Sugar Creek Sediment Mitigation Project

Site Assessment, Conceptual Solutions, and Preferred Alternatives

Prepared For:

Douglas County
South Platte Enhancement Board
US Forest Service
Trout Unlimited

Prepared By:

CH2MHILL

Kyle Hamilton, Will Voss, Trent Miller/CH2M HILL

April 30, 2009

Table of Contents

Project Overview

Introduction

Sugar Creek is one of the primary tributary streams to the South Platte River, a world-class trout fishery. In the past, Sugar Creek provided refuge for young-of-the-year trout spawned in the river, but sediment is impairing that function. Douglas County Road 67 (CR 67), an existing gravel road immediately adjacent to Sugar Creek, contributes high levels of sediment into Sugar Creek, and that sediment ultimately enters the South Platte River. The natural geology, which consists of decomposing granite, also contributes upland sediment into the creek.

Sugar Creek is listed on Colorado Department of Public Health and Environment's (CDPHE) Regulation #94 – Colorado's Monitoring and Evaluation List due to sediment (Reg. #94 Effective 4/30/08). The sediment reduces the function of Sugar Creek and the South Platte River, impairs watershed health, and reduces the amount of effective habitat available for macroinvertebrates, trout, and riparian dependent species, such as the federally-threatened and protected Preble's Meadow Jumping Mouse (PMJM).

The South Platte River has numerous dams along its extents, thus creating reaches of stream that must maintain their ecosystem function between each dam. Since Sugar Creek is one of the few places where young-of-the-year trout can find refuge, it is a critical element to the function of the ecosystem between Strontia Springs Dam and Cheeseman Dam.

This project has two primary objectives:

- Provide solutions to decrease the amount of sediment entering the creek to improve stream habitat and function.
- Act as a pilot project related to dirt and gravel roads adjacent to streams, such that the processes, tools, and concepts developed herein can be applied to other watersheds and forests in Colorado.

The stakeholders realize that there are many road and stream corridors with similar issues throughout the state. This pilot project will define a repeatable process that can be refined over time to be used on other streams, watersheds, and forests in Colorado. By investigating all facets related to the road, stream, and environmentally sensitive areas, truly multi-objective solutions will be obtained. The road assessment addresses operational improvements, culvert crossings, road erosion, snow plowing operations, and more. The stream assessment addresses stream stability, erosion, substrate condition, invertebrate habitat, fish cover, and more. The biological assessment addresses PMJM habitat areas, wetland areas, and other areas needing special protection and permitting. This project also investigates the use of the Streamside Systems technologies for bed load sediment removal and in-situ sediment removal.

Project Area

The project is located along Sugar Creek and CR 67 in Douglas County, Colorado within the Pike National Forest, as shown on **Figure 1**. Sugar Creek enters the South Platte River upstream of Nighthawk, a small town located approximately 10 miles upstream of Strontia Springs Reservoir. The center of the project area is near coordinates 105°10’00” and 39°18’00” (NAD83). The Sugar Creek watershed is approximately 8,400 acres in area and is at an average elevation of 7,500 feet.

Project Team

The Management Team for this project consists of the following staff and agencies:

- Garth Englund, P.E., Douglas County
- Denny Bohon, USFS, South Platte RD
- Sharon Lance, Trout Unlimited
- Kyle Hamilton, P.E., CH2M HILL

The lead sponsor for the project is Douglas County, Colorado. Douglas County has a vested interest in this project because the road adjacent to Sugar Creek is a Douglas County Road, and is one of the two primary access routes for metro Denver residents to reach the South Platte River. Ensuring safe and environmentally sustainable roads is a key goal for Douglas County, in support of both the local citizens, tourists visiting the area, and associated economic development. Douglas County has partnered with the South Platte Enhancement Board (SPEB), USFS, Trout Unlimited, CH2M HILL, and others in order to execute this collaborative project.

The project has a diverse array of project sponsors and partners. Stakeholders and partners at this time are listed in **Table 1**.

TABLE 1
Stakeholders and Partners

Douglas County	Colorado Division of Wildlife
South Platte Enhancement Board (SPEB)	US Forest Service, San Isabel NF
US Forest Service, South Platte RD (USFS)	Colorado State Forest Service
US Forest Service, Pike NF	Denver Water
Coalition for the Upper South Platte (CUSP)	USGS
Trout Unlimited	CH2M HILL
US Fish and Wildlife Service	Streamside Systems
Colorado Dept. Public Health and Environment	

Pilot Project Concept

As stated above, one of the primary goals for the project is to be a pilot project related to forest roads adjacent to streams. The processes, tools, and designs developed herein can be applied to other watersheds and forests. By using this project as a pilot, lessons will be learned and the results will be used as a launching pad for other projects in the South Platte Watershed, as well as other watersheds. Representatives from the Salida Ranger District of the San Isabel National Forest, which is located near Salida, Colorado and the Arkansas River, are involved in this project because they have similar stream and road corridor issues. This project may also provide opportunities to construct various improvement features as pilot studies, to try new technologies or concepts, learn which alternatives are preferred, and provide field examples for stakeholders and other interested parties to view.

Project Phasing

The project is multi-phased and is separated into five anticipated phases, as shown in **Table 2**.

TABLE 2
Project Phasing Summary

PHASE	TASK / MILESTONE	SCHEDULE
1	Watershed Assessment, Alternatives Analysis, and Conceptual Solutions	2008
2	Permitting, Funding Acquisition, and Detailed Environmental Surveys	Spring to Summer 2009
3	Final Design	Summer 2009
4	Construction	Fall 2009
5	Monitoring and Reporting of Results	Fall 2009 and beyond.

Data Collection

Existing data relating to Sugar Creek and the South Platte watershed was collected, and included the following:

- Aerial Photography (Douglas County)
- Flow Rate, Sediment, Water Quality, and Fish Population Data (USFS)
- GIS layers for PMJM Habitat Limits, Off Highway Vehicle (OHV) Trail Extents, and Burn Area Limits (USFS)
- Stream Centerlines (USGS National Hydrologic Dataset)
- Various reports and documents by others, as summarized in the References section

The GIS data was organized in a GIS Personal Geodatabase Format. New data created during the project was added to the GIS database.

GIS Map Book

Appendix E contains a GIS and aerial photo-based Map Book (Map Book) with thirteen 11”x17” plots. The Map Book highlights areas of significant erosion, road wash boarding, sediment sample locations, fish shocking locations, head cut locations, significant creek drops, and other key features identified during the site investigations. The Map Book also identifies potential sites for stabilization, settling ponds, and Best Management Practices (BMPs), such as sediment traps.

The stream network shown in the Map Book is based on the USGS National Hydrologic Dataset (NHD). In some locations, the Map Book notes that the actual location of Sugar Creek is different than shown in the NHD GIS layer. However, in general, Sugar Creek and the many tributaries and dry gullies in the Sugar Creek watershed are represented well by the NHD layer. According to the NHD data, Sugar Creek leaves CR67 at Station 246+00 and heads west.

Listed below is additional information related to the terms and symbols used in the Map Book:

- Protection Reaches (High and Moderate Priority): These are areas where sediment from the road should be controlled so that it does not enter the stream. The majority of these areas are where the road and the stream are adjacent to each other, and there is little or no vegetative buffer to capture sediment from the road.
- Sediment Sample: The symbols indicate where sediment samples were taken, as described in **Table 4**.
- Major Roadside Erosion: The symbols indicate where roadway runoff has concentrated and is flowing down the road embankment causing erosion. In many cases this is where the roadside berm has a low point or has been breached and allows flow to pass through the berm.
- Existing Rundown: These are areas where a graded ditch or natural ditch conveys concentrated from the road to an overbank area or the creek. The rundowns are similar to the Roadside Erosion locations, but are more significant and formalized.
- Potential BMP Site: These sites are locations where a sediment trap or other feature may be applicable. These BMPs would typically be located at the upstream or downstream ends of the existing culverts.
- Area to Stabilize: These areas are currently eroding and stabilization is recommended.
- Potential Settling Pond Area: These areas were identified as potential sites for sediment traps, settling ponds, or other features that would trap sediment. The locations were selected based on having relatively flat ground, enough area to construct a feature, are in locations that would capture concentrated runoff, and are adjacent to the road for ease of maintenance and sediment removal.
- Potential Wetland: These areas are potential existing wetlands, based on general field investigations. A detailed wetland survey was beyond the scope of this phase of the project.

- Existing Washboard: These are areas where the existing gravel roadway surface has transformed from a smooth surface to a “washboard” surface consisting of consecutive small bumps and dips aligned perpendicular to the direction of travel.
- Reach Extents: In some cases, reach extents are shown by black leader lines, such as for the beaver ponds on Map Book Page 2.

Decision Model Workshop

A Decision Model Workshop was conducted on August 15, 2007 with many stakeholders. The purpose of the workshop was to bring the stakeholders together to discuss and understand the concerns from each group, discuss the key problems along Sugar Creek, and rank the problems so that the solutions identified can address the highest ranking problems.

An Excel-based Decision Model was used for the following:

- Establish Project Criteria (problems and goals).
- Prioritize the Criteria using a process called Forced Ranking

Due to budget constraints, the next steps of the Decision Model process were not included at this time, but the typical next steps are as follows:

- Score each Project Alternative against the Criteria, to develop a Benefit Score for each project.
- Combine the estimated Alternative Project Costs with the Benefit Scores to determine the projects with the highest Benefit to Cost ratios.
- Perform a sensitivity analysis and run "what if" scenarios to determine if any of the results change due to varying stakeholder input.

The stakeholders ranked the key issues of concern for Sugar Creek as presented in **Table 3**. The results of the Decision Model were provided to the stakeholders on August 22, 2007. The USFS has indicated that they might like to standardize the Decision Model process, so that it can be easily used on other streams and watersheds.

TABLE 3
Decision Model Forced Ranking of Key Areas of Concern

Criteria	% Wins	Rank
Safety (flooding, drowning potential, etc.)	12.5%	1
Sediment Source - Road / Trails (adjacent to streams, stream crossings)	11.7%	2
Sediment Source – Stream (bank erosion, bottom degradation)	10.8%	3
Road – Envir. Impacts (habitat connectivity, oil/grease, etc.)	9.2%	4
Sediment Source – Upland (upland erosion into the stream)	8.3%	5
Sediment Impacts - Conveyance Capacity (stream, culvert, and sediment transport capacity)	7.5%	6
Water Quality (chemical, not sediment)	7.5%	6
Road – Quality (surface type, speeds, curves, curbs, standards met / not met)	6.7%	8
Sediment Impacts - Stream Morphology (channel migration - vertical & horiz.)	5.8%	9
Habitat – In-stream (within the water: fish, invertebrates)	5.0%	10
Sediment Impacts - Fish Habitat (young of year, spawning, adult)	4.2%	11
Road Maintenance (snow plowing, sediment removal, etc.)	4.2%	11
Habitat - Riparian / Upland (beyond the water limits)	3.3%	13
Sediment Impacts - Reservoir Capacity (impacts to Strontia Springs)	1.7%	14
Public Impacts (flooding, sediment on private land, property destruction, etc.)	1.7%	14
Total	100.0%	

Site Assessment and Analysis

The assessment of Sugar Creek along CR 67 was conducted in order to accomplish the following:

- Identify and analyze areas of critical concern related to the key Criteria identified in the Decision Model Workshop.
- Develop recommended stream restoration and roadway improvement solutions, or BMPs, to address those concerns.

The assessment focused on the Sugar Creek and CR 67 corridors, as shown in the Map Book. The assessment of Sugar Creek included the stream and adjacent riparian areas from the confluence with the South Platte River to Station 243+50 in the Map Book. The assessment of CR 67 started at the confluence of the South Platte River and Sugar Creek, and ended at the Sugar Creek Watershed Boundary. The assessment also considered areas beyond the riparian and road corridors that may have an impact on Sugar Creek, such as highly erosive gullies, sediment sources, OHV trail impacts, and other similar conditions. Analysis related to rerouting or closure of OHV trails was previously conducted by others, and was not included in this study. Field logs for the stream and roadway assessments are included in Appendix A.

Stream Assessment

The goal of this task was to determine the condition of the stream corridor, and identify the key problem areas.

Flow Rates

USFS conducted on site flow rate analysis from 2004 to 2008. The base flow rate is typically near one cubic feet per second (cfs), and runoff rates reached 13.4 cfs. The flow rates measured in 2008 were 2.96 cfs at the USFS Established Cross Section (near Station 28+00), and 1.18 cfs near Station 154+00.

Sugar Creek flood peaks were obtained from the USGS report *Analysis and Mapping of Post-Fire Hydrologic Hazards for the 2002 Hayman, Coal Seam, and Missionary Ridge Wildfires, Colorado,* Table 3-7 (Elliot, 2004). Sugar Creek is represented as Basin UB3, and has the following estimated flow rates: 10yr = 0.23 cfs, 50yr = 62 cfs, 100yr = 105 cfs, and 500yr = 290 cfs.

Geometry and Flow Regimes

The USFS Landscape Assessment, Upper South Platte Watershed (USFS Landscape Assessment) Map W-1 classifies the lower two-thirds of Sugar Creek as Rosgen Type B, and the upper third as Rosgen Type A.

The base flow in Sugar Creek during this study began near Station 240+00. The stream is conveyed through upland grasses in a six inch deep by one foot wide channel to approximately Station 193+00, where the creek is two feet wide with a flow depth of six to twelve inches. In the lower reaches, Sugar Creek typically varies in width from four to eight feet, varies in bank height from one to three feet, and has an average flow depth from four to eight inches.

Sugar Creek has a good variety of riffles and small pools, all on a small scale typical for this size of stream. The overall change in elevation of the stream along the study reach is approximately 1,500 feet, which results in an average grade of 310 feet per mile. There are two locations where the stream is segmented by large drops. The first drop is at Station 8+50 and is approximately 10 feet high. The second drop is at Station 218+50 and is approximately six feet high. Both of these drops are significant enough in height to prevent fish passage in an upstream direction. Due to the sediment being transported in the stream, there are very few deep pools along the creek. Deep pools occur at a two of the beaver ponds, and at the base of the 10 foot boulder drop.

Bed and Bank Conditions

The bed material in the creek varies from silts to boulders. Pebble Count data was collected by USFS and is included in Appendix B. On average, the D50 grain size is between 2 mm and 4.3 mm, and the material is primarily comprised of gravel, sand, and silt/clay. In addition to the pebble count data, the site investigations confirmed that the bed material varied from silt/clay to boulders, with all intermediate sizes present.

The channel banks are typically at relatively steep slopes, varying from nearly vertical to 1H:1V in most cases. In some cases, flatter banks slopes of 2H:1V occur. The banks are well vegetated with riparian and upland vegetation in almost all reaches. Pea-sized gravel is very common on the hill slopes, as well as in the creek.

Only one reach had moderate bank erosion, as shown in photo to the right. This erosion is typical of streams and is caused by the soil and vegetation being unable to withstand the erosive forces of the channel flow. The toe of the bank has eroded, and the upper banks have thus sloughed off and the erosion now extends from the creek invert to the top of the right bank. Some loss of vegetation has occurred in this reach, including the right bank riparian fringe.

The eroded bank could be repaired by laying back the slope and protecting the bank with willows, erosion control blanket, or buried rock. Due to the low occurrence of this poor bank condition, and the relatively short reach where erosion has occurred, this area could be improved or identified as a “watch area”.

Tributaries

The most significant tributaries enter Sugar Creek at the following Stations, and have the characteristics shown:

- Station 130+50: Riffle regime, 1 foot wide, 1 foot deep, 3 inches of flow, sand and gravel bed material, and stable banks. Some sediment is accumulating at the confluence, but appears to be flushing adequately. No fish were seen in this area.
- Station 147+80: Riffles and small pools, 2 feet wide, 2 feet deep, 4 inches of flow. Sand, gravel, and cobble bed material, and stable banks. No sediment deposition at the confluence. Six 6-inch trout seen at the confluence.
- Station 205+00 (Deep Creek): Cascading regime, 1 foot wide, 1 foot deep, 1 to 3 inches of flow, gravel bed material, high quality cover, and stable banks. Some sediment deposition at the confluence was present (6 inches). Road base material was also present, which corresponds with a culvert and rundown in the area. Two 8-inch trout seen in the tributary.

Fish and Macroinvertebrate Populations

The Environmental Assessment for the Upper South Platte Watershed Protection and Restoration Project (Upper South Platte EA) lists Sugar Creek as one of only six tributaries in the 140,000 acre Upper South Platte River study area that supports fish populations. However, the USFS Landscape Assessment Map W-9 does not show Sugar Creek as a "Probable Range" area for where Brook Trout might be expected to occur.

The site assessment conducted with this study herein has shown that Brook Trout do inhabit Sugar Creek. Fish population data was provided by USFS and is included in Appendix C. The data is summarized below:

- Fish shocking occurred near Stations 28+00 and 154+00.
- The data shows that the stream contains brook trout ranging in size from 23 to 207 mm in length. Fish biomass estimates ranged from 43 kg/ha to 105 kg/ha. No other types of fish were found.
- Water temperatures were 46 to 48 degrees F. The cold water temperature indicates the riparian over story is performing well and keeping the temperatures low.
- TDS, pH, and nitrates were all well below the EPA's potable water standards.
- The largest fish was almost 9 inches.

The site investigations conducted in this study agree with the fish shocking data. Brook trout were seen in over fifteen locations, ranging in size from one inch to eight inches. The beaver ponds that have accumulated sediment were found to provide good habitat and protection for the fry, as they collected in the small pools formed on the sediment accumulation zones where the creek meanders and slows in velocity. The larger trout were found under cut banks, in pools, behind small boulders, and near underwater structure.

The site assessment also included informal macroinvertebrate investigations. In nearly all cases, a selected and reviewed 6-inch diameter cobble resulted in between two and 10 macroinvertebrates. Detailed identification was not conducted, but stoneflies, mayflies, and caddis larva were present.

Water Quality

Sugar Creek is currently listed on the CDPHE Water Quality Control Commission Regulation #94 – Colorado's Monitoring and Evaluation List, effective April 30, 2008. Sugar Creek is listed due to sediment. Water quality analysis was not part of this project. However, water quality data was obtained from the USFS for Sugar Creek and Pine Creek, the tributary to the north of Sugar Creek, and is included in Appendix D. Pine Creek has a similar road adjacent to the stream, and has similar geologic and vegetative conditions. The water quality data could be used as reference information for Sugar Creek in future phases if needed.

Sediment Composition and Transport

The USFS Landscape Assessment Map W-2 classifies the entire length of Sugar Creek as a "Transport" stream, as opposed to "Source" or "Response". This study found that the beaver ponds and upstream of both large drops are significant localized deposition areas.

Sediment Composition

Shovel samples of the stream bed, hill slopes, and beaver ponds were collected to determine the general characteristics of the top four to eight inches of material (armor layer and sub-armor layer). A sample of the road base material on CR 67 was also collected. The sample locations and characteristics are presented in **Table 4**. Detailed lab analysis was not included in this phase of the project.

Sediment Sources

Primary sediment sources are the natural hill slopes, CR 67 (imported gravel and natural material), the roadway fill slope adjacent to the creek, and some tributaries and hill side gullies. Tributaries with flow appear to be stable, and no major erosion was present. Some of the sediment from tributaries is being deposited at the confluences with Sugar Creek, but the deposition is localized and Sugar Creek appears to be flushing the sediment adequately.

Sediment Production Rates and Ongoing Studies

Calculating sediment production was beyond the scope of this phase. However, data has been collected for similar areas in the Upper South Platte River Watershed. One study reviewed both forest roads and off-highway vehicle (OHV) trails (Welsh, 2008). The study indicates that the amount of sediment reaching a stream is a function of precipitation, summer erosivity, segment slope, segment length, proximity to the stream, and other factors. Roads were found to produce on average 3.1 kg m-2 yr-1, and OHV trails could produce up to 53.3 kg m-2 yr-1. Although OHV trails were found to have higher production rates than forest roads, forest roads are adjacent to creeks for much greater lengths. Where roads and OHV trails are connected to streams, the average sediment production is 1.1 Mg km-2 yr-1 for roads and 0.8 Mg km-2 yr-1 for OHV trails.

Another study by Colorado State University provides the following summary (Welsh 2006):

> *"Unpaved roads are often the dominant source of sediment in forested areas, and they are of particular concern in the Upper South Platte River (USPR) watershed because this is the primary source of drinking water for Denver, has a high-value fishery, and has a high density of roads and off-highway vehicle (OHV) trails. The goal of this project is to quantify sediment production and delivery from unpaved roads and OHV trails, as there are no data on these sources in the USPR watershed. Since summer 2001 we have been measuring rainfall, sediment production, and segment characteristics from up to 20 road segments, and in August 2005 we began making similar measurements on OHV segments. Sediment delivery is being assessed by detailed surveys of selected roads and OHV trails. Summer rainstorms larger than 10 mm typically produce sediment from each road and OHV segment while undisturbed areas generally produce no surface runoff. The mean annual sediment production from unpaved roads has ranged from 0.4 to 6.7 kg m-2 yr-1, and this variation is largely due to differences in the amount and intensity of summer precipitation. In summer 2006 the mean sediment production from OHV trails was 18.4 kg m-2, or more than 5 times the mean value from unpaved roads. A survey of 17.3 km of unpaved roads showed that 14% of the total road length was connected to the stream network; initial surveys on 3 km of OHV trails indicate a similar degree of connectivity. The overall road density in the study area is about 1.1 km km-2, so unpaved roads are contributing about 1.3 Mg km-2 yr-1 of sediment to the stream network. The results suggest that unpaved roads and OHV trails may be the largest chronic sediment source in the Upper South Platte River watershed."*

Sediment Deposition Areas

Sugar Creek is primarily a Transport stream, but deposition is occurring at the beaver ponds, in localized depressions along the entire length of the stream, at the upstream side of boulders and debris blockage locations, at a few inside meander bends, and at the confluence with the South Platte River (see photo to the right). The high quantity of sediment is limiting the creek's ability to form deeper pools, thus fish habitat is limited by the sediment.

The imported gravel road base material from CR 67 was found in numerous locations along Sugar Creek. The imported road base gravel differs in color and shape from the natural hill slope material, and is visually distinguishable. The gradation of the imported material is not significantly different from the native material, and appears to be transported by Sugar Creek downstream of its input location.

TABLE 4
Sediment Collection - Shovel Samples

Sample No.	Station	Location Description	Composition
1	8+00	Stream Bed	Silty, sandy, gravel, cobble (to 3”) Granitic (pink feldspar), well graded, angular
2	13+00	Southern Hill Side	Clayey (10%), silty, sandy, gravel (to 1”) Granitic (pink feldspar), well graded, angular
3	16+00	Beaver Pond	Friable, clayey (5%), silty, sandy, gravel (to 1/4“) Granitic (pink feldspar), well graded, subangular
4	24+00	Beaver Pond	Friable, clayey (5%), silty, sandy, gravel (to 1/2“) Granitic (pink feldspar), well graded, subangular
5	55+00	Stream Bed	Fine sand, gravel, cobble Granitic (pink feldspar), well graded, subangular
6	123+50	Stream Bed, downstream of eroded gully	Fine sand to coarse gravel (to 1”) Granitic (pink feldspar), well graded, angular 5% Road base
7	172+50	Northern Hill Slope	Organics (sticks, pine needles) Silty, sandy, gravel, cobble (to 3”) Granitic (pink feldspar), well graded, angular
8	172+50	Stream Bed at deposition area	Fine sand, gravel, cobble (to 3”) Granitic (pink feldspar), well graded, angular 5% Road base
9	211+00	Road Base from CR 67	Grey and white granitic quartz, subangular to angular 99% non-native material (imported)
10	220+00	Upstream of Boulder Drop	Friable, clayey (5%), silt, sand, gravel (to ½”) Some organics (grasses, sticks) Granitic (pink feldspar), well graded, angular

Most Erosive Areas

The following areas (listed from downstream to upstream) were found to have the most erosion, and should be considered for stabilization. The prioritization of these areas will be based on stakeholder input, funding availability, and other factors such as ongoing OHV trail relocation plans.

- Major Roadside Erosion areas as identified in the Map Book
- Station 70+00, Northern gully
- OHV trail and parking areas
- Station 108+50, Southern gully
- Station 116+50 Northern gully
- Station 122+50, Northern gully
- Station 144+00, Northern gully (sediment excavation has already occurred here)
- Station 144+00 to 148+00, USFS / Private roadway

Bed Load Estimate

Streamside Systems installed a two feet wide stainless steel bed load collector in Sugar Creek to estimate the bed load. The installation occurred on April 23, 2008. This time of year is typically near the peak of the runoff hydrograph based on historic data. The installation was attended by Douglas County, USFS, and CH2M HILL. The installation went well; however, no bed load was collected after installations in numerous locations. It was determined that the sediment size in Sugar Creek (typically the pea gravel seen on the hill slopes), was not being transported under the given flow conditions. The collector was also imbedded in the stream in order to force a head cut, but this too resulted in no mobilization of sediment.

This finding implies that the majority of bed load transported in Sugar Creek occurs during higher flows, which may be related to storm flows or very heavy snow melt runoff. The bed load collector was then provided by Streamside Systems to USFS so that it could be installed during a large storm event during the summer of 2008. No large storm events occurred on Sugar Creek during the summer of 2008, and the equipment was returned to Streamside Systems.

The result of the installation indicates that the Streamside Systems bed load collector is likely not a feasible alternative for sediment removal from Sugar Creek. Using the collector for only extreme events would be difficult due to start up, shut down, security, and other factors.

However, this does not rule out that the collector may be a feasible alternative on other streams with different sediment composition and flow rates.

Beaver Pond Sediment Estimate

There are nine major beaver ponds along Sugar Creek between Stations 15+00 and 30+00. This is an area where the valley widens slightly and provides good beaver pond habitat. The beaver dam widths vary from 15 feet to 60 feet at the dam, and vary in height from only a couple feet to over six feet high.

The beaver ponds are acting as natural sediment traps. The upstream ponds are filled with sediment, while the downstream ponds are in relatively good condition. Some of these ponds have completely filled in with sediment and have vegetation growing on the sediment accumulation zones. Other ponds have minimal sediment accumulation and have nearly their full depth of water available (based on the distance between the original channel invert elevation and the water surface elevation upstream of the dam). No beavers were seen during this study.

The beaver ponds provide an opportunity to excavate sediment from Sugar Creek, which will decrease the amount of sediment in lower reaches of Sugar Creek, and decrease the sediment input from Sugar Creek into the South Platte. If sediment excavation is determined to be a desired solution, it is recommended that only the middle reach of ponds be used for sediment removal (see Page 2 of the Map Book). This recommendation leaves the downstream ponds functional, and leaves the upper ponds as-is to maintain the shallow, slow flow habitat where many trout fry were seen. If additional sediment trapping capacity is desired, the upper ponds, as identified in the Map Book, could also be excavated. Excavation of sediment would need to be done carefully to not destabilize the dam or the pond's banks.

If no excavation is to occur, the downstream ponds that are currently functional could be filled with sediment over time. This would result in no functioning beaver ponds, no deep water for wintering trout, and could eventually result in an increase in sediment entering the South Platte River, because it is no longer being trapped by the ponds.

The volume of sediment that is estimated to be trapped in each pond is presented in **Table 5**. A long reach excavator, or the Streamside systems Wand technology, could be used to remove the sediment if desired. The left overbank area identified on Map Book Page 2 would allow for staging of excavation equipment and material stockpiling. The contractor would be required to excavate only the interior of the pond in order to maintain bank and dam stability, and protect the perimeter riparian vegetation.

Measuring the rate at which sediment is filling the ponds, and determining the resulting sediment removal frequency were beyond the scope of this study. However, the USFS is considering using the WEPP or other model to estimate these values during a future phase of this project, or on other projects that that utilize this pilot project's approach.

TABLE 5
Beaver Pond Sediment Volume Estimate

Beaver Pond No.	Approx. Longitude at Dam	Sediment Volume (cubic feet)
1	105° 11' 33.0"	225
2	105° 11' 32.3"	2000
3	105° 11' 31.5"	5500
4	105° 11' 30.2"	900
5	105° 11' 27.7"	1300
6	105° 11' 26.6"	312.5
7	105° 11' 25.9"	2150
8	105° 11' 23.5"	15750
9	105° 11' 19.7"	3000

*Volume of accumulated sediment estimated using historic channel invert and sediment accumulation elevations, and the average-end-area volume calculation method.

Sediment Haul Cost Information

Douglas County had previously obtained from Denver Water an estimated cost to haul sediment from the South Platte River corridor. They estimated the cost to haul sediment is $10 (2004 dollars) per cubic yard for approximately a six mile haul distance. Assuming 5 percent inflation, the estimate would be $12.16 (2008 dollars) per cubic yard.

The Urban Drainage and Flood Control District Construction Bid Tabulation Database states Excavation with Haul Off Site has an average unit cost of $14.22 (2008 dollars) per cubic yard (haul distances vary).

Haul Truck Impacts to Roadways

Haul trucks or vacuum trucks would be anticipated to be the primary means for removing sediment from the Sugar Creek area. The impact of these trucks on CR 67 is not expected to be more significant than the affects of existing traffic. Given that motor graders and haul trucks are already used on CR 67 by Douglas County, the road has the capacity to accommodate the type of equipment used to remove sediment.

Roadway Assessment

Transportation Corridor Assessment

The assessment of CR 67 started at the confluence of the South Platte River and Sugar Creek, and ended at the Sugar Creek Watershed Boundary. The goal of this task was to characterize the condition of the transportation corridor adjacent to the creek, identify alternatives for improvement in the level of service, and identify potential solutions to the problems. The analysis and recommendations focus on minimizing the sediment contribution from the road to the creek.

General Road Conditions

Horizontal Geometrics

CR 67 within the project limits generally parallels Sugar Creek and passes over the creek multiple times. The roadway has numerous horizontal curves ranging from 80 to 900 feet, with varying tangent lengths in between. In general, the roadway width varies from approximately 20 to 22 feet.

