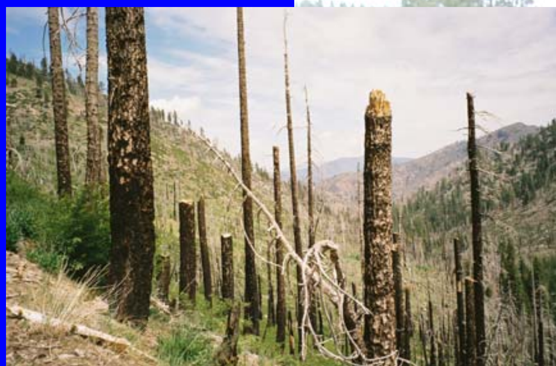
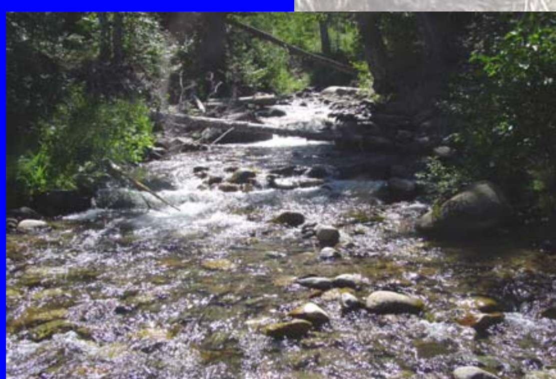
Gray Creek Watershed Assessment and Restoration Plan



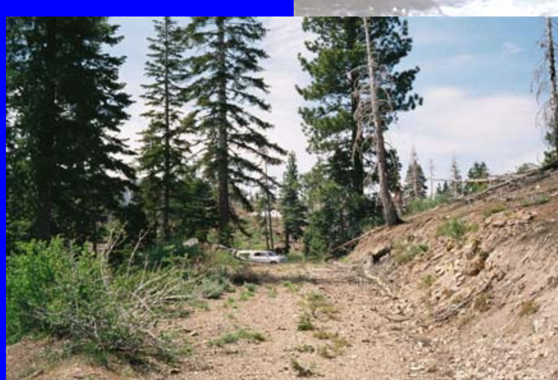
FINAL REPORT

December 29, 2006



This project has received support through a grant from the California State Water Resources Control Board under the Proposition 13 Non-Point Source Pollution Control Grant Program

Prepared for:
Truckee River Watershed Council



Prepared by:
northwest hydraulic consultants

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Executive Summary

The Gray Creek Assessment and Watershed Restoration Plan received support through a grant from the California State Water Resources Control Board under the Proposition 13 Non-point Source Pollution Control Grant Program. The Truckee River Watershed Council (TRWC) managed the preparation of the plan with the overall goals of reducing sediment contributions to the Truckee River and improving riparian and aquatic habitat within the watershed. Both Gray Creek and the Truckee River in California are listed as impaired by sedimentation under Section 303(d) of the Clean Water Act.

The objectives of the Plan were to describe the characteristics of Gray Creek, identify sediment sources and assess their potential for restoration, assess habitat in stream reaches and identify restoration opportunities and constraints and provide the TRWC with a strategy for restoration that prioritizes projects and allows effective expenditure of funds.

The Gray Creek watershed is in the northern Sierra Nevada Mountains and joins the Truckee River near Hirschdale, just east of Truckee, CA. The watershed is very steep and almost entirely covered by highly erodible soils derived from volcanic rocks and moraine. Erosion has been exacerbated by the 2001 Martis Fire, which burnt the majority of the watershed. Sediment gaging at the mouth of Gray Creek indicates greatly increased sediment yields since the fire. It is assumed these yields will reduce over the long-term, as vegetation recovers.

The sediment source inventory, combined with a review of previous studies, indicates that landslides, both as individual features and in erosion zones, are the dominant erosion mechanism, followed by roads and trails, gully erosion and bank erosion. A few of the landslides result from disturbance, such as drainage diversion on roads, but most occur naturally although at an accelerated rate because of the 2001 Martis Fire. Anthropogenic impacts in the watershed include logging, grazing, and road construction. Based on available historical information, logging and grazing are now less significant than roads, which are the most important anthropogenic source of sediment and are concentrated in the West Fork.

The sediment source inventory showed that the number of erosion sites and area of erosion zones is greatest in the Middle Fork, less in the North Fork and Main Stem, and least in the West Fork, consistent with previous observations by the Forest Service. The Middle Fork is nearly unaffected by human activities and much of the sediment seems to come from large erosion zones developed along the rim of the subwatershed.

Field reconnaissance, literature review and inventory also indicated that many stream channels are not very stable. The Middle Fork channel seems particularly unstable and field reconnaissance indicates that the main stem of Gray Creek is also very disturbed. Given the sediment supply to these two streams from their tributaries and slopes, instability is likely to continue and hinder any efforts to restore aquatic or riparian habitat. The West Fork, which has the least slope erosion and a relatively broad valley bottom to intercept sediment, provides the best opportunity for restoration along the stream corridor.

The habitat assessment focused on the aquatic and riparian habitats along the stream corridor and adjacent uplands along lower Gray Creek, the West Fork, and the lower part of the North Fork and concluded that nearly all existing constraints for common and special-status species result from natural environmental patterns and disturbances rather than anthropogenic sources.

The assessment noted that riparian zones are narrow, with discontinuous vegetation cover, are subject to frequent disturbance, and are bordered by steep, rocky terrain. Overall habitat values for wildlife are lower than in nearby watersheds because of the narrow and patchy habitat, fast-moving water and lack of saturated soils on the floodplain. Despite the lower values, Gray Creek does provide valuable habitat for some important species, as described in the report.

The field reconnaissance identified extensive areas where most or all trees were killed by the 2001 Martis Fire; these areas have little or no conifer regeneration and are now shrub-dominated. Several species of nonnative invasive plants were observed during the field assessment. Observed species were cheatgrass, musk thistle, bull thistle, woolly mullein, and Russian thistle.

Aquatic habitat consisted mostly of step-pools formed by boulders, bedrock and logjams that may act as fish passage barriers at some flows. A large number of potential barriers were identified in all the subwatersheds, as described in the report. Most reaches provided low-value breeding habitat for amphibian communities, due to fast flows and lack of backwater.

The feasibility and benefits of various erosion control and habitat restoration opportunities were examined based on the assessments. Roads were an important source of anthropogenic sediment, particularly to the West Fork. The inventory identified 22 significant erosion sites on the road network and provided priorities and rough cost to address these sites. We recommend development of a road management plan that will review access requirements, inventory the road system and identify environmental protection and mitigation actions as an important step in managing road erosion and developing an overall plan to treat the road network.

Rehabilitation and erosion control options for the natural erosion sites in Gray Creek are very limited, primarily because they are on steep slopes and lack road access, there are a very large number of erosion sites and erosion areas to treat, and new sections of the slope may contribute sediment during any particular flood. Only five of the natural landslides are close enough to roads for a potential for bioengineering or other treatments of the landslide tracks. In general, the success of bioengineering treatments in managing sediment and restoring vegetation is not well understood and work at these sites could be treated as an experiment to test techniques that might be suitable in this part of the northern Sierra Nevada Mountains.

Bank erosion is also an important source of erosion. Field inspections, previous reports, and air photo analysis indicate that the Middle Fork and lower Gray Creek are particularly unstable. Treatment methods are constrained by the steep slopes but one potential approach is to install structures to trap sediment and stabilize the floodplain, aiding in riparian vegetation re-establishment and reducing sediment transport. This was seen as a low priority for most areas, because the steep channel would require large anchors to stabilize the structures, requiring heavy equipment and road construction. The most feasible site for stream erosion control is the lowest reach of Gray Creek, Reach MF1.

The restoration strategy recommended the following goals for Gray Creek watershed: 1) develop erosion control projects that eliminate or reduce human-caused erosion, particularly where this improves riparian and aquatic habitat value; 2) develop erosion control projects on lands owned by the Truckee-Donner Land Trust (TDLT); and, 3) improve riparian and aquatic habitat where sediment contributions are least (or can be reduced) and channel and floodplains are most stable. The strategy also recommended the West Fork as the highest priority for restoration work, given the network of roads, reasonable access, a low concentration of erosion sites, and potential to achieve habitat benefits.

