Report on 2003 Field Season

Monitoring the Effectiveness and Validating Response to the Road Related Mitigation Practices Implemented on the Pike's Peak Highway

Initial Year

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Executive Summary

Monitoring the Effectiveness and Validating Response to the Road Related Mitigation Practices Implemented on the Pike's Peak Highway

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This report describes the first year's monitoring effort to determine effectiveness and validate response to road related mitigation practices implemented on the Pike's Peak highway as part of the Settlement Agreement between the Sierra Club and the United States Department of Agriculture – Forest Service in Sierra Club v. Venneman, Civil Action No. 98-M-662 (D. Colo.). The effectiveness-monitoring plan has been designed to determine how well the mitigation practices implemented contribute to meeting their objectives and focuses on the 14 mile-long, 300 foot-wide highway corridor (150 feet each side of highway centerline) starting at mile marker 7 and continuing to the summit. Validation monitoring documents how the properly implemented intervention practices affect the riparian, wetland and aquatic system of catchments within the influence of the Pike's Peak highway.

The objectives for this first year of monitoring were to locate, identify, and establish a baseline measure for the various features of interest by which to compare future surveys against. Baseline surveys of cross sections, used to measure erosion and deposition, on 10 of 80 identified conveyance channel sites, 16 drainage ditch sites, and 11 road cross section sites were made. Silt fences were installed on 10 cut slope and 19 fill slope sites to monitor sediment contributions from these features. Measurable sediment was captured and surveyed at 4 fill slope sites but no sediment accumulation was note in the cut slope sites. Baseline surveys of all rock weirs constructed along the highway to intercept sediment in Priority Basin's 1 and 2 were made, with accumulated sediment from 2003 measured for those in Priority Basin 1. Rain gauges were installed at approximately 10,100, 11,800, and 13,000 ft a.s.l. along the highway to index seasonal storm volume and intensity with the erosional processes being monitored. All told, the effectiveness phase of the monitoring study had 77 sites surveyed in 2003 with more than 70 others identified for future evaluation.

Monitoring sites and baseline surveys were made on 17 different reaches from 9 streams (2 reaches per stream except for Oil Creek which had 1). Pattern, profile, and dimension of the channel and particle size distribution of the bed material were measured at each reach and the vegetation component quantified. The objective is to compare the relative change in these attributes for reference streams (North and South Catamount, Oil, and Boehmer creeks) to the change in attributes of impaired streams (East and West Fork Beaver, Severy, North Fork Crystal, and Ski creeks). In time, we expect to observe changes in the impaired streams attributable to the road mitigation practices implemented on the highway.

Included with this report is a data DVD containing all survey data (field and post processing) plus digital photographs (recommended viewing) for all sites.

Acknowledgements

Many thanks go out to all the people and agencies that cooperated in this effort, and there were quite a few.

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My personal thanks to SI International (formerly MATCOM Corporation), US Forest Service Inventory and Monitoring Institute, Black Creek Hydrology, Levi Howell and Scott Smith for helping make year 1 of 15 a success.

Introduction

This report describes the first year's monitoring effort to determine effectiveness of road restoration practices and to validate response to road related mitigation practices implemented on the Pike's Peak highway as part of the Settlement Agreement between the Sierra Club and the United States Department of Agriculture – Forest Service in Sierra Club v. Venneman, Civil Action No. 98-M-662 (D. Colo.). The five major objectives of the road mitigation work are to:

- Stabilize road surface materials, cut slopes and fill slopes
- Reduce runoff velocities and dissipate erosive energy
- Collect runoff in armored ditches and conveyance channels
- Reduce erosion and sediment deposition in drainage channels
- Retain sediment in traps and ponds to reduce downstream sedimentation.

The effectiveness-monitoring plan was designed to determine how well the implemented mitigation practices contribute to meeting these objectives and focuses on the 14 mile-long, 300 foot-wide highway corridor (150 feet each side of highway centerline) starting at mile marker seven and continuing to the summit. Validation monitoring documents how the properly implemented intervention practices affect the riparian, wetland and aquatic system of catchments within the influence of the Pike's Peak highway.

The objectives for this first year of monitoring were to locate, identify, and establish a baseline for the various features of interest against which to compare future surveys. The monitoring plan called for replicating "like" conditions for each feature measured, whether they're treated or untreated, control or impacted. Comparisons will be made, over time, of the relative change observed within a particular treatment type or control, against the relative change observed between treatment types. In this way we might be able to separate natural (expected) change from change observed as a result of some disturbance or treatment. Since this is the first year of sampling, what follows in this report is a description of the monitoring installation and data collected in 2003. Data comparisons will come in future years.

In addition, 2003 was a learning year with respect to installation and measurement techniques of the various monitoring apparatuses. The experience gained this year, particularly with respect to silt fences, will be employed in the future to improve the monitoring effort.

Site Location and Identification

A proposed 15 year monitoring study not only requires the initial identification of suitable sites, but the ability to relocate them, as well. Location of each cut and fill slope, road cross section, conveyance channel and drainage ditch, rock weir and sediment trap, precipitation gauge, and stream site were identified as a waypoint using a handheld Garmin ETrex Vista Global Positioning unit (GPS) which recorded latitude, longitude, and altitude. Each waypoint was given a unique code to distinguish it in the field as well a as provide an easy identifier for post processing convenience. The naming convention used for the effectiveness monitoring was a 5 character alpha-numeric code starting with three digits followed by two letters (e.g. 001RW, 007FS, etc.) where the numbers are sequential and the letters signify feature type (CS = Cut Slope, RX = Road Cross Section, etc.). The validation monitoring sites use a similar five character naming convention except the first four letters identify the stream and the last digit signifies the reach (e.g. OILC1 = Oil Creek, Reach 1; SVRY2 = Severy Creek, Reach 2; etc.). Appendix A has complete listing of all the sites including Site ID, Latitude, Longitude, Altitude, and Feature Description. It should be noted that while GPS technology is very good, accuracy is still dependent upon the available satellite constellation at the specific time of need and these coordinates should get one reasonably close to the desired feature but not necessarily to within one foot of a control point.

Every site has at least three Temporary Bench Marks (TBM's) or control points for use as relative reference points in order to repeatedly complete spatially similar three dimensional surveys. These TBM's are comprised of three foot lengths of 0.5 inch rebar pounded into the ground and protective with plastic yellow caps. Aluminum nursery tags identify the TBM's. Sites close in proximity may share TBM's so that every site may not have three unique control points, but every site has at least three points with which to register the survey.

