EFFECTIVENESS OF FORESTRY RELATED BEST MANAGEMENT PRACTICES IN THE TROUT CREEK WATERSHED, COLORADO

Submitted by

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Effectiveness Of Forestry Related Best Management Practices In The Trout Creek Watershed, Colorado

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ABSTRACT

EFFECTIVENESS OF FORESTRY RELATED BEST MANAGEMENT PRACTICES IN THE TROUT CREEK WATERSHED, COLORADO

In multiuse forests the majority of nonpoint source pollution is typically sediment. Best management practices (BMPs) are implemented to reduce or prevent this pollutant, however little research has been done to quantify the effectiveness of individual types of BMPs. The overall goal of this project was to evaluate the effectiveness of three BMPs implemented to reduce sediment in Trout Creek: cattle fences, off-road vehicle (ORV) signs, and road culverts.

Fenced, unfenced, and ungrazed control pastures were measured. In the unfenced pasture, on average, a cow spent 1.0 min/day in the creek, and 11.5 min/day on the banks. The fenced, unfenced, and control pastures had significantly different ($p<0.05$) eroded bank areas, 363 m^2, 780 m^2, and 683 m^2 of eroded bank area per km, respectively. Total suspended solids (TSS) and turbidity samples were collected above and below each pasture, and no significant differences ($p<0.05$) were found. These results suggest fences are an effective BMP.

ORV signs were installed in the Trout Creek watershed to discourage use of illegally created trails. Illegal trails were used by 5.8% of the ORVs, and of this, signed trails were used by 3.4% of the ORVs, unsigned trails used by 2.4%, and control areas (no ORV activity) were never used. 94.2% of ORV activity was not on the illegal trails, and remained on legal trails. Mean total suspended solids (TSS) were similar between above and below ORV area samples. Soil erosion was measured from 14 runoff events, and had no significant difference ($p<0.05$) between signed and unsigned trails. Mean trail erosion was higher on signed trails than unsigned trails, 44 g/m^2 and 28 g/m^2. The use and erosion results suggest that ORV signs are ineffective on illegally created trails.

Culverts were installed along the unpaved Rampart Range Road to control and direct road drainage. Gully erosion volumes at road sections with and without culverts were not significantly different ($p<0.05$). Mean erosion at the road sections with culverts was 29 kg/m^2 and 9 kg/m^2 at road sections without culverts.

The effectiveness of the combined BMPs in the land-use area was evaluated by comparing water quality and Wolman pebble counts with an upstream reference area. A reference area was selected based on soil type, vegetation type, elevation, and absence of cattle grazing and ORV use. But the reference area had a narrower floodplain, and was separated from the land-use area by a reservoir used for recreation. The selection of a reference area is difficult, and the variability in results between the water quality and WPCs, and instream effects, make determining BMP effectiveness at this scale difficult at best.

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1.0 INTRODUCTION

Best Management Practices (BMPs) are an accepted approach to decrease, attenuate, or eliminate nonpoint source pollution. BMPs are also implemented to ensure that the land can continue to be managed for multiple uses (Whitman, 1989). Voluntary compliance with BMPs is used for nonpoint source pollution regulation in Colorado. Audits show that BMPs are used, however little research has been conducted to quantify the effectiveness of individual types of BMPs, and standard methods of effectiveness evaluation do not exist.

The U.S. Environmental Protection Agency created a 'three part feedback loop for nonpoint pollution management.' This loop includes establishing water quality standards to protect beneficial uses, implementing BMPs to ensure these standards are met, and monitoring the effectiveness of BMPs (Whitman, 1989). Colorado managing agencies have addressed two of the three aspects of the loop. However, the third element of the loop, measuring BMP effectiveness for understanding and improvement, has proven expensive and difficult to quantify. Because of this, monitoring implementation has been a surrogate for measuring effectiveness (Whitman, 1989). This has proven simpler and less expensive, yet the question still remains: are BMPs working effectively to control nonpoint source pollution?

There is a need for monitoring BMP effectiveness (Whitman, 1989; Edwards *et al*., 1996; Sparrow, 2000) not only to concentrate efforts for BMP improvement but also to provide managers with generalizations, so intensive studies and resources are not needed with each land-use project. It is essential we know BMP effectiveness to complete the 'loop' for stream health, for continued forest multiple-use, and for an evolution in procedure and management. Recently there has been a recognized need not only for understanding BMP effectiveness but also for developing cost effective techniques for quantitatively measuring these (Sparrow *et al*., 2000). Because of the wide variety of BMPs put into place for a wide variety of land-uses, a standard for evaluation has not been created. This makes site-to-site comparisons and watershed generalizations difficult. Each site has a different set of characteristics, problems, and records of data that add to the complexity.

Cattle fences are a common BMP used to exclude cattle from stream banks and waterways. Cattle use riparian zones and creeks for food, shade, drinking water, and crossing. However, riparian zones are critical habitats that maintain fish and wildlife populations, and protect water quality and quantity. Grazing in these areas can increase total suspended sediment, bank slough-off, and accelerate sedimentation through the loss of riparian vegetation and the mechanical breakdown of the stream bank (Benke and Raleigh, 1978). Fencing these areas can help stabilize banks, reduce erosion, improve water quality, and improve habitat, as well as reduce livestock injury (Davis, 1991).

Off-road vehicle (ORV) use is also widely known to cause negative impacts to wildlands, and increased use has resulted in indiscriminate use of federal lands (Wilshire *et al*., 1977; Webb *et al*., 1978; Stull *et al*., 1979). ORV use damages vegetation, and increases erosion (Griggs *et al*., 1981). In an effort to protect the land and to discourage use of illegally created trails, BMPs such as signs are put into place marking all areas ORVs should or should not go (Wilshire *et al*., 1977). And although the effects of ORVs have been quantified, the BMPs implemented to control use have not.

On public lands, along unpaved forest roads, culverts are a common technique to divert overland flow off the road. However, this concentrated flow can cause gully erosion that links to stream systems (Wemple *et al*., 1996; Croke and Mockler, 2001; Luce and Black, 2001). It is well known that unpaved roads contribute to an increase in erosion with increasing road slope and length, but data on road maintenance practices including culverts is limited (Luce and Black, 1999). Rather than using ditches and culverts to convey water off the road, it is now suggested that dispersing road runoff over space and time can decrease gully erosion and increase infiltration (Constantini, *et al*., 1999; Grace, 2002; Nyssen *et al*., 2002).

Watershed scale comparisons determining the cumulative effectiveness of all BMPs implemented has been used most widely in research arenas, however there are three main limitations to this approach. The first is that one or more reference sites must be identified for comparison. The second limitation is that monitoring at this scale assumes 100% BMP implementation. The third drawback to this approach is the inability to link sediment inputs to a specific BMP technique. Monitoring BMP effectiveness at the watershed scale is commonly done in watersheds with one major land-use that has multiple associated BMPs, such as clear cutting and confined animal feeding operations (Edwards *et al*., 1996; Wynn and Mostaghimi, 2002). Pre and post BMP comparisons have been made to determine effectiveness by looking at sediment loadings at a watershed scale (Park *et al*., 1994). This approach is invaluable, however pre land use data are not always available and even less likely to be available over the long time periods necessary to account for natural variation in sediment yield and transport.

Another method used to determine BMP effectiveness is the plot study, comparing areas with and without BMPs. Plot studies have been valuable but are less practical for managing agencies because they limit the land-use, and require the evaluation to occur in a research setting. The use of models such as the Universal Soil Loss Equation, to compare baseline conditions to BMP data has also been implemented (Rice and Iznuno, 1998). Like many models, the problem lies in how representative the input parameters are and how accurately they can predict real conditions. Site specific comparisons of use areas with and without BMPs is a technique that can single out individual types of BMPs. This method is especially effective when measuring sediment produced at the hillslope scale (Park *et al*., 1994). Each of these approaches answer to a call for more practical application, yet the differences lie in the individual convictions of one approach over the other, watershed characteristics, cost, and accuracy.

This research is not above the complexities of the natural world or the demands of the land-users. In an attempt to balance these complexities with a sampling method that has a close link to land-use and erosion, can be done without pre-existing data or high input models, and explores cost effective methods, this research measures BMP effectiveness at different spatial and temporal scales.

In the Trout Creek Watershed, Colorado, and other multi-use forests, the majority of nonpoint source pollution tends to be sediment or sediment related (NCASI, 1994; Stednick, 2000). Trout Creek has been identified as having an excess amount of sediment, and is listed on the states 303(d) list and targeted for a sediment Total Maximum Daily Load (TMDL). Sources of sediment include roads, logging, grazing, off-road vehicle (ORV) use, other recreation, bank erosion, and natural erosion. Sediment nonpoint source pollution usually enters the stream from precipitation and runoff events, and from bank erosion. The runoff of sediment and location of entry into the stream make modeling of nonpoint source pollution and BMP monitoring difficult. Because of the large spatial and temporal variability of both the land-use and pollutant, determining BMP effectiveness will not only be a function of the BMP, but of the measurement used for evaluation as well.

BMP effectiveness was tested for significance ($p<0.05$) using the following hypotheses.

1) The fenced cattle pasture will have statistically similar eroded bank area as the unfenced pasture.

2) Off-road vehicle trails with signs will be statistically similar to unsigned trials.

3) Gully erosion will be statistically similar between road sections with culverts and road sections without culverts.

4) Total suspended solids will be statistically similar between above and below BMPs.

5) Water quality and Wolman pebble counts in the land-use area will be statistically similar to the reference area.

2.0 SITE DESCRIPTION

Trout Creek watershed is located approximately 45 km west of Colorado Springs, Colorado. The creek begins an elevation of 2941 m above sea level and runs 40 km north to an elevation of 2011 m. Trout Creek meets with West Creek, becoming Horse Creek and continues to flow to the South Fork of the South Platte River at the town of Deckers (Figure 2-1). The approximately 135 km^2 Trout Creek watershed is defined by Rampart Range to the east and West Creek Range to the west. Approximately half of the area lies within Pike National Forest.

The climate in this area is characterized as dry subhumid, with cold dry winters and warm summers. Approximately 70% of the annual precipitation comes during the months of April to September (Stanley, 1992), and is produced by convective storms. The average precipitation at the Manitou Experimental Forest Headquarters, gathered by the National Oceanic and Atmospheric Administration (NOAA) station, from 1937 to 2002 was 40.25 cm a year. In 2002, 19.8 cm of rain was recorded, and was the lowest precipitation in over 60 years. The creek typically runs year round, however during the 2002 summer season sections near Rainbow Falls Park off-road vehicle (ORV) area went dry (Figure 2-2). There are numerous tributaries to Trout Creek, however only Missouri Gulch flowed in 2002, during storm events. Beaver dams are dense along Trout Creek and attenuate flows. The creek bed is a sandy gravel.

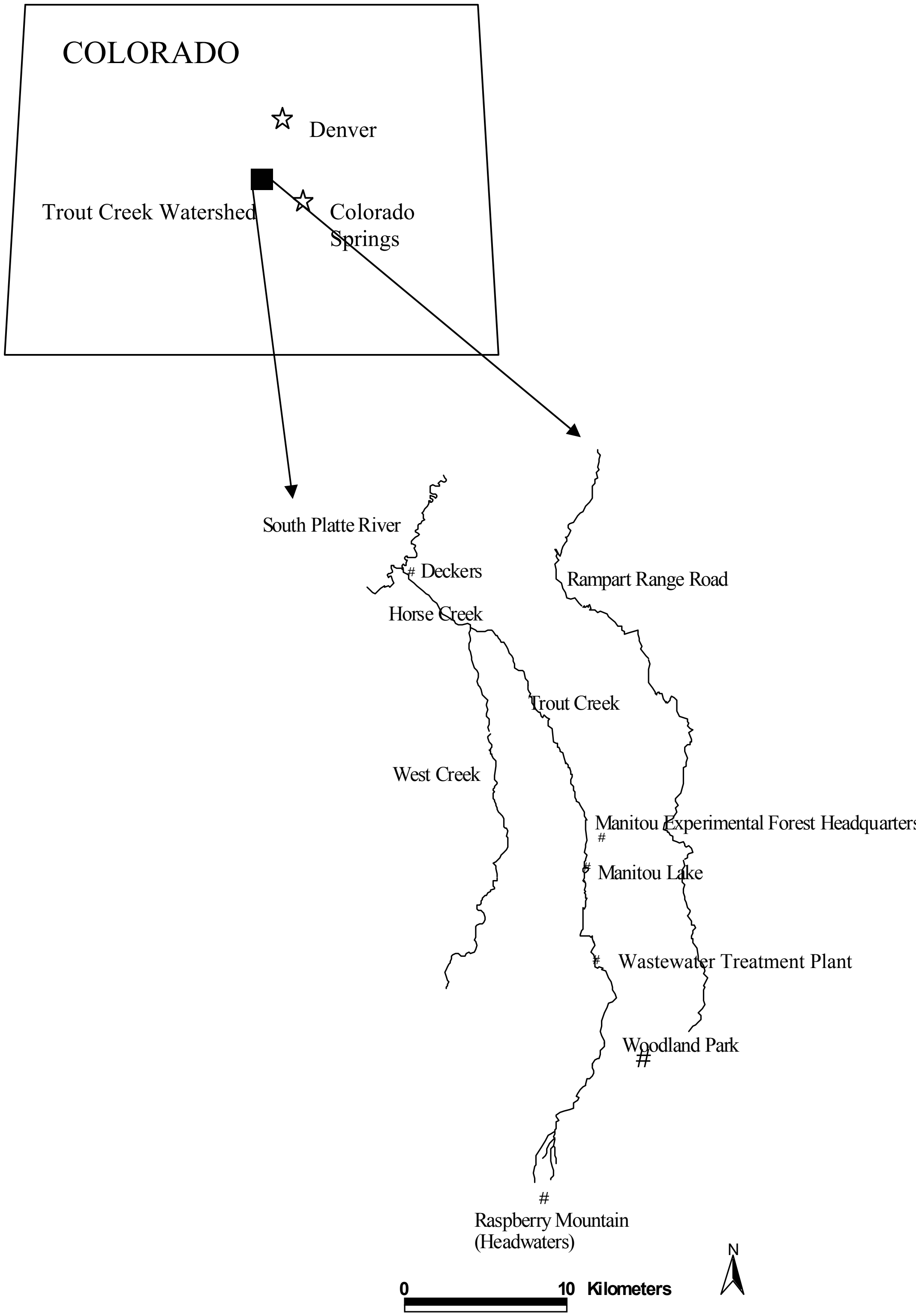


Figure 2-1. General location map of the Trout Creek Watershed, Colorado.

Figure 2-2. Dry creek bed, looking north towards the bridge at Rainbow Falls Park. Trout Creek, CO. August 24, 2002.

Vegetation in the upland areas is mostly composed of ponderosa pine (*Pinus ponderosa*). The dominant species in the floodplain are willows (*Salix* spp.). Other vegetation consists of rushes (*Juncas* spp.), sedges (*Carex* spp.), and wheatgrasses (*Agropyon* spp.) (Gary, 1985). Thistle and other weedy species are present and dense along some sections of the riparian zone.

The dominant soil series is the Boyett-Frenchcreek-Pendant, formed from weathered limestone and granite. In the valley bottom and in the floodplain area the dominant soils are Aquolls, which support abundant and lush vegetation and are characterized by 1-10% slopes, slight acidity, a shallow water table, slow runoff, and a slight hazard for water erosion. This soil type is deep, with a fine loam at the surface and a deep profile of gravely loam to coarse sand (USDA Soil Conservation Service, 1992).

Trout Creek watershed is a multi-use forest that has been identified as having an excess amount of sediment from data collected by the Forest Service and Colorado Department of Public Health and Environment. Trout Creek is listed on Colorado state's 303(d) list, and targeted for a Total Maximum Daily Load (TMDL). Water quality designation (beneficial uses) in Trout Creek include aquatic life cold 1, recreation 1a, water supply, and agriculture (CDPHE, 2005). The narrative sediment standards state that "state surface waters shall be free from substances attributable to human caused point source or nonpoint source discharge in amounts, concentrations or combinations which: can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom build up of materials which include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud" and "are harmful to the beneficial uses" (CDPHE, 2001). Much of the concern over Trout Creek is its ability to support its beneficial uses, namely fish habitat. Brook trout, sucker, white sucker, rainbow trout, and dace have all been found during electrofishing conducted by a cooperative effort from the Colorado Division of Wildlife, Trout Unlimited, and United States Forest Service (USFS) (Winters, undated).

Comparison of the waterbody of concern with a reference area is the system of evaluation recommended by the Colorado Water Quality Control Commission (CWQCC) to determine if beneficial uses area being supported (Oppelt, Pers. Comm., 2002; CDPHE, 2002). As no local watersheds were similar to Trout Creek in terms of watershed size and topography, a section of Trout Creek upstream was identified as the reference area. Characteristics such as elevation, soils, vegetation, hydrology, topography, and land-use were considered to determine representativeness (CDPHE , 1998) (Table 2-1) (Figure 2-3). The reference area had a narrower floodplain than the land-use area, and a recreational reservoir was located between the two areas. These conditions have the potential to cause differences in flow regime between the two areas, which can effect sediment amounts and transport.

Table 2-1. Characteristics of the land-use area and the upstream reference area in Trout Creek, CO. (USDA Forest Service, 1985; USDA Soil Conservation Service, 1992; USGS topographic, 1994)

	Land-use Area	Reference Area
Elevation	2316 m above sea level	2423 m above sea level
General Soil Type	Boyett-Frenchcreek-Pendant (Well drained soils formed from weathered limestone and granite)	Boyett-Frenchcreek-Pendant (Well drained soils formed from weathered limestone and granite)
Vegetation Type	Riparian – Willow (*Salix* spp.), bunchgrasses, and weedy species Upland – Ponderosa pine	Riparian – Willow (*Salix* spp.), bunchgrasses, and weedy species Upland – Ponderosa pine
Hydrology	Typically the creek flows year-round. Beaver dams attenuate flows. Flow regime may be affected by Manitou Lake Dam	Typically the creek flows year-round. Beaver dams attenuate flows
Topography	Valley bottom/flood plain	Valley bottom, with a narrower riparian zone and steeper surrounding upland slopes.
Land-uses	Cattle grazing, logging, ORV recreation, reservoir, scattered housing	Upland camping, scattered housing, golf course

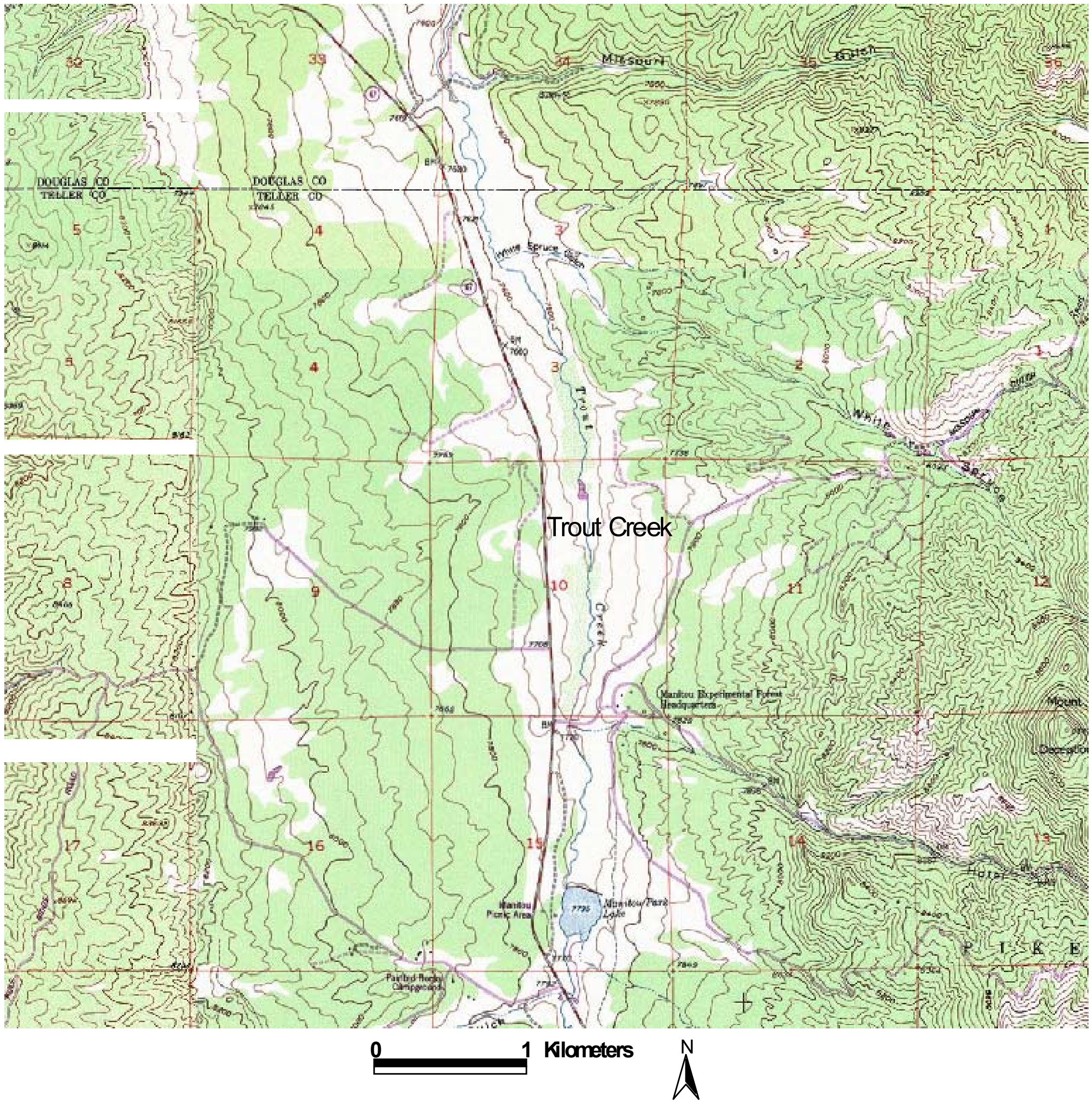


Figure 2-3. Topographic map showing the land-use study area on Trout Creek. (USGS, revised topographic, 1984)

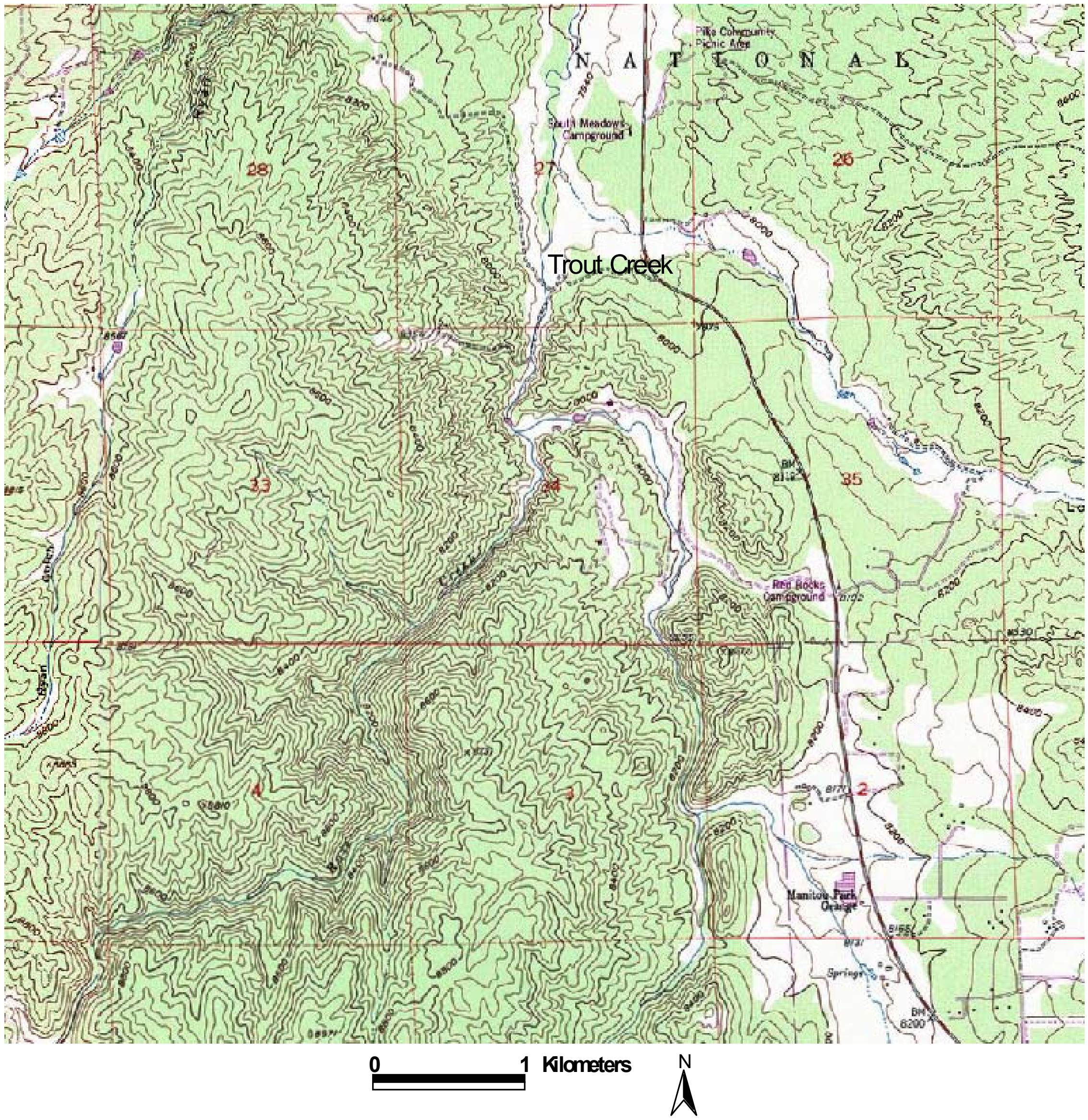


Figure 2-4. Topographic map showing the reference area on Trout Creek. (USGS, revised topographic, 1984)

A history of cattle grazing exists along Trout Creek. In 2002 one rancher had a permit to graze 50 AUMs from May through October (Lamb, Pers. Comm., 2005). Structural and non-structural BMPs exist such as exclosure fences, cattle rotations, stubble height requirements, and bank impairment thresholds (Lamb, Pers. Comm., 2002). From 1987 to 1990 stream restoration was implemented in all the pastures, and a fence was installed in the Manitou Lake pasture excluding cattle from the creek (Stanley, 1992). Log toe protectors and root wads were installed and some were still in place during this study, while others had been dislodged and occasionally seen midstream or incorporated into beaver dams.