As initial actions under the strategy, we recommend developing a detailed assessment and erosion control program for the roads in Gray Creek, with the West Fork as the highest priority. The most feasible habitat restoration options for initial action are control of invasive plants, focusing on bull thistle, and of conifer saplings encroaching into black cottonwood and aspen stands along the West Fork. These projects are suitable for volunteer labor and may be appropriate for Truckee River Day projects where access is available.

To the extent possible, all data and results for this study were prepared in a Geographic Information System (GIS). The database developed for this study can be obtained from Beth Christman at:

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Table of Contents

List of Figures

List of Tables

List of Appendices

1. INTRODUCTION

1.1 Study Background

Gray Creek is located in the northern Sierra Nevada Mountains just east of Truckee, California. Gray Creek is one of the larger tributaries of the upper Truckee River and it flows west through high, alpine terrain before joining the Truckee River near Hirschdale. The watershed of Gray Creek extends through California and into the Mt. Rose Wilderness in Nevada. Both Gray Creek and the Truckee River in California are listed as impaired by sedimentation under Section 303(d) of the Clean Water Act.

The Truckee River Watershed Council (TRWC) is committed to watershed restoration in the Truckee watershed and their overall goals for Gray Creek are to reduce sediment contributions to the Truckee River and improve riparian and aquatic habitat within the watershed. This study provides an important first step towards the Council's goals, by developing an understanding of the geomorphology and aquatic habitat in the watershed, identifying sediment sources, and developing a restoration strategy for the watershed. The strategy allows the TWRC to move from opportunistic sediment control and restoration projects to an overall approach that identifies and prioritizes projects to meet their goals, allowing the effective expenditure of restoration funds in the watershed.

1.2 Study Objectives

The particular goals of this study are to:

- Describe the characteristics of the Gray Creek watershed, particularly as they affect erosion, sediment production and habitat
- Identify and assess sediment sources from air photos and field reconnaissance, evaluate their significance and evaluate the potential for restoration
- Delineate stream reaches and assess habitat in the Gray Creek watershed, evaluating existing conditions and identifying habitat restoration opportunities and constraints. The assessment focuses on aquatic, riparian, and wetland habitat functions.
- Prepare a list or matrix of feasible and beneficial erosion control and habitat enhancement projects, including suitable projects for Truckee River Day. The erosion control and habitat objectives intersect in the stream corridor and restoration there has the potential to benefit both objectives.

As this is a first step towards restoration in Gray Creek watershed, one of the study objectives also will be to identify gaps in existing information or in our understanding of Gray Creek that affect restoration plans, and suggest studies or other actions when appropriate.

1.3 Study Approach

A number of studies have been completed, or are underway, that examine different aspects of sediment production and aquatic habitat in Gray Creek. We have met our study objectives by reviewing and consolidating these previous studies and then filling gaps and acquiring new information through both air photo analysis and field reconnaissance.

The sediment source assessment depended mostly on air photo analysis – supplemented by limited ground truthing – because of the large size of the watershed, its steep, rugged terrain and the lack of road access (Section 3). The habitat assessments also incorporated air photo analysis, as described in Section 4. Consequently, it was important to have up-to-date, good quality air photos. A review of the existing air photo coverage of the Gray Creek watershed at the start of the project showed that the most recent photos pre-dated the 2001 Martis Fire. We subcontracted with Tri State Surveying & Photogrammetry to fly new air photos (July 2006) and our analyses are mostly based on these photos.

Field reconnaissance was limited to lower Gray Creek, the West Fork, and the lower North Fork subwatersheds. The remote Middle Fork subwatershed was not visited. Photographs from the field reconnaissance are included under the "Photos" tab following the Figures and are numbered by report section and referred to in the text where appropriate.

To the extent practical, the study analyses and results were prepared in a GIS environment. We see this as valuable for presenting the results of this study, incorporating previous studies, and for future monitoring and planning of restoration projects in Gray Creek.

1.4 Acknowledgements

We would like to thank Beth Christman of the Truckee River Watershed Council for providing project direction, arranging access to the watershed, and introducing us to individuals who were familiar with the watershed. We thank Jeff Cutler for taking time to visit the watershed with us and share his knowledge. We would also like to thank Larry Andresen for sharing his knowledge of the Gray Creek, particularly of the reach near the mouth.

Deborah Urich, fisheries biologist, Chris Mease and Dan Schulz of the U.S. Forest Service, Tahoe National Forest, kindly described their program of aquatic habitat measurements in Gray Creek and provided the results of their summer sampling. Section 4 of this report partly relies on that information.

The report was prepared by Ken Rood and René Leclerc of **nhc**, with contributions from Steve Henderson and John Hunter of EDAW. Toby Haines of Hydro Science reviewed earlier drafts of this report.

1.5 Access to GIS Data

Requests for GIS data from this study should be directed to Beth Christman at the TRWC.

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2. GRAY CREEK WATERSHED

The following sections describe the topography, geology, soils, hydrology, and disturbance history of the Gray Creek watershed. These watershed characteristics provide an important background for understanding geomorphic and sediment production processes in the watershed.

The analysis of watershed characteristics is based on existing datasets and, to the extent practical, all data have been prepared in a GIS environment (Appendix 1). Standards for geologic, soil and fire history maps are different in Nevada and California; as a result, discontinuities occur along the border between the two states.

2.1 Ownership and Land Cover

The Gray Creek basin covers 17.8 square miles of mountainous terrain in the Sierra Nevada Mountains east of Truckee, California (Figures 2.1 and 2.2). Most of the watershed lies in Nevada and is part of the Humboldt-Toiyabe National Forest. The Truckee-Donner Land Trust (TDLT), California Department of Fish and Game, and private individuals own several land parcels on the California side of the watershed (USDA Forest Service, 2005). Figure 2.1 shows the parcels that were recently purchased by the TDLT. The TDLT lands are a focus for restoration activities in the Gray Creek watershed.

Land cover consists almost entirely of evergreen forest (National Land Cover Dataset; Figure 2.3). Forests are generally denser on north facing slopes. The lower two-thirds of the basin were burned by the 2001 Martis fire and are in varying stages of recovery.

2.2 Physiography

The Gray Creek basin is rugged and mountain slopes are very steep. The maximum elevation is 10,490 ft at Mt. Houghton and the minimum elevation is 5,400 ft at the confluence of Gray Creek with the Truckee River. For this study, the basin was divided into four subwatersheds, the Main Stem, West Fork, Middle Fork, and the North Fork (Figure 2.4). General characteristics of each subwatershed are summarized in Table 2.1.

Table 2.1 Gray Creek Subwatershed Characteristics

Subwatershed	*Area (mi^2)*	*Elevation*		*Relief (ft)*	*Average Basin Slope (%)*
		max (ft)	*min (ft)*		
North Fork	2.4	9,919	6,330	3,589	53.8
Middle Fork	4.9	10,490	6,330	4,160	57.9
West Fork	8.0	10,338	6,250	4,088	50.0
Main Stem	2.5	7,610	5,400	2,210	59.2
Total Watershed	17.8	10,490	5,400	5,090	54.0

Average basin slope is very steep at 54% with the Middle and North forks exhibiting steeper topography than the West Fork (Figure 2.5). The West Fork is less steep than the Middle and North Forks due to the broad bottom of its main valley and to several small, gradually sloping valleys in its headwaters (see Figure 2.5). The average stream gradient is 14.5%, but ranges from

6.4% on the Main Stem to 18.7% on the Middle Fork (Myers et al., 1996). Longitudinal stream profiles are shown in Figure 2.6.

2.3 Geology

The geology of the Gray Creek watershed is dominated by andesitic volcaniclastic rocks (Figure 2.7). These rocks consist of highly erodible Tertiary-age volcanic flows characterized by plagioclase feldspar and poorly stratified tuff-breccia, the latter generally in steeper portions of the basin. Volcanic deposits are composed of lava flows, lahars (volcanic mudflows), and undifferentiated volcaniclastic sediments such as pyroclastic flows, ash flows, and other volcanic ejecta. Volcanic activity in the region occurred in the middle to late Miocene, approximately 5 to 16 million years ago (Saucedo, 2005). Older, deeply weathered Cretaceous granite underlies the volcanic material and has been exposed by erosion in a few places in the West Fork headwaters. The most recent geologic material in the basin consists of terminal and lateral moraines deposited near the end of the Tioga Glaciation (30,000 B.P. to 10,000 B.P.; B.P. = Before Present). Moraines are located mainly in less steeply sloping terrain along stream channels in the upper Middle and West Fork subwatersheds.

