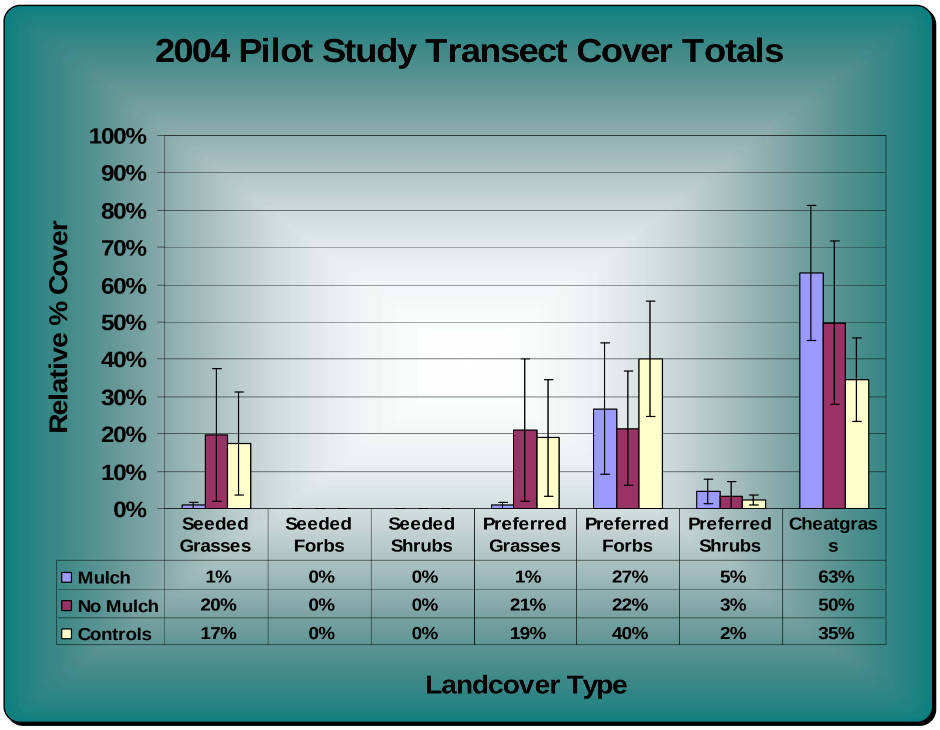


Figure 3.7: Relative % Cover of Landcover Types in Pilot Study 2004.

Several revisions were made to the FY2004 pilot study before sampling began and several are suggested for FY2005. During the pilot study it was observed that the line-point intercept method was underestimating the cover of the seeded grasses. The line-point intercept method does not work well when cover values are less than 15% (Bonham, 1989). In other words, the seeded species were present in low abundance and cover but were not being adequately quantified by this method. Compounding this problem is the fact that the most accessible data acquisition window occurs during a dynamic part of the growing season. Cover values are highly susceptible to the phenological stage of the plant (Bonham, 1989) which had a significant effect on the 2004 pilot study data. A method that was able to quantify rare species and was less susceptible to the phenological stage of the plant was needed.

Nested frequency was initiated in FY2005 along with the continued collection of cover data. Nested frequency is less susceptible to phenological stages and better able to quantify the presence of rare species. Cover data was still collected as it is more directly related to biomass and can be correlated with erosion potential. FY2005 cover data collection was initiated on July 1 during the warm season prior to the onset of monsoon precipitation when composition and cover were more static. The 2005 macroplot data collection period ended on August 25.

In order to reduce both the sampling time and the sampling variability, density quadrats and 1m x 1m photoplots were dropped from the sampling methodology for both FY2004 and FY2005. The time savings was used to sample additional plots in an attempt to minimize sampling variability. Additionally, the sampling intensity at each site was reduced in 2005, by eliminating lower canopy hits and recording only top-canopy hits.

2. 2005 Ground Monitoring Study

The data from the 2005 ground study are reported by treatment below. Photoplot data is qualitatively analyzed and each macroplot is individually compared against the target/threshold objective to determine any spatial variability in the success/failure of the defined objectives. When reporting results for the management objectives there are some cases of uncertainty where the cover or frequency estimate and the upper bound of the confidence interval crossed the target threshold but the lower bound of the confidence interval has not. In these cases, if the majority of the confidence interval, including the mean, has crossed the threshold than the objective will be considered to be met. If the confidence interval is fairly evenly distributed on either side of the threshold then no solid conclusion can be made and the objective will not be considered met. The 24" x 24" nested frequency quadrat was used for all species and functional groups for the purposes of this analysis.

A) Treatment 1 (Qualitative Monitoring)

Four photopoints were established on slopes of 20-40 degrees on varying aspects in the uplands. Each photoplot contained from three to five seeded species (Table 3.3, Figure 3.8). *Pseudoroegneria spicata spp. Inermis* and *Elymus trachycaulus* occurred in all of the photoplots. *Leymus cinereus* occurred in one of the four photoplots. *Elymus lanceolatus* occurred in three of the four photoplots. *Purshia tridentata* was not present in any photoplot. *Achillea millefolium* occurred in three out of four photoplots. *Linum lewisii* occurred in one of four photoplots. When consolidated into functional groups, seeded grasses occurred in all of the photoplots; seeded forbs occurred in 3 out of the four photoplots; and the seeded shrubs occurred in zero of the photoplots (Figure 3.9).

Occurrence of Seeded Species at each Photoplot (0=absence; 1=presence)						
Seed Species	**Photoplot 1**	**Photoplot 2**	**Photoplot 3**	**Photoplot 4**	**Total**	**%**
Pseudoroegneria spicata spp. Inermis	1	1	1	1	4	100%
Elymus trachycaulus	1	1	1	1	4	100%
Leymus cinereus	1	0	0	0	1	25%
Elymus lanceolatus	1	1	1	0	3	75%
Purshia tridentata	0	0	0	0	0	0%
Achillea millefolium	1	0	1	1	3	75%
Linum lewisii	0	0	1	0	1	25%
Total # of seeded species present	5	3	5	3		

Table 3.3: Occurrence of seeded species in uplands.

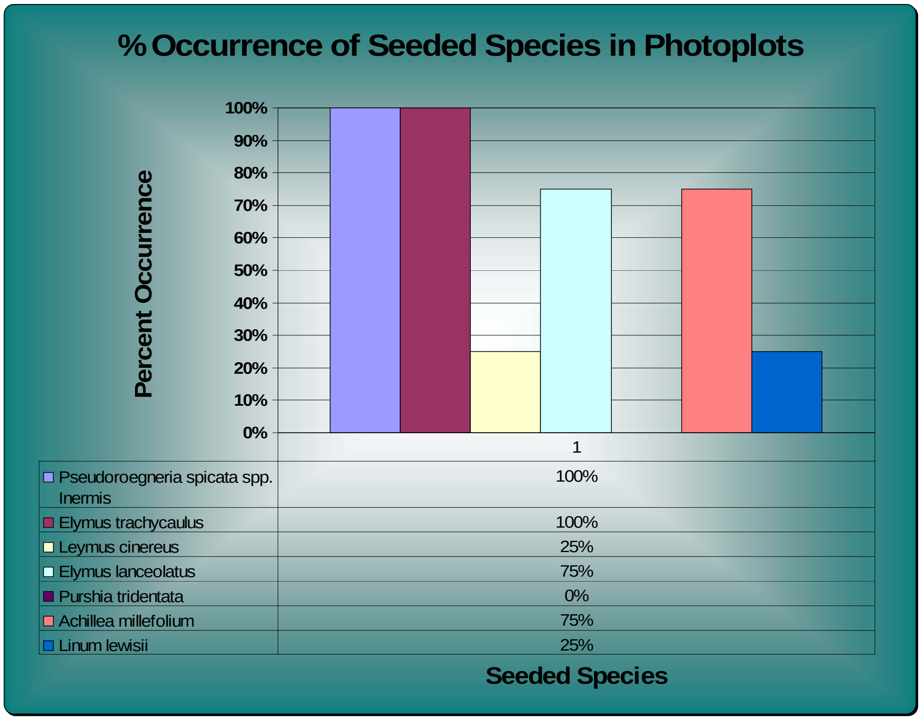


Figure 3.8: Percent occurrence of seeded species in uplands.

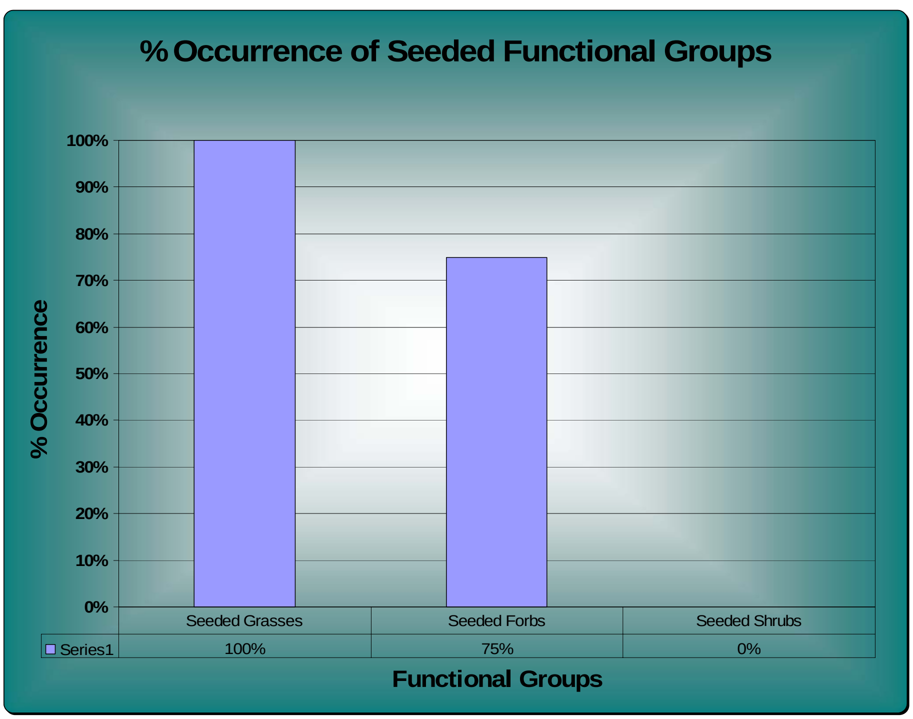


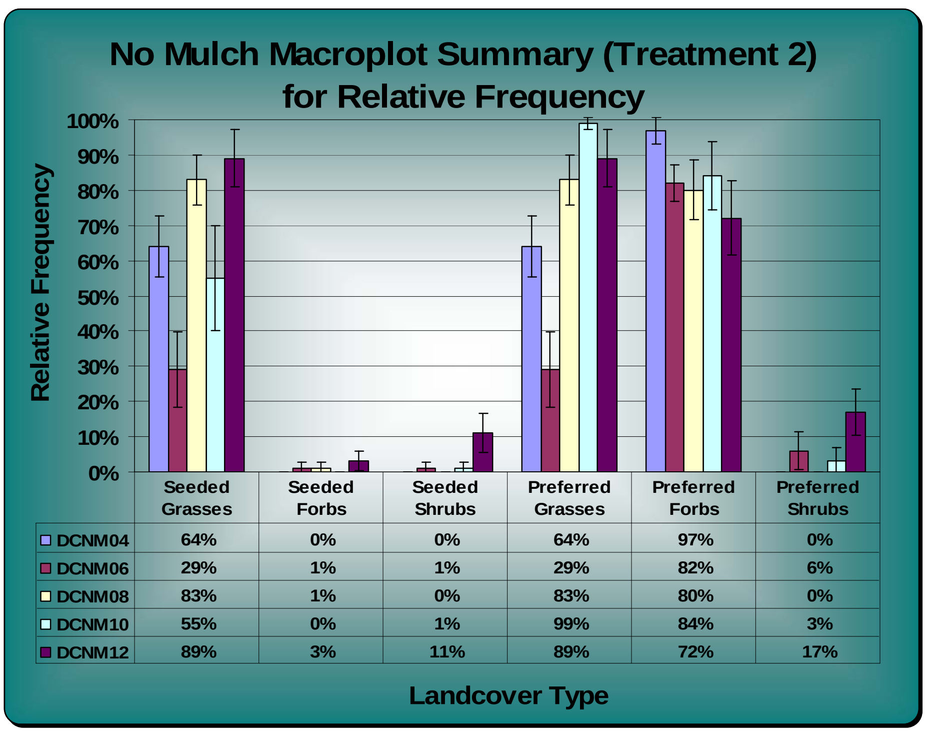
Figure 3.9: Percent occurrence of seeded functional groups in uplands.

B) Treatment 2 (No Mulch)

The Frequency Objective 4 for treatment effectiveness was not fully achieved by all of the macroplots. The objective was reached by four out of the five (i.e. 80%) macroplots with respect to seeded grasses (Figure 3.10). None of the macroplots reached this objective for seeded forbs. While only one of out of five (i.e. 20%) reached this objective for seeded shrubs. The Cover Objective 3 for treatment effectiveness was reached by four out of the five (i.e. 80%) macroplots as the mean cover of cheatgrass was below 50% (Figure 3.11).

There were no macroplots that fully achieved the Cover Objective 1 for overall vegetative recovery for each functional group (Figure 3.11). Four out of five (i.e. 80%) macroplots reached the objective for preferred grasses. Three out of five (i.e. 60%) macroplots reached the objective for preferred forbs. A fourth macroplot was within 1% of reaching this objective. Only one out of five (i.e. 20%) macroplots reached the cover objective for preferred shrubs.

