DAM REMOVAL AND CHANNEL RESTORATION AT FOSSIL BUTTE NATIONAL MONUMENT

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ABSTRACT: This paper describes the demolition of two stockpond dams at Fossil Butte National Monument and restoration of associated gullies. The project was part of a plan to remove four man-made stockponds from the Chicken Creek watershed to return the drainage to a properly functioning hydrologic condition and mimic the natural channel geometry. Other human activities have affected the stability of Chicken Creek and its tributaries, including construction of the Oregon Shortline Railroad, domestic livestock grazing, road building, and agricultural activities. Although Chicken Creek is still responding to base level changes caused by railroad construction, most of its headcuts are small and relatively stable. Since the elimination of livestock grazing in 1989 some gullies have begun to heal. The restoration goal was to initiate a trend towards a stable, naturally functioning ecosystem. We describe an innovative approach to gully restoration, discuss project effectiveness, and make suggestions for improvement in project implementation.
KEY TERMS: dam removal; erosion control; gully restoration.

INTRODUCTION

Physical Environment

Fossil Butte National Monument (FOBU) comprises 8,198 acres in southwest Wyoming. Most of the 4,450-acre Chicken Creek watershed is within the Monument boundary as seen in Figure 1. Four stockpond dams existed along Chicken Creek and its tributaries at the beginning of 1997; the West and East dams were removed during that year with the South and North dams to be removed later. The contributing watersheds above the West and East Dams are 645 and 860 acres, respectively. The dams, located in the Chicken Creek watershed, were constructed prior to the establishment of the Monument in 1972. Park management determined it appropriate to remove man-made structures which could impair the future healing process.

The area is high cold desert dominated by Sagebrush Steppe vegetation (Dorn et al., 1984). Mountain Big Sagebrush, Aspen, Mountain Shrub, and Mixed Timber vegetation types dominate the higher elevations along the northern and northeastern perimeter of the watershed. A Barren type also occurs there. Precipitation ranges between 9 and 12 inches per year; most of it falls as snow.

The Wasatch Formation underlies most of the Chicken Creek watershed, including the dam sites. Fossil Butte and neighboring ridges are capped with more resistant, horizontally bedded, sedimentary rocks of the fossil bearing Green River Formation. The Wasatch Formation consists of multi-colored, flat-lying mudstones, marlstones, siltstones, claystones, and fine-grained sandstones. Although the Green River Formation forms portions of the eastern and northern watershed divide boundaries, it is not present in most of the drainage basin (McGrew and Casilliano, undated).

The confluence of the mouth of Chicken Creek with Twin Creek is approximately 6,620 feet above sea-level. This is approximately 1,200 feet lower than the highest elevation in the watershed. Chicken Creek has four principal tributaries and the main channel is approximately 4.5 miles long. The stream gradients in the lower reaches of Chicken Creek vary from 1 to 2 percent. Steeper gradients occur elsewhere, especially in

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actively-eroding reaches of the stream, headwater areas of the main stream and its tributaries, areas with bedrock control, and ephemeral tributaries that normally convey small volumes of runoff. The majority of the channel in the lower reaches of Chicken Creek is unprotected by outcrops of resistant strata. Soils have low permeabilities and high runoff and erosion potentials.

Riparian Environment

Most of the bottom land along Chicken Creek and its major tributaries is occupied by the Wet Meadow vegetation type (Dorn et al., 1984). Wet Meadow vegetation is dominated by Baltic Rush (*Juncus balticus*), several sedge species (*Carex* spp.), wheatgrass species (*Elymus* spp.), and bluegrass species (*Poa* spp.). Basin Big Sagebrush, Alkali Sagebrush, and Saline vegetation types dominate the uplands in the lower portion of the watershed.