Data

Data loggers and digital cameras make it easy to collect large quantities of data in a relatively short amount of time. It is not the intent of this report to produce hardcopy reproductions of every piece of data or image collected to date. Instead, pertinent and/or interesting examples will be presented in the body of this report while all relevant figures, tables, and charts will be contained in an appendix. All the data is available on a DVD so that interested parties might have access to it.

The data on the DVD is organized in hierarchical directories by monitoring type (effective or validation), by site or feature type, and by photo or survey type. File types encountered in the survey data include MS Excel 2002, Trimble Geomatics Office (TGO) 1.61, AutoDesks AutoCad 2004, and text files. Precipitation data was collected with a HOBO data logger and converted to MS Excel 2002 files. The TGO software is based on MS Access 2000 with surveying applications built in so if you have MS Access (or MS Excel) you do not need TGO to be able to read the raw survey data files. All photos are formatted as .jpg files and can be read by most operating systems.

Photograph location is defined by the directory it is located in (e.g. 011CS_08262003 contains photos of cut slope ID number 0011CS taken on August 26, 2003.). Please note that cross section photos in the validation monitoring section have a photo board in them identifying cross section and bank (e.g. AL on the photo board denotes Cross Section A, Left Bank; BR denotes Cross Section B, Right Bank; etc.). In the future, photos of cross sections in the effectiveness monitoring study will also contain these ID boards.

Effectiveness Monitoring

The objective of effectiveness monitoring is to assess the effectiveness of the intervention techniques in meeting their intended purpose. By installing silt fences on cut and fill slopes, permanent cross sections on drainage ditches, conveyance channels, and road surfaces and establishing baseline surveys of sediment traps, we hope to document , over time, the direct effects of the various mitigation practices implemented to stabilize those features.

Precipitation Gauges

Three Onset tipping bucket rain gauges with HOBO event data loggers were installed at approximate elevations of 10,000, 11,500, and 13,000 feet a.s.l. to index precipitation over the elevational range of the highway. Each gauge was mounted on top of a pressure treated six foot 4”x 4” post buried two feet into the ground. Hose clamps and silicone caulk were used to secure the gauges to the post, plumb and level. Rain gauge 075RG was located just uphill from the Halfway Picnic point near mile marker ten which is at the upper end of Priority Basin 2, in the subalpine zone. Rain gauge 076RG was located near the Severy Creek trailhead at the transition between the subalpine and the alpine zones. Rain gauge 077RG is located near the Devil’s Playground well into the alpine. Table 1 contains the specific coordinates and precipitation totals for each gauge.

Table 1. Location, precipitation accumulation, and dates of operation for 3 rain gauges.

Gauge ID	Latitude (hddd°mm.mmm)	Longitude (hddd°mm.mmm)	Altitude (ft)	Total (in)	Dates of Operation - 2003
075RG	N38 53.797	W105 03.890	10,109	11.79	5/22 – 9/29
076RG*	N38 52.582	W105 03.970	11,810	9.52	6/19 – 9/29
077RG	N38 51.783	W105 03.999	13,069	12.70	5/22 – 9/29

*Note that rain gauge 076RG was installed on May 22 but did not start recording tips until June 19 which we attribute to a software problem.

The data loggers record a datetime stamp for each tip of the rain gauge bucket (1 tip = 0.01 in) from which volume, duration, and intensity (or rate) of each storm event can be determined. For our purposes, a storm event is defined as a series of tips where the time interval between successive tips is less than or equal to 60 minutes. The recorded storm events (total volume) for all three rain gauges for the entire period of record in 2003 are shown in Figure 1. From Figure 1 we can see that rainfall amounts can vary dramatically over relatively short distances so we should not assume that a storm event measured at one place on the mountain can be directly extrapolated to a different location. Table 2 provides a summary of the largest storm events recorded at the three gauges where volume was greater than 0.4 inches and rainfall intensity exceeded 0.4 inches/hour. The intensity of the July 29 storm was the largest event recorded at all sites and was the only large storm recorded simultaneously by each gauge. Appendix B contains a complete listing of storm event tabulations for each rain gauge.

Table 2. Rainfall events where Volume > 0.4 inches and Intensity > 0.4inches/hour.

Gauge ID	DateTime First Tip	Volume (in)	Duration (hr)	Intensity (in/hr)
075RG	05Jun03 14:01:20.0	0.52	0.94	0.554
075RG	29Jul03 16:29:08.5	0.49	0.59	0.833
075RG	05Aug03 19:20:38.0	0.48	0.84	0.572
075RG	11Aug03 19:33:12.5	0.55	1.03	0.532
076RG	29Jul03 16:36:31.5	0.48	0.49	0.970
076RG	02Sep03 15:38:12.5	0.43	0.69	0.623
077RG	29Jul03 16:36:40.0	0.60	0.57	1.055
077RG	01Aug03 14:06:33.5	0.71	1.72	0.413
077RG	02Aug03 17:20:02.0	0.41	0.81	0.504