Off-road vehicle (ORV) use in the Trout Creek watershed is extensive and tends to concentrate in various areas throughout the forest. This portion of the study was conducted in Rainbow Falls Park, 6.2 km north of Manitou Dam. In this area an estimated 80% of the trails were illegally created (Hovermale, Pers. Comm., 2002), and use is frequently discouraged with 'closed to motorized use' signs (USDA, 1985).

Along Rampart Range Road, ditch relief culverts are present, but not maintained. Culverts are installed to divert water from the road and improve drainage, however this concentrated flow is known to cause gully erosion downslope (Wemple *et al*., 1996; Croke and Mockler, 2001). Rampart Range Road is an older road and typically would contribute little to surface erosion, however it is graded, which is a source of soil erosion (Luce and Black, 1999). Gullies created by culverts have the potential to link to streams and increase sediment delivery to them.

3.0 METHODS

The Trout Creek Watershed was chosen for study based on the presence of USDA Forest Service implemented BMPs, and because the creek was identified as having excess sediment. Signs discouraging ORV use, and cattle fences were chosen for study based on their implementation, and proximity to Trout Creek. From May through August 2002, both the ORV signs and cattle fences were maintained and in place according to the Pike and San Isabel National Forests Land and Resource Management Plan (USDA, 1985). Road culverts were studied because they are a common BMP and the large number of unpaved road miles in the watershed.

3.1 Cattle Fences

Cattle Use

Cattle graze on 6 pastures below Manitou Lake Dam. Two grazed pastures and one ungrazed control pasture were monitored. The South Trout pasture was unfenced, the Manitou Lake pasture was fenced, and the control pasture was located between the two, adjacent to the Manitou Experimental Forest (MEF) Headquarters, and has not had cattle grazing on it since the 1970s (Lamb, Pers. Comm., 2002) (Figure 3-1).

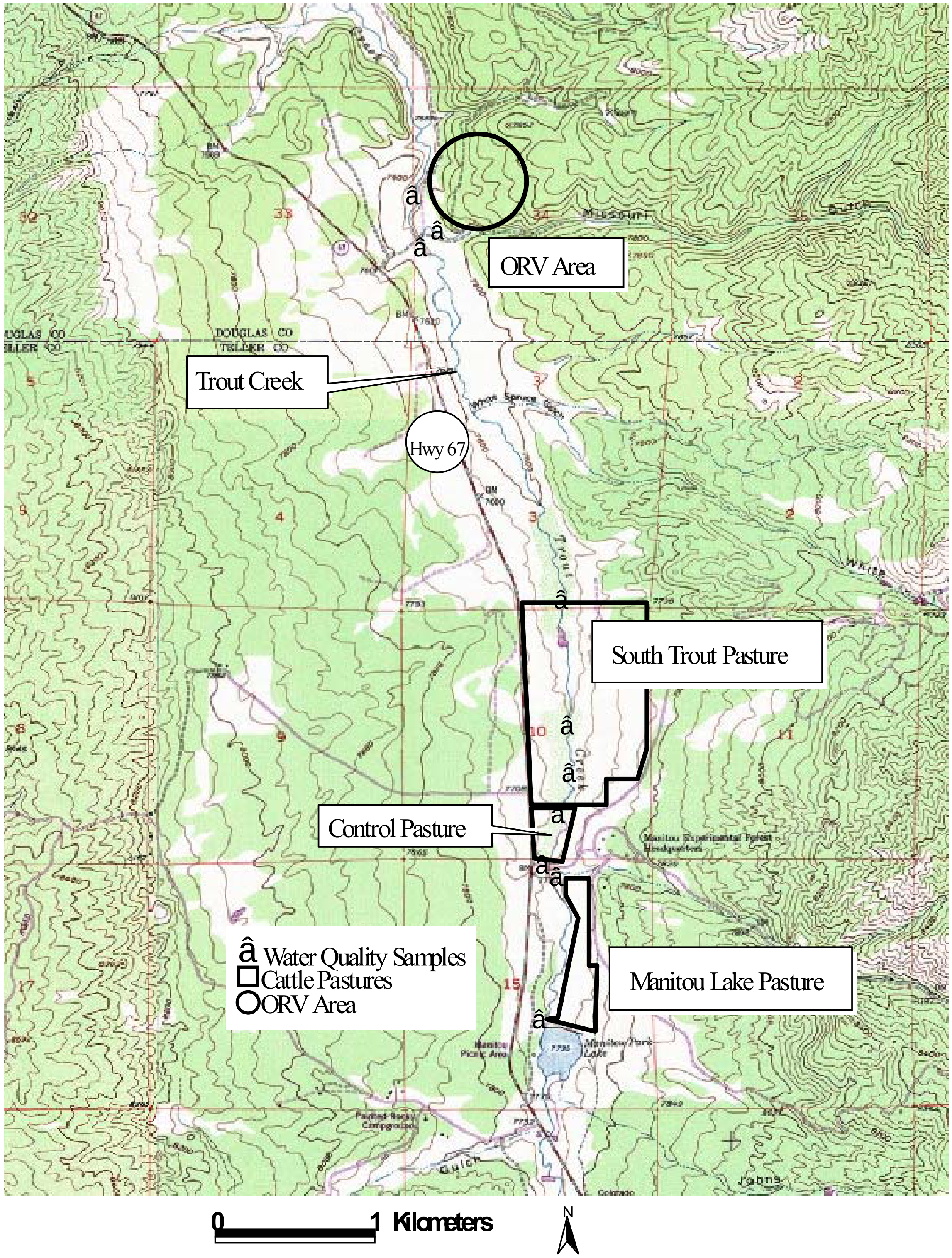


Figure 3-1. Location map of the grazing pastures and the Rainbow Falls Park off-road vehicle area. Trout Creek, CO. 2002

Cattle were monitored during May and June, in the unfenced South Trout pasture to characterize creek and bank use. When cattle are present in the fenced pasture, fences are maintained and are assumed to be 100% effective at excluding cattle. Quantifying use in the unfenced pasture describes what the fences are preventing. Cattle were observed from 5:40 am to 7:30 pm, daybreak until dark. The dark hours were not monitored as there is very little cattle activity during the darkness (Miner *et al*., 1992). Observation periods ranged from 2-4 hours, and were conducted over 10 days. The cattle were observed for a total of 35 hours and 42 minutes. Although the total herd size was 50, the pasture was large, so at any given time the observer could only monitor cattle present and visible, which ranged from 16 to 50 individual cows. The time cattle were in the creek or on the bank, and their activity, including crossing, standing, drinking, grazing or sleeping was recorded to narrow down the purpose for behavior, and intensity of use. For purposes of analysis, the bank was defined as approximately 6 meters horizontal distance from the banks edge in order to discern the streamside area from the upland area (Sheffield *et al*, 1997). The total number of minutes the cattle spent in the creek, and on the banks was divided by the total number of cows sampled, and then divided by the number of days observed, to obtain an average time per cow spent in the creek or on the bank, per day.

Eroded Stream Bank

Eroded banks were measured in July and August at the fenced, unfenced, and control pastures. The method used did not require pre-existing data and was an alternative to measuring erosion over time, and was adapted from a previous study (Rashin *et al*., 1993). The method involved measuring the width, height, percent vegetation cover, and angle of eroded banks. All the eroded banks were measured along the entire stretch of both left and right banks in each pasture. The total distances within each pasture measured varied because of the pasture delineation. All soil exposed to flowing water was considered eroding and was measured. Although the adjacent banks may not represent bankful discharge and may be incised (Pike and San Isabel Forest, 1991), they were included in the study if they directly connected to the creek. Although the control was relatively small and had grazing up until the 1970's, it was the only non-grazed pasture in the area with similar characteristics. Measurements were begun at the most downstream point in each pasture and data were collected along a continuous stretch of the right bank and then the left bank. Eroded banks were numbered heading upstream. The length of an eroding bank was measured at 50% of its height to the nearest 0.1 m. The eroded height of each bank was measured by extending a tape measure vertically at the 25%, 50%, and 75% distances from the start of the eroded bank length, and cumulating height of bare soil. The eroded bank heights were averaged and multiplied by bank length for an area. Animal trails and slumps less than 1.0 m wide were measured to quantify total eroded area, but were not numbered as eroded banks. Total eroded bank area per pasture was calculated by cumulating the eroded area and dividing this by the distance of bank measured, to obtain m^2/km. Type of erosion such as trampling, sloughing and toppling, the channel width and height, and if erosion was caused by beaver dams was measured.

3.2 Off Road Vehicle Signs

Off Road Vehicle Use

To determine if BMPs were effective at discouraging ORV use of illegally created trails, signed and unsigned trails, and control areas were observed. The study area is located at Rainbow Falls Park, north of the Manitou Experimental Forest (MEF) headquarters (Figure 3-1). In this area there is an extensive illegal trail system, and most of the trails have signs discouraging use. Eight signed trails were selected for measurement based on slope, trail length, contributing area, and access. Of the unsigned trails in the area, 3 were paired with signed trails. There were 7 control areas similar to the signed trails in topography, slope, hillslope length, contributing area, aspect, and access, however the control areas had no defined trails or indications of ORV caused erosion. In all cases the control areas and signed trails were adjacent to each other.

Trail use was evaluated using a monitoring plan that involved counting the number of times ORVs used the illegal trails, and comparing this to the total number of ORVs that could have used the trails. Initially each trail was to be observed for 30 hours, however 6 of the signed trails were only observed for 6 hours due to limited access resulting from a parking area revegetation project (Figure 3-2). Pre-sampling in spring showed that use was almost exclusively on the weekends, and so only these days plus holidays were sampled throughout the summer. All trails were observed from three different locations, which were sampled at different times of the day and the order of observation rotated. Observers were inconspicuous so as not to discourage use and bias the results.

Figure 3-2. ORV trails shown in the background were inaccessible after parking area revegetation. Trout Creek Watershed, CO. July 2002.

Hillslope Erosion

The same trails used in the ORV use monitoring were used in the erosion study, to relate trail use to soil erosion. Erosion from the signed and unsigned trails, and control areas was monitored using soil erosion traps, a technique that represents erosion rates by integrating inputs over time (Wells and Wohlegemuth, 1987; Corner, 1996). Trap design was modified from an earlier version (Bassman, 1996). Each trap consisted of two foil trays attached, one on top of the other, to form a covered container 30.5 cm wide, 20.3 cm long, and 7.6 cm tall. An opening was created on the 20.3 cm side of the container, with a 2.54 cm lip extending out to conform to the ground surface. Holes were poked on the down slope side of the trap near the top to allow water to flow through after the sediment settled out. Two traps were secured down with 13 cm nails across each trail in concentrated runoff areas, such as rills (Figure 3-3).

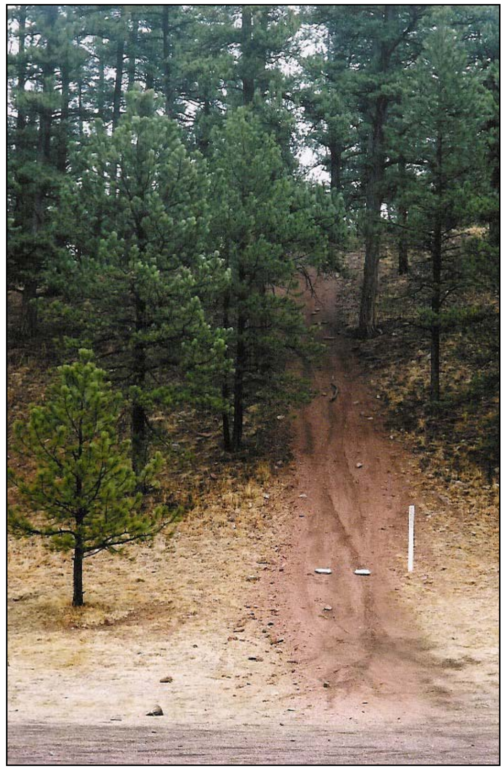


Figure 3-3. Two traps placed on a signed ORV trail. Trout Creek Watershed, CO. Summer, 2002

Traps were left on the trails during the week and removed during the weekend to not interfere with trail use. A field technician was in the Trout Creek area at all times and available to respond to each rain event. This was critical due to the few storms that typically occur in this region (Gowen, 1981). If rain was expected, traps were installed during the weekend and monitored closely. During the week, traps were checked each day for samples as well as vandalism. Traps were collected following each rain event, and soil erosion samples were labeled with meta data and preserved in plastic bags. In most cases the two samples per trail were kept separate in order to calculate the variation in sediment production across a trail. Traps were then cleaned and prepared for installation. The samples were oven dried for 24 hours and weighed to the nearest 0.01 gram at Colorado State University and California State University Chico.

3.3 Culverts

Eighteen road sections were measured, 9 with culverts and 9 without culverts, to determine the effects of culverts on road related erosion. Road sections without culverts were selected to represent comparable slope, contributing area, and road length as road sections with culverts. During the study period, the culverts were not maintained. Culvert condition was documented and included; percent plugged, presence of armoring, extent of erosion, and overhang height (Rashin *et al*., 1993). On each section of road with and without culverts, road length, contributing area, road slope, gully presence, and gully volume was measured. The length of each gully was measured, and width and depth were measured to the nearest 0.01 m, at the 25%, 50%, and 75% length locations.

Total length of the gully was multiplied by the average width and depth for approximate volume.

3.4 Above and Below BMP, and Reference Comparisons

Total Suspended Solids and Turbidity

Water quality samples were collected at 17 locations along Trout Creek, 11 sites were in the land-use area (ORV area and cattle pastures), and 4 were in the upstream reference area, and 2 were downstream (Figure 3-4). Locations were chosen to characterize above and below the ORV area and cattle pastures, an upstream reference condition, and total suspended solids (TSS) concentrations entering West Creek, and the South Platte River. Water quality samples were collected from the creek during all rain events that resulted in overland flow. Samples were also collected during non-rain events to provide baseline information. Meta data were recorded on each sample bottle. The order that samples were collected was routinely switched to avoid bias. Within a week of collection the samples were taken to Colorado State University and analyzed in the water quality lab for total suspended solids and turbidity. QA/QC protocol were implemented in 30% of the samples in the field and in the lab, and included duplicates, splits, blanks, and equipment calibration.

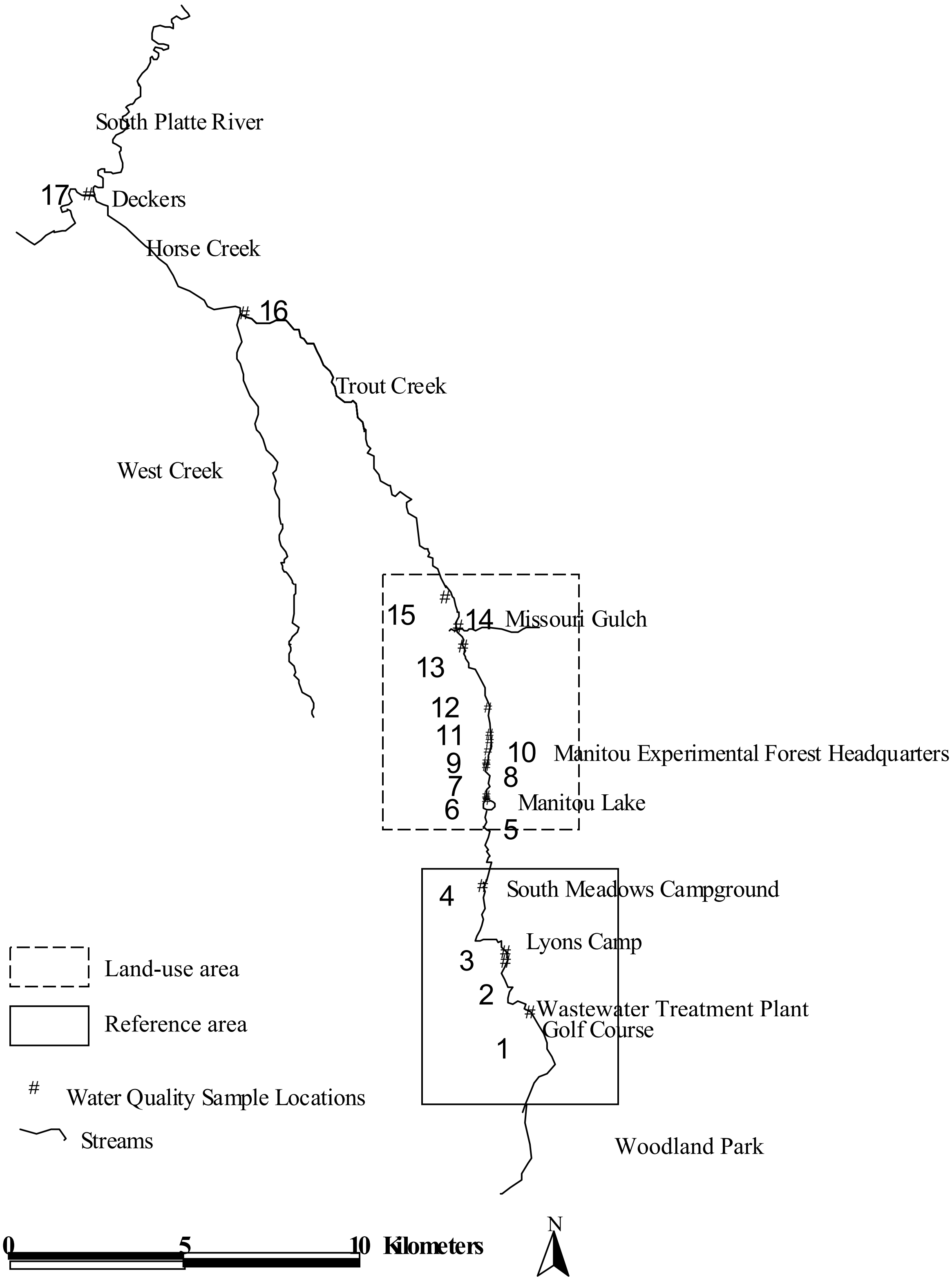


Figure 3-4. Water quality sample locations 1-17 along Trout Creek, CO.

Wolman Pebble Counts

Wolman pebble counts (WPCs) were conducted to compare streambed particle size distributions. The WPC is a simple and rapid technique used to evaluate if BMPs are effectively reducing sediment entering streams (Potyondy and Hardy, 1994). The WPC is the standard method for the USDA Forest Service and the Colorado Water Quality Control Division (WQCD) (Oppelt, Pers. Comm., 2002). Twenty WPCs were conducted in riffle/run sections; ten in the land-use area, and ten in the reference area. The WPC method involved running a tape measure across a uniform cross section perpendicular to the flow. Pebbles were chosen at a pre-determined measurement along the tape measure by picking up the first pebble the tip of the index finger touched. The intermediate axis of 100 particles was measured at each sample location. In Trout Creek, because the creek width was narrow, this often involved measuring across multiple transects in a single riffle heading from downstream to upstream. All particles smaller than 2 mm were grouped together as less than 2 mm (Wolman, 1954). All 20 WPCs were completed within a week to avoid differences in particle size caused by changes in streamflow. D_{50}, representing the median particle diameter, were compared between the land-use area and the reference area. To define content of fine particles, 8 mm can used (Potyondy and Hardy, 1994). The percent of pebbles with diameters smaller than 8 mm were compared between the land-use are and the reference area.

4.0 RESULTS

4.1 Cattle Fences

Cattle Use

Cattle behavior was monitored in the unfenced pasture to determine use of the stream bank and creek. Cattle spent an average of 1.0 minute per cow per day crossing, drinking, and standing in Trout Creek, and an average of 11.5 minutes per cow per day grazing, walking, or sleeping on the stream bank (Appendix A1).

Eroded Stream Bank

A total distance of 2.45 km of fenced pasture, 4.15 km of unfenced pasture, and 1.16 km of ungrazed control pasture were measured for eroded bank. The fenced pasture had 363 m^2/km of eroded bank, the unfenced pasture had 780 m^2/km of eroded bank, and the control pasture had 683 m^2/km of eroded bank (Appendix A2). The eroded bank areas between the fenced, unfenced, and control pastures were significantly different ($p<0.05$).

Characteristics such as type of erosion, bank angle, if the eroded area was associated with a beaver dam, and bankful width and height, were measured. Type of erosion was grouped by trampling, sloughing, and toppling to indicate cause of eroded bank. Trampling caused 3 m^2/km of eroded area in the fenced pasture, 516 m^2/km in the unfenced pasture, and 50 m^2/km in the control pasture. Sloughing accounted for 217 m^2/km of eroded area in the fenced pasture, 173 m^2/km in the unfenced pasture, and 519 m^2/km in the control pasture. Toppling totaled 137 m^2/km of eroded area in the fenced pasture, 89 m^2/km in the unfenced pasture, and 110 m^2/km in the control pasture (Figure 4-1). Trampling resulted in sloped eroded banks that were patchy and with small clumps of vegetation. Sloughing tended to erode in larger chunks of soil that were steep at the top but provided a gentler slope at the lower end of the bank for vegetation establishment. Toppling typically had high eroded bank areas with near vertical faces. The pastures combined had 8 eroded banks located at the edges of a beaver dams, with an average density of one eroded bank per km.