Gray Creek soils are largely composed of cobbly to sandy loams weathered from underlying volcanic rocks (Figure 2.8). The National Resource Conservation Service (NRCS) classifies these soils as moderately to excessively well drained and experiencing moderate to rapid runoff with a high erosion hazard. Soils formed on tuff-breccia and moraine are reported to be the most erodible in the basin (USDA Forest Service, 2005). Field observations have identified the moraine in the Middle Fork as a very significant source of fine sediment in the basin (USDA Forest Service, 1995; Myers et al., 1996).

The Gray Creek watershed lies near the western margin of the most seismically active area in Nevada, which occurs along a roughly north-south line from Reno to south of Carson City. DePolo et al. (1997) report 13 earthquakes exceeding magnitude 6.0 in the region since 1850. In addition, the Truckee area is located near the North Tahoe-Incline Village Fault Zone. This fault is the largest in the north Lake Tahoe area and experienced a magnitude 4.9 earthquake in 1998. The earthquake epicenter was located approximately one mile east of the Gray Creek watershed (Ichinose et al., 1999).

2.4 Stream Network

The Gray Creek watershed stream network was digitized from the most recent USGS 1:24,000 quadrangles (see Figure 2.1). The network includes the larger tributaries to Gray Creek but does not include the gullies, zero-order channels, or swales that are clearly visible on the hill shade map (Figure 2.2), other large-scale maps, or that can be identified during field inspections (Photo 2-10). The overall drainage density for the stream network is 1.37 mi/mi^2 and varies by less than 10% between the North, Middle, and West Fork subwatersheds (Table 2.2). Overall drainage densities including gullies and zero-order channels would be much higher.

The main channels in the subwatersheds of Gray Creek were divided into reaches by the U.S. Forest Service for their aquatic habitat assessment. We have adopted their divisions for our study (see Figure 2.9). Table 2.4 describes each of these reaches, summarizing channel characteristics, the reach type (see Table 2.3) and its geomorphic characteristics based on air photo interpretation, field reconnaissance and available reports and GIS data. Field reconnaissance was limited to lower Gray Creek (MF 1 through MF 4; Photos 2-1 to 2-8 for MF1), the West Fork (WF1 and WF2), and the North Fork (NF 1). No field reconnaissance was conducted in the Middle Fork subwatershed (reaches MF 5 and higher).

Table 2.2 Gray Creek Stream Length and Drainage Density by Subwatershed

Subwatershed	*Area (mi^2)*	*Stream Length (mi)*	*Drainage Density (mi/mi^2)*
North Fork	2.4	3.51	1.46
Middle Fork	4.9	7.43	1.52
West Fork	8.0	11.16	1.40
Main Stem	2.5	2.24	0.90
TOTAL (Gray Creek watershed)	17.8	24.34	1.37

Figure 2.9 also provides a morphologic description or "typing" of the stream network, based on the Montgomery and Buffington (1993) classification system (Table 2.3). This system was adopted for the study area because of the following advantages:

- It can be applied at a reconnaissance level using aerial photos and topographic maps. Although preferred, field surveys are not required for application to stream networks.

- It is a process-based approach designed for application in watershed-based studies of channel form and its response to natural and human disturbance.

- It was designed for forested mountain watersheds in the North American Pacific region where there is a significant large woody debris (LWD) component to stream morphology.

The Montgomery-Buffington system identifies three main morphologic scales; the watershed, the valley segment and the channel reach. Table 2.3 describes the different stream types. Note that gradient boundaries between types are not fixed and may vary with sediment supply and transport capacity. Watersheds are divided into hillslope and valley segments; valley segments are then divided into colluvial, bedrock and alluvial types. Colluvial segments store sediment derived from hillslopes by creep, tree throw and slope failure, occur in upper watersheds, and are often dominated by debris flow or landslide processes. Sediment transport capacity generally exceeds sediment supply in bedrock segments, exposing bedrock along the channel bed. Alluvial segments are those where streams flow in a self-formed channel through their own deposits.

Colluvial and alluvial valley segments are characterized by a range of stream types that change in a consistent manner with distance downstream providing a stable morphology for the given valley characteristics, sediment supply and sediment transport.

The stream channel classification shown in Figure 2.9 is based on the elevation and slope data available in the GIS. Examination of Figure 2.9 shows that the majority of stream reaches in the study area should exhibit step-pool morphology (see Table 2.3; Photos 2-15 and 2-17), which is consistent with observations during the field reconnaissance.

Table 2.3 Summary of Valley Segment and Reach Types in the Montgomery Buffington Method

Valley Segment Type	Reach Type	Site in Watershed	Slope Range (%)	Primary Sediment Process	Instream Sediment Storage	Notes
Colluvial	Un-channeled (Hollow)	Upper	S > 20%	Supply	N/A	Hollows are located in the uppermost sections of the drainage network. There is insufficient flow to form a channel but sediment accumulates in hollows over years or decades and, during infrequent large storm or seismic events, mass wasting processes such as a debris flow and landslides convey this sediment into the drainage network. The cycle begins again with the hollow gradually refilling with sediment.
Colluvial	Channeled	Upper / Middle	S > 20%	Supply	High	These stream channels characterize the uppermost streams in a watershed. Colluvial processes (slope failure) dominate sediment production and channel morphology in these reaches; landslides, debris flows, and soil creep are common. Sediment supply is abundant and sediment throughput is transport limited. Bed material is typically unsorted, containing abundant fine-grained material due to limited stream flows.
Alluvial	Cascade	Upper	30% > S > 10%	Transport	Very Low	Cascade channels are very steep and exhibit very coarse bed material (up to boulder sizes). Higher stream flows in these reaches appear as white-water, tumbling around larger boulders and cobbles. Sediment storage is very limited and restricted to low-velocity areas in small pools or behind debris jams. These channels can maintain their configuration for decades, until very large storms re-mobilize the stream bed.
Alluvial	Step-Pool	Middle	10% > S > 3%	Transport	Low / Medium	Step-pool channels exhibit alternating pools and steps (steep, often vertical, drops usually located near a bed control such as a very large boulder or a debris jam). Steps typically contain very coarse bed material whereas pools allow finer material to accumulate, providing some sediment storage.
Alluvial	Plane-bed	Middle	3% > S > 1%	Transport	Low / Medium	Plane-bed channels exhibit a relatively flat bed that lacks significant variability and has few bedforms. Occasional steps, pools, or rapids may form but are infrequent or absent. Bed material is typically coarse and the bed is armored. Plane-bed channels may be either supply or transport limited.
Alluvial	Pool-riffle	Middle / Lower	2% > S > 0.1%	Transport / Deposition	Medium / High	Pool-riffle channels exhibit significant morphologic variability. The bed alternates between steeper (riffle) sections with coarse bed material to shallower sloping pool sections where fine sediments accumulate and are stored until the next high flow. Instream bars are regularly observed and act as additional sediment storage sites. Pool-riffle channels are considered to be transport limited during flood flows.
Alluvial	Regime	Lower	S < 0.1%	Deposition	High	Regime channels have low-slopes and predominantly sand bed material. Channel roughness is low and sediment is transport limited at all flow stages.
Bedrock	Bedrock	Upper / Middle	30% > S > 0.1%	Transport	Low	Bedrock channels are largely devoid of bed material. They have high transport capacities and, other than local pockets of sediment accumulation, are scoured to bedrock of all available sediment.