Longitudinal Grade

The roadway generally slopes down from east to west beginning with an approximate elevation of 7,800 feet and ending at 6,320 feet at the Platte River. This results in an overall grade of 5.4 percent for the project's 5.2 miles, with some locations as steep as 9 percent.

Cross Slope

The roadway cross slopes includes crowned or sloped sections through straight reaches, and superelevated sections through the curves. In general, the cross slope is sloped toward the creek when the creek is on the inside of a roadway curve, and sloped away from the creek when the creek is on the outside of a roadway curve. Where the creek parallels the road in a relatively straight direction, the cross slope is typically crowned or sloped toward the creek. These straight reaches provide the opportunity to reverse the roadway cross slope so that roadway runoff does not flow down the erosive side slopes into the creek. Additional cross culverts may be needed to convey runoff from the reversed sections to the creek. In most cases the roadway curves can not be reversed in order to maintain roadway safety and meet roadway design criteria.

Summarized below are the roadway reaches that could be reversed, and the proximity of the reach to the creek. The closer the reach is to the creek, the more beneficial reversing the cross slope in that reach will be in reducing sediment into the creek. The total length of the reaches identified below is 12,350 feet.

- Station 3+00 to Station 11+00: Roadway slope enters creek
- Station 23+00 to Station 42+00: Roadway slope enters creek
- Station 50+50 to Station 66+00: Roadway slope enters creek
- Station 69+00 to Station 75+00: Roadway slope enters creek
- Station 77+50 to Station 90+00: Roadway slope enters creek, overbank varies
- Station 92+50 to Station 99+00: Roadway slope enters creek
- Station 120+00 to Station 128+00: 30′ to 100′ flat overbank between road and creek
- Station 138+00 to Station 143+00: Roadway slope enters creek
- Station 161+00 to Station 164+00: 0′ to 40′ flat overbank between road and creek
- Station 171+50 to Station 174+00: Roadway slope enters creek
- Station 177+50 to Station 181+00: Roadway slope enters creek
- Station 182+50 to Station 185+50: Roadway slope enters creek
- Station 189+00 to Station 206+00: 5′ to 40′ flat overbank between road and creek
- Station 208+00 to Station 223+00: 40′ flat overbank between road and creek

Road Surface Material

The surface of the roadway generally consists of compacted native decomposed granite. Douglas County places road base material as needed consisting of either native material or imported road base gravel. In some areas, the surface has experienced extensive "washboarding" and edge raveling.

Design Criteria

CR 67 falls under the category of a low volume local road used primarily by familiar drivers. As noted above, the roadway horizontal curves have an existing range in radius from 80 to 900 feet. For a gravel road with snow conditions, these curves yield a design speed ranging from 15 mph to 45 mph, with most curves around 35 mph. Assuming a design speed of 35 mph, the roadway width for a recreational/scenic road per AASHTO could be as low as 18 feet; however, maintaining the existing wider section is preferred. The maximum grade for the road should be held to 10 percent.

Culvert Investigations

Culverts and Ditches

CR 67 has 55 corrugated metal pipe (CMP) crossings within the project limits. Sugar Creek passes through seven of these culverts ranging in diameter from 24 inches to 54 inches. The remaining culverts range in diameter from 15 to 30 inches. The creek also has two crossings that do not pass under CR 67, located at Station 91+50 and Station 144+00.

Many of the minor culverts have sedimentation ranging from 1 inch to 6 inches deep. A few of the culverts are 75-percent plugged. Many of the culverts appear to transport sediment from the hill-side of the road to the creek side, and none of the culverts use inlets to trap the sediment. A few of the outlets trap sediment through use of vegetated swales and natural check dams.

In general, the culverts do not cause significant fish migration problems, especially compared to the two major stream drops present on Sugar Creek. The USFS has recommended that the FishXing model be used to analyze culverts being considered for replacement.

Culvert Hydraulics

Douglas County stated that the design capacity for culverts on county roads such as CR67 is typically the 10-yr flow rate. CulvertMaster software was used to analyze each major culvert crossing, and determine its adequacy in passing the 50-yr flow rate. The Sugar Creek 50-yr flow rate of 62 cfs at the confluence of the South Platte River is based on analysis by USGS. The culvert analysis herein assumes the inlet headwater and outlet tailwater elevations are equal to the top of pipe elevation, and the pipe slope is 0.5 percent. The results are presented in **Table 6**.

TABLE 6
Culvert Hydraulics Summary

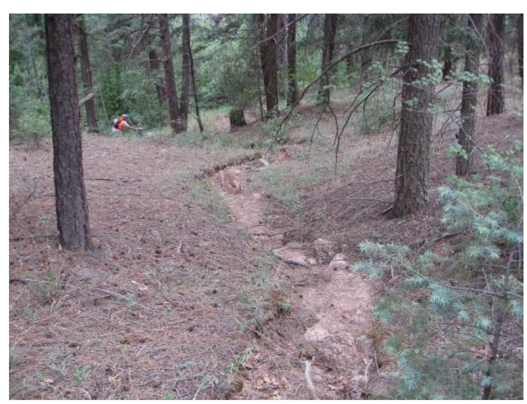
Culvert	Station	Dia. (inches)	Type	Length (ft)	Capacity (cfs)	50-yr Flow Rate at Culvert* (cfs)	Capacity (% of 50-Yr Flow)
1 (CR67)	14+00	54	CMP	80	46.7	58.6	80%
2 (private)	91+50	36 x 2	CMP	20	23.3	39.8	59%
3 (CR67)	107+50	54	CMP	40	36.5	36.2	101%
4 (CR67)	115+00	54	CMP	40	36.5	34.4	106%
5 (CR67)	118+50	54	CMP	40	36.5	33.6	109%
6 (USFS)	144+00	24 x 2	CMP	30	11.1	27.4	40%
7 (CR67)	164+00	36	CMP	50	16.2	22.6	72%
8 (CR67)	184+50	36	CMP	36	14.5	17.7	82%
9 (CR67)	225+00	30	CMP	36	9.7	8.0	121%

* 50-Yr Flow Rate per USGS, using linear interpolation from Station 0+00 (62 cfs) to Station 255+00 (0 cfs).

The culvert analysis shows that four of the nine crossings have sufficient capacity to convey the 50-yr flow without major overtopping of the road, which would have the potential to cause significant erosion. Although the remaining five culverts do not convey the 50-yr flow, they may be able to convey the 10-yr flow, which Douglas County states is the typical design flow rate. The USGS flow rate data did not contain the 10-yr flow rates needed to conduct a 10-yr culvert capacity analysis.

Culverts are known to impact wildlife migration to some extent. There are cases in the Colorado Front Range where “walking shelves” have been added inside of culverts to allow PMJM to walk through the culverts above the water elevation. USFS has indicated for this project that modifying the culverts in order to increase wildlife migration is not a high priority at this time. However, if culverts are to be replaced, the USFS would like the culverts to accommodate small mammals.

Culvert Discharges and Sediment Transport



Loose sediment from the roadway or cut slopes is conveyed into roadside ditches and eventually into the cross culverts. This sediment is then carried through the culverts to the creek side of the roadway, or gets trapped and plugs the culvert. The flow is then discharged into the creek, onto the creek bank, or is conveyed down a rundown or swale to the creek. These rundowns are typically not stabilized with a hard surface, and rundown erosion is often present.

Sediment from Roadway

The existing roadway is a gravel surface. Over time the gravel can be loosened due to vehicle wear, rain, snow, and freeze/thaw conditions. The sediment is then able to migrate off of the road towards the creek. Roadway grading operations also loosen the existing material, or apply new road base, which can over time be conveyed to the creek. This is especially true when the road material is pushed to the creek side of the road by grading operations. In these instances, the material could reach the creek by either transporting down the creek side fill slope, or via the cut slope ditch and cross culvert. The following sections address roadway related erosion.

Buffer Between Road and Stream

Sugar Creek runs parallel with CR 67 for the most part; however, its offset from the road is not constant. There are stretches where the creek has 40 feet of overbank with enough vegetation to naturally filter the sediment before it reaches the creek. However, there are also stretches where the creek meanders much closer to the road, including seven instances where the creek crosses under the road. The overbank in these locations is non-existent, and the road fill slope enters the creek. In these locations, it is very easy for road material to enter the creek.

Roadside Scour – Erosion and Safety

In some locations, roadway gravel berms have developed on the creek side of the road. These berms are the result of roadway grading operations where excess gravel has been pushed to one side. Many of the berms have failed after roadway runoff has collected along the berm without a location to appropriately discharge into the creek. Some of these failures are very substantial, with erosion cutting back into the travel lane, and a large amount of sediment flowing into the creek.

Hillside Erosion

In general, the cut slope along the roadway has very low vegetation and a high tendency to erode into the roadside ditch. In some cases, the sediment will completely fill in the ditch, and ditch flow is forced onto the road. Thus, hillside sediment can be transported onto the road, which can then be transported across the road and into the creek.

Private Road Approaches

Private road approaches exist at approximately Stations 15+00 RT, 91+50 LT, and 265+00 LT. A USFS service road is near Station 144+00 RT. This forest service road is a significant contributor of sediment, primarily due to the hill slope below the road on the south side of Sugar Creek. The private approaches at Stations 15+00 RT and 91+50 LT do not appear to be contributing much sediment to the creek. The approach at Station 265+00 LT is contributing some sediment to the creek. Potential treatments for these roads are discussed in the Conceptual Solutions section below.

OHV Trail Crossings

The OHV crossings of Sugar Creek have eroded deeply into the ground surface. The erosion has mobilized sediment which is being conveyed downhill by gravity, rainfall, and erosion. The USFS has a trail relocation plan underway to realign trails in order to minimize their impact on the creek. Depending on the timing of the trail relocation, stabilization of the trail crossings may be needed. Silt fence has been installed by Colorado State University to study the magnitude of the erosion (see photo). Additional stabilization measures could be considered, as shown in the Map Book.

Current Roadway Operational and Maintenance Procedures

Equipment Used / Available

Douglas County road maintenance typically consists of blading with a motor grader to remove the washboards, regrading roadside ditches, adding spot gravel, restoring the shoulder using a skid steer loader, and using a vacuum truck to clean out culverts. The sediment is often reclaimed back into the roadway. A minor amount of excess sediment is hauled back to the county maintenance yard. A water truck is used to apply water for dust control and stabilization; however, no amendments are used in the Sugar Creek area of CR 67.

Douglas County noted that the gravel berm is not by design, and could removed. Removing the berms will allow sheet flow to be conveyed off the roadway, as opposed to allowing flow to concentrate and breach the roadside berm, thereby causing erosion.

Douglas County Maintenance Costs

The 2007 Douglas County Public Works records show road maintenance work performed for CR 67 from the Platte River to Sprucewood, a length of approximately nine miles, costs about $61,500 per year. **Table 7** summarizes the approximate maintenance costs for the Sugar Creek reach by taking 50% of the total quantity and costs associated with the nine mile reach.

TABLE 7

DOUGLAS COUNTY ROAD MAINTENANCE SUMMARY – SUGAR CREEK

Item	Quantity	Cost
Chemical Weed Control	1 hour	$394
Culvert Cleaning	31 culverts	$1,382
Culvert Repair	Lump Sum	$1,477
Ditch Maintenance	2.7 miles	$302
Equipment Transport	4 hours	$432
Erosion Control	4.2 hours	$298
Flagging/Traffic Control	17.7 hours	$762
Gravel Road Blading	31.7 miles	$4,439
Hauling Miscellaneous Materials	27.1 Units	$572
Loading	3 hours	$228
Manual Brushing	4 hours	$311
Mowing	1 swath mile	$54
Mechanical Brushing	42 hours	$3,882
Restoring Shoulders	20 hours	$1,652
Road Stabilization	11,730 square yards	$4,245
Spot Grading	19 hours	$1,813
Spot Graveling	52 tons	$1,132
Travel Time	41 hours	$2,925
Water Roads	38,000 gallons	$4,645

Biological Assessment

Overview of Previous Studies

The Upper South Platte EA identifies “Vegetation Treatment Areas” in localized locations along Sugar Creek. Vegetation Treatments could include thinning and controlled burning. Revegetation efforts could include planting vegetation, strategic placement of woody debris and boulders, reshaping sediments using conventional equipment, and using biosolids to amend soil and enhance vegetative growth. The water quality impacts of biosolids are discussed in the report, primarily related to increased nitrogen levels.

The Upper South Platte EA also includes mention of Sugar Creek Riparian Restoration, which could include continuation of efforts to decrease sediment into Sugar Creek from CR67. Work could also include riparian enhancement and road drainage improvements to reduce water velocities and sediment runoff. Changes in road maintenance methods are also encouraged.

Upland Areas

River Right Hill Slopes

Where slopes are greater than 25°, little to no vegetation exists (30 percent vegetative cover or less). There is little to no topsoil present and the slope is very dry due to the south facing nature of the slopes. Where the slope is less than 25°, upland vegetation is good and provides good upland habitat, including for the PMJM.

River Left Hill Slopes

Generally, the north facing slopes consist of Douglas-fir forests, good under story vegetation, and a more defined topsoil layer. Upland vegetation is more diverse than that on the opposite side of the canyon.

Riparian Areas

The riparian corridor along Sugar Creek is in very good condition and is currently included within an area determined by the U.S. Fish and Wildlife Service to provide critical habitat for the PMJM. According to USFWS, typical habitat for the Preble’s meadow jumping mouse is comprised of well-developed plains riparian vegetation with adjacent, relatively undisturbed grassland communities and a nearby water source. These riparian areas include a relatively dense combination of grasses, forbs, and shrubs (USFWS 2009).

Based upon observations conducted during this project, it has been determined that vegetative species composition in this area is very high and relatively diverse with little observed outside, human impact. Very few non-native species are identified within this corridor. Where weeds are found, it is usually an area of previous disturbance. Outside of the riparian corridor, areas of upland grasses were also identified. In terms of PMJM habitat, the riparian corridor and adjacent upland grassy areas along Sugar Creek are providing the requisite habitat needed by the mouse, and is supported by the USFWS' designation of this area as Critical Habitat; a designation that provides federal protection under the Endangered Species Act.

In a more general sense and due to the overall health of the vegetation, the riparian corridor is providing much needed protection for the stream from outside sources of sedimentation, stream bank erosion, and high water temperatures. This all equates to a well functioning stream with fish and invertebrate life at least up to Deep Creek, if not higher.

Biological Assessment by Reach

The following sections provide key biological based findings for each sub-reach.

Station 00+00 to 14+00

- Riparian corridor is in great condition with numerous (30+) different vegetative species present. This creates many different strata of over story. The corridor is narrow in some areas (<50 feet), but in very good condition. Steep canyon walls and banks exist in some areas.
- Great PMJM habitat consisting of the same features mentioned above.
- Stream bed and banks are in very good condition with little bank erosion identified.
- Water quality appears good. Water temperatures are certainly affected by the high quality riparian habitat. As a result of the multi-strata of cover provided by the existing shrubs and trees, the water is protected from the heating effect of direct sunlight which can raise the overall water temperature to a point where certain aquatic species can't survive. In this stretch and others along Sugar Creek, cooler water temperatures allow for yearly survival of brook trout in the creek.
- South facing slopes: The upland is very dry with little to no vegetation (< 30 percent ground cover) and little to no litter, resulting in natural erosion above the road. This intensifies below the road. The most active erosion is on slopes steeper than 30°. There is very little to no topsoil available as a growth medium. Areas of open canopy appear to have less vegetative and other organic cover than those areas with more tree cover. Very few shrubs; mostly grasses and some forbs exist. Ponderosa pine is the dominant tree species.
- North facing slopes: High level of plant and litter ground cover. Higher diversity of plant life and species composition is found in this Douglas fir forest. Topsoil is present, and the erosive nature is much less than south facing slopes.

Station 14+00 to 38+00

- Riparian area is wider (50 feet to 100 feet), more open and flat.
- Slopes on river right (RR) are not as steep, thus less erosive with more natural vegetation and litter. The road is on river left (RL). Natural rills exist, but not to the extent as compared to the rills from the road.
- Station 21+00 - Sediment from culverts does not reach the creek. The riparian area is acting as a buffer and a sediment filter for the creek.
- 23+00 – Sediment /erosion has discharged from the road into a small upland area between the road and the creek.
- Station 24+00 – Upland vegetation is on both sides of creek. Natural sediment has accumulated in the creek, but its source is unknown (road base or natural erosion).
- 24+50 – Old beaver pond that has filled in with sediment and pea gravel. Potential wetland immediately downstream on RR.
- 28+50 –Filled in beaver pond. All natives are reestablishing.
- From 18+00 to 38+00 - The riparian vegetation is dominated by willows with very few alders, contrary to the riparian corridor downstream where the alders are the dominant shrub. The corridor is not as complex from a vegetative standpoint, but very healthy with multiple strata of grasses, forbs, and shrubs.

Station 38+00 to 105+00

- 102+50 – Sediment erosion is occurring from the road. The riparian vegetation is creating an effective buffer, stopping the sediment from reaching the creek.

- 90+00 to 94+00 – Narrow riparian corridor (<50 feet) due to the private property on RR.
- Station 82+00 Noddle Trail Crossing – Some sediment contribution from the recreational creek crossing. Sediment from road and parking lot on opposite side of the road are the main contributors of sediment, spilling into the upland areas along the creek.
- Station 78+00 - No riparian corridor on RR due to exposed bedrock, and a very narrow riparian corridor on RL. Some evidence of road side stabilization (retaining wall); however, more is needed as runoff has flowed around it. In this area, due to the close proximity of the creek to the road, sediment is being conveyed directly into the creek. There is not enough

vegetation to act as an active buffer or filter. Some rills from the road are very serious and are beginning to extend into the road.

- Station 75+00 – Sediment is being conveyed directly into the creek.

Station 105+00 to 164+00

- Dense undergrowth of grasses and forbs on RL exists, within a thick Douglas fir forest. The hillside is at a 30° slope. The riparian width is reduced in this area to less than 50 feet, but the vegetation is still healthy and complex.
- 164+00 to 154+00 – There are more conifers within this riparian corridor than downstream. Vegetative cover on RR slopes is approximately 15 percent.
- The creek is immediately adjacent to the road (< 5 feet). In some areas, the creek may be undermining the road. Road base is being conveyed directly into the creek.
- Station 145+00 Private Property Entrance – In most areas of disturbance, noxious weeds exist. Erosion and sediment from the private road enters into the creek.
- Station 142+75 – Sediment from the road enters directly into the creek.

Station 164+00 to 244+00

- Both sides of the valley are thickly forested with ponderosa pine dominating the south-facing slopes and Douglas fir dominating the north-facing slopes, while normal forest floor vegetation and litter exists. There is less natural erosion from the slopes in this area.
- The creek is much smaller in this reach, with surface water beginning on the east side of the road. Where the creek crosses to the west side of the road, there is a wetland/seep area.
- With the exception of specific areas (see below), the general riparian corridor is very small and basic (lower species composition) and less diverse aerial strata consisting of mainly grasses, forbs, and trees with very few shrubs.
- 242+00 – Complex riparian area and start of open water. This is a specific site where the aerial strata of grasses, forbs, shrubs, and trees are all present. Plant species composition is also higher in this area compared to other sites in this reach.
- The creek drops down and away from road. Very little sediment is making it all of the way to the creek. Where it does, much of the sediment deposited in the creek is road base. Scrub oak occurs in this area. The riparian corridor is becoming dense, lush, and complex.

Potentially Sensitive Areas

Potentially Sensitive Areas (PSAs) were identified for areas that may be wetlands, PMJM Critical Habitat, or other areas requiring special permitting for construction activities. A formal wetland delineation and T&E surveys will be conducted as needed in future phases of the project. It is assumed that these surveys will be conducted after projects are identified and funded, and after the associated design and impact areas are better defined. During Final Design, efforts will be made to protect and minimize disturbance to PSAs. If impacts will occur, mitigation will likely be required.

Jurisdictional Stream

Sugar Creek is a perennial stream with defined bed and banks, and base flow. Thus, it is assumed that Sugar Creek is a jurisdictional Water of the U.S., and is protected by the Clean Water Act with jurisdictional authority belonging to the U.S. Army Corps of Engineers and the U.S. Environmental Protection Agency. An Ordinary High Water Mark (OHWM) is present, and will be used should permitting through the Corps be necessary.

Wetlands

Riparian wetlands were identified along the entire length of the creek. Many of the wetlands were associated with the immediate banks of the creek. Commonly, these types are referred to as fringe wetlands. Additional wetlands were visually identified in areas where current and past beaver activity has dammed up the creek, creating wetland meadows. During Final Design, detailed wetland delineation will be needed to minimize impacts to wetlands, as well as determine mitigation needs, if any.

PMJM Habitat

As stated above, the riparian corridor is in very good condition. However, the upland component to the overall habitat is very small and lacking. In many areas along RR, the upland habitat is missing or very sparse. Along the RL banks, the upland habitat is much more conducive to PMJM use.

The USFS provided CH2M HILL with a GIS layer showing the PMJM habitat area along Sugar Creek, as shown in the Map Book. The PMJM habitat, as previously identified by USFWS, USFS and documented in GIS, appears to be reasonable based on the site investigations. However, the area identified appears to be a broad level identification of PMJM habitat areas, as opposed to detailed identification, based on detailed site investigations or PMJM trapping. It is recommended that during Final Design, detailed investigations occur to minimize the area of PMJM habitat that might be impacted by construction. However, reduction of the current PMJM habitat boundary would not occur, as this is the boundary established by USFWS during the legally required Critical Habitat designation process required under the Endangered Species Act.

Other Species

Pawnee Montane Skipper (butterfly) Habitat has been identified the Upper South Platte EA, primarily on the north side of Sugar Creek. The Mexican Spotted Owl habitat identified in the Upper South Platte EA does not occur in the Sugar Creek watershed. Bald Eagles move through the South Platte Corridor, but no seasonal concentration areas are known to exist in the Upper South Platte area.

Cultural or Historical Features

Cultural and historic surveys were beyond the scope of this phase of the project. Surveys will be conducted prior to any disturbance activities.

Riparian Corridor Preservation

In general, the entire riparian corridor within the study area is in very good condition, and is a sensitive, high quality area – both as a protector of the stream and as habitat for the PMJM. The following items summarize the key findings related to riparian corridor preservation.

- Protection of this area should be of the highest priority as part of the effort to protect the stream. High quality vegetation, such as willows, alders, and other native forbs and grasses exist throughout the corridor. Care should be taken to minimize the impact to these high quality areas. If the riparian vegetation is impacted during improvement activities, concurrence from other agencies and permits may be required.
- Noxious and invasive weeds are minimal to non-existent along the entire riparian corridor. Areas where weeds were identified were mostly associated with areas of past and current disturbance. Disturbance areas should be minimized during any improvement activities.
- Due to the very good nature of the riparian corridor, it is recommended that any attempt to enhance, restore, or create PMJM riparian habitat be carefully considered. At a minimum, efforts should be taken to protect the existing habitat.
- Upland enhancement beyond the riparian corridor is not recommended on the south facing slopes, due to the lack of topsoil. Enhancement of north facing slopes may also prove to be difficult.

Field Assessment Summary

The field assessment identified the existing conditions, key problems areas, and potential locations for improvements, as shown in the Map Book in Appendix E.

The follow items were determined to be the most significant findings in the Sugar Creek and CR 67 corridor:

1. The riparian corridor is very healthy. However, in locations where the creek is very close to the road, the riparian buffer is unable to prevent sediment from entering the creek.
2. The creek is stable, with vegetated slide slopes and sufficient sediment armoring for the flow velocities that occur. One area of bank erosion was found that is contributing sediment to the creek.
3. Although there are few deep pools along Sugar Creek, a fish population exists in most of the reaches. Two large creek drops prevent upstream migration of fish.
4. The hill slopes, especially south facing slopes, are prone to erosion. Establishing vegetation on these slopes will be unlikely.

5. Roadside erosion from cut slopes, fill slopes, and the road surface is occurring, and sediment is entering the creek. This is true for CR 67, as well as the private road at Station 144+00. Areas of significant erosion are identified in the Map Book as Major Roadside Erosion. The priority areas where the road and stream interaction is most severe have been identified in the Map Book as High Priority Protection Reaches and Moderate Priority Protection Reaches.
6. Gullies and culverts are discharging sediment into the creek. Areas where stabilization is recommended are identified in the Map Book as Area to Stabilize.
7. The OHV trail crossings are unstable. Depending on the trial relocation plan timing, additional stabilization should be considered.
8. The beaver ponds are acting as large sediment traps. Excavation of the sediment will restore the sediment trapping capacity.
9. The CR 67 road base material is entering the creek. Operational changes may be able to efficiently reduce the sediment input from the road. Modifying the road's surface material would eliminate the need for road base material.
10. Roadside ditches and rundowns are unprotected. Hardening these conveyance elements will decrease erosion. Potential BMP sites and Settling Pond Areas, which could be used to collect sediment being conveyed in ditches and rundowns, are identified in the Map Book.

Conceptual Solutions

Conceptual Solutions Summary Table

Based on the field investigations described above, Conceptual Solutions have been identified, and are summarized in **Table 8**. The conceptual solutions are designed to be a menu of options, some of which may not be applicable to Sugar Creek, but may be beneficial on other roadway and stream corridors that benefit from this Pilot project. Stakeholder input, funding availability, maintenance needs, and other factors will determine the desired and recommended improvements.

The unit costs shown in the table are based on 2008 construction cost information obtained from the Colorado Department of Transportation, Urban Drainage and Flood Control District, CH2M HILL project libraries, and engineering judgment. The unit costs do not include contingencies or account for costs associated with engineering, permitting, and other standard project components.

The qualitative Benefit to Cost Ranges in Table 8 are based on a basic, qualitative review of each feature for the Sugar Creek conditions, and account for the feature's cost, ability to control sediment, longevity, stability in the Sugar Creek environment, and anticipated success rate.

Conceptual Solution Guidelines

Based on discussions with the stakeholders, the following are desires of the stakeholders, to be used as solution guidelines as much as possible:

- Use eco-friendly solutions that protect the environment. For example, the beaver ponds may be used for sediment collection, as opposed to building new man-made sediment traps. A future goal is for the beaver ponds to again function as beaver ponds.
- Maintain the channel geometry (no major excavation, channel realignment, etc. should be considered), unless the channel has left its original alignment due to high sediment loading.
- Use natural products.
- Focus on the most cost efficient solutions.
- Minimize long term maintenance needs.
- Revegetation can be difficult - limit disturbance areas.
- Set realistic expectations.
- Preserve prime habitat.
- Focus on the “bad” and don’t try to convert “good” to “better”.
- Don’t spend money on natural hill slope erosion protection (via hydroseed, erosion control blankets, mats, additional vegetation, etc.), per USFS.

Similarly, the Upper South Platte EA has recommendations on approaches to use. Relevant recommendations are as follows:

- Do not relocate streams if avoidable.
- Construct roads with rolling grades, and harden as needed.
- Use filter strips and sediment traps. Remove sediment when 80 percent full.
- Discharge cross drains to stable areas, and disperse flow into filter strips. Add additional cross drains if needed.
- In erosive areas, armor outlets.