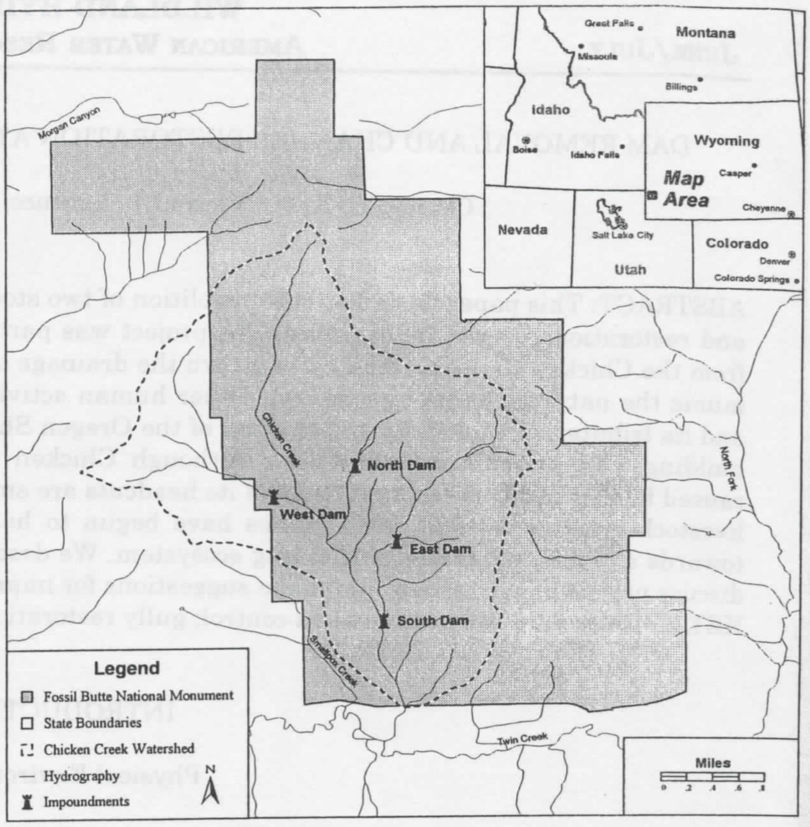

Figure 1. Location map.

The Chicken Creek watershed exhibits many of the characteristics described by David Sturges, a forestry researcher who studied sagebrush watersheds in several Western states (Sturges, undated). Chicken Creek resembles the studied watersheds in that 1) summer rains are usually small; 2) snow usually accumulates in winter; 3) snow melt usually produces the highest-volume, and longest-lasting continuous streamflow; 4) over-snow flow occurs when the stream channel is filled with wind-packed snow, and the rate of snow melt exceeds the rate of soil infiltration; 5) most sediment transport and streambank erosion occurs during periods of major runoff; 6) stream flow and suspended solids levels rise as snowmelt increases with higher daytime temperatures; 7) furthermore, those parameters decrease as the temperatures drop at night and; 8) suspended solids decline rapidly as the period of rapid snowmelt ends.

The main channel of Chicken Creek exhibits interrupted-intermittent flow. Perennial flows and saturated soils persist in a few short reaches, but intervening stream segments flow only in response to storm or snowmelt events. Downstream of the West Fork confluence, Chicken Creek rarely flows continuously beyond the end of June. Except around seeps, the lower reaches of the stream are usually dry from early summer until the end of winter when the accumulated snow begins to melt.

Upstream from its confluence with Twin Creek, Chicken Creek is incised until a few hundred yards below the South Dam throughout much of the southern half of the watershed. The main channel in the middle reach is confined (Rosgen Type E6) above the South Dam, nearly to the confluence with the West Fork. The West Fork is not incised inside the Monument boundary; however, it is incised in the steeper headwaters outside the Monument. Chicken Creek has an inner floodplain of 40 to 60 feet across in the more stable channels in the middle reach and a few places in the southern reach. The East Fork is incised for much of its length. The Rosgen morphological description would range between G6 near the headcuts to F6b and E6 in the more stable reaches (Rosgen, 1996).

Beaver are present in the upper reaches of Chicken Creek. They impact the headwater areas of the watershed significantly, especially where aspen groves exist.