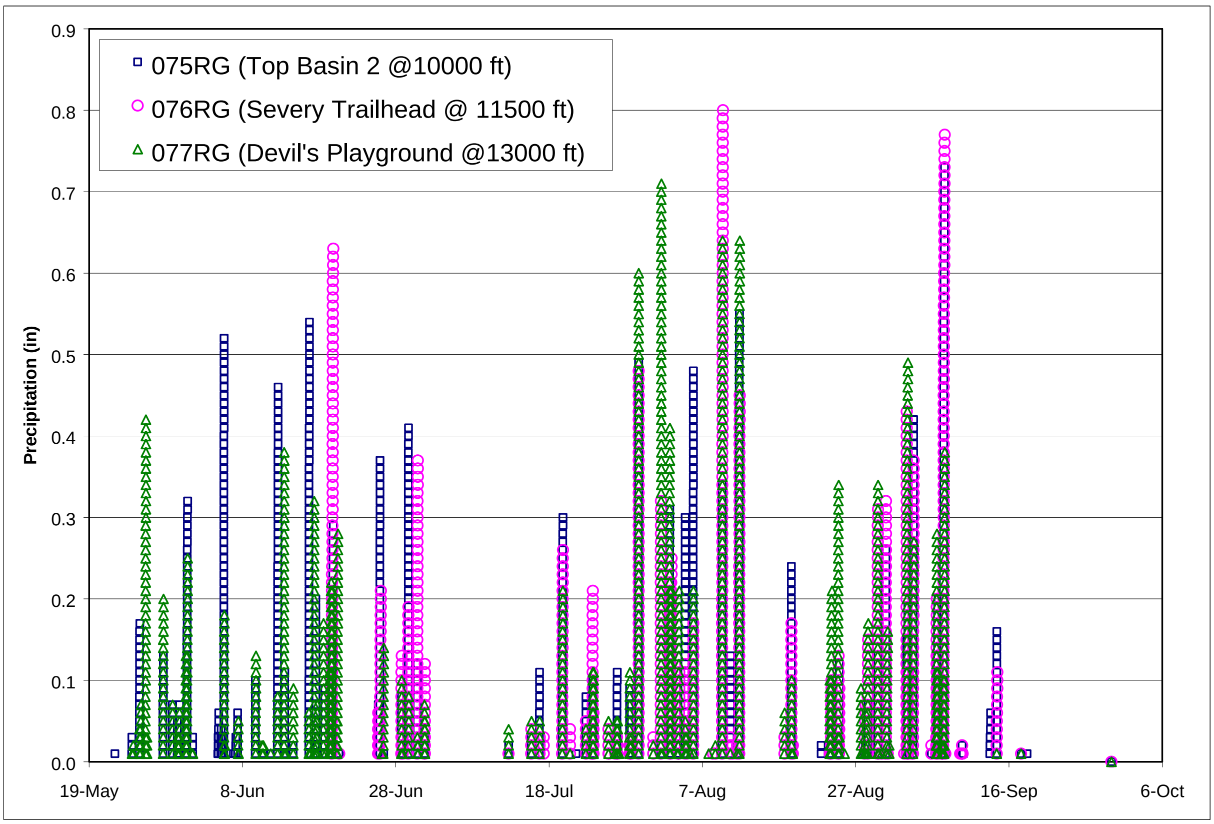

Figure 1. Comparison of storm events (total volume) for 3 the rain gauges on the Pike's Peak Highway.

Cut and Fill Slopes

Stability on cut and fill slopes, and erosion reduction, may be achieved by reestablishing natural vegetation or through the use of geosynthetic erosion control netting, gunite, shotcrete, riprap, or the construction of various types of retaining walls. The best monitoring approach is to determine the effectiveness of these practices in reducing cut and fill slope erosion and subsequent sediment transport. Silt fencing installed at the base of the cut or fill slope will catch and retain the eroded material, or sediment from the slope. Comparing the rate of eroded material being trapped, over time, at the base of treated and untreated cut and fill slopes is the best measure of the effectiveness of the mitigation practice in reducing erosion.

In 2003, ten cut slope and 19 fill slope sites were monitored for stability using silt fences to capture eroding material. Site selection was based on stratifying by treatment type as well as distributing sites over the length of the highway. Recall that Priority Basin 1 (from mile maker seven to eight) was paved in 2001 and the cut and fill slopes were treated with a mulch or fiber matrix cover to promote stability. With respect to other, pre-existing cut slope treatments, retaining walls are present in Priority Basin 7 (Glen Cove and Ski Creek basins) and several sites were selected for silt fence installation to monitor the effectiveness of the retaining walls.

In terms of road surface treatments effecting fill slopes, recycled asphalt exists on some reaches of the highway in Priority Basin 7, and several monitoring sites were installed in these reaches. Because of road construction in Priority Basin 2 (Crystal and lower Ski Creek) no cut or fill slope monitoring sites were established there in 2003. Also excluded from this type of monitoring were slopes with many large cobbles and boulders on them. The coarseness makes silt fence installation difficult and when/if the particles move they damage the fence.

Silt fences were installed at each monitoring site as discussed in the proposal with two 30 foot long fences per site. At cut slope sites, one fence was installed at the base of the cut slope, just above the drainage ditch, and the other installed on the hill slope, directly above, at the transition between the hill and cut slope. The fence at the base captures material from just the cut slope and the upper fence intercepts hill-slope transported material. For fill slope sites, the first fence was placed at the base of the fill slope while the second fence is offset and placed downhill from the first, up to 150 feet from the road. The first fence traps the material from just the fill slope and the second measures sediment transported downhill, beyond the base of the fill slope.

To install the silt fence, a six inch-wide 30 foot long shallow trench was dug along the contour of the slope. The silt fence was laid out along the downhill side of this trench and the upright supports (wooden stakes and rebar) were driven into the ground until the bottom six inches of fence material could be laid flat in the trench on the uphill side of the silt fence. Staples were used to secure the six inch fold of silt fence material to the ground and then the trench is backfilled to prevent the fence from being undercut by flowing water and providing a good seal to capture sediment. In the interest of time, all silt fences were installed before surveying began.

Determining amount of sediment accumulation in the silt fences was accomplished by surveying a grid on the uphill side of the silt fence, establishing a baseline, then resurveying the grid after the fence had filled. The surveys were performed using a Trimble 5603 Robotic Total Station and all surveys were tied to temporary benchmarks located at each site to obtain consistent and comparable three dimensional data. Digital terrain models (DTM's) were generated for each survey grid using Trimble Geomatics Office v 10.61 software, which calculated volumes above a specified elevation. The difference in volume between the two surveys equals the amount of sediment accumulated behind the silt fence. This method worked well in all but one instance where a fill slope fence (007FS) filled beyond capacity, the fence became deformed, and the sediment flowed over and around the silt fence. In this case, we generated cross sectional areas for a series of transects (generated from DTM's) above the fence, calculated the area difference between two survey dates, and multiplied the difference by the weighted distance between each transect to obtain a reasonable estimate of sediment volume. Full silt fences were cleaned after surveying and new surveyed baselines were established.

Cut Slopes

A summary of the ten cut slope monitoring sites established in 2003 are listed Table 3. Of the ten sites measured, four had treated slopes, one with fiber matrix in Basin 1, and three retaining wall cut slopes in Basin 7, and six untreated cut slopes. We expect to gain more replicates of treated slopes like the one in Basin 1 next year in Basin 2, and in succeeding years in other Basins as road construction proceeds. It is interesting that under the conditions present this year, no cut slope silt fences (upper or lower), whether treated or untreated, accumulated any sediment from the time the baseline surveys were performed, listed under Survey Date in Table 3, to the end of September.

Table 3. Summary of cut slope monitoring sites and survey dates for 2003.