TABLE 8
Sugar Creek Conceptual Solutions, Approximate Unit Costs, and Qualitative Benefit to Cost Range

Treatment	Description	Considerations	Representative Item	Unit	Unit Cost	Benefit to Cost Range
Roadway Improvements - Surface Material						
Asphalt Paving	Reconstruct the roadway with a pavement section consisting of base course and asphalt (or full depth asphalt) to eliminate surface sediment.	This option will eliminate surface sediment and provide a more durable surface. Paving a roadway tends to encourage a higher speed of travel, which for safety, may lead to upgrading the roadway geometrics. Due to the project budget, this may not be feasible at this time.	Pave with Asphalt	Mile	$ 550,000	Moderate
Concrete Paving	Reconstruct the roadway with concrete to eliminate surface sediment.	This option will eliminate surface sediment and provide a more durable surface. Paving a roadway tends to encourage a higher speed of travel, which for safety, may lead to upgrading the roadway geometrics. Due to the project budget, this may not be feasible at this time.	Pave with Concrete	Mile	$ 585,000	Moderate
Chip Seal	Chip seal a base course surface with three layers to stabilize and improve durability.	The USFS indicates this is a preferred option. Douglas County indicates the road is likely too steep for chip seal. Washington County in Oregon uses this technique on many of its gravel roadways with very good results, and some of their roads receive plowing in the winter.	Pave with Chip Seal	Mile	$ 105,000	Moderate
Cementious Additive	Scarify the surface and mix in additives, such as Portland cement, fly ash, or lime.	This treatment stabilizes the roadway, but may have water quality impact concerns. Environmentally sensitive projects should also be considered.	Treat with Cement	Mile	$ 100,000	Moderate
Magnesium Chloride	Treat the roadway periodically with magnesium chloride to reduce surface erosion.	Magnesium chloride is used by other counties in Colorado to control dust and harden the surface. A potential hazard with the chemical is its reaction with the environment. Product users have stated it produces good results for controlling dust and stabilizing roads. A sample of this is on Cottonwood Pass, south of Buena Vista, CO. Douglas County currently uses a magnesium chloride and lignite mixture.	Treat with Stabilizer (Magnesium Chloride)	Mile	$ 10,000	Moderate
Road Stabilizers	Treat the roadway periodically with commercially available road stabilizer.	This treatment stabilizes the roadway, and some brands are environmentally safe. Products include Gorilla Snot, Road Oyl, Soiltac, and others. Some products have been approved by the Federal Government.	Treat with Polymer Stabilizer (Soiltac)	Mile	$ 18,000	Moderate
			Treat with Stabilizer (Mag/Lignin)	Mile	$ 10,000	High
Roadway Improvements - Geometrics						
Major Realignment	Major realignment includes changing the vertical or horizontal alignment of the roadway.	Due to the narrow road and stream corridor, any major realignment would be costly. Moderate realignment, in order to increase the buffer distance between the road and stream, would also be costly. The impact to the environment during construction would likely outweigh the benefit of an increased buffer.	Varies by location.	--	Varies	Low
Reverse Roadway Cross Slope	Change the roadway cross slope so that the road drains away from the creek.	Changing the cross slope will allow flow and sediment to be directed to a roadway ditch instead of the creek. This can be accomplished in long tangent reaches and flat curve areas. Sediment may still need to be trapped before reaching the creek. It is assumed that the change in the flow area draining to each culvert is negligible, but should be confirmed if this option is selected. Culvert upsizing or placement of additional culverts may be needed. The presence of subsurface rocks or boulders will impact the construction practicality and cost.	Reverse Roadway Cross Slope (assumes only road base modifications required, does not include additional culverts if needed)	Ft	$ 1.00	High
Rolling Dips	Provide subtle rolling dips along the roadway to shorten the length of road that collects subarea runoff.	Rolling dips may be feasible in some locations. The low points of the dips will need to be stabilized to convey runoff from the road down the embankment. Additional speed control signing may be required.	Varies by location and depends on the type of earthwork involved.	Each	$5,000 to $10,000	Moderate
Flatten Ditch Backslope (hill slope)	Cut the slope back to reduce sediment sloughing into the ditch.	The hill slope would need to be flattened significantly for the sediment sloughing to stop. This would be a very large project with potentially significant impacts. The flattened slope may still be erosive due to the geology and low vegetation coverage in the area. Shotcrete may be used to mitigate the low vegetation and geology where the hill slope was flattened. Retaining walls could also be used to stabilize hill slopes. The costs for this treatment and hauling off excavated material can be significant.	Varies by location.	--	Varies	Low
Water Control						
Swales, Ditches, Gutters	Water conveyance elements that route flow to cross culverts or to rundowns.	Many roadside swales exist along CR67, and are typically V-shaped ditches cut into the natural ground material. The ditches at the time of the site assessment appear to be stable, and not actively eroding. The swales are transporting sediment from the roadway and natural slopes to the culverts and rundowns. If the roadway cross slope is not changed, consideration should be given to adding a swale or gutter on the creek side of the road, likely with a hardened surface. These features could be impacted by grading or snow plow operations. See Roadside Stream Protection Barrier below.	Construct Roadside Swale (assumes dirt grading, on hill slope side of road)	Ft	$ 0.45	Moderate to High
Inlets	A concrete structure that connects a ditch, swale, or gutter to a pipe.	There are currently no inlets along CR67. Inlets and pipe could be added at the rundown locations to convey flow from the road surface elevation to the overbank elevation. Mountain roads often use simple inlets (or even a flared pipe end section) and flexible pipe for these purposes. Asphalt, rock, or other material is often used at the inlet or pipe entrance to control erosion. A sample of this is just east of Eisenhower Tunnel on I-70.	Inlet, CDOT Type C	Each	$ 4,000.00	Low
Curb and Gutter	Water conveyance elements that route flow to cross culverts or to rundowns.	These roadside elements have a hardened bottom and side wall to increase the conveyance capacity and provide a road barrier. Curbs and gutters are not typically placed on gravel roads. In order to consider the curb and gutter function, but for a gravel road, see Roadside Stream Protection Barriers below.	8" Curb and Gutter	Ft	$ 25.00	Moderate to High
			Half Buried Type 7 Concrete Barrier	Ft	$ 36.00	
			18" Wide Concrete Swale	Ft	$ 9.00	
			2' Dia Boulders keyed in 6"	Ft	$ 35.00	

TABLE 8
Sugar Creek Conceptual Solutions, Approximate Unit Costs, and Qualitative Benefit to Cost Range

Treatment	Description	Considerations	Representative Item	Unit	Unit Cost	Benefit to Cost Range
Pipes / Downspouts	Flow conveyance elements.	Pipes are used to convey flow and can be concrete, metal, or plastic. They could be used to replace the existing rundowns. The stability of pipes on the steep roadway slopes would need to be considered. Constructability would also need to be addressed in the very loose decomposed granite. The USFS prefers the use of corrugated metal pipes to help decrease velocities. Downspouts can be connected to pipes to convey flow down the road embankment.	Cross Culvert, 24" CMP	Ft	$ 110.00	Moderate to High
Stabilized Rundown	Use stabilized rundowns to convey flow from the road elevation to the overbank elevation. This applies to roadside ditches and culvert discharges.	Rundown lining includes grass (not applicable here), soil riprap, riprap, concrete, brush/slash lined, and others. In addition to lining, small check dams built of rock or bioengineered products can be used to trap sediment and slow velocities. However, these check dams will fill with sediment quickly and may become maintenance intensive. There are also rundown stabilization products which may be applicable to this area, such as the "SmartDitch". Major erosion is occurring from flow conveyance from the road to the creek. Stabilized rundowns are a practical, feasible solution on CR67.	Concrete Rundown	CY	$ 300.00	High
			Soil Riprap	CY	$ 100.00	High
			Straw Bales	Ft	$ 8.00	Low to Moderate
Sediment Trap at Culvert Entrance / Exit	Use an inlet to trap sediment from the roadside ditch before it enters cross culverts.	Inlets can be constructed with depressed inverts, such that sediment is captured inside the inlet. The depression can be 2' to 3'. Once sediment fills the depressed area, sediment would then have the potential to be conveyed through the pipe. The inlet grates could be hinged, and a vacuum truck could be used to remove the sediment. A sediment trap could also be placed at the downstream end of the culvert to increase the trapping capacity, and keep the sediment close to the road and accessible by a vacuum truck. Alternatively, small rock walls could be constructed at culvert entrances to provide the same effect, but would be less stable than using a concrete inlet, and may not be able to have the same depression height. A geotube could also potentially be used to trap sediment exiting a pipe, while allowing water to continue downstream. The maintenance effort and associated costs for this treatment could be significant.	Depressed Inlet Box	Each	$ 6,000.00	Moderate to High
Culvert Outlet Protection	Erosion control located at the end of a pipe.	Soil riprap, riprap, and other hard materials are the most common types of outlet protection. Vegetation, turf reinforcement mat, or other materials may be feasible.	Soil Riprap	CY	$ 100.00	High
Roadside Stream Protection Barriers						
Curbing	Use curb and gutter to control and convey flow to a stabilized location.	The concept here is to provide a curb and gutter solution to a gravel road. This feature would contain flow and sediment on the roadway, and prevent it from being pushed down the slope and into the creek. A hardened gutter would likely be needed at the base of the curbing (riprap, concrete, other). The curbing could consist of a small structural trench wall, a row of grouted boulders, sheet pile with a concrete cap, or a buried CDOT Jersey Barrier. The features need to be stout to withstand potential impact by grading and snow plow equipment. It is unknown if this concept has been used elsewhere, so its performance is unknown. However, this is a more durable option than the existing dirt berm, and is likely a very good candidate for this pilot project. The impact to the roadway width would need to be considered. The same concept can be applied to the uphill side of the road to trap sediment from crossing the road. This application of curbing would require regular maintenance to ensure that the capacity is maintained.	8" Curb and Gutter	Ft	$ 25.00	High
			Half Buried Type 7 Concrete Barrier	Ft	$ 36.00	Moderate
			18" Wide Concrete Swale	Ft	$ 9.00	Moderate
			2' Dia Boulders keyed in 6"	Ft	$ 35.00	Moderate to High
Guard Rail with Curb or Running Board	Use a roadway guard rail and running board to control sediment.	Guard rails are often installed in combination with curbs. In some cases, a running board consisting of a 6" to 12" tall barrier is placed on the guard rail support posts to control sediment. A sample of this is on Highway 24 west of Colorado Springs, CO. With this solution, the curb or running board would be protected from grading or snow plow equipment by the guard rail. However, the cost and roadway width needed to construct this feature may not be feasible for this project.	Guard Rail with Running Board	Ft	$ 25.00	Moderate to High
Roadside Infiltration	Place a device along the creek side of the road to allow runoff infiltration.	The devices used here could be a vegetative strip, a rock trench, soil wraps, of other components that would capture runoff and let it infiltrate, as opposed to allowing the flow to run down the roadway side slope. Plugging and maintenance needs of these devices would need to be considered.	Rock Trench	CY	$ 100.00	Moderate to High
Roadway Operational Changes						
Grade and Snow Plow Away from Creek	Grade and snow plow away from the creek.	In order to not push sediment and contaminants into the creek, operational crews would manage equipment in a way to push road material and snow away from the creek. It is understood that this may be more time consuming and difficult, but is a cost effective solution. Douglas County has indicated that snow plowing away from the creek is likely not feasible, since there is not room for the storage of snow on the uphill side of the road. They have stated that grading away from the creek should be acceptable.	The cost for this work was calculated using the grading costs provided by Douglas County and increased by 20% to account for the extra work required in grading and reestablishing the road side ditch.	Mile	$ 300.00	High
Culvert Cleaning	Control sediment removed from culverts.	As culverts are cleaned by jetting water and using a vacuum truck, additional sediment control measures should be considered to minimize the loss of sediment. BMPs consisting of coconut logs, filter socks, or geotubes (dewatering tubes) could be used to trap sediment close to the end of pipe. A geotube could be temporarily attached to the end of the culvert prior to flushing, to ensure all sediment is captured.	12" Erosion Log	Ft	$ 5.00	High
Identify Critical Habitat Areas	Identify critical habitat areas for awareness during road operations.	Use USFS posts, reflectors, boulders, or signage to identify critical habitat areas to operational crews. The markers would designate where operational crews should perform certain activities, such as grading to the uphill side of the road.	Reflective Markers and Posts	Each	$ 20.00	High

TABLE 8
Sugar Creek Conceptual Solutions, Approximate Unit Costs, and Qualitative Benefit to Cost Range

Treatment	Description	Considerations	Representative Item	Unit	Unit Cost	Benefit to Cost Range
Slope Stabilization - Roadway and Natural Slopes						
Seeding, Plantings	Plant native, noxious weed-free seed to establish vegetation for erosion protection.	Due to the lack of topsoil and the erosive nature of the geology along Sugar Creek, seed establishment will be difficult. Import of noxious weed-free topsoil would likely be needed, but even with that, seeding success rates may be low. Seeding of flatter slopes, the creek overbanks, and the riparian corridor would have higher success rates. Additional riparian vegetation would trap additional sediment and increase water quality, even for relatively narrow buffer areas.	Upland Seeding	Acre	$ 5,000.00	Low
			Riparian Seeding	Acre	$ 7,000.00	Moderate
			Willow Staking	Each	$ 5.00	Low
			Wetland Plugs	Each	$ 3.00	Moderate
Mulch	Typically weed-free straw scattered on to or crimped into the ground.	Mulch is typically used in combination with seeding to establish vegetation and prevent erosion until the seed is established. The existing loose granite slope will be a challenge to support vegetation, and the mulch may not be stable. Crimping the mulch into the soils in this area is likely not practical. Unless importing topsoil is an option, this is not recommended for further consideration. Mulch can also consist of bark, shredded wood, or other materials.	Mulch, Crimped Straw	SF	$ 0.06	Low
Erosion Control Blanket	Use erosion control blanket and seeding to reduce sediment from the slope.	Erosion control blanket is used to temporarily stabilize an area until the underlying seed is established. Blankets must be placed on smooth ground, keyed in, and have staking and check slots appropriate for the ground conditions. Incorrect installation can lead to erosion under the blanket. The existing loose granite slope will be a challenge to support vegetation, and the blanket could be a hazard to the PMJM and other animals. Unless importing topsoil is an option, this is not recommended for further consideration.	Erosion Control Blanket	SY	$ 4.00	Low
Turf Reinforcement Mat (TRM)	Similar to erosion control blanket, but TRM is more stout, may have a significant thickness, and has a longer life span.	TRM must be installed similar to erosion control blanket, but is more resistant to flow, is more sturdy, and does not rely on the underlying vegetation to establish. TRM can be a reasonable replacement for soil riprap or riprap. TRM can be used for outlet protection, lining gullies, and other uses. However, the unstable soils in this project area may make TRM impractical.	Turf Reinforcement Mat	SY	$ 7.00	Moderate
Hydroseed / Hydromulch	Spraying seed or mulch from a nozzle for large area applications.	These products are common, but result in mixed opinions. Many of the products do not work well on loose soils, on steep slopes, or where concentrated flow will occur. Also, many metro Denver agencies do not allow their use. It is assumed that due to the conditions along Sugar Creek, these products would not have the anticipated success rates needed for implementation.	Native Seeding with Hydromulch	SF	$ 0.60	Low
Soil Riprap and Riprap	Angular rock used to stabilize swales, ditches, and streams.	Riprap is angular rock categorized by its D50 particle size. Riprap is often placed on a layer of more finely graded angular rock (filter material) or on geotextile, to prevent piping of smaller particles through the riprap. Soil riprap is riprap that has all of its void spaces filled with the native soil. Soil riprap is compacted, and typically has an additional layer of soil placed on top, then seeded with noxious weed-free seed. After the seed has established, the soil riprap is no longer visible and the area mimics the natural vegetated surroundings. These features can be used for slope stabilization, toe scour protection, creating small drop structures in streams, and more, and are applicable to this project.	Soil Riprap	CY	$ 100.00	Moderate
Boulder Wall / Stream Protection	Stack tiers of boulders to prevent erosion of the slope, or to allow a flatter slope between the road and the stream.	With this feature, boulders are placed at the edge of the stream, stacked to the height needed, and then backfilled from the top of boulder back to the tie in grade. This is a method often used to provide both stream stabilization at the toe of a slope, while also creating a flatter slope to the top of the boulders. Grout or concrete can be used to make the boulders much more sturdy, and prevent piping of soil from behind the boulders. When grout is used, the grout is typically kept to 1/2 to 3/4 the boulder height, so that the grout is not seen. Other features such as soil wraps, gabion walls, crib walls, live retaining walls, brush layers, and sheet pile can be used to create walls or steep slopes. These features should be considered where the creek and the road are adjacent to each other.	2' diameter boulders, single row, ungrouted	Ft	$ 35.00	Moderate
Soil Stabilizers, Tackifiers	Treat the slope periodically with a product to reduce slope erosion.	These products stabilize the slope, and some brands are environmentally safe. However, due to the erosive nature of the geology in the area, the success rates for these products may be low.	Soil Binder	Acre	$ 600.00	Low
Slope Interceptors	Barriers or ditches placed on long slopes to minimize flow concentration and erosion.	These features may consist of bio-logs, natural logs, and ditches. Ditches are often placed at a slope to direct slope runoff to one side of the slope to a stabilized location. Due to the erosive nature of the soils along Sugar Creek, the applicability of these features is limited.	12" Erosion Log	Ft	$ 5.00	Low
Sediment Control						
Silt Fence / Sediment Barriers	Sediment barrier attached to wooden posts and keyed into the ground.	Silt fence is a very good product for trapping sediment, but it is typically not a long term solution. The sediment will need to be removed, and the fabric and posts have a relatively short life span. Silt fence is a great product to use during construction to limit sediment dispersion. Live vegetative barriers, brush fences, and other features work similar to silt fences.	Silt Fence	Ft	$ 4.00	Moderate
Check Dams	Small dams used to slow down velocities and trap sediment.	Small dams could be placed on overbank areas, in swales, or in gullies to slow velocities and trap sediment. The most common material used is riprap, but logs, coconut logs, willow bundles, brush, and other materials can be used as long as they can withstand the hydraulic forces in the stream or gully.	Riprap Check Dam	CY	$ 100.00	Moderate
Proprietary Water Quality Devices	Sediment traps and water quality devices.	There are many proprietary sediment trap and water quality devices on the market today. However, they often have small flow rate capacity, can be expensive, and their function is often questioned. It is recommended that depressed inlets, settling ponds, and other proven features be used on this project. Proprietary devices have not been considered at this time.	N/A	N/A	N/A	Low

TABLE 8
Sugar Creek Conceptual Solutions, Approximate Unit Costs, and Qualitative Benefit to Cost Range

Treatment	Description	Considerations	Representative Item	Unit	Unit Cost	Benefit to Cost Range
Settling Ponds	Surface ponds that allow for sediment trapping.	These ponds could be placed in wider overbank areas, and receive flow from the road ditches or rundowns. The ponds could be lined with rock to allow for excavation, and have perimeter vegetation installed to visually hide the ponds. A vacuum truck or long reach excavator could be used to dredge the ponds. An overflow area should be provided and stabilized to prevent erosion in large storms.	Settling pond costs will vary by site, access to the pond, pond depth, and erosion control required. See Beaver Dams for haul cost information.	Each	$3,000 - $15,000	High
Filter Strips	Control sediment on flatter slopes using vegetation or bioengineered products.	Where flatter slopes exist and sediment needs to be controlled, filter strips can be used to trap the sediment. Filter strips can consist of vegetative strips (willows, etc.), strategically placed logs, coconut logs, or other products. These products must be installed to create a "sheet flow" effect over them to minimize flow concentration and erosion on the downhill side of the feature. As sediment builds up, additional features can be added on top of the collected sediment. A good location for this type of feature would be near Station 108+50, where sediment from a gully is making its way across an overbank and nearly reaching the creek.	12" Erosion Log	Ft	$ 5.00	Moderate
Beaver Dams	Existing beaver dams along Sugar Creek.	The beaver dams along Sugar Creek are acting as excellent sediment traps. The ponds are located near the downstream end of Sugar Creek, and thus most of the watershed flows into these ponds prior to entering the South Platte River. However, many of the ponds are filled with sediment to capacity, and only a couple of ponds have any significant water depth remaining. Several of the ponds could be excavated, such that sediment trapping capacity is restored. The excavation would need to not impact the stability of the dam or surrounding slopes. The beaver population should be protected, because the beavers keep the dams intact.	Beaver Pond Sediment Removal & Disposal, varies by site conditions and disposal haul distance.	CY	$15 - $50	High
Stream Improvements						
Channel Realignment / Buffer Width	Move the stream to increase the buffer between the road and the stream.	The project stakeholders have stated channel realignment is not desired. This is also consistent with the USDA Environmental Assessment. The costs associated with channel realignment or increasing the buffer width will vary depending on the site.	Varies by location.	--	Varies	Low
Bank Stabilization / Toe Protection	Stabilize the toe of the bank to control stream bank erosion.	Bank stabilization typically consists of laying back an eroded slope and using stabilization such as vegetation, erosion control blanket, turf reinforcement mat, soil riprap, or riprap. Only one section of Sugar Creek has significant bank erosion. Access to the location is difficult, and it is recommended that if stabilization of the reach is desired, a TRM and vegetation controls are used. These materials can be hand carried to the site, are cost effective, and will not damage the surrounding area. Willow staking and riparian seed at the water's edge would provide additional bank stability.	Soil Riprap	CY	$ 100.00	Moderate
Drop Structures / Velocity Reduction	Drop structures are regularly used to flatten a stream's longitudinal slope and decrease flow velocities.	Given the condition of Sugar Creek, the minimal bank erosion, and sufficient armoring material in the stream bed, drop structures are not recommended. The two head cuts near Stations 232+50 and 237+00 are small, and could be stabilized. Small rock drop structures, vegetation, TRM, or other approaches could be used to control the migration of the erosion.	Varies based on drop size, materials, and needed erosion protection.	Each	$1,000 to $10,000	Low
Habitat Improvements	Use the Streamside Systems Wand for selective sediment removal in localized areas.	Sugar Creek has high quality habitat, including the riparian corridor, varied flow regimes, and vegetative cover. It is recommended that the sediment input be controlled first, and let natural processes clean the system of excess sediment. Habitat improvements may then result without additional effort. If additional habitat is desired, such as deeper pools for fish habitat, the Streamside Systems Wand could be used. Based on the site testing, the Streamside Systems Bed Load Collector does not appear to be applicable for this site.	In-Stream Sediment Removal - Sand Wand (excludes sediment disposal).	CY	$ 80.00	Low

NOTES:
1. Costs are for planning purposes only, and do not include engineering, permitting, mobilization, water control, contingencies, or adjustments for current economic conditions.
2. Costs (2008 dollars) are based on CDOT, Urban Drainage and Flood Control District (UDFCD), and Engineering Judgment. Costs were increased to account for increased costs associated with the Sugar Creeks location.
3. Benefit to Cost Ranges are based on a basic, qualitative review of each feature for the Sugar Creek conditions, and account for the feature's cost, ability to control sediment, longevity, stability in the Sugar Creek environment, and anticipated success rate.

Sediment Removal and Disposal

Most of the conceptual solutions identified above relate to control, capture, or removal of sediment. The following sections describe options for the removal of sediment that has been mobilized.

Natural Processes

Sugar Creek is currently using natural processes to remove sediment. However, the input is exceeding the streams ability to transport sediment out of the system. This is evident by the following:

- A large amount of sediment has been captured in the beaver ponds.
- There are very few deep pools in the stream.
- The Streamside Systems installation confirmed that no bed load is occurring during normal runoff flow conditions.

Although fish and macroinvertebrates were found, the sediment input load is impacting habitat. Natural processes could continue to be used to remove sediment, but intervention will help improve the system. It is unknown at this time if the current sediment input could reach a breakpoint in which habitat would start to drastically be impaired. This is why Sugar Creek is on the CDPHE Monitoring List. With the possibility of Global Climate Change, high mountain streams such as Sugar Creek could become even more critical in maintaining ecosystems.

Sediment Removal with a Vacuum Truck

Douglas County currently uses a vacuum truck when cleaning culverts. A vacuum truck could also be used to remove sediment from inlet catch basins, sediment traps, small sediment ponds, and from other BMPs that trap small amounts of sediment.

Excavation with Heavy Equipment

Excavation of the beaver ponds could be performed with long reach excavators. A contractor located in metro Denver that CH2M HILL has worked with in the past was contacted related to the feasibility of removing sediment from the beaver ponds. The contractor owns two specialized excavators with very long reach capability. Mobilization to the Sugar Creek area appears to be feasible. Additional information can be obtained during final design, if excavation of the ponds is selected as a preferred alternative. Excavation costs for haul off site are typically around $8 to $15 per cubic yard. Additional mobilization and haul costs may be applicable.

Excavation with Streamside Systems Technologies

Streamside Systems has two primary technologies for removing sediment from streams, as follows:

Bed Load Collector

This device is placed flush with the invert of the channel and collects bed load material that is traveling along the bed of the stream. The material is then collected and sluiced by gravity or a pump to a desired discharge location. Discharge locations may be a dewatering tank, overland placement, or a holding tank. The cost for sediment removal with this device is dependant on the application. Engineering is typically needed related to installation location, power source, sediment stockpiling and disposal, sediment haul off site, security, freeze protection, noise, and other factors.

For base flow and normal runoff conditions, the site findings were that insufficient bed load is being transported to warrant installation of a permanent bed load collector. It appears that the bulk of the sediment transport in Sugar Creek is occurring during large thunderstorm events. The need for quick response and the maintenance needs of a bed load collector solely for thunderstorm events is likely not practical. CH2M HILL and Streamside Systems agree that based on the field investigations, the Bed Load Collector is not a feasible solution for Sugar Creek.

Wand

The wand is a section dredge device that can remove sediment sizes up to a desired size (up to small gravel) from streams. The device has a low impact to the stream and does not result in a high level of stream turbidity. The device has several applications, such as improving invertebrate and fish habitat, and removing contaminated soils. The device can be used as a final polishing step after typical dredging or excavation occurs. The cost for wand cleanup averages $80 per cubic yard of sediment removed from the stream and placed on the stream bank (excludes costs for hauling material off site), and is thus much more expensive than standard excavation.

Sediment Disposal Options

Four potential sediment disposal options were investigated with this project. The four options are summarized below.

Sugar Creek Corridor Disposal Sites

The Sugar Creek corridor is narrow, with minimal areas in which disposal of large quantities of sediment could occur. There are several large overbank areas, but these areas are often parking areas, or are areas that may be primary candidates for sediment collection and removal. Thus, it is anticipated that the majority of sediment collected and removed from the Sugar Creek corridor will need to be hauled off site. Investigation of disposal sites outside of the Sugar Creek corridor was not included in this project.

Ability to Place Additional Sediment in Denver Water’s Strontia Springs Slurry Pipeline

Denver Water stated their current plan is to suction dredge the sediment from Strontia Springs Reservoir and slurry pipe it from the sediment delta area down Waterton Canyon. They expect to move 800,000 CY of sediment (the dam has trapped 1.2M CY through 2008). The operation may not occur until the year 2010. They stated the slurry pipe may be designed with a wall thickness only sufficient for their need, and that the system may be dismantled when they are complete. They were open to discussing the engineering options for conveying additional sediment in the slurry pipe, which may mean increasing the pipe wall thickness to allow for additional sediment transport. Cost sharing of the pipeline, and the need for increased wall thickness, could be discussed more if desired.

Commercial Uses of Dredged Sediment Identified by Denver Water

Denver Water has not yet identified any commercial uses of the sediment. If they are unable to sell the sediment, they may use it on Denver Water projects as pipe trench material or for other suitable uses.

Disposal Sites for Dredged Sediment Identified by Denver Water

Denver Water did not consider any disposal sites upstream of Strontia Springs Reservoir or within the upper watershed. They want the sediment downstream of the reservoir, and not have the chance of it returning to the reservoir. Regarding in-town disposal sites, they have not investigated any at this time.

Preferred Alternatives and 5-Year Plan

Douglas County and the USFS have determined their preferred conceptual solutions and priority areas, as described below. The recommendations are based on the information provided in this study, field investigations, and anticipated available funding.

Douglas County 5-Year Plan

Douglas County developed a 5-Year Improvement Plan (Plan) for the Sugar Creek corridor. In general, the Plan recommends improvements starting at the downstream end of the corridor, and then progresses in an upstream direction.

Plan Year 1

- Station 14+00: Improve the CR 67 creek crossing (riprap, extend culvert, end sections or headwall and wingwalls, and rundowns).
- Station 21+00: Provide inlets or catch basins on two existing culverts, and monitor effectiveness.
- Station 25+00 to Station 30+00: Reverse roadway cross slope away from the creek and evaluate effectiveness. Install cross culvert if needed.
- Remove dirt berms along the road shoulders where possible to allow sheet flow runoff.

Plan Year 2

- Station 45+00 to Station 52+00: Test curb treatments along the roadway shoulder that is adjacent to the creek.
- Station 50+00: Stabilize parking lot erosion.
- Station 80+00: Stabilize parking area.

Plan Year 3

- Station 65+00 to Station 75+00: Place riprap along the roadway slope that is adjacent to the creek.
- Station 91+50: Improve the private driveway stream crossing (riprap, extend culvert, end sections or headwall and wingwalls, and rundowns).

Plan Year 4

- Station 108+00: Improve the CR 67 creek crossing (riprap, extend culvert, end sections or headwall and wingwalls, and rundowns).
- Station 120+00 to Station 128+00: Reverse roadway cross slope and evaluate effectiveness. Install cross culvert if needed.

Plan Year 5

- Station 115+00 and Station 119+00: Improve CR 67 creek crossings (riprap, extend culverts, end sections or headwalls and wingwalls, and rundowns).
- Station 144+00: Improve private driveway creek crossing (riprap, extend culvert, end sections or headwall and wingwalls, and rundowns).
- Evaluate the improvements, and develop the next 5-Year Plan.

USFS Priority Areas

The USFS identified priority areas to focus improvements along the Sugar Creek corridor. In general, the highest priority for the USFS is to take actions that prevent erosion from occurring, and secondly focus on improvements that capture and remove sediment that has become mobile.

Priority 1 - Roadway Berm Removal and Cross Slope Reversal

Removal of all roadside berms is desired to prevent concentrated runoff from leaving the roadway. Changing the roadway cross slope to slope away from the creek, where feasible, is also desired. These measures will help prevent sediment from becoming mobile. Based on discussions with Douglas County, these requests appear feasible. Douglas County may begin removing berms in 2009.

Priority 2 – Stabilize Roadside Erosion Locations

Assuming Priority 1 occurs, the second highest priority includes the preventative measure of stabilizing all sites identified as “Major Roadside Erosion” (blue squares in the Map Book) where sediment is currently and consistently entering Sugar Creek. The erosion areas downstream of the beaver pond (at Station 18+00) have a higher priority than those above the beaver ponds. The beaver ponds help maintain the lower reach, which is habitat for young fish from the South Platte River. In particular, the USFS recommends working on the erosion areas from Station 4+00 to Station 18+00.

After Priority 1 occurs and the roadside berms are removed, it is recommended that the erosion areas be reviewed to determine which areas will continue to contribute sediment to the creek. These areas would have a higher priority. Stabilization of the hill slope rills and gullies between the road and the creek may be needed, even after the roadway changes occur.

In some locations, such as Station 5+00, the hill slope above the roadway may be conveying runoff that is crossing the road and contributing to the erosion on the creek side of the road. Formalizing some uphill roadside ditches may be needed to capture hill slope runoff so that it is conveyed to culverts and stabilized rundowns.

Priority 3 – Priority Protection Reaches

The third priority should be given to all locations where the road is immediately adjacent to the creek and there is evidence of active erosion into the creek. In general these areas are identified as High and Moderate Priority Protection Reaches in the Map Book. In particular, USFS recommends working at station 14+00, where exposed banks on both the upstream and downstream ends of the CR 67 culvert crossing are contributing sediment into the creek.

Priority 4 – Sediment Collection BMP Test Site

The culvert crossing at approximately Station 222+00, shown as a potential BMP site in the Map Book, would be a recommended site to test a drop inlet structure, or other sediment catchment device. Other locations, such as at Station 144+00 (where sediment has previously been removed from the uphill side of the road), could be reviewed to ensure an appropriate test location is selected.

Priority 5 – Trail Stabilization

The Noddle Trail bridge crossing and upland slopes at Station 82+00 and the Stabilization Area at Station 50+00 are currently being addressed by the USFS via their Rampart Range Motorized Trails Plan, and under the Upper South Platte Watershed Restoration Project.

Priority 6 – Private Road Crossing

The fill slope and culvert crossings on the private access road where sediment is directly entering stream (Station 144+00) are currently being addressed by the USFS under the Special Use Permit authority.

Next Steps

The following sections provide the anticipated next steps related to the Sugar Creek Sediment Mitigation project.