Graf (1988) notes that channel erosion is the result of the disruption of some previous state of near equilibrium by changing the amount or rate of delivery of water, sediment, or both to the channel system. He summarizes the causal mechanisms on channel entrenchment generally contain three common themes: land management, climate change, and internal adjustments (Graf, 1988). It is likely that channels in FOBU have been affected by all three mechanisms.

Livestock Grazing and National Monument Establishment

Beetle and Marlow (1974) observed that sheep and cattle grazing occurred throughout much of the year prior to the establishment of the Monument in 1972. They were unable to determine how long this pattern of grazing had been practiced, but they concluded it had been in use for at least several decades. They also noted that the cattlemen often placed salt blocks near water sources which concentrated cattle on riparian areas. They also noted: "....combined grazing by both sheep and cattle during the growing season rapidly inhibits annual production [of cool-season grasses and forbs]."

A grazing impact study conducted for FOBU by Mountain West Environmental Services determined that mostly sheep grazed the area prior to 1973, and cattle had replaced sheep as the primary grazer by 1977. The study noted that the closer to water, the condition of the range was worse, and areas along Chicken Creek were particularly overgrazed, trampled, and severely eroded. They observed that although the vegetation in the riparian zone was overgrazed, the upland areas of the watershed were generally in good condition (Dorn et al., 1984).

The discontinuation of grazing following 1989 by the National Park Service and improved fence maintenance have greatly reduced the impact of grazing. Vegetative change is occurring as a consequence. Perhaps the most obvious vegetative change has been the expansion of aspen groves into meadows at many locations in the upper watershed because the cattle no longer remove the new aspen shoots, which appear each spring. Willow is also regenerating at several mesic sites for the same reason (C. R. Kyte, personal observation, 1997).

FOBU management began implementing erosion control practices with marginal success in Chicken Creek in 1989. These practices included installing small log and rock check dams in gullies, constructing a gabion drop-structure to stabilize the furthest upstream headcut on the mainstem, reclaiming a small stockpond downstream of a large spring near the headwaters, and establishing willows in favorable reaches.

Land Use Summary

Human land uses have affected the Chicken Creek watershed in multiple ways. Railroad construction in the 1880s, and again during the 1950s, has lowered the base level of Twin Creek through extensive channelization and shortening of the creek as much as 50 percent by cutting off numerous meanders. This may have caused the incision of the Chicken Creek channel above its confluence with Twin Creek. The lowered base level caused widespread erosion, headcutting, and channel down-cutting throughout the Chicken Creek watershed. Controlling wildfire has affected vegetation, primarily by increasing the abundance of sagebrush and decreasing the abundance of grasslands. Grazing and trampling by domestic livestock has damaged riparian vegetation along Chicken Creek and its tributaries. Vegetative loss and altered species composition resulting from overgrazing and other agricultural practices such as building stockponds and diversions has undoubtedly increased runoff , soil loss, headcutting, and gullying. Hay farming and associated ditching conducted by homesteaders during the early 1900s until the creation of the Monument has impacted the riparian area in the vicinity of the Chicken Ranch because the creek has multiple channels, saline soils are present, and the area is infested with native and introduced annual weeds. Stockpond construction has caused gullying (downstream) and silt accumulation (upstream) of the dams. National Park Service programs continue to change the watershed by eliminating grazing, constructing visitor facilities, paving roads, developing drinking water supplies and leach fields, controlling exotic plants, and by implementing stream channel stabilization projects.

RESTORATION WORK

Preliminary Studies

Chicken Creek and its major tributaries were studied for three years prior to the removal of the dams to increase understanding of stream ecology and hydrologic condition and to form a baseline against which to evaluate restoration results. Information acquired during these studies were incorporated into the reclamation designs (C. R. Kyte, unpublished documentation, 1997).