There was only one out of five (i.e. 20%) macroplots that reached the Frequency Objective 2 for overall vegetative recovery for all functional groups (Figure 3.10). Four out of five (i.e. 80%) reached the frequency objective for preferred grasses. The fifth macroplot was within 1% of reaching the objective. Five out of five (i.e. 100%) macroplots reached the frequency objective for preferred forbs. Only one out of five (i.e. 20%) reached the frequency objective for preferred shrubs.



	Seeded Grasses	Seeded Forbs	Seeded Shrubs	Preferred Grasses	Preferred Forbs	Preferred Shrubs
DCNM04	64%	0%	0%	64%	97%	0%
DCNM06	29%	1%	1%	29%	82%	6%
DCNM08	83%	1%	0%	83%	80%	0%
DCNM10	55%	0%	1%	99%	84%	3%
DCNM12	89%	3%	11%	89%	72%	17%

Figure 3.10: Relative Frequency values for each macroplot in Treatment 2.

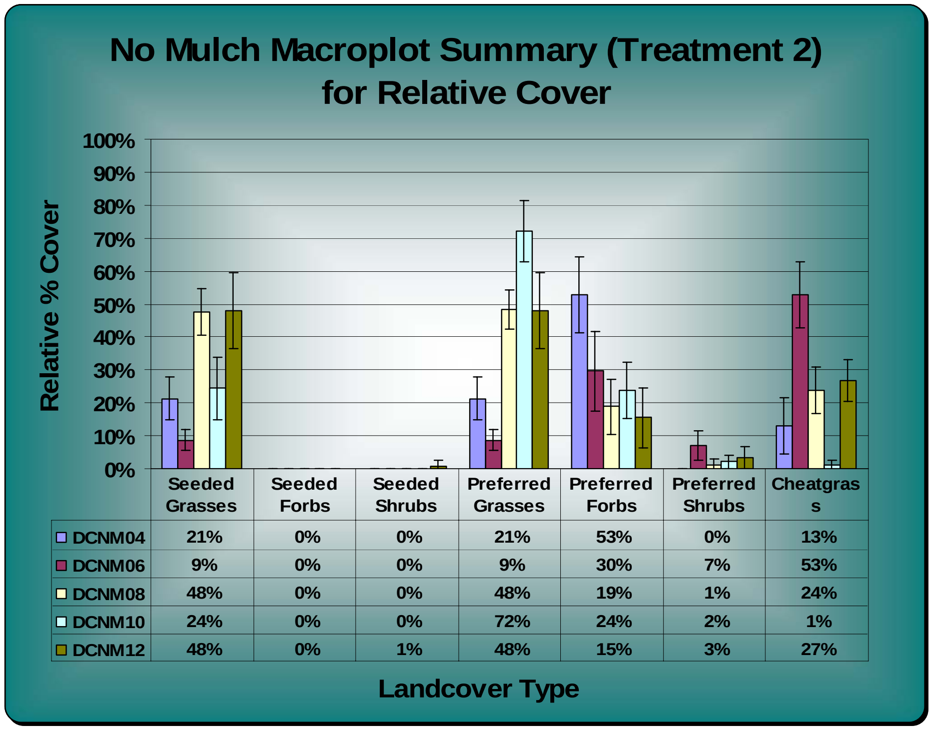


Figure 3.11: Relative Cover values for each macroplot in Treatment 2.

C) Treatment 3 (Mulch)

The Frequency Objective 4 for treatment effectiveness was reached by all five (i.e. 100%) macroplots with respect to seeded grasses (Figure 3.12). None of the macroplots reached this objective for seeded forbs or seeded shrubs. The Cover Objecctive 3 for treatment effectiveness was reached by only two macroplots indicating that three macroplots had cheatgrass cover greater than 50%. One of which was within 2% of failing to meet the objective. The overall mean cheatgrass cover was 52% (+ or – 15.1%).

There were no macroplots that fully achieved the Cover Objective 1 for overall vegetative recovery for each functional group (Figure 3.13). Two out of five (i.e. 40%) macroplots reached the objective for preferred grasses. Two out of five (i.e. 40%) macroplots reached the objective for preferred forbs. A third macroplot was within 1% of reaching this objective. Only four out of five (i.e. 80%) macroplots reached the cover objective for preferred shrubs.

There were four out of five (i.e. 80%) macroplots that reached the Frequency Objective 2 for overall vegetative recovery for all functional groups. Five out of five (i.e. 100%) reached the frequency objective for preferred grasses. Four out of five (i.e. 80%) macroplots reached the frequency objective for preferred forbs. Four out of five (i.e. 80%) reached the frequency objective for preferred shrubs.

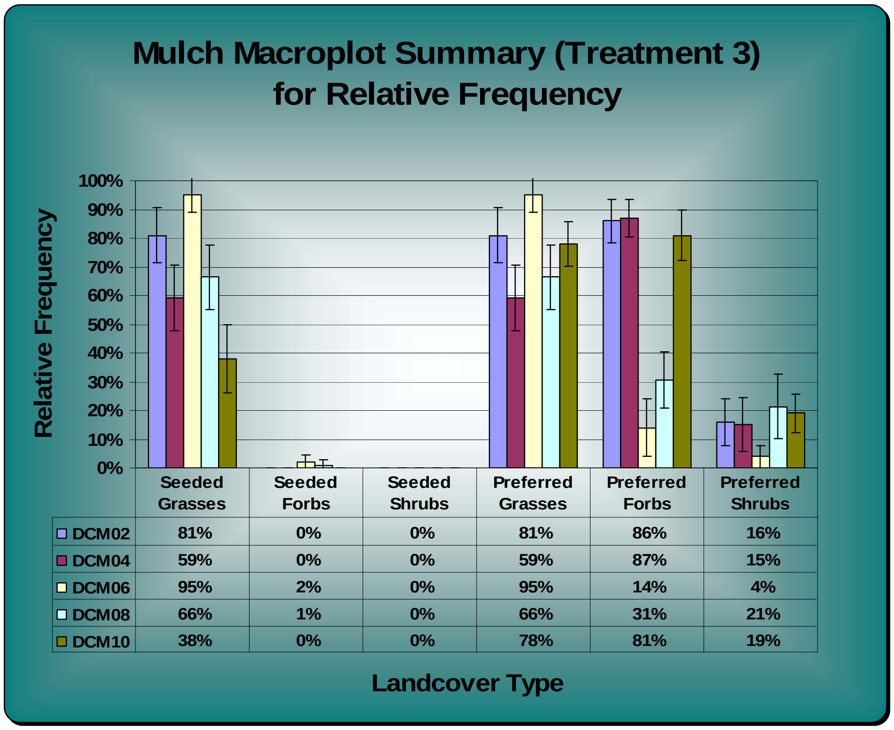


Figure 3.12: Relative Frequency values for each macroplot in Treatment 3.

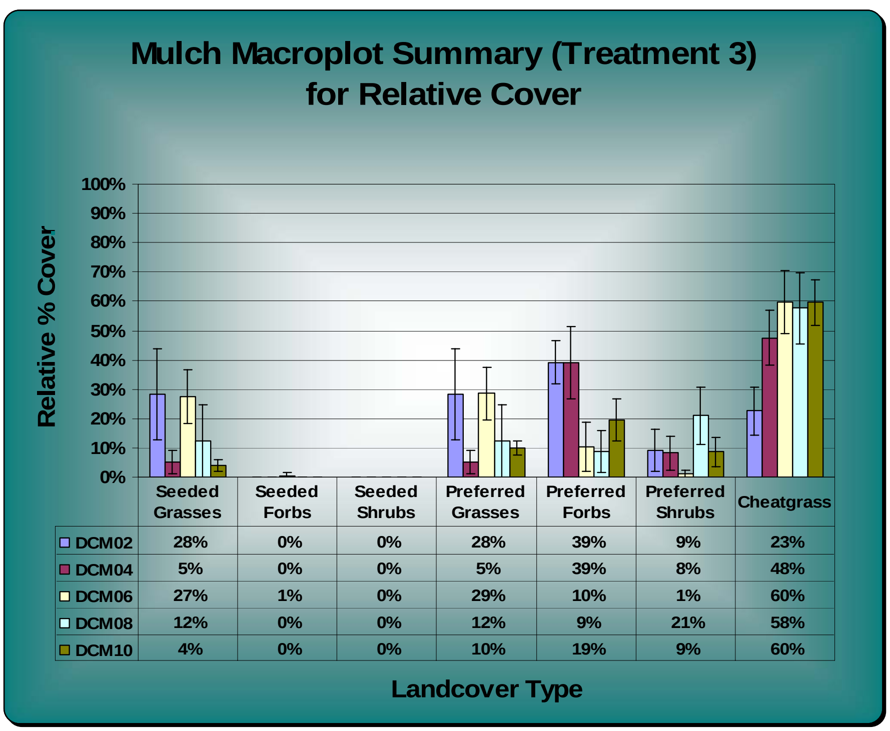


Figure 3.13: Relative Cover values for each macroplot in Treatment 3.

3. Mulch vs. No Mulch

The mean cover and frequency values for each landcover type and 90% confidence intervals are shown below (Figures: 3.14, 3.15, 3.16). The width of the confidence intervals are notably increased as the variation between macroplots is incorporated into a single statistic. A T-test was performed between the mulch and no mulch treatments for each functional group and cheatgrass using an alpha of 10% (Tables 3.4 and 3.5). The null hypotheses being tested were:

H_0 = There is no significant difference between the means of the mulch (TRT 3) and no mulch (TRT 2) treatments.

H_1 = There is a significant difference between the mean of the mulch (TRT 3) and no mulch (TRT 2) treatments.

The mulch treatment had a significantly higher cover and frequency value for preferred shrubs and higher cheatgrass cover. Conversely, the no mulch treatment had a significantly higher cover value for preferred grasses. There were no statistical differences between any other categories. The assumptions of normality and homogeneity of variances were met according to the guidelines reported in Measuring and Monitoring Plant Populations (Elzinga et.al., 1998) which allows for differences in variances of a factor of 2 to 3. Only the frequency of preferred forbs was questionable on the assumption of homogeneity of variances.

T-test for Relative Frequency											
	Mulch			No Mulch							
	Means(X_1)	SD(s_1)	n_1	Means(X_2)	SD(s_2)	n_2	s^2 =	T=	Degrees of Freedom (2(n-1))	Critical T	Reject H_o
Seeded Grasses	67.9	21.7	5	64.0	23.9	5	521.71	0.27	8	1.86	No
Seeded Forbs	0.6	0.9	5	1.0	1.2	5	1.15	-0.59	8	1.86	No
Seeded Shrubs	0.0	0.0	5	2.6	4.7	5	11.15	-1.23	8	1.86	No
Preferred Grasses	75.9	13.9	5	72.8	27.6	5	477.66	0.22	8	1.86	No
Preferred Forbs	59.8	34.7	5	83.0	9.1	5	644.16	-1.44	8	1.86	No
Preferred Shrubs	15.1	6.7	5	5.2	7.0	5	47.26	2.27	8	1.86	Yes
Cheatgrass	89.4	19.3	5	63.2	32.3	5	707.25	1.56	8	1.86	No

Table 3.4: T-test for Relative Frequency

T-test for Relative Cover											
	Mulch			No Mulch							
	Means(X_1)	SD(s_1)	n_1	Means(X_2)	SD(s_2)	n_2	s^2=	T=	Degrees of Freedom (2(n-1))	Critical T	Reject H_o
Seeded Grasses	14.2	11.7	5	29.7	17.3	5	218.11	-1.66	8	1.86	No
Seeded Forbs	0.1	0.3	5	0.0	0.0	5	0.03	0.69	8	1.86	No
Seeded Shrubs	0.0	0.0	5	0.2	0.3	5	0.06	-1.01	8	1.86	No
Preferred Grasses	15.6	10.9	5	42.0	25.0	5	372.43	-2.16	8	1.86	Yes
Preferred Forbs	22.0	14.9	5	26.9	14.7	5	219.56	-0.53	8	1.86	No
Preferred Shrubs	10.0	7.2	5	2.9	2.7	5	29.72	2.07	8	1.86	Yes
Cheatgrass	51.5	15.8	5	22.8	19.2	5	309.65	2.58	8	1.86	Yes

Table. 3.5: T-test for Relative Cover

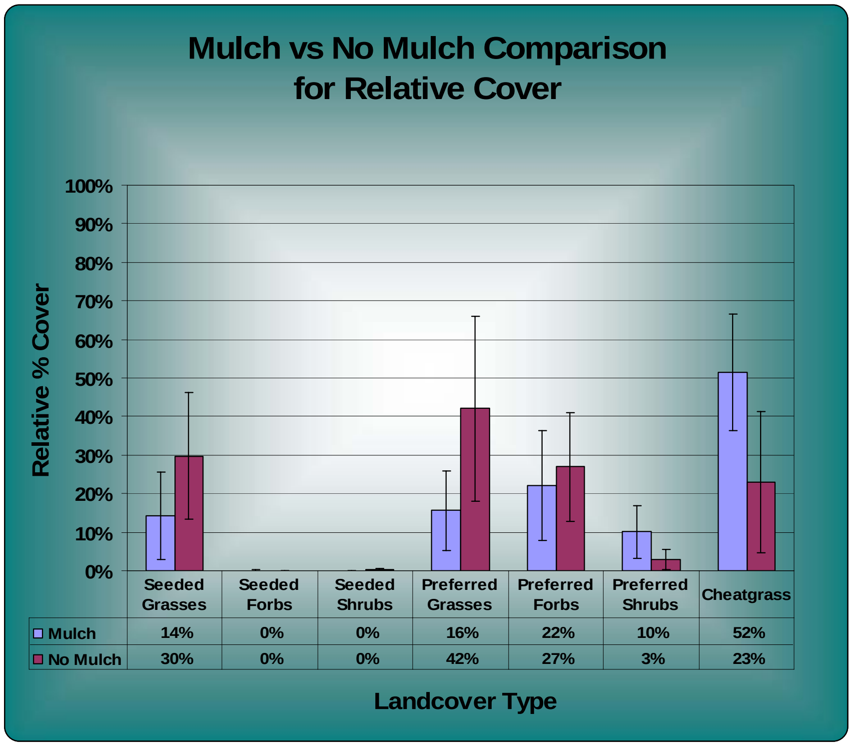


Figure 3.14: Comparison of Relative Cover between Treatments 2 & 3.