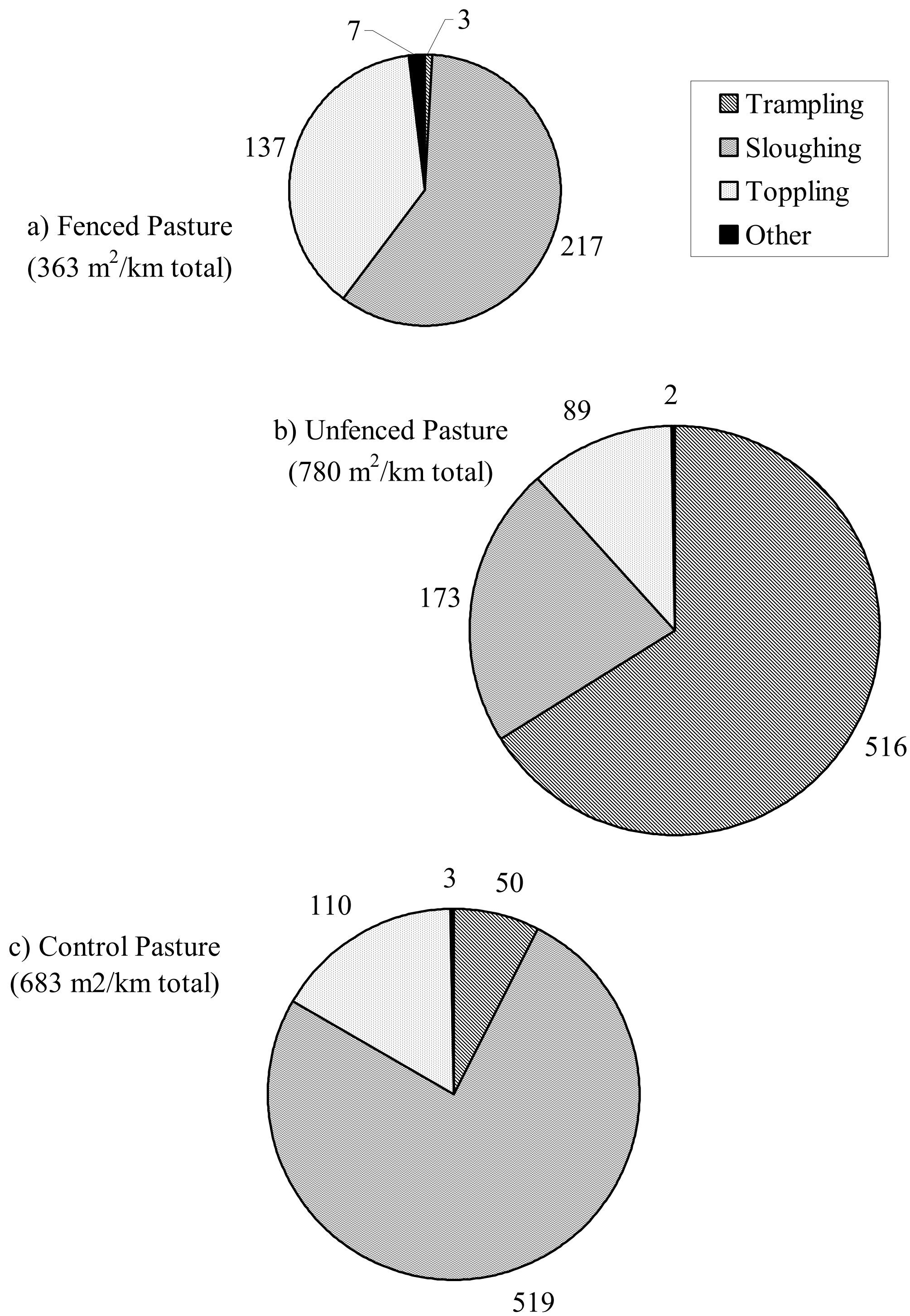


Figure 4-1. Eroded bank by type of erosion, m^2/km, a) fenced pasture b) unfenced pasture c) control pasture. Trout Creek, CO. July and August 2002

There were 80 eroded banks in the fenced pasture, with a density of 33 banks/km. The unfenced pasture had 139 eroded banks, with a density of 34 banks/km, and the control pasture had 39 eroded banks, and a density of 34 banks/km. The average width of an eroding bank at the fenced, unfenced, and control pastures were 9.8 m, 14.7 m, and 13.4 m respectively. The unfenced pasture had wider eroded banks, with more eroded area per bank, while the fenced pasture had approximately the same density of eroded banks per km, yet the banks were not as wide, indicating intermittent eroded banks and larger vegetated areas between each bank.

The channel width and depth were measured at each eroding bank to give an indication of the channel form. In a few cases the creek depth was estimated because it was behind a beaver dam and too deep to wade. The fenced pasture had an average bank height of 1.6 m, an average width of 16.3 m, and width to depth ratio of 10.0. The unfenced pasture had an average bank height of 1.9 m, an average width of 11.3 m, and a width to depth ratio of 5.9. The control pasture had an average height of 1.8, with an average width of 18.4 m, and a width to depth ratio of 10.5. These all represent low width to depth ratios (Rosgen, 1994).

4.2 Off Road Vehicle Signs

Off Road Vehicle Trail Use

Effectiveness of the ORV signs was measured by comparing use on signed trails, unsigned trails, and control areas. A total of 8 signed trails, 3 unsigned trails, and 7 control areas were observed. Slope, contributing area, trail width and length, and percent vegetation cover was measured on each trail and all control areas (Table 4-1).

Table 4-1 Signed and unsigned trails, and control area (no ORV activity) characteristics. Rainbow Falls Park, CO. Summer 2002

	Slope, percent	Trail length, m	Average trail width, m	Contributing area, m^2	Percent vegetation and pine needle cover
Signed trail 1	16.5	32.0	2.2	70.4	14.9
Signed trail 2	14.5	28.5	4.3	122.6	79.7
Signed trail 3	22.0	38.5	2.6	100.1	70.3
Signed trail 4	21.0	39.5	1.1	43.5	33.3
Signed trail 5	13.0	22.0	1.6	35.2	91.5
Signed trail 6	23.0	18.5	1.7	31.5	79.2
Signed trail 7	14.0	14.0	4.7	65.8	99.4
Signed trail 8	18.0	28.0	6.3	176.4	98.2
Unsigned trail 2	14.0	31.0	4.2	130.2	92.9
Unsigned trail 5	15.0	24.0	3.5	84.0	94.4
Unsigned trail 7	15.0	13.0	2.6	33.8	89.9
Control 1	16.0	33.0	NA	192.4	95.0
Control 2	14.5	28.0	NA	270.0	100.0
Control 3	20.0	41.0	NA	380.2	100.0
Control 5	15.0	21.0	NA	98.5	100.0
Control 6	24.0	19.0	NA	73.1	100.0
Control 7	14.0	12.0	NA	21.0	95.0
Control 8	21.0	25.5	NA	109.9	70.0

Use was compared by measuring the total number of ORVs that used illegal trails, divided by the total number of ORVs that had access to them, and multiplied by 100 for a percentage. On average, 5.8% of ORVs used illegal trails, of this 5.8%, 3.4% used the illegal signed trails, 2.3% used the illegal unsigned trails, and the control areas were never used. An average of 94.2% of the ORVs did not use the illegal trails but remained on the legal trails (Appendix A3).

A second comparison was made using data from the 3 paired signed and unsigned trails. This was done to ensure that differences in use were not because of trail characteristics, but because of the presence or absence of signs. On average, the 3 paired signed trails were used by 4.6% of the ORVs, and the 3 unsigned trails were used by 2.3% of the ORVs.

Hillslope Erosion

The same ORV trails were measured for soil erosion. Erosion was measured after 14 storm events resulting in overland flow. Average erosion on the signed trails was 42.6 g/m^2, 28.3 g/m^2 on the unsigned trails, and 0.12 g/m^2 on the control areas (Figure 4-2) (Appendix A4). Analysis of variance (ANOVA) indicated a significant difference ($p=0.02$) using a 2-tailed test, between the signed trails and control areas. There was no significant difference between the control areas and the unsigned trails, nor the signed trails and the unsigned trails. Variation between soil erosion in the two traps on each trail was large (Table 4-2). This was expected however, as traps were placed in areas of likely runoff such as rills, and often only one rill was present on each trail.

The second analysis comparing erosion on the 3 paired signed and unsigned trails, showed no significant difference ($p<0.05$). However, erosion was higher on the signed trails than the unsigned trails, 57.3 g/m^2 and 28.3 g/m^2 (Figure 4-3). Comparisons of trail characteristics, including slope, percent use, contributing area and trail length to erosion, between the signed and unsigned trail showed no significant differences ($p<0.05$), suggesting that erosion can be attributed to signs rather than trail characteristics.

Table 4-2 Total soil eroded, g/trap, from the ORV trails. Trout Creek Watershed, CO. May through August, 2002.

Trail number	Trap 1	Trap 2	Total grams
Signed trail 1	11	0	11
Signed trail 2	7425	3164	10590
Signed trail 3	2135	1058	3194
Signed trail 4	2130	187	2318
Signed trail 5	237	442	679
Signed trail 6	28	265	293
Signed trail 7	95	4261	4357
Signed trail 8	6924	5517	12442
			Mean erosion per trail = 4235g
Unsigned trail 2	3332	381	3713
Unsigned trail 5	68	4135	4204
Unsigned trail 7	61	155	217
			Mean erosion per trail = 2711g

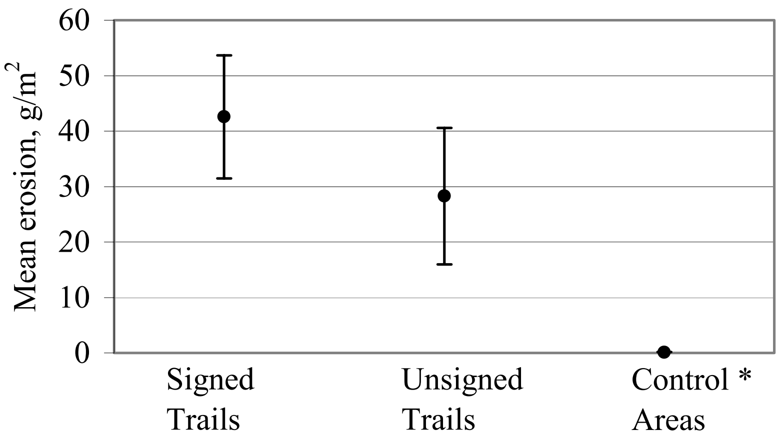


Figure 4-2. Comparison of mean erosion, including plus and minus standard error of the means, on all the signed and unsigned trails, and control areas in Rainbow Falls Park. Trout Creek Watershed, CO. June – August 2002.
***the control area standard error is plus and minus .069**

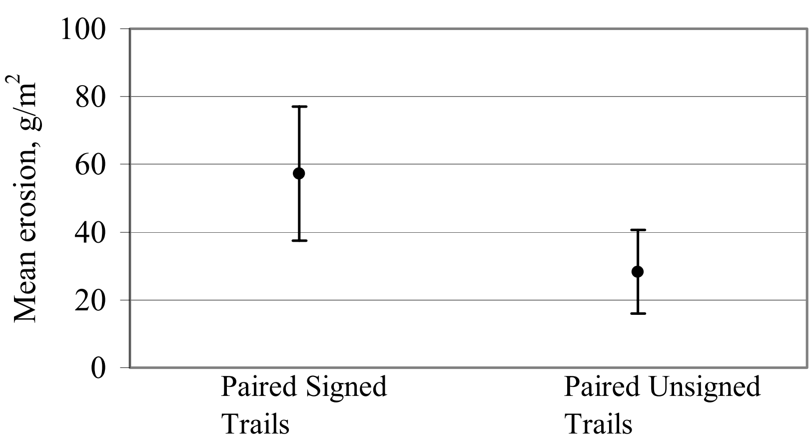


Figure 4-3 Comparison of mean erosion, including plus and minus standard error, on the paired signed and unsigned trails, in Rainbow Falls Park. Trout Creek Watershed, CO. June – August 2002.

4.3 Culverts

Sections of road were measured along 7.0 km Rampart Ridge Road representing road sections with culverts, and without culverts. All road sections measured were unpaved. Culvert type varied from circular pipe at the outslope to cemented inlets that channeled water under the road (Figure 4-4). Culverts were not maintained. Culverts had a mean eroded gully volume of 27 m^3, and 29 kg erosion per m^2 of contributing road, while road sections without culverts had a mean gully volume of 7 m^3, and 9 kg of erosion per m^2 of contributing road (Figure 4-5) (Appendix A5). Using ANOVA, no statistical difference ($p<0.05$) was found in gully erosion between the areas with culverts and without culverts. Of the 17 gullies in areas with culverts, 10 linked to a channel, while 7 out of 14 gullies in areas without culverts areas linked to a channel.

Regressions between gully volume and road slope, gully erosion and road length, and gully volume and contributing area were plotted (Figure 4-6). In the culvert sections, gully volume, and road slope and contributing area had a positive relationship. When comparing gully volume and road slope, there was a negative relationship in the culvert areas. In the areas without culverts, as contributing area and road length increased, there was no increase in gully volume. However, in the areas without culverts there was a relationship between gully volume and road slope.

Figure 4-4. Photos of different culvert types along Rampart Range Road. Trout Creek Watershed, CO. 2002.

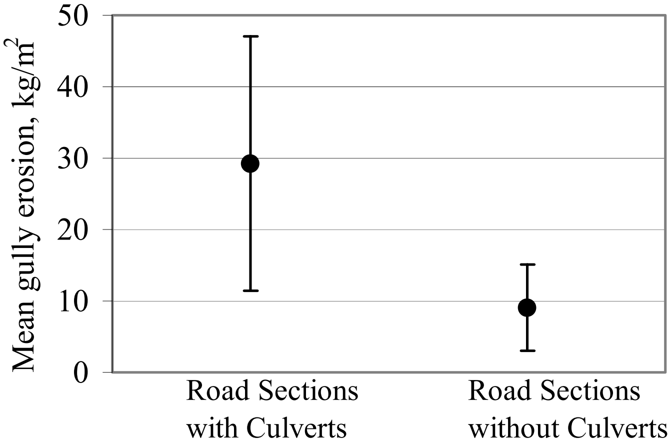
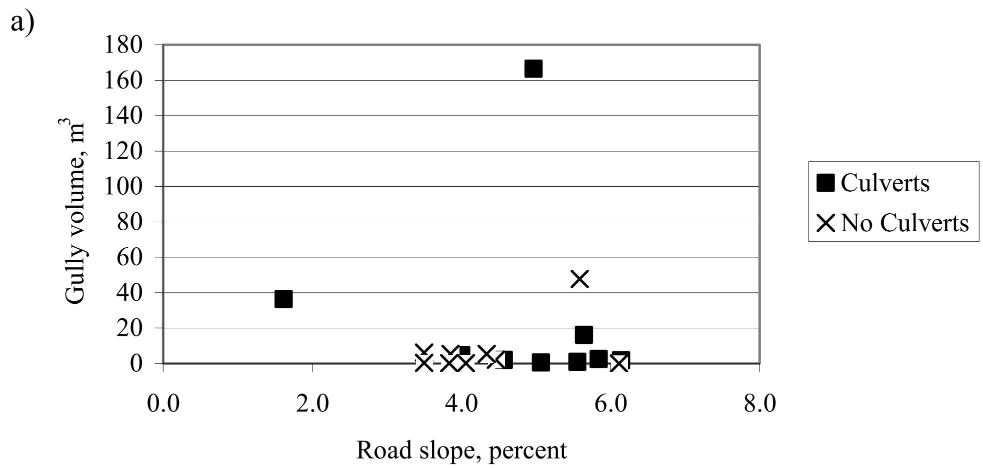
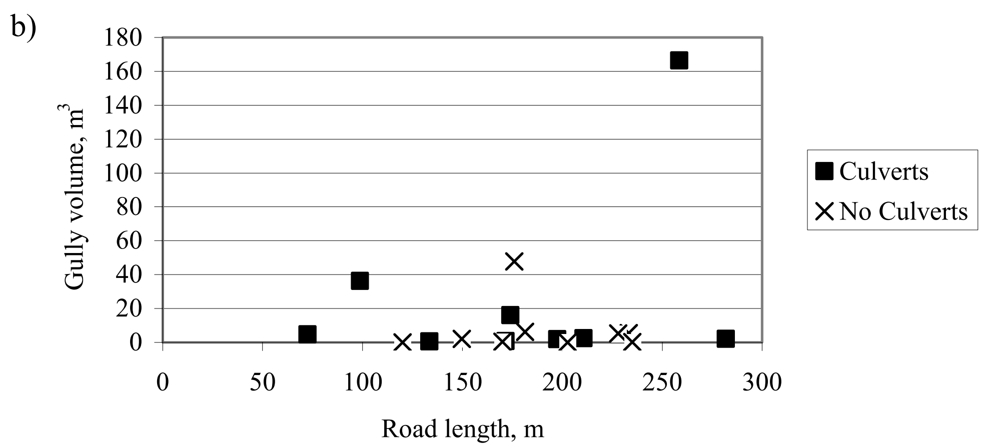


Figure 4-5. Mean gully erosion per area of road, plus and minus one standard error. Trout Creek Watershed, CO. August, 2002.





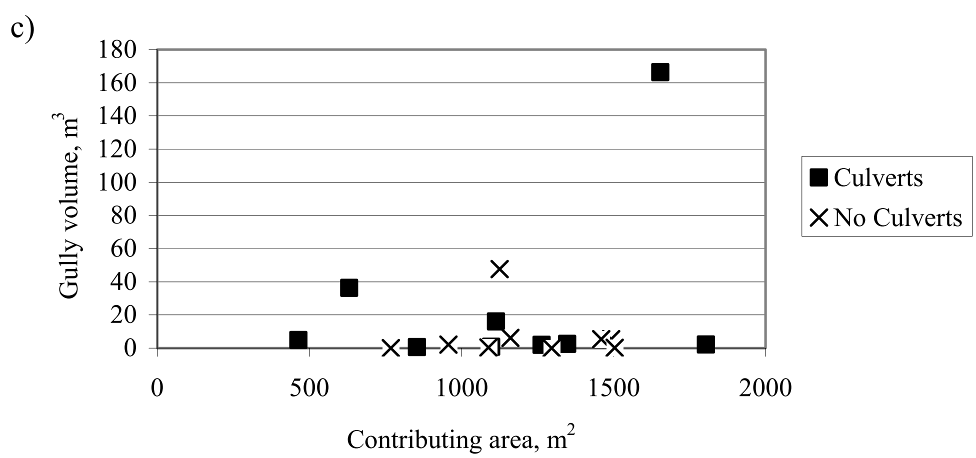


Figure 4-6. Gully volume at the road sections with and without culverts as a function of a) road slope b) road length and c) contributing area.

4.4 Above and Below BMP, and Reference Comparisons

Total Suspended Solids and Turbidity

Water quality samples were analyzed for total suspended solids (TSS) and turbidity to determine effectiveness of individual BMPs by above and below sampling at the cattle pastures and ORV area. Combined effectiveness of the BMPs was evaluated by averaging the above and below samples, representing the land-use area, and comparing these to 4 locations averaged in the upstream reference area along Trout Creek. Mean TSS and turbidity varied among all 17 sites.

The reference area had less variable TSS and turbidity, remaining lower than 15.6 mg/L, and 8.3 NTUs. Water quality in the land-use area consistently had higher TSS and turbidity than the reference area, never below 19.2 mg/L or 15 NTUs, and as high as 85.5 mg/L and 30 NTUs.

In the fenced cattle area, above TSS samples were higher than the below samples, means of 85.5 mg/L and 19.0 mg/L, respectively. Mean turbidity also was higher above than below samples, 30 NTUs and 16 NTUs. This indicates that the fence is effectively controlling sediment input into Trout Creek. However, directly above the fenced location is the Manitou Dam, which most likely had an instream effect. When comparing above and below the control area samples, mean TSS and turbidity was higher in the above samples, 28.0 mg/L and 22 NTUs, and 19.2 mg/L and 15 NTUs, respectively. In the unfenced area, mean TSS and turbidity was lower in the above samples than the below samples, 21.6 mg/L and 17 NTUs, and 33.6 mg/L and 22 NTUs.

Mean TSS and turbidity was the same in the above and below ORV samples, 19 mg/L and 14 NTUs. However, Missouri Gulch, a tributary that enters Trout Creek between the above and below ORV locations, had an average TSS concentration of 33.7 mg/L, and an average turbidity of 36 NTUs. Missouri Gulch flowed only during storm events, and only for approximately 100 m above the confluence with Trout Creek.

Samples were originally collected to help characterize sediment transport from Trout Creek, and its relative contribution to the South Platte River. The Hayman Fire changed the goals of this sampling to a before and after fire study. Post fire results were largest above the confluence with the South Platte River, increasing in mean TSS from 3.2 mg/L to 243.2 mg/L and mean turbidity from 2 NTUs to 266 NTUs. Above the confluence with West Creek, also increased in mean TSS and mean turbidity from 7.5 mg/L to 66.0 mg/L, and from 4 NTUs to 37 NTUs respectively (Figure 4-7 and 4-8) (Appendix A6). These results indicate Trout Creek contributed a greater amount of sediment before the Hayman Fire, and West Creek transported more sediment after the Hayman Fire.

A rating curve was developed to describe the relationship between TSS and turbidity in Trout Creek (Figure 4-9). 153 samples consisting of both storm and non-storm samples resulted in an R^2 of 0.88, and a p value of 0.0001.