In 1994, five stream reaches along Chicken Creek were identified for intensive measurements. Three erosion control pin stations and three bottom chain stations were established in each reach for the purpose of monitoring the movement of streambank soils and channel sediments. The stream's longitudinal profile in each of the five reaches were surveyed in 1994. In addition, permanent cross-sections were marked with reference pins and surveyed in each reach. Measurements indicate that downcutting is not occurring in the study reaches; however, headcuts were advancing upstream several feet a year.

In 1995, the longitudinal profile of Chicken Creek from the southern boundary of FOBU, to the end of Reach 5 was surveyed. Also surveyed was the longitudinal profile of the East Fork from its confluence with Chicken Creek to the East Dam. The locations and heights of headcuts were determined during this survey.

Monitor wells were drilled to a depth of approximately 9 feet in Reaches 1, 2, 3, and 5 during the fall of 1994. Water table elevation data have been collected from these wells for the past three growing seasons. Depth to water ranges from the ground surface in late spring declining to greater than the depth of the wells in the fall. A staff gauge and a water-level recording device were installed at the downstream end of Reach 1 in 1994. Water levels in Chicken Creek have been measured regularly during the growing season.

The particle size distributions of sediment samples, taken at regular intervals from the Chicken Creek and East Fork streambeds, were determined in 1996. The majority of the sediments were composed of silt; however, gravel and cobble-sized material was present in the vicinity of the South Dam.

West Dam Site Conditions

The original crest of the West Dam was approximately 6 to 10 feet high and 280 feet long. A survey determined that the dam contained approximately 1,300 bank cubic yards (BCY- volume of intact soil as opposed to loose material after excavation) of material. A spillway channel approximately 200 feet long and 4 feet deep extended east from the northeast corner of the dam. No concrete or rock was utilized in the construction of the spillway.

Either the dam, or the spillway, was inadequate because the center of the dam was breached. Two other gullies extended outward from the eastern face of the dam suggesting that the dam had failed more than once before removal. The south gully was approximately 10 feet deep; the north gully was less than six feet deep.

Dam construction and siltation affected the historic channel upstream of the West Fork dam. The historic channel was partly obliterated when material was removed and placed in the dam embankment. After the dam was built, siltation behind the structure obliterated the historic channel. Since the dam failed years ago, however, the stream has formed a new channel upstream of the breach. The formerly impounded area supports stands of Baltic Rush (*Juncus balticus*) and sedge (*Carex* spp.). Drier sites behind the dam support stands of Big Sagebrush (*Artemisia tridentata*) and Silver Sagebrush (*A. cana*).

Another borrow site needing restoration existed near the summit of a ridge south of the dam. This borrow area supported meager vegetation, probably because it had been stripped to sandstone bedrock when the dam was constructed.

Several acres of saline soils are present immediately downstream of the West Dam. The vegetation of these areas is dominated by Greasewood (*Sarcobatus vermiculatus*) and Gardner Saltbush (*Atriplex nuttallii*). The

Mountain West biologists speculated that the West Dam pond may have caused these saline soils by raising the water table which allowed the upward migration of soil salts (Dorn et al., 1984).

East Dam Site Conditions

Engineering drawings of the dam from a recent survey show the embankment stood approximately 7 feet above the historic floodplain and was approximately 100 feet long at the crest. The volume of the dam embankment was calculated to be 584 BCY. The structure diverted streamflow in the East Fork of Chicken Creek through an entrenched spillway channel approximately 200 feet long. Streamflow returned to the historic channel at the spillway outlet. The dam detained minor volumes of water following runoff events.

The channel of the East Fork, immediately downstream of the spillway mouth, was severely gullied for nearly 600 feet. The gully was approximately 8 feet deep immediately downstream of the headcut; its bottom width varied from less than ten feet near the headcut, to nearly fifty feet at the downstream end.

Portions of the East Fork's historic floodplain formed a narrow terrace along the southeast side of the gully. By surveying the terrace surface, it was determined that the overall gradient of the East Fork's historic floodplain was 3% before the gully developed. Presently, the stable, well-vegetated floodplain lying immediately downstream of the East Fork gully has a gradient of 2.9%. A 1995 survey of the East Fork, from its confluence with Chicken Creek to the East Fork dam, determined that its overall gradient was 2.5% (R. R. Inglis, Jr., unpublished survey, 1995).