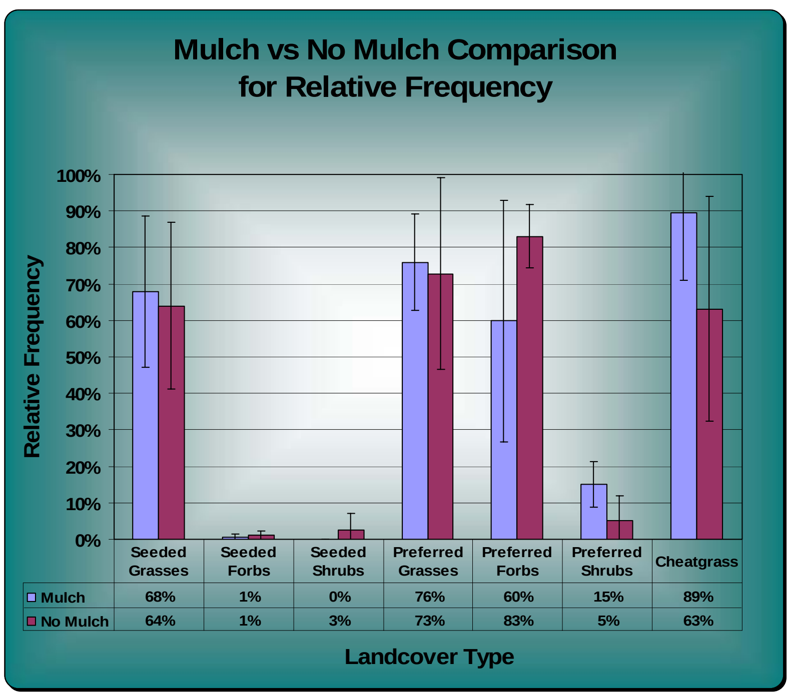


Figure 3.15: Comparison of Relative Frequency between Treatments 2 & 3.

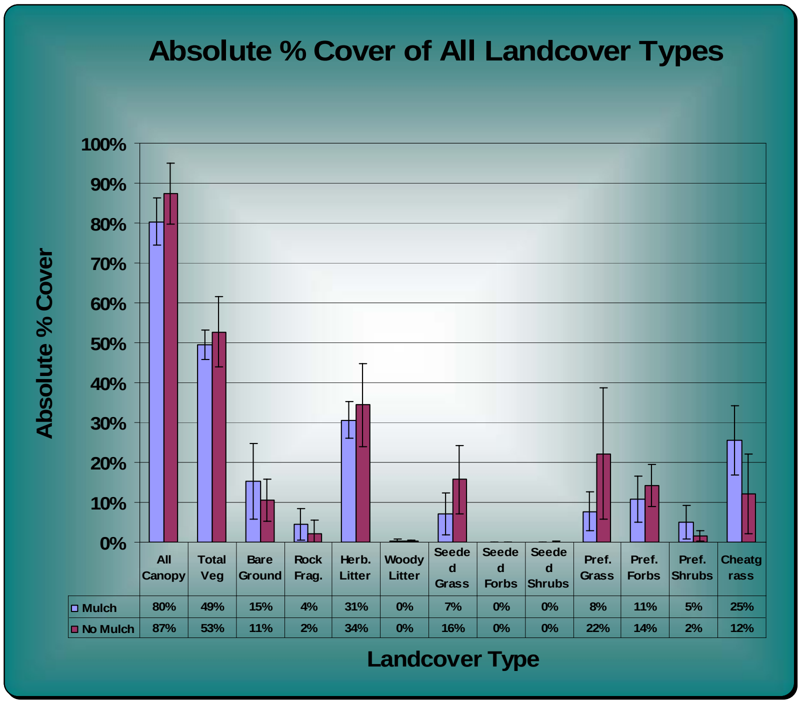


Figure 3.16: Absolute Percent Cover of Landcover Types

F. INTERPRETATION OF RESULTS

Treatment effectiveness was hindered by prevailing drought conditions during the 2003 and 2004 growing seasons. Precipitation levels returned to normal by August 2004 and were above normal during the 2005 growing season. The effect of above average precipitation on seeded and native bunchgrasses included higher levels of germination, increased establishment and increased growth in 2005. Future drought and fire conditions will play a key role in the persistence of the seeded and preferred species.

Photo 3.3: Annual Chenopod species establishing in mulch in 2004.

Treatment effectiveness is considered to be low during the growing season of 2004. Seeded species exhibited low cover and abundance and were difficult to quantify using only the line-point intercept cover method. Cheatgrass was prevalent with high cover values in many areas.

The invasion and dominance of cheatgrass was attenuated in more mesic areas by the presence of native annual forb species like *Chenopodium pratericola*, *Chenopodium fremontii*, and *Chenopodium simplex*. These forb species were prolific in and around the floodplain areas often growing in mulch (Photo 3.3). Cheatgrass cover was very low in areas dominated by Chenopodium species indicating a positive competitive advantage.

Ecological intuition suggests that these species are able to compete for light and water resources during the early part of the growing season when cheatgrass is initiating growth. They grow rapidly and their tall broadleaf growth form may significantly limit the light and water resources available to cheatgrass seedlings germinating in the understory. In terms of ES&R objectives, these Chenopodium species appear to fill a key primary successional niche in this ecosystem by quickly providing extensive annual groundcover and competition against cheatgrass. The prevalence of annual Chenopod species diminished by 2005 and they were replaced by other preferred species except on more xeric sites where cheatgrass established. Populations of these species appear to be short-lived early seral cheatgrass competitors that may reserve a niche for successional transitions towards perennial grasses and forbs given the right climatic conditions.

Sphaeralcea parviflora was also very prevalent in both 2004 and 2005 occurring in extensive areas outside the floodplains (see report cover photo montage). *Sphaeralcea parviflora* co-dominated sites with cheatgrass and limiting cheatgrass cover to low and moderate levels. The competitive pressure from *Sphaeralcea parviflora* appears to less than that of the annual Chenopod forbs. Although *Sphaeralcea parviflora* is also a broad-leaved forb species its canopies provide less cover allowing more light and water resources to reach the ground. Populations of this species appear to be longer lived early seral species providing moderate levels of competition against cheatgrass.

Treatment effectiveness during the growing season of 2005 is considered to be high. The above average precipitation resulted in significant germination, establishment and growth of some of the seeded species. A discussion of treatment effectiveness and overall vegetative recovery for the 2005 growing season follows below.

<u>1. Uplands - Treatment 1 Effectiveness and Overall Vegetative Recovery</u>

Treatment 1 is considered to be a partial success based on the qualitative monitoring which included species lists, site descriptions, photos, and site reconnaissance. Seeded grasses and forbs exhibit good distribution and vigor occurring on 100% and 75% of sites respectively. Although only four photopoints were established to monitor upland areas, site reconnaissance in other areas indicates that the uplands as a whole can be characterized by these photopoints. Drier aspects and slopes have decreased cover but the seeded species are present. In contrast, the shrub component consisting of *Purshia tridentata* appears to be completely unsuccessful as it was not detected at any of the photopoints. The absence of seeded shrub species may be due to inadequate site conditions for germination, inability of the seed to reach a safe site by aerial seeding, or the ecological timeline on upland sites may be longer than 3 years for

Photo 3.4: Upland Photopoint 1

germination and establishment. The density and cover of grasses and forbs does not appear to be high enough to competitively exclude seeded shrubs from germinating in the upland treatment area. *Purshia tridentata* was observed, albeit rarely, in the bottomland areas indicating that it can establish in the deeper bottomland soils of the Book Cliffs but still may not be the best choice for either short-term stabilization or rehabilitation objectives.

Overall vegetative recovery and the influence of the upland seeding on post-fire succession are largely based upon the existing pre-fire vegetative community. ReGAP vegetation data show that Treatment 1 spanned 17 vegetative communities (Table 3.6). These 17 vegetative communities, among others, were lumped into a smaller more manageable subset of vegetative communities during the development of the Normal Year Fire Rehabilitation Plan (NFRP) for the Moab Fire District. Table 3.7 shows the NFRP groupings that were treated in 2002. Pinyon and Juniper Woodlands, Mountain Shrub (i.e. Rocky Mountain Gambel Oak-Mixed Shrubland), and Douglas Fir/Mixed Conifer/Aspen were the three dominant vegetative communities. A brief discussion about the levels of natural vegetative recovery and the treatment effect for each of these community types is included below.

Pinyon-Juniper Woodland comprised the largest pre-fire vegetative community treated at 11,559 acres. Pinyon and Juniper woodlands located in the RFC were frequently burned by both natural and man-made fires. Until 1951, grazing permitees were allowed to burn areas in the Book Cliffs to maintain grass and forb abundance for cattle and sheep grazing (Ed Maloney, personal correspondence). The relatively high fire frequency in pinyon-juniper forests of the Book Cliffs resulted in age classes presumed to be approximately 55 and 100 years old in many areas. Old growth pinyon-juniper stands are not common in the Book Cliffs and therefore overall vegetative recovery to pre-fire conditions will be based on younger age classes.

A model of succession for Pinyon-Juniper Woodlands in southwestern Colorado progresses from skeleton forest and bare ground, to annual stage, to perennial grass-forb stage, to shrub stage, to shrub-open tree stage, to climax woodland (Brown et.al., 2000). The abundance of seeded grass and forb species from the 2002 seeding indicate that the treatment was successful in establishing a more dominant, vigorous and diverse perennial grass-forb stage after 3 years than might otherwise occur. There has been some natural establishment of shrubs but the transition into a well developed shrub stage is expected to occur within next 5-15 years. Tree reestablishment will occur slowly through the introduction of juniper berries and pinyon cones by gravity or animal vectors. Large burned patches are expected to colonize slowly from the outside in as seed sources are distant from the interior. The progression to well developed climax woodland similar to pre-fire conditions may take from 45-150 years depending on the aspect and regional climatic patterns in the future.

The Mountain Shrub (i.e. Rocky Mountain Gambel Oak-Mixed Shrubland) was the second largest treated vegetative community occurring on 6,075 acres. These Gambel-Oak communities burned very hot but skeleton stands remained. Their extensive rhizomatous root systems provided an important soil stabilization component on the shallow rocky upland soils. Gambel Oak stands resprouted from root crowns within days of the fire containment and have shown considerable foliar regrowth by the end of the 2005 growing season. Stands are very dense with little to no grass-forb understory beneath the overstory canopy. Grasses and forbs have established in the open spaces between oak canopies. The photos below show a Box Elder (*Acer negundo*) in the foreground and Gambel Oak in the background. Although photo 3.3 was taken in 2004 it shows what the post-fire skeleton forest looks like. Photo 3.4 shows the considerable resprouting that occurred by the early part of the 2004 growing season. Gambel Oak communities are extremely resilient to fire due to there extensive rhizomatous root system and their ability to resprout quickly and stabilize the soil. These communities should generally be considered a low priority for seeding treatments because of their fire resiliency and their competitive exclusion of other vegetation.

Photo 3.5: Box elder and Oak Skeleton forest on 04/18/04.

Photo 3.6: Box elder and Oak Skeleton Forest on 06/04/04

The Douglas Fir/Mixed Conifer/Aspen comprised the third largest treated vegetative community at 3,075 acres. Post-fire germination and establishment of Douglas Fir after severe wildfire will typically rely on wind-dispersed seeds. Seed bearing cones usually travel only a few hundred feet from the source. Successful establishment of seedlings relies on the seed reaching a site with bare mineral soil and the optimal moisture conditions. There are pockets of Douglas Fir that have survived in unburned or low burn severity areas which will provide a seed source for regeneration. However, areas where moderate and high burn severities occurred that are more remote from seed trees may see minimal conifer regeneration for many years. Aspen stands burned in the RFC are expected to resprout quickly from the extensive root system that typically remains after fire. Aspen may be more prolific in some areas as the post-fire competition from coniferous species is reduced.