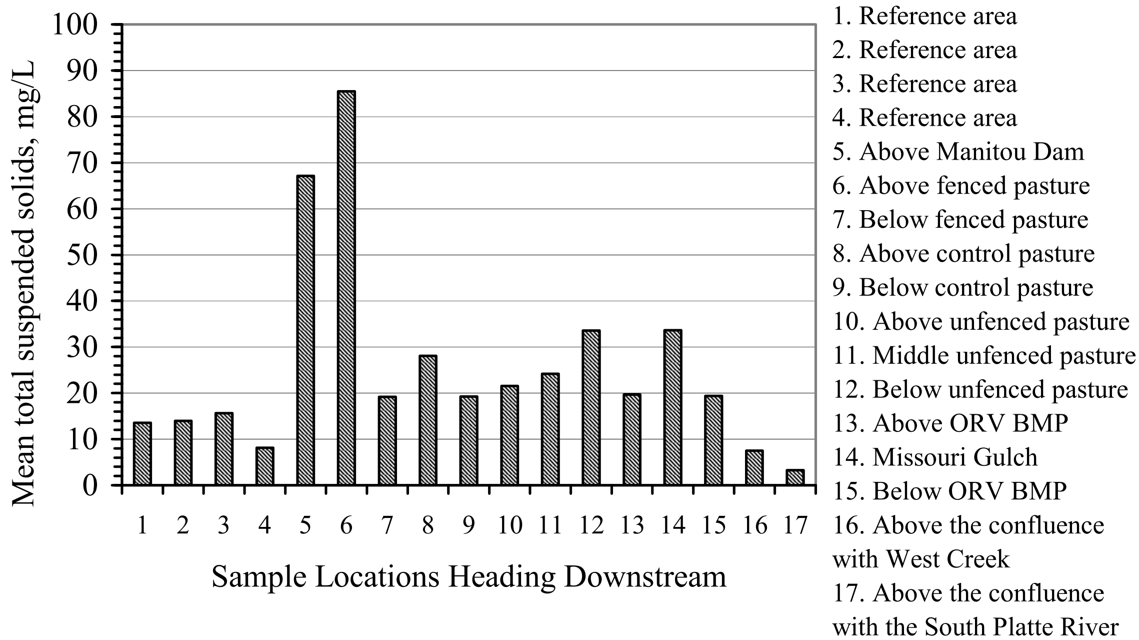


Figure 4-7. Mean TSS from storm samples at 17 locations. Trout Creek, CO. May through August 2002. ***Averages values for locations 16 and 17 do not include post Hayman Fire samples**

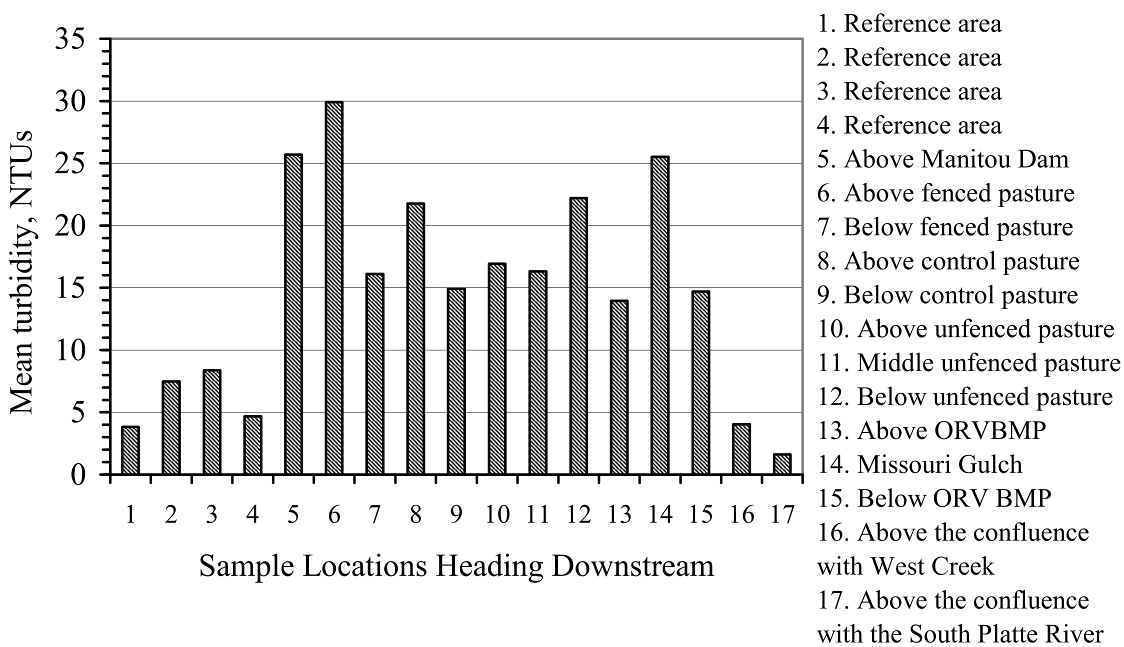


Figure 4-8. Mean turbidity from storm samples at 17 locations. Trout Creek, CO. May-August 2002. ***Average values for locations 16 and 17 do not include post Hayman Fire samples**

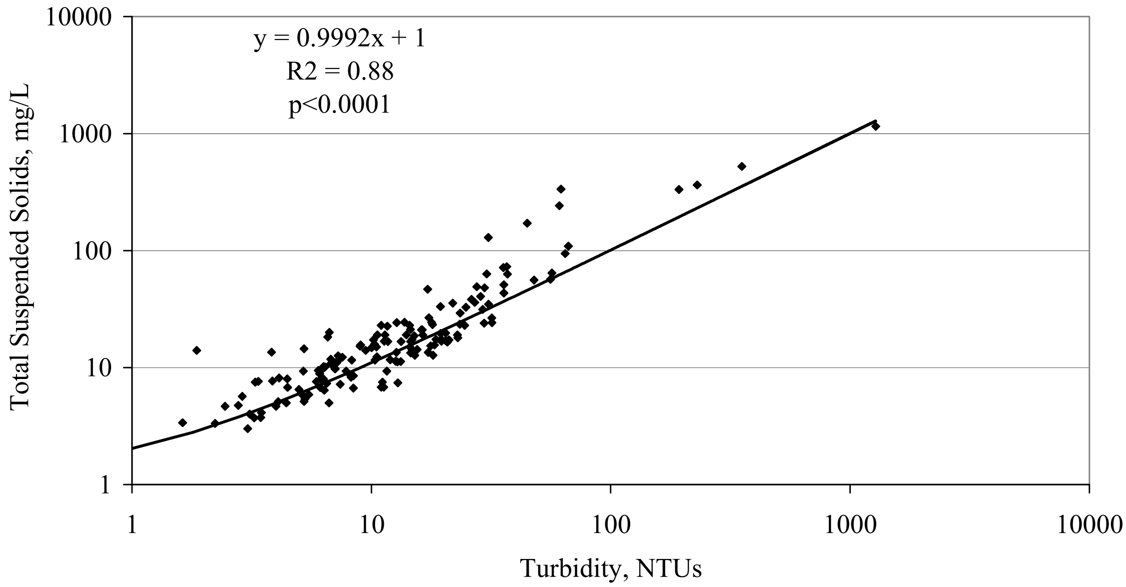


Figure 4-9. Regression between turbidity and total suspended solids. Trout Creek, CO. May through August 2002.

ANOVAs were run on 10 water quality comparisons to test for significance. All hypotheses were compared for both TSS and turbidity. Data were log transformed for normality. Storm samples, and three baseline samples were compared for significant difference ($p<0.05$) and none was found, so the data were combined.

Ten comparisons tested:

- Was there a significant difference between above the fenced pasture and below the fenced pasture? No significant difference was found in TSS ($p=0.26$) or turbidity ($p=0.14$).
- Was there a significant difference between above the unfenced pasture and below the unfenced pasture? No significant difference was found in TSS ($p=0.26$) or turbidity ($p=0.40$).
- Was there a significant difference between above the control pasture and below the control pasture? No significant difference was found in TSS ($p=0.88$) or turbidity ($p=0.97$).
- Was there a significant difference between the fenced and unfenced cattle pastures? No significant difference was found in TSS ($p=0.67$) or turbidity ($p=0.88$).
- Was there a significant difference between the control cattle pasture and fenced pasture? No significant difference was found in TSS ($p=0.40$) or turbidity ($p=0.60$).
- Was there a significant difference between the control cattle pasture and the unfenced pasture? No significant difference was found in TSS ($p=0.60$) or turbidity ($p=0.65$).

- Was there a significant difference between the above and below ORV area samples? No significant difference was found in TSS ($p=0.94$) or turbidity ($p=0.56$).
- Was there a significant difference between above and below the Manitou Dam samples? No significant difference was found in TSS ($p=0.78$) or turbidity ($p=0.93$).
- Was there a significant difference between the upstream reference area and the land-use area? A significant difference was found between TSS ($p=0.02$) and turbidity ($p=0.0001$).

Wolman Pebble Counts

Wolman pebble counts were conducted at 10 locations in the land-use area, and 10 locations in the reference area. Mean D_{50} for the land-use and reference area was 6.6 mm and 8.6 mm respectively. In the land-use area 55% of the streambed particles were smaller than 8 mm, and in the reference area 47% of the particles were smaller than 8 mm (Figure 4-10).

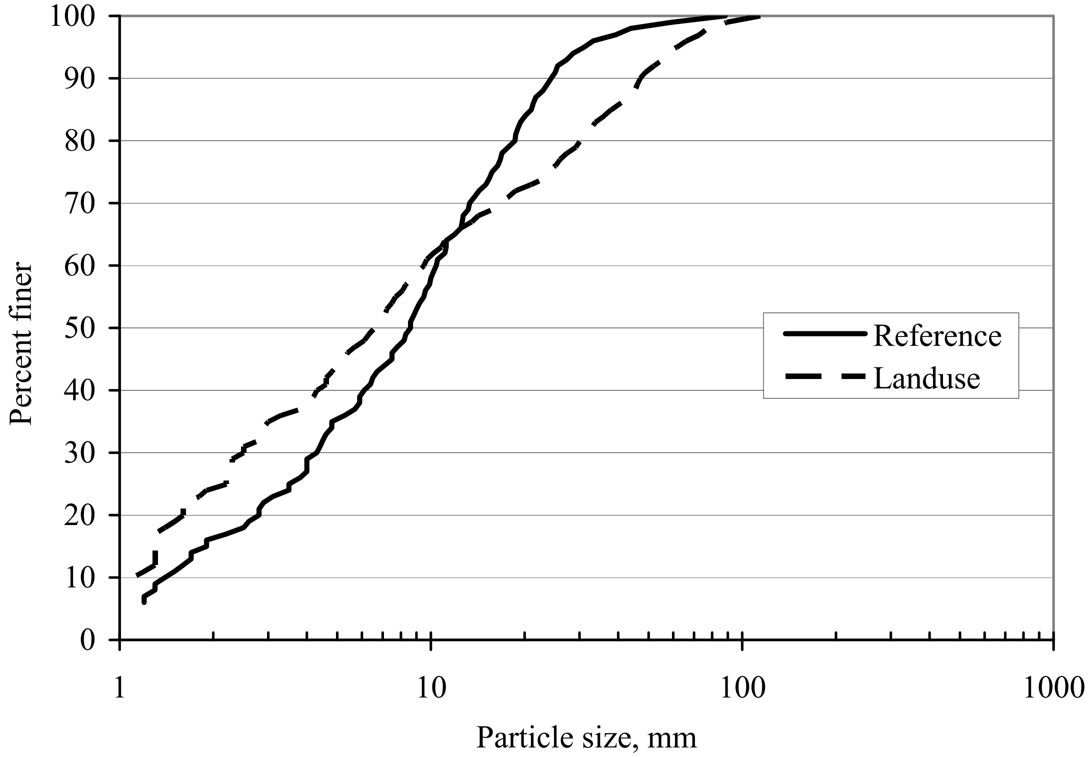


Figure 4-10. Wolman pebble count results at the land-use and reference areas. Trout Creek, CO. August 2002.

5.0 DISCUSSION

5.1 Cattle Fences

Cattle fences are a common yet expensive BMP implemented to exclude cattle from creeks with the intent of reducing bank erosion and maintaining water quality. It was important to quantify effectiveness as a justification for future fencing projects, as well as for comparison with other less expensive cattle BMPs. Effectiveness was determined by observing cattle use of the banks and creek, by measuring eroded bank, and by above and below TSS and turbidity samples. Cattle grazing rotations were different during the 2002 summer compared with other years due to the Manitou Dam repair, the drought (Lamb, 2002), and the Hayman Fire. The source of water in the fenced Manitou Lake pasture is typically seepage from the Manitou Lake Dam. However, in 2000 the lake was drained to upgrade the dam, and was not filled by 2002 because of the drought. Additionally, the cattle were removed from the area before their scheduled rotation to the Manitou Lake pasture because of the nearby fire.

Cattle were observed in the unfenced pasture, and on average each cow spent 1.0 minute per day in the creek, and 11.5 minutes per day on the banks. This is a relatively small proportion of their total time, yet produces large differences in eroded bank. The main challenge with observation as a technique, was keeping track of individual cows.

Other studies have quantified cattle use of creeks in an effort to determine the effectiveness of off-stream sources of water. One study found the average time spent by each cow in the creek dropped 89%, from 6.7 minutes to 0.07 minutes after an alternative water source was installed, and the average time spent on the banks dropped from 12.7 to 6.2 minutes per cow per day (Sheffield *et al*., 1997). Another study observed cattle for 8 days and found that the minutes per cow per day spent in the creek was 25.6 at the pasture without a water tank and 1.6 at the pasture with a water tank (Miner *et al*., 1992). The day length in both studies was 9.5 hours, whereas at Trout Creek the day was 14 hours. The average time per cow spent in Trout Creek was less than both studies, however possible reasons for this include differences in the length of a day, forage amounts along the creeks, or temperature.

When comparing eroded bank, the unfenced pasture had more than twice the area of eroded bank than the fenced pasture, 780 m^2/km and 363 m^2/km respectively. The eroded bank areas between the fenced, unfenced, and control pastures were significantly different ($p<0.05$). Trampling caused the largest eroded bank area in the unfenced area. This is encouraging and shows the fence was successful in reducing bank erosion. The control area with no grazing had 683 m^2/km of eroded bank. This high eroded bank area may be because banks have not yet stabilized since the removal of cattle in the 1970's. Although bank height was not measured, this can effect eroded area and may explain the area of eroded bank in the control pasture. Channel width and depth were measured at each eroding bank. The fenced pasture had width to depth ratio of 10.0, the unfenced pasture had a width to depth ratio of 5.9 and the control pasture had a width to depth ratio of 10.5. It is not surprising that the unfenced area had a lower width to depth ratio and wider cross sections than the fenced area, as the effects of trampling are sloped out banks and wider cross sections.

All studies measuring cattle effects on stream banks measured erosion over time, so are not directly comparable to the one time eroded bank measurements in this study. However, the increased eroded areas in this study are similar to other studies looking at the effects of grazing. One study found significantly greater horizontal stream bank losses in grazed areas compared with ungrazed areas, 27 cm and 9 cm, respectively (Kauffman *et al*., 1983). A study conducted for two years found that a stream bank in a grazed area eroded 16 cm and 14 cm per year, and an ungrazed stream bank eroded 11 cm and 8 cm each year, although the difference was not significant ($p<0.10$) (Buckhouse *et al*., 1981). In a pre and post fencing study, bank erosion was 0.66 m before fencing, and 0.15 m after fencing, representing a 77% decrease in erosion (Sheffield *et al*., 1997).

A previous study was conducted along Trout Creek, measuring land-use effects on TSS concentration. No significant difference using an alpha of 0.01, between the ORV area, the fenced pasture, or the unfenced pasture was found (Stanley, 1992). Mean TSS concentrations were also comparable to the results of this study (Stanley, 1992). There was no significant difference when comparing above and below water quality samples at each pasture, or between the pastures. Mean TSS was lower below the fenced area than above, 85.5 mg/L and 19.2 mg/L. Mean TSS was 28.1 mg/L above the control area, and 19.2 mg/L below. Mean TSS was 33.6 mg/L below the unfenced pasture, and 21.6 mg/L above. A likely explanation for the lower TSS concentrations in the fenced and control areas was a result of sediment released from behind Manitou Lake Dam.

The results of this study are comparable to other cattle BMP studies. In a before and after study, when comparing TSS inflow and outflow there was a 65% reduction in sediment loads after fencing (Winegar, 1977). Water quality was actually improved and the assumption was that the vegetation that returned trapped the sediment and more settled out on the stream bottom (Winegar, 1977). In another before and after fencing study, annual concentrations of TSS decreased 57% from 1.98 g/L to 0.87 g/L (Owens, 1996). Another study found that TSS in cattle areas before and after an off-stream water source was installed decreased 89% from 132 mg/L to 14 mg/L (Sheffield *et al*., 1997).

These results suggest fencing is an effective BMP.

5.2 Off Road Vehicle Signs

ORV use causes degradation of plant life, increases erosion, and increases TSS in adjacent streams (Wilshire *et al*., 1977; Griggs *et al*., 1981). ORV signs are a commonly used BMP in the Trout Creek watershed. Effectiveness was measured by observing ORV use, soil erosion traps, and above and below water quality samples. Initially, each trail was to be observed for 30 hours, however in June, the Hayman Fire began, causing the Pike National Forest to close through mid July. During closure, the Forest Service took the opportunity to restore the parking area below the ORV site, making 6 of the 8 signed trails inaccessible to ORV traffic. When the area reopened to the public, access was prevented to the 6 signed and 6 control areas by a barbed wire fence protecting the newly seeded parking area. This resulted in trails being observed for different amounts of time.

Because there was an unequal number of signed and unsigned trails observed, two comparisons were made. The first comparison included all 8 signed trail, all 3 unsigned trails, and the 7 control areas. To eliminate differences in erosion that may be caused by trail characteristics, a second comparison was made between only the 3 paired signed and unsigned trails.

Of the total ORVs, 3.4% used the signed trails, 2.3% of the ORVs used the unsigned trails, and no ORVs used the control areas. When comparing only the 3 paired trails, again use was higher on the signed trails than the unsigned trails, 4.6% and 2.3% respectively. Use may have been higher on the signed trails because of the placement of the trails in relation to the legal trail, proximity to the parking area, or visibility. Another possibility is that the signs may actually encourage use by indicating a ‘safe’ trail where others have already ventured. One problem with measuring use, is there is no direct correlation as to how much use is appropriate. The signs may be 99% effective, but even less than 1% may be the threshold that leaves an area denuded and exposed for erosion.

Signed trails 1 and 2 were compared because of their differences in percent litter and vegetation cover. Trail 1 was undefined and had 85% litter and vegetation cover, while trail 2 was well defined and had only 20% cover. Although the trails were similar in slope, contributing area, aspect, and length, trail 1 was never used , while trail 2 was used 8% of the time, suggesting signs may be effective when used to prevent trail initiation.

Erosion from 14 storm events was measured to determine the effectiveness of the signs at reducing erosion. Two soil erosion traps were used on each trail and variation between the two traps was large. This was expected however, as traps were placed in areas of likely runoff such as rills, and often only one rill was present on each trail. When comparing erosion rates between the signed and unsigned trails, no significant difference ($p<0.05$) was found. The finding of no significant difference suggests that signs are ineffective at controlling erosion on illegally created trails. The signed trails produced over 60% more sediment than the unsigned trails 43 g/m^2 and 28 g/m^2, respectively. This higher erosion on the signed trails corresponds to the higher use on these trails.

Erosion was compared between the 3 paired signed and unsigned trails, and signed trails produced an average of 57.3 g/m^2, compared to 28.0 g/m^2 from unsigned trails, and were not statistically different.

Previous studies show that ORV use increases erosion on dirt trails when compared to unused areas. A study in southern California found average soil loss on ORV trails to be 600 kg/m^2 (Stull *et al*., 1979). Another study in California's San Francisco area, found that ORV areas had large differences in erosion. The unused areas produced 17 kg/m^2 and 7 kg/m^2 on sandy and silty soils respectively, and 370 kg/m^2 and 1180 kg/m^2 on sandy and silty soils in the used areas (Wilshire *et al*., 1978). Both these studies resulted in much larger sediment yields than in the Trout Creek Watershed. Differences between studies could be due to climate, soil type, age of trails, or various sampling techniques. All of the studies found, measured the effects of ORVs on erosion, but none included BMPs in the evaluation.

Traps as a sampling technique to measure ORV trail erosion were effective, but were labor intensive. Traps needed to be checked following each storm, and maintenance due to vandalism was required between collections. A second limitation to traps is that traps were purposely placed in areas of likely runoff, and so it was not possible to average the erosion results across the trail. This resulted in an underestimate of sediment eroding from each trail.

There was no difference in mean TSS between the above and below ORV area samples. This indicates the signs were effective at maintaining water quality. However given the results of the observation and erosion studies, and the higher TSS from Missouri Gulch entering between the above and below samples, a more likely explanation is that instream effects were greater than the land-use effects. Another likely explanation is that the effects of the ORVs were not reaching the creek yet.

Unlike in Trout Creek, other studies did in fact measure differences in sediment concentration in creeks adjacent to ORV areas. A study conducted in southern California found, TSS at an unused area, a moderately used ORV area, and a heavily used ORV area, was 4, 5, and 721 tons of soil per square mile respectively, eroded each day (Griggs et al., 1981).

5.3 Culverts

Culverts are placed to drain road surfaces, however the channelized flow can cause downslope erosion. Sections of road along Rampart Range Road were compared to determine the effect of culverts on gully erosion. Sections with culverts had a larger average gully volume than road sections without culverts, 27 m^3 and 7 m^3 respectively.

Other studies have found an increase in road length does not necessarily result in increased erosion, however it is the combination of slope and length that causes erosion (Megahan *et al*., 2001; and Luce and Black, 1999). However, as these findings show, gully erosion was more a function of the presence of culverts, as there was an increase in erosion when compared both to length and slope. Comparable to this study, others have found that variability in erosion between road segments is typically high (Luce and Black, 1999).

Ten of the 17 gullies in areas with culverts connected to a channel, while 7 out of 14 gullies in areas with out culverts areas linked to a channel. One study found that gully connectivity below ditch relief culverts was significantly related to hillslope curvature, and downslope distance to the stream channel. They also found, using modeling, that 724 out of the 1447 ditch relief culverts were connected to the stream network (Lamarche and Lettenmaier, 2001).

5.4 Land-use and reference comparisons

Water quality samples can quantify land-use effects, however, it is difficult to separate in-stream processes from land-use causes. As well, the effects of some land-uses may not be seen in the creek for decades or longer. Measuring individual BMP effectiveness by above and below sampling showed no statistical differences. Water quality samples did show a significant difference between the land-use area and the reference area, both TSS and turbidity were lower in the reference area than in the land-use area. This water quality difference may be due to differences in the reference area compared to the land-use area. These differences include physical characteristics of the watersheds, flow regimes, sediment transport capacity, and probably different past land-uses. As well, the location of Manitou Lake Dam directly upstream of the land-use area changes the flow regime, and is a source of sediment since lake dredged sediments were disposed on the floodplain.

Comparison of water quality results to the state's standards for sediment are difficult because quantitative standards do not exist, and sediment varies greatly from to creek to creek, and storm to storm.

Wolman pebble counts were conducted and mean D_{50} was 6.6 mm in the land-use area and 8.6 mm in the reference area. The percent of streambed particles smaller than 8 mm in the land-use area was 55%, and 47% in the reference area. Wolman pebble counts may be misleading here because of the lack of riffles present, and a pool to riffle ratio may be a more appropriate measurement. In the land-use area and the reference area, sample size was limited to 20 due to the few number of riffles present to choose for measurement. This lack of riffles was because of the high density of beaver dams causing pools. As well, upon observation and crossing the creek at every eroded bank, the creek bottom was often sandy and silty, especially upstream of beaver dams.

The differences as measured by water quality and WPC's between the reference area and land-use area, prevents the direct evaluation of the BMPs and their effectiveness. The comparison is further compounded by the following factors.

5.5 Factors influencing sediment sources, transport, and deposition along Trout Creek

Drought

In 2002, the study area was experiencing a 60 year drought. The headwaters in the early summer began at the Woodland Park Golf Course, and at the end of the summer the headwaters were the downstream wastewater treatment plant. The lower flow may have the potential to increase the concentration of total suspended solids. This provided a great opportunity to document extreme circumstances, however the short term nature of the study during drought conditions may not be representative of typical water quality conditions.

Manitou Lake Dam

The Manitou Lake Dam was built in 1937, and normally traps all sediment moving down stream (Gary, 1985). In 2000 the dam was renovated, and approximately 50,000 cubic yards of sediment was removed from behind the dam. During the upgrade, the gates were lifted without permission and could not be closed again due to debris under the gates, releasing 5,000-6,000 cubic yards of sediment (Tapia, Pers. Comm., 2002, and Gallager, 2002). This amount was estimated by sediment volume and flow calculations, and trapped sediment removed from the beaver dams (Tapia Pers. Comm., 2002). Sediment released was detained in the first thirteen beaver dams, and emergency mitigation was put into place to control the transport of sediment and to remove the trapped sediment behind the beaver dams (Gallagher, 2000). This released sediment had the potential to affect the water quality in this study.

Beaver Dams

Trout Creek has optimal habitat for beaver, characterized by deposits of fine clay for dam building (Gurnell, 1998), a patchy riparian zone offering a range of vegetation, willow for food, soft soils (Hacker and Conblentz, 1993), and a low gradient (Howard and Larson, 1985). The cumulative effect of beaver dams on erosion and sediment transport is unknown, as they both cause and prevent erosion and sediment transport. Beavers can contribute to erosion by excavating canals and burrows (Gurnell, 1998), and by causing bank failure upstream or at dams edges (Figure 5-1) (Ruedemann and Schoonmaker, 1938). Another source of sediment is from dam failure, however this is rare and occurs on large dams storing a large volume of water (Gurnell, 1998). A potentially larger effect of beaver dams is they attenuate and inhibit sediment transfer, restore riparian habitat, and stabilize banks (Ruedemann and Schoonmaker, 1938). Evidence of this exists along Trout Creek, as mean TSS at locations 16 and 17 was lower that all upstream samples. Dams also decrease current velocity and shear stress on the channel bed and banks by attenuating stream flow energy (Hammerson, 1994, Gurnell, 1998).