Site ID	Basin #	Year Treated	Treatment Type	Survey Date
011CS	1	2001	Fiber Matrix	5/16
045CS	7	N/A	N/A	7/4
049CS	7	N/A	N/A	7/9
059CS	7	N/A	N/A	7/10
078CS	7	?	Retaining Wall	7/14
087CS	7	?	Retaining Wall	7/8
090CS	7	?	Retaining Wall	7/8
102CS	3	N/A	N/A	7/15
123CS	6	N/A	N/A	7/8
141CS	6	N/A	N/A	7/10

Fill Slopes

A summary of the fill slope monitoring sites established in 2003 are listed in Table 4. Of the 19 sites measured, three had fiber matrix treated slopes in Basin 1, five were below road reaches paved with recycled asphalt, and 11 existed on non-treated slopes. Unlike the cut slope silt fences, sediment was captured at four of the 19 fill slope sites. At two of the sites, 007FS and 039FS, the silt fences filled prior to the initial baseline survey so the first survey date in Table 4 refers to the "filled" survey and the second survey date refers to the post-cleaning baseline survey. In all other cases, the first date refers to the baseline survey. The lower rain gauge, 075RG, is the best index for sites s007FS, 039FS, and 055FS, while the alpine rain gauge, 077RG, would be the best index for site 101FS.

Table 4. Summary of fill slope monitoring sites survey dates and total volumes for 2003.

Site ID	Basin #	Year Treated	Treatment Type	Survey Dates	Sediment Volume Upper/Lower (ft^3)
001FS	1	2001	Fiber Matrix	7/2	
007FS	1	2001	Fiber Matrix	6/30, 7/3, 7/16, 9/23**	45.05 / 0
039FS	1	2001	Fiber Matrix	7/2, 7/7, 7/16, 7/27, 9/24	32.95 / 57.78*
043FS	7	N/A	N/A	7/8	
048FS	7	N/A	N/A	7/21	
052FS	7	N/A	N/A	7/10	
055FS	7	N/A	N/A	7/14, 8/12	12.64 / 0
074FS	7	N/A	N/A	7/3	
079FS	7	?	Recycled Asphalt	7/3	
083FS	7	?	Recycled Asphalt	7/10	
086FS	7	?	Recycled Asphalt	7/9	
088FS	7	?	Recycled Asphalt	7/8	
093FS	7	?	Recycled Asphalt	7/3	
098FS	3	N/A	N/A	7/14	
101FS	3	N/A	N/A	7/15, 8/13**	5.68 / 8.20
103FS	6	N/A	N/A	7/14	
105FS	6	N/A	N/A	7/10	
124FS	6	N/A	N/A	7/8	
128FS	5	N/A	N/A	7/14	

*38.11 ft^3 accumulated 7/2 survey, 19.67 ft^3 accumulated between 7/7 and 9/24 surveys
**Grab samples taken for particle size analysis

At two of the sites, 007FS and 039FS, the silt fences filled prior to the initial baseline survey so the first survey date in Table 4 refers to the “filled” survey and the second survey date refers to the post-cleaning baseline survey. In all other cases, the first date refers to the baseline survey. The lower rain gauge, 075RG, is the best index for sites s007FS, 039FS, and 055FS, while the alpine rain gauge, 077RG, would be the best index for site 101FS.

The chronology of events at site 007FS started with the silt fence installation on May 14. Between May 15 and June 11, a storm generates enough water to cause rilling (probably the June 5 storm, see Table 1 or Appendix B) and the highway crew installed excelsior logs with wooden stakes along the shoulder of the highway and additional fill material was dumped on the fill slope. By June 30, 45.1 ft^3 of fill had accumulated in the upper fence (Table 4), though some material flowed over the center of the fence and some around the right edge (Figure 2). The lower fence had no fill material in it. On July 3, the upper silt fence was cleaned out and a baseline area was surveyed.

On July 16, a second fence was installed behind (and slightly offset) the upper fence to capture any material that might overtop the first fence, and then the area between the two upper fences was surveyed. On August 5, pictures (see DVD) were taken of the fill slope just up the road from where the silt fences were installed where large gullies had formed in the fill slope despite the excelsior logs. This fill slope material was not captured in the silt fences (nor could it have been) and thus not quantified, but the images do depict the impact storms (probably July 29, 075RG) can have on exposed fill slopes. On September

23, the upper silt fence area was cleaned out, a grab sample taken to get a particle size distribution of the fill material, and an end of year baseline survey was made.

Figure 2. Surveying fill slope material in 007FS upper fence, June 30, 2003.

The chronology of events for site 039FS is similar to that of 007FS. The silt fence was installed on May 27. Then, the fill slope experienced rilling and by June 11, excelsior logs and straw bales had been placed along the shoulder of the pavement. A photograph taken on June 30 (Figure 3) shows the erosion of the fill slope just above the upper silt fence. On July 2, fill material in both the upper and lower fences was surveyed. On July 7, both fences are cleaned out and surveyed which indicated 32.9 ft^3 of fill had accumulated in the upper fence and 38.1 ft^3 in the lower (Table 4). Because fill slope material had overtopped the upper fence, a second fence was installed below the original fence on July 16 and that area was surveyed. On July 28, a rain event measuring 0.09 inches at 075RG, generated 19.7 ft^3 sediment in the lower fence (Table 4) and because water was observed going around the left side of the fence (see DVD for photographs), a second lower fence was installed and both lower fence areas were surveyed. On September 24, the upper and lower silt fence areas were cleaned and resurveyed. No sediment accumulation was noted in the upper fences after the July 16 survey or in the lower fences after the July 28 survey.

Both 007FS and 039FS are in Basin 1, which was paved in 2001, located on inside bends of curves and each slope was treated with mulch or fiber matrix to increase stability. Along each of these road curves, there is no design to control drainage and when the fill

Figure 3. View of fill slope 039FS from the upper silt fence taken on June 30. Note the straw bales lining the top of the slope and in the upper right of the picture.

slopes began to fail excelsior logs were installed as a temporary measure to control rilling from surface runoff. However, reducing surface runoff increased water infiltration and saturation of the fill slope exacerbating erosion potential and lead to mass failure of the bank (Figure 4). From the silt fence measurements and these photographs, the effectiveness of mulch or fiber matrix as a sole means to stabilize fill slopes is minimal. Additional photographs of each site area on the data DVD under their respective directories.