ReGAP Vegetative Communities Treated with the 2002 Seeding	
DESCRIPTION	**ACREAGE**
Colorado Plateau Pinyon-Juniper Woodland	10,825
Rocky Mountain Gambel Oak-Mixed Montane Shrubland	6,075
Rocky Mountain Montane Dry-Mesic Mixed Conifer Forest and Woodland	1,720
Rocky Mountain Montane Mesic Mixed Conifer Forest and Woodland	834
Colorado Plateau Pinyon-Juniper Shrubland	717
Rocky Mountain Aspen Forest and Woodland	474
Inter-Mountain Basins Big Sagebrush Shrubland	368
Inter-Mountain Basins Montane Sagebrush Steppe	305
Rocky Mountain Lower Montane Riparian Woodland and Shrubland	182
Inter-Mountain Basins Greasewood Flat	148
Rocky Mountain Alpine-Montane Wet Meadow	79
Inter-Mountain West Aspen-Mixed Conifer Forest and Woodland Complex	44
Rocky Mountain Cliff and Canyon	18
Colorado Plateau Mixed Bedrock Canyon and Tableland	17
Southern Rocky Mountain Montane-Subalpine Grassland	7
Inter-Mountain Basins Mixed Salt Desert Scrub	3
Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland	2
TOTAL	21,819

Table 3.6: ReGAP Vegetative Communities

NFRP Vegetative Communities Treated with the 2002 Seeding	
NFRP VEGETATIVE COMMUNITY	**ACREAGE**
Pinyon and Juniper Woodland	11,559
Mountain Shrub	6,075
Douglas Fir/Mixed Conifer/Aspen	3,075
Sagebrush	673
Riparian Wetland	261
Salt Desert Scrub/Shrub	151
Insignificant Vegetation Type	26

Table 3.7: NFRP Vegetative Communities

2. Bottomlands

A) Treatment 2

Treatment 2 was effective in establishing seeded grass species and minimizing cover of *Bromus tectorum* but was ineffective in establishing seeded forbs and shrubs. The overall vegetative recovery of the treatment area is acceptable based upon an early seral grass-forb dominated ecological model. Seeded grasses, preferred grasses, and preferred forbs exhibited a high frequency with variable relative cover. Variable cover can be explained by several factors including differences in microsite water characteristics, life stage characteristics, or species growth form.

1) Treatment Effectiveness

The mean value for the entire treatment shows that Frequency Objective 4 was met for seeded grasses despite the lower bound of the 90% confidence interval dropping to 40%. This uncertainty could be minimized by reducing the level of confidence or increasing the sample size. However, since the majority of the 90% confidence interval, including the mean, lies above the threshold it is considered a success. Mean relative cover of seeded grasses was 30% + or - 16.5%. Reaching the relative frequency objective for seeded grasses with a significantly lower relative cover value is interesting. There are several likely factors influencing this phenomenon. First, the line-point intercept method tended to underestimate the cover of seeded bunchgrasses. Secondly, the wetter 2005 growing season resulted in increased germination of seeded grass species. While the frequency of seedlings is high their biomass and aerial cover are still low indicating that given another wet growing season frequency should stay static while cover values would increase. Thirdly, the mean value for the entire treatment incorporates data from sites on a soil moisture continuum.

It was observed that the drier sites which typically occurred on the transition from bottomland to upland had significantly less cover and frequency than wetter sites closer to the channel. These areas exhibited a noticeable decrease in both absolute vegetative cover and relative cover of preferred species. Additionally, increased late spring/summer precipitation in the 2005 growing season influenced the germination of seedlings creating a landscape with an abundance of small seedlings. Water availability appears to be a driving factor behind the magnitude of both frequency and cover metrics. This is an important concept in understanding the variance incorporated into the 90% confidence interval surrounding the parameter estimates.

In contrast, Frequency Objective 4 for seeded forbs was not met. The mean value for the entire treatment was 1% with upper confidence limits well below the 5% target/threshold. There were no macroplots that reached this objective. The relative cover of seeded forbs was less than 1% with very little variance. These seeded forbs were qualitatively observed in the bottomlands during sampling but with extremely low cover and frequency. The lack of germination and establishment cannot be attributed to a lack of available seeds because seeded forbs comprised 10.38% of the seed mix for *Achillea millefolium* and 2.93% for *Linum lewisii* based on the number of viable seeds (Figure 3.5). *Achillea millefolium* was observed frequently in the uplands indicating that aerial seeding can be successful for seeded forbs. One explanation is that these seeded forbs did not compete well with the abundance of other annual/perennial grasses and forbs present in the bottomlands.

Frequency Objective 4 for seeded shrubs was also not met. The mean value for the entire treatment was 3% with upper confidence limits well below the 10% target/threshold. Only one macroplot was borderline and did reach a frequency of 11% + or - 5.6% for *Artemisia tridentata spp. wyomingensis*. However, overall the ability of seeded shrubs to germinate and establish was minimal and this component of treatment 2 was not effective. One explanation for the lack of establishment of seeded shrubs is that the seeding rate was too low. *Cowania mexicana*, *Atriplex canescens*, *Purshia tridentata,* and *Cercocarpus ledifolius* comprised only 0.67% of the entire seed mix when evaluated by the number of viable seeds. A second hypothesis may be that the high absolute cover of vegetation (49%) in the bottomland areas competitively excludes the germination of shrubs. Beyers (2004) indicates that in a post-fire seeding treatment 30% cover of seeded ryegrass during the first year caused increased shrub seedling mortality. Interestingly, ryegrass cover values of 55% reduced shrub seedling density to zero by the end of the first summer. A third possibility may be that seeded shrubs may also be on a longer ecological timeline for germination or establishment. Treatment 2 was not successful in establishing seeded forbs and shrubs in the bottomlands to this point.

The Cover Objective 3 for minimizing *Bromus tectorum* cover was met. The mean value for the entire treatment shows that the relative cover of *Bromus tectorum* was limited to 23% + or – 18.3%. The upper end of the confidence interval was well below the target/threshold of 50%. Treatment 2 was effective in establishing seeded grasses and in conjunction with vigorous natural revegetation of preferred grasses and forbs was able to minimize the cover of *Bromus tectorum*.

2) Overall Vegetative Recovery
The mean value for the entire treatment shows that Frequency Objective 2 was met for preferred grasses with statistical certainty. The mean frequency and 90% confidence interval for preferred grasses are 73% (+/- 26.3%). This indicates an abundance of preferred grass species present on the landscape. The Cover Objective 1 for preferred grasses was met with a mean of 42% (+/- 23.9%). The lower bound falls slightly below the target/threshold of 20% creating a small amount of uncertainty. When examining the cover data from individual macroplots it is statistically certain that three of the five macroplots have exceeded and one did not meet the preferred grass target defined in Objective 1. Only one of the macroplots was a borderline case for cover of preferred grasses. The two macroplots that were either borderline or did not reach the cover objective occurred on more xeric sites. The area defined by treatment 2 has reached a sufficient level of vegetative recovery for preferred grass species.

The mean value for the entire treatment shows that Frequency Objective 2 was also met for preferred forbs with statistical certainty. The mean frequency and 90% confidence interval for preferred forbs are 83% (+/– 8.6%). This indicates an abundance of preferred forb species within the treatment area. The Cover Objective 1 was met for preferred forbs with a mean of 27% (+/- 14.1%). However, the lower bound of the 90% confidence interval dropped below the target/threshold objective of 20% relative cover creating some uncertainty in this conclusion. Preferred forb targets for Objective 1 were met by only one macroplot with absolute certainty with confidence intervals on the remaining four hovering above and below the threshold. Since, 75% of the confidence interval for the entire treatment and the majority of individual macroplot means are above the target/threshold the objective is considered met, albeit barely.

Preferred shrubs did not reach the target/threshold of 10% defined in Frequency Objective 2 or 5% defined in Cover Objective 1. The mean relative frequency was 5% (+/- 6.8%) and mean relative cover 3% (+/- 2.6%). There is slight uncertainty as the upper confidence boundary of each metric is slightly above the target/threshold. However, the means and majority of the confidence intervals are below the target/threshold indicating that preferred shrub objectives were not met.

Preferred shrubs like *Chrysothamnus nauseosus* and *Chrysothamnus viscidiflorus* have the ability to resprout quickly after fire if the buds located in the root crown are not damaged in the fire. The treatment area was exposed to high burn severities which resulted in the almost complete consumption of above ground biomass but also increased the mortality of buds in the root crown. This high bud mortality would both minimize shrub regeneration from resprouting and increase the time of shrub recovery as regeneration becomes more reliant on off-site seed sources. This treatment area will likely be in a grass-forb dominated early successional stage for a longer period of time than areas of more moderate burn severities.

B) Treatment 3

Treatment 3 was applied to 392 acres of bottomland area in both Diamond and Cottonwood. Treatment 3 was effective in establishing seeded grass species and ineffective in establishing seeded forbs, establishing seed shrubs and minimizing cover of *Bromus tectorum*. The overall vegetative recovery of the treatment area is acceptable based upon an early seral grass-forb dominated ecological model. Seeded grasses, preferred grasses, preferred forbs, and preferred shrubs exhibited a high frequency with variable relative cover. Variable cover can be explained by several factors including microsite water characteristics, life stage, or species growth form characteristics.

1) Treatment Effectiveness

The mean value for the entire treatment shows that Frequency Objective 4 was met for seeded grasses despite the lower bound of the 90% confidence interval dropping to 47%. This uncertainty could be minimized by reducing the level of confidence or increasing the sample size. However, since the mean and the vast majority of the confidence interval lies above the threshold it is considered a success. Mean relative cover of seeded grasses was 14% + or – 11.2% which is considerably lower than in Treatment 2. A T-test does not show this to be a statistically significant difference although qualitative field observations support a difference. Reaching the relative frequency objective for seeded grasses with a low relative cover value is interesting. The hypotheses explaining this phenomenon are the same as discussed above. First, the line-point intercept method generally underestimates cover of seeded bunchgrasses. Secondly, the wetter 2005 growing season resulted in increased germination of seeded grass species. While the frequency of seedlings is high their biomass and aerial cover are still low indicating that given another wet growing season frequency should stay static while cover values would increase. Thirdly, the mean value for the entire treatment incorporates data from sites on a soil moisture continuum.

It was observed that the drier sites which typically occurred on the transition from bottomland to upland had significantly less cover and frequency than wetter sites closer to the channel. These areas exhibited a noticeable decrease in both absolute vegetative cover and relative cover of preferred species. Additionally, increased late spring/summer precipitation in the 2005 growing season influenced the germination of seedlings creating a landscape with an abundance of small seedlings. Water availability appears to be a driving factor behind the magnitude of both frequency and cover metrics. This is an important concept in understanding the variance incorporated into the 90% confidence interval surrounding the parameter estimates

In contrast, Frequency Objective 4 for seeded forbs was not met. The mean value for the entire treatment was 1% with upper confidence limits well below the 5% target/threshold.

There were no individual macroplots that reached this objective. The cover value for seeded forbs was less than 1% with very little variance. These seeded forbs were qualitatively observed in the bottomlands during sampling but with extremely low cover and frequency. The lack of germination and establishment cannot be attributed to a lack of available seeds because seeded forbs comprised 10.38% of the seed mix for *Achillea millefolium* and 2.93% for *Linum lewisii* based on the number of viable seeds (Figure 3.5). *Achillea millefolium* was observed frequently in the uplands indicating that aerial seeding can be successful for seeded forbs. One explanation is that these seeded forbs did not compete well with the abundance of other annual/perennial grasses and forbs present in the bottomlands.

Frequency Objective 4 for seeded shrubs was also not met. The mean value for the entire treatment was 0% with no variance as no seeded shrubs were recorded in any of the individual macroplots. Overall the ability of seeded shrubs to germinate and establish was minimal and this aspect of Treatment 3 was not effective. One explanation for the lack of establishment of seeded shrubs is that the seeding rate was too low. *Cowania mexicana*, *Atriplex canescens*, *Purshia tridentata*, and *Cercocarpus ledifolius* comprised only 0.67% of the entire seed mix when evaluated by the number of viable seeds. A second hypothesis may be that the high absolute cover of vegetation (49%) in the bottomland areas competitively excludes the germination of shrubs. Beyers (2004) indicates that in a post-fire seeding treatment 30% cover of seeded ryegrass during the first year caused increases shrub seedling mortality. Interestingly, ryegrass cover values of 55% reduced shrub seedling density to zero by the end of the first summer. A third possibility may be that seeded shrubs may also be on a longer ecological timeline for germination or establishment. Treatment 3 was not successful in establishing seeded forbs and shrubs in the bottomlands to this point.

The Cover Objective 3 for minimizing *Bromus tectorum* cover was not met. The mean value for the entire treatment shows that the relative cover of *Bromus tectorum* was limited to 52% (+/- 15.1%). The mean is right on the target/threshold objective and confidence interval is evenly distributed on both sides. Treatment 3 was effective in establishing seeded grasses and but was not able to minimize the cover of *Bromus tectorum*.

2) Overall Vegetative Recovery

The mean value for the entire treatment shows that Frequency Objective 2 was met for preferred grasses with statistical certainty. The mean frequency and 90% confidence interval for preferred grasses are 76% (+/- 13.5%). This indicates an abundance of preferred grass species present on the landscape. However, the Cover Objective 1 for preferred grasses was not met with a mean relative cover of 16% (+/- 10.4%) for the entire treatment. The mean and majority of the confidence interval fall well below the target/threshold of 20% creating a indicating the failure to meet this objective. When examining cover data from individual macroplots it is statistically certain that only one macroplot exceeded and two did not meet the preferred grass target defined in Objective 1. Two of the macroplots were borderline cases for cover of preferred grasses. The area defined by treatment 2 has reached a sufficient level of vegetative recovery with respect to the abundance of preferred grass seedlings but biomass and cover are still lower than desired.