A beaver dam inventory along Trout Creek was conducted to aid in the characterization of depositional zones and provide a reference for future studies. The beaver dam inventory took place on August 10th, 2002 and covered the distance from the waste water treatment plant (the headwaters of Trout Creek at the time of the inventory) to the confluence of Trout Creek and West Creek. Ten volunteers aided with the inventory covering 3 to 11 kilometers per team, counting dams, estimating dam height, width, and noting if the dam was broken, had signs of recent use, or had associated bank erosion. Landowner permission was gained and approximately 22 km were covered. Measuring the dimensions of the dam provided an estimate of sediment storage capacity as well as what may be released during a dam breaking flow event. Where the dam leaks can be an indicator of the age of the dam and if there is current beaver activity. Typically dams with water flowing over the top are active, dams with gapflow or underflow are older, and dams with throughflow are relic (Woo and Waddington, 1990).

Along the continuous 22 km walked, 344 beaver dams were present. Of these, 209 (61%) were in tact and trapped water and sediment. Of the total number of dams, 57 (17%) had new twigs visibly incorporated into the dams, and 17 (5%) had bank erosion at the dam edges (Figure 5-1). It was possible to identify where the water leaked on 137 dams, and of these, 19% leaked from the top, 73% of the dams leaked from the bottom and/or from gapflow, and 8% had through flow. Average dam height and length were 0.7 m and 13.0 m respectively (Table 5-1) (Appendix A8).

Figure 5-1. Bank erosion related to beaver dams. Trout Creek, CO. Summer 2002.

Table 5-1. Beaver dam inventory results. Trout Creek, CO. August 10th, 2002.

Total Beaver Dams	Average Height, m	Average Width, m	Total Unbroken Dams	Total number of dams that had new twigs incorporation	Total number of dams with erosion at edges	Total number of dams where leaking was observed
344	0.7	13.0	209 (61%)	57 (17%)	17 (5%)	137

Leaking from the top	Leaking from the bottom	Leaking from throughflow
19%	73%	8%

Fire

Adding to the complexity of the sediment problems in Trout Creek, from June 8th through July 2nd 2002, the Hayman Fire burned the lower portion of the watershed and reached Trout Creek just downstream of the land-uses in this study (USFS, 2004).

The Hayman Fire was the second to occur in the area that summer, following the Deckers Fire. By removing vegetation, creating a source of unstable debris, and causing a hydrophobic layer, fire has the potential to significantly increase turbidity and TSS in waterways. Fire also can increase flow and peak flows in receiving creeks causing an increase in channel scour (Tiedemann, 1979). These effects are consistent to the findings of this study, as TSS concentrations at location 17, above the confluence with the South Platte River, increased 80 times from 3 mg/L to 243 mg/L, and caused overland flow and road flooding (Figure 5-2). Location 16, above the confluence with West Creek was 7.5 mg/L before the fire and 67 mg/L after the fire. A comparable study found an increase in runoff and sediment yield relative to an undisturbed forest in the first year after a fire. Runoff was 500 times higher and sediment yield was 100,000 higher than at non burn areas (Inbar *et al*., 1998).

Figure 5-2. First storm event and runoff following the Hayman Fire. Photo taken in the West Creek Watershed, CO. July 4th, 2002.

6.0 CONCLUSIONS

The effectiveness of BMPs was measured using multiple techniques in the Trout Creek watershed. Cattle behavior was observed to characterize their use of the creek. Cows spent an average of 1.0 min/day in the creek, and 11.5 min/day on the banks. Fenced, unfenced, and control (ungrazed) pastures were measured for eroded bank area. The fenced pasture had 363 m^2/km, the unfenced pasture had 780 m^2/km, and the control pasture had 683 m^2/km. There was a significant difference ($p<0.03$) between the fenced pasture and the unfenced pasture, the control pasture and the fenced pasture ($p<0.0002$), and the control and the unfenced pasture ($p<0.0007$). TSS and turbidity samples were collected above and below each pasture, and were not statistically different ($p< 0.05$). These findings indicate that fences along creek channels to exclude cattle use is an effective BMP.

Signs discouraging use of illegally created ORV trails were measured for effectiveness using three techniques. ORV use was observed on illegal signed and illegal unsigned trails, and control (no ORV activity) areas. The illegal trails were used by 5.8% of the ORVs, of this signed trails were used by 3.4% of the ORVs, unsigned trail were used by 2.3% of the ORVs, and the control areas were never used. An average of 94.2% of the ORVs did not use the illegal trails. When comparing 3 paired signed and unsigned trails, use was higher on the signed trails, 4.6% and 2.3% respectively. Hillslope erosion from storm events was measured on all the trails and erosion was correlated with the use measurements, higher use had higher erosion. There was no statistical difference in mean TSS between above and below ORV activities. It is possible the effects of ORVs were not reaching the creek. The use and hillslope erosion results suggest signs are ineffective.

Road sections along Rampart Range Road were measured for volume of gully erosion originating from the road and below culverts. On average, sections with culverts had 27 m^3 of gully erosion, and 29 kg of erosion per m^2 of contributing road, and sections without culverts had 7 m^3 of gully erosion and 9 kg of erosion per m^2 of contributing road, and were not significantly different. These results suggest that culverts are not an effective BMP.

Effectiveness of BMPs using above and below water quality sampling could not be determined (no statistical differences). Comparing water quality at a larger scale between the land-use area and an upstream reference area did not provide insight as to overall water quality and combined BMP effectiveness. The reference area was not a good match to the land-use area because it had a narrower valley bottom, a different flow regime, and a different sediment transport capacity. Mean TSS in the land-use area was 33.7 mg/L and 12.8 mg/L in the reference area and significantly different ($p=0.02$). Wolman pebble counts were conducted in each area and mean D_{50} were 6.6 in the land-use area, and 8.6 mm in the reference area. 55% of the particles in the land-use area were smaller than 8 mm (the minimum particle size for suitable fish habitat), and 47% were smaller than 8 mm in the reference area.

This study took place during one field season, in unique conditions. The results of this study are partially a result of the dominant soil type in the area, the weather in

2002, and the confounding effects of the Manitou Lake dredging and modified streamflow.

In both the ORV area and the cattle pastures, use was positively related to hillslope and bank erosion. Use measurements were a simple, inexpensive technique to determine effectiveness. Measuring erosion at the ORV area, cattle pastures, and culvert areas, had the most direct link to the land-use and the associated effects. Erosion measurements required more time and training than the use measurements, and the hillslope erosion studies were dependent upon storm events. Water quality sampling has the potential to characterize stream health and link land-use effects with water quality, however in this study instream effects and other sources of sediment made it difficult to attribute TSS to a particular BMP. Determining BMP effectiveness is a function of the scale at which it is measured, the technique used, and the BMP.

7.0 RECOMMENDATIONS

There are two main areas in need of future study. The first is characterizing sediment sources and their relative contributions in Trout Creek, as this area is complex with its multiple land-uses and unique circumstances. The second area is in BMP development.

Sediment standards in Colorado require "state surface waters shall be free from substances attributable to human caused point source or nonpoint source discharge in amounts, concentrations or combinations which: can settle to form bottom deposits detrimental to the beneficial uses. Depositions are stream bottom build up of materials which include but are not limited to anaerobic sludges, mine slurry or tailings, silt, or mud" and "are harmful to the beneficial uses" (CDPHE, 2001). As observed in this study, there was a lack of riffles and often a silty stream bottom behind beaver dams. A pool to riffle study, and sediment volume measurements behind beaver dams would be valuable to characterize sediment deposition and storage in the creek. It is clear that cattle in unfenced pastures and ORVs are causing erosion, but to understand their relative contribution and focus management resources, a more thorough sediment budget in Trout Creek is recommended.

Recommended future studies for measuring BMP effectiveness include:
1) Conduct long-term studies that include a wide range of storm events, and land-use

characteristics.

2) This study quantified BMPs at multiple scales, but did not measure the beneficial uses. It would be valuable to measure BMP effectiveness by the creek's ability to support its beneficial uses.

3) Creating regressions between the results of the numerous techniques used in measuring BMP effectiveness would be an area for further research. This would have the potential to reduce the cost of monitoring.

5) Measure the effectiveness of other common BMPs using multiple techniques, as was done in this study for ORV signs, cattle fences, and road culverts.

6) Prioritize the land-uses and conditions where BMPs can have the biggest effect.

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APPENDIX

A1. Cattle Observation Data

A2. Eroded Bank Data

A3. Off Road Vehicle Trail Use Data

A4. Hillslope Erosion Data

A5. Culvert Data

A6. Water Quality Data

A7. Wolman Pebble Count Data

A8. Beaver Dam Inventory Data

A1. Cattle Observation Data

Activity Key:1)crossing creek 2) standing/walking 3)laying 4)grazing 5)drinking

Location: Trout Creek, Colorado South Trout Allotment, Treatment: No fence

Date: 5/22/2002 Start time: 12:09 PM End time: 5:00 PM

Average number of cattle observed: 50

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	12:09	12:12	3	2	1	12:11	5:00	169	3
1	12:30	12:33	3	2, 1	1	12:12	12:30	18	4
1	12:45	12:57	12	2	1	12:12	12:31	19	4
1	12:50	12:56	6	2	1	12:25	12:50	25	3
1	12:54	12:56	2	2	1	12:26	1:03	37	4
1	1:02	1:05	3		1	12:43	1:03	20	4
1	1:11	1:20	9	2, 1	1	12:45	12:57	12	4
1	1:20	1:24	4	2	1	12:48	12:57	9	4
1	1:20	1:22	2	2	1	1:05	1:10	5	4
1	1:23	1:26	3	2	1	1:05	1:10	5	4
1	1:23	1:26	3	2	1	1:07	1:09	2	4
1	2:07	2:14	7	2, 1	1	1:07	1:09	2	4
1	2:10	2:15	5	2	1	1:07	1:14	7	4
1	2:11	2:12	1	2	1	1:21	5:00	219	4
1	2:11	2:20	9	2, 1	1	1:21	5:00	219	4
1	2:24	2:27	3	2	1	1:26	1:50	24	4
1	2:23	2:40	7	2	1	1:26	1:50	24	4
1	2:49	3:00	11	2	1	1:51	1:55	4	4
1	2:49	3:00	11	2	1	1:54	5:00	186	4
1	2:49	2:57	8	2	1	1:55	2:30	35	4
1	2:50	2:57	7	2	1	2:00	5:00	180	3
1	3:00	3:05	5	2, 1	1	2:05	2:30	25	4
1	3:10	3:24	14	2	1	2:12	5:00	168	3
1	3:10	3:24	14	2	1	2:12	5:00	168	3
1	3:10	3:25	15	2	1	2:27	3:00	33	4
1	4:05	4:10	5	2	1	2:35	2:49	14	4
					1	2:35	2:49	14	4
					1	2:50	2:57	7	4
					1	2:50	3:00	10	4
					1	2:55	3:00	5	4
					1	2:55	3:00	5	4
					1	2:56	5:00	124	3
					1	3:00	3:22	22	4
					1	3:00	3:22	22	4
					1	3:05	3:27	22	4
					1	3:05	3:39	34	4
					1	3:05	3:44	39	4
					1	3:08	4:00	52	4
					1	3:10	4:07	57	4
					1	3:12	5:00	108	4
					1	3:44	5:00	76	4

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
					1	3:44	5:00	76	4
					1	4:10	5:00	50	4
					1	4:10	5:00	50	4

Date: 5/24/2002 Start time: 5:30 PM End time: 7:39 PM

Average number of cattle observed: 23

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	5:11	5:42	33	2 (lost track)	1	5:35	5:41	6	2
1	5:42	5:42	0	2(lost track)	1	5:35	5:50	15	2
1	5:43	5:48	5	2	1	5:35	5:50	15	2
1	5:43	6:00	17	2	1	5:35	6:01	26	2
1	6:13	6:13.5	0.5	1	1	5:35	6:11	36	2
1	6:14	6:14.5	0.5	1	1	5:35	6:11	36	2
1	6:20	6:21	1	5	1	5:57	6:14	17	2
1	6:31	6:31.5	0.5	1	1	5:57	6:14	17	
1	6:51	6:51.5	0.5	1	1	5:57	6:16	19	
1	7:11	7:12	1	1	1	6:03	6:16	13	
1	7:20	7:20.5	0.5	1	1	6:04	6:16	12	
					1	6:04	6:20	16	
					1	6:06	6:34	28	2
					1	6:18	6:37	19	4
					1	6:36	6:43	7	4
					1	6:43	6:58	15	4
					1	6:55	7:06	11	4
					1	6:55	7:06	11	4
					1	6:59	7:00	1	4
					1	7:20	7:21	1	2
					1	7:25	7:30	5	

Date: 5/25/2002 Start time: 7:30 AM End time: 12:30 PM

Average number of cattle observed: 15.6

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	7:40	07:40.5	0.5	1	1	7:46	7:58	12	4
1	7:40	07:40.5	0.5	1	1	7:51	8:14	23	4
1	7:41	07:41.5	0.5	1	1	8:10	8:14	4	
1	7:42	07:42.5	0.5	1	1	8:18	8:19	1	
1	7:42	07:42.5	0.5	1	1	8:21	8:22	1	
1	7:43	07:43.5	0.5	1	1	8:31	8:37	6	

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	7:43	07:43.5	0.5	1	1	8:40	8:51	11	4
1	7:44	07:44.5	0.5	1	1	8:57	9:14	17	
1	7:44	07:44.5	0.5	1	1	8:58	9:14	16	
1	7:45	07:45.5	0.5	1	1	9:02	9:14	12	
1	7:45	07:45.5	0.5	1	1	9:27	9:34	7	3
1	7:49	07:49.5	0.5	1	1	9:27	9:47	20	4
1	7:49	07:49.5	0.5	1	1	9:27	9:47	20	4
1	8:18	8:21	3	1	1	9:27	9:47	20	4
1	8:27	8:31	4		1	9:27	9:51	24	4
1	9:43	9:46	3	1, 2, 5	1	9:27	10:17	50	3
1	10:17	10:17.5	0.5	1	1	9:27	10:17	50	4
1	10:17	10:17.5	0.5	1	1	9:27	10:17	50	4
1	10:17	10:17.5	0.5	1	1	9:27	10:53	86	4
1	10:46	10:58	12	1, 2	1	9:27	10:54	87	4
1	10:48	10:50	2		1	9:29	10:54	85	4
1	10:55	10:57	2	2, 5	1	9:29	10:54	85	4
1	11:03	11:06	3		1	9:47	11:02	65	2
1	11:16	11:20	4		1	10:23	11:12	60	4
1	11:17	11:21	4		1	10:33	11:15	42	4, 3
1	11:27	11:27.5	0.5		1	10:33	11:33	60	4, 3
1	11:41	11:42	1	5	1	10:44	11:33	49	4, 3
1	12:05	12:07	2	5	1	10:44	11:33	49	4
1	12:24	12:24.5	0.5	1	1	11:07	11:40	33	4
					1	11:07	11:40	33	2, 4
					1	11:07	11:45	38	2, 4
					1	11:11	12:30	79	3
					1	11:16	12:30	84	3
					1	11:18	12:30	82	3
					1	11:34	12:30	56	3
					1	12:24	12:30	6	2

Date: 5/26/2002 Start time: 10:30 AM End time: 3:30 PM

Average number of cattle observed: 31

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	11:06	11:09	3	2	1	10:35	12:00	85	3
1	11:53	11:57	4	2, 1	1	10:35	12:00	85	3
1	11:53	12:05	12	2	1	10:35	11:00	25	4
1	11:56	12:12	16	2	1	10:35	11:18	43	3
1	12:00	12:12	12	2	1	10:35	11:35	60	3, 4
1	12:50	1:03	13	2	1	11:11	11:15	4	4
1	1:30	1:38	8	2	1	11:24	12:00	36	4
1	2:05	2:21	16	2, 1	1	11:29	12:00	31	4
1	2:41	2:50	9	2	1	11:54	12:12	18	4
1	2:58	3:00	2	2	1	11:55	12:17	22	4
					1	12:07	12:17	10	4

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
					1	12:14	12:30	16	4
					1	12:18	12:30	12	4
					1	12:50	lost track		4
					1	12:50	1:28	38	3
					1	12:50	1:20	30	3
					1	1:12	1:46	34	4
					1	1:15	1:30	15	4
					1	1:35	2:20	45	4
					1	1:58	2:22	24	4
					1	2:20	2:41	21	4
					1	2:20	2:41	21	4
					1	2:29	3:30	59	3
					1	2:29	3:30	59	3
					1	2:49	2:57	8	4
					1	2:58	lost track		4
					1	3:11	3:30	19	4
					1	3:11	3:30	19	4

Date: 5/27/2002 Start time: 7:00 AM End time: 12:00 PM

Average number of cattle observed: 34

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	7:40	7:56	16	2, 1	1	7:05	7:40	35	4
1	7:58	8:02	4	2, 1	1	7:20	8:04	44	4
1	7:58	8:00	2	2, 1	1	7:57	8:10	13	4
1	8:07	8:09	2	2, 1	1	7:57	8:10	13	4
1	8:09	8:13	4	2, 1	1	8:00	8:18	18	4
1	8:09	8:13	4	2	1	8:02	8:23	21	4
1	8:13	8:18	5	2	1	8:02	8:23	21	4
1	8:18	8:18	0.5	1	1	8:03	8:25	22	4
1	8:38	8:40	2	2	1	8:04	8:46	42	2, 4
1	8:47	8:47	0.5	1	1	8:07	8:33	26	4
1	8:50	8:55	5	2, 1	1	8:09	8:33	24	4
1	8:55	8:56	1	2, 1	1	8:11	8:26	15	4
1	8:59	9:01	2	2, 1	1	8:13	8:44	31	4
1	9:00	9:01	1	2	1	8:14	8:51	37	4
1	9:10	9:17	7	2	1	8:21	8:50	29	4
1	9:12	9:15	3	2, 1	1	8:21	8:55	34	4
1	9:16	9:18	2	2	1	8:22	9:05	43	4
1	9:24	9:26	2	2	1	8:34	9:03	29	4
1	9:26	9:26	0.5	1	1	8:41	9:10	29	4
1	9:45	9:45	0.5	1	1	8:43	9:22	21	4
1	9:50	9:54	4	2	1	8:49	9:23	26	4
1	9:50	9:54	4	2	1	8:57	9:25	28	4
1	10:00	10:03	3	2, 1	1	8:57	9:26	29	4

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	10:52	10:55	3	2	1	8:57	9:37	40	4
1	11:20	11:25	2	2	1	9:08	9:44	36	4
					1	9:10	9:46	36	4
					1	9:12	9:52	40	4
					1	9:20	9:51	31	4
					1	9:24	10:00	36	4
					1	9:24	10:00	36	4
					1	9:24	10:00	36	4
					1	9:25	10:10	45	4
					1	9:28	10:10	42	4
					1	9:29	10:10	41	4
					1	9:38	10:05	27	4
					1	9:39	10:05	26	4
					1	9:56	10:30	34	4
					1	10:02	10:53	51	4
					1	10:35	lost track		3, 4
					1	10:35	11:20	45	4
					1	10:53	11:20	27	4
					1	10:53	11:40	47	4
					1	11:14	12:00	46	4
					1	11:14	12:00	46	4
					1	11:39	12:00	21	4

Date: 5/29/2002 Start time: 1:58 PM End time: 6:00 PM

Average number of cattle observed: 38

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	2:00	2:03	3	2	1	2:00	2:07	7	4
1	2:03	2:05	2	2	1	2:00	2:07	7	4
1	2:15	2:30	15	2	1	2:00	2:11	11	3, 4
1	3:05	3:15	10	2	1	2:00	2:38	38	3
1	3:13	3:25	12	2	1	2:00	2:14	14	4
1	3:40	3:43	3	2, 1	1	2:01	3:04	3	4
					1	2:03	3:15	12	4
					1	2:28	3:18	10	4
					1	2:33	3:18	15	4
					1	3:05	3:25	20	4
					1	3:13	3:28	15	4
					1	3:19	3:50	31	4
					1	3:26	lost track		4
					1	3:50	lost track		4
					1	4:12	5:00	18	4
					1	4:12	5:00	18	4

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
					1	4:30	5:02	32	4
					1	4:42	4:50	8	4
					1	5:00	5:32	32	4
					1	5:00	6:00	60	4

Date: 5/31/2002 Start time: 1:30 PM End time: 7:00 PM

Average number of cattle observed: 45.6

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	2:50	2:51	1	1	1	1:40	1:44	3	
1	2:50	2:51	1	1	1	1:42	1:44	2	
1	2:51	2:52	1	1	1	1:53	1:54	1	4
1	2:52	2:52	1	1	1	1:53	2:16	23	4
1	3:28	3:31	3		1	3:10	3:22	12	4
1	3:30	3:36	6		1	3:25	3:31	6	4
1	3:30	3:36	6		1	3:30	3:31	1	4
1	3:31	3:36	5		1	3:31	3:55	24	4
1	3:33	3:36	3		1	3:36	3:55	19	4
1	3:39	3:50	11		1	3:40	3:55	15	4
1	3:46	3:51	5		1	3:40	3:55	15	4
1	3:46	3:53	7		1	3:40	3:55	15	4
1	4:19	4:20	1		1	3:40	3:55	15	4
1	4:26	4:28	2		1	3:45	3:55	10	4
1	4:29	4:31	2	5	1	3:45	4:14	29	4
1	4:33	4:33	1		1	4:05	4:14	9	4
1	4:36	4:39	3		1	4:05	4:14	9	4
1	4:41	04:41.5	0.5	1	1	4:10	4:15	5	4
1	4:45	04:45.5	0.5	1	1	4:10	4:15	5	4
1	4:45	4:47	2		1	4:12	4:16	4	4
1	4:47	4:50	3		1	4:12	4:33	21	4
1	4:49	4:53	4		1	4:20	4:43	23	4
1	4:50	4:53	3		1	4:28	4:53	25	4
1	5:01	5:02	1	1	1	4:28	4:53	25	4
1	5:02	5:05	3		1	4:31	4:53	22	4
1	5:08	5:09	1		1	4:38	4:53	15	4
1	5:09	5:12	3	1	1	4:54	5:02	8	4
1	5:09	5:14	5		1	4:57	5:12	15	4
1	5:10	5:14	4		1	5:01	5:20	19	4
1	5:11	5:16	5		1	5:01	5:38	37	4
1	5:14	5:17	3		1	5:01	5:38	37	4
1	5:18	5:22	4	5	1	5:15	5:38	23	4
1	5:24	5:26	2		1	5:15	5:38	23	4
1	5:26	05:26.5	0.5	1	1	5:15	5:38	23	4
1	5:28	5:30	2	1	1	5:22	5:40	18	4
1	5:32	05:23.5	0.5	1	1	5:23	5:48	25	4
1	5:32	5:33	1	1	1	5:23	5:54	31	4

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	5:36	5:40	4	5	1	5:23	6:03	40	4
1	5:41	05:41.5	0.5	1	1	5:28	6:05	37	4
1	5:41	5:42	1	1	1	5:43	6:11	28	4
1	5:44	6:25	39	1	1	5:43	6:11	28	4
1	5:51	5:53	2	5	1	5:58	6:28	30	4
1	5:59	6:00	1	5	1	6:16	6:29	13	4
1	6:16	6:17	1	5	1	6:16	6:38	22	4
1	6:19	6:20	1	5	1	6:16	6:42	26	4
1	6:22	06:22.5	0.5	5	1	6:18	6:51	33	4
1	6:22	6:24	2		1	6:18	7:00	42	4
1	6:24	6:25	1	5	1	6:25	7:00	35	2, 4
1	6:24	6:29	5	1	1	6:32	7:00	28	4
1	6:35	6:37	2		1	6:40	7:00	20	4
					1	6:42	7:00	18	4