Coordination of Priority Areas and Decision Model Review

Douglas County and the USFS have identified their recommended priority areas, as stated above. Douglas County, USFS, and the other stakeholders should continue to coordinate as funding becomes available, so that the most beneficial and cost-effective projects can be constructed first. The results of the Decision Model should be reviewed as each project is developed, to ensure that each project is consistent with the stakeholder's desires.

Design and Construction of Preferred Solutions

Design is needed for permitting, construction cost estimating, and to construct the improvements. The level of detail with each design can be tailored to the construction approach used, which might vary from using county or USFS staff to an open public bid process. Depending on the level of design, various types of data will need to be collected, as described below in the Future Data Needs section.

The Design process will include detailed cost estimates for each project. Operations and maintenance costs can also be estimated, once the project details are known. The cost estimates performed during design can build on the unit costs in **Table 8**, and will also include costs for mobilization, surveying, water control, and other construction components.

Anticipated Permitting Requirements

Based on the PSAs identified, it is expected that the following permits may be required for construction:

- Corps of Engineer's 404 permit
- Colorado Department of Public Health and Environment Stormwater Permit and Stormwater Management Plan (SWMP)
- Douglas County Grading, Erosion, and Sediment Control (GESC) Permit
- If the disturbance area is large, a CDPHE Air and Dust Control Permit may be required
- If the riparian vegetation is impacted, concurrence from other agencies and permits may be required
- Other permits as determined to be required during Design

Future Data Needs

The following items are anticipated to be needed for Design and/or permitting:

- 1-foot Design Topography
- Infrastructure Information
- Utility Locates (utilities exist along CR67)
- Wetlands Surveys for the Impact Areas
- Threatened and Endangered Species, Cultural, and Historic Surveys
- Survey of the Ordinary High Water Mark for Corps of Engineers 404 Permitting
- Sediment production estimates, if needed, in order to set expectations related to sediment removal and maintenance activities

Preble's Mitigation for Chatfield Reallocation Project

There have been discussions with USFS, the Colorado Water Conservation Board, and CH2M HILL about adding a task to this project related to identifying PMJM habitat improvement areas along Sugar Creek, and possibly elsewhere in the South Platte watershed. At this time, there appears to be a desire to embrace this inter-agency partnering opportunity, but the details are still being discussed. This effort could be added to the next phase of the project if desired by the stakeholders.

References

Culver, S., Gaines, P., Shakarjian, K. 2005. 2005 Aquatic MIS Monitoring Summary for the Pike and San Isabel National Forests. USDA, Forest Service.

Elliott, J.G., Smith, M.E., Friedel, M.J., Stevens, M.R., Bossong, C.R., Litke, D.W., Parker, R.S., Costello, C., Wagner, J., Char, S.J., Bauer, M.A., and Wilds, S.R. 2004. Analysis and mapping of post-fire hydrologic hazards for the 2002 Hayman, Coal Seam, and Missionary Ridge Wildfires, Colorado. U.S. Geological Survey Scientific Investigations Report 2004-5300, 104 p.

Foster Wheeler Environmental Corporation. 1999. Landscape Assessment, Upper South Platte Watershed. Prepared for US Forest Service, Colorado State Forest Service, Denver Water Board, US EPA. Volume 1, Volume 2, and Volume 3.

Keller, G.; Sherar, J. 2003. Low-Volume Roads Engineering, Best Management Practices Field Guide. USDA, Forest Service.

Libohova, Z. 2004. Effects of Thinning and a Wildfire on Sediment Production Rates, Channel Morphology, and Water Quality in the Upper South Platte River Watershed. Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University.

Rivas, T. 2006. Erosion Control Treatment Selection Guide. USDA, Forest Service.

USDA Forest Service. 2000. Environmental Assessment for the Upper South Platte Watershed Protection and Restoration Project.

U. S. Fish and Wildlife Service (USFWS). 2009. Preble's Meadow Jumping Mouse Fact Sheet. http://www.fws.gov/mountain-prairie/species/mammals/preble/mouse_factsheet.htm.

Welsh, M. J.; MacDonald, L. H.; Brown, E.; Libohova, Z. 2006. Erosion and Sediment Delivery From Unpaved Roads and Off-Highway Vehicle (OHV) Trails in the Upper South Platte River Watershed, Colorado. American Geophysical Union, Fall Meeting 2006, Abstract #B23B-1086.

Welsh, M. J. 2008. Sediment Production and Delivery from Forest Roads and Off-Highway Vehicle Trails in the Upper South Platte River Watershed, Colorado. Department of Forest, Rangeland, and Watershed Stewardship, Colorado State University.

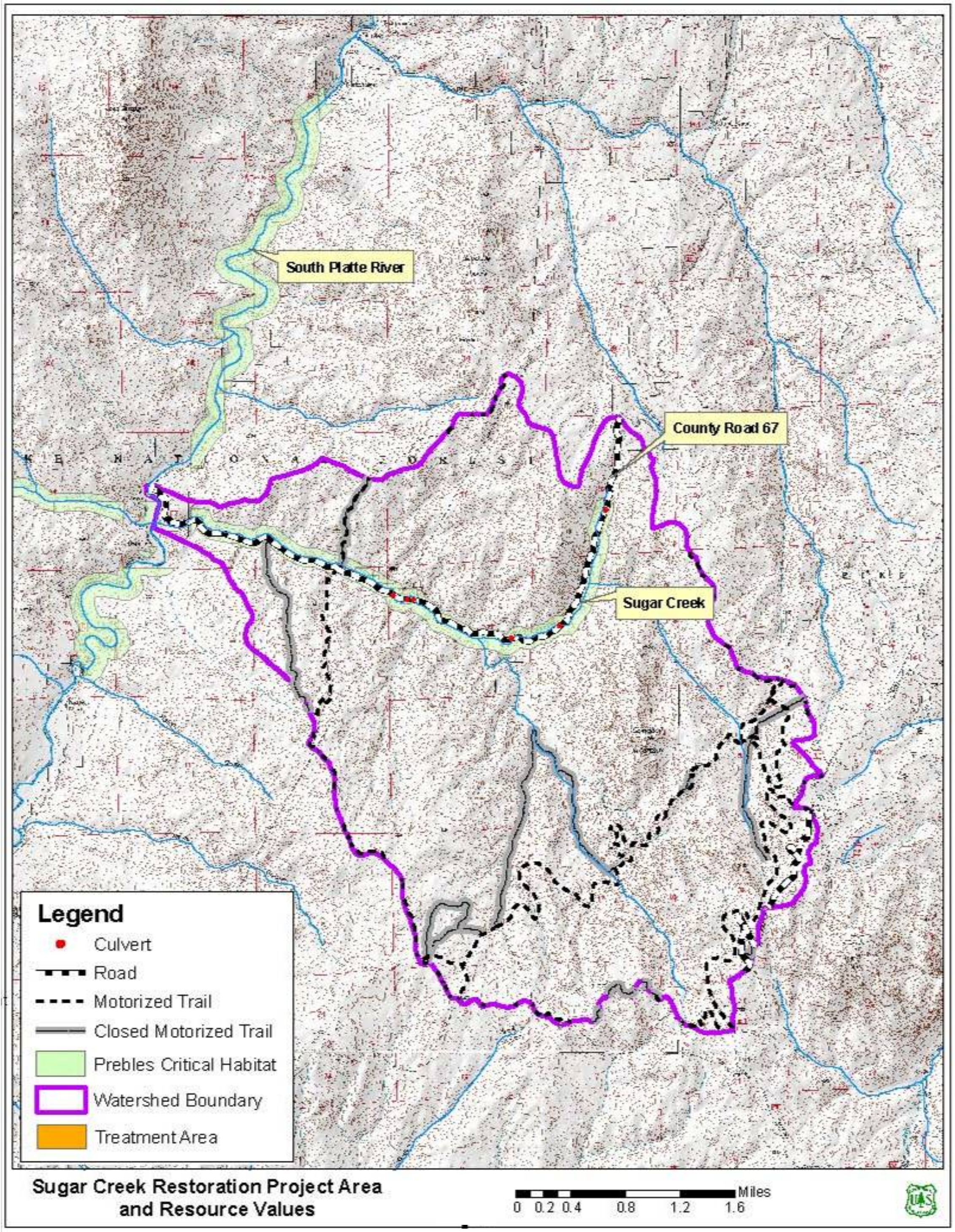


FIGURE 1
SUGAR CREEK ASSESSMENT CORRIDOR (provided by USFS)

Appendices

Appendix A – Stream and Roadway Field Logs

Appendix B – Stream Profile, Cross Sections, and Pebble Count Data

Appendix C – Fish Population Data

Appendix D – Water Quality Data

Appendix E – Map Book

APPENDIX A

Sugar Creek
Stream Assessment Field Log

Reach		Channel Conditions					Bank Stability		Bank Veg.		Cover	Substrate			
Start Sta, or Sta Point	End Sta	Avg. Width	Avg. Invert to TOB	Flow Regime (Cascade, Riffle-Run, Glide-Pool)	Flow Depth	Freq. of Riffles, Sinuosity	Left Bank Slope and Condition	Right Bank Slope and Condition	% Cover Left Hill (opt.) / Creek Bank	% Cover Right Hill (opt.) / Creek Bank	Trees, undercuts, root mats, deep pools, etc.	Avg. Surface Mat'l Type (Cobble, Gravel, Sand, Silt)	Deposit. Depth if Applic.	6" Dia Rock M-Invert. Count	Notes / Fish Count
(ft)	(ft)	(ft)	(ft)	(C, RR, GP)	(inch)	(freq.)	(OSMP)	(OSMP)	(%)	(%)	(NLMH)	(% C,G,S,Silt)	(inch)	(#)	
0+00	0+00	4.0	5.0	RR	6-8"	10' - 15'	2:1 O	2:1 O	100	100	H	10/30/30/30	0"-12"	8	
0+00	5+00	3.0	3.0	RR/Small pools	6"	15'	2:1 S	2:1 S	100/30-50	100/25-50	H	10/30/30/30		n/a	
5+00	10+00	4.0	3.0	Small Cascade, 8-12" Drop	6-12"	15'	1.5:1 O	2:1 O	75/50-75	75/25-75	H	0/0/50/50	6-8"	n/a	
8+00		8.0	3.0	Cascade, 2' Drop	4"-2'	10'	Vertical	Vertical	Rock	Rock	L	Bldr, G, Silt	1'	7	
9+00		1.0-4.0	N/A	10' drop	2"-2'	Cascade	Vertical	Vertical	Rock	Rock	L	0/75/15/10	0-15"	n/a	1-8" trout; 2' pools
10+00		3.0	2.0		6"	Small Cascade/ RR Pool	2:1 O	1.5:1 O	75-100	75-100	H	30/40/30/0	0-6"	n/a	
15+00	20+00	4.0	3.0-4.0	RR	6"	10'								n/a	Fish blockage
18+50		8.0	2.5'	Micro pools in gravel	3"	15'	3:1 S	2:1 M	50-75	25-50	M			n/a	Stick dams trapping sediment, 1-2" fish
20+00	25+00	4.0	1.0-2.0	Run	2-6"	Minimal	O	O	75/75	75/>50				n/a	
25+00	30+00	split		RR	4"	5'	1:1 S	3:1 O	50-75/50-75	>75/25-50	M-H	30/30/30/10	Ponds filled	n/a	
30+00	35+00	4.0	2.0	RR, Step pools	4"	20'+					H	0/90/10/0		n/a	
35+00	40+00	4.0	5	RR, Small pools	4-12"	20'+	1:1 S	1:1 P	>75	25-50/25-50	M-H	0/75/25/0	0-12"	n/a	
40+00							1:1 O	1:1 S	50-75/Road	>55/25-50	H	0/80/10/10	0-12"	No Cobble	One 8" fish, debris dam.
52+00		2.5	3.0	C, RR	8"	10.0'	1:1 O	1:1 M	50-75	50-75	H-M	10/50/30/10	0-4"	n/a	2-8" fish
70+00		2.0	3.5	C/RR/GP	3.0-12.0"	8.0'	1:1 M	1:1 M	50-75	50-75	H	Bldr,30/40/30/0	Minimal	4 - big stoneflies	
78+00		2.0	1.0	C	12"	Multiple 2'-3' jumps	1/2:1 M	1/2:1 M	Rock/50	Rock/50	L	30/60/10/0		n/a	
83+00	U/S Trail	3.0	5.0	RR	6.0"	Continuous	1:3 O	1:3 O	>75	>75/	H	20/60/10/10	0-6"	n/a	
94+00		2.0		RR	4.0	Continuous 5.0'	1:2 S	1:2 S	>75/Road	0-25/>75	H	10/70/20	0-4"	n/a	Two 6" fish.
107+00	108+00	2.5	3.0	RR	4.0	Continuous 5.0'	1:1 S	1:1 M		/0-25	H	30/60/10	6-18"	5	Four 6" trout
115+00	119+00	2.5		RR	6"-8"	10'	2:1 S	2:1 S	50-75	50-75	H	20-Bldr,40/20/20/0	Good, Healthy	6	One 8" trout
123+00		2.0	2-3	RR	3"-6"	15'	2:1 S	2:1 S	50-75	50-75	H	0/80/20/0	Debris Dam,8"	No Cobble	Slower reach, deposition
135+00		3.0		C	3"-12"	10'	1:1 M	1:1 O	50-75	75-100	M	30/30/30/10	0"-6"	5	
143+50	Private Road	2.0		RR	2"-12"	20'	1:1 O	2:1 S	>75	>75	M	0/80/10/10	6"-12"	n/a	100' D/S back to typical w/ 70% Gravel
154+00		2.0		C, 6" Drops	5"	6'	3:1 S	2:1 S	50-75	50-75	M	40/20/20/20	Minimal	n/a	Healthy
163+00		2.0		C, 1' Drops	2"-1'	10'	1:1 O	2:1 S	>75/>75	Road/>75	H	30/30/20/10	0"-18"	8	Debris dam, no fish, road base
193+00		2.0	4.0	C/RR	1"-6"	8'	1:1 S	1:2 S	50-75	50-75	H	Bldr,20/60/10/0		12	6"-12" drops
215+00		1.0	1.5	C/RR	2"	8'	1:1 S	1:1 S	50-75	50-75	H	30/30/15/15		n/a	
218+00	Drop			6' Drop			Vertical	Vertical	Rock	Rock	n/a	Bldr		n/a	6' drop
237+00		1.0	2-3'		2"		Vertical, P	Vertical, P	0B/>75	0B/50-75	M	0/70/30/0		No cobble	2'-2.5' vertical drop at headcut
242+00		1.0	1-2'	Trickle flow	1"		1:1 M	1:1 M	50-75	50-75	L	0/60/40/0		No cobble	Trickle flow from ditch

NOTES: All measurements taken looking downstream
NLMH = None, Low, Medium, High
OSMP = Optimal, Suboptimal, Marginal, Poor

Reach			Road - General					Road Section				Overbank			Hillslope Above Rd / Crk			
Start Sta, or Sta Point	End Sta	Photo Point #	Posted Speed	Horizontal Curve (Sharp, Flat)	Grade (Steep Flat)	Rutting	Guard Rail Left, Right	Tilt To / Away from Creek	Ditch on Left, Right, Both	Crk Side Road Embkmt - Fill or Natural	Edge Scour due to Runoff	Dist - Edge of Road or Toe to Creek	Sloped or Flat	OB Veg % Ground Cover.	Veg % Coverage: Left & Rt	Valleys, Gullies, Rills: Left & Rt	Sed Source to Creek	Notes
(ft)	(ft)	(#)	(mph)	(Sh, F)	(St, F)	(NLMH)	L / R	(T or A)	(L, R, B)	(F or N)	(NLMH)	(ft)	(S or F)	L / R	L / R	L / R	(NLMH)	
277		3, 4	N/A	Sh	F	L	N/A	T		F	L	Long	F	90	90/90	L/ R	N	Culvert
270		6	N/A	Sh	St	N	N/A	T, A	B	N	N	0	S	90	90/90	L	L	
265			N/A	F	St	L	N/A	T	B	N	L	20	F	90	90/90	L	L	Culvert
225			N/A	Sh	St, F	L	N/A	T	R	N	N	0	S	90	90/10	N/A	L	
220	215		N/A	F	St	N	N/A	T	R	F	L	40	F	90	90/5	N/A	M	
207	185	10, 11	N/A	Sh	St	M	N/A	T, A	R	F	M	5-40	F	90	50/0	L	H	Potential to tilt away from stream.
185	180	Same as 10, 11	N/A	Sh	St	L	N/A	T	L	B	M	0	S	90	1/50	R	M	Cant tilt away. Keep superelevation.
180	165	Same as 10, 11	N/A	Sh	St	L	N/A	T, A	L	N	L	0	S	90	40/90	R	L	
165	155	13	N/A	F	F	M	N/A	T	R or None	N	L	0	S	90	90/40	L	L	
155	147		N/A	F	F	N	L	T	B	F	L	0-40	F	90	90/10	L	L	Shallow ditches.
145		15, 16	N/A	Sh	St	N	L	T, A	R	N	L	0-40	S	90	90/5	R	M	Cable rail is falling down slope.
145	123		N/A	Sh, F	F	M	L	T, A	B	N	L	0-40	S	90	90/50	L	L	Right side is sedimentation slope.
107	80	17, 18, 19, 20	N/A	F	F	M	L	T, A	B	F	M	0-20	F	90	70/70	R	L	Parking area at 105 is sed source. Picture 19 and 20 tilt toward stream.
77		21, 22	N/A	Sh	St	N		T	L	F	H	0	S	90	5/70	R	H	Major erosion. Right side is steep.
77	70		N/A	Sh	F	L		T	L	N	H	0	S	90	20/80	R	H	Major erosion. Right side is steep.
70	13		N/A			H												
13	0		N/A	Sh	St, F	H		T	N/A	F	H	0	S	80	10/10	B	H	Lots of flow outlets on south side of road.
12		1	N/A	None	F	N	N/A	Crown	None	N	L	Long	S	80	80/30	L	M	
9		2	N/A	None	F	N	N/A	Crown	None	N	L	Long	S	80	80/30	L	M	

NOTES: All measurements taken looking downstream
NLMH = None, Low, Medium, High

Reach		Creek Crossing - Bridges and Culverts								Flow Data - Upstream of Bridge / Culvert				Culvert Discharge			
Start Sta, or Sta Point	End Sta	Type (bridge, culvert)	Mat'l	Dimen. (Dia or H by W)	Depth Plug w/ Sed.	Length	Inlet or other components to note?	U/S End of Pipe - Area for BMP?	D/S End of Pipe - Area for BMP?	Channel Bottom Width	Height to top of Bank	Avg. Channel Side Slope	Photo Taken for n-value	Bank Erosion due to Culvert	D/S End of Culvert - Ht above OB	Sed Delta Distance Across OB, does it reach the creek?	Notes
(ft)	(ft)			(ft)	(ft)	(ft)		(ft)	(ft)	(ft)	(ft)	(_H:1V)	(confirm)	(NLMH)	(ft)	(ft) (yes, no)	
272			CMP	1.5	0.3	40	No	Plenty	Plenty					N	0	No	No BMP needed
269			CMP	1.5	1.5	35	No	Plenty	Plenty					N	0	No	Use BMP on U/S
263			CMP	1.5	0	35	No	3.5	Plenty					L	3	20', No	Plenty of OB
258+50			CMP	1.5	1.5		No	5	5					L	0	N/A	Driveway
258			CMP	1.25	1.25		No	4	Plenty					L	0	20', No	Plenty of OB
252			CMP	1.25	0.1		No	2.5	Plenty					L	3	20', No	Plenty of OB
243			CMP	1.5	0		No	2	4					L	6	20', No	Maybe 1st BMP on U/S
235+50			CMP	1.5	0.5		No	3	4					L	0	20', No	
230+50			CMP	1.25	0.2		No	1.5	6					L	1	15', Yes	Creek is close to road
225			CMP	2.5	0.1	36	No	3	5	1.5	3	1.5:1	Y	N	0		Pea gravel in creek
222			CMP	1.5	0.5		No	5	10					M	3	10', Yes	Use BMP
212			CMP	1.5	0.3		No	4	6					M	2	5', No	
207			CMP	1.5	0		No	6	Not needed					L	2	0', No	No BMP needed
195			CMP	1.5	0		No	6	Plenty					M	0	15', Yes	Use BMP
192			CMP	1.5	0		No	2	Plenty					M	0	10', Yes	Riprap in channel
184+50			CMP	3	0	36	No	6	8	2	4	>1:1	Y	N	0.5		Logs filter the creek
176+50			CMP	2	0.1		No	4	Plenty					N	3	0', No	No BMP needed
171			CMP	1.25	0.4		No	2	6					L	0	10', Yes	Use BMP
164			CMP	3	0.4	50	No	10	8	2	3	2:1	Y	M	0		
155+50			CMP	2	0.7		No	3	6					L	0	2', Yes	Erosion above pipe outlet
144			CMP	Dbl - 2	0.5	30	No	6	6					L	0		Side Road
143+50			CMP	2.5	2.5		Rock headwall at otulet	Plenty	8	10	3	2:1	Y	M	0	10', Yes	Use BMP on D/S

NOTES: All measurements taken looking downstream
NLMH = None, Low, Medium, High
NV = Not Visible

Reach		Creek Crossing - Bridges and Culverts								Flow Data - Upstream of Bridge / Culvert				Culvert Discharge			
Start Sta, or Sta Point	End Sta	Type (bridge, culvert)	Mat'l	Dimen. (Dia or H by W)	Depth Plug w/ Sed.	Length	Inlet or other components to note?	U/S End of Pipe - Area for BMP?	D/S End of Pipe - Area for BMP?	Channel Bottom Width	Height to top of Bank	Avg. Channel Side Slope	Photo Taken for n-value	Bank Erosion due to Culvert	D/S End of Culvert - Ht above OB	Sed Delta Distance Across OB, does it reach the creek?	Notes
(ft)	(ft)			(ft)	(ft)	(ft)		(ft)	(ft)	(ft)	(ft)	(_H:1V)	(confirm)	(NLMH)	(ft)	(ft) (yes, no)	
134+50			CMP	1.5	0.5		No	3	8					L	0.5	2, Yes	
128+50			CMP	1.5	0.75		No	3	Plenty					N	NV	0, Yes	D/S is very vegetated. Could not see outlet.
123			CMP	2	0.1		No	Plenty	Plenty					N	0	25, Yes	
118+50			CMP	4.5	0	40	No	7	10	5	5	1:1	Y	N	1		
114+50			CMP	4.5	0	40	No	10	10	5	4	1:1	Y	N	0.5		
107+50			CMP	4.5	0	40	No	10	10	5	4	1:1	Y	L	0		
94			CMP	2.5	1.25		No	5	NV					NV	NV	NV	D/S is very vegetated. Could not see outlet.
91+50			CMP	Dbl - 3	0	20	No	8	Plenty	5	3	3:1	Y	N			Driveway
86+50			CMP	1.5	1		No	3	Plenty					N	0	10, No	
80+50			CMP	1.5	1.5		No	3	Plenty					N	0	20, Yes	Sediment from road and parking area.
76+50			CMP	1.5	0		No	4	Plenty, but steep					L	0.5	10, Yes	
70			CMP	2	2		No	4	Plenty, but steep					L	NV	0, Yes	Could not see outlet.
67			CMP	2	0		No	2	Plenty, but steep					L	NV		Could not see outlet.
63+50			CMP	2	0		No	2	Plenty, but steep					L	NV	10, Yes	Could not see outlet.
61+50			CMP	2	0.5		No	2	Plenty, but steep					L	NV	10, Yes	Could not see outlet.
57			CMP	1.5	1		No	6	2					?	NV	2, Yes	Cound see outlet. Stream is close to road.
53			CMP	1.5	0		No	2	2					?	NV	2, Yes	Cound see outlet. Stream is close to road.
50+50			CMP	2	1.3		No	Plenty	2					N	NV	2, Yes	Cound see outlet. Stream is close to road.
47			CMP	1.5	0		No	2	Plenty, but steep					H	2	10, Yes	
45			CMP	2	0		No	2	Plenty, but steep					H	NV	10, Yes	Could not see outlet.
43			CMP	2	0.4		No	5	Plenty					M	0	15, Barely	
41			CMP	2	0		No	4	Plenty					N	1	No	
38			CMP	1.5	0		No	2	Plenty, but steep					N	NV	No	Could not see outlet.

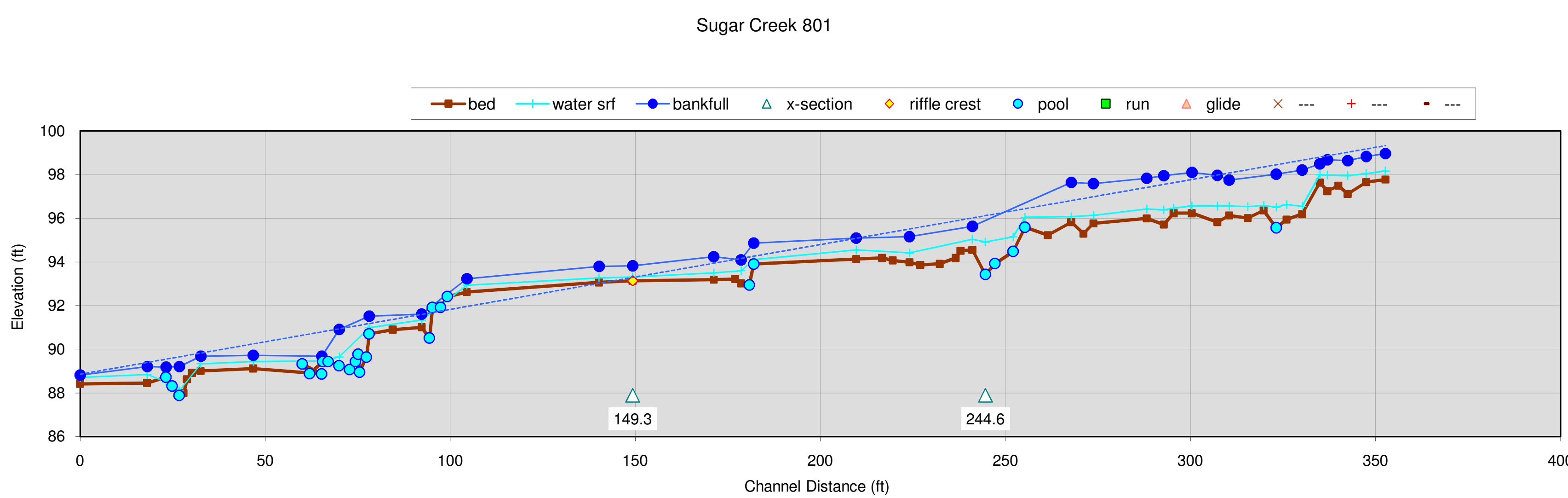
NOTES: All measurements taken looking downstream
NLMH = None, Low, Medium, High
NV = Not Visible

Reach		Creek Crossing - Bridges and Culverts								Flow Data - Upstream of Bridge / Culvert				Culvert Discharge			
Start Sta, or Sta Point	End Sta	Type (bridge, culvert)	Mat'l	Dimen. (Dia or H by W)	Depth Plug w/ Sed.	Length	Inlet or other components to note?	U/S End of Pipe - Area for BMP?	D/S End of Pipe - Area for BMP?	Channel Bottom Width	Height to top of Bank	Avg. Channel Side Slope	Photo Taken for n-value	Bank Erosion due to Culvert	D/S End of Culvert - Ht above OB	Sed Delta Distance Across OB, does it reach the creek?	Notes
(ft)	(ft)			(ft)	(ft)	(ft)		(ft)		(ft)	(ft)	(_H:1V)	(confirm)	(NLMH)	(ft)	(ft) (yes, no)	
30+50			CMP	2	0		No	4	Plenty					M	NV	20, Maybe	Could not see outlet.
29			CMP	1.5	0.5		No	4	Plenty					L	0.5	15, Maybe, but not much	
25+50			CMP	1.5	0.5		No	4	Plenty					N	0	No	No BMP needed
25			CMP	1.5	0		No	4	Plenty					N	NV	No	Could not see outlet.
21+50			CMP	1.5	0		No	4	Plenty					L	1	30, Yes	Long channel of silt
14			CMP	4.5	0	80	No	Plenty	Plenty	6	6	2:1	Y	N	0	No	
6+50			CMP	2	0.5		No	4	Plenty, but steep and low					H	0	90, Yes. A lot	A lot of sed below retaining wall
3			CMP	1.5	0.3		No	2	Plenty, but steep and low					H	NV	90, Yes, but barely	Could not see outlet.
2+50			CMP	1.5	0.2		No	6	Plenty, but steep and low					H	0	90, Yes, but barely	
2+00			CMP	2	0.2		No	6	Plenty, but steep and low					L	0	90, Yes, but barely	

NOTES: All measurements taken looking downstream
NLMH = None, Low, Medium, High
NV = Not Visible