The mean value for the entire treatment shows that Frequency Objective 2 was also met for preferred forbs with statistical certainty. The mean frequency and 90% confidence interval for preferred forbs are 60% (+/– 33.1%). This indicates an abundance of preferred forb species within the treatment area. The Cover Objective 1 was not met for preferred forbs with a mean of 22% (+/- 14.2%). The mean is slightly above the target/threshold with the confidence interval fairly evenly distributed on either side. When examining cover data from individual macroplots the forb target was met by two macroplots and not met by two macroplots with absolute certainty. Only one macroplot was statistically borderline. These data indicate the relative abundance of preferred forbs with low levels of biomass.

The preferred shrub target/thresholds of 10% defined in Frequency Objective 2 and 5% defined in Cover Objective 1 were met. The mean relative frequency was 15% (+/- 6.48%) and mean relative cover 10% (+/- 6.9%). There is slight uncertainty as the lower bounds of each metric's confidence interval are slightly below the target/threshold but there is enough certainty to assume the objectives have been met.

C) Mulch vs. No Mulch

The mulch treatment had no significant effect on treatment effectiveness or success. There were no statistical differences in the cover or frequency of *seeded* grasses, forbs or shrubs. However, the mulch treatment had a significantly higher cover and frequency of *preferred* shrubs and higher cheatgrass cover but also had a significantly lower cover of preferred grasses when compared against the no mulch treatment using a T-test. According to ReGAP data, SSURGO data and post-fire evidence the macroplots were located on similar pre-fire vegetative communities dominated by decadent sagebrush/cheatgrass communities with soils consisting of the Flatnose Family Loamy Bottomland Ecosite. The two likely factors that may explain these differences in vegetation are either differences in burn severity or the application of mulch.

The mulch treatment area in Diamond watershed suffered a moderate burn severity while the treatment area without mulch was characterized by high burn severities. While both moderate and high burn severities will top-kill most shrubs by eliminating above ground biomass the increased temperatures associated with higher burn severities often increases the mortality of buds at the root crown. *Chrysothamnus naseosus* and *Chrysothamnus viscidiflorus* both resprout from the buds located at the root crown and are the most abundant components of the preferred shrub category. The increased shrub cover and frequency in the mulch treatment area are likely due to an increased survival of buds at the root crown resulting from the lower temperatures of a moderate burn severity. Regeneration of these rabbitbrush species in the no mulch treatment (i.e. high burn severities) will likely occur more slowly by seed effectively extending the early seral grass-forb stage for a longer period of time. The difference in shrub cover and frequency is not likely due to the influence of mulch.

The difference in burn severity is also the most likely factor explaining the difference in cheatgrass cover between these treatments. Cheatgrass seeds are susceptible to heat kill and seed densities are typically higher on sites of lower burn severity (Zouhar, 2003). The immediate post-fire densities of cheatgrass seed may have been higher in the mulch treatment area resulting in higher cheatgrass cover and increased competition against seeded/preferred grasses. An untested alternate hypothesis suggests that the increased winter/spring soil moisture trapped by the layer of hydromulch may be depleted by early cheatgrass growth. In this scenario, much of the additional soil moisture trapped by the hydromulch is utilized and depleted by cheatgrass before native grass and forb species initiate growth. There is essentially a net increase in water availability for cheatgrass but little to no increase for later growing cool season species. This may provide a competitive advantage to winter annuals that initiate growth early in the growing season. This effect will likely be increased in drought years like 2003 and 2004 and minimized in years of above average precipitation like 2005.

It is the opinion of this author that the increased cover of cheatgrass in the mulch treatment is a significant factor contributing to the difference in preferred grass cover. In the mulch treatment, 59.2% of the preferred grass frequency consisted of the seeded warm season grass *Sporobolus cryptandrus* with no other warm season grasses present. In the "no mulch" treatment only 1.6% of the preferred grass frequency consisted of *Sporobolus cryptandrus* without any other warm season grasses present. Field observations show seedlings and juvenile *Sporobolus cryptandrus* growing through mats of senescent cheatgrass during the warm season (Photo 3.7). The prevalence of this seeded warm season grass over seeded cool season grasses in the mulch treatment indicates that it has a competitive advantage in areas of higher cheatgrass cover. The competitive advantage of *Sporobolus cryptandrus* is apparently gained through its phenological difference in growing season as it initiates growth under hotter and drier conditions when cheatgrass is senescent. *Sporobolus cryptandrus* has a growth form that even in the adult stage has significantly less cover than many of the cool season grasses occurring within the no mulch treatment area (Photo 3.8). In this case many *Sporobolus cryptandrus* individuals are seedlings or juveniles with lower cover than adults. The difference in preferred grass cover between treatments is accounted for by the growth form and life-stage of *Sporobolus cryptandrus*.

Photo 3.7: Sand Dropseed growing through Cheatgrass in the warm season.

D) Success of Seeded Grasses Species

The success of the seeding treatments is based upon the successful germination and establishment of the seeded grass species. Germination and establishment varied greatly between species. An understanding of which species were the most successful would be useful in terms of future seeding treatments in fire prone areas similar to the Book Cliffs. The frequency metric is used to evaluate the distribution and effectiveness of individual species (Figure 3.17). The first ten species were seeded and the last seven occurred naturally (Figure 3.17).

The species that had the highest frequencies across variable burn severities and treatments were *Elymus trachycaulus*, *Elymus lanceolatus*, *Pascopyrum smithii* and *Pascopyrum spicatum inermis*. These cool season species were marginally successful in the first two post-fire years most likely in response to persistent drought conditions. These species responded dramatically with the above average precipitation in 2005. *Elymus lanceolatus* and *Pascopyrum smithii* were present in large high frequency sod-forming patches by the end of the 2005 growing season. *Leymus cinereus* did not account for a large portion of the absolute vegetative frequency but was well established when the pilot study was initiated in 2004. The early success of this species under drought conditions, monsoonal scouring and strong competition from annual forbs and grasses is worth noting. These perennial grass species should be considered in future seeding treatments in similar ecosystems.

Photo 3.8: High cover of seeded cool season

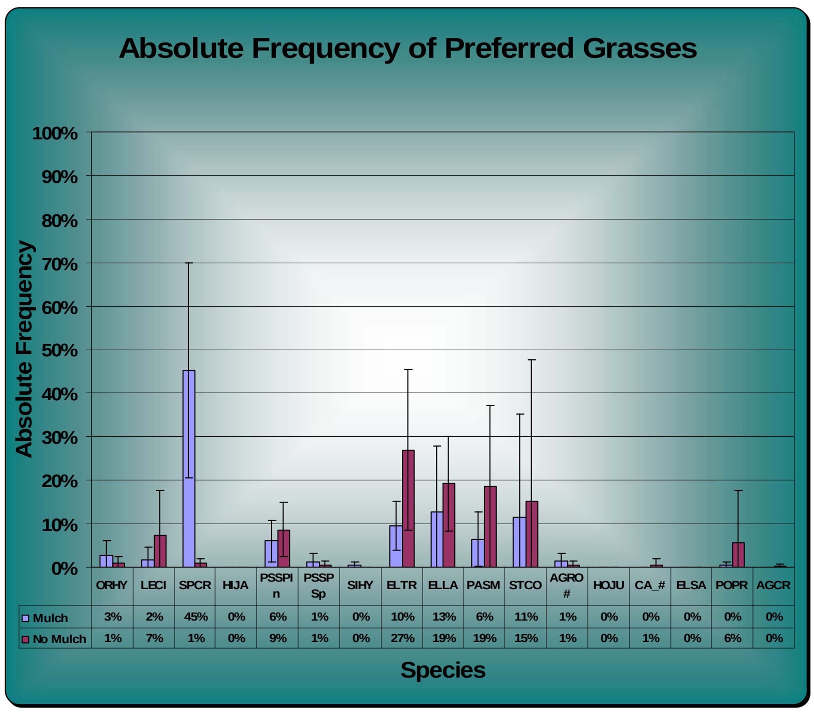


Figure 3.17: Absolute Frequency of Preferred Grass Species

Seedlings of *Orhyzopsis hymenoides* and *Sporobolus cryptandrus* were prolific during the 2005 growing season (Photos 5.2 and 3.7). High densities of *Orhyzopsis hymenoides* seedlings were noticed on fresh alluvial deposits within the main channel and are not likely to persist. Orhyzopsis hymenoides seedlings were also present in lower numbers in areas outside the channels. Persistence of these seedlings will depend on future climatic conditions and frequency of fire disturbance. The prevalence of *Sporobolus crypatandrus* seedlings growing in areas of high cheatgrass cover highlight the potential role of warm season grasses. The potential effectiveness of incorporating warm season grasses into ES&R seed treatments should be further examined. *Hilaria jamesii*, *Pascopyrum spicatum spicatum* and *Sitanion hystrix* exhibited low levels of germination and establishment and should not be considered for future seeding treatments in the Book Cliffs.

E) Mycorrhizae

It is impossible to quantify the effect of the mycorrhizal coating on germination and establishment without the proper control treatments or sites. There were no areas where the same seed mix was applied without the mycorrhizal component. However, some field observations support a possible effect on the establishment and vigor of *Pascopyrum smithii*. In the DCNM08 macroplot *Pascopyrum smithii* was observed growing in strong sod-forming monoculture with heights approximately 12 inches taller than typically observed in the region (Photo 3.9). It is possible that the mycorrhizal treatment has influenced this phenomenon. However, these monitoring studies cannot provide conclusive evidence indicating either success or failure of the mycorrhizal coating. Establishing control treatments and sites prior to treatment application is necessary to evaluate the success or failure of mycorrhizal coatings.

Photo 3.9: Vigorously growing Pascopyrum smithii.

F) Inferences to Cottonwood Canyon

The levels of treatment effectiveness and overall vegetative recovery of the adjacent Cottonwood watershed are expected to be very similar to that of the Diamond watershed. Extending this ecological inference to Cottonwood is considered reasonable based on the rationale presented in chapter 3, section D.2. Additionally, the observations and data associated with the 2004 pilot study showed considerable similarities between the two watersheds. The validity of this ecological inference will be addressed in the remote sensing analysis scheduled for completion in May 2006.

The seeding treatments on the uplands of the Cottonwood watershed are expected to be highly successful in establishing the same vigorous perennial grass community present on the cooler upland aspects in Diamond watershed. Seeded forbs are expected to be moderately abundant with *Achillea millefolium* being more abundant than *Linum lewisii*. Native forbs species (i.e. asters, penstemon, etc.) are also expected to be abundant. Seeded shrubs are not expected to have germinated or established to any significant degree. Drier upland aspects are expected to have a similar composition and less abundant distribution of both the seeded and native species. The overall vegetative recovery of the upland areas in Cottonwood watershed are expected to be similar to the recovery in Diamond as described for the Pinyon-Juniper Woodland, Mountain Shrub and Douglas Fir/Mixed Conifer/Aspen.

The effectiveness of the seeding treatments and overall vegetative recovery in the bottomland areas are expected to by largely dependent on the burn severity. Areas of moderate burn severity are likely to have higher cover and frequency of preferred shrubs but little germination and establishment of seeded shrubs or forbs. Cheatgrass will have generally higher cover and seeded grass species are expected to exhibit low cover but relatively high frequencies. The warm season grass, *Sporobolus cryptandrus*, is expected to comprise the majority of seeded grasses present. Areas of higher burn severity are expected to have lower cover and frequency of preferred shrubs. Germination and establishment of seeded forbs and shrubs is expected to be minimal. Cheatgrass cover will likely be lower as seeded and native grass cover is expected to be higher. Seeded grass species will predominately consist of the cool season grasses, *Pascopyrum smithii*, *Elymus lanceolatus*, *Elymus trachycaulus*, *Pascopyrum spicatum inermis* and *Leymus cinereus*. Bottomland areas of high burn severity are expected to exhibit higher cover of preferred grasses.

IV. WATERSHED MONITORING

A. INTRODUCTION

By monitoring watershed conditions, we can better understand how effective ES&R treatments were at reducing fire effects on the watershed. The BAER plan recommended watershed treatment effectiveness monitoring, with details in specification #13 (BAER plan, p. 71). The estimated cost for monitoring over three years was $59,000 (BAER plan, p. 7).

Monitoring was initiated within a month of fire control and continued for three years. Total cost for three years of watershed monitoring was approximately $190,000. These costs were high due to extensive helicopter use due to limited access.

Photo 4.1: Diamond Creek, road crossing #1 (3 miles downstream of burn)

The area monitored includes both Diamond Creek and Cottonwood Creek watersheds. Diamond and Cottonwood Creeks have perennial to intermittent stream flows. There are several springs in the upper tributaries of each canyon. Oak Springs is a large spring located in mid-Diamond Canyon.

Watershed monitoring techniques include collection of climate data, stream channel cross section surveys, water quality sampling and repeat photography. Dozens of photo points were established throughout the burned area within one month of fire containment. Water chemistry and macro-invertebrate sample sites were established at several burned and unburned sites in 2002. Stream channel survey sites were established at 17 locations within and downstream of the burned area in 2002. One Remote Automated Weather Station (RAWS) was installed in the burned area, along with five tipping-bucket raincans, to monitor climatic conditions.