Table 2.4a Gray Creek Geomorphic Reach Descriptions – Main Stem

Reach Name	Length (miles)	Channel Width (ft)[1]	Average Slope	Reach Type	Notes
MF 1	0.78	15 - 20	0.048	Plane-bed / Step-pool	Single thread, slightly sinuous channel confined within narrow canyon. Evidence of channel shifting, large-scale bed material mobilization, loss of floodplain vegetation and woody debris transport during the January 2006 flood; net incision of about 1-2' in downstream part of reach. Road crossing acts as a weir at low flow, is partially eroded during high flows and requires annual maintenance. Numerous local sediment sources from small drainages enter Gray Creek along the right bank; active bank erosion observed in some locations during 2006 field reconnaissance.
MF 2	0.76	10 - 15	0.071	Step-pool / Plane-bed	Channel narrows with distance upstream and becomes increasingly sinuous, reflecting greater confinement by steep canyon slopes. Narrower and more stable channel bed than reach MF1 with moderate riparian cover. Active bank erosion observed during 2006 field reconnaissance but generally less than reach MF1. Few large point sediment sources; upstream end of reach located at base of large landslide runout.
MF 3	0.71	10 - 15	0.053	Step-pool / Plane-bed / Pool-riffle	Narrow, confined channel with moderately sinuous planform controlled by steep canyon slopes. Well-established riparian vegetation. Few local point sediment sources. Active bank erosion, particularly opposite tributary junctions.

'--' - indicates this information is not available
[1] - width of the stream channel as observed on 1:10,000 scale air photos taken July 2006
Left bank and right bank are with reference to looking in the downstream direction

Table 2.4b Gray Creek Geomorphic Reach Descriptions – Middle Fork

Reach Name	Length (miles)	Channel Width (ft)[1]	Average Slope	Reach Type	Notes
MF 4	0.33	10 - 15	0.097	Step-pool / Plane-bed	Short reach of Gray Creek between confluence with West Fork (downstream) and North Fork (upstream). Narrow channel corridor has moderate riparian cover with stream bends controlled by frequent bedrock outcrops and steep canyon topography. Channel is deeply incised above and below a bedrock-controlled portion of the reach (stream bend). Local point sediment sources include active bank erosion and landslides.
MF 5	0.47	10 - 15	0.090	Step-pool	Slightly sinuous channel in narrow, confined canyon that broadens near upstream end of reach. Moderate riparian cover along most of low flow channel. Point source bank erosion observed in reach and abundant slope failures with rill and gully formation observed in a large erosion zone along the left bank slope. Tributary at upstream end of reach delivers abundant sediment supply from large upstream erosion zone. Active stream incision and bank erosion reported by Myers et al. (1996).
MF 6	0.43	10 - 15	0.079	Step-pool	Channel exhibits very small meanders within a less confined but still narrow valley bottom. Recent recovery in riparian corridor along the low flow channel is evident following high flows in 2006. active bank erosion and stream incision reported by Myers et al. (1996)
MF 7	0.48	10	0.092	Step-pool	Channel exhibits very small meanders within a less confined but still narrow valley bottom. Well-established riparian vegetation. Benches above existing channel suggest historic stream incision in this reach, also reported by Myers et al. (1996). A large erosion zone with abundant slope failures and rill and gully formation is located on left side slope. A very large landslide deposit shows visible toe erosion at the upstream end of the reach.
MF 8	0.44	10	0.097	Step-pool	Channel exhibits very small meanders within a less confined valley bottom in the downstream part of the reach. The canyon narrows again in the middle and upstream parts of the reach and planform is slightly sinuous, following the narrow canyon topography. Riparian cover is moderate. Benches above the existing channel suggest historic stream incision in the downstream part of this reach. A large landslide runout is located at the downstream end of this reach.
MF headwaters	--	5 - 10	--	Step-pool / Cascade	Channel is typically straight to slightly sinuous, very narrow and with steep side banks. Riparian vegetation cover varies from well-vegetated to none. Banks with less vegetation cover exhibit locally abundant sediment supply with nearly continuous active toe erosion and subsequent sediment supply into the creek. Erosion zones and point sediment sources are abundant in the Middle Fork headwaters, generally consisting of landslides and other types of slope failure. Stream incision is reported by Myers et al. (1996) for this area.

'--' - indicates this information is not available
[1] - width of the stream channel as observed on 1:10,000 scale air photos taken July 2006
Left bank and right bank are with reference to looking in the downstream direction

Table 2.4c Gray Creek Geomorphic Reach Descriptions – West Fork

Reach Name	Length (miles)	Channel Width (ft)[1]	Average Slope	Reach Type	Notes
WF 1	1.26	15 - 20	0.0952	Step-pool	Slightly to moderately sinuous, narrow channel in confined canyon reach. Instream logs and woody debris are common. Riparian cover is moderate to well-established. Minor bank erosion is observed throughout the reach. No large, recent local point sources of sediment or erosion zones are noted for this reach.
WF 2	1.16	10 - 15	0.0835	Step-pool	Slightly sinuous channel in less confined reach with less steeply sloping side slopes than Reach WF1. Instream logs and woody debris are common. Bench surfaces above the existing channel suggest historic stream incision in the downstream part of this reach. Active bank erosion is observed, particularly along steeply sloping left bank in downstream part of reach. Left bank slope exhibits numerous slope failures and rill and gully formation in this reach.
WF 3	1.05	10	0.1096	Step-pool	Slightly to moderately sinuous narrow channel with less steeply sloping side-slopes than reach WF1. The riparian zone is well-established with many large trees. Local point sediment sources include active bank erosion although the channel generally shows fewer bank erosion sites than downstream reaches WF2 and WF1. Rilling and gullying delivers sediment from the right bank slope on the downstream part of the reach.
WF 4	0.78	10	0.1053	Step-pool	Straight to slightly sinuous channel with less confined valley bottom and some floodplain surfaces. The riparian zone is well-established with many large trees. intact bridge (condition unknown) at dirt road crossing. Minor bank erosion is observed in a few areas but the reach appears generally stable. An erosion zone on right bank slope delivers sediment from abundant landslide, slope failure and rill and gully sources.
WF headwaters	--	5 - 10	--	Step-pool / Cascade / Plane-bed / Colluvial	Slightly sinuous channel is narrowly confined by steep slopes in lower part of headwaters and opens to upland meadows in upper headwaters. Riparian vegetation cover varies from well-vegetated in meadow areas to none in confined areas. Steep banks with less vegetation exhibit frequent toe erosion and subsequent sediment supply into the creek. Large scree slope erosion zones deliver sediment to the upstream part of headwater reach.

'--' - indicates this information is not available
[1] - width of the stream channel as observed on 1:10,000 scale air photos taken July 2006
Left bank and right bank are with reference to looking in the downstream direction

Table 2.4d Gray Creek Geomorphic Reach Descriptions – North Fork

Reach Name	Length (miles)	Channel Width (ft)[1]	Average Slope	Reach Type	Notes
NF 1	0.42	10	0.129	Step-pool	Moderately sinuous channel is narrowly confined by steep canyon slopes. The creek is almost completely obscured by well-established riparian cover. Steep side slopes exhibit frequent toe erosion and subsequent sediment supply into the creek. Landslide point source erosion site delivers sediment to upstream part of reach.
NF 2	0.45	10	0.097	Step-pool	Narrow, confined channel with slightly sinuous planform controlled by canyon slopes. Less confined than Reach NF1. Well-established riparian vegetation. Landslide point source erosion site on right bank. Limited bank erosion along reach and significantly less than in Reach NF1.
NF 3	0.41	10	0.111	Step-pool	Slightly sinuous channel is confined by steep canyon slopes. The creek is almost completely obscured by moderately well-established riparian cover. Abundant instream woody debris is visible in the downstream part of this reach. Limited bank erosion and no active erosion zones or point source erosion sites are identified. The upstream reach boundary is located at a large debris fan deposit on the left bank.
NF 4	0.45	10	0.125	Step-pool	Slightly sinuous channel is narrowly confined by steep canyon slopes. The creek is almost completely obscured by well-established riparian cover. Limited bank erosion and no erosion zones or point source erosion sites identified in this reach.
NF headwaters	--	5 - 10	--	Step-pool / Cascade	Moderately sinuous channel is narrowly confined in downstream part of reach and becomes less confined further upstream. Riparian cover is well-established and obscures much of the creek. Minor bank erosion is observed, particularly along steeply sloping areas adjacent to the stream channel. A landslide point source of erosion is located on the right bank slope. No erosion zones are located in this reach.

'--' - indicates this information is not available
[1] - width of the stream channel as observed on 1:10,000 scale air photos taken July 2006
Left bank and right bank are with reference to looking in the downstream direction

2.5 Climate and Hydrology

Climate in the Gray Creek watershed consists of mild summers and cold winters. Highs in Truckee average 78 °F in summer and 41 °F in winter whereas lows average 59 °F and 28 °F, respectively. The majority of precipitation falls as snow from November through March when winter weather patterns form Pacific lows that deliver moist air to California. These air masses rise over the Sierra Nevada and cool, resulting in snowfall that generally increases in depth with elevation.