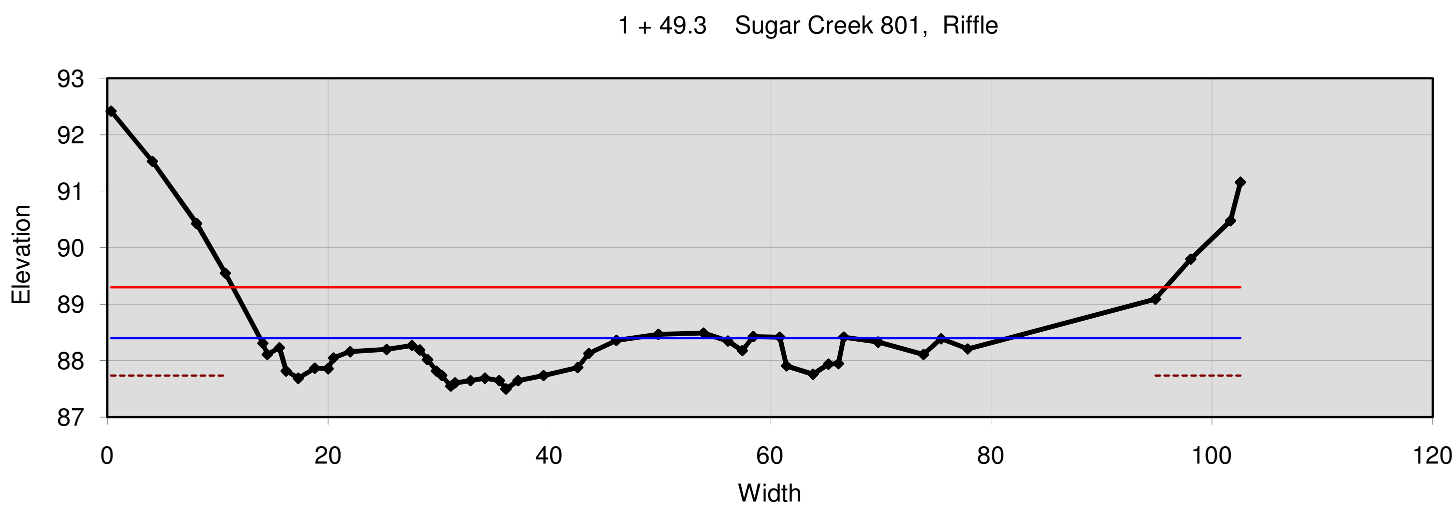
APPENDIX B

Longitudinal Slope Profile



	slope (%)	slope ratio	length (ft)	length ratio	pool-pool spacing (ft)	p-p ratio
reach	2.7	---	352.7 (6.2 channel widths)	---	---	---
riffle	0.6	0.2	31.5	0.6	---	---
pool	#DIV/0!	---	8.9 (0 - 64.5)	0.2 (--- - 1.1)	12.0 (-5.3 - 81.6)	0.2 (-0.1 - 1.4)
	---	---	---	---	---	---
	---	---	---	---	---	---

Cross Section 1



Bankfull Dimensions	
19.9	x-section area (ft.sq.)
56.5	width (ft)
0.4	mean depth (ft)
0.9	max depth (ft)
57.4	wetted parimeter (ft)
0.3	hyd radi (ft)
160.3	width-depth ratio

Flood Dimensions	
84.5	W flood prone area (ft)
1.5	entrenchment ratio
0.2	low bank height (ft)
0.3	low bank height ratio

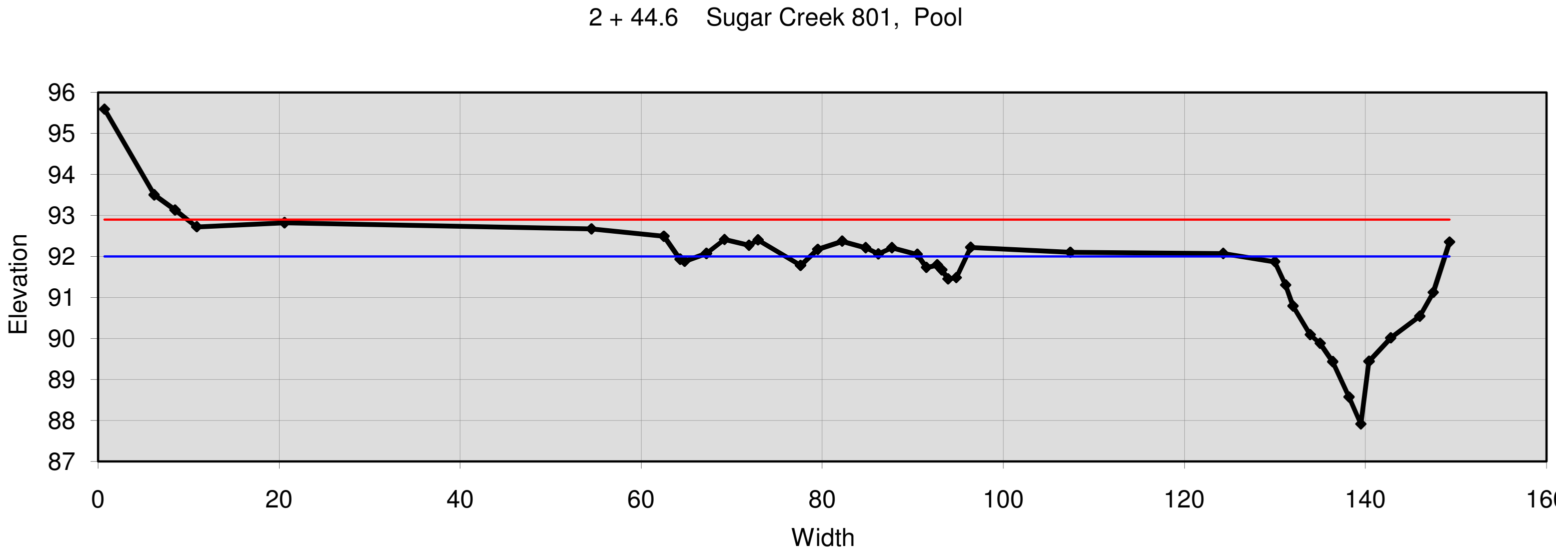
Materials	
4.6	D50 Riffle (mm)
10	D84 Riffle (mm)
29	threshold grain size (mm):

Bankfull Flow	
5.2	velocity (ft/s)
104.4	discharge rate (cfs)
1.57	Froude number

Flow Resistance	
0.023	Manning's roughness
0.09	D'Arcy-Weisbach fric.
9.5	resistance factor u/u*
10.7	relative roughness

Forces & Power	
2.7	channel slope (%)
0.59	shear stress (lb/sq.ft.)
0.55	shear velocity (ft/s)
3.1	unit strm power (lb/ft/s)

Cross Section 2



Bankfull Dimensions

38.6	x-section area (ft.sq.)
32.7	width (ft)
1.2	mean depth (ft)
4.1	max depth (ft)
35.2	wetted parimeter (ft)
1.1	hyd radi (ft)
27.8	width-depth ratio

Flood Dimensions

---	W flood prone area (ft)
---	entrenchment ratio
---	low bank height (ft)
---	low bank height ratio

Materials

4.6	D50 Riffle (mm)
10	D84 Riffle (mm)
91	threshold grain size (mm):

Bankfull Flow

12.4	velocity (ft/s)
478.0	discharge rate (cfs)
2.08	Froude number

Flow Resistance

0.021	Manning's roughness
0.05	D'Arcy-Weisbach fric.
12.7	resistance factor u/u*
35.9	relative roughness

Forces & Power

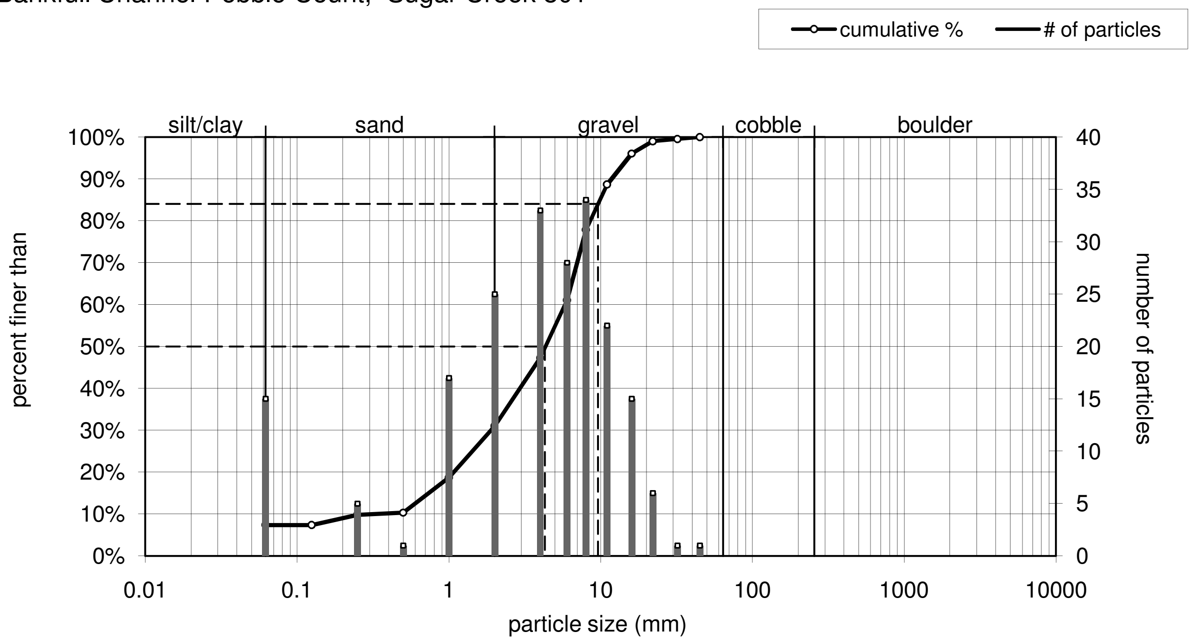
2.7	channel slope (%)
1.85	shear stress (lb/sq.ft.)
0.98	shear velocity (ft/s)
25	unit strm power (lb/ft/s)

Bankfull Channel

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	**15**
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	**5**
medium sand	0.25 - 0.5	**1**
coarse sand	0.5 - 1	**17**
very coarse sand	1 - 2	**25**
very fine gravel	2 - 4	**33**
fine gravel	4 - 6	**28**
fine gravel	6 - 8	**34**
medium gravel	8 - 11	**22**
medium gravel	11 - 16	**15**
coarse gravel	16 - 22	**6**
coarse gravel	22 - 32	**1**
very coarse gravel	32 - 45	**1**
very coarse gravel	45 - 64	
small cobble	64 - 90	
medium cobble	90 - 128	
large cobble	128 - 180	
very large cobble	180 - 256	
small boulder	256 - 362	
small boulder	362 - 512	
medium boulder	512 - 1024	
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
total particle count:		203
bedrock	---------------------	
clay hardpan	---------------------	
detritus/wood	---------------------	
artificial	---------------------	
total count:		203

Note:

Bankfull Channel Pebble Count, Sugar Creek 801

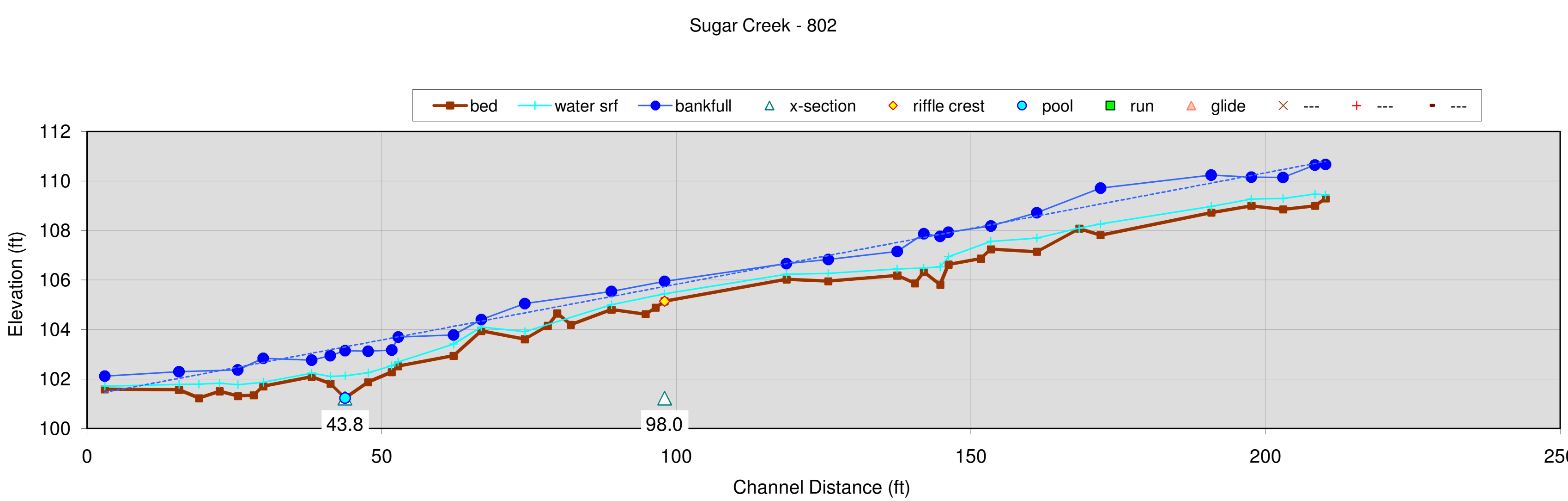


Size (mm)		
D16	0.8	3.4
D35	2.4	12
D50	4.3	17
D65	6.4	20
D84	9.6	29
D95	15	39

Size Distribution	
mean	2.8
dispersion	3.8
skewness	-0.18

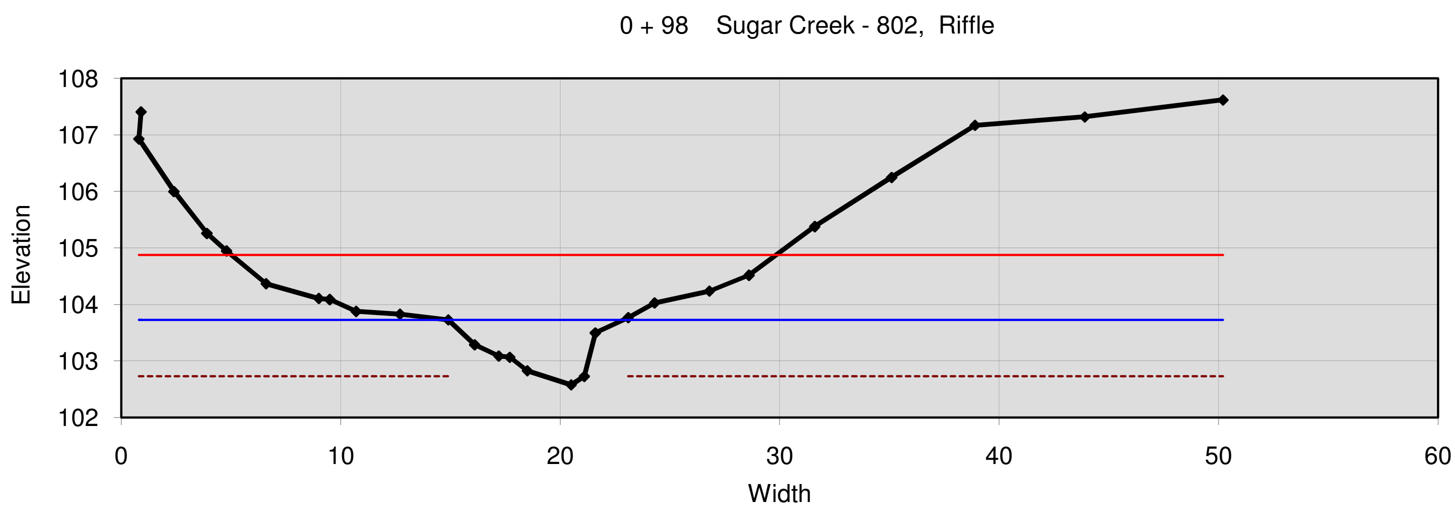
Type	
silt/clay	7%
sand	24%
gravel	69%
cobble	0%
boulder	0%

Longitudinal Slope Profile



	slope (%)	slope ratio	length (ft)	length ratio	pool-pool spacing (ft)	p-p ratio
reach	3.7	---	210.2 (26.3 channel widths)	---	---	---
riffle	---	---	---	---	---	---
pool	0	0	54.2	6.8	---	---
	---	---	---	---	---	---
	---	---	---	---	---	---

Cross Section 1



Bankfull Dimensions

5.0	x-section area (ft.sq.)
8.0	width (ft)
0.6	mean depth (ft)
1.2	max depth (ft)
8.6	wetted parimeter (ft)
0.6	hyd radi (ft)
12.8	width-depth ratio

Flood Dimensions

24.8	W flood prone area (ft)
3.1	entrenchment ratio
0.2	low bank height (ft)
0.1	low bank height ratio

Materials

3.1	D50 Riffle (mm)
41	D84 Riffle (mm)
66	threshold grain size (mm):

Bankfull Flow

5.9	velocity (ft/s)
29.0	discharge rate (cfs)
1.36	Froude number

Flow Resistance

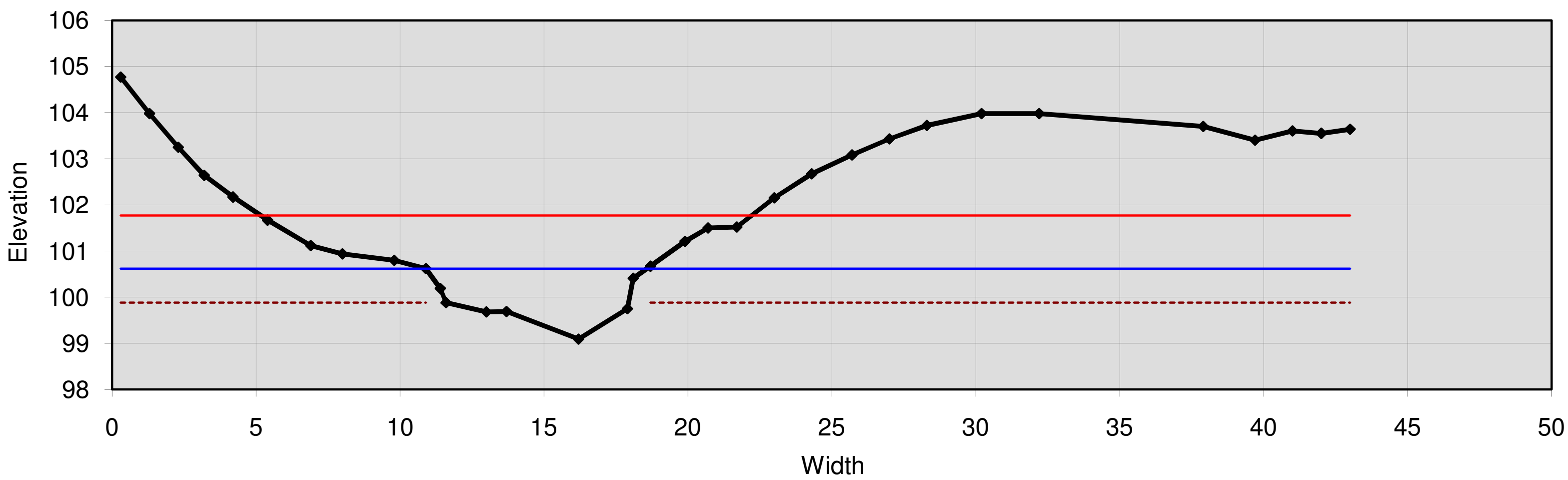
0.034	Manning's roughness
0.16	D'Arcy-Weisbach fric.
7.1	resistance factor u/u*
4.6	relative roughness

Forces & Power

3.7	channel slope (%)
1.33	shear stress (lb/sq.ft.)
0.83	shear velocity (ft/s)
8.4	unit strm power (lb/ft/s)

Cross Section 2

0 + 43.8 Sugar Creek - 802, Pool



Bankfull Dimensions

7.3	x-section area (ft.sq.)
7.7	width (ft)
1.0	mean depth (ft)
1.5	max depth (ft)
8.8	wetted parimeter (ft)
0.8	hyd radi (ft)
8.1	width-depth ratio

Flood Dimensions

17.1	W flood prone area (ft)
2.2	entrenchment ratio
0.8	low bank height (ft)
0.5	low bank height ratio

Materials

3.1	D50 Riffle (mm)
41	D84 Riffle (mm)
95	threshold grain size (mm):

Bankfull Flow

7.9	velocity (ft/s)
58.0	discharge rate (cfs)
1.52	Froude number

Flow Resistance

0.032	Manning's roughness
0.13	D'Arcy-Weisbach fric.
7.9	resistance factor u/u*
7.1	relative roughness

Forces & Power

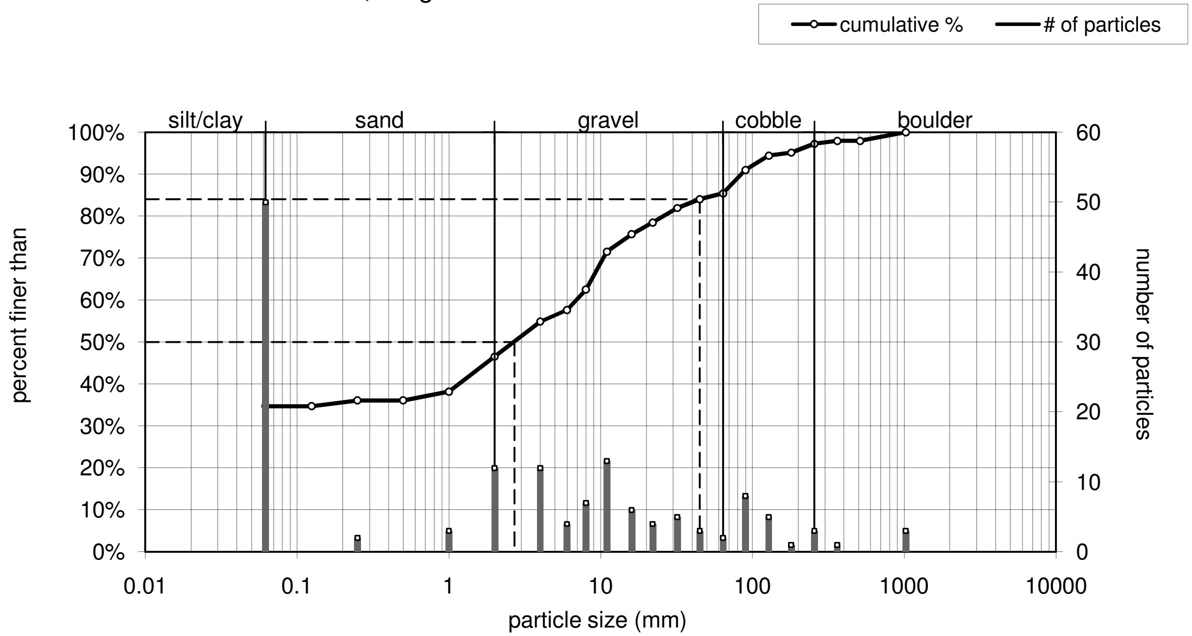
3.7	channel slope (%)
1.93	shear stress (lb/sq.ft.)
1.00	shear velocity (ft/s)
17.4	unit strm power (lb/ft/s)

Bankfull Channel

Material	Size Range (mm)	Count
silt/clay	0 - 0.062	**50**
very fine sand	0.062 - 0.125	
fine sand	0.125 - 0.25	**2**
medium sand	0.25 - 0.5	
coarse sand	0.5 - 1	**3**
very coarse sand	1 - 2	**12**
very fine gravel	2 - 4	**12**
fine gravel	4 - 6	**4**
fine gravel	6 - 8	**7**
medium gravel	8 - 11	**13**
medium gravel	11 - 16	**6**
coarse gravel	16 - 22	**4**
coarse gravel	22 - 32	**5**
very coarse gravel	32 - 45	**3**
very coarse gravel	45 - 64	**2**
small cobble	64 - 90	**8**
medium cobble	90 - 128	**5**
large cobble	128 - 180	**1**
very large cobble	180 - 256	**3**
small boulder	256 - 362	**1**
small boulder	362 - 512	
medium boulder	512 - 1024	**3**
large boulder	1024 - 2048	
very large boulder	2048 - 4096	
total particle count:		144
bedrock	---------------------	
clay hardpan	---------------------	
detritus/wood	---------------------	
artificial	---------------------	
total count:		144

Note:

Bankfull Channel Pebble Count, Sugar Creek - 802



Size (mm)		
D16	0.062	3.4
D35	0.14	12
D50	2.7	17
D65	8.7	20
D84	45	29
D95	170	39

Size Distribution	
mean	1.7
dispersion	30.1
skewness	-0.12

Type	
silt/clay	35%
sand	12%
gravel	39%
cobble	12%
boulder	3%

APPENDIX C

BROOK TROUT

DONE

Water	**Sugar Creek**	Date	6/2/2008
Location	"SUGAR CR, NE of Deckers; Reach 801"	Water Code	15885
Drainage	Upper South Platte	UTM Zone	13N
Crew	"Steve Culver, Bonnie Meyers, Ryan Prioreschi"	UTM X	483654
		UTM Y	4350690
		Station Length (ft)	353
		Station Width (ft)	6.6

Notes

Temperature 7.8C; pH 7.93; conductivity 127 uS; TDS 63 ppm; Alkalinity 68ppm; phosphate <0ppm; nitrate <1ppm; electrofisher voltage 520v; pass 1 seconds 1270; pass 2 seconds 874; pass 3 seconds 756

Metric

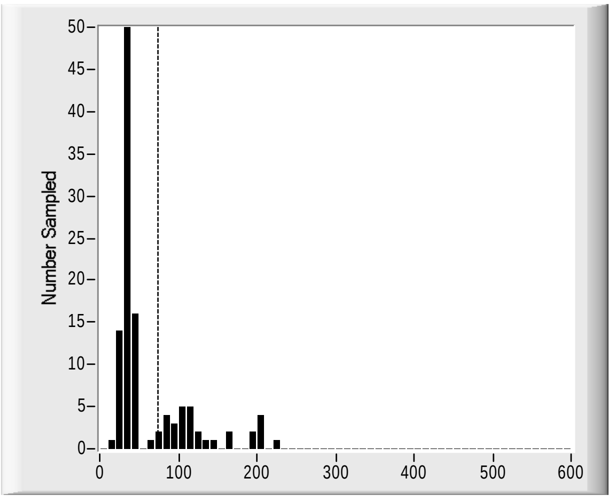
	Estimate	95% CI (+/-)
NUMBER/HA	1469	334
kg/HA	43	10
NUMBER/km	296	67
kg/km	9	2

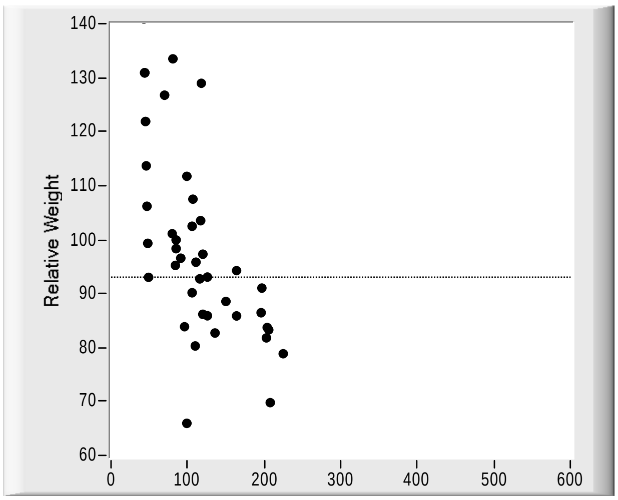
1st PASS	22
2nd PASS	7
Capture P	0.70
Pop Estimate	31.80
95% CI (+/-)	7.22

English

	Estimate	95% CI (+/-)
NUMBER/Acre	595	135
Lbs/Acre	39	9
NUMBER/Mile	476	108
Lbs/Mile	31	7

1st PASS	22
2nd PASS	7
Capture P	0.70
Pop Estimate	31.80
95% CI (+/-)	7.22





MIN CUT	75
MAX CUT	-1

After Length (mm)

BROOK TROUT

DONE

Water: **Sugar Creek**

Location: SUGAR CR, NE of Deckers; Reach 802

Drainage: Upper South Platte

Crew: Steve Culver, Bonnie Meyers, Ryan Prioreschi

Notes:

Temperature 8.8C at 1430; pH 8.00; conductivity 101 uS; TDS 50 ppm; alkalinity 53ppm; electrofisher voltage 520v; pass 1 seconds 1084; pass 2 seconds 726; pass 3 seconds 580

Date: 6/12/2008

Water Code: 15885

UTM Zone: 13N

UTM X: 486654

UTM Y: 4349449

Station Length (ft): 207

Station Width (ft): 4.4

Metric

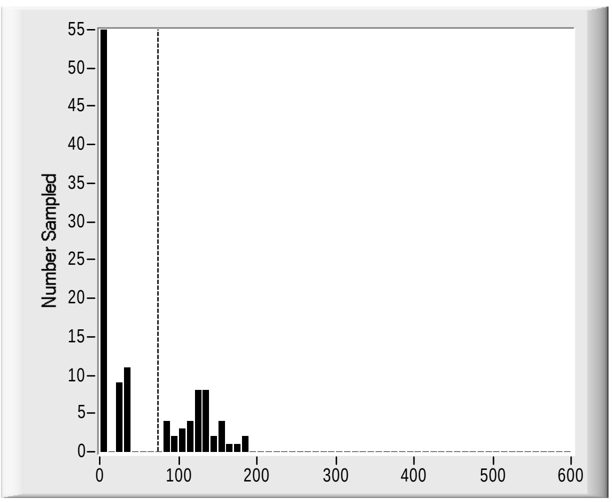
	Estimate	95% CI (+/-)
NUMBER/HA	4422	221
kg/HA	105	5
NUMBER/km	593	30
kg/km	14	1

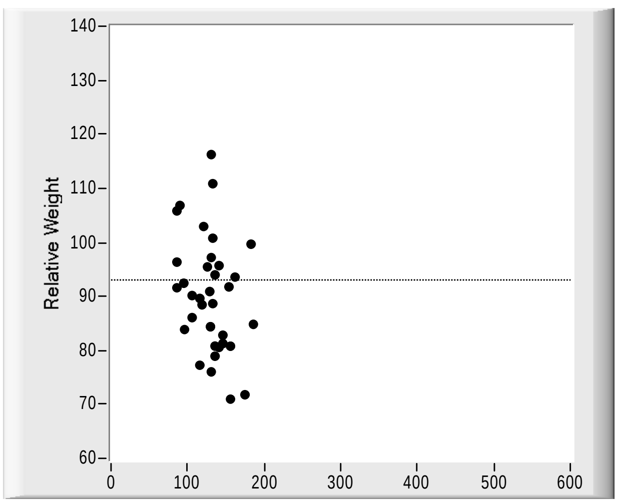
1st PASS	33
2nd PASS	4
Capture P	0.88
Pop Estimate	37.41
95% CI (+/-)	1.87