Date: 6/2/2002 Start time: 5:40 AM End time: 7:00 AM

Average number of cattle observed: 13.3

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	5:53	6:01	8	2, 5	1	5:48	6:13	25	4
1	6:00	6:02	2		1	5:49	6:13	24	4
1	6:06	6:06*5	0.5	1	1	5:49	6:13	24	4
1	6:07	6:09	2		1	5:53	6:13	20	4
1	6:13	6:15	2		1	6:02	6:26	24	4
1	6:19	6:21	2		1	6:20	6:34	14	4
1	6:21	6:23	2		1	6:20	6:34	14	4
1	6:36	6:36*5	0.5	1	1	6:20	6:34	14	4
1	6:38	6:38*5	0.5	1	1	6:29	6:40	11	4
1	6:44	6:44*5	0.5	1	1	6:37	6:45	8	4
1	6:47	6:48	1	1, 5	1	6:39	6:52	13	4
					1	6:48	6:56	8	4
					1	6:48	6:56	8	4
					1	6:49	6:56	7	
					1	6:49	6:56	7	
					1	6:49	7:00	11	

Date: 6/3/2002 Start time: 5:40 AM End time: 7:00 AM

Average number of cattle observed: 20.6

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	5:40	5:41	1	5	1	5:40	6:02	22	4
1	6:10	6:13	3	4	1	5:53	6:04	11	4
1	6:21	6:23	2		1	5:55	6:32	37	4
1	6:23	6:25	2		1	6:10	6:32	22	4
1	6:43	6:49	6		1	6:18	6:32	14	4
1	6:48	6:49	1		1	6:34	6:39	5	4
1	6:49	6:51	2		1	6:35	6:39	4	4
1	6:52	6:53	1		1	6:37	7:00	23	4
					1	6:42	7:00	18	2
					1	6:43	7:00	17	4
					1	6:49	7:00	11	4
					1	6:49	7:00	11	4

Date: 6/6/2002 Start time: 6:00 PM End time: 7:30 PM

Average number of cattle observed: 17.6

# in stream	Time in	Time out	Total time, minutes	Activity	# on bank	Time on	Time off	Total time, minutes	Activity
1	6:03	6:05	2	5	1	6:00	6:12	12	4
1	6:11	6:14	3	5	1	6:00	6:12	12	4
1	6:16	6:18	2	5	1	6:00	6:14	14	4
1	6:21	6:22*5	0.5	1	1	6:00	6:24	24	4
1	6:21	6:26	5	1, 2	1	6:03	6:24	21	4
1	6:38	6:39	1	5	1	6:03	6:24	21	4
1	6:44	6:46	2	5	1	6:10	6:24	14	4
1	6:47	6:47*5	0.5	5	1	6:10	6:28	18	4
1	6:51	6:52	1		1	6:16	6:28	12	4
1	7:02	7:03	1	5	1	6:18	6:33	15	2
					1	6:18	6:33	15	4
					1	6:27	6:40	13	4
					1	6:27	6:46	19	4
					1	6:27	6:46	19	4
					1	6:36	6:58	22	4
					1	6:36	6:58	22	4
					1	6:42	6:58	16	4
					1	6:44	7:06	22	4
					1	6:44	7:11	27	3, 4
					1	7:01	7:11	10	2
					1	7:02	7:11	9	4
					1	7:05	7:19	14	4
					1	7:10	7:19	9	4
					1	7:16	7:27	11	4
					1	7:18	7:30	12	
					1	7:21	7:30	9	4

A2. Eroded Bank Data

Fenced Manitou Lake Pasture in the Trout Creek Watershed
Date: 7/23/02 through 8/6/02 Crew: Teves, Herzog, and Martinelli

S = Sloughing less than 1m wide, T = Animal Trail less than 1m wide
LW = Exposed bank due to low water (numbers were not included in calculations), * = estimate

Bank length walked, m	Eroded bank #	Eroded bank length, m	Total length of eroded bank, m	% Exposed surface	Total eroded bank width, m	Mean eroded bank width, m	m^2 of eroded bank	Bank shape	Type of erosion	Is erosion at the edge of a beaver dam?
50	1	0-2	2	76-100	0.4	0.13	0.27	vertical	sloughing/ undercut	no
	2	11.5-13	1.5	76-100	0.9	0.30	0.45	vertical	sloughing/ undercut	no
	S	16.4-16.8	0.4	76-100	1.5	0.50	0.20	outslope	sloughing	no
	3	21-23	2	76-100	0.9	0.30	0.60	vertical	sloughing/ undercut	no
	4	28-34	6	76-100	2.1	0.70	4.20	vertical/ 10%outslope	toppling/ sloughing	no
	S	34.5-35	0.5	76-100	1.2	0.40	0.20	vertical	sloughing	no
	S	44.3-44.9	0.6	76-100	0.6	0.20	0.12	vertical	sloughing	no
1.6	5	48-51.6	3.6	51-75	0.7	0.23	0.84	vertical	sloughing	no
50	6	5.5-8.8	3.3	76-100	3.6	1.20	3.96	outslope/ 10%vertical	50%sloughing/ 50%trampling	no
	7	10.3-13	2.7	76-100	2	0.67	1.80	vertical	toppling/undercut	no
	8	23.7-31	7.3	26-50	2.6	0.87	6.33	outslope	sloughing	no
	9	32.7-37.1	4.4	51-75	2.8	0.93	4.11	outslope	sloughing/ 10%trampling	no
	10	44.4-47	2.6	0-26	1.8	0.60	1.56	outslope	sloughing	no
	11	46.8-49.3	2.5	0-26	0.5	0.17	0.42	outslope	sloughing	no
50	12	4.7-17	12.3	0-26	2.3	0.77	9.43	vertical/ concave	sloughing	no
50					0	0.00	0.00			
50	13	31.5-36	4.5	76-100	1.2	0.40	1.80	overhang	toppling	no
13	14	36.5-63.5	27	76-100	4.6	1.53	41.40	vert/10%out	sloughing/toppling	no

Bank length walked, m	Eroded bank #	Eroded bank length, m	Total length of eroded bank, m	% Exposed surface	Total eroded bank width, m	Mean eroded bank width, m	m^2 of eroded bank	Bank shape	Type of erosion	Is erosion at the edge of a beaver dam?
50	S	2.2-2.6	0.4	76-100	1.3	0.43	0.17	outslope	sloughing	no
	15	8.4-48.5	40.1	51-75	4.7	1.57	62.82	vertical/conc	sloughing/toppling	no
	16	0-21	21	76-100	3.4	1.13	23.80	60%vertical/ 40%outslope	40%sloughing/ 60%toppling	no
	17	31-38	7	26-50	4.9	1.63	11.43	vertical/ concave	toppling	no
9	18	41-59	18	76-100	5.5	1.83	33.00	overhang, vert-conc	toppling	no
	19	15.5-18.1	2.6	0-25	2.5	0.83	2.17	outslope	sloughing	no
	20	20.7-46.1	25.4	51-75	4.9	1.63	41.49	outslope/ vertical/ concave	sloughing/toppling	no
50	21	1.7-11.3	9.6	26-50	1.7	0.57	5.44	outslope, topling- overhang	sloughing	30%
	S	15-15.6	0.6	76-100	0.9	0.30	0.18	vertical	sloughing	no
	22	18-20.3	2.3	76-100	2.9	0.97	2.22	outslope	sloughing	no
	23	22.2-44.2	22	26-50	1.5	0.50	11.00	outslope	sloughing	no
50	24	31.8-35.2	3.4	76-100	0.9	0.30	1.02	vertical/ 10%outslope	sloughing/ trampling	no
	25	41.6-44.3	2.7	50-75	1	0.33	0.90	outslope	trampling	no
	26	14.3-17	2.7	26-50	1.2	0.40	1.08	vertical/ concave	sloughing	no
20.4	27	23.8-70.4	46.6	76-100	3.8	1.27	59.03	20%vertical/ 80%concave	toppling/sloughing	no
50	28	7.2-31	23.8	26-50	5.2	1.73	41.25	20%outslope/ 40%vertical/ 40%concave	sloughing/toppling	no
	29	44.5-46.7	2.2	26-50	0.8	0.27	0.59	outslope	trampling	no
50	30	7-12m	5	76-100	1.4	0.47	2.33	outslope	sloughing	no
	31	30-38.3	8.3	50-75	3.7	1.23	10.24	top overhang/ outslope	sloughing	no

Bank length walked, m	Eroded bank #	Eroded bank length, m	Total length of eroded bank, m	% Exposed surface	Total eroded bank width, m	Mean eroded bank width, m	m^2 of eroded bank	Bank shape	Type of erosion	Is erosion at the edge of a beaver dam?
	S	44.6-45.6	1	76-100	2.7	0.90	0.90	outslope	deposition	no
50	32	0-4.7	4.7	50-75	5.1	1.70	7.99	vertical/conc	sloughing/toppling	no
	33	9.1-13.6	4.5	76-100	6.6	2.20	9.90	vertical/conc	sloughing/toppling	no
	34	19.6-22.2	2.6	50-75	5.7	1.90	4.94	vertical/ concave	sloughing/toppling	no
	35	37-39.6	2.6	76-100	1.4	0.47	1.21	outslope	LW/sloughing	no
11.5	36	46-61.5	15.5	76-100	7.7	2.57	39.78	vertical	toppling	70%
50	37	.5-11.3	10.8	26-50	2.2	0.73	7.92	vertical/ overhang/ 10%outslope	toppling/ 10%sloughing	no
	T	29-29.7	0.7	76-100	1	0.33	0.23	outslope	trampling	no
46	38	45.6-96	50.4	76-100	3.5	1.17	58.80	outslope	sloughing	no
50	39	3.7-8.5	4.8	0-25	0.8	0.27	1.28	outslope	sloughing	no
50	S	48-48.8	0.8	76-100	1.15	0.38	0.31	outslope	sloughing	no
50	40	5.3-9.2	3.9	26-50	1.8	0.60	2.34	outslope	sloughing	no
50	41	19.3-24	4.7	0-25	1.7	0.57	2.66	vertical/ concave	toppling	no
50					0	0.00				
50	42	13-15.5	2.5	76-100	1	0.33	0.83	outslope	sloughing	no
	43	18.5-22.5	4	76-100	2	0.67	2.67	outslope	sloughing	no
50	No Erosion									
50	No Erosion									
50	44	30.3-32.5	2.2	76-100	1	0.33	0.73	vertical/ 20%outslope	LW	no
	S	45-45.9	0.9	76-100	0.8	0.27	0.24	vertical/ concave	sloughing/LW	no
50	No Erosion									
2	No Erosion									
50	45	3-4.5	1.5	76-100	2.6	0.87	1.30	outslope	anthill	no
	S	13.6-14.5	0.9	76-100	0.8	0.27	0.24	vertical	sloughing	no
	S	16.9-17.6	0.7	76-100	0.6	0.20	0.14	vertical	sloughing	no

Bank length walked, m	Eroded bank #	Eroded bank length, m	Total length of eroded bank, m	% Exposed surface	Total eroded bank width, m	Mean eroded bank width, m	m^2 of eroded bank	Bank shape	Type of erosion	Is erosion at the edge of a beaver dam?
	46	21.8-24	2.2	76-100	0.8	0.27	0.59	vertical/ overhang	sloughing	no
	S	36.3-37	0.7	76-100	1	0.33	0.23	vertical/ overhang	sloughing	no
	S	38.2-38.9	0.7	51-75	0.6	0.20	0.14	vertical/conc	sloughing	no
50	47	6.5-10.7	4.2	0-25	0.6	0.20	0.84	outslope	sloughing/ trampling	no
	S	15-15.9	0.9	76-100	2	0.67	0.60	vertical	sloughing	no
	48	19.8-25.6	5.8	0-25	1.5	0.50	2.90	outslope	sloughing	no
4.8	49	27.7-54.8	27.1	51-75	4.3	1.43	38.84	vertical/ concave	toppling/sloughing	no
50	T	4.2-4.9	0.7	26-50	0.7	0.23	0.16	outslope	trampling	no
	S	23-23.7	0.7	26-50	1.5	0.50	0.35	vertical/ concave	sloughing	no
	50	27.4-38	10.6	76-100	4	1.33	14.13	vertical/ concave	sloughing	no
51	51	7.4-51	43.6	76-100	6.3	2.10	91.56	outslope/ top overhang	sloughing	no
50	52	8-11m	3	26-50	3.2	1.07	3.20	outslope	sloughing	no
	53	13.1-18.2	5.1	0-25	2.1	0.70	3.57	outslope	sloughing	no
	54	23.8-35.6	11.8	0-25	1.1	0.37	4.33	outslope	sloughing	no
50	S	13.8-14.2	0.4	76-100	1.4	0.47	0.19	outslope	sloughing	no
	T	35.7-36	0.3	0-25	0.4	0.13	0.04	outslope	trampling	no
	T	36.6-37.2	0.6	26-50	1.3	0.43	0.26	outslope	trampling/ sloughing	no
	S	40-40.6	0.6	76-100	1.5	0.50	0.30	outslope	sloughing	no
	S	44.1-44.6	0.5	76-100	0.7	0.23	0.12	vertical	sloughing	no
2.4	55	47.9-52.4	4.5	0-25	1.4	0.47	2.10	outslope	sloughing/ trampling	no
50	56	.5-4.8	4.3	26-50	0.7	0.23	1.00	outslope	sloughing/ trampling	no
	T	39.9-40.3	0.4	76-100	1.9	0.63	0.25	outslope	trampling/LW	no

Bank length walked, m	Eroded bank #	Eroded bank length, m	Total length of eroded bank, m	% Exposed surface	Total eroded bank width, m	Mean eroded bank width, m	m^2 of eroded bank	Bank shape	Type of erosion	Is erosion at the edge of a beaver dam?
	S	42.3-42.7	0.4	76-100	0.8	0.27	0.11	outslope	trampling/LW	no
	S	44.1-44.2	0.1	76-100	1	0.33	0.03	outslope	trampling/LW	no
	T	48-48.3	0.3	76-100	1.1	0.37	0.11	outslope	trampling	no
33.4	57	49.5-83.4	33.9	76-100	4.2	1.40	47.46	vertical/ concave	toppling/sloughing	no
50	No Erosion				0	0.00				
50	T	6.1-6.5	0.4	26-50	0.5	0.17	0.07	outslope	trampling	no
50	58	24.7-37.3	12.6	76-100	1.3	0.43	5.46	vertical	sloughing	no
	S	39.7-40.1	0.4	76-100	0.7	0.23	0.09	vertical	sloughing	no
	S	6.7-7	0.3	26-50	0.8	0.27	0.08	outslope	sloughing/ trampling	no
	S	9.4-10.1	0.7	76-100	0.4	0.13	0.09	vertical	sloughing	no
	59	12.9-16.5	3.6	51-75	0.9	0.30	1.08	outslope	sloughing/ 10%trampling	no
	60	17.7-21.3	3.6	76-100	1.8	0.60	2.16	vertical/ overhang	sloughing	no
	61	21.8-49.4	27.6	51-75	2	0.67	18.40	vertical/ concave/ overhang	sloughing	no
50	62	1-3.7	2.7	26-50	0.9	0.30	0.81	vertical	sloughing/toppling	no
	S	4.2-4.6	0.4	51-75	0.8	0.27	0.11	vertical/ concave/ overhang	sloughing	no
	S	5-5.5	0.5	0-25	1.2	0.40	0.20	outslope	sloughing	no
50	S	15-15.9	0.9	76-100	0.5	0.17	0.15	outslope	sloughing	no
	T	24-24.2	0.2	26-50	0.7	0.23	0.05	outslope	trampling	no
	S	28.6-29.6	1	76-100	1	0.33	0.33	vertical	sloughing	no
	63	30-33.3	3.3	0-25	0.7	0.23	0.77	outslope	sloughing	no
50	S	31.2-31.4	0.2	76-100	0.4	0.13	0.03	vertical	sloughing	no
	S	33.8-34.3	0.5	0-25	0.3	0.10	0.05	outslope	sloughing	no
	S	36-36.3	0.3	76-100	1.4	0.47	0.14	outslope	sloughing	no

Bank length walked, m	Eroded bank #	Eroded bank length, m	Total length of eroded bank, m	% Exposed surface	Total eroded bank width, m	Mean eroded bank width, m	m^2 of eroded bank	Bank shape	Type of erosion	Is erosion at the edge of a beaver dam?
	S	37.2-37.7	0.5	51-75	1.3	0.43	0.22	vertical/conc	sloughing	no
	64	41-49.4	8.4	26-50	1.9	0.63	5.32	vertical/conc	sloughing	no
	S	.8-1.6	0.8	0-25	0.4	0.13	0.11	outslope	sloughing	no
	T	7.4-7.9	0.5	76-100	3.1	1.03	0.52	outslope	trampling	no
	S	15.9-16.4	0.5	76-100	1.3	0.43	0.22	vertical/ concave	sloughing	no
50	65	33.2-36.5	3.3	51-75	3.9	1.30	4.29	outslope/ vertical/ concave	sloughing	no
17.7	66	40-67.7	27.7	25-50	3.8	1.27	35.09	outslope/ 10%vertical/ concave	sloughing	no
50	67	5.6-20.3	14.7	76-100	2.3	0.77	11.27	vertical/ overhang	toppling	no
50	68	9.5-39	29.5	76-100	1.6	0.53	15.73	vertical/ 40%outslope	70%toppling/ 10%rill/ 20%sloughing	no
50	69	2.2-8.7	6.5	76-100	3.5	1.17	7.58	vertical/ concave/ overhang	toppling	no
	70	9.5-12	2.5	76-100	3.3	1.10	2.75	vertical	toppling	no
	71	13-16	3	76-100	1.3	0.43	1.30	overhang	toppling	yes
	72	17.5-22.4	4.9	76-100	1.1	0.37	1.80	vertical	sediment pile	no
	73	23.2-24.7	1.5	76-100	1.3	0.43	0.65	vertical	sediment pile	no
	S	26.1-27	0.9	51-75	0.7	0.23	0.21	overhang	toppling	no
	74	27-42	15	26-50	1.9	0.63	9.50	vertical/ concave	toppling/sloughing dirt pile	no
	S	44.7-45.3	0.6	76-100	1.1	0.37	0.22	vertical/ concave	sloughing	no
	75	47.5-49.5	2	0-25	1.3	0.43	0.87	vertical/ overhang	toppling/sloughing	no
50	76	6.5-17.5	11	26-50	2.2	0.73	8.07	vertical/conc	toppling/dirt pile	no

Bank length walked, m	Eroded bank #	Eroded bank length, m	Total length of eroded bank, m	% Exposed surface	Total eroded bank width, m	Mean eroded bank width, m	m^2 of eroded bank	Bank shape	Type of erosion	Is erosion at the edge of a beaver dam?
	S	18.7-19.2	0.5	76-100	2.6	0.87	0.43	outslope	sloughing	no
	S	20.2-20.8	0.6	76-100	1.5	0.50	0.30	vertical/conc	sloughing	no
	77	21.8-24.2	2.4	0-25	3.2	1.07	2.56	outslope/ vertical	50%toppling/ dirt pile	no
50	No Erosion									
50	S	40-40.4	0.4		3.5	1.17	0.47	outslope	sloughing	no
50	No Erosion									
50	No Erosion									
50	No Erosion									
	78	20.9-22.7	1.8	76-100	2.9	0.97	1.74	outslope	sloughing	no
	79	40.2-42.7	2.5	76-100	0.3	0.10	0.25	vertical	LW	no
	S	46.7-47.1	0.4	0-25	0.3	0.10	0.04	vertical	exposed roots	no
	80	48.2-49.9	1.7	26-50	1.1	0.37	0.62	vertical	sloughing	no
37	No Erosion									

A3. Off-Road Vehicle Trail Use Data

Location: Rainbow Falls Park, Trout Creek Colorado

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 1	6/1/2002	11:00-1:00	17	0
Signed Trail 2	6/1/2002	11:00-1:00	17	0
Signed Trail 3	6/1/2002	11:00-1:00	17	0
Signed Trail 4	6/1/2002	11:00-1:00	17	0
Signed Trail 5	6/1/2002	11:00-1:00	17	0
Signed Trail 6	6/1/2002	11:00-1:00	17	0
Signed Trail 7	6/1/2002	3:03-5:03	16	1
Signed Trail 8	6/1/2002	3:03-5:03	16	0
Unsigned Trail 2	6/1/2002	1:01-3:01	30	0
Unsigned Trail 5	6/1/2002	1:01-3:01	30	1
Unsigned Trail 7	6/1/2002	1:01-3:01	30	1

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 1	6/2/2002	12:10-2:10	34	0
Signed Trail 2	6/2/2002	12:10-2:10	34	5
Signed Trail 3	6/2/2002	12:10-2:10	34	3
Signed Trail 4	6/2/2002	12:10-2:10	34	0
Signed Trail 5	6/2/2002	12:10-2:10	34	1
Signed Trail 6	6/2/2002	12:10-2:10	34	0
Signed Trail 7	6/2/2002	10:05-12:05	27	2
Signed Trail 8	6/2/2002	10:05-12:05	27	0
Unsigned Trail 2	6/2/2002	2:15-4:15	26	0
Unsigned Trail 5	6/2/2002	2:15-4:15	26	0
Unsigned Trail 7	6/2/2002	2:15-4:15	26	0

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 1	6/9/2002	3:30-5:30	11	0
Signed Trail 2	6/9/2002	3:30-5:30	11	0
Signed Trail 3	6/9/2002	3:30-5:30	11	0
Signed Trail 4	6/9/2002	3:30-5:30	11	3
Signed Trail 5	6/9/2002	3:30-5:30	11	0
Signed Trail 6	6/9/2002	3:30-5:30	11	2
Signed Trail 7	6/9/2002	1:30-3:30	15	1
Signed Trail 8	6/9/2002	1:30-3:30	15	0
Unsigned Trail 2	6/9/2002	11:30-1:30	22	0
Unsigned Trail 5	6/9/2002	11:30-1:30	22	0
Unsigned Trail 7	6/9/2002	11:30-1:30	22	0

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 7	7/27/2002	9:30-12:30	21	2
Signed Trail 8	7/27/2002	9:30-12:30	21	0
Unsigned Trail 2	7/27/2002	12:42-3:30	6	0
Unsigned Trail 5	7/27/2002	12:42-3:30	6	1
Unsigned Trail 7	7/27/2002	12:42-3:30	6	1

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 7	7/28/2002	1:10-4	27	1
Signed Trail 8	7/28/2002	1:10-4	27	0
Unsigned Trail 2	7/28/2002	10:06-1:03	8	0
Unsigned Trail 5	7/28/2002	10:06-1:03	8	0
Unsigned Trail 7	7/28/2002	10:06-1:03	8	0

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 7	8/3/2002	8:32-11:32	41	0
Signed Trail 8	8/3/2002	8:32-11:32	41	0
Unsigned Trail 2	8/3/2002	11:40-1:45	38	2
Unsigned Trail 5	8/3/2002	11:40-1:45	38	0
Unsigned Trail 7	8/3/2002	11:40-1:45	38	6

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 7	8/4/2002	12:35-2	24	1
Signed Trail 8	8/4/2002	12:35-2	24	0
Unsigned Trail 2	8/4/2002	9:30-12:25	13	0
Unsigned Trail 5	8/4/2002	9:30-12:25	13	0
Unsigned Trail 7	8/4/2002	9:30-12:25	13	0

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 7	8/11/2002	10:05-1:02	28	1
Signed Trail 8	8/11/2002	10:05-1:02	28	0
Unsigned Trail 2	8/11/2002	1:08-4:02	18	2
Unsigned Trail 5	8/11/2002	1:08-4:02	18	0
Unsigned Trail 7	8/11/2002	1:08-4:02	18	2

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 7	8/18/2002	12:05-3:05	46	0
Signed Trail 8	8/18/2002	12:05-3:05	46	0
Unsigned Trail 2	8/18/2002	9-12	41	0
Unsigned Trail 5	8/18/2002	9-12	41	0
Unsigned Trail 7	8/18/2002	9-12	41	0

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 7	8/24/2002	12:57-6:05	36	1
Signed Trail 8	8/24/2002	12:57-6:05	36	2
Unsigned Trail 2	8/24/2002	12:44-5:44	47	0
Unsigned Trail 5	8/24/2002	12:44-5:44	47	0
Unsigned Trail 7	8/24/2002	12:44-5:44	47	0