The Gray Creek watershed is very steep and responds rapidly to storm rainfall. Runoff is concentrated over a short period of time, resulting in high peak flows. Rain on snow in winter and early spring as well as summer thunderstorms can produce high peak discharges, which may be heightened in the near term by increased runoff from burned areas. Minimum flows occur in winter from November through February and are typically around 10 cfs. Summer base flows from August through October typically range from 10 cfs to 25 cfs.

The U.S. Geological Survey (USGS) has operated a stream gage at the mouth of Gray Creek (gage no. 10345490) from November 2001 to present. The maximum discharge at the gage of 248 ft^3/s occurred on May 8, 2003. The flow on December 31, 2005 may have been significantly higher than this. We requested a peak discharge estimate from the USGS for this date but have obtained no response yet. Additionally, the Desert Research Institute (DRI) collected discharge data near the mouth of Gray Creek from March through October 2000 (McGraw et al., 2001). Records at the Bronco Creek at Floriston gage (10345700), a similar-sized watershed just south of Gray Creek, extend from 1993 to 1998.

Large peak flows occurred on Gray Creek in 1880, 1884, 1890, 1965, 1983, 1986, 1992, 1995, 1997, 2003, 2005, and 2006 (Nevada Division of Water Resources, 1997; USGS gage data). These floods usually have high sediment concentrations. Following a summer storm in 1890, Gray Creek flows were described as, '…mud flows emanating from Gray Creek caused the Truckee River to run red with sediment for a week.' (Nevada Division of Water Resources, 1997). In more recent time, heavy sediment loads from Gray Creek have forced the closure of the Reno-Sparks water treatment plant due to resultant turbidity in the Truckee River. In 1992 and 1995, high sediment loads were produced by summer thunderstorms in July or August (Voyles, 1992; Bremner, 1995); in 1997 and 2006, peak flows occurred in the winter from heavy frontal precipitation and rain on snow.

2.6 Sediment Transport

Suspended sediment concentrations in Gray Creek have been measured by DRI (McGraw et al., 2001) and the USGS (gage no. 10345490). DRI collected suspended sediment concentrations following USGS procedures from March to October 2000, one year prior to the 2001 Martis Fire, whereas the USGS collected data between November 2001 and August 2004. Both data sets were collected at the gage site near the mouth over a range of discharges (Figure 2.10). The suspended sediment rating curves prepared from these two datasets show that suspended sediment concentrations have typically been about four to five times greater since 2001. The higher transport rates likely result from erosion associated with the 2001 Martis Fire, but may also reflect changes in the watershed from the large flood that occurred in 2003.

No data are available regarding bedload transport rates or grain size distributions of bed material in Gray Creek. Field reconnaissance shows that bed material on the lower part of Gray Creek is very coarse, consisting primarily of cobbles and gravel with a few boulders. These coarse sediments are mobile during large floods.

DRI (2001) estimated suspended sediment loads (primarily medium and fine sand, silt and clay) for Gray Creek for the 1996 and 1997 water years, from their sediment rating curve and daily flows transferred from the Bronco Creek gage. Estimated loads were 2,500 tons in 1996 and 6,600 tons in 1997, with broad confidence bands around these estimates. When normalized by area, suspended sediment loads on Gray Creek are high in comparison with other Truckee River subwatersheds (McGraw et al., 2001).

Application of the USGS sediment rating curve to the daily flows measured since 2001 in Gray Creek by the USGS produces an average annual load of 10,100 tons. This load is considerably higher than those estimated for 1996 and 1997. Combining the recent and older estimates suggests that average annual suspended loads may have been about 7,000 to 8,000 tons, recently, or about 400 tons to 500 tons/mi^2. Such a load is equivalent to about 0.004 inches of soil erosion per year (0.4 inches per century), when spread over the entire watershed.

2.7 Watershed Disturbance

2.7.1 Road Network

Figure 2.11 shows the forest roads in the Gray Creek watershed, as identified from July 2006 air photos. Figure 2.11 also includes a short private road along the north side of Gray Creek near the mouth of the watershed. Table 2.5 summarizes road lengths by subwatershed.

Table 2.5 Road Network Characteristics by Subwatershed

Subwatershed	*Subwatershed Area (mi^2)*	*Roads observed in 2006 air photos*	
		Miles of Road	*Road Density (mi/mi^2)*
North Fork	2.4	4.1	1.71
Middle Fork	4.9	0.2	0.04
West Fork	8.0	14.0	1.75
Main Stem	2.5	1.3	0.52
TOTAL TDLT Lands	2.1	3.4	1.62
TOTAL WATERSHED	17.8	19.5	1.10

All roads in the watershed are unpaved. Although clearly visible on 2006 air photos, many of these roads are no longer maintained and are now impassable to vehicles due to erosion, logs and other debris in the roadway, or damage to bridges (Photos 2-9 to 2-18). Field inspection showed that the bridges over the West Fork have been destroyed. Most forest roads observed during our field inspection of the West Fork subwatershed near Murphy Meadows exhibited various erosion features. Myers et al. (1996) conducted site visits of forest roads in 1992 and 1995 in the North Fork subwatershed and reported similar observations.

The road inspection was supplemented by a GIS analysis of the road network. Although not a replacement for on-site inspection, the GIS analysis provided a reconnaissance level assessment of drainage and terrain conditions in the Gray Creek road network and a useful starting point for the development of road rehabilitation or maintenance strategies.

The following terrain and drainage information was documented in the GIS for all the road segments in the Gray Creek watershed. The road network catalog provides baseline information for the development of erosion control projects at road sites and provides planning level information for the development of watershed road network management plans as discussed in Section 5.:

- *Road Segment ID* – Roads are divided into 500 ft segments for cataloging purposes. Each road segment is given a subwatershed identifier (NF = North Fork, MF = Main Fork, WF = West Fork, MS = Main Stem) followed by a unique segment number.

- *Ownership* – Owner of the property on which the majority of the road segment is located.

- *Road Segment Length (ft)* – Length of road segment in feet.

- *Road Segment Elevation Start (ft)* – Elevation at start of road segment in feet.

- *Road Segment Elevation End (ft)* – Elevation at end of road segment in feet.

- *Road Slope (%)* – Average percent slope of road segment as calculated from the elevations at the start and end and the segment length.

- *Hillside Slope at Road Site (%)* – Average percent slope of the hillside gradient the road segment crosses.

- *Road Crosses Stream* – An ‘X’ in this field indicates that the road segment crosses a stream channel shown on 1:24,000 scale USGS topographic maps.

- *Road Crosses Small Drainage* – An ‘X’ in this field indicates that the road segment crosses a drainage channel that is too small to be mapped as a stream channel in 1:24,000 scale USGS topographic maps.

- *Road Drains Into Stream* – An ‘X’ in this field indicates that the road segment extends down the slope towards a stream crossing and may increase the drainage density of the watershed.

The results of the road network GIS analysis are illustrated in Figures 2.12 and 2.13. Figure 2.12 shows road slopes and the location of stream crossings whereas Figure 2.13 shows hillside slope for each road segment. Table 2.6 combines the information from Figures 2.12 and 2.13, showing the length of road in the various combinations of road slope and hillside slope classes.

Table 2.6: Miles of Road in the Hillside Slope and Road Slope Classes [1]

Hillside Slope (%)	8 – 10	10 – 20	20 – 30	30 – 40	40 – 50	50 – 60	60 – 70	TOTAL
Road Slope (%)								
0 – 2%	--	0.19	0.36	0.32	0.09	0.19	0.38	*1.54*
2 – 5%	0.09	0.04	0.82	0.63	0.67	1.19	0.25	*3.69*
5 – 10%	--	0.21	0.60	0.46	1.33	1.99	1.28	*5.86*
10 – 15%	--	0.01	0.28	1.23	1.56	1.46	0.38	*4.93*
15 – 20%	--	--	--	0.34	0.73	0.69	0.51	*2.27*
20 – 25%	--	--	--	0.07	0.11	0.38	0.05	*0.61*
25% +	--	--	--	0.10	0.09	0.41	--	*0.60*
TOTAL	*0.09*	*0.46*	*2.07*	*3.14*	*4.59*	*6.31*	*2.85*	*19.50*

[1] This information is illustrated spatially in Figures 2.12 and 2.13.