B. CLIMATE

<u>1. Precipitation</u>

A) Monitoring Techniques

One Remote Automated Weather Station (RAWS) was installed in Diamond Canyon in May 2003 by National Interagency Fire Center (NIFC) staff (Photo 4.2). The station sits in a wide section of Diamond Canyon, at an approximate elevation of 6100'. The station recorded precipitation, soil moisture, relative humidity, air temperature, solar radiation, and wind speed and direction. Annual maintenance was conducted each spring by NIFC staff.

Photo 4.2: RAWS Station Installation

This weather station recorded rainfall on an hourly basis with an accuracy of .01". In early 2005 the station was moved several hundred feet to a slightly higher location, away from a growing gully. Severe flooding deposited several feet of sediment at the original is site on several occasions, affecting soil moisture meter depths and measurements. Rainfall measurements were not affected.

The Bryson Canyon RAWS is located about 10 miles east of Diamond Canyon, and has been in operation since 1987. The station sits in a canyon bottom at an elevation of 5320', almost 800' lower than the Rattle RAWS. The Bryson Canyon data was useful in generating annual and monthly precipitation averages to correlate with Rattle RAWS data.

Analysis of both RAWS datasets includes annual, seasonal and monthly rainfall averages. Dr. Don Jensen (Utah Climate Center) provided technical assistance with and analysis of this climate data. The seasons were delineated, based on findings from long-term range studies in the area, as follows:

Spring: March 1 – May 31
Summer: June 1- September 30
Fall: October 1- November 30

Five tipping bucket HOBO raincans (Photo 4.3) were set up in the burned area to understand precipitation patterns within the burned area. These raincans record with an accuracy of .01", noting the time of each tip of the measuring bucket. This data was also used to generate storm duration and storm intensity statistics.

Photo 4.3: Hobo raincan on Cottonwood Ridge

An additional tipping-bucket HOBO raincan was set up in Floy Canyon, several miles west of the burned area. This is a control station, and is co-located at a control stream channel cross section survey site.

B) Monitoring Results

At the time of the fire, the area was experiencing a regional drought which began in 1998. "The 12 month period ending in August 2002 was the driest in recorded history throughout the Southwest (Merriam Powell, 2003)". Tree ring research suggests it may have been the driest period in 1400 years (USGS, 2003). Soil moisture and fuel moisture levels were at record low conditions.

Drought conditions were documented at seven National Weather Service (NWS) weather stations in Grand County from 2002 through 2004, including the Bryson Canyon station (Appendix F). Averages from the Bryson Canyon RAWS data (almost 30 years of data) were compared to the Rattle RAWS data, as the 2 datasets have a close correlation.

In summer 2003, rainfall amounts were 43% of normal at the Bryson Canyon RAWS and 50-60% of normal at the Rattle RAWS. Most precipitation came during scattered summer thunderstorms, with low storm intensity and duration. During July 2003 there was no measurable rainfall at 5 of the 6 raincans. This affected the recovery of the hydrophobic soils.

Generally, monthly precipitation totals returned to normal by late summer 2004. Storm intensity, duration and extent increased as well. Because of the extended nature of the drought, the effects on soil moisture levels continued through 2004.

Monthly and seasonal precipitation totals in 2005 exceeded normal amounts. Soil moisture conditions returned to more normal levels. This correlates closely with regional conditions.

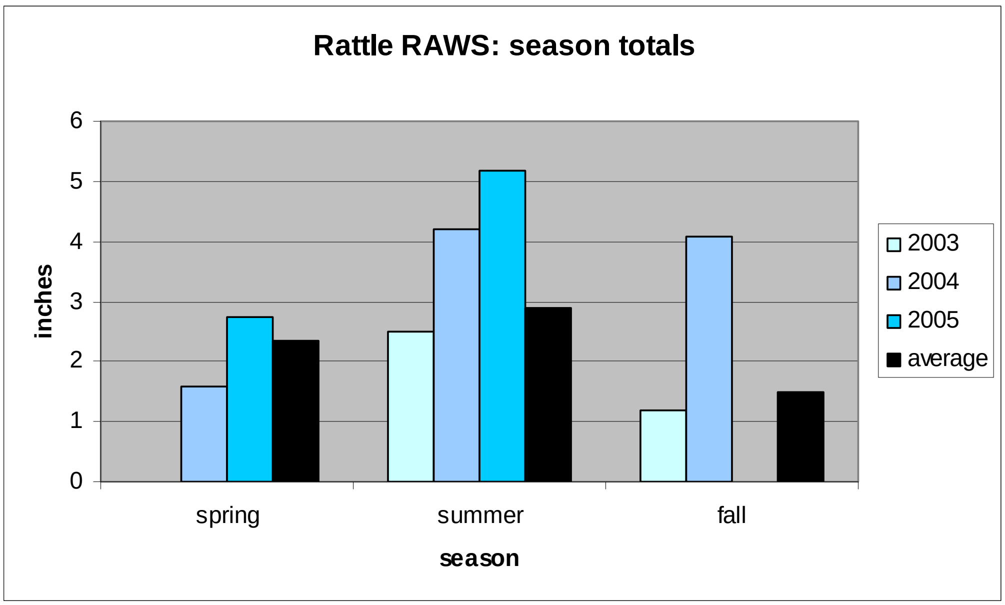


Figure 4.1: The average is derived from Bryson Canyon data, which is 800' lower in elevation than the Rattle RAWS station location.

<u>2. Soil Moisture</u>

A) Monitoring Techniques

Two soil moisture probes were included with the Rattle RAWS. One probe was buried at 6", the other probe was buried at 18". The two probes would monitor conditions pertaining to shallow rooted plants (grasses) and deeper rooted plants (shrubs).

The Rattle RAWS soil moisture data is suspect due to repeated flooding and subsequent sedimentation. Repeated flooding events either deposited or scoured sediment around the probes, making the meter depths unknown. After one storm event in fall, 2004, the station was buried 3 feet deep (Photo 4.4). The wiring was compromised at least once from critter activity.

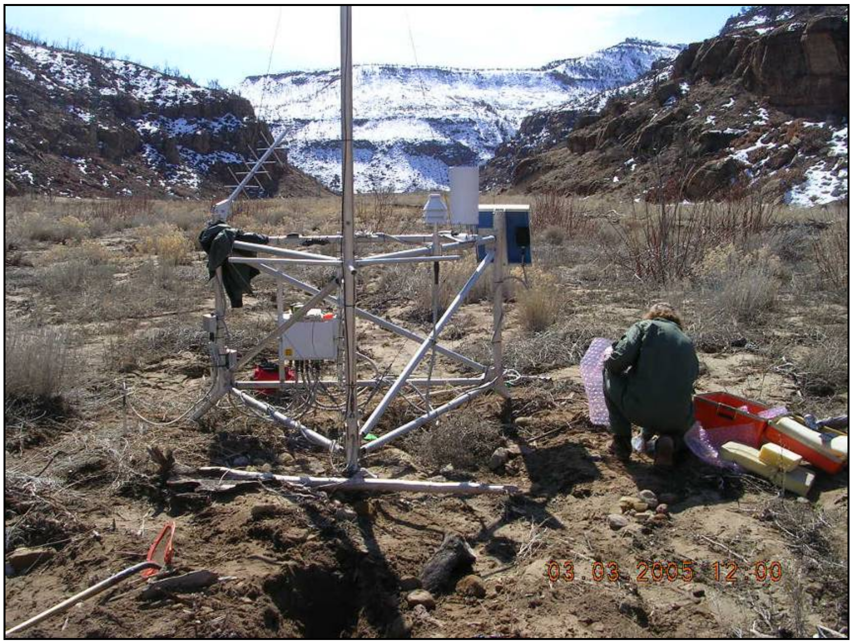


Photo 4.4: Note: 3’ legs buried in sediment

The Bryson Canyon RAWS is located about 10 miles to the east in similar terrain, 800’ lower in elevation than the Rattle RAWS. This station has 3 soil moisture sensors at different depths; 6”, 12” and 18”.

B) Monitoring Results
In general, soil moisture data correlates to precipitation. Soil moisture conditions at Rattle can be inferred from Bryson Canyon data, confirmed by similar rainfall totals.

Soil moisture conditions during the 2002-2004 growing seasons were low. Conditions were more normal during the 2005 growing season.

C. STREAM CHANNEL CROSS SECTION SURVEYS

1. Monitoring Techniques

Immediately after the fire, 17 permanent stream channel cross-section survey sites were established. The sites were located within the burned area, downstream of the burn, and in adjacent canyons for control. Most sites were resurveyed annually. See Map 9, Appendix A for locations.

Surveying was conducted with a transit and level (Sokkia survey instrument), noting all major changes in the channel. Sites were permanently marked with rebar or fence posts at both ends of the cross section. Survey techniques follow those described in Stream Channel Reference Sites: An illustrated guide to field technique, USFS GTR- RM-245, 1994.

Photo 4.5: Diamond Canyon, downstream of Oak Springs

Surveys were also conducted on three large gullies forming upstream and downstream of Oak Springs in Diamond Canyon. These surveys included lineal (extent and direction), horizontal (width) and vertical (depth) measurements. These surveys were repeated in 2005 as access and time permitted.

Photo 4.6: Gully growing downstream of Halfway Canyon

2. Monitoring Results

A) Control Sites in Adjacent Canyons

Three control sites were established in adjacent canyons. One site was located in Westwater Canyon several miles to the east. The second site was located in Flume Canyon, an unburned tributary of Diamond Canyon downstream of the fire. The third site was established in Floy Canyon, a similar watershed several miles to the west.

All the control sites showed about 6” of sediment accumulation in the channel by 2005 and no overall change in channel geometry.

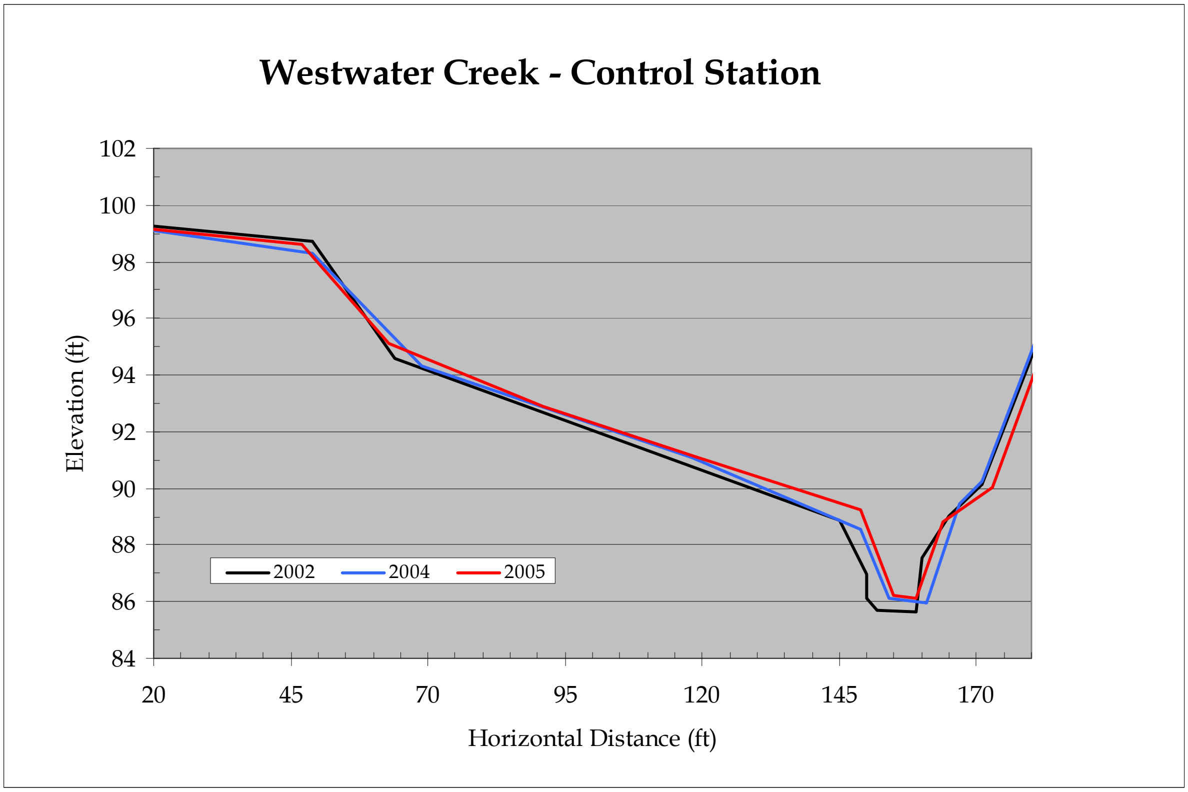


Figure 4.2: Control survey site

B) Downstream of Burn (I-70 and Railroad Bridge Crossings)

Two sites were established approximately 20 miles downstream of the burn, at the railroad and I-70 overpasses. These sites showed less than 6” of sediment accumulation. There were no changes to overall channel geometry.

C) Diamond Canyon, Burned Area

Most channel surveys conducted within or near the burned area showed an average drop in channel bottom elevations between 5-10’. Some channel segments were scoured over 30’ deep. The stream channel sometimes moved laterally, over 100’ in places. At times, surveys showed aggradation in the channels (up to 3’ per storm event). The floodplains and terraces gained several feet of sediment overall. Major changes to the channel geometry were evident throughout Diamond Canyon (Figure 4.3).