Trail #	Date	Time	Total # of ORVs	# used trails
Signed Trail 7	8/25/2002	5:12-8	56	4
Signed Trail 8	8/25/2002	5:12-8	56	0
Unsigned Trail 2	8/25/2002	2:49-5:10	38	2
Unsigned Trail 5	8/25/2002	2:49-5:10	38	0
Unsigned Trail 7	8/25/2002	2:49-5:10	38	2

A4. Hillslope Erosion

Location: Rainbow Falls Park, Trout Creek Colorado
*BMP = signed trails, ILL = unsigned trails, C = control areas

Signed Trails

Sample	Storm Date	Sample weight, grams	Sample	Storm Date	Sample weight, grams
BMP 2, T1	5/17/2002	5.937	BMP 4, T1	6/4/2002	2111.9
BMP 2, T1	5/17/2002	10.849	BMP 4, T2	6/4/2002	174.12
BMP 3, T1	5/17/2002	2.739	BMP 5, T1	6/4/2002	174.443
BMP 3, T2	5/17/2002	198.812	BMP 5, T2	6/4/2002	410.37
BMP 4, T1	5/17/2002	1.145	BMP 6, T1	6/4/2002	4.911
BMP 4, T2	5/17/2002	1.446	BMP 6, T2	6/4/2002	201.736
BMP 5, T1	5/17/2002	1.334	BMP 7, T1	6/4/2002	25.34
BMP 5, T2	5/17/2002	2.21	BMP 7, T2	6/4/2002	3253.98
BMP 6, T1	5/17/2002	2.904	BMP 8, T1	6/4/2002	4479.75
BMP 6,. T2	5/17/2002	11.076	BMP 8, T1	6/4/2002	2177.5
BMP 7, T1	5/17/2002	3.209	BMP 8, T2	6/4/2002	5457
BMP 7, T2	5/17/2002	327.55	BMP 2, T1	6/8/2002	4.621
BMP 7, T2	5/17/2002	10.29	BMP 2, T2	6/8/2002	1.544
BMP 7, T2	5/17/2002	390.86	BMP 3, T1	6/8/2002	97.766
BMP 7, T2	5/17/2002	117.2	BMP 3, T2	6/8/2002	77.841
BMP 8, T1	5/17/2002	1.149	BMP 4, T1	6/8/2002	3.013
BMP 8, T2	5/17/2002	6.965	BMP 5, T2	6/8/2002	15.624
BMP 1, T1	8/28/2002	7.63	BMP 6, T2	6/8/2002	29.185
BMP 1, T2	8/28/2002	0.28	BMP 7, T1	6/8/2002	7.663
BMP 3, T1	8/28/2003	28.845	BMP 7, T2	6/8/2002	9.908
BMP 3, T2	8/28/2002	23.7	BMP 8, T1	6/8/2002	241.64
BMP 4, T1	8/28/2002	2.648	BMP 8, T2	6/8/2002	21.467
BMP 4, T2	8/28/2002	7.61	BMP 1, T1	7/7/2002	0.14
BMP 6, T1	8/28/2002	6.911	BMP 2, T1	7/7/2002	2.54
BMP 6, T2	8/28/2002	8.36	BMP 2, T2	7/7/2002	178.63
BMP 3, T1	5/23/2002	60.965	BMP 3, T1	7/7/2002	2.48
BMP 3, T1	5/26/2003	129.843	BMP 3, T2	7/7/2002	2.85
BMP 3, T2	5/26/2003	0.377	BMP 4, T1	7/7/2002	10.11
BMP 6, T2	5/26/2003	2.272	BMP 4, T2	7/7/2002	0.03
BMP 7, T1	5/26/2003	19.359	BMP 5, T1	7/7/2002	0.5
BMP 7, T2	5/26/2003	1.281	BMP 5, T2	7/7/2002	0.2
BMP 8, T2	5/26/2003	7.449	BMP 6, T1	7/7/2002	6.97
BMP 2, T1	8/26/2002	24.74	BMP 6, T2	7/7/2002	0.49
BMP 2, T2	8/26/2002	89.8	BMP 7, T1	7/7/2002	0.41
BMP 5, T1	8/26/2002	12.767	BMP 7, T2	7/7/2002	47.9
BMP 5, T2	8/26/2002	5.95	BMP 8, T1	7/7/2002	0.55
BMP 2, T1	6/4/2002	4337.18	BMP 8, T2	7/7/2002	22.71
BMP 2, T1	6/4/2002	3015.93	BMP 2, T1	7/11/2002	21.12
BMP 2, T2	6/4/2002	2879.3	BMP 2, T2	7/11/2002	15.59
BMP 3, T1	6/4/2002	1787.8	BMP 3, T1	7/11/2002	19.33
BMP 3, T2	6/4/2002	213.61	BMP 3, T2	7/11/2002	19.348
BMP 3, T2	6/4/2002	266.743	BMP 4, T1	7/11/2002	0.7
BMP 3, T2	6/4/2002	254.852	BMP 4, T2	7/11/2002	4.57

Sample	Storm Date	Sample weight, grams
BMP 5, T2	7/11/2002	5.64
BMP 6, T1	7/11/2002	4.91
BMP 6, T2	7/11/2002	7.21
BMP 7, T1	7/11/2002	24.62
BMP 7, T2	7/11/2002	84.24
BMP 8, T1	7/11/2002	10.32
BMP 8, T2	7/11/2002	1.78
BMP 7, T1	7/22/2002	6.68
BMP 7, T2	7/22/2002	13.31
BMP 2, T1, T2	7/26/2002	8.83
BMP 3, T1, T2	7/26/2002	25.31
BMP 4, T1, T2	7/26/2002	12.49
BMP 5, T1, T2	7/26/2002	5.92
BMP 6, T1, T2	7/26/2002	4.7
BMP 6, T2	8/4/2002	5.511
BMP 8, T1	8/4/2002	0.46
BMP 1, T1	8/5/2002	3.11
BMP 2, T1	8/5/2002	0.517
BMP 3, T1	8/5/2002	1.58
BMP 5, T1	8/5/2002	42.12
BMP 5, T2	8/5/2002	2.127
BMP 7, T2	8/5/2002	1.67
BMP 2, T1, T2	8/9/2002	2.4
BMP 3, T1, T2	8/9/2002	3.794
BMP 4, T1, T2	8/9/2002	9
BMP 5, T1, T2	8/9/2002	13.963
BMP 6, T1, T2	8/9/2002	5.13
BMP 7, T2	8/9/2002	3.732
BMP 8, T1, T2	8/9/2002	6.97
BMP 8, T1, T2	8/21/2002	29.876
BMP 2, T1, T2	8/22/2002	7.936
BMP 3, T1, T2	8/22/2002	5.391
BMP 5, T1, T2	8/22/2002	0.474
BMP 6, T1, T2	8/22/2002	9.743
BMP 7, T1, T2	8/22/2002	12.953
BMP 8, T1, T2	8/22/2002	1.328
BMP 1, T1	8/24/2002	0.26
BMP 2, T1	8/24/2002	2.38
BMP 3, T1	8/24/2002	4.65
BMP 4, T1	8/24/2002	0.78
BMP 5, T1	8/24/2002	1.22
BMP 6, T1	8/24/2002	1.41
BMP 7, T1	8/24/2002	8.11
BMP 8, T1	8/24/2002	13.42

Unsigned Trails

Sample	Storm Date	Sample weight, grams	Sample	Storm Date	Sample weight, grams
ILL 2, T1	8/24/2002	6.87	ILL 5, T1	6/8/2002	15.923
ILL 5, T1	8/24/2002	4.52	ILL 5, T2	6/8/2002	0.979
ILL 7, T1	8/24/2002	2.33	ILL 7, T1	6/8/2002	1.762
ILL 5, T2	8/28/2002	3.68	ILL 7, T2	6/8/2002	1.953
ILL 2, T1	5/17/2002	101.233	ILL 2, T1, T2	8/9/2002	0.76
ILL 2, T2	5/17/2002	9.018	ILL 5, T1, T2	8/9/2002	8.33
ILL 5, T1	5/17/2002	10.404	ILL 7, T2	8/9/2002	3.51
ILL 5, T2	5/17/2002	4.337	ILL 2, T1	8/5/2002	3.355
ILL 7, T1	5/17/2002	23.285	ILL 5, T1	8/4/2002	0
ILL 7, T2	5/17/2002	4.053	ILL 5, T2	8/4/2002	5.166
ILL 2, T1	5/26/2003	2.164	ILL 7, T1	8/4/2002	0.421
ILL 2, T2	5/26/2003	2.839	ILL 7, T2	8/4/2002	4.862
ILL 5, T1	5/26/2003	0.633	ILL 2, T1, T2	7/26/2002	11.63
ILL 5, T2	5/26/2003	0.327	ILL 5, T1, T2	7/26/2002	46.11
ILL 7, T1	5/26/2003	3.583	ILL 7, T1, T2	7/26/2002	7.18
ILL 7, T2	5/26/2003	1.39	ILL 2, T2	7/22/2002	21.64
ILL 2, T1	6/4/2002	3211.61	ILL 2, T1	7/11/2002	2.03
ILL 2, T2	6/4/2002	249.79	ILL 2, T2	7/11/2002	10.69
ILL 5, T1	6/4/2002	28.129	ILL 5, T1	7/11/2002	9.26
ILL 5, T2	6/4/2002	4078.38	ILL 5, T2	7/11/2002	42.29
ILL 7, T1	6/4/2002	20.292	ILL 7, T1	7/11/2002	9.74
ILL 7, T2	6/4/2002	122.99	ILL 7, T2	7/11/2002	4.85
ILL 2, T1, T2	8/22/2002	1.096	ILL 2, T1	7/7/2002	0.95
ILL 5, T1, T2	8/22/2002	15.212	ILL 2, T2	7/7/2002	68.18
ILL 7, T1, T2	8/22/2002	4.16	ILL 5, T2	7/7/2002	0.37
ILL 2, T1	6/8/2002	3.902	ILL 7, T1	7/7/2002	0.1
ILL 2, T2	6/8/2002	19.39	ILL 7, T2	7/7/2002	12.3

Control Areas

Sample	Storm Date	Sample weight, grams
C1, T1	8/28/2002	18.3
C1, T2	8/28/2002	1.75
C2, T1	8/28/2002	0.21
C2, T2	8/28/2002	0.19
C3, T1	8/28/2002	2.52
C3, T2	8/28/2002	0.95
C5, T1	8/28/2002	-0.26
C5, T2	8/28/2002	1.78
C6, T1	8/28/2002	0.78
C6, T2	8/28/2002	0.7
C7, T1	8/28/2002	0.6
C7, T2	8/28/2002	3.78
C8, T1	8/28/2002	32.89
C8, T2	8/28/2002	22.49

A5. Culvert Data

Location: Rampart Range Road, Date August, 2002 and 12/6/04
Average road width = 6.4 meters, Road condition = rutted
*Location = begins at the Y of Forest roads 300 and 320

Road sections with Culverts

	Contributing Road Data						**Culvert Data**			
Culvert #	*Location miles	Length of South side of road, m	Length of North side of road, m	Total Contributing area, m2	South slope, %	North slope, %	Culvert plugged, %	Armoring below culvert?	Extent of erosion	Culvert over-hang height, m
Culvert 1	0.1	106.7	151.8	1654.4	3.5	6	0	none	high	0.1
Culvert 2	1.2	67.4	106.7	1114.0	3.5	7	0	none	none	none
Culvert 3	1.7	37.8	61.0	632.1	1	2	0	none	moderate	0.2
Culvert 4	2	43.0	90.5	854.5	1	7	0	none		0
Culvert 5	2.4	38.1	133.5	1098.4	0.5	7	50	yes	slight	0
Culvert 6	3.05	121.0	160.9	1804.6	4	5	0	yes	slight	0.2
Culvert 7	3.55	67.1	130.5	1264.2	3.5	7.5	0	yes		0
Culvert 8	4.1	72.5	0.0	464.3	4	N/A	0	yes		0
Culvert 9	6.35	88.7	121.9	1348.1	7	5	100	none	moderate	0

Gully Data

Culvert #	Gully length, m	Width at 25% of length, m	Depth at 25% of length, m	Width at 50% of length, m	Depth at 50% of length, m	Width at 75% of length, m	Depth at 75% of length, m	Gully Volume (triangle), m3	% Vegetation cover in the gully	Connected to a channel?
Culvert 1	66	1.7	0.5	4.5	1.5	5	1.5	166.1	5	yes
second gully	3.8	0.7	0.3	0.4	0.3	0.6	0.1	0.2	0	no
Culvert 2	43.5	1	0.1	1	0.2	0.6	0.1	2.6	0	yes
second gully	41	3	0.6	0.7	0.2	0.3	0.1	13.5	0	yes
Culvert 3	79	1.6	0.3	1.7	1.1	0.6	0.1	31.7	8	yes
second gully	15	1.7	0.6	1.6	0.3	1.1	0.3	4.6	0	
Culvert 4	43	0.3	0.05	0.5	0.1	0.3	0.05	0.6	0	yes
Culvert 5	36	0.8	0.1	0.8	0.05	0.4	0.05	0.8	0	no
Culvert 6	50	0.5	0.1	0.7	0.1	0.3	0.1	1.3	20	yes
second gully	32	1.2	0.05	0.5	0.1	0.8	0.05	0.8	4	no
Culvert 7	31	0.6	0.15	0.6	0.1	0.7	0.1	1.1	5	yes
second gully	8	0.7	0.3	1	0.25	0.7	0.1	0.7	0	no
Culvert 8	35.5	0.7	0.1	0.6	0.1	1.3	0.05	1.2	0	yes
second gully	44.5	1.1	0.2	1.1	0.2	0.5	0.1	3.6	0	yes
Culvert 9	26	0.5	0.1	0.5	0.05	0.4	0.05	0.4	1	no
second gully	18	0.7	0.05	0.5	0.1	0.3	0.1	0.3	1	no
third gully	37	0.4	0.2	0.2	0.05	0.5	0.2	1.2	1	no
fourth gully	17	0.7	0.23	0.2	0.1	0.3	0.1	0.6	46	no

Road sections without culverts

Contributing Road Data

Culvert #	*Location miles	Length of South side of road, m	Length of North side of road, m	Total Contributing area, m2	South slope, %	North slope, %	Extent of erosion
No Culvert 1	0.3	134.4	41.5	1125.7	7	1	medium
No Culvert 2	0.7	121.9	27.7	957.9	5.25	1	slight
No Culvert 3	2.6	126.2	107.0	1492.5	5	2.5	
No Culvert 4	2.9	15.2	104.9	768.7	0	7	none
No Culvert 5	3.4	89.9	91.4	1160.8	3.5	3.5	moderate
No Culvert 6	4.3	137.2	65.5	1297.4	4	3.5	slight
No Culvert 7	4.6	167.6	60.4	1459.3	5	2.5	moderate
No Culvert 8	4.9	89.3	80.8	1088.6	3.5	3.5	
No Culvert 9	6.1	147.5	87.5	1504.2	3.5	5	

Gully Data

Culvert #	Gully length, m	Width at 25% of length, m	Depth at 25% of length, m	Width at 50% of length, m	Depth at 50% of length, m	Width at 75% of length, m	Depth at 75% of length, m	Gully Volume (triangle), m3	% Vegetation cover in the gully	Connected to a channel?
No Culvert 1	67	2.1	0.9	2.3	0.9	1	0.3	47.6	9	yes
Second gully	2	0.9	0.2	0.6	0.2	0.4	0.2	0.1	0	no
No Culvert 2	32.5	0.4	0.2	0.9	0.2	0.7	0.2	2.2	5	yes
No Culvert 3	1.5	0.8	0.2	0.7	0.3	0.5	0.2	0.1	0	no
Second gully	35.5	0.9	0.1	1.3	0.6	0.6	0.05	5.3	2	yes
No Culvert 4	0	0	0	0	0	0	0	0.0	0	0
No Culvert 5	66	0.8	0.15	1.2	0.1	1.6	0.2	6.2	11	yes
No Culvert 6	2	0.7	0.05	0.7	0.1	0.6	0.1	0.1	0	no
Second gully	1	0.7	0.15	0.7	0.1	0.5	0.1	0.0	0	no
No Culvert 7	44	1.1	0.1	0.3	0.1	0.4	0.1	1.3	0	yes
Second gully	68	0.7	0.3	1	0.1	0.9	0.05	4.0	0	yes
No Culvert 8	6	0.9	0.2	0.6	0.2	0.4	0.05	0.3	5	no
No Culvert 9	4	0.8	0.3	0.8	0.05	0.6	0.1	0.2	2	no

A6. Water Quality Data

Sample Location Reference
1 = reference area
2 = reference area
3 = reference area
4 = reference area
5 = above Manitou Dam
6 = below Manitou Dam/above fenced pasture
7 = below fenced pasture
8 = above control pasture
9 = below control pasture
10 = above unfenced pasture
11 = middle unfenced pasture
12 = below unfenced pasture
13 = above ORV area
14 = Missouri Gulch
15 = below ORV area
16 = above the confluence with West Creek
17 = above the confluence with the South Platte River

Storm 5/16/02

Sample location	TSS, mg/L	Turbidity, NTU
17	3.37	1.63
16	5.67	2.89
15	10.11	6.40
14	6.00	5.08
13	6.50	4.98
12	9.44	6.16
10	63.25	30.33
8	9.44	6.01
7	6.78	4.47
6	335.25	62.03
5	241.50	61.00
4	7.50	3.27

Storm 6/4/02

Sample location	TSS, mg/L	Turbidity, NTU
17	4.67	2.45
16	9.33	5.20
15	9.83	7.04
14	16.50	20.77
13	9.33	7.85
12	8.86	6.08
11	11.50	7.25
10	15.00	10.51
9	21.17	14.57
8	23.00	14.43
7	22.60	11.67
6	171.00	44.80
5	129.25	30.83
4	18.22	6.57
3	20.00	6.68
2	14.00	1.86
1	13.56	3.83

Storm 7/4/02

Sample location	TSS, mg/L	Turbidity, NTU
17	1.67	0.79

*sample taken during the storm, but before the pulse of runoff

Storm 7/4/02

Sample location	TSS, mg/L	Turbidity, NTU
16	332.50	193.00

*first runoff event after the fire

Storm 7/6/02

Sample location	TSS, mg/L	Turbidity, NTU
17	1151.00	1282.00
16	7.67	3.86
15	23.00	11.00
14	19.00	16.40
13	19.00	14.00
12	72.67	36.80
11	48.00	29.70
10	51.00	35.80
9	26.67	17.40
8	43.33	35.80
7	38.33	26.20
6	21.00	16.20
5	19.00	11.40
4	3.75	3.45
3	14.50	5.23
2	12.25	7.57
1	dry creek	

Storm 7/10/02

Sample location	TSS, mg/L	Turbidity, NTU
17	40.50	28.60
16	4.75	2.78
15	16.67	14.60
14	16.67	13.30
13	9.33	11.60
12	7.33	6.50
11	11.00	7.17
10	15.00	14.50
9	12.33	10.55
8	17.33	14.80
7	18.67	15.10
6	11.67	12.00
5	13.33	14.60
4	3.00	3.04
3	14.00	9.47
2	17.25	10.20
1	dry creek	

Storm 7/21/02

Sample location	TSS, mg/L	Turbidity, NTU
17	5.00	4.41
16	46.67	17.20
15	29.29	23.50
14	34.75	30.90
13	36.00	27.03
12	56.75	56.03
11	8.56	8.20
10	7.20	7.40
9	24.33	17.87
8	31.33	29.20
7	15.33	17.70
6	24.00	29.63
5	18.00	22.97
4	15.60	9.01
3	15.80	10.30
2	15.20	8.97
1	dry creek	

Baseline collection on 8/1/02. no rain storm

Sample location	TSS, mg/L	Turbidity, NTU
17	7.60	5.89
16	5.14	5.24
15	13.50	12.73
14	dry creek	
13	8.00	4.45
12	64.33	56.83
11	19.75	20.47
10	9.71	7.05
9	6.40	6.36
8	21.00	16.30
7	14.00	14.83
6	6.80	11.27
5	26.60	31.83
4	3.71	3.24
3	7.62	3.37
2	8.14	4.12
1	dry creek	

Storm 8/3/02

Sample location	TSS, mg/L	Turbidity, NTU
17	8.00	6.30
16	5.11	4.08
15	14.25	15.53

Storm 8/4/02

Sample location	TSS, mg/L	Turbidity, NTU
17	11.57	10.37
16	4.00	3.10
15	32.75	24.87

Storm 8/3/02

Sample location	TSS, mg/L	Turbidity, NTU
13	24.22	12.77
12	8.25	8.23
11	11.25	13.27
10	24.40	13.77
9	7.50	11.13
8	23.00	24.53
7	12.75	18.10
6	24.25	31.93
5	35.50	21.90
4	4.67	4.00
3	12.60	7.27
2	10.20	6.31
1	dry creek	

Storm 8/4/02

Sample location	TSS, mg/L	Turbidity, NTU
13	33.25	19.43
12	71.60	35.60
11	15.60	18.37
10	16.80	19.60
9	23.33	18.00
8	49.17	27.57
7	19.60	19.47
6	11.17	12.87
5	13.50	17.27
4	4.13	3.47
3	16.80	11.33
2	14.80	10.03
1	dry creek	

Baseline collection, no storm 8/13/02

Sample location	TSS, mg/L	Turbidity, NTU
17	3.33	2.23
16	6.75	6.12
15	56.00	47.83
14	524.50	353.00
13	94.33	64.57
12	dry creek	
11	6.67	8.41
10	11.57	8.28
9	363.67	230.00
8	16.67	11.73
7	17.40	18.63
6	63.00	37.07
5	11.33	12.63
4	5.88	5.47
3	11.80	6.77
2	10.83	6.76
1	dry creek	

Baseline collection 8/28/02 no storm

Sample location	TSS, mg/L	Turbidity, NTU
17	5.00	6.65
16	8.50	8.42
15	dry creek	
14	dry creek	
13	dry creek	
12	dry creek	
11	17.00	20.40
10	6.80	11.00
9	12.75	15.20
8	17.40	19.60
7	17.25	21.10
6	7.40	12.90
5	23.50	23.40
4	5.40	5.28
3	19.00	10.60
2	7.97	6.14
1	dry creek	

*Some data points are missing due to the creek drying up or in the case of storms 5/16 and 7/4 it was too dark to finish sampling.