Table 2.6 shows that about 3.5 miles of road have slopes steeper than 15%. Surface and inboard ditch erosion is a concern for these steep segments. The table also shows that about 9.2 miles of road cross hillslopes steeper than 2:1 (50%), where initiation of landslides is a concern.

2.7.2 Fire

Figure 2.14 shows the extent of historical fires in the watershed. The extent of the 1926 fire was only available for the California side of the watershed; its extent in Nevada is not known and not documented. The 2001 Martis Fire affected the majority of the watershed.

Erosion control treatments were not recommended following the fire (USDA Forest Service, 2001a). Potential treatments were considered hazardous to implement and likely to be ineffective due to steep topography.

2.7.3 Logging

Logging is reported to have first occurred in the Gray Creek watershed in the Comstock era (1850 – 1900; Kuchnicki, 2001) and then again in the 1920s. Steep slopes and overall inaccessibility of the watershed greatly restricted the areas logged during this period (Myers et al, 1996). Most logging is thought to have occurred near stream courses in the lower reaches of the watershed (Jeff Dowling, CDF, pers. comm.).

Logging resumed in the early 1960s when approximately 0.7, 0.9, and 0.04 mi^2 were logged in the North Fork, West Fork, and Main Stem subwatersheds, respectively (Myers et al, 1996). No logging occurred in the Middle Fork. No logging has occurred on USFS land since 1960, although land acquired since 1960 may have been previously logged (Julia Richardson, USFS, pers. comm.).

In the California portion of the watershed, during the 1990s, four Timber Harvest Plans (THPs) included logging within the Gray Creek watershed (Jeff Dowling, CDF, pers. comm.). The locations and areas cut under these THPs (in T17N R18E) were:

- Section 19: 50 acres of sanitation, salvage, and selection cut;
- Section 19: 176 acres of selection cut, and 55 acres of sanitation and salvage;
- Sections 7, 17, and 18: 240 acres of selection cut; and
- Sections 17, 18, 19, and 30: over 300 acres of selection cuts.

The logging occurred on private land on the west side of the West Fork and Main Stem subwatersheds and primarily involved the selective removal of large trees through aerial and cable logging (Jeff Dowling, CDF, pers. comm.). Some logged sites are within 500 feet of the stream network including sites along Main Stem Reach 2 and West Fork Reach 2 (John Hunter, EDAW, pers. obs.).

After the 2001 Martis Fire, there was additional salvage logging on private property in lower portions of the watershed; however, the sites where this occurred are not known (Julia Richardson, USFS, pers. comm.).

2.7.4 Grazing

Sheep grazing has occurred in the watershed since about 1870. Grazing peaked around 1900 and has declined through the 20th century. Historic grazing was widespread and reported to have caused significant watershed degradation due to trampling and vegetation removal (Cole, 1969). Myers et al (1996) report that sheep grazing has not been allowed in the Gray Creek watershed since the 1960s. Nonetheless, they observed sheep grazing in a limited area of the West Fork subwatershed as recently as 1992. The areas where grazing was observed were relatively flat and the grazing was not considered to contribute to sediment production.

2.8 Summary

The Gray Creek watershed is very steep and almost entirely covered by highly erodible volcanic rocks and moraine. Erosion of these soils has been exacerbated by loss of vegetation cover following the 2001 Martis Fire. Sediment gaging at the mouth of Gray Creek suggests greatly increased sediment yields in the years since the fire. It is assumed these yields will reduce over the long-term, as vegetation recovers.

Anthropogenic impacts in the watershed include logging, grazing, and road construction. Based on available historical information, logging and grazing have become less significant since the 1960s and have had minimal impacts over the last two decades. Roads are currently the most important anthropogenic source of sediment production in the watershed.

3. SEDIMENT SOURCE ASSESSMENT

The sediment source assessment proceeded through three steps: 1) a review of previous studies and field reconnaissance to identify the dominant erosion processes, 2) an inventory of the dominant point-source erosion processes, and 3) assessment of the overall significance and distribution of erosion sites in the watershed. The sediment source assessment forms the basis for the development and prioritization of erosion site restoration alternatives discussed later in this report.

3.1 Previous Studies

Gray Creek watershed sediment production has been discussed in several studies (Meyers et al., 1996; USDA Forest Service, 1995, 2001a, 2001b, 2005; Kuchnicki, 2001; McGraw et al., 2001). Steep slopes in the middle and lower elevations of Gray Creek have been identified as key sediment source areas (USDA Forest Service, 1995; Meyers et al., 1996). Although smaller than the West Fork subwatershed, the Middle Fork is reported to have the greater potential for sediment production due to its steeper topography (Myers et al., 1996).

The dominant erosion processes in Gray Creek are mass wasting, surface wash or erosion, and fluvial (bank and bed) erosion (Myers et al., 1996; USDA Forest Service, 2001a). Landslides, debris flows, soil slumps and rockfalls are the most important forms of mass wasting to sediment production. The incidence and relative importance of different erosion processes varies dramatically between wet and dry years. Dry years exhibit less frequent mass wasting and are often dominated by small-scale erosion processes such as dry ravel and slide, soil creep, and frost heave. In contrast, in wet years, sediment production is dominated by large-scale processes such as landslides and debris flows (Maholland, 2002).

Myers et al (1996) inspected the watershed in 1992 and 1995 following major floods. Although both floods occurred in July, the 1992 flood was preceded by dry conditions following an early snowmelt whereas the 1995 flood was preceded by saturated basin conditions, partial snow cover, and moderate flows caused by ongoing snowmelt. The post-1992 flood site visit found mud high in the trees along lower Gray Creek and the lower part of the West and Middle Forks whereas no evidence of high flows was seen on the North Fork. Active bank erosion was observed on the lower 2.5 miles of the West Fork and throughout the Middle Fork; mature trees were left in the channel and deposited along the floodplain of the West Fork, Middle Fork, and lower Gray Creek. A very large debris jam – 200 ft long by 65 ft wide and 12 ft high – formed on the Middle Fork; it was later cleared by the 1995 flood. Numerous landslides were noted on either side of the steep ridge separating the Middle and West Fork subwatersheds. The landslides appeared natural and not the result of anthropogenic activity.

The site visit following the 1995 storm event indicated that flow turbidity and land surface erosion were greatest in the Middle Fork subwatershed. A two meter (7-foot) high headcut was observed to be migrating up the Middle Fork and the total stream incision or degradation in recent times appeared to be about 6 m (20 feet). Erosion and sedimentation characteristics were similar to those observed in the 1992 flood event.

Following these site visits, Myers et al. (1996) concluded that the majority of sediment production on Gray Creek occurred in the Middle Fork. Given that this subwatershed is the least disturbed in the basin, shows no record of logging, and exhibits virtually no roads, Myers et al. (1996) concluded that naturally unstable geology and soils combined with steep topography contribute to the erosion and high suspended sediment concentrations observed during floods. The extent and magnitude of naturally occurring erosion led them to conclude that application of BMPs on existing anthropogenic sediment sources in the Gray Creek watershed would have minimal impact on overall basin sediment production.

Our field reconnaissance and discussions with the landowner at the mouth of Gray Creek (Larry Andresen; personal communication) indicated that debris flows occurred in many of the tributaries leading to canyon in lower Gray Creek (Reaches MF 1 and MF 2), carrying in large volumes of sediment during the 2006 flood. Other active erosion processes that we observed included bank and bed erosion along the main stream and landslides and slumping from the valley walls. Field inspection in the West Fork of Gray Creek indicated active surface wash on the slopes near the creek.

Anthropogenic land uses, namely logging, grazing, and road building have historically contributed to higher sediment yields on Gray Creek, primarily by increasing surface wash or surface erosion on exposed soils but also by increasing rates of landsliding on steep slopes. McGraw et al. (2001) report that even prior to the 2001 Martis Fire watershed forest canopy cover was less than that during pristine ‘pre-disturbance’ conditions and observed that this has likely increased nonpoint source sediment production. The extent and density of native-surface roads are also reported to be a major sediment source to stream channels in the Middle Truckee River basin, including Gray Creek (McGraw et al., 2001; USDA Forest Service, 2001b). Road segments leading to or crossing streams are particularly important as they can increase direct sediment delivery.