Fill slope site 055FS was installed on May 29/30 and was first surveyed on July 14 having accumulated no sediment to date. On August 12, a resurvey of the site showed 12.6 ft^3 of sediment had been captured by the upper fence and the lower fence had trace amounts (Table 4). Heavy vegetative cover and large rocks between the toe of the fill slope and the lower fence likely impeded sediment delivery down slope. This site is in Basin 7, on a ridge directly across Ski Creek from 075RG, where storms in late July/early August (see Table 2) were responsible for causing this erosion. After cleaning the fill material out of the upper fence on August 12, no additional accumulation was noted by the end of September.

Figure 4. Fill slope failure near 007FS associated with temporary excelsior log control. Note crust of mulch or fiber matrix treatment on slope.

Fill slope site 101FS was installed on June 23, above timberline near the “W” switchbacks, and was first surveyed on July 15 having accumulated no sediment to date. On August 13, the site was resurveyed and the upper fence contained 5.7 ft^3 of fill and the lower fence had 8.2 ft^3 (Table 4). Storms recorded in late July/early August by rain gauge 077RG (see Table 2 and Appendix B) were most likely responsible for causing the erosion, but as was the case for 055FS, we do not know if the sediment accumulation was the result of one or several storms. After cleaning the silt fences on August 13, no additional accumulation was observed by the end of September.

Both 055FS and 101FS are on untreated fill slopes and though neither had the dramatic volumes of sediment that 007FS and 039FS accumulated, the images on the data DVD are well worth looking at to see how material moves down slope in different settings.

Highway Surface Stabilization

Initially, this phase of the monitoring plan was going to look at the effectiveness of several different kinds of treatments with respect to stabilizing the road surface. Since road stabilization has been narrowed down to one option (paving with asphalt) there was little need to implement a study design matrix containing one treatment. However, we did measure several sites in unpaved reaches of the road and stratify these reaches by slope; less than 10% and greater than 10% road slope. Table 5 lists the sites, Priority Basins and survey dates of all road cross section measured in 2003.

Table 5. Summary of road cross section monitoring sites measured in 2003.

Site ID	Basin	Slope Category	Slope	Survey Date
044RX	7	Class 1	0.0751	7/29
047RX	7	Class 2	0.1007	7/30
050RX	7	Class 2	0.1038	8/5
056RX	7	Class 2	0.1049	8/12
060RX*	7	Class 2	0.1006	8/6
062RX	7	Class 1	0.0971	8/7
072RX	7	Class 1	0.0966	8/6
154RX	3	Class 2	0.1032	8/11
156RX	6	Class 2	0.1022	8/11
158RX	6	Class 1	0.0483	8/12
160RX	6	Class 1	0.0268	8/12

*Only road reach without a corresponding drainage ditch survey

Our objective here is to estimate volumetric change in road surface elevation, using cross sectional area as a surrogate measure, to determine what contribution the road surface material makes to sediment on the hill slopes and, eventually, stream channels. Five cross sections (labeled A-E) were established for each road reach. Rebar was used to monument the cross section end points on the cut slope side of the road while no permanent markers were installed on the fill slope side for safety concerns. In this way, five permanent benchmarks (at least) were established per road reach and by resectioning (i.e. relocating the survey instrument relative to known or previously established points) off those points, the fill slope end points can be relocated in successive surveys to insure measuring the same cross section.

In several surveys, drainage ditches were measured at the same time but those will be discussed in the next section. A tape pulled across the road to a temporary reference point on the fill slope side served as a tag line to guide the survey along the cross section. Each road cross section was measured from the edge of the drainage ditch to the edge of the fill slope.

When calculating the geometry of the road cross sections, two things were done to the data to promote consistency and comparability between successive surveys. The first was to add two reference points, one or two foot in elevation above the left and right endpoints of the survey, to provide a reference elevation for cross sectional area calculations and graphing purposes. It makes the graphs easier to see and accounts for the crown and any other undulations in the road surface. The second is a procedure applied to all cross section surveyed with a total station in this monitoring study and that is a correction to align all points in the cross section to the left pin-right pin vector (i.e. cross section end points). Even though we use a tag line between the end points to guide the cross section survey, directly positioning the prism over the tape for each and every shot is impossible and so by correcting the northing and easting coordinates of each internal cross section shot to match the vector between the left and right end pins, we get a true measure of distance. This correction typically is very small but is necessary when comparing measurements over time. With the arbitrary end point elevations and vector corrections made, road geometry calculations and graphs of all road cross sections were done. Appendix C contains a tabulation of all road cross section geometry and graphs for each reach of the surveys done this year. Photographs of all sites are on the data DVD.

Armoring Drainage Channels

The effectiveness monitoring for this phase focuses on measuring cross sections in roadside drainage ditches and conveyance channels to determine if the implemented mitigation practices reduce erosion and deposition in these features. The current mitigation treatments implemented in Basins 1 and 2 and proposed for the balance of the highway differ from what was initially planned. For example, instead of armoring drainage ditches, all reaches except those meeting the criteria stated in the latest Forest Service Design Review (Burke 2002) will be lined with shotcrete, which in Basin 2 was virtually the entire length of the road. We would expect little deposition and no erosion in ditches lined with shotcrete, so post-construction monitoring will be limited to ditches lined with erosion control fabric or ditches left untreated. Instead of relying solely on energy dissipating devices for erosion control in conveyance channels, where possible, completely removing the energy from the conveyance channels, as in Basin 2, is preferred. Here approximately 1.3 miles of the highway is drained by a single shotcrete-lined ditch which is routed into a single shotcrete-lined conveyance channel which flows into a large sediment detention pond eliminating many discharge points. Post-construction monitoring treatments for conveyance channels now include energy reduction or elimination, as well as energy dissipation.

Drainage Ditches

A summary of the drainage ditch monitoring sites established in 2003 are listed in Table 6. Six of the sites are associated with some treatment; the two ditches in Basin 1 are lined with erosion control blankets, and the four ditches in Basin 7 are adjacent to road surfaces paved with recycled asphalt but have no other treatment applied to the ditch. In Basin 1, 005DD and 010DD are the only drainage ditches not lined with shotcrete. The ditches in Basin 7 will provide the longest measure of erosion as Basin 7 is currently the last basin scheduled for construction (USDA Forest Service 2000).