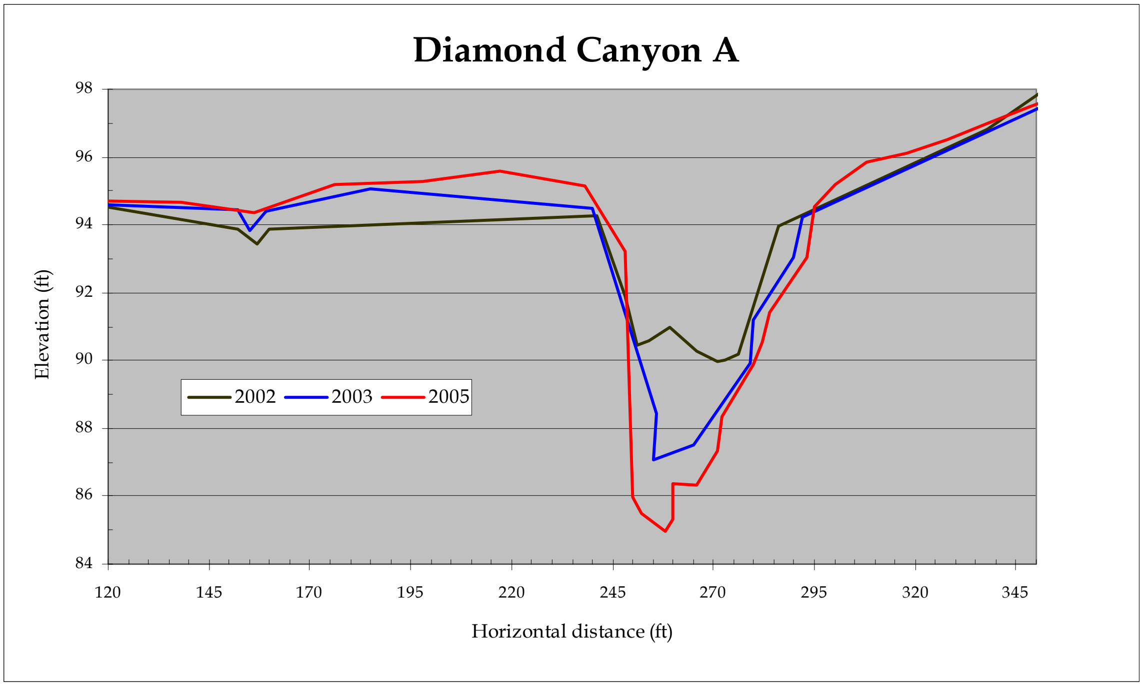


Figure 4.3: Diamond Creek, upstream of Oak Springs

D) Gully Surveys

In 2002 there were three separate gullys growing in Diamond Creek. These gullys became one long gully by 2005, over one mile in length and an average of 30' deep (Photo 4.7).

Photo 4.7

E) Diamond Canyon, Downstream of Burn

Downstream of the burn suffers the same erosion and sedimentation as in the burn area. Sediment slugs are moving through the system, burying stream channels in sections. The sediment is redistributed with each storm.

Photo 4.8: pre-burn

Photo 4.9: May 26, 2005

Diamond Creek, 1 mile above ranch

F) Cottonwood Canyon, Burned Area

Cottonwood Canyon had less burned acres with high to moderate burn severity. There is both downcutting and channel widening in Cotttonwood Canyon, but not to the extent in Diamond Canyon. Several tributaries of Cottonwood Canyon did erode to the same extent as Diamond Canyon and tributaries, including Spruce and Cherry Canyons (Photo 4.10).

Photo 4.10: Spruce Canyon, Tributary to Cottonwood Canyon, April 2005

D. WATER QUALITY

1. Water Chemistry

A) Monitoring Techniques

Water quality monitoring involved testing an irrigation pond in 2002 and annual sampling in Cottonwood and Diamond Creeks. Each stream was sampled in the burn and several miles downstream of the burn (Map 9, Appendix A).

Photo 4.11: Cottonwood Canyon, 4 miles downstream of burn

Field parameters included: stream flow, pH, specific conductivity, turbidity, water temperature, salinity, and dissolved oxygen. Lab parameters included a basic chemistry suite, nutrients (nitrites + nitrates, total phosphorous), total suspended sediments (TSS) and total dissolved solids (TDS). Lab analysis in 2002 and 2003 was done at American West Analytical Labs in Salt Lake City (State of Utah/ EPA approved lab). In 2004 and 2005, lab analysis was done by the State of Utah Health Lab in Salt Lake City.

A YSI 85 probe was used to measure specific conductivity, water temperature, salinity, dissolved oxygen on site. A Beckman 11 meter or an Oakton Acorn pH5 meter was used to measure pH. Turbidity was measured with an Orbeco- Hellige meter (white light turbidimeter, EPA 180.1 compliant). All are EPA approved meters, and were calibrated regularly. USGS sampling techniques (TWRI Book 9) and lab recommended holding times were followed. Stream flow was measured with a Marsh McBurney flow meter when conditions allowed.

B) Monitoring Results

1) Irrigation Pond

The upper irrigation pond filled with ash, debris and reddish water from post-fire storms by mid-August, 2002 (one month from fire containment). The irrigation ditch to the lower pond was blocked, and therefore this pond was not contaminated with post-fire debris, ash and sediment. A contractor was hired to dredge the sediments from the upper pond in early September 2002.

Photo 4.12

Photo 4.13

Water samples were collected at the upper pond in July and September, 2002. Analysis was conducted for cyanide, nitrate as N and total suspended sediments (TSS). Cyanide and nitrates were not detected. TSS levels dropped from 98 mg/l to 68 mg/l, pH levels dropped from 8.1 to 7.6. Turbidity levels dropped from 1600 to 147 NTUs. The pond completely filled again with sediment, ash and debris by summer 2003 (Photos 4.14 and 4.15).

Photo 4.14: Upper pond after initial dredging of sediments, 9/10/02

Photo 4.15: Upper pond after filling a second time with sediment, 11/11/03

In the fall of 2004, most of the sediment was dredged out of the pond and spread out on the banks. The current storage capacity of the pond is reduced from pre-fire conditions. Diversion flows from Cottonwood Creek are still very sediment rich.

2) Cottonwood and Diamond Creeks

Water quality sampling (Table 4.1) of Cottonwood and Diamond Creeks was conducted both within and downstream of the burn (Map 9, Appendix A). Minimal baseline data was available for pre-fire conditions. Water quality tests indicate poor stream conditions regarding sediment loads.

Nitrate and phosphate levels vary with no apparent trend (possible seasonal variations). State standard for nitrates = 4 mg/L. Sediment levels are generally high, with no downward trend. TSS ranges from 8 to 10,000 mg/L. Turbidity values range from 28 to 314 NTUs.

Stream	Site	Sample date	N	P	TSS	Turbidity
Diamond Creek	.8 miles ab ranch	8/21/2002			46	45
Diamond Creek	.8 miles ab ranch	3/10/2003	0.1	2.5	3,100	
Diamond Creek	.8 miles ab ranch	8/18/2003	1.7	4.4	5,300	62
Diamond Creek	.8 miles ab ranch	11/5/2003	0.02	0.69	1,000	
Diamond Creek	.8 miles ab ranch	6/16/2004	-nd-	0.03	87	40/ 28
Diamond Creek	.8 miles ab ranch	5/26/2005	1.45	0.62	10,040	276
Diamond Creek	.8 miles ab ranch	8/29/2005	1.06	-nd-	9,150	142
Diamond Creek	5.4 mile ab ranch	8/21/2002			600	285
Diamond Creek	5.4 mile ab ranch	11/4/2003	0.1	0.14	210	
Diamond Creek	5.4 mile ab ranch	6/16/2004	-nd-	0.07	172	76
Diamond Creek	5.4 mile ab ranch	5/26/2005	1.5	0.71	326	729
Cottonwood Ck	2.9 mile ab ranch	9/1999 *pre-fire	-nd-	0.05	47	81
Cottonwood Ck	2.9 mile ab ranch	8/27/2002			6	
Cottonwood Ck	2.9 mile ab ranch	3/10/2003	0.11	0.37	280	
Cottonwood Ck	2.9 mile ab ranch	11/5/2003	0.07	1.4	2,300	
Cottonwood Ck	2.9 mile ab ranch	6/15/2004	-nd-	0.26	479	314
Cottonwood Ck	2.9 mile ab ranch	8/29/2005	0.74	-nd-	2,142	268
Cottonwood Ck	4.1 mile ab ranch	8/27/2002			8	28
Cottonwood Ck	4.1 mile ab ranch	11/5/2003	0.08	1.1	1,900	
Cottonwood Ck	4.1 mile ab ranch	6/15/2004	-nd-	0.13	316	14

Table 4.1: Diamond and Cottonwood Creeks Water Quality Sampling

<u>2. Macro-Invertebrates</u>

A) Monitoring Techniques

Macro-invertebrate sampling was conducted along with water quality testing 1-2 times/year at each site. Sample sites were located at both burned and unburned stream segments in both Diamond and Cottonwood Creeks (Map 9, Appendix A). Samples were collected and sent to the Utah State University Bug Lab for identification and quantification.

B) Monitoring Results
Initial post-fire sampling found no macro-invertebrate organisms in either Diamond or Cottonwood Creeks. As of 2005, the population had not recovered. Although the Bug Lab final reports are not received yet, field analysis indicates few to no macro-invertebrates in the samples.

E. REPEAT PHOTOGRAPHY

1. Monitoring Road Treatments

At each of the 10 road treatments, several sites were established for repeat photo work. These photos were retaken at least annually, sometimes more often. Appendix D is a select set of these photos and are representative of changing conditions.

Treatments were constructed in April and May 2003. All the treatments had failed by July, 2003 after minor rainfall events. Either the stream channel was downcut 4-5' or more, or the crossing was clogged with 2-5' of additional sediment and debris.

Photos 4.16 & 4.17: These photos were taken at road crossing #6 in Diamond Canyon. The first photo was taken on July 23, 2003 to show road stabilization treatment. The second photo was taken on July 28, 2003 after an isolated storm dropped .23 inches of rain in 40 minutes (less than a one year event). You can see the erosion control material exposed in the second photo.

These same erosional and depositional events occurred repeatedly in and downstream of the burn. Since 2003 had few precipitation events, there were only a few floods to make changes. In 2004 and 2005, there were more frequent precipitation events with higher storm totals. Flooding was damaging to the roads throughout 2004 and 2005. Although the Grand County Road Dept. graded both roads several times a year, road conditions remained poor.

Photo 4.18: Diamond Creek, road crossing #8, May 2005 (30’ cut)

In the burn area and for several miles downstream, the stream channel has incised 2 - 5’ deep on average. In some places the incision is over 30’ deep. This makes road access and maintenance problematic.

3. Monitoring General Watershed Conditions

Dozens of photo monitoring sites were located throughout and downstream of the burned area, focusing on areas with high potential for accelerated erosion (floodplains, steep slopes, treated valley bottoms). Photos were taken at least annually, up to several times a year to show changes from a single storm event. Appendix D is a select set of photo comparisons which are representative of changing conditions.

Repeat photos show channel incision as it grows and extends aerially. Cottonwood Canyon had less overall channel change than Diamond Canyon. Diamond Canyon had more areas with high burn severity in the canyon bottoms than Cottonwood Canyon.

F. SUMMARY OF FIRE EFFECTS

Significant erosion began almost immediately after fire containment. Several small storms in early August, 2002 caused large flood events. Runoff rates were high, due to extremely hydrophobic soils and no ground cover. Tons of ash and debris were transported downstream with each storm. The aquatic macro-invertebrate community disappeared. Downcutting in the stream channels and uplands was minimal. Neither the I-70 highway bridges nor the railroad bridges were affected, located approximately 20 miles downstream of the burn.

Even with low precipitation levels in 2003, erosion became significant both in the uplands and stream channel systems. Hydrophobic soil conditions persisted, and ground cover levels remained low, exaggerating storm runoff rates. Gullying and sediment overload were rampant. The protective riparian zone began to disappear, especially in Diamond Creek.

Precipitation totals returned to normal by late summer 2004. The uplands became revegetated and more stable, while erosion rates remained high in the stream channel systems. As vegetation was re-established, surface runoff rates decreased, water infiltration rates improved and upland soils were stabilized.

Photo 4.19

The canyon bottoms and floodplains remain in very unstable condition in 2005. There is accelerated erosion and sedimentation both in the burn area and for several miles downstream. Peak stream flows are still exaggerated. Bank storage capacity has been reduced due to major bank erosion and channel downcutting. The water table has dropped an average of 5-10’ throughout the area. The stream channels continue to be unstable, moving laterally and vertically. Large slugs of sediment continue to move downstream. The ranch access and irrigation ditch system 5 miles downstream of the burn are still impacted by excessive sediment loads in the stream channel.

V. CONCLUSIONS

A. ASSESSMENT OF TREATMENTS AND MONITORING PROJECTS

1. Treatments

The road, seeding, and mulching treatments applied to the RFC achieved varying levels of success with respect to both hydrological and ecological objectives. The road treatments were completely unsuccessful in stabilizing the low water crossings during peak flows resulting from rain events of low intensity. The seeding treatments were reasonably successful in achieving the ecological goals but failed to meet hydrological goals. The mulch treatments had no effect on either ecological or hydrological goals.