Restoration Design

The restoration design was based on multiple objectives. The basic objectives are to minimize all land disturbances, salvage topsoil and other suitable surficial soils wherever practicable, and spread after the disturbed areas had been recontoured, minimize the visual impact of the dams and disturbed areas, reduce site erosion, and use only native species. The design of the new channels incorporates the pattern of existing stable channels in that a small, active channel meanders across a confined low gradient floodplain composed of vegetation typical of wet meadows. Knowing that unprotected channels exposed to flowing water immediately erodes, biodegradable grade control structures would be needed until establishment of a wet meadow. The grade control structures were designed to spread larger flows over the width of the floodplain to disperse the erosive energy of higher velocity flows by decreasing stream power (the product of depth and velocity).

Using these objectives the following methods were incorporated in the restoration design: 1) material from the dam embankments would be used to fill and contour the spillway channels, gullies, and borrow areas associated with the dams; 2) new segments of channel constructed during the dam removal process would be configured to mimic natural channels nearby, stabilized to minimize erosion, and maintain the hydrologic integrity of the stream; 3) disturbed areas would be regraded to blend in with the surrounding topography; 4) site erosion would be minimized by installing erosion control netting or native stone rip-rap at critical locations, constructing temporary structures to control the depth and course of streamflow, and taking immediate steps to revegetate disturbed areas; 5) only native plant species and a sterile hybrid wheatgrass (Regreen) would be planted during reclamation; and 6) reclamation seed mixes would comprise only dominant components of the natural vegetation immediately adjacent to the areas being reclaimed.

Project Implementation

West Dam Site

Work began in the fall of 1997, when funding became available. The West Dam site required some preparation to meet the restoration objectives of minimizing disturbance to the stream and riparian areas. Sagebrush was removed from the dam, placed on the channel bottom in the breach, and covered with a canvas tarp to identify the location of the channel floor. A D-7 Caterpillar tracked dozer (D-7) covered the sagebrush and canvas with soil, thereby forming a pad for crossing the channel bottom with minimal disturbance. Some cobble size sandstone was salvaged from the channel running through the dam breach and stockpiled for use as rip-rap.

The D-7 was used to salvage approximately 6 inches of surficial material from the crest of the dam and the spillway channel and to demolish the West Dam. When final contouring was done the stockpiled soil was spread over the disturbed area as a natural source of seed. Earth from the northern portion of the dam embankment (north of the dam breach) was moved to the spillway channel. Material from south of the breach was used to fill the south gully, and cover the poorly vegetated borrow area.

The D-7 was inefficient because the material had to be moved considerable distances. Earth movers would have been more appropriate equipment in hindsight. The maximum push was approximately 350 feet; the average push was estimated to be 175 feet. Approximately 900 BCY of material were removed from the dam embankment. The 400 BCY remaining in the embankment were graded to blend with the adjacent topography.

Once the dam was removed, the D-7 constructed a crude floodplain. The D-7 was too cumbersome to implement the final design, so a John Deere, 4-wheel drive tractor, equipped with a 0.5 cubic yard capacity bucket and a backhoe, was used to finish leveling the new floodplain. A level transit was utilized to determine the relative elevations of the floodplain.

After leveling the floodplain, a small, meandering channel was constructed by hand within the confines of the broader floodplain. The channel was approximately 4 feet wide, 50 feet long and 0.75 feet deep. Approximately 1.5 cubic yards of native sandstone rip-rap were distributed over the floor of the inner channel, and the broader floodplain to help control erosion. Plugs of sod, consisting of Baltic rush and sedges, were removed from a wet meadow nearby, and planted along the meandering channel bed to prevent downcutting of the new channel.