Similar to the road cross section surveys, there are five cross sections (labeled A-E) per drainage ditch monitoring site. The cross section end points are monumented on the cut slope side with rebar and on the road side with a temporary marker. The procedure for surveying and relocating these cross sections is the same as for the road cross sections. Using a tape stretched across the cross section as a guide, we survey as many verticals as needed to define the shape of the ditch. Post processing involves correcting the internal, channel defining shots to the left and right vector of cross section end points but we used surveyed “top of ditch” points as our reference for calculating the channel geometry. Appendix D contains a tabulation of channel geometry for all drainage ditch monitoring sites and graphs of each cross section. Photographs of all drainage ditch sites are on the data DVD.

Table 6. Summary of drainage ditch monitoring sites established in 2003.

Site ID	Basin #	Year Treated	Treatment Type	Survey Date
005DD**	1	2001	Erosion Control Fabric	5/14
010DD*	1	2001	Erosion Control Fabric	7/28
042DD	7	N/A	N/A	7/29
046DD	7	N/A	N/A	7/30
051DD	7	N/A	N/A	8/5
057DD	7	N/A	N/A	8/12
061DD	7	N/A	N/A	8/7
071DD	7	N/A	N/A	8/6
080DD*	7	?	Recycled Asphalt	8/20
082DD*	7	?	Recycled Asphalt	8/25
085DD*	7	?	Recycled Asphalt	8/25
092DD*	7	?	Recycled Asphalt	8/25
107DD	3	N/A	N/A	8/11
155DD	6	N/A	N/A	8/11
157DD	6	N/A	N/A	8/12
159DD	6	N/A	N/A	8/12

*Drainage ditch sites not associated with road cross section surveys
**Survey associated with Rock Weir 006RW survey

Conveyance Channels

Of the 80 conveyance channels identified along the highway in 2003, ten were surveyed and four others photographed (Table 7). Each channel had a series of three cross sections (labeled A-C) located within the 150 foot boundary of the highway corridor. Left and right cross section end points were monumented with rebar, providing a minimum of 6 fixed points by which to relocate future surveys. A tape stretched between the left and right end points was used as a tag line to guide the cross section survey and enough verticals were taken to describe the features of the channel. Post processing was similar

Table 7. Summary of conveyance channel monitoring sites visited in 2003.

Site ID	Basin #	Year Treated	Treatment Type	Survey Date
004CC	1	2001	Fiber Matrix	7/21
012CC	2	2003	Sediment Trap	7/23
013CC	2	2003		7/23
028CC**	2	2003	Bypassed	5/20
040CC	1	2001		7/2
053CC	7	N/A	N/A	7/21
054CC	7	N/A	N/A	7/21
063CC	7	N/A	N/A	7/25
064CC*	7			
068CC	7	N/A	N/A	7/25
070CC	7	N/A		7/3
081CC*	7			
084CC*	7			
127CC*	6			

*Photographs only, no surveys performed.
**Forest Service may have previously surveyed Cross Sections A and B but we have not located the data as yet.

to that of the drainage ditches where all points in the cross section were corrected to the left-right end point vector and "top of bank" reference points were used to calculate channel geometry. Appendix E contains tabulations of all channel geometry calculations and graphs of each cross section.

Sediment Ponds and Traps

In 2003, ten rock weirs and one sediment trap were surveyed to determine their effectiveness in capturing sediment. The rock weirs were constructed (five in 2001, five in 2003) as part of the road erosion mitigation practices while the "sediment trap" was a pond to be used for snow making at the Ski Area (Burke 2002) and is now the proposed site for sediment pond 650+00. Volume of sediment captured by each structure is determined using a grid survey of the basin empty, compared against a survey of the same basin full. The same field procedures and software used to reference elevations and calculate volumes in the cut and fill slope silt fences is employed here except we calculated void volumes from the DTM's as opposed to volumes above a specific base elevation. To determine effectiveness in trapping sediment, we installed 30 foot long silt fences below the rock weirs to capture any material that might pass over, under, or through the structure. These fences were surveyed in the same manner as the cut and fill slope silt fences.

A summary of survey location, dates and sediment volume accumulated is presented in Table 8. The five rock weirs located in Basin 1 captured between 5.8 and 40.2 ft^3 of sediment with no accumulation in the corresponding silt fences. The largest sediment accumulation occurred in 008RW which had a sediment plume that extended the entire length of the weir basin (Figure 5). Baseline surveys of the five weirs in Basin 2 were

Table 8. Summary of sediment trap monitoring sites and sediment volumes in 2003.

Site ID	Basin #	Year Constructed	Survey Date	Sediment Volume (ft^3)
002RW	1	2001	7/1, 9/16	7.29**
003RW	1	2001	7/1, 9/16	30.49**
006RW	1	2001	6/30, 9/16	5.80**
008RW	1	2001	7/1, 9/16	40.20**
009RA	1	2001	7/2, 9/16	12.36**
073ST	7	?	8/5	
152RW	2	2003	7/29, 9/16	198.00*
153RW	2	2003	9/16	
161RW	2	2003	9/17	
162RW	2	2003	9/17	
163RA	2	2003	9/22	

*Value reflects volume of excavated material, not necessarily storm generated sediment.
** Particle size analysis of fill material will be reported in Validation Monitoring section.

made in mid to late September except for 152RW. Just after installing the silt fence below the weir on July 29, a rain event (approximately 0.5 inches in 0.5 hours, 075RG) washed large quantities of sediment into the structure, flowing both around and under the rock weir. The road above 152RW was under construction but had not been paved yet, nor had the drainage ditch been treated, all of which likely contributed to the sediment load produced. The weir was surveyed after the storm runoff subsided on July 29 and

Figure 5. Note extent of sediment plume in 008RW on September 22, 2003.

subsequently resurveyed on September 16, after the basin was cleaned, yielding a 198 ft^3 difference in volume (Table 8). Without a pre July 29 survey of the weir this volume is speculative at best, but the photographs on the data DVD qualitatively show the extent of the sediment. It should be noted that excelsior logs installed downhill of the weir intercepted sediment that passed under or around the rock weir (Figure 6).

Sediment trap 073ST, surveyed on August 5 and 6, acts as an instream sediment detention area on Ski Creek below Glen Cove. This broad, flat area has a large accumulation of sands and gravels which the stream meanders through and will be resurveyed prior to the construction of sediment pond 650+00. Photographs of all sites are contained on the data DVD.

Energy Dissipaters

No monitoring of energy dissipaters was performed in 2003. In Basins 1 and 2, rock weirs and the elimination of discharge points, are the methods of energy dissipation employed.

Figure 6. Slope below 152RW after storm on July 29. Note lack of transported material below excelsior logs.