English

	Estimate	95% CI (+/-)
NUMBER/Acre	1789	89
Lbs/Acre	94	5
NUMBER/Mile	954	48
Lbs/Mile	50	2

1st PASS	33
2nd PASS	4
Capture P	0.88
Pop Estimate	37.41
95% CI (+/-)	1.87





MIN CUT: 75

MAX CUT: -1

After

Length (mm)

APPENDIX D

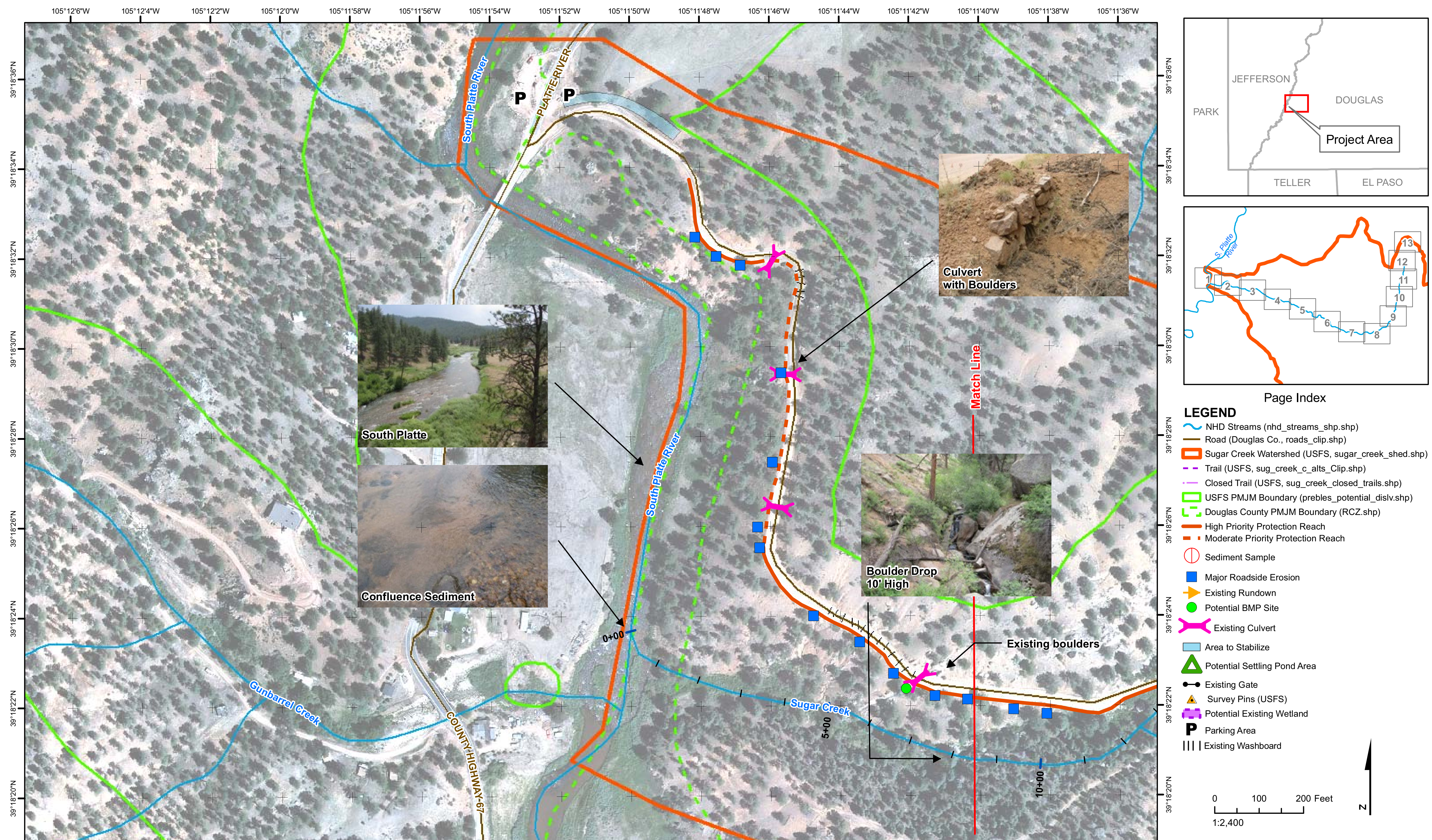
Sample #	Sample ID	pH (field)	Cond (field) uS	Water Temp degC	Air Temp deg C	Date	Received Date	dry filter	filtered wgt	wgt sample +flask	wgt flask	wgt sample	wgt solids	solids mg/l	Turbidity
Sugar Creek															
SED120	Sugar Creek					01/06/03	01/09/03	1.3699	1.3784	994.7	106.3	888.4	0.0085	9.6	3.21
SED128	Sugar Creek	7.3	162	0.1	1000	02/10/03	02/13/03	1.3502	1.3698	1086.7	106.4	980.3	0.0196	20.0	0.5
SED152	Sugar Creek	7.36	136	4.2		04/09/03	04/11/03	1.3847	1.3879	949.9	107.3	842.6	0.0032	3.8	2.83
SED179	Sugar Creek							1.4198	1.4227	972.0	107.7	864.3	0.0029	3.4	0.55
SED187	Sugar Creek				1430	7/29/2003	7/31/2003	1.4309	1.4312	1064.7	108.7	956.0	0.0003	0.3	1.43
SED197	Sugar Creek	7.32	188	15.3	1430	8/19/2003	9/3/2003	1.4268	1.4274	1022.4	104.4	918.0	0.0006	0.7	0.76
SED211	Sugar Creek	7.19	180	12.0	1400	10/09/03	10/23/03	1.376	1.3774	1031.9	105.7	926.2	0.0014	1.5	0.52
SED219	Sugar Creek	6.86	167	6.4	1345	11/13/03	11/19/03	1.4199	1.4208	789.1	80.2	708.9	0.0009	1.3	1.39
SED231	Sugar Creek	6.77	161	1.0	1330	12/11/03	12/17/03	1.4175	1.4186	833.8	81.7	752.1	0.0011	1.5	1.14
SED238	Sugar Creek	6.16	33	3.4		02/25/04	03/02/04	1.4042	1.4073	980.7	108.1	872.6	0.0031	3.6	1.64
SED247	Sugar Creek	6.93	147	3.4		03/26/04	03/30/04	1.4217	1.4261	872.8	81.3	791.5	0.0044	5.6	1.54
SED257	Sugar Creek	6.84	121	12.7	32	05/17/04	05/18/04	1.4085	1.4122	1055.3	109.2	946.1	0.0037	3.9	5.26
DED263	Sugar Creek	6.42	139	12.2	22	06/24/04	06/29/04	1.4044	1.4067	303.5	36.8	266.7	0.0023	8.6	6.74
SED274	Sugar Creek	7.77	141	13.4	23	07/21/04	07/27/04	1.4238	1.5651	1024.2	107.6	916.6	0.1413	154.2	7.81
SED284	Sugar Creek	8.07	126	11.8	18	8/12/04	8/17/04	1.3656	1.3784	1026.8	109.2	917.6	0.0128	13.9	8.44
SED292	Sugar Creek	7.69	149	11.2	19	8/31/2004	9/3/2004	1.4234	1.4300	1067.1	105.2	961.9	0.0066	6.9	8.97
SED307	Sugar Creek	7.35	154	9.7	17	10/4/2004	10/7/2004	1.4285	1.4302	1018.6	103.6	915.0	0.0017	1.9	2.8
SED340	Sugar Creek	7.35	135	1.3	10.5	01/10/05	01/13/05	1.4215	1.4282	1073.0	107.2	965.8	0.0067	6.9	3.44
SED351	Sugar Creek	6.85	134	1.1	14	02/14/05	02/15/05	1.4244	1.4259	1005.4	91.1	914.3	0.0015	1.6	1.38
SED382	Sugar Creek	7.62	127	12.6	24	06/02/05	06/08/05	1.4315	1.4389	1114.6	106.3	1008.3	0.0074	7.3	2.85
SED396	Sugar Creek	7.85	147	11.5	25	06/29/05	07/01/05	1.4132	1.4203	1078.5	107.2	971.3	0.0071	7.3	1.78
Pine Creek															
SED125	Pine Creek					01/06/03	01/09/03	1.36	1.3620	957.8	104.7	853.1	0.002	2.3	1.15
SED145	Pine Creek	7.37	187	0.5	1400	03/25/03	03/27/03	1.4171	1.9971	1005.7	91.4	914.3	0.58	634.4	364
SED155	Pine Creek	7	190	5.6		04/09/03	04/11/03	1.3781	1.5385	972.5	105.3	867.2	0.1604	185.0	18.4
SED182	Pine Creek							1.4166	1.4189	1001.4	92.0	909.4	0.0023	2.5	0.35
SED190	Pine Creek				1500	7/29/2003	7/31/2003	1.4205	1.4235	1070.8	107.6	963.2	0.003	3.1	2.66
SED202	Pine Creek	7.78	224	14.8	1600	8/19/2003	9/3/2003	1.4104	1.4164	1010.7	106.7	904.0	0.006	6.6	0.79
SED212	Pine Creek	6.86	205	9.0	1500	10/09/03	10/23/03	1.3819	1.4115	1042.8	105.2	937.6	0.0296	31.6	0.9
SED220	Pine Creek	7.02	181	4.1	1415	11/13/03	11/19/03	1.4174	1.4375	851.8	81.4	770.4	0.0201	26.1	1.85
SED232	Pine Creek	7.01	175	0.1	1400	12/11/03	12/17/03	1.4149	1.4164	853.4	81.3	772.1	0.0015	1.9	3.36
SED237	Pine Creek	6.17	36	1.3		02/25/04	03/02/04	1.4245	1.4292	867.2	105.8	761.4	0.0047	6.2	5.08
SED246	Pine Creek	7.05	152	2.5		03/26/04	03/30/04	1.4017	1.4463	883.5	80.3	803.2	0.0446	55.5	5.91
SED258	Pine Creek	7.02	128	10.9	25	05/17/04	05/18/04	1.4074	1.4852	1041.1	108.7	932.4	0.0778	83.4	12.1
SED266	Pine Creek	7.1	131	10.8		06/24/04	06/29/04	1.4252	1.4404	295.7	35.3	260.4	0.0152	58.4	24.7
SED272	Pine Creek	7.83	142	12.5	22.5	07/21/04	07/27/04	1.4226	1.6437	1042.7	108.0	934.7	0.2211	236.5	16.6
SED283	Pine Creek	8.2	135	10.9	13	8/12/04	8/17/04	1.4099	1.7111	1076.4	104.0	972.4	0.3012	309.7	16.3
SED294	Pine Creek	7.84	171	10	19.1	8/31/2004	9/3/2004	1.4235	1.4350	1075.4	106.6	968.8	0.0115	11.9	7.55
SED308	Pine Creek	7.45	167	6.8	16.2	10/4/2004	10/7/2004	1.4137	1.4187	1031.3	105.8	925.5	0.005	5.4	6.28
SED338	Pine Creek	7.91	152	0.6	8	01/10/05	01/13/05	1.4296	1.4401	1080.5	107.7	972.8	0.0105	10.8	6.49
SED353	Pine Creek	6.91	147	0.3	9	02/14/05	02/15/05	1.4125	1.4263	1058.4	91.3	967.1	0.0138	14.3	4.13
SED383	Pine Creek	7.75	140	12	24	06/02/05	06/08/05	1.4086	1.4318	1099.8	106.1	993.7	0.0232	23.3	4.49
SED395	Pine Creek	8.1	168	11.2	26	06/29/05	07/01/05	1.4292	1.4371	1083.9	107.0	976.9	0.0079	8.1	4.45

FS ID#	SAMPLE ID	NP OR NF	MILITARY TIME	SAMPLE DATE	RECEIVE DATE	pH	uE/L ANC	uS/cm Conduct.		mg/l Na	mg/l NH4	mg/l K	mg/l Mg	mg/l Ca	mg/l F	mg/l Cl	mg/l NO3
Sugar Creek																	
ME395	Sugar Creek		1410	10/09/03	10/15/03	7.833	1399.3	190.40		7.803	0	3.075	4.97	23.564	3.148	4.108	0
ME405	Sugar Creek			11/13/03	11/19/03	7.851	1232.0	168.30		7.248	0	2.736	4.578	21.196	3.182	3.296	0.031
ME417	Sugar Creek		1330	12/11/03	12/17/03	7.814	1075.0	161.80		6.637	0	2.523	4.34	19.714	3.063	2.94	0.176
ME424	Sugar Creek		1101	02/25/04	03/02/04	7.891	948.6	148.7		6.328	0	2.31	4.036	18.218	3.326	2.688	0.266
ME434	Sugar Creek			03/26/04	03/30/04	7.8571	905.5319	151.6		6.328	0	2.289	3.891	17.48	3.075	3.431	0.177
ME447	Sugar Creek			05/17/04	05/18/04	7.8798	742.5436	127.4		5.382	0	2.138	3.101	14.445	2.896	2.698	0.059
ME451	Sugar Creek			06/24/04	06/29/04	7.8931	979.1145	145.1		6.091	0	2.582	3.765	17.37	2.808	3.06	0.093
ME462	Sugar Creek			7/21/2004	07/27/04	7.8613	1012.085	147.8		6.176	0	2.347	3.742	17.73	2.774	2.967	0.149
ME472	Sugar Creek			8/12/2004	08/17/04	7.8163	965.9798	140.2		5.851	0	2.433	3.585	16.723	3.335	2.434	0.086
ME480	Sugar Creek			8/30/2004	9/3/2004	7.806	1135.059	157.2		6.515	0	2.577	4.202	19.566	1.645	2.947	0.113
ME495	Sugar Creek			10/4/2004	10/7/2004	7.8735	1228.678	170.3		6.905	0	2.714	4.402	20.273	2.944	3.404	0
ME528	Sugar Creek			01/10/05	01/13/05	7.35	135	1.3			7.7883	966.1431	149	6.094	0	2.187	4.054
ME539	Sugar Creek			02/14/05	02/15/05	6.85	134	1.1			7.8371	955.8163	147.7	6.196	0	2.159	3.395
ME551	Sugar Creek			04/14/05	04/21/05	7.62	102	4.3			7.6285	586.8195	111.3	5.225	0	1.939	2.648
ME564	Sugar Creek			05/13/05	05/17/05	7.92	93	7.4	19		7.7121	579.1119	102.2	2.458	0	1.281	2.487
ME570	Sugar Creek			06/02/05	06/08/05	7.62	127	12.6	24		7.7977	880.0858	132	5.5	0	2.353	3.595
ME584	Sugar Creek			06/29/05	07/01/05	7.85	147	11.5	25		7.877	1140.515	161	7.003	0	2.53	4.307
Pine Creek																	
ME396	Pine Creek		1500	10/09/03	10/15/03	7.982	1408.6	222.00		10.225	0	2.274	4.803	27.141	1.893	5.631	0
ME407	Pine Creek		1415	11/13/03	11/19/03	7.970	1188.3	186.70		9.217	0	1.785	4.236	23.574	1.82	6.958	0.282
ME418	Pine Creek		1400	12/11/03	12/17/03	7.889	1061.9	179.20		8.26	0	1.674	3.922	21.762	1.794	6.41	0.937
ME423	Pine Creek		1026	02/25/04	03/02/04	7.941	933	177.4		9.308	0	1.622	3.784	21.039	1.909	6.114	1.117
ME433	Pine Creek			03/26/04	03/30/04	7.8026	740.6538	152.5		7.253	0	1.563	3.212	18.24	1.653	6.93	0.988
ME444	Pine Creek			05/17/04	05/18/04	7.8273	709.5989	133.3		6.116	0	0	2.743	15.931	1.514	6.673	0.517
ME454	Pine Creek			06/24/04	06/29/04	7.9441	843.6023	134		6.343	0	2.303	2.812	16.64	1.593	5.157	0.517
ME460	Pine Creek			7/21/2004	07/27/04	7.9729	954.6113	144.5		6.207	0	1.648	3.103	18.558	1.547	5.342	0.469
ME471	Pine Creek			8/12/2004	08/17/04	7.9725	977.5494	148.3		6.874	0	1.91	3.348	19.21	1.638	6.315	0.331
ME482	Pine Creek			8/30/2004	9/3/2004	7.9783	1175.486	174.1		7.3	0	2.016	3.859	22.478	1.842	7.019	0.45
ME496	Pine Creek			10/4/2004	10/7/2004	8.023	1200.285	182.5		7.86	0	1.944	3.988	22.731	1.586	7.537	0.309
ME526	Pine Creek			01/10/05	01/13/05	7.91	152	0.6			7.845	956.81	167.1	7.453	0	1.539	3.608
ME541	Pine Creek			02/14/05	02/15/05	6.91	147	0.3			7.9345	965.626	172.4	7.661	0	1.576	3.354
ME554	Pine Creek			04/14/05	04/21/05	7.62	98	2.8			7.6137	546.9686	112.6	5.394	0	1.592	2.21
ME563	Pine Creek			05/13/05	05/17/05	8.08	112	6.4	19		7.7629	669.2912	122.7	2.293	0	0.956	2.597
ME571	Pine Creek			06/02/05	06/08/05	7.75	140	12	24		7.9325	924.8016	152	6.356	0	1.807	3.557
ME583	Pine Creek			06/29/05	07/01/05	8.1	168	11.2	26		8.0718	1169.908	185.6	8.77	0	1.794	4.197

FS ID#	SAMPLE ID	mg/l PO4	mg/l SO4	ueq/L ANC	ueq/L pH	ueq/L Ca	ueq/L Mg	ueq/L Na	ueq/L K	ueq/L NH4	ueq/L F	ueq/L CL	ueq/L NO3	ueq/L SO4	ueq/L [ANC]	SUM ANIONS
Sugar Creek																
ME395	Sugar Creek	0	10.76	1399.3	0.014689	1175.848	408.969	339.412	78.648	0.000	165.698	115.872	0.000	224.032	1399.3	1417.32
ME405	Sugar Creek	0	12.057	1232.0	0.014093	1057.685	376.713	315.271	69.977	0.000	167.488	92.968	0.500	251.037	1232.0	1250.57
ME417	Sugar Creek	0	12.895	1075.0	0.015346	983.733	357.128	288.694	64.530	0.000	161.224	82.927	2.838	268.485	1075.0	1094.07
ME424	Sugar Creek	0	13.218	948.60	0.013	909.082	332.113	275.253	59.082	0.000	175.067	75.819	4.290	275.210	948.6	1478.99
ME434	Sugar Creek	0	12.967	905.53	0.014	872.255	320.181	275.253	58.545	0.000	161.856	96.776	2.855	269.984	905.5	1437.00
ME447	Sugar Creek	0	10.12	742.5436	0.013189	720.808	255.174	234.104	54.683	0.000	152.434	76.101	0.952	210.707	742.5436	1182.74
ME451	Sugar Creek	0	9.542	979.1145	0.012791	866.766	309.813	264.944	66.039	0.000	147.802	86.311	1.500	198.672	979.1145	1413.40
ME462	Sugar Creek	0	9.086	1012.085	0.013763	884.731	307.920	268.641	60.028	0.000	146.012	83.688	2.403	189.178	1012.085	1433.37
ME472	Sugar Creek	0	8.554	965.9798	0.015265	834.481	295.001	254.505	62.228	0.000	175.541	68.654	1.387	178.101	965.9798	1389.66
ME480	Sugar Creek	0	8.391	1135.059	0.015631	976.347	345.772	283.387	65.911	0.000	86.586	83.124	1.822	174.708	1135.059	1481.30
ME495	Sugar Creek	0	8.578	1228.678	0.013381	1011.627	362.230	300.351	69.415	0.000	154.960	96.014	0.000	178.601	1228.678	1658.25
ME528	Sugar Creek	18.31	2.716	2.51	0.329	0	10.447	966.1	0.016	913.673	333.594	265.074	55.936	0.000	142.959	70.798
ME539	Sugar Creek	16.164	2.623	2.57	0.299	0	10.505	955.8	0.015	806.587	279.366	269.511	55.220	0.000	138.064	72.490
ME551	Sugar Creek	12.182	2.623	3.083	0.566	0	11.283	586.8195	0.023523	607.884	217.898	227.275	49.593	0.000	138.064	86.960
ME564	Sugar Creek	12.162	2.754	1.945	0.257	0	9.822	579.1119	0.019404	606.886	204.649	106.917	32.764	0.000	144.960	54.861
ME570	Sugar Creek	16.514	2.583	2.675	0.259	0	10.809	880.0858	0.015933	824.052	295.824	239.237	60.182	0.000	135.959	75.452
ME584	Sugar Creek	19.483	3.036	2.928	0.197	0	10.704	1140.515	0.013274	972.206	354.413	304.614	64.709	0.000	159.803	82.588
Pine Creek																
ME396	Pine Creek	0	14.597	1408.6	0.010423	1354.341	395.227	444.763	58.161	0.000	99.640	158.830	0.000	303.922	1408.6	1430.72
ME407	Pine Creek	0	14.929	1188.3	0.010715	1176.347	348.570	400.917	45.654	0.000	95.798	196.260	4.548	310.834	1188.3	1212.29
ME418	Pine Creek	0	15.211	1061.9	0.012912	1085.928	322.732	359.290	42.815	0.000	94.429	180.803	15.112	316.706	1061.9	1086.25
ME423	Pine Creek	0	15.491	933.00	0.011	1049.850	311.376	404.876	41.485	0.000	100.482	172.454	18.015	322.536	933.0	1546.49
ME433	Pine Creek	0	14.793	740.65	0.016	910.180	264.308	315.488	39.976	0.000	87.007	195.470	15.934	308.003	740.7	1347.07
ME444	Pine Creek	0	11.275	709.5989	0.014883	794.960	225.715	266.031	0.000	0.000	79.691	188.221	8.338	234.755	709.5989	1220.60
ME454	Pine Creek	0	9.885	843.6023	0.011374	830.339	231.393	275.905	58.903	0.000	83.849	145.460	8.338	205.814	843.6023	1287.06
ME460	Pine Creek	0	9.525	954.6113	0.010644	926.048	255.338	269.990	42.150	0.000	81.428	150.678	7.564	198.319	954.6113	1392.60
ME471	Pine Creek	0	9.502	977.5494	0.010654	958.583	275.499	299.003	48.851	0.000	86.218	178.123	5.338	197.840	977.5494	1445.07
ME482	Pine Creek	0	10.226	1175.486	0.010512	1121.657	317.548	317.533	51.562	0.000	96.956	197.980	7.257	212.914	1175.486	1690.59
ME496	Pine Creek	0	10.756	1200.285	0.009484	1134.281	328.163	341.891	49.721	0.000	83.481	212.591	4.983	223.949	1200.285	1725.29
ME526	Pine Creek	20.055	1.562	4.826	1.296	0	11.778	956.8	0.014	1000.749	296.894	324.188	39.362	0.000	82.217	136.124
ME541	Pine Creek	19.703	1.507	8.539	1.201	0	11.614	965.6	0.012	983.184	275.993	333.235	40.309	0.000	79.322	240.854
ME554	Pine Creek	12.659	1.394	5.884	1.459	0	9.89	546.9686	0.024339	631.687	181.856	234.626	40.718	0.000	73.375	165.966
ME563	Pine Creek	15.459	1.352	5.382	0.643	0	10.373	669.2912	0.017262	771.407	213.701	99.740	24.451	0.000	71.164	151.807
ME571	Pine Creek	19.785	1.444	9.36	0.557	0	11.361	924.8016	0.011682	987.275	292.697	276.471	46.217	0.000	76.006	264.012
ME583	Pine Creek	22.944	1.553	12.968	0.589	0	11.407	1169.908	0.008476	1144.910	345.361	381.474	45.884	0.000	81.744	365.780

FS ID#	SAMPLE ID	SUM CATIONS	TOTAL ION	%ION DIFF	SUM BASES	SUM ACIDS	DIFF= ALK	ANC	FLAG %ION	% COND DIFF	FLAG % COND	THEOR. COND
Sugar Creek												
ME395	Sugar Creek	2002.89	3420.21	-17.121	2002.88	14.87	1988.01	1399.3	Check	-13.58	OK	164.55
ME405	Sugar Creek	1819.66	3070.23	-18.536	1819.65	15.38	1804.26	1232.0	Check	-12.16	OK	147.84
ME417	Sugar Creek	1694.10	2788.17	-21.520	1694.08	16.01	1678.07	1075.0	Check	-16.82	OK	134.59
ME424	Sugar Creek	1575.54	3054.53	-3.161	1575.53	355.32	1220.21	948.6	OK	-0.85	OK	147.44
ME434	Sugar Creek	1526.25	2963.25	-3.012	1526.23	369.61	1156.62	905.5	OK	-4.91	OK	144.16
ME447	Sugar Creek	1264.78	2447.52	-3.352	1264.77	287.76	977.01	742.5436	OK	-7.42	OK	117.94
ME451	Sugar Creek	1507.57	2920.97	-3.224	1507.56	286.48	1221.08	979.1145	OK	-3.05	OK	140.68
ME462	Sugar Creek	1521.33	2954.70	-2.977	1521.32	275.27	1246.05	1012.085	OK	-3.99	OK	141.91
ME472	Sugar Creek	1446.23	2835.89	-1.995	1446.21	248.14	1198.07	965.9798	OK	-4.32	OK	134.15
ME480	Sugar Creek	1671.43	3152.73	-6.031	1671.42	259.65	1411.76	1135.059	OK	-2.14	OK	153.83
ME495	Sugar Creek	1743.64	3401.89	-2.510	1743.62	274.62	1469.01	1228.678	OK	-4.46	OK	162.71
ME528	Sugar Creek	5.306	217.515	966.1	1402.72	1568.29	2971.02	-5.573	1568.28	293.62	1274.66	966.1
ME539	Sugar Creek	4.822	218.723	955.8	1389.92	1410.70	2800.61	-0.742	1410.68	296.04	1114.65	955.8
ME551	Sugar Creek	9.128	234.922	586.8195	1055.89	1102.67	2158.57	-2.167	1102.65	331.01	771.64	586.8195
ME564	Sugar Creek	4.145	204.502	579.1119	987.58	951.24	1938.82	1.875	951.22	263.51	687.71	579.1119
ME570	Sugar Creek	4.177	225.052	880.0858	1320.73	1419.31	2740.04	-3.598	1419.29	304.68	1114.61	880.0858
ME584	Sugar Creek	3.177	222.866	1140.515	1608.95	1695.95	3304.90	-2.633	1695.94	308.63	1387.31	1140.515
Pine Creek												
ME396	Pine Creek	2252.50	3683.22	-22.311	2252.49	20.23	2232.26	1408.6	Check	-19.97	OK	177.66
ME407	Pine Creek	1971.50	3183.79	-23.846	1971.49	22.17	1949.32	1188.3	Check	-17.66	OK	153.73
ME418	Pine Creek	1810.78	2897.03	-25.009	1810.77	22.56	1788.21	1061.9	Check	-21.82	Check	140.10
ME423	Pine Creek	1807.60	3354.09	-7.785	1807.59	513.00	1294.58	933.0	OK	-4.23	OK	169.89
ME433	Pine Creek	1529.97	2877.04	-6.357	1529.95	519.41	1010.54	740.7	OK	-2.86	OK	148.13
ME444	Pine Creek	1286.72	2507.33	-2.637	1286.71	431.31	855.39	709.5989	OK	-4.44	OK	127.38
ME454	Pine Creek	1396.55	2683.62	-4.080	1396.54	359.61	1036.93	843.6023	OK	0.56	OK	134.75
ME460	Pine Creek	1493.54	2886.14	-3.497	1493.53	356.56	1136.97	954.6113	OK	-0.35	OK	143.99
ME471	Pine Creek	1581.95	3027.01	-4.522	1581.94	381.30	1200.63	977.5494	OK	2.10	OK	151.41
ME482	Pine Creek	1808.31	3498.90	-3.364	1808.30	418.15	1390.15	1175.486	OK	0.11	OK	174.30
ME496	Pine Creek	1854.07	3579.36	-3.598	1854.06	441.52	1412.53	1200.285	OK	-1.75	OK	179.31
ME526	Pine Creek	20.902	245.228	956.8	1441.28	1661.21	3102.49	-7.089	1661.19	402.25	1258.94	956.8
ME541	Pine Creek	19.369	241.813	965.6	1546.99	1632.73	3179.72	-2.697	1632.72	502.04	1130.68	965.6
ME554	Pine Creek	23.530	205.918	546.9686	1015.76	1088.91	2104.67	-3.476	1088.89	395.41	693.47	546.9686
ME563	Pine Creek	10.370	215.975	669.2912	1118.61	1109.32	2227.92	0.417	1109.30	378.15	731.15	669.2912
ME571	Pine Creek	8.983	236.546	924.8016	1510.35	1602.67	3113.02	-2.966	1602.66	509.54	1093.12	924.8016
ME583	Pine Creek	9.499	237.503	1169.908	1864.43	1917.64	3782.07	-1.407	1917.63	612.78	1304.85	1169.908