The application of road treatments in a severely burned and highly topographic watershed like those in the Book Cliffs is not effective. The extensive removal of vegetation and the organic litter layer on vast areas of the upland slopes and bottomland areas by fire, resulted in decreased canopy and litter interception, hydrophobic soil conditions, and increased overland flow which created critically high stream flows during monsoonal precipitation events. These flows are sediment laden waters with higher densities and more power for channel erosion. The peak stream flow response during one isolated low intensity rain event was enough to destroy all of the low water crossing treatments within three months of application.

Photo 5.1: Naturally occurring check dam

Future low water crossing treatments, in highly unstable watersheds, should be postponed until the stream channel stabilizes. It may be more appropriate to support the local county in their maintenance activities, and keep low water crossings graded as needed. Coordination with the county to temporarily close road segments that do not provide critical access is also important.

Watershed monitoring documents continuing unstable conditions in the stream channels within the burn and over 5 miles downstream. Channel incision has been dramatic over the three year project. Channel downcutting appears to be slowing down, channels are widening, and small terraces and point bars are starting to form. Natural check dams occur where boulders and Box Elder and Cottonwood snags located in highly incised reaches are undercut and fall into the channel (Photo 5.1). This phenomenon acts to slow water velocities, reshape bank geometry, and increase the coarse woody debris component of the system. Watershed stability will be achieved as the affected channels continue to develop desired channel geometry, bank stability, and riparian vegetation. The application of road treatments may be more successful when these desired conditions are achieved.

The hydrological goal associated with the seeding treatments was to stabilize the watershed by establishing preferred vegetation in an attempt to prevent the loss of private property and minimize erosion. Increasing the vegetative cover and organic litter layer on the denuded and hydrophobic upland and bottomland zones of the watershed are essential in minimizing channel incision and bottomland degradation from flooding. The seeding treatments were not able to quickly establish enough groundcover or litter to stabilize the watershed. It is unlikely that any seeding treatment would be able to achieve complete watershed stability in the RFC within the first two years following treatment.

The high rates of post-fire erosion, often 100-1000% higher than pre-fire rates, is the natural process that carved this region into its present physiographic condition with steep canyon walls and narrow canyon bottoms. Watershed stabilization through seeding treatments may be successful in burns of smaller magnitude and lower burn severity assuming near perfect treatment application and climatic conditions. While the upland seeding has been deemed successful in establishing a more vigorous grass-forb component than would occur naturally, the benefits to watershed stabilization are unlikely to be realized within the three year monitoring window in analogous ES&R projects in the Book Cliffs. The contributions of the upland seeding to watershed stability may be evident years later when the period of time between the fire disturbance and full watershed stability may be reduced.

The primary ecological goal of the seeding treatments was to quickly establish a diverse groundcover of native grass, forb and shrub species that would competitively exclude cheatgrass to some degree. The effectiveness of the seeding treatments was limited in the 2003 and 2004 growing seasons by persistent drought conditions. Precipitation patterns were more favorable in the 2005 growing season which resulted in a dynamic response from seeded grasses. Seedlings that established in 2003 and 2004 grew vigorously and many new grass seedlings germinated during the 2005 growing season (Photo 3.7 & 5.2).

Photo 5.2: Indian Ricegrass seedlings in 2005

The seeding treatments were successful in establishing a strong grass component in the uplands and in the bottomland areas of high burn severity but were less successful in bottomland areas of moderate burn severity. The shrub component of both the upland and bottomland seeding was completely unsuccessful in establishing a significant shrub component by 2005. The forb component was only successful in the upland treatment area with very few seeded forbs present in the bottomlands. In general, the data suggest that the seeding treatments were successful in establishing a more dominant early seral native grass component than would otherwise occur naturally. Cheatgrass is still a significant component of the ecosystem but has not significantly invaded the uplands. In the bottomlands, cheatgrass has been controlled in the areas where seeded grasses, native *Sphaeralcea parviflora*, annual *Chenopodium* species, and *Quercus gambelii* have become established.

The effectiveness of the seeding treatments may have been limited by a skewed proportion of species in the seed mix. It would have been more appropriate to determine the mix of seeding treatments based upon the number of viable seeds as opposed to using bulk weight. As stated previously, the use of bulk pounds to determine the seed mix resulted in a mix heavily skewed to a few species (Figures 4.2 & 4.3). The species that were the most abundant were those that had composed a larger proportion of the seed mix. A disproportionate seed mix will be limited in its ability to establish a diverse post-fire plant community.

The primary goal of the mulch treatment was to minimize the loss of applied seed from erosion or predation. The mulch treatment had no effect on the establishment of seeded species as quantified by cover and frequency metrics. Additionally, the mulch treatment had no effect on minimizing channel incision or stabilizing the watershed. The use of mulch to stabilize watershed conditions may have been more effective in the upland areas and upper reaches.

2. Monitoring

The vegetation monitoring portion of the project was an adaptive process. Quantitative vegetation monitoring commenced in 2004 with the pilot study. The pilot study proved to be an invaluable tool in identifying the strengths and weaknesses of monitoring such a vast and heterogeneous landscape. The weaknesses exposed in the 2004 pilot study were subsequently changed in 2005 in order to increase both the statistical power and maximize the cost-effectiveness of data collection. The combination of nested frequency and the line-point intercept cover method provided a more complete picture of treatment effectiveness and overall vegetative recovery than using only the line-point intercept method. The migration to a macroplot approach over a transect approach was successful in minimizing variation at each site. The overall project could have been improved by initiating a quantitative vegetation monitoring pilot study in 2003. This would have allowed knowledge from the pilot study to be implemented during data collection in 2004 and provide better consistency between years 2004 and 2005 monitoring. However, treatments were applied in both 2002 and 2003 forcing quantitative vegetative monitoring to begin in 2004.

The watershed monitoring project was successful in assessing overall watershed conditions. Climate monitoring was essential for understanding treatment effectiveness. The stream channel surveys and repeat photos were good monitoring techniques for fire impact assessments. Water quality sampling supplemented other monitoring data, and was relatively easy and inexpensive. The challenging aspect of the watershed monitoring was access to the burned area. Although the treatments were not effective at reducing fire impacts to the valley bottoms, the monitoring program provided real data as to the contributing factors such as climate.

B. MANAGEMENT RECOMMENDATIONS

1. Change in Management/Treatments

The Rattle Fire Complex ES&R and monitoring project has illuminated several issues that should be considered when implementing treatments on future ES&R projects. Recommendations include: (1) definition of treatment effectiveness; (2) realistic watershed objectives; (3) realistic seeded shrub objectives; (4) seed mix based on number of viable seeds; (5) increased reporting time; and (6) increased funding flexibility on large and complex ES&R projects.

A) Define Treatment Effectiveness

In the case of the RFC we were not able to address the effectiveness of the mycorrhizal coating or quantitatively compare our seeding treatments against a no-treatment action. The necessary controls needed to address these questions were not established during the treatment implementation phase. In order to assess treatment effectiveness, the management objectives of each treatment and the definition of treatment effectiveness should be defined prior to the application of the treatment. Do we want to know what would have happened had we not seeded? Control sites would be necessary to evaluate treatment effectiveness using this approach. Do we want to know the effectiveness of using mycorrhizae? In this case, control treatments would be necessary to make comparisons against. Do we want to evaluate treatment effectives against target/threshold objectives defined by ecosite potential? These are key questions regarding treatment effectiveness that will help determine how the treatments are applied and how the monitoring is approached. The monitoring plan should include methodologies that are able to quantify treatment effectiveness based upon the questions being asked. The ability of the monitoring project to assess treatment effectiveness can be significantly minimized without a clear understanding of how treatment effectiveness is being defined.

B) Be realistic about watershed health objectives

The application of seeding and mulching treatments to meet watershed stabilization goals in steep terrain should be carefully considered. In the Book Cliffs, post-fire erosion and channel incision are natural geomorphological processes that are likely to be significant even with reasonable establishment of vegetation. Management objectives may be better framed around the attenuation and not the prevention of the erosion/incision response in systems like the RFC.

C) Plan shrub seeding carefully

The seeded shrub component of the seeding treatments in the RFC was not successful and raises some concerns regarding the use of shrubs in ES&R treatments. Grasses and forbs often dominate the early successional stages following fires of moderate and high burn severities. The post-fire grass-forb community may create strong competition against the establishment of slower-growing shrubs especially in drought years. ES&R objectives that involve seeded shrub germination and establishment may not be realistic within the three year ES&R funding cycle. However, success of seeded shrub species may or may not be evident five to ten years after treatment. Seeding shrubs is clearly essential in sagebrush and other shrub restoration projects but should be carefully considered for short-term rehabilitation and stabilization objectives.

D) Use Number of Viable Seeds to Determine Seed Mix

The proportion of species in the seed mixes applied to the RFC was determined using pounds of seed as a reference (Table 4.1). The effectiveness of the seeding treatments may have limited by a skewed proportion of species in the seed mix. This approach makes little sense ecologically because the amount of seeds per pound varies enormously between species. Therefore, in a seed mix the number of pounds of various species may be similar but the actual number of seeds may be highly disproportionate (Figures 4.2 & 4.3). In terms of rehabilitation, number of seeds equates more to the number of potential individuals that may be established than does a weighted metric such as pounds of seed. Figures 4.4 and 4.5 show the proportion of seeds in each treatment based on the number of viable seeds derived using PLS values. It is recommended that future seed mixes be determined based upon the number of viable seeds and not by pounds of seed.

E) Increase Reporting Time

The report deadline should be longer than 60 days for large and complex monitoring projects like the RFC. Time is needed to enter and integrate data collected in year three with previous data. Additional time is needed for data analysis before compiling it into a final comprehensive report. The multi-disciplinary collaborative nature of this monitoring project requires additional time for discussion and integration of both the vegetative and watershed perspectives.

F) Increase Funding Flexibility

BAER plans should anticipate larger monitoring expenditures. Effective monitoring of complicated and innovative treatments with difficult access can drive cost up significantly. Flexibility within the Rattle budget was essential to overcome these logistical barriers. These types of issues should be considered during the compilation of BAER plan.

2. Change in Monitoring

Monitoring vast and highly topographic ES&R projects like the RFC is challenging from both logistical and statistical perspectives. Recommendations for monitoring include: (1) year one pilot study; (2) incorporate several quantitative vegetation metrics; (3) minimize data collection window for vegetation; (4) climate and watershed monitoring; and (5) long-term monitoring.

A) Pilot Study

It is recommended that the first year of monitoring be approached as a pilot study. The pilot study should consist of defined management objectives, sampling objectives and methodologies. The goal of first year pilot monitoring is to both monitor ES&R projects and assess the strengths and weaknesses of the monitoring plan to increase the cost-effectiveness and utility of the data. The 2004 vegetation pilot study illuminated several problems with the monitoring plan that were invaluable for improving monitoring in 2005. The pilot study can also help determine if immediate follow-up treatments are needed.

B) Combine Cover Data with Other Metrics

The line point intercept cover method and the nested frequency method were combined to provide a more powerful assessment of treatment effectiveness and overall vegetative recovery. The use of the nested frequency method allowed rare plants and small plants to be quantified and was less susceptible to phenological changes in the vegetation. The contribution of individual species and functional groups to the total vegetative cover was provided by the line point intercept method. The line-point intercept method is also more directly related to biomass. It is recommended that cover be integrated with either nested frequency or density to achieve a more well-rounded assessment of vegetative condition.

C) Minimize Data Collection Window

The line point intercept method was also highly susceptible to the changes in vegetation as the growing season progressed. During the pilot study, data collection was initiated at the end of May and progressed into July due to the logistical difficulties of accessing 23 transects on foot. This data collection window spanned a dynamic portion of the growing season which resulted in differences in cover among treatments that were attributed to the timing of the sampling and not the treatments themselves. It became clear that data collection needed to occur during a shorter time frame when vegetation was more static. Data collection was streamlined for efficiency and initiated during the late warm season when vegetation was more static.

D) Climate & Watershed Monitoring

It is recommended that watershed and climate monitoring become a routine part of ES&R monitoring for projects with high burn severity, varied or steep terrain, and complicated or innovative treatments. Drought conditions play a significant role in the effectiveness of seeding and watershed treatments. In the RFC, seeding success was limited by drought conditions through the first two growing seasons following initial treatment. In many cases, the seed mix may consist of the best available species for the site but will be unsuccessful due to drought conditions. If possible, monitoring of climate variables like precipitation and soil moisture should be undertaken. Additionally, watershed monitoring of the stream channel helps provide information regarding the level of fire impacts to both the burned area and downstream. Correlations between climatic variables, watershed response variables, and vegetative treatments provide a more complete picture of treatment effectiveness.

E) Long Term Assessment

It is recommended that follow-up monitoring be initiated five to ten years after the fire containment. Monitoring of ES&R vegetation treatments typically occurs within the early successional stages of post-fire succession when community composition is predominately grass-forb. Success or failure may be evident within this short window of time but may not persist through subsequent successional changes or disturbance. Long-term monitoring would provide important information about long term treatment effectiveness in subsequent successional stages and climatic conditions. The first three years of watershed monitoring in the RFC occurs when erosion rates are 100-1000% higher than pre-fire conditions and channel conditions are unstable. Long term monitoring would also provide better understanding of the effectiveness of ES&R treatments and the recovery time needed to achieve stable watershed conditions.

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