Validation Monitoring

Validating the effect the proposed road restoration practices have on aquatic, wetland, and riparian conditions is much more difficult than determining the effectiveness of the mitigation practice in reducing erosion and sedimentation on-site. On-site response to the mitigation practices should be direct, dramatic, and occur in real time. Off-site response is likely to be much more diffused, less dramatic, cumulative in nature, and subject to offsetting degradation from elsewhere in the watershed, all of which make detection of the mitigation response difficult. It would appear that the watersheds of concern have been subject to, and reflect the cumulative effect of, road related impacts that have been ongoing for over 80 years. If one assumes the existing degradation is the aggregate result of long-term road related discharge and sediment pulses, the interruption of those pulses as a result of road rehabilitation, might be too insignificant to be detectable in the near term. Because the off-site response to the road improvement practices can be expected to be subtle and occur over a long time frame, the choice of the metrics to be monitored to document change down stream is critical if Validation Monitoring is to have a reasonable chance of success in documenting long-term improvement in the aquatic, wetland, and riparian environments.

The objective of validation monitoring is to document the effect road mitigation practices have on the aquatic, wetland, and riparian communities that are within the influence of the Pike’s Peak Highway. By monitoring features in both reference (non-highway influenced) and impaired streams, relative (converging or diverging) changes observed in these features over time between the 2 groups would be attributed to the road mitigation practices. The nine streams identified as either impacted or non-impacted by the presence and maintenance of the Pikes Peak Highway by ERO Resources Corporation (1999) are: North Catamount, South Catamount, Oil, and Boehmer Creeks as reference or non-impacted streams; and Ski, Severy, East Fork of Beaver, North Fork of Crystal, and West Fork of Beaver Creeks as stream systems impacted by the highway.

Stream Reach Selection

Properties of a single reach on each stream have been monitored for several years by Chadwick and Associates and the City of Colorado Springs with respect to water quality, biological, and physical characteristics. We have taken over the responsibility for monitoring the physical attributes at these sites using them as our first reach (Reach ID label = 1) and selecting a second reach (Reach ID label = 2), upstream of the first. For the impaired streams, we tried to select particularly degraded reaches so that, in theory, with excess sediment intercepted and storm flows attenuated by the mitigation efforts, we might detect a response more readily than in moderately impacted reaches. Locating the second reach upstream from the first also places it closer to the road and the road impacts, which theoretically could reduce the time factor for response.

This protocol was consistent except for two streams. The original monitoring site on Oil Creek (OILC1) though on National Forest land is surrounded by private property and requires permission to access the site. Logistics precluded the establishment of a second site and so we decided to monitor just the one reach on Oil Creek. The original monitoring site on Ski Creek is located in a diverted channel that contours through a berm at the mouth of the canyon and flows into South Catamount Creek above a stream gauging station. So instead, we chose to locate SKIC1 about 200 yards upstream from the mouth of the canyon in a natural stream channel. Also in Ski Creek, about 50 yards up from the mouth of the canyon, we located single cross section monumented by rebar end points with “FS” stamped in the plastic caps. We named the site SKIFS and surveyed the cross section but have not located any (Forest Service) survey data associated with this site. We do have a question about the status of South Catamount Creek as a reference stream. Glen Cove Creek, which is impacted by the highway, flows into South Catamount Creek about 0.5 miles above our second reach. Until this designation can clarified and for the purpose of this report, South Catamount Creek will be treated as a control.

Stream Reach Descriptions

Following are some brief observations made in the field at each site.

Boehmer Creek is a small, steep, alpine stream that flows through a shallow “U” shaped valley. Both reaches have an open canopy and a narrow active channel, with grade controlled by large cobbles and boulder though the bed material contains a fair amount of sands and fine gravels. There are no depositional features (bars) in either reach. Bank stability is fair to good with evidence of over bank flows creating side channels in the floodplain which are abandoned at base flows.

East Fork Beaver Creek is the highest elevation stream. Reach 2 has a narrow, deep, sinuous channel that flows through an alpine wetland characterized by grasses, sedges and forbs and is relatively low gradient. Banks throughout the reach are actively eroding. Reach 1, in contrast, is steep and straight, with a broader active channel and boulder/bedrock grade control with dense growth of willows on either bank. Pools are characterized by large deposits of sand and fine gravels. Banks tend to be very stable though at the downstream end of the reach the channel splits around a mass of willows (which over hang both channels) and then comes back together.

North Catamount Creek is a small, fine grained, relatively low gradient stream meandering through a meadow in a broad valley. The reaches are similar except Reach 2 has a dense shrub component which provides more bank stability than in Reach 1. In fact, the right bank in Reach 1 is actively eroding between Cross Sections B and E.

North Fork Crystal Creek is a small, steep, ephemeral drainage in close proximity to the Pike's Peak Highway in Priority Basin 2. The reaches, close together, have a closed canopy comprised mainly of aspen and the channels contain mostly sands and fine gravels. Reach 1 has a poorly defined channel that appears to shift across the valley floor, while the somewhat better defined channel in Reach 2 is actively eroding both banks the entire length of the reach.

Oil Creek is a small, meandering stream of moderate gradient flowing through a broad valley with an open canopy and strong riparian shrub component. Bank stability is good to very good, with a well developed floodplain inside of terrace. Bed material is mostly well sorted gravel and cobble with some fines. Beaver dams upstream of reach probably function to regulate sediment transport.

Severy Creek is a small drainage near the Pike's Peak Highway in Priority Basin 3. Reach 1 and 2 are very different in their settings and characteristics. Reach 1 is a narrow, single thread channel meandering through a broad meadow below a very large alluvial fan. Bed material is mostly fines with some larger particles including a bedrock outcrop between Cross Sections D and E. A strong shrub component for the entire length of the reach contributes to good to very good bank stability. In contrast, Reach 2, near the toe of the hill slope, is deeply incised into an alluvial fan at the upstream end, and flows subsurface at the downstream end of the reach. Bed and banks are comprised of sand, gravel, and cobble outwash with abundant dead spruce, standing and not, on the fan. Over the entire length of the reach we found 1 spruce seedling near Cross Section C, the only living vegetation near the channel.