A seedbed was prepared by loosening the spread soil with a spike harrow towed behind a Honda all-terrain vehicle. Native grass and shrub seed was distributed using a broadcast seeder at approximately 20 pounds pure live seed per acre. Species seeded at the West Fork Dam were separated into two mixes. Mix 1 was planted on upland areas and included Thickspike Wheatgrass (*Elymus lanceolatus*), Slender Wheatgrass (*Elymus trachycaulus* var. *trachycaulus*), Western Wheatgrass (*Elymus smithii*), and Sandberg Bluegrass (*Poa secunda* var. *secunda*). Mix 2 was planted on channel bottoms and include Thickspike Wheatgrass, Slender Wheatgrass, Western Wheatgrass, Big Bluegrass (*Poa juncifolia*), Tufted Hairgrass (*Deschampsia caespitosa*), and Silver Sagebrush (*Artemisia cana*). Mix 2 was supplemented with Regreen, a patented sterile wheatgrass hybrid. Approximately 125 shrubs were salvaged from the adjacent land and planted on the disturbed upland areas.

East Dam Site

Demolition began with the salvage of approximately 6 inches of soil material from the crest and spillway of the dam embankment. This material was stockpiled for use as topsoil during site reclamation. The D-7 conveyed approximately 450 BCY of material from the dam embankment to recontour the spillway channel. The remainder of the dam embankment was left in-place and contoured to blend with the surrounding topography leaving a large meander in the channel.

A new channel, connecting the upstream and downstream portion of the East Fork was constructed as the dam was removed. This new channel has a gradient of 1.3% and a level bottom approximately 20 feet wide. The D-7 spread topsoil over the disturbed areas once the new channel was finished.

The second phase of the East Dam site reclamation involved reclaiming the severely gullied segment of the East Fork downstream of the dam. The D-7 began by stripping approximately 6 inches of topsoil from approximately 0.75 acres that were adjacent to the upstream end of the gully. This area served as a borrow site for the earth used to fill the gully. The topsoil was stockpiled for use during the reclamation of the borrow area.

Between 3,000 and 4,000 BCY of earth were removed from the borrow area, and conveyed to the gully by the D-7. A TD-7 International track-dozer towing a sheepsfoot roller compacted the earth in 6-inch lifts. Dry soils were watered before being compacted. When the gully was filled and leveled, a narrow, meandering channel was constructed by the TD-7 dozer. The dimensions of this channel were approximately 7 feet wide by 0.75 feet deep. After the gully had been filled and leveled, the borrow area was graded to a rolling contour by the D-7. Finally, the stockpiled topsoil was spread by the D-7.

Grade controls, made from 8-foot panels of 3/4-inch exterior plywood 16 inches wide, were installed across the new floodplain in order to control the depth and course of streamflow. Wherever a grade control crossed the inner floodplain channel, the 8-foot long panel intersecting the smaller channel was lowered by approximately 3.5 inches. These controls were intended to spread flows exceeding 3 - 4 inches in depth across the new floodplain. The panels were fastened together and reinforced by 8-foot lengths of 2x4 inch lumber. The panels were set into trenches which had been excavated across the width of the new floodplain. The wooden controls were set into 18-inch deep trenches which had been dug across the width of the floodplain. Earth was compacted around the plywood using a gasoline-powered tamper. The top of each wooden dam protruded above the ground 4 - 6 inches when the installation was complete. The wooden controls varied in length from 32 feet to 56 feet and were installed at approximately 50-foot intervals along the entire 560-foot long, reclaimed section of the East Fork.

After the grade controls were installed, the floodplain was seeded with Mix 2. Jute netting was installed in the bottom of the meandering, inner channel. Then the entire width of the new floodplain was covered with erosion control matting. Finally, the borrow area was scarified with the spike harrow and seeded with Mix 1. After the seed was broadcast, the area was tilled to cover the seed.

RESULTS AND CONCLUSIONS

The National Park Service is restoring areas of Chicken Creek and its tributaries that have been altered by dam construction and excessive erosion. In 1997, stream restoration projects removed two stockpond dams and several hundred yards of the East Fork's highly eroded stream bed were returned to their approximate pre-erosional configuration.