A7. Wolman Pebble Counts

Location: Land-use area, Riffles between Manitou Dam and Rainbow Falls Park
Date: 8/21/2002 Crew: Teves and Martinelli Units: mm *lt2 = less than 2mm
Transects #1-10

#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
102	195	305	170	145	24	11	30	20	140
90	190	120	165	130	17	11	25	20	120
77	175	105	120	120	16	10	17	19	115
55	170	105	110	120	15	10	17	14	110
50	165	90	100	90	14	10	16	14	110
50	160	90	95	78	14	10	15	13	90
45	140	87	87	75	12	8	15	13	90
45	135	80	85	75	11	7	14	11	90
40	130	75	80	62	11	7	13	11	90
40	120	75	77	60	10	6	12	10	78
38	120	70	75	60	10	5	12	10	70
38	110	70	75	60	10	5	12	9	70
36	104	70	75	60	10	5	12	9	70
35	98	70	70	55	9	5	12	9	70
35	93	70	55	53	9	5	10	9	66
30	90	70	55	43	9	5	10	9	58
28	89	69	50	40	8	5	10	9	52
26	80	65	45	40	8	5	10	8	50
25	80	64	40	38	7	5	9	8	50
25	79	63	40	35	7	5	9	7	45
25	75	59	40	34	7	4	9	7	41
25	72	58	37	33	7	4	9	7	40
24	70	50	35	30	7	4	9	7	37
23	65	50	30	30	7	4	9	6	35
20	62	50	30	30	7	3	8	6	35
20	54	47	30	28	7	3	8	6	35
20	53	45	30	27	6	3	8	6	34
19	50	35	30	26	6	3	7	6	27
17	49	27	28	25	6	3	7	5	20
16	47	22	28	25	6	3	7	5	18
16	45	18	25	22	6	3	7	5	17
15	45	18	23	22	5	3	6	5	15
13	41	17	22	20	5	3	6	5	10
12	40	16	21	20	5	2	6	5	8
11	33	15	20	20	5	2	6	5	8
11	33	15	20	17	5	2	6	5	7
10	26	14	20	16	5	2	6	5	7
10	25	13	20	16	5	2	6	5	6
10	23	13	19	15	4	2	6	4	6
10	22	13	15	15	4	2	6	4	6
10	21	13	15	15	4	2	6	4	5
9	20	12	14	15	4	2	6	4	5
9	19	11	14	14	4	2	5	4	5
9	18	11	13	13	4	2	5	3	5
9	16	11	13	13	4	2	5	3	5
8	16	10	12	12	4	2	5	3	5
8	15	10	12	11	4	2	5	3	5

#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
8	15	10	11	11	3	2	5	3	4
8	15	10	11	10	3	2	5	3	4
7	14	9	11	10	3	2	5	3	4
7	13	9	11	10	3	2	5	3	3
7	13	8	10	10	3	2	4	3	3
7	11	8	10	10	3	2	4	3	3
7	11	6	10	9	3	2	4	3	2
7	10	6	10	9	3	lt2	4	2	2
7	10	6	10	8	3	lt2	4	2	2
7	9	6	10	7	2	lt2	4	2	2
6	9	5	10	7	2	lt2	4	2	2
6	8	5	10	6	2	lt2	4	2	2
6	8	5	10	6	2	lt2	4	2	2
6	8	4	9	5	2	lt2	4	2	2
6	8	4	9	5	2	lt2	3	2	2
5	8	4	8	4	2	lt2	3	2	2
5	8	4	7	4	2	lt2	3	2	2
5	6	4	7	3	lt2	lt2	3	2	lt2
5	6	3	6	3	lt2	lt2	2	2	lt2
5	6	3	6	2	lt2	lt2	2	2	lt2
5	6	3	6	2	lt2	lt2	2	2	lt2
5	5	3	6	2	lt2	lt2	2	2	lt2
5	5	2	5	2	lt2	lt2	2	lt2	lt2
5	5	2	5	2	lt2	lt2	2	lt2	lt2
4	5	2	5	lt2	lt2	lt2	2	lt2	lt2
4	5	2	5	lt2	lt2	lt2	2	lt2	lt2
3	5	2	5	lt2	lt2	lt2	2	lt2	lt2
3	5	2	5	lt2	lt2	lt2	2	lt2	lt2
3	5	2	5	lt2	lt2	lt2	2	lt2	lt2
2	5	2	4	lt2	lt2	lt2	lt2	lt2	lt2
2	4	2	4	lt2	lt2	lt2	lt2	lt2	lt2
2	4	lt2	3	lt2	lt2	lt2	lt2	lt2	lt2
2	4	lt2	3	lt2	lt2	lt2	lt2	lt2	lt2
2	4	lt2	3	lt2	lt2	lt2	lt2	lt2	lt2
2	3	lt2	3	lt2	lt2	lt2	lt2	lt2	lt2
2	2	lt2	3	lt2	lt2	lt2	lt2	lt2	lt2
2	2	lt2	2	lt2	lt2	lt2	lt2	lt2	lt2
2	2	lt2	2	lt2	lt2	lt2	lt2	lt2	lt2
2	2	lt2	2	lt2	lt2	lt2	lt2	lt2	lt2
2	2	lt2	2	lt2	lt2	lt2	lt2	lt2	lt2
2	2	lt2	2	lt2	lt2	lt2	lt2	lt2	lt2
2	2	lt2	2	lt2	lt2	lt2	lt2	lt2	lt2
2	2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2

Location: Reference area, riffle sections above South Meadows Campground
Date: 8/25/02 Crew: Teves and Campion
Transects #1-10

#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
40	50	300	44	130	75	55	37	61	90
20	42	190	20	105	44	40	25	40	65
20	42	130	16	65	40	35	15	38	37
19	35	125	14	60	37	26	15	35	26
17	32	102	13	54	35	16	15	32	16
15	30	95	13	50	30	16	15	30	16
14	30	85	13	45	26	16	13	28	16
13	30	80	12	42	26	15	13	27	15
13	25	75	12	41	22	14	13	25	15
12	25	75	11	40	21	14	13	25	15
11	25	70	11	40	21	13	13	25	14
11	25	70	11	38	20	13	12	24	12
11	25	70	11	32	20	12	12	24	12
10	23	65	10	31	20	12	12	23	11
10	23	64	10	30	19	12	12	22	11
10	23	62	10	30	19	11	12	22	11
10	20	60	10	28	18	11	12	21	11
10	20	60	10	23	17	10	12	21	11
9	20	60	10	22	17	10	12	20	10
9	20	60	9	20	17	10	12	20	10
9	20	60	9	20	16	10	12	20	10
8	17	60	9	17	16	10	11	19	10
7	17	55	9	17	15	10	11	18	10
7	17	55	9	17	15	9	10	18	10
7	17	54	9	17	15	9	10	17	9
7	15	50	9	16	15	9	10	17	9
7	15	50	9	15	14	9	10	16	9
6	15	50	8	15	13	8	10	16	9
6	15	45	7	15	13	8	10	15	9
6	15	42	7	15	13	8	10	14	8
6	15	40	7	15	12	7	9	14	8
5	15	40	7	15	12	7	9	14	8
5	15	39	7	14	11	6	9	13	8
5	15	39	7	13	11	6	9	13	8
5	15	39	7	13	11	6	8	13	8
5	13	37	6	13	10	6	8	13	8
5	13	34	6	12	10	5	7	13	7
5	13	34	6	12	10	5	7	13	7
5	12	34	6	12	10	5	7	13	7
5	11	32	6	12	10	5	6	12	6
5	11	31	6	12	10	5	6	12	6
4	11	31	6	11	10	5	6	12	6
4	11	30	6	11	10	5	6	11	6
4	11	30	6	11	9	5	6	11	6
4	10	30	5	10	9	5	6	11	6
4	10	30	5	10	9	5	6	11	5
4	10	27	5	10	9	5	6	11	5
3	10	26	5	10	9	5	6	11	5
3	10	25	5	10	9	5	6	10	5

#1	#2	#3	#4	#5	#6	#7	#8	#9	#10
3	10	24	5	10	9	4	6	10	5
3	10	24	5	10	9	4	6	10	5
3	10	23	5	10	8	4	5	10	5
3	10	22	5	10	8	4	5	10	5
3	10	22	4	9	8	3	5	9	5
3	9	20	4	9	8	3	5	9	5
3	9	20	4	9	8	3	5	9	5
3	7	20	4	8	7	3	5	9	5
3	7	17	4	8	7	3	4	9	5
2	7	17	4	7	7	3	4	9	5
2	7	16	4	7	7	3	4	9	5
2	6	16	4	6	6	3	4	9	5
2	6	15	4	6	6	3	4	8	5
2	6	15	4	6	6	3	4	8	5
2	6	13	4	6	6	3	4	8	5
2	6	12	4	6	6	3	3	7	4
2	6	11	3	5	5	3	3	6	4
2	6	11	3	5	5	3	3	6	4
2	6	10	3	5	5	2	3	6	4
2	6	9	3	5	5	2	3	6	4
2	6	9	3	5	5	2	3	6	3
2	6	9	3	5	5	2	3	5	3
lt2	5	8	3	5	5	2	3	5	3
lt2	5	8	3	5	5	2	3	5	3
lt2	5	8	3	5	5	2	3	5	3
lt2	5	6	3	5	5	2	3	5	3
lt2	5	6	3	5	4	2	2	4	3
lt2	5	6	3	5	4	2	2	4	3
lt2	5	5	2	4	4	2	2	3	3
lt2	5	5	2	4	3	2	2	3	2
lt2	4	5	2	4	3	2	2	3	2
lt2	4	5	2	4	3	2	2	3	2
lt2	4	4	2	3	3	2	2	3	2
lt2	4	4	2	3	3	lt2	2	3	2
lt2	3	4	2	2	3	lt2	2	2	2
lt2	3	3	lt2	2	2	lt2	2	2	2
lt2	3	3	lt2	2	2	lt2	2	2	2
lt2	3	3	lt2	lt2	2	lt2	2	2	lt2
lt2	3	3	lt2	lt2	2	lt2	2	2	lt2
lt2	2	3	lt2	lt2	2	lt2	2	2	lt2
lt2	2	2	lt2	lt2	2	lt2	2	2	lt2
lt2	2	2	lt2	lt2	2	lt2	2	lt2	lt2
lt2	2	2	lt2	lt2	2	lt2	lt2	lt2	lt2
lt2	2	2	lt2	lt2	2	lt2	lt2	lt2	lt2
lt2	2	2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	2	2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2
lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2	lt2

A8. Beaver Dam Inventory Data

Location: Trout Creek, wastewater treatment plant to the confluence with West Creek Date: 8/10/2002
Crew: Nani, Jonas, Melinda, Lynn, Jason, Brad, Cherie, and Eric

Section: Bridge above Lions Camp to the wastewater treatment plant

no beaver dams in this section

Section: Manitou Experimental Forest Headquarters to bridge above Lions Camp

Beaver Dam	Broken Y/N	Height, m	Length, m	Erosion at dam sides Y/N	Leaking	New twigs?
1	no	1.2	40	no	yes	yes
1	no	0.6	17	no	N/A	yes
1	yes	0.3	15	yes	top	no
1	no	0.8	15	no	top	yes
1	no	0.5	10	no	top	yes
1	no	1.1	12	yes	top	yes
1	no	0.2	12	no	top, many leaks	yes
1	yes	0.3	11	no	big hole in middle	no
1	no	0.9	10	no	top	yes
1	no	0.6	11	no	top and side	yes
1	no	1.5	25	no	top all over	yes
1	yes	0.3	9	no	N/A	no
1	no	0.8	11	no	top	yes
1	yes	0.3	5	no	N/A	no
1	no	0.8	15	no	top	yes
1	no	1.1	11	no	top	yes
1	no	1.1	20	no	top	yes
1	yes	0.9	50	yes	N/A	no
1	yes	0.6	13	yes	N/A	no
1	yes	0.6	30	no	N/A	no
1	yes	0.6	7.5	no	N/A	no
1	yes	0.8	100	no	N/A	no
1	yes	0.6	100	no	N/A	no
1	yes	0.9	100	no	N/A	no
1	yes	0.9	11	no	N/A	no
1	yes	0.2	6	no	N/A	no
1	no	1.2	12	no	top	yes
1	yes	1.2	11	yes	bottom	no
1	no	1.4	12	no	bottom	no
1	no	0.9	10	no	top and bottom	yes
1	no	0.5	20	no	top and bottom	yes
1	no	0.8	8	no	top and side	yes
1	no	1.2	13	no	bottom	no
1	no	0.8	10	no	bottom	yes
1	no	0.6	10	no	top	yes
1	no	0.6	8	no	bottom	no
1	no	0.8	10	no	top and bottom	no
1	no	0.6	11	no	top	no
1	yes	0.2	9	no	N/A	no
1	no	0.3	8	no	top and bottom	no
1	no	1.2	11	no	bottom	no
1	no	1.4	13	no	bottom	no

Beaver Dam	Broken Y/N	Height, m	Length, m	Erosion at dam sides Y/N	Leaking	New twigs?
1	no	0.9	10	no	bottom	no
1	no	0.6	12	no	bottom	no
1	no	0.6	14	no	bottom	no
1	no	0.9	14	no	bottom	no
1	yes	0.2	9	no	N/A	no
1	no	0.9	11	no	top and bottom	no
1	no	0.9	11.5	no	top	yes
1	no	0.3	15	no	bottom	yes
1	no	1.5	33	no	top and side	yes
1	no	0.6		no	top and side	
1	no	0.3	7	no	top	no
1	no	1.5	35	no	side	yes
1	no	0.3	7	no	top and side	yes
1	yes	0.3	12	no	N/A	no
1	no	0.9	12	no	bottom and side	yes
1	no	1.8	60	no	bottom	no
1	no	0.6	22	no	bottom	no
1	no	0.6	11	no	bottom	no
1	no	0.6	15	no	bottom	no
1	no	0.9	28	no	top and bottom	yes
1	no	0.5	18	no	N/A	no
1	no	0.9	45	no	N/A	no
1	no	0.6	12	no	bottom and side	yes
1	yes	0.3	12	yes	N/A	no
1	no	0.8	21	no	N/A	no
1	no	0.6	30	yes	bottom	no
1	no	0.9	20	no	bottom	no
1	no	0.6	12	no	bottom	no
1	no	0.9	9	no	bottom	no
1	no	0.9	20	no	bottom	no
1	no	0.8	100	no	N/A	no
1	no	0.6	9	no	side and top	no
1	no	0.6	35	no	top	yes
1	no	0.8	20	no	top	yes
1	no	0.6	40	no	top and bottom	yes
1	no	0.3	20	no	top and bottom	no
1	no	0.6	10	no	top	no
1	no	0.9	6	no	N/A	no
1	no	0.3	20	no	top and bottom	no
1	no	0.6	10	no	top	no
1	yes	0.3	6	no	N/A	no

Section: Rainbow Falls Park to Manitou Experimental Forest Headquarters

Beaver Dam	Broken Y/N	Height, m	Length, m	Erosion at dam sides Y/N	Leaking	New twigs?
1	No	1.5	6	No	trickle out side and bottom	yes
1	Yes	0.25	4	No	Middle	no
1	No	0.25	4	No	low water level, can't tell	no

Beaver Dam	Broken Y/N	Height, m	Length, m	Erosion at dam sides Y/N	Leaking	New twigs?
1	No	0.25	10	No	bottom/side	no
1	No	0.5	10	No	bottom	no
1	No	0.25	30	No	N/A	no
1	No	0.5	30	No	N/A	yes
1	yes middle	0.25	15	No	side	no
1	yes side	0.5	40	No	bottom	yes
1	No	0.25	0.5	Yes	N/A	no
1	No	0.25	2	No	N/A	no
1	yes middle	0	8	Yes	N/A	no
1	yes	0	8	No	N/A	no
1	No	0.5	20	No	N/A	yes
1	yes	0	10	No	yes	no
1	No	0.25	1	No	yes sides, bottom	no
1	No	0.25	3	No	N/A	yes
1	No	0.25	20	No	bottom	no
1	yes	0.5	8	No	N/A	no
1	yes	0.75	80	No	middle	no
1	yes	1	10	Yes	N/A	no
1	yes	1.5	30	No	N/A	no
1	yes	1	7	yes	N/A	no
1	no	0.05	1	No	N/A	yes
1	no	1	14	yes	N/A	no
1	no	1.5	20	no	N/A	no
1	no	1.5	2	No	N/A	no
1	yes	1	100	no	N/A	no
1	no	0.75	3	no	N/A	yes
1	no	0.5	2	No	N/A	no
1	yes	0.5	15	no	N/A	no
1	yes	0.5	7	no	N/A	no
1	no	1.5	40	no	N/A	no
1	no	1.5	12	no	N/A	yes
1	no	1.5	7	no	N/A	no
1	no	1.25	7	no	N/A	no
1	no	1	3	no	N/A	no
1	no	1.5	7	no	N/A	no
1	yes	0.5	7	yes	N/A	no
1	no	1.25	15	no	N/A	no
1	no	1	8	no	N/A	yes
1	no	0.25	2	no	N/A	yes
1	yes	1.5	8	no	Middle	no
1	yes	0.5	8	no	N/A	no
1	no	0.75	13	no	N/A	no
1	no	0.5	3	no	bottom	yes
1	no	2	50	no	N/A	no
1	no	1.5	40	no	N/A	no
1	yes	0.25	10	no	Middle	no
1	yes	0.5	10	no	Middle	no
1	no	0.75	7	no	N/A	no
1	no	0.75	14	no	N/A	no
1	no	1	30	no	N/A	yes
1	no	0.25	3	no	N/A	yes

Beaver Dam	Broken Y/N	Height, m	Length, m	Erosion at dam sides Y/N	Leaking	New twigs?
1	no	1.5	100	no	N/A	no
1	no	0.5	25	no	N/A	no
1	no	0.5	40	no	N/A	no
1	yes	0.5	33	no	N/A	no
1	yes	0.5	12	no	bottom	no
1	no	0.25	10	no	N/A	no
1	no	0.5	12	no	N/A	no
1	no	0.25	6	no	bottom	no
1	no	1.5	35	no	N/A	no
1	yes	0.25	12	no	N/A	no
1	yes	0.75	10	no	N/A	no
1	no	1	20	no	N/A	no
1	No	0.5	10	no	N/A	no
1	no	0.75	10	no	N/A	no
1	no	0.5	5	no	N/A	no
1	no	0.5	12	no	N/A	no
1	no	0.5	10	no	N/A	no
1	no	0.75	2	no	N/A	no
1	yes	0.25	1	no	N/A	no
1	yes	0.25	15	no	N/A	no
1	no	1	10	no	N/A	no
1	yes	0.75	3	no	N/A	no
1	yes	1	20	no	N/A	no
1	yes	0.5	10	no	N/A	no
1	yes	1	15	no	N/A	no
1	no	0.75	20	no	N/A	no
1	no	2	12	no	N/A	no
1	yes	1	11	no	N/A	no
1	no	0.25	1	no	N/A	yes
1	yes	0.5	5	no	N/A	no
1	no	0.5	3	no	N/A	no
1	no	1.5	6	no	N/A	no
1	yes	0.5	7	yes	N/A	no
1	no	0.75	7	no	N/A	no
1	no	0.75	2	no	N/A	no
1	no	1	5	no	bottom	no
1	no	1	12	no	N/A	no
1	no	1.5	12	no	N/A	no
1	no	0.75	5	no	N/A	no
1	no	0.75	5	no	N/A	no
1	yes	0.75	5	no	N/A	no
1	no	0.75	6	no	N/A	no
1	no	0.5	5	no	N/A	no
1	no	1	5	no	N/A	no
1	no	0.75	10	no	N/A	yes
1	no	0.75	6	no	N/A	no
1	no	0.75	9	no	N/A	yes
*18	0-5m high					
28	5-10m high					
7	10-15m high					
3	15+m high					

*Beaver dams were grouped by beaver dam height to cover the complete section before dark. The other data (length, leaking…) were not collected for these dams.

Section: Rainbow Falls Park to the confluence with West Creek

Beaver Dam	Broken Y/N	Height, m	Length, m	Erosion at dam sides Y/N	Leaking	New twigs?
1	no	0.3	5.2	no	bottom	no
1	yes	0.2	3.7	no	bottom	no
1	no	0.6	4.6	no	bottom	no
1	yes	0.2	1.5	no	through middle	no
1	yes	0.2	1.5	no	through middle	no
1	no	0.3	5.2	no	N/A	no
1	no	0.9	1.8	no	bottom	no
1	no	0.9	7.9	no	bottom	no
1	no	0.3	7.0	no	bottom	no
1	yes	0.2	1.8	no	N/A	no
1	no	0.8	7.6	no	bottom	no
1	yes	0.3	5.5	no	bottom	no
1	no	0.6	3.7	no	bottom	no
1	no	0.8	5.5	no	bottom	no
1	no	0.5	3.7	no	bottom	no
1	no	0.2	3.0	no	bottom a lot	no
1	no	0.2	2.4	no	bottom a lot	no
1	no	0.5	4.9	no	bottom	no
1	no	0.9	5.5	no	bottom	no
1	no	0.8	4.6	no	bottom	no
1	no	0.8	5.2	no	bottom	no
1	no	0.8	2.7	no	bottom	no
1	yes	0.2	2.7	no	bottom and middle	no
1	no	0.8	2.4	no	bottom	no
1	no	0.8	3.7	no	bottom	no
1	no	0.8	5.5	no	bottom	no
1	yes	0.9	8.2	no	N/A	no
1	no	0.8	4.3	no	bottom	no
1	no	0.5	6.4	no	bottom	no
1	no	0.8	3.7	no	bottom	no
1	no	0.8	7.0	no	bottom	no
1	no	0.9	13.7	no	bottom	no
1	no	0.9	13.7	no	bottom	no
1	yes	0.3	3.4	no	N/A	no
1	no	1.2	7.3	no	bottom	no
1	no	0.9	3.7	no	side	no
1	yes	0.0	4.0	no	N/A	no
1	no	1.1	5.5	no	top	yes
1	yes	0.3	5.5	no	N/A	no
1	no	0.8	4.6	no	top	yes
1	yes	0.2	4.6	NO	N/A	no
1	no	1.2	5.5	no	bottom	no
1	no	1.2	9.1	no	top	no
1	no	1.1	6.7	no	bottom	no
1	no	0.9	4.6	no	bottom	no
1	no	1.1	12.2	no	bottom	no
1	no	0.6	3.4	no	bottom	no
1	no	0.3	4.3	no	bottom	no
1	no	0.8	5.5	no	bottom	yes
1	no	0.9	12.2	no	bottom	yes

Beaver Dam	Broken Y/N	Height, m	Length, m	Erosion at dam sides Y/N	Leaking	New twigs?
1	no	0.3	12.8	no	N/A	yes
1	no	1.1	15.2	no	N/A	yes
1	no	0.3	2.4	no	side	no
1	no	0.5	3.0	no	top	no
1	no	0.5	4.0	no	N/A	no
1	no	0.5	9.8	no	top	yes
1	no	1.2	7.6	no	top and bottom	no
1	no	0.6	3.0	no	N/A	no
1	yes	0.6	1.5	no	N/A	no
1	no	0.3	6.7	yes	side	no
1	no	1.2	6.1	no	bottom	yes
1	yes	0.5	2.1	no	N/A	no
1	no	0.3	3.7	no	bottom	no
1	yes	0.3	2.4	no	N/A	no
1	no	1.1	6.7	no	bottom	no
1	no	0.9	5.5	on	bottom	no
1	no	0.8	3.7	no	bottom	no
1	no	1.1	6.1	no	bottom	no
1	yes	0.5	5.5	no	N/A	no
1	yes	0.3	2.7	no	N/A	no
1	yes	0.8	6.1	no	N/A	no
1	yes	0.3	3.7	no	N/A	no
1	yes	0.6	6.1	no	N/A	no
1	yes	0.3	6.1	no	N/A	no
1	yes	0.3	2.7	no	N/A	no
1	no	0.6	15.2	no	bottom	no
1	yes	0.5	3.7	yes	N/A	no
1	yes	0.6	3.0	no	N/A	no
1	no	1.2	9.1	no	Side/bottom	no
1	yes	0.5	3.0	no	bottom	no
1	no	0.6	6.7	yes	top	yes
1	no	0.8	6.1	no	bottom	yes
1	no	1.2	10.7	no	top	yes
1	no	1.2	15.2	no	bottom	no
1	no	0.9	9.1	no	N/A	no
1	no	0.9	6.1	no	N/A	no
1	yes	0.6	4.6	no	N/A	no
1	yes	0.9	6.1	no	N/A	no
1	yes	0.6	4.6	no	N/A	no
1	no	0.9	27.4	no	N/A	no
1	no	0.3	4.6	no	N/A	no
1	no	0.6	4.6	no	N/A	no
1	no	0.6	30.5	no	N/A	no
1	no	0.3	4.6	no	N/A	no
1	no	0.3	12.2	no	N/A	no
1	no	0.5	9.1	no	N/A	no
1	no	0.6	15.2	no	N/A	no
1	no	0.3	3.0	no	N/A	no
1	no	0.5	12.2	no	N/A	no
1	no	0.6	18.3	no	N/A	no
1	no	0.8	12.2	no	N/A	no
1	no	0.3	1.5	no	N/A	no
1	no	0.3	3.0	no	N/A	no
1	no	0.3	1.5	no	N/A	no