Ski Creek is a small, steep stream flowing through a "V" shaped valley. There is a fair distance between the 2 sites as Reach 1 is near the mouth of the canyon where it flows into South Catamount Creek and Reach 2 is just below the lowest culvert crossing in Priority Basin 7. In Reach 1, the bed material is mostly gravel with depositional features present on both the inside and outside of meander bends and bank stability rates fair. The closed canopy of conifers in the canyon grows right down to the stream margins. Reach 2 is a true step pool system with large boulders providing grade control and sands and fine gravels filling the pools. The abundance of inorganic and organic debris has resulted in a main channel with one to four overflow channels depending on lateral constraint. The canopy is closed and the dominant vegetation is a mixture of conifers and alder. Where not protected by boulders and tree roots, the banks can be undercut by as much as three feet.

South Catamount Creek is a small, gravel bed stream with a closed canopy of spruce with some alder and willow present in the riparian. Reach 1 is less steep than Reach 2 and appears to have more depositional features and finer grained material. Both sites have good bank stability.

West Fork Beaver Creek is the largest drainage in the study. Reach 1 has a steep gradient, coarse bed material, and flows through a dense corridor of willows with little sinuosity. Bank stability is very good and the only deposition of fines is in a pool at the downstream end of the reach. In contrast, Reach 2 is in a broad valley characterized by large deposits of unconsolidated sand and fine gravels. There are some shrubs present but provide little bank protection and bank stability is generally very low. Several remnants of old beaver dams are present and lots of woody organic debris.

Stream Channel Surveys

Like all surveys performed on the effectiveness monitoring aspect of this study, each stream reaches pattern, profile and dimension were measured with a Trimble 5603 Robotic Total Station. Cross section end points (10) were monumented with rebar and will be used as reference coordinates to spatially locate features for the duration of this monitoring study. The objective is to measure change in these features over time and contrast the relative change in the impacted to the relative change in the reference channels.

Planview

The planview, or pattern, of left and right edge water, thalweg, and cross section location for each stream reach measured is presented in Appendix F. This perspective of the stream reach will provide a general index to lateral channel adjustment or migration over time. Four of the stream reaches have a thalweg survey only, with no left and right edge of water measurements. North Fork Crystal Creek 1 and 2 (NCRY1, NCRY2) are ephemeral stream reaches and in September there was no water. Severy Creek 2 (SVRY2) is an intermittent stream in September where, especially in the lower end, the stream flow went subsurface. For these three reaches, lateral channel movement can be adequately defined with just a thalweg survey. In contrast, there is low potential for lateral adjustment of channel pattern in Ski Creek 2 (SKIC2) because of its narrow valley bottom and the abundance of large boulders and debris.

Cross Sections

Five cross sections per reach were established to document changes in active channel geometry. Cross section end points were monumented with rebar capped with yellow plastic to provide ten permanent reference locations per reach to maintain continuity in monitoring over the course of the study. A tape was stretched between the two endpoints to act as a tagline to guide the survey across the cross section. Top of bank, or bankfull, elevation identified at each cross section is used as a reference for calculating the active channel dimensions which are presented in Appendix G along with graphs of each cross section. The one exception is Cross Section E on Severy Creek 2 (SVRY2) where no defined channel exists (ergo no geometry calculated) and in fact the shape of the cross section is convex. The plan here is to wait until a channel forms (when and if) and compare that channel to this initial survey. The same procedures used to measure, correct, and calculate cross section geometry at road cross sections and drainage ditches is employed here. Consistently monitoring channel dimensions at the same location provides an excellent measure of both lateral and vertical channel adjustment within each reach. Photographs of left and right bank and upstream and downstream views at each cross section, with photograph ID board, are contained on the data DVD.

Slope

Left and right edge of water and thalweg were surveyed over the length of each reach, except for those sites mentioned in the Planview section. Slope was calculated by dividing the change in elevation by the total distance measured for each feature. No attempt was made to normalize distance to a consistent feature (e.g. thalweg) so the total distance measured at each reach can vary by feature. Summary of slopes between cross sections A and E and graphs of all reaches are presented in Appendix H. These measurements, particularly the thalweg, will be useful in detecting vertical channel adjustment (erosion/deposition) over time. As a side note, all the raw survey data (Point Number, Northing, Easting, Elevation, Feature Code) for each stream is contained in a MS Excel file under the Profile directory for each stream on the data DVD.

Particle Size Distribution

Pebble Counts

Pebble counts (300 particles) in each reach were done to characterize the bed material of the active channel using the Bevenger and King Pebble Count Procedure (Bevenger and King, 1995). A tabulation of the 15th, 35th, 50th, 84th, and 95th percentile and graphs of the distributions are presented in Appendix I. Comparing the particle size distributions from successive pebble count surveys, to document trends in the percent fines between control and impacted sites, will be useful in defining one aspect of the in-channel impact of the reduction in sediment supply or discharge.

Grab Samples

Particle size distributions of sediment taken with grab samples from eight stream reaches (one reach per stream except Boehmer Creek) and eight highway sites (three fill slope silt fences and five rock weirs in Basin 1) are presented in Appendix J. Unlike pebble counts, the particle size distribution of the grab sample is based on the cumulative percent ash-free dry weight-per-size fraction of the sample, as defined by the sizes of the nested sieves the sample is passed through. Comparing the distribution of material captured in traps near the highway to sediment deposits (bars) in the streams should validate response to highway mitigation practices. Since bars are not present in either Boehmer Creek reach, no grab sample was taken.

Bank Erosion

Cross section monitoring locations in each reach should adequately document bank erosion and lateral channel migration. Photographs at each cross section facing up and downstream and towards the right and left bank will provide supporting evidence if active erosion is observed over the course of the study. The planview surveys can also document lateral channel migration or pattern changes over the entire reach, which if dramatic, can help quantify the extent of bank erosion in conjunction with the cross section surveys.

Vegetation

Vegetation photo points were established at the top of the left and right banks at each cross section to document changes in species composition and percent cover over time. Vegetation was grouped into general categories of moss, grass, sedge, forb, or shrub to document presence, and percent cover estimated for the top of bank area 1.5 feet on either side of the cross section. A tape stretched between the cross section end pins was used to determine the distance from the left bank pin for the top of bank as well as the camera position. A pocket rod was used to indicate the three foot transect of interest at the top of bank and an ID board was used to indicate cross section and bank ID (AL = Cross Section A, Left Bank; DR = Cross Section D, Right Bank) for the photograph. All photographs were taken with an Olympus Stylus 400 digital camera and our field procedures generally follow those outlined in the Photo Point Monitoring Handbook (Hall 2002). Appendix K provides a tabulation of the data recorded and photographs taken at each site. Photographs taken of the same site, from the same location, should provide good documentation of trends in specie composition and percent cover over time.

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