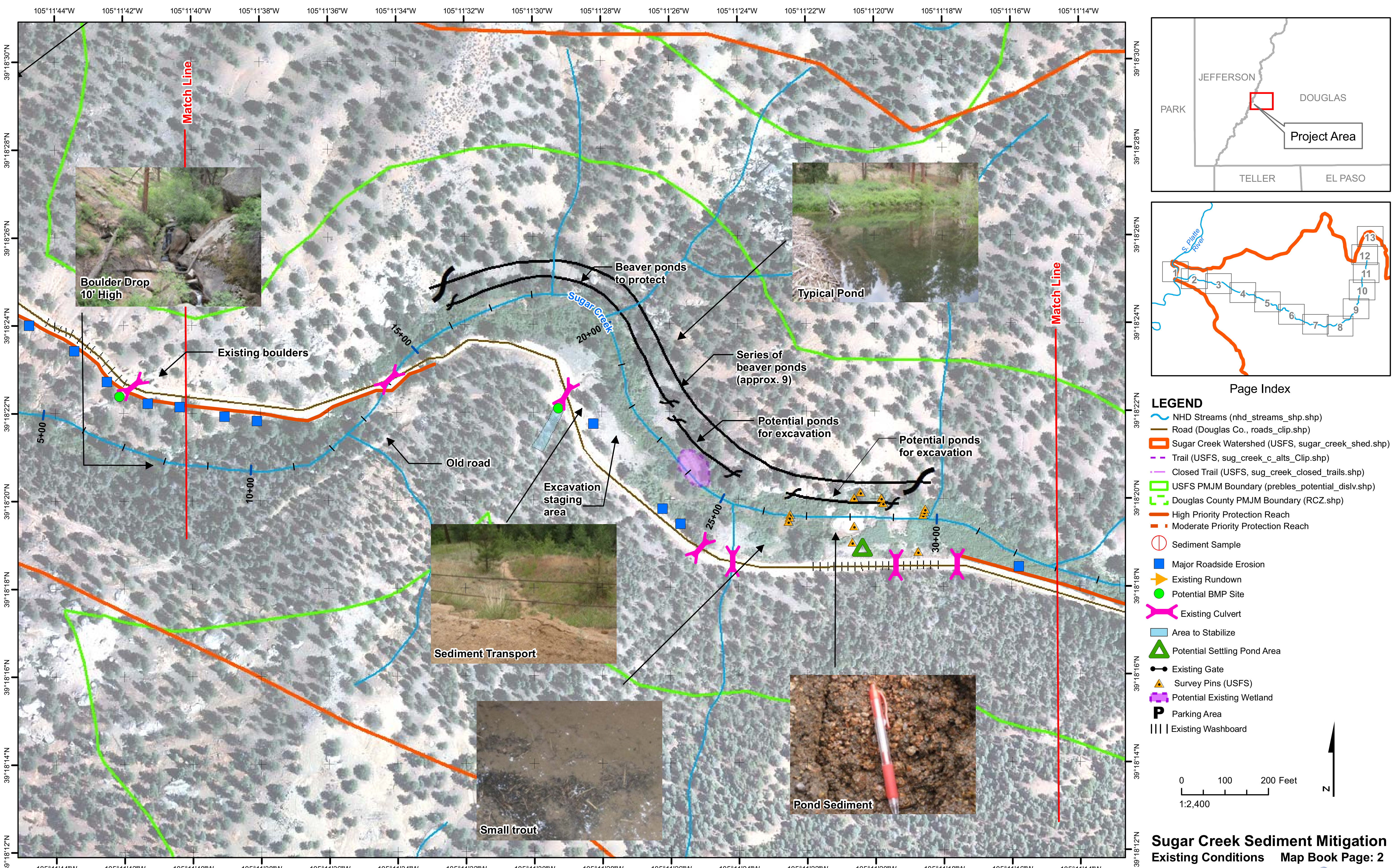
APPENDIX E



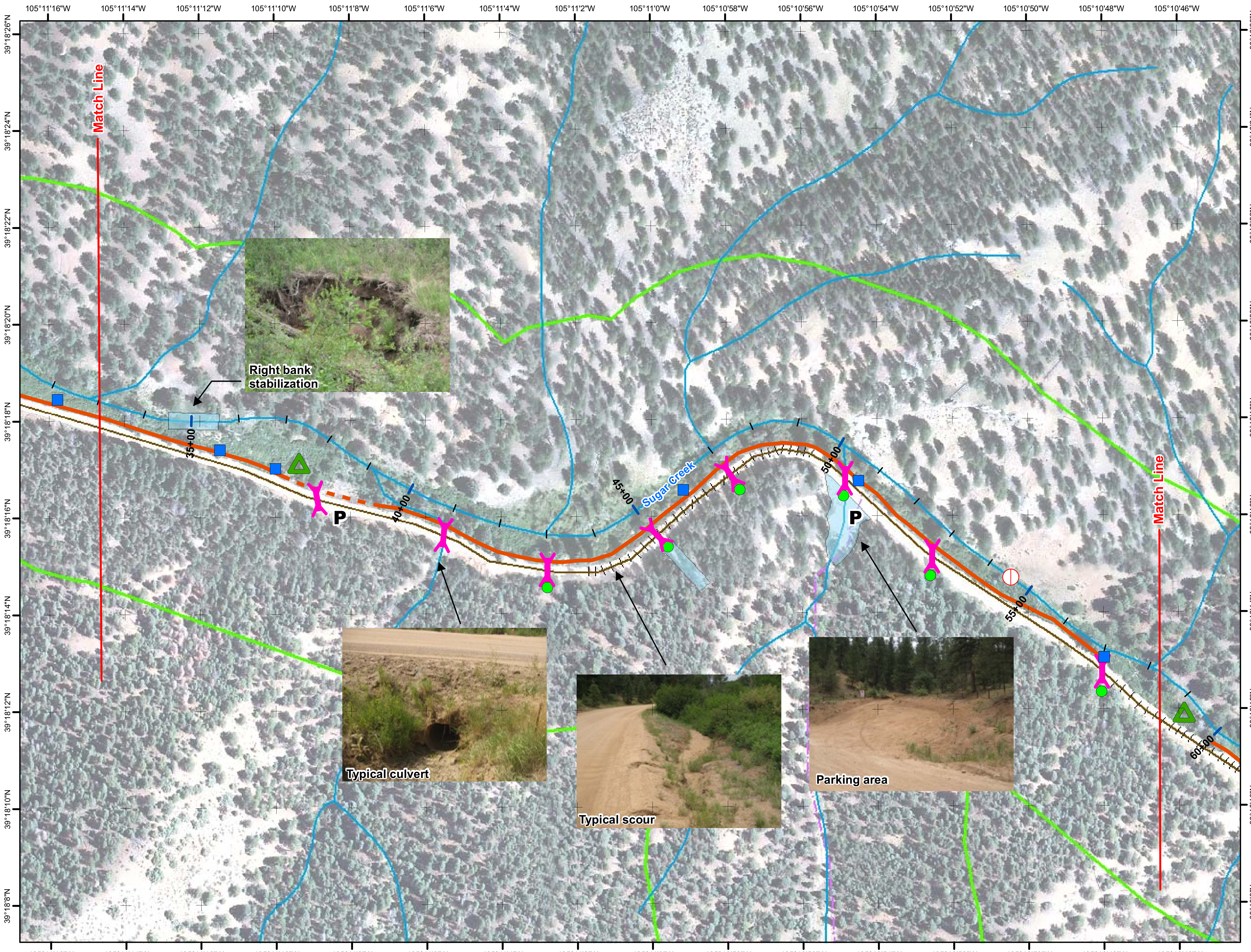
Sugar Creek Sediment Mitigation
Existing Conditions Map Book Page: 1

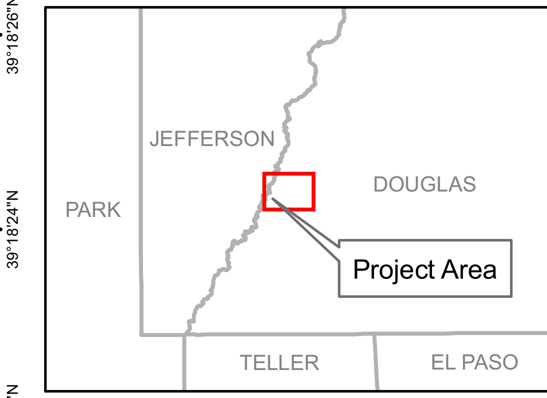
CH2MHILL

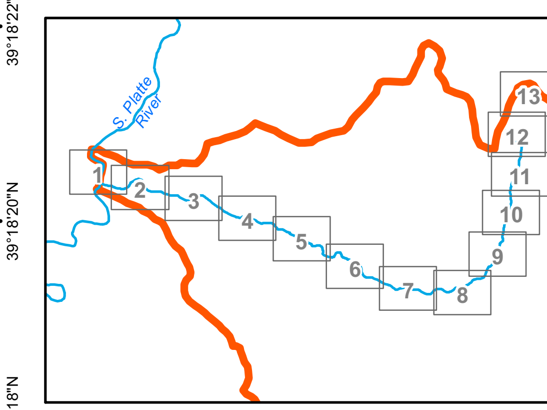
\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42



\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42







Page Index

LEGEND

- NHD Streams (nhd_streams_shp.shp)
- Road (Douglas Co., roads_clip.shp)
- Sugar Creek Watershed (USFS, sugar_creek_shed.shp)
- Trail (USFS, sug_creek_c_alts_Clip.shp)
- Closed Trail (USFS, sug_creek_closed_trails.shp)
- USFS PMJM Boundary (prebles_potential_dislv.shp)
- Douglas County PMJM Boundary (RCZ.shp)
- High Priority Protection Reach
- Moderate Priority Protection Reach
- Sediment Sample
- Major Roadside Erosion
- Existing Rundown
- Potential BMP Site
- Existing Culvert
- Area to Stabilize
- Potential Settling Pond Area
- Existing Gate
- Survey Pins (USFS)
- Potential Existing Wetland
- P Parking Area
- Existing Washboard

0 100 200 Feet

1:2,400

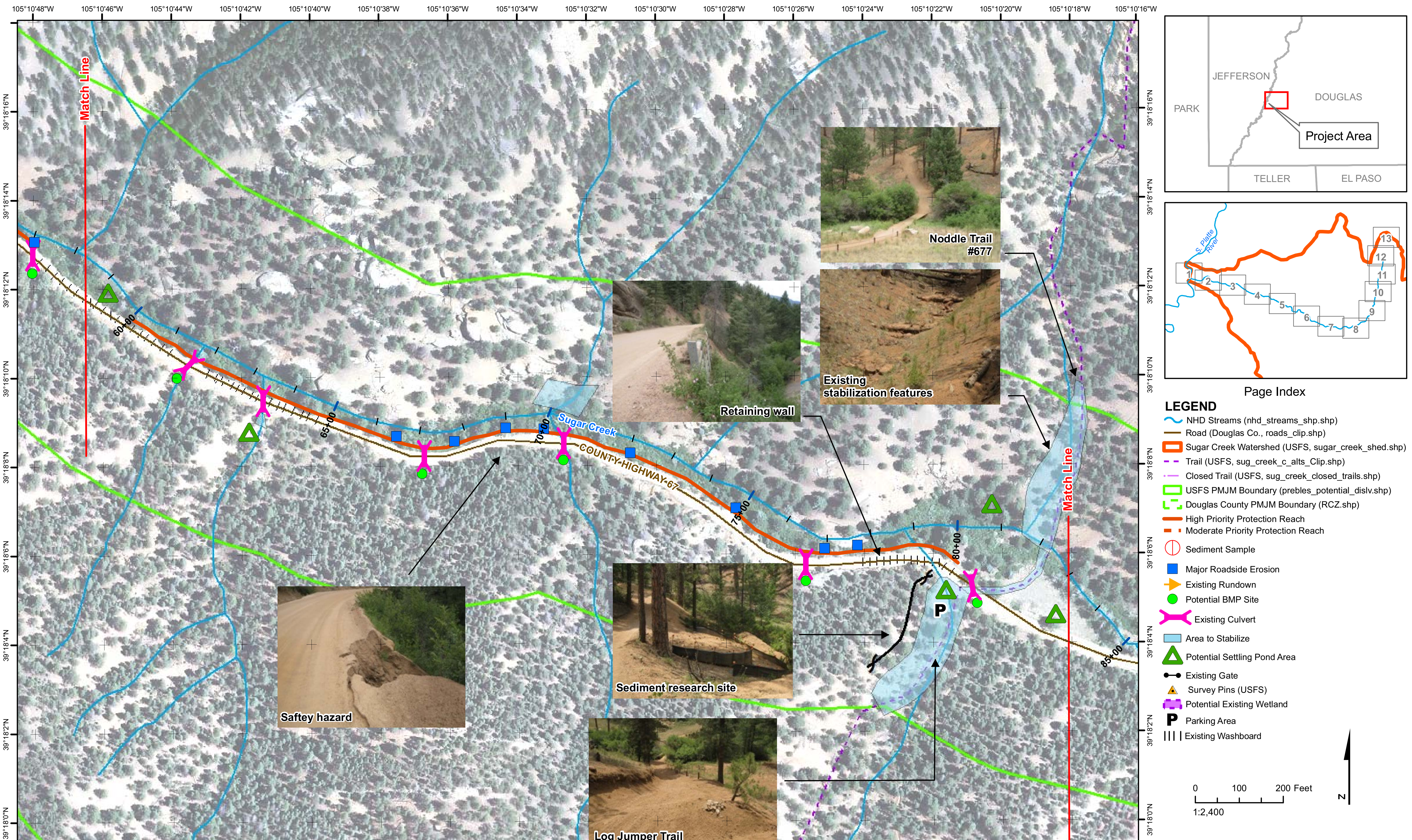
N

Sugar Creek Sediment Mitigation

Existing Conditions Map Book Page: 3

\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42

CH2MHILL

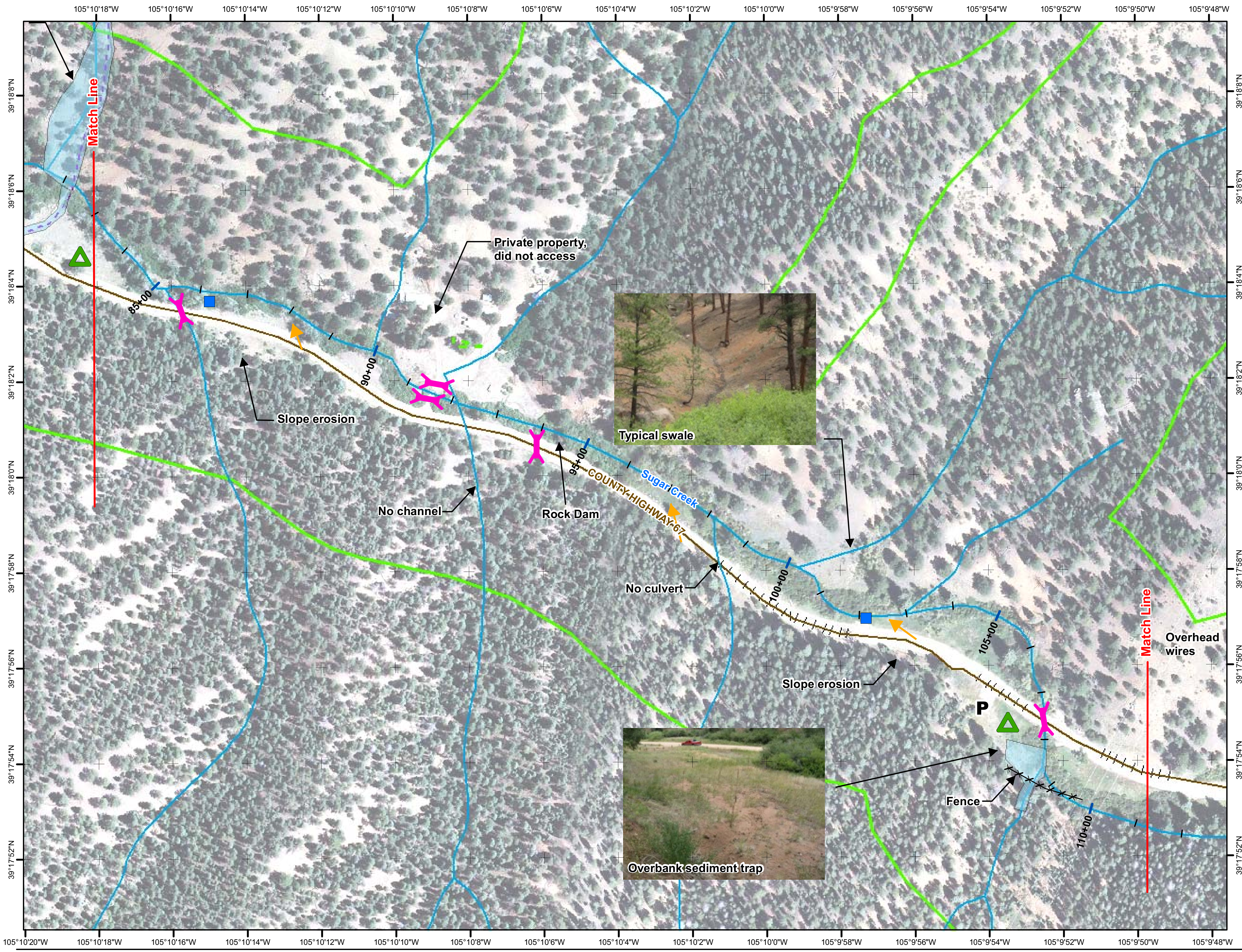


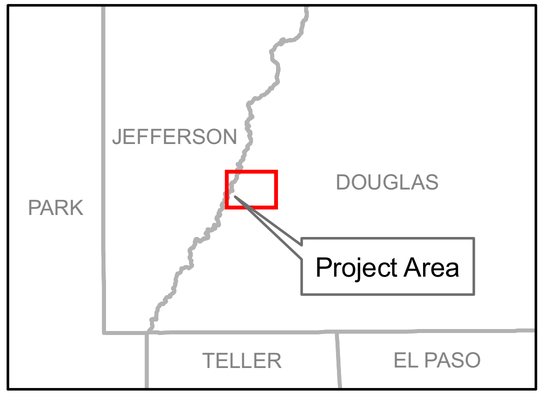
Sugar Creek Sediment Mitigation

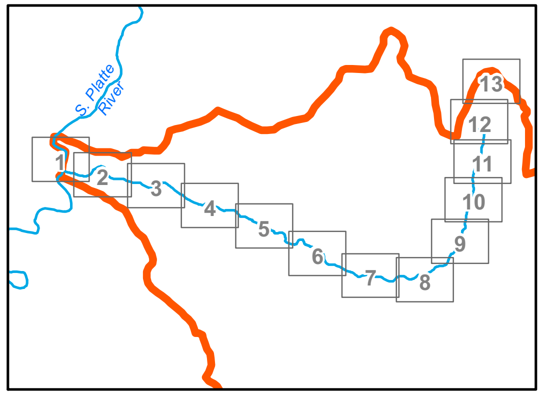
Existing Conditions **Map Book Page: 4**

CH2MHILL

\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42







Page Index

LEGEND

- NHD Streams (nhd_streams_shp.shp)
- Road (Douglas Co., roads_clip.shp)
- Sugar Creek Watershed (USFS, sugar_creek_shed.shp)
- Trail (USFS, sug_creek_c_alts_Clip.shp)
- Closed Trail (USFS, sug_creek_closed_trails.shp)
- USFS PMJM Boundary (prebles_potential_dislv.shp)
- Douglas County PMJM Boundary (RCZ.shp)
- High Priority Protection Reach
- Moderate Priority Protection Reach
- Sediment Sample
- Major Roadside Erosion
- Existing Rundown
- Potential BMP Site
- Existing Culvert
- Area to Stabilize
- Potential Settling Pond Area
- Existing Gate
- Survey Pins (USFS)
- Potential Existing Wetland
- Parking Area
- Existing Washboard

0 100 200 Feet

1:2,400

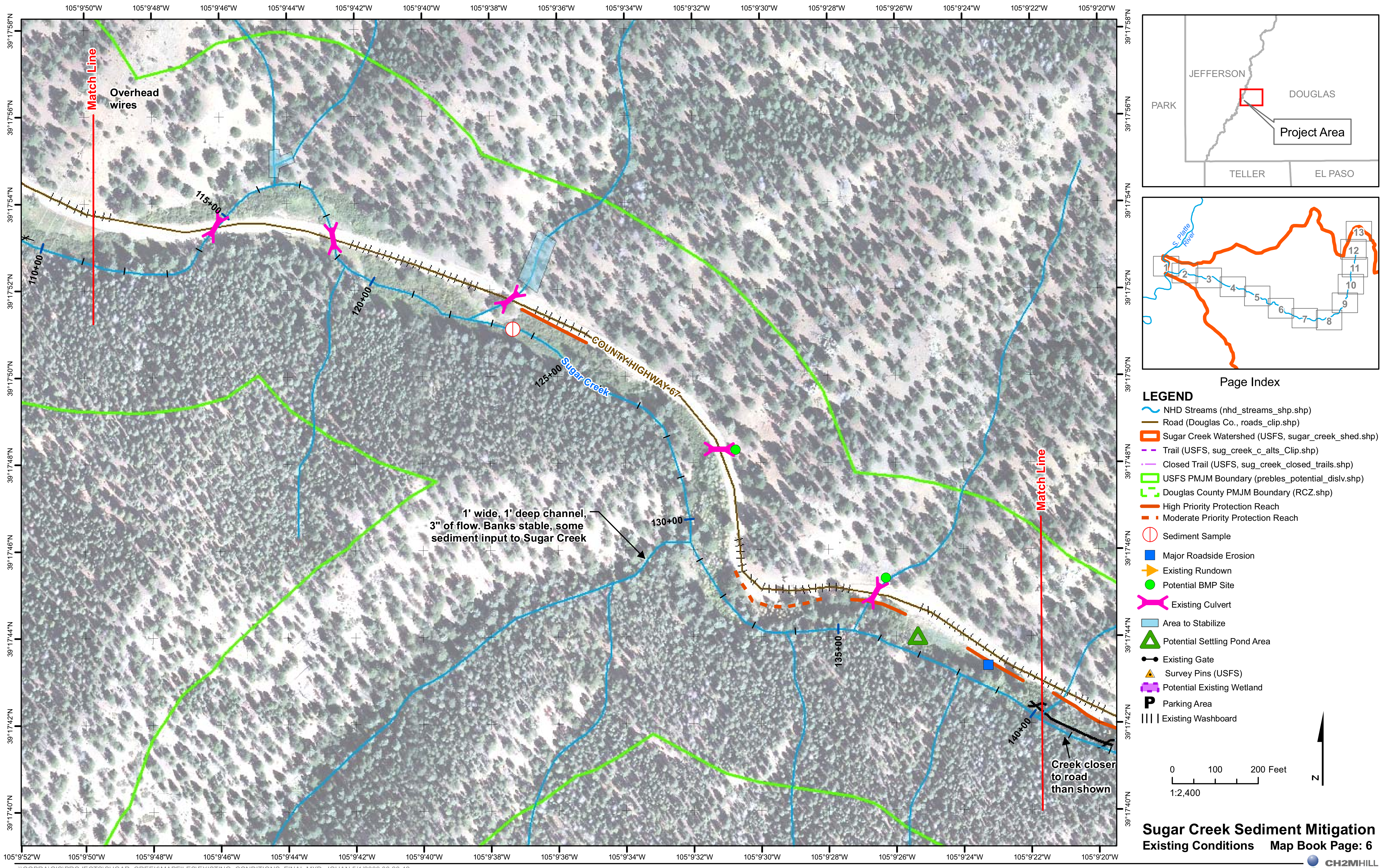
N

Sugar Creek Sediment Mitigation

Existing Conditions Map Book Page: 5

CH2MHILL

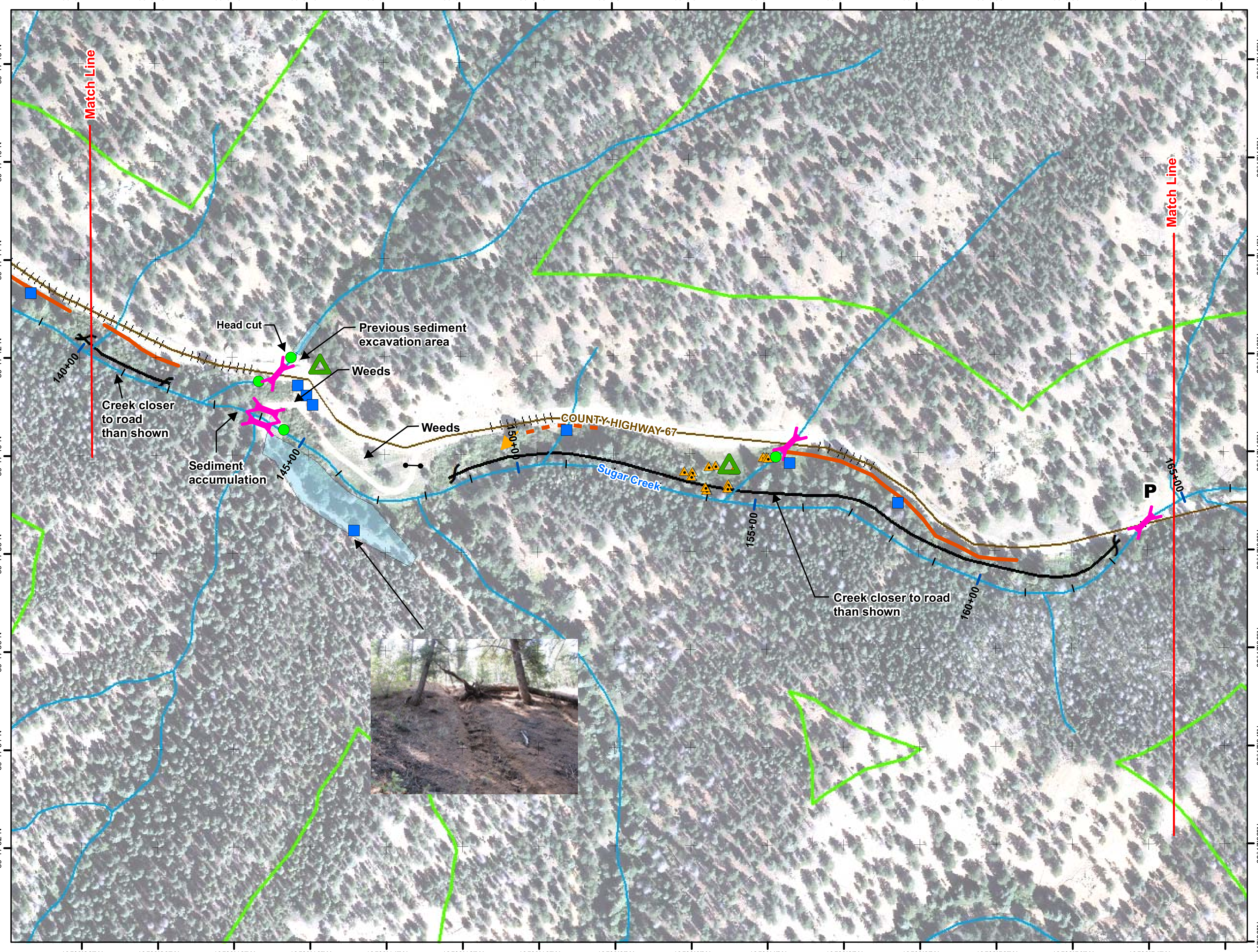
\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42

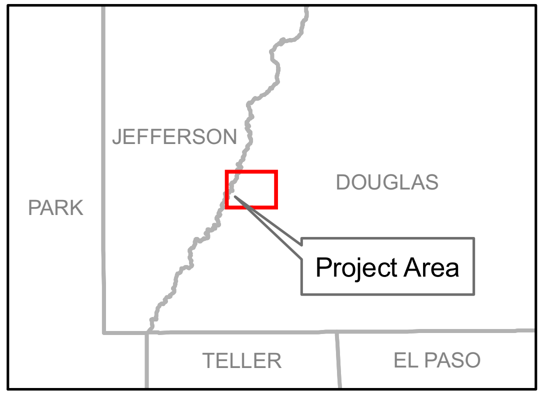


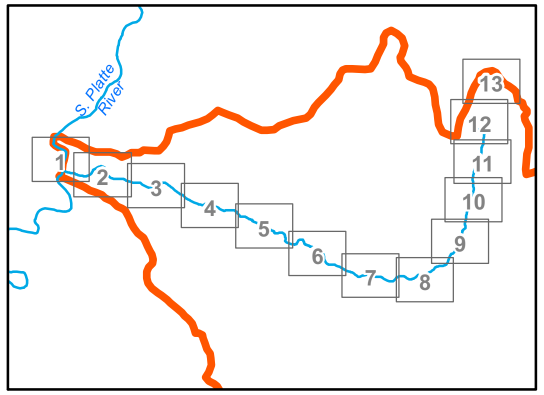
Sugar Creek Sediment Mitigation

Existing Conditions **Map Book Page: 6**

CH2MHILL







Page Index

LEGEND

- NHD Streams (nhd_streams_shp.shp)
- Road (Douglas Co., roads_clip.shp)
- Sugar Creek Watershed (USFS, sugar_creek_shed.shp)
- Trail (USFS, sug_creek_c_alts_Clip.shp)
- Closed Trail (USFS, sug_creek_closed_trails.shp)
- USFS PMJM Boundary (prebles_potential_dislv.shp)
- Douglas County PMJM Boundary (RCZ.shp)
- High Priority Protection Reach
- Moderate Priority Protection Reach
- Sediment Sample
- Major Roadside Erosion
- Existing Rundown
- Potential BMP Site
- Existing Culvert
- Area to Stabilize
- Potential Settling Pond Area
- Existing Gate
- Survey Pins (USFS)
- Potential Existing Wetland
- Parking Area
- Existing Washboard