The two existing stockpond dams were removed and initiated the restoration of the hydrologic functioning of Chicken Creek, the major drainage within Fossil Butte National Monument. The dams had changed the creek by impounding minor volumes of water, diverting the stream from its historic channel, causing sediment deposition, and causing unnecessary erosion and gullying by changing the morphological form of the channel.

The installation of innovative wooden grade controls helped maintain the configuration of the new floodplain after the East Fork gully was filled and reshaped (Figure 2). The controls were designed to 1) prevent channel incision until sufficient vegetation could be established to control erosion, 2) minimize the stream gradient by maintaining the meandering pattern of the smaller channel incised within the broader floodplain, and 3) spread the flow of larger runoff events across the broader floodplain, thereby minimizing streamflow velocities and erosional forces.

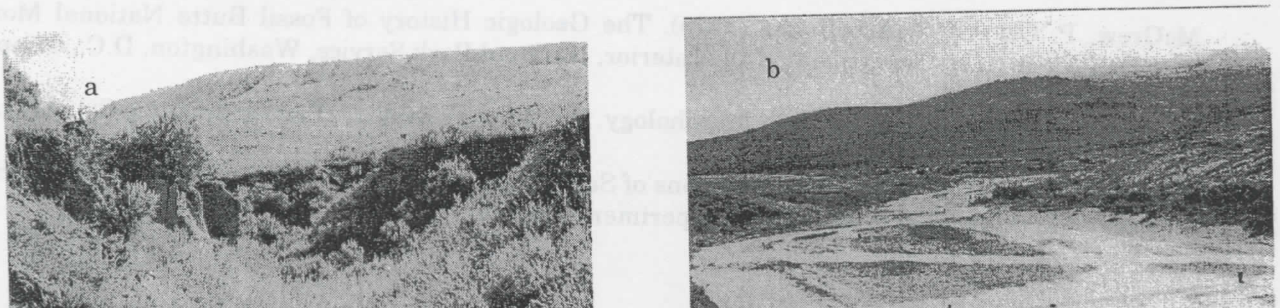

Figure 2. East Fork gully prior to restoration (a) and during a runoff event following restoration (b).

In other respects (width, gradient, sinuosity, overall shape) the reclaimed streambed was designed to resemble the streambed of stable stream segments seen elsewhere in the Chicken Creek drainage.

On June 17, 1998, an extraordinary flood event occurred which tested the reclamation design of the restored East Fork channel segment. The reclaimed streambed withstood the runoff event with minimal damage, indicating that the reclamation design was adequately controlling erosion. By the fall of 1998, the reclaimed flood plain supported an excellent growth of vegetation consisting of rhizomatous wheatgrasses and Silver Sagebrush seedlings. As it matures, the vegetation should increase the channel roughness, which should, in turn, help decrease future stream velocities and the potential of channel erosion. There were few undesirable plants at the east dam site, and weed growth at the west dam site was within acceptable limits. Some small areas of saline soils at the West Dam where vegetative growth was poor are expected to improve with time. Several native species of plants, not contained in the seed mixes, were also observed at the reclaimed sites. This occurred when topsoil, containing native seeds and/or rhizomes, was salvaged from the sites beforehand and redistributed over the surface afterwards.

The restoration design was based on sound objectives and studies of nearby stable channels. New segments of channel constructed during the dam removal process were configured to mimic natural channel geometry, stabilized to minimize erosion, and maintain the hydrologic integrity of the stream course. Results were seen during the first runoff events when flows spread across the new floodplain minimizing erosion. Growth of seeded plant material and natural recruitment has been outstanding. It is premature to say that a wet meadow riparian zone was created by the project; however, conditions are now favorable for natural processes to establish this vegetation type. This project was possible due to funding provided by the National Park Service Dam Safety Program. Technical assistance was provided by the National Park Service Water Resources Division.

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