McGraw et al. (2001) produced a rough estimate of the long-term impact of anthropogenic effects on nonpoint source sediment yield in the California portion of the Truckee River, including Gray Creek, by applying the AnnAGNPS soil erosion model. The model was roughly calibrated to existing suspended sediment load data and then adjusted to simulate watershed conditions prior to human activities by removing roads and increasing the canopy cover. Based on this analysis, they concluded that suspended sediment load averaged 53% lower in Gray Creek prior to any disturbance. Construction of roads caused most of the calculated increase in sediment loads, with the remainder attributed to reduced canopy cover.

3.2 Sediment Source Inventory

The inventory characterized active sediment sources on slopes in the Gray Creek watershed, focusing on those that contributed sediment directly to the stream network. Due to the remoteness and size of the basin, air photo stereo pairs were the main tool for inventorying and documenting sediment sources. Air photos flown in July 2006 provide an up-to-date mapping base and reflect the current status of basin recovery from the 2001 Martis Fire. Limited field observations and other GIS data layers such as 1998 digital orthophotos, geology, soils, land cover, and DEM data were used to supplement the air photo interpretation. To the extent possible, all data and results were entered into the project GIS (Appendix 1).

Sediment sources were classified as either “erosion sites” or “erosion zones” (Figure 3.1). An erosion site is an individual source, such as a landslide, debris flow, road, eroding bank, or slump. On the other hand, an erosion zone is a larger area that combines numerous active erosion sites, sites that have been active in the recent past, or sites that have a high potential for erosion. Erosion zones are generally found on steep, poorly vegetated slopes, often where talus accumulates below steep slopes along the basin margins and then is eroded during large storms. These areas exhibited a high albedo in 2006 air photos, indicating the lack of surface vegetation cover and the high degree of soil exposure.

The minimum size of a mapped erosion site is about 300 square feet (about 0.5 mm by 0.5 mm at the nominal photo scale). Smaller erosion sites could not be satisfactorily identified and characterized. The smaller erosion sites are relatively abundant but are not thought to provide a significant contribution to the overall sediment yield, particularly the overall yield to streams.

The following site characteristics were documented in the GIS database at each erosion site:

- *Site ID* – A unique number identification for the erosion site.
- *Land Cover* – Erosion site vegetation type or land use. Areas within the 2001 Martis Fire burn area are noted as such.
- *Erosion Class* – Identifies the erosion site as a natural or anthropogenic erosion source. All anthropogenic erosion sites in the watershed are associated with roads.
- *Erosion Type* – Erosion sites are divided into one of four broad classes: 1) mass wasting, 2) gullies, rills, or other features of surface wash erosion; 3) stream bank erosion, and 4) roads and tracks.
- *Erosion Sub-Type* – A brief description of the erosion feature.
- *Erosion Width / Length / Area* – Approximate dimensions of the erosion feature as observed in 2006 air photos.
- *Visible in 1998* – Identifies the appearance and activity of the erosion feature by noting whether or not it was present in 1998 digital orthophotos.
- *Erosion Status* – Identifies whether the site is actively eroding based on comparing the feature observed in 2006 to that in 1998.
- *Sediment Delivery Zone* – Identifies the location of sediment delivery from the erosion site, either to a location further down the slope or directly into the drainage network.
- *Stream Proximity* – Measures the distance (miles) down the slope (perpendicular to contours) to the nearest stream in the drainage network.

- *Road Proximity* – Measures the lineal distance (miles) to the nearest road.

The erosion sites in the GIS database are described in Appendix 2. The Site ID column in Appendix 2 refers to the site locations shown in Figure 3.1. Table 3.1 summarizes the erosion site inventory.

Table 3.1 Summary of Erosion Sites by Subwatershed

Subwatershed	*Area (mi^2)*	*No. of Erosion Sites*	*No. of Erosion Sites / mi^2*	*Erosion Class*			
				Mass Wasting	*Rill & Gully*	*Stream Bank*	*Roads & Tracks*
North Fork	2.4	10	4.2	4	0	0	6
Middle Fork	4.9	24	4.9	15	5	4	0
West Fork	8.0	34	4.3	19	5	2	8
Main Stem	2.5	20	8.0	11	1	1	7
Total	*17.8*	*88*	*4.9*	*49*	*11*	*7*	*21*

A total of eighty-eight erosion sites were identified in the Gray Creek watershed. The Main Stem subwatershed exhibited the highest concentration of erosion sites with 8 per square mile whereas the North Fork has the lowest at 4.2 per square mile. Of the four erosion classes, mass wasting accounted for 56% of erosion sites followed by roads and trails at 24%. Rill and gully and stream bank erosion accounted for the remaining erosion sites at 12% and 8%, respectively.

Table 3.2 summarizes the erosion zone inventory shown in Figure 3.1. All erosion zones identified in the watershed are natural and appear unaffected by development. A brief description of erosion processes observed in each zone is included in the GIS database (Appendix 2) and summarized by subwatershed in Table 3.2.

Table 3.2 Summary of Erosion Zones by Subwatershed

Subwatershed	*Area (mi^2)*	*Area of Erosion Zones (mi^2)*	*Percent of Subwatershed Identified as Erosion Zone*	*Description*
North Fork	2.4	0.02	1%	numerous small slope failures / rill formation
Middle Fork	4.9	1.64	33%	numerous slope failures, small to large landslides / rill and gully formation
West Fork	8.0	0.64	8%	numerous slope failures, small to large landslides / rill and gully formation / scree slopes and rock falls in headwaters
Main Stem	2.5	0.13	5%	several slope failures, small to large landslides / some rill and gully formation
Total	17.8	2.43	14%	

The majority of the erosion zones are in the Middle Fork subwatershed, followed by the West Fork and Main Stem. Erosion zones cover about one-third of the Middle Fork subwatershed, a very high percentage in comparison to other subwatersheds. Small slope failures are the dominant erosion feature observed in erosion zones, followed by medium and large landslides and rill and gully formation. Most erosion zones adjoin a stream channel (see Figure 3.1), suggesting good connectivity between sediment production and sediment delivery to Gray Creek and the Truckee River.

3.3 Erosion Hazard Analysis

An erosion hazard map was prepared for the Gray Creek watershed from the GIS data layers. The purpose of the analysis was to provide a qualitative or relative weighting of erosion hazard based on key variables that affect erosion and sediment production, namely slope, geology, soils, 2001 Martis Fire coverage area, and road density. The analysis is intended as a planning tool, useful in differentiating between areas of higher or lower potential for erosion and sediment production in the watershed and helping to plan restoration or other activities.

All GIS data layers were first converted to rasters and a relative hazard rating was assigned to the data types in each layer. For example, areas affected by the 2001 Martis Fire were assigned a higher hazard rating than unburned areas. More erosive volcanic rocks and glacial moraine deposits were assigned a higher rating than less erosive granite, and so on. (The ratings assigned to each data category are shown in Appendix 3.)

Erosion hazards are divided into high, medium, and low (Figure 3.2). High hazards generally occurred in steeply sloping areas in the middle and lower basin whereas moderate and low hazard areas occurred mainly in the basin headwaters where slopes are generally less steep, there are few roads, and the area is unaffected by the 2001 Martis Fire. More steeply sloping areas in the upper third of the watershed correspond well with the erosion zones identified in Figure 3.1. The upper West Fork subwatershed exhibits the lowest erosion hazard in the Gray Creek watershed, due largely to gradually sloping topography in this area.

3.4 Summary

The sediment source inventory, combined with a review of previous studies, indicates that landslides, both as individual features and in erosion zones, roads and trails, gully erosion and bank erosion are the dominant erosion mechanisms in Gray Creek watershed. Landslides provide most of their erosion and sediment delivery to streams during large floods, such as occurred in 2006, 2003, 1997, 1995, 1986 and 1983. A few of the landslides result from disturbance, such as drainage diversion on roads, but most occur naturally although at an accelerated rate because of the 2001 Martis Fire.

The watershed analysis and inventory show that the number of erosion sites and area of erosion zones is greatest in the Middle Fork, less in the North Fork and Main Stem, and least in the West Fork, consistent with previous observations of turbidity and erosion by the USFS. As was discussed earlier, the Middle Fork is nearly unaffected by human activities and much of the sediment seems to come from large erosion zones along the rim of the subwatershed.