0 100 200 Feet

1:2,400

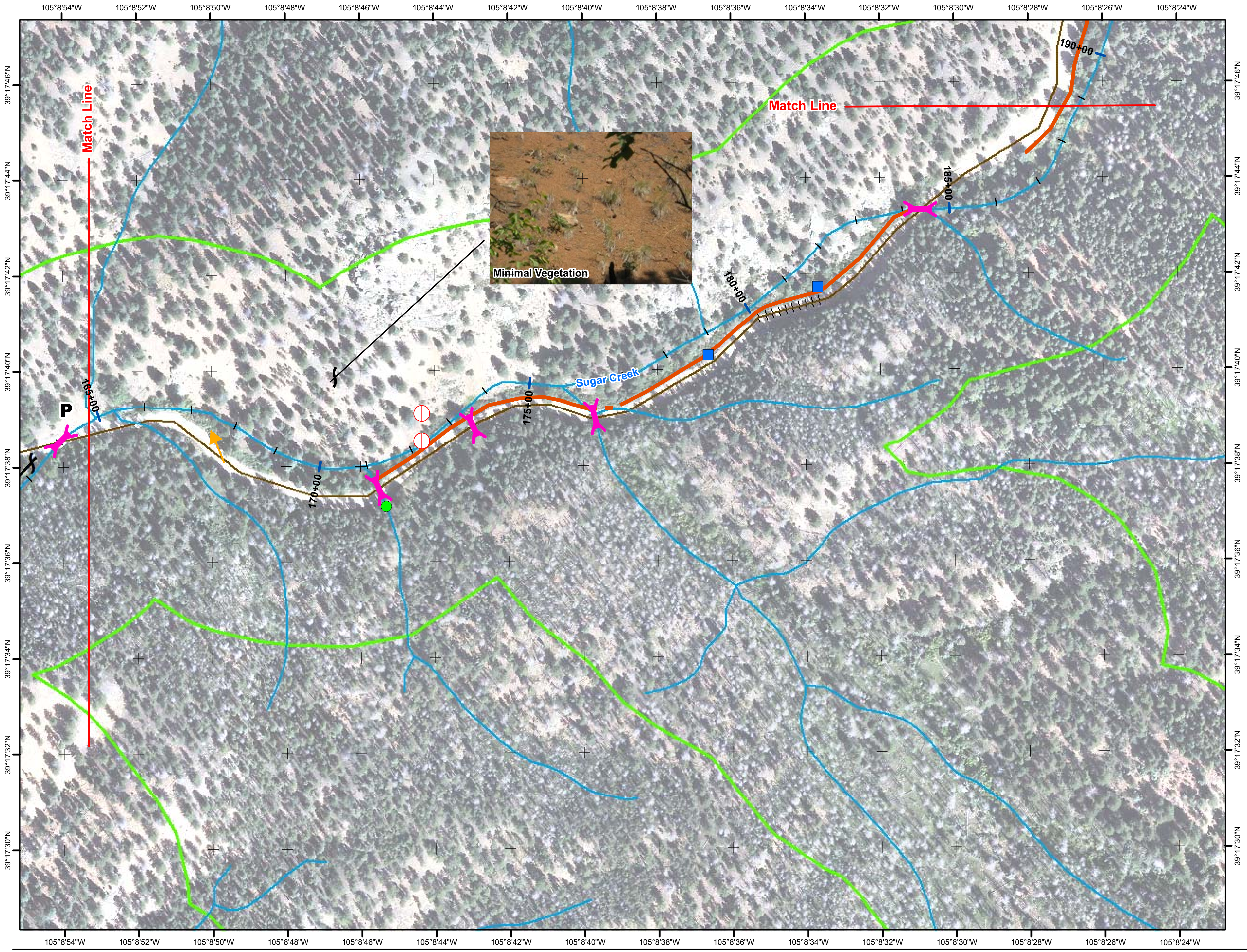
N

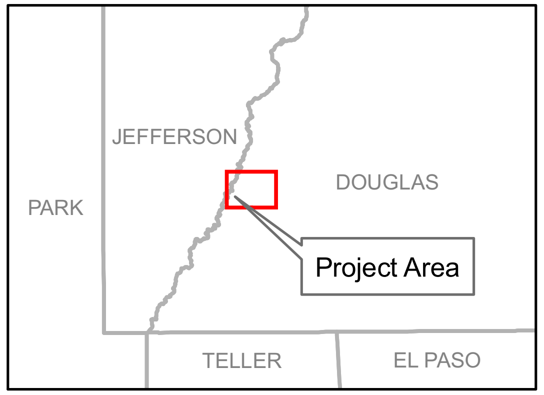
Sugar Creek Sediment Mitigation

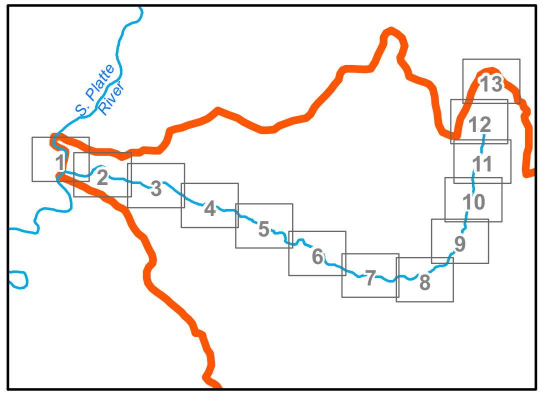
Existing Conditions Map Book Page: 7

CH2MHILL

\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42







Page Index

LEGEND

- NHD Streams (nhd_streams_shp.shp)
- Road (Douglas Co., roads_clip.shp)
- Sugar Creek Watershed (USFS, sugar_creek_shed.shp)
- Trail (USFS, sug_creek_c_alts_Clip.shp)
- Closed Trail (USFS, sug_creek_closed_trails.shp)
- USFS PMJM Boundary (prebles_potential_dislv.shp)
- Douglas County PMJM Boundary (RCZ.shp)
- High Priority Protection Reach
- Moderate Priority Protection Reach
- Sediment Sample
- Major Roadside Erosion
- Existing Rundown
- Potential BMP Site
- Existing Culvert
- Area to Stabilize
- Potential Settling Pond Area
- Existing Gate
- Survey Pins (USFS)
- Potential Existing Wetland
- P Parking Area
- Existing Washboard

0 100 200 Feet

1:2,400

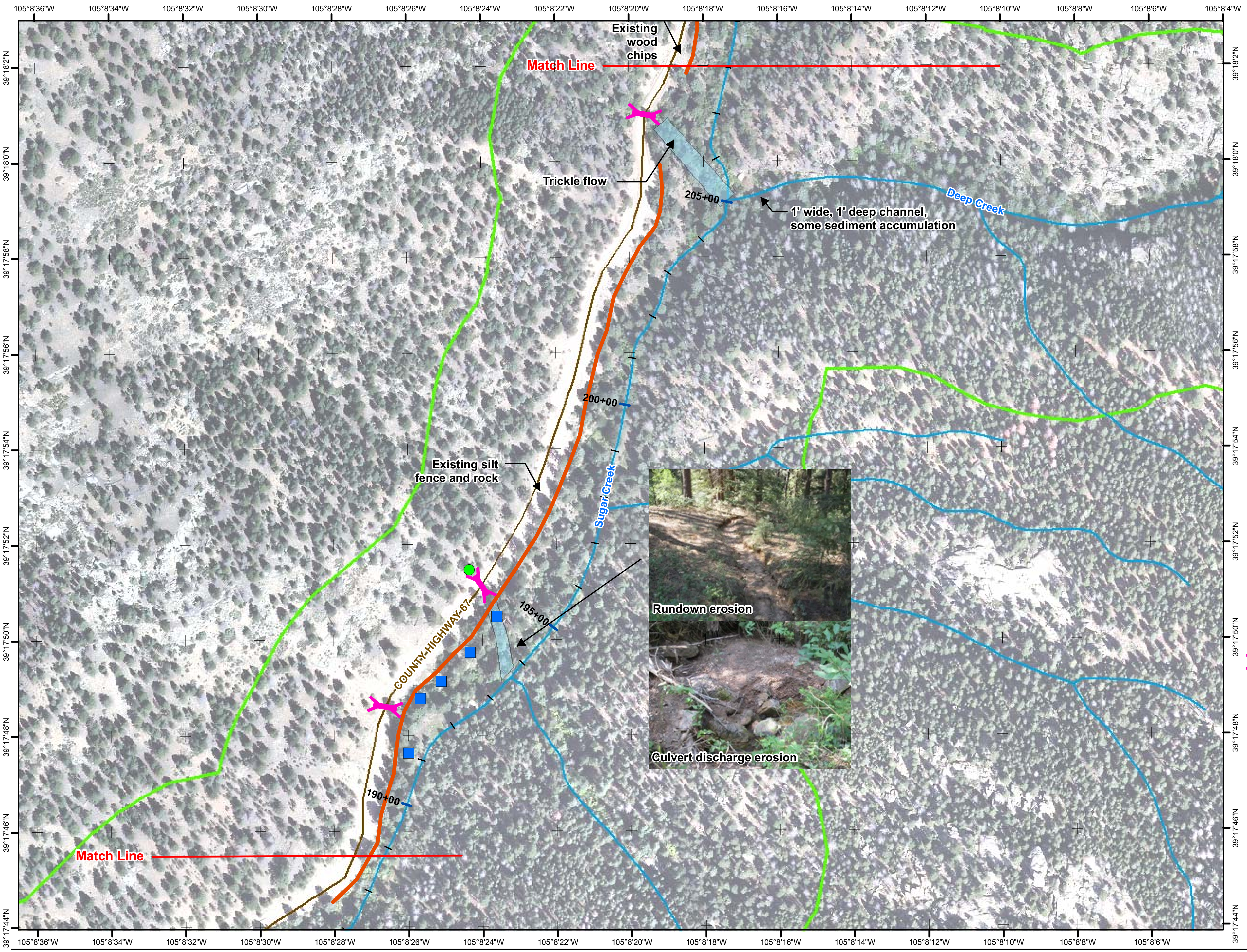
N

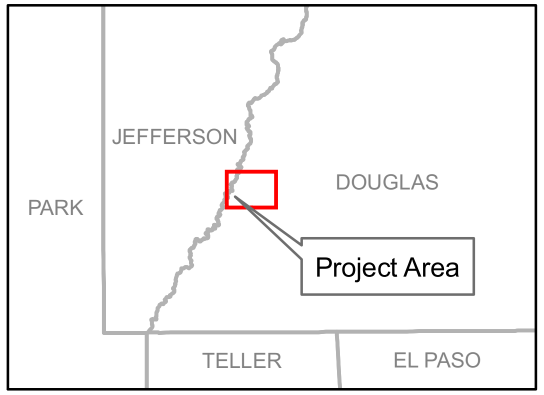
Sugar Creek Sediment Mitigation

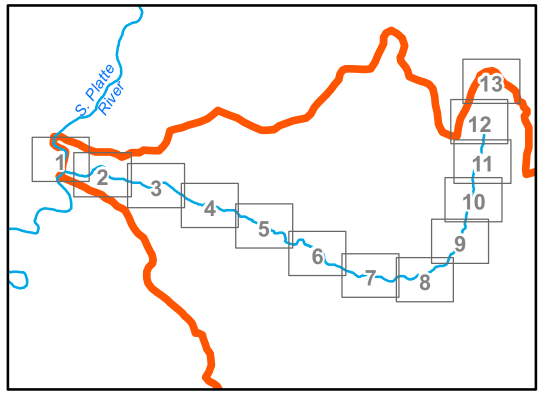
Existing Conditions Map Book Page: 8

CH2MHILL

\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42







Page Index

LEGEND

- NHD Streams (nhd_streams_shp.shp)
- Road (Douglas Co., roads_clip.shp)
- Sugar Creek Watershed (USFS, sugar_creek_shed.shp)
- Trail (USFS, sug_creek_c_alts_Clip.shp)
- Closed Trail (USFS, sug_creek_closed_trails.shp)
- USFS PMJM Boundary (prebles_potential_dislv.shp)
- Douglas County PMJM Boundary (RCZ.shp)
- High Priority Protection Reach
- Moderate Priority Protection Reach
- Sediment Sample
- Major Roadside Erosion
- Existing Rundown
- Potential BMP Site
- Existing Culvert
- Area to Stabilize
- Potential Settling Pond Area
- Existing Gate
- Survey Pins (USFS)
- Potential Existing Wetland
- Parking Area
- Existing Washboard

0 100 200 Feet

1:2,400

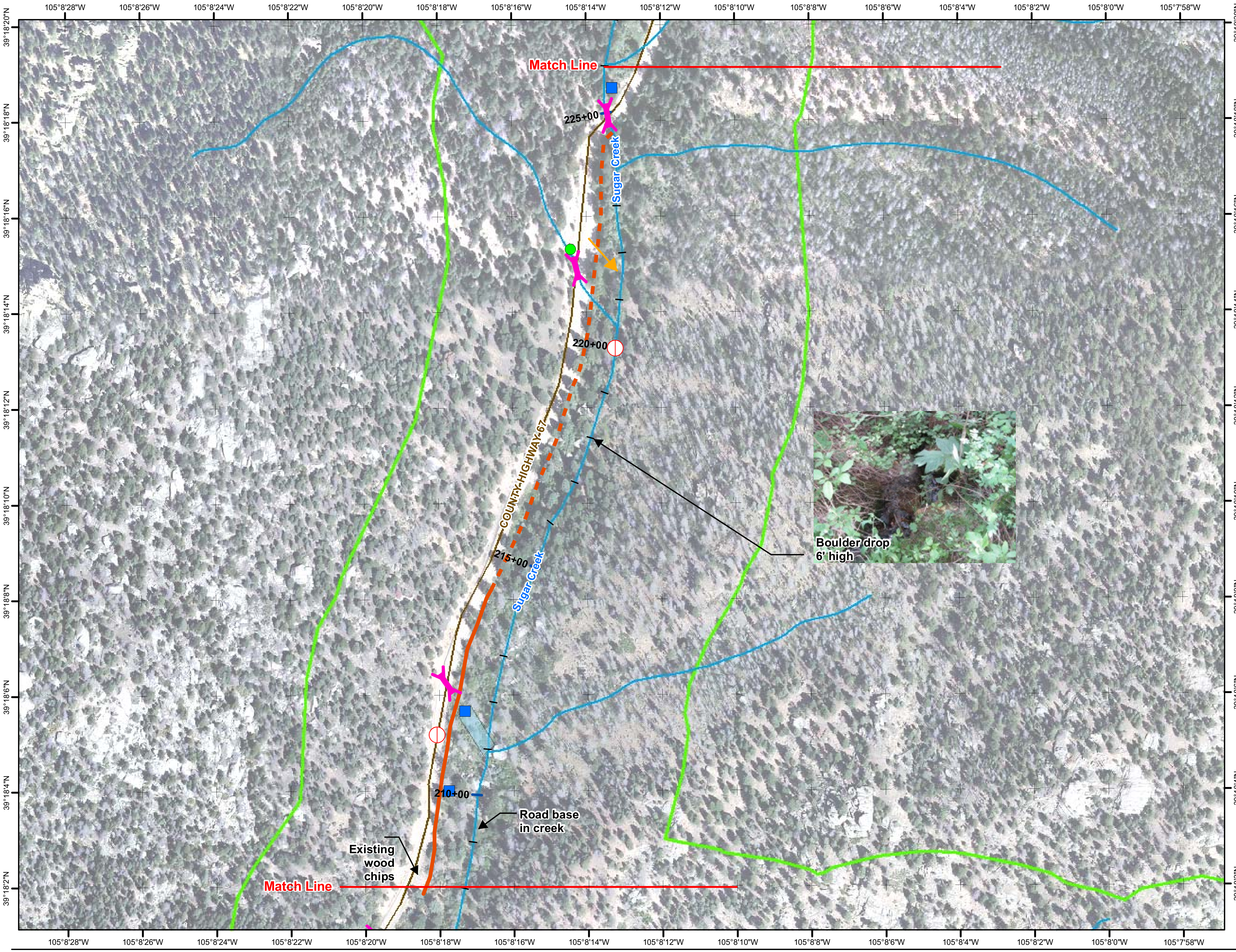
N

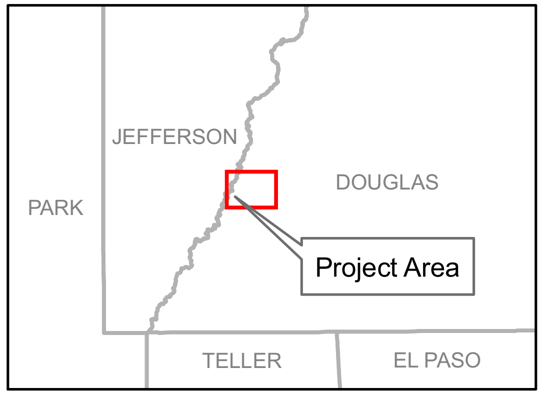
Sugar Creek Sediment Mitigation

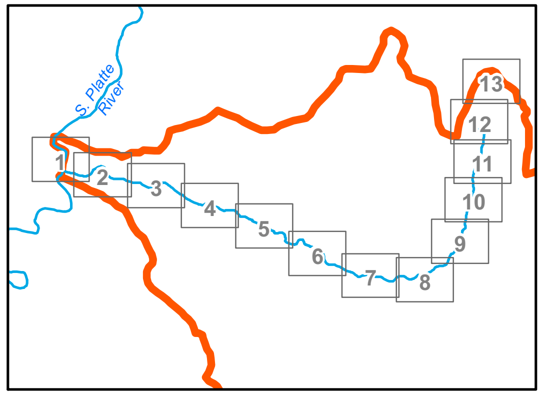
Existing Conditions **Map Book Page: 9**

\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42

CH2MHILL







Page Index

LEGEND

- NHD Streams (nhd_streams_shp.shp)
- Road (Douglas Co., roads_clip.shp)
- Sugar Creek Watershed (USFS, sugar_creek_shed.shp)
- Trail (USFS, sug_creek_c_alts_Clip.shp)
- Closed Trail (USFS, sug_creek_closed_trails.shp)
- USFS PMJM Boundary (prebles_potential_dislv.shp)
- Douglas County PMJM Boundary (RCZ.shp)
- High Priority Protection Reach
- Moderate Priority Protection Reach
- Sediment Sample
- Major Roadside Erosion
- Existing Rundown
- Potential BMP Site
- Existing Culvert
- Area to Stabilize
- Potential Settling Pond Area
- Existing Gate
- Survey Pins (USFS)
- Potential Existing Wetland
- Parking Area
- Existing Washboard

0 100 200 Feet

1:2,400

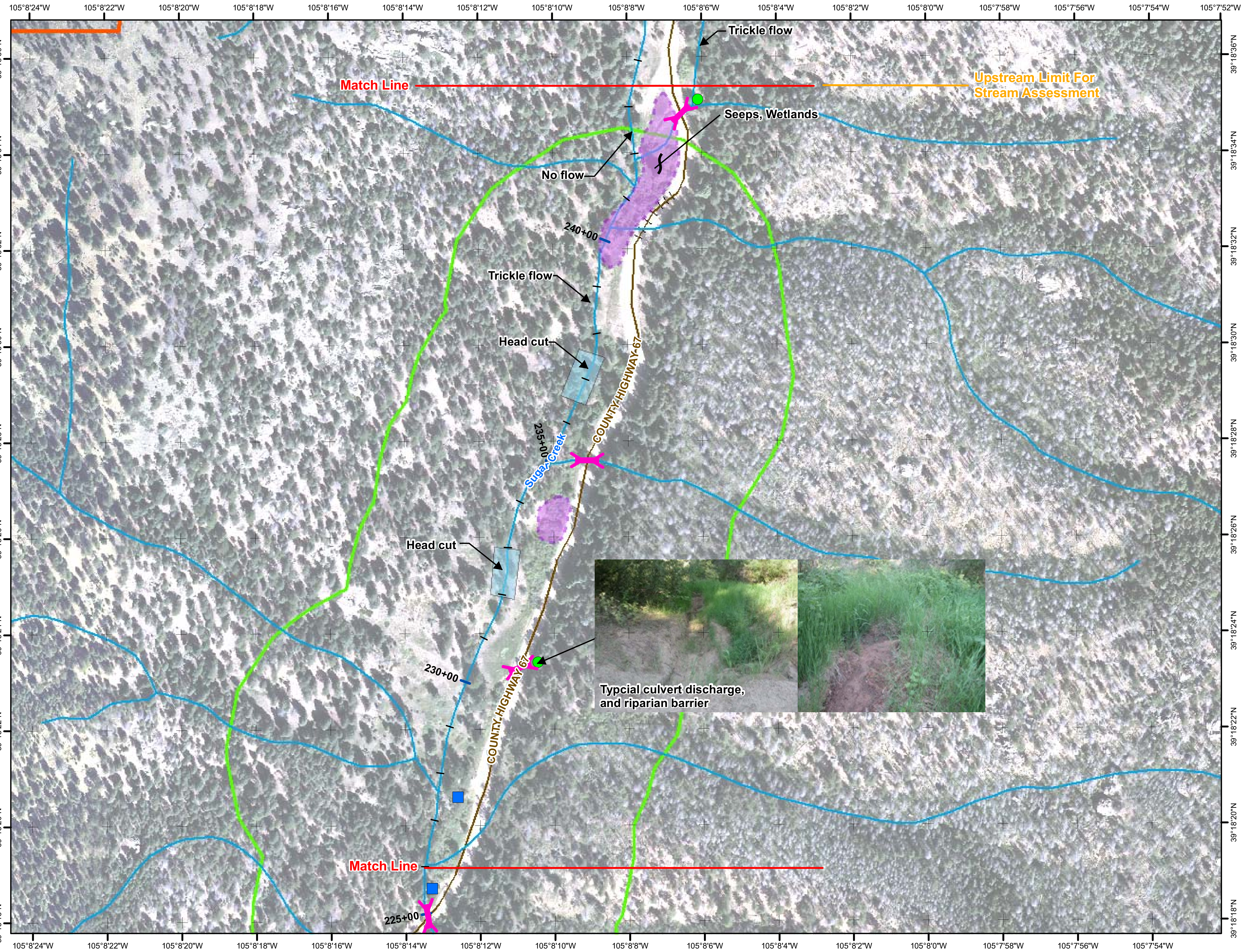
N

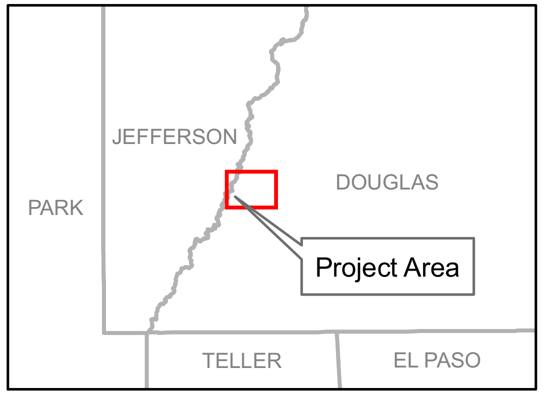
Sugar Creek Sediment Mitigation

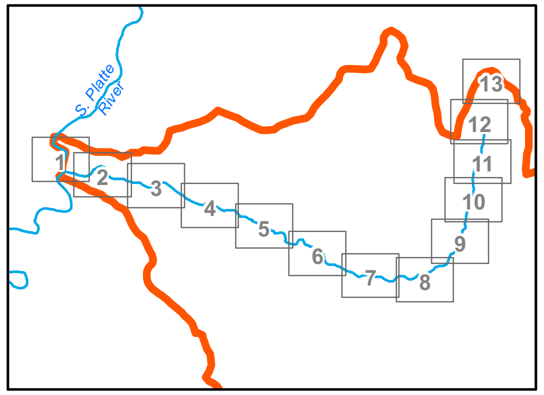
Existing Conditions **Map Book Page: 10**

CH2MHILL

\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42







Page Index

LEGEND

- NHD Streams (nhd_streams_shp.shp)
- Road (Douglas Co., roads_clip.shp)
- Sugar Creek Watershed (USFS, sugar_creek_shed.shp)
- Trail (USFS, sug_creek_c_alts_Clip.shp)
- Closed Trail (USFS, sug_creek_closed_trails.shp)
- USFS PMJM Boundary (prebles_potential_dislv.shp)
- Douglas County PMJM Boundary (RCZ.shp)
- High Priority Protection Reach
- Moderate Priority Protection Reach
- Sediment Sample
- Major Roadside Erosion
- Existing Rundown
- Potential BMP Site
- Existing Culvert
- Area to Stabilize
- Potential Settling Pond Area
- Existing Gate
- Survey Pins (USFS)
- Potential Existing Wetland
- Parking Area
- Existing Washboard

0 100 200 Feet

1:2,400

N

Sugar Creek Sediment Mitigation

Existing Conditions Map Book Page: 11

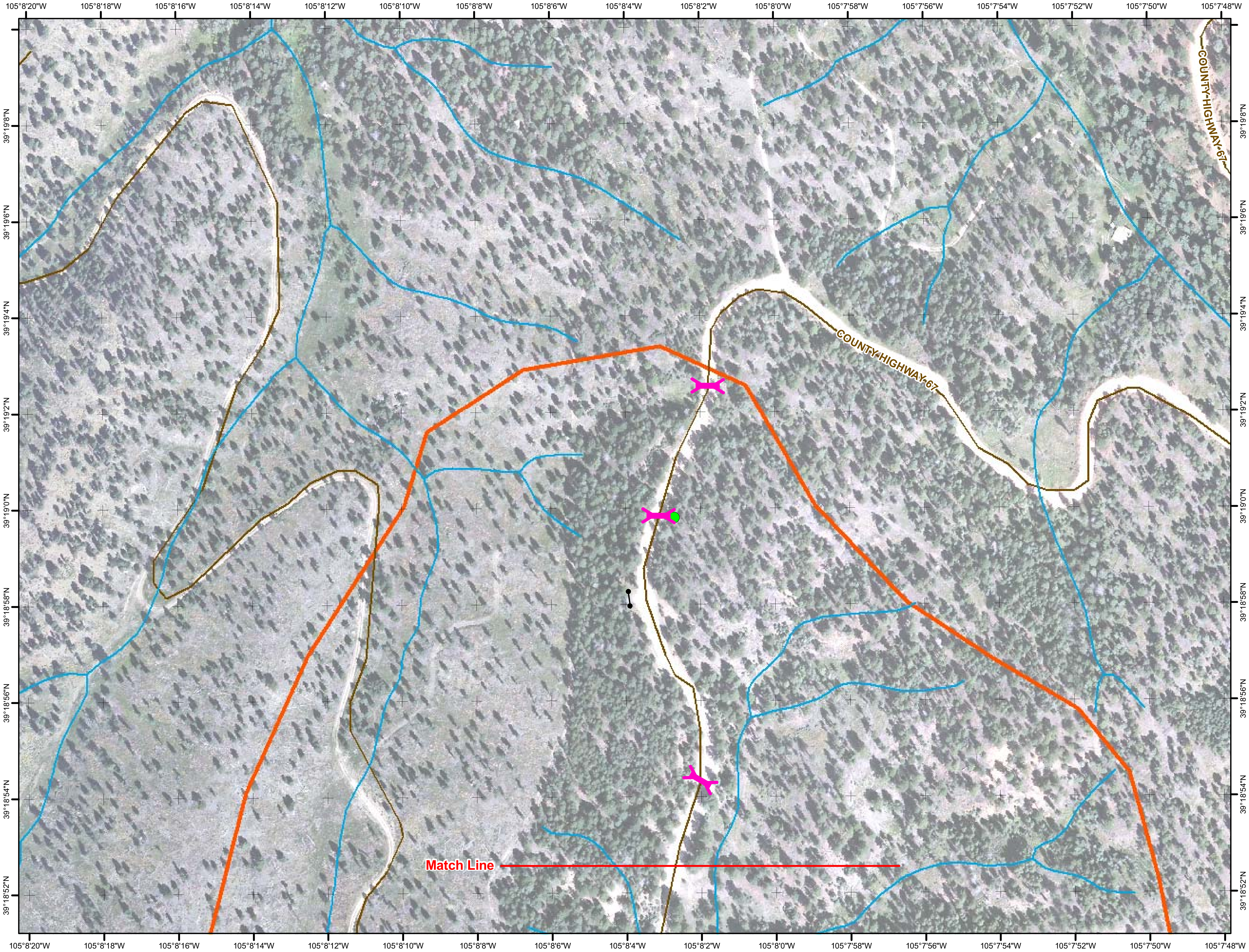
CH2MHILL

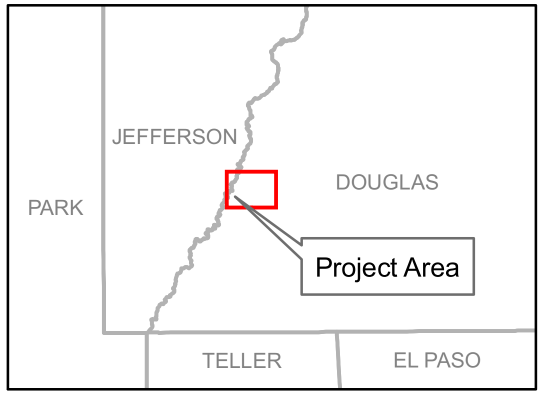
Sugar Creek Sediment Mitigation

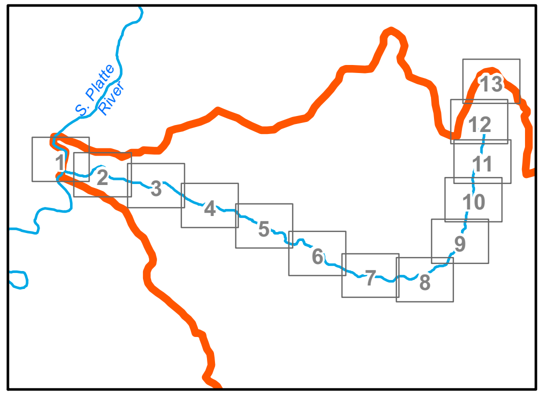
Existing Conditions Map Book Page: 12

\\COBRA\GIS\PROJECTS\SUGAR_CREEK\MAPFILES\EXISTING_CONDITIONS_FINAL.MXD JQUAN 5/1/2009 08:28:42

CH2MHILL







Page Index

LEGEND

- NHD Streams (nhd_streams_shp.shp)
- Road (Douglas Co., roads_clip.shp)
- Sugar Creek Watershed (USFS, sugar_creek_shed.shp)
- Trail (USFS, sug_creek_c_alts_Clip.shp)
- Closed Trail (USFS, sug_creek_closed_trails.shp)
- USFS PMJM Boundary (prebles_potential_dislv.shp)
- Douglas County PMJM Boundary (RCZ.shp)
- High Priority Protection Reach
- Moderate Priority Protection Reach
- Sediment Sample
- Major Roadside Erosion
- Existing Rundown
- Potential BMP Site
- Existing Culvert
- Area to Stabilize
- Potential Settling Pond Area
- Existing Gate
- Survey Pins (USFS)
- Potential Existing Wetland
- Parking Area
- Existing Washboard

0 100 200 Feet
1:2,400

N

Sugar Creek Sediment Mitigation

Existing Conditions **Map Book Page: 13**

CH2MHILL