The results of the literature review and sediment source inventory have implications for watershed restoration planning. First, many of the stream channels are not very stable. The Middle Fork channel seems particularly unstable (see Myers et al 1996) and field reconnaissance indicates that the main stem of Gray Creek is also very disturbed and unstable. Given the sediment supply to these two streams from their slopes, channel instability is likely to continue and efforts to restore aquatic or riparian habitat are not likely to be successful. The West Fork, which has the least slope erosion and a relatively broad valley bottom to intercept sediment, provides the best opportunity for restoration along the stream corridor.

Second, the most important sediment sources seem to landslides. Landslide erosion is very difficult to control or manage because the landslides usually occur on very steep slopes with very limited access, they occur unpredictably and suddenly during large floods, and they often deposit their sediment directly in the channel. Treatment (seeding) of the landslide tracks after failure can reduce subsequent erosion of the disturbed area, but this is generally small relative to the volume carried away by the slide.

Third, anthropogenic sediment sources (roads and trails) are important along the North Fork, Main Stem and West Fork. Treatment of these sources, particularly in the West Fork, can significantly reduce local sediment contributions, future damage to the streams, and the volume of sediment carried by Gray Creek during small floods. However, their treatment is not expected to greatly reduce the erosion that occurs during large floods or to greatly reduce the volume of sediment carried to the Truckee River.

4. HABITAT ASSESSMENT

4.1 Overview

The Gray Creek Habitat Assessment is designed to assist the Truckee River Watershed Council (TRWC) in gaining an understanding of habitat functions and values in the Gray Creek watershed, with a focus on the riparian and aquatic habitats along lower Gray Creek, the West Fork, and North Fork. This assessment is also intended to support Chapter 5 (*Gray Creek Restoration Projects*) and help TRWC develop a long-term plan to restore the natural processes that support ecosystem function in the watershed.

This chapter includes assessments of the watershed's existing biological conditions and the physical and ecological processes that support its terrestrial and aquatic habitats. It is organized into the following sections:

- **4.1 Overview** briefly describes the organization of this chapter, and the goals and specific objectives of this assessment.
- **4.2 Methods** summarizes the analytical and field approaches to the assessment.
- **4.3 Ecological Processes** provides general assessments of existing biological communities and vegetation dynamics in the watershed, and key ecological and physical processes that support them.
- **4.4 Upland, Riparian, and Aquatic Habitat Conditions** describes the specific characteristics of riparian vegetation and aquatic communities, and the habitat functions they provide, within each subwatershed of Gray Creek. This section also describes the species, locations, and relative abundance of invasive plants observed in the study area during field surveys.
- **4.5 Key Findings** summarizes key results of this habitat assessment and their implications for identifying potential restoration projects.

4.1.1 Habitat Assessment Goals and Objectives

TRWC's goals in commissioning this habitat assessment are to understand existing biophysical conditions of the watershed and use this information to enhance habitats where there is opportunity. The specific objectives of this chapter are to:

- Describe the characteristics and habitat functions of riparian and aquatic communities, and past or ongoing management actions or natural disturbances that affect those communities;
- Summarize the physical processes that create and sustain native habitat and ecosystem functions as well as factors that presently constrain or stress those functions; and
- Identify "problem areas" in the watershed and, if appropriate, feasible restoration opportunities and constraints.

4.1.2 Other Key Issues and Special-status Species

In addition to the assessment goals and objectives outlined above, a set of key issues and special-status animal species were initially identified to focus on priority management issues and habitat functions that restoration or enhancement could address, and evaluate the potential for habitat restoration to benefit sensitive fish and wildlife species that are known to occur in the region. The following issues were identified based on an initial data and literature review (Section 4.2) and input from TRWC staff.

- Status of invasive plant species in the watershed and opportunities to control their populations.
- Effects of the 2001 Martis Fire on habitat conditions.
- The watershed's present and potential future habitat functions and values for special-status species or other species of management concern, including the Loyalton-Truckee mule deer (*Odocoileus hemionus*) herd.

4.2 Methods

Analysis of habitat conditions and restoration opportunities in the Gray Creek watershed was performed using a combination of: 1) analytical methods, including literature and data reviews, geographic information systems (GIS) analyses, and aerial photo interpretation; 2) summarizing and interpreting Gray Creek stream inventory data provided by USDA Forest Service; and 3) conducting a rapid aquatic and riparian habitat field assessment. The following sections describe these components.

4.2.1 Literature and data review

The primary data sources reviewed for this chapter included:

- *Martis/Interstate 80 Corridor Landscape Assessment and Strategy* (Tetra Tech, 2005).
- *Martis Fire Burned Area Emergency Rehabilitation (BAER) Report* (USDA Forest Service, 2001a).
- 2006 Gray Creek Stream Inventory results, provided by USFS, Tahoe National Forest, Truckee Ranger District (USDA Forest Service, 2006a).
- California Natural Diversity Database (CNDDB, 2006).

Other literature sources that were reviewed are cited throughout this chapter and listed in the References section.

4.2.2 Target Habitats and Special-Status Animal Species

The study area supports a variety of vegetation communities, wildlife habitat types, and aquatic resources. A set of target habitats were identified to focus the field assessment on resources that were considered to be the most biologically significant within the planning area, and where potential restoration actions would likely have the greatest benefits. Target habitats in this assessment are stream riparian and aquatic resources. In addition to assessing the overall habitat functions and values of target habitats, special-status animals associated with these habitats were initially identified to evaluate the potential for habitat restoration to benefit sensitive fish and wildlife species that are known to occur in the region. In this assessment, special-status species include animals that are legally protected or that are otherwise considered sensitive by federal, state, or local resource conservation agencies and organizations. These include:

- species listed or proposed for listing as threatened or endangered under the Federal Endangered Species Act (ESA) or California Endangered Species Act (CESA);
- species considered as candidates for listing as threatened or endangered under ESA or CESA;
- species identified by California Department of Fish and Game (DFG) as California Species of Special Concern;
- animals fully protected in California under the California Fish and Game Code; and
- other wildlife species of high-priority management concern locally or regionally (e.g., Loyalton-Truckee mule deer herd).

To identify special-status species that are known to occur in the vicinity of the Gray Creek watershed, a records search of the CNDDB was performed for the following 7.5-minute U.S. Geological Survey (USGS) quadrangles: Martis Peak, Truckee, Tahoe City, Boca, and Hobart Mills. Table 4.1 lists the special-status animal species associated with aquatic and riparian habitats that are known to occur in the vicinity of the study area, and biophysical attributes that affect the quality or suitability of these resources. Table 4.8 in Section 4.4 (*Upland, Riparian, and Aquatic Habitat Conditions*) summarizes the habitat associations of these species, and the assessment results with respect to potential for occurrence of these species in the Gray Creek watershed.

4.2.3 Aerial Photograph interpretation and GIS Analyses

Aerial photographs and GIS data layers were used as part of the assessment of the structure and distribution of vegetation types. Aerial photographs were examined both in conjunction with other GIS data layers, and as stereo pairs. Vegetation data layers included the Nevada GAP vegetation data set (USGS, 2004) and CALVEG 2000 (CDFFP and USDA Forest Service, 2005). Both of these maps were developed from imagery from before the Martis Fire. Also, each used a different classification of vegetation, and these classifications consisted of regional categories whose descriptions did not accurately reflect the structure and composition of vegetation in the Gray Creek watershed. Therefore, a crosswalk was developed between these two classifications (Table 4.2), and based on the field assessment, the categories were modified to provide classification that better described the vegetation within the Gray Creek watershed. This classification was applied to produce a vegetation map for the Gray Creek watershed. The vegetation types within this classification are described in Table 4.3.

Together with the aerial images and other GIS data (e.g., topographic data), this Gray Creek vegetation map and aerial photographs, together with information from the field survey, were used to characterize the width and vegetation structure and composition (e.g., tree and shrub cover, dominant species) in riparian areas and adjacent and other uplands.

Table 4.1: Gray Creek Watershed Assessment Target Habitats and Special-status Animal Species Known to Occur in the Vicinity				
Target Habitat	Key Ecological Functions	Special-Status Species Associated with Target Habitat		
		Species	**Status**	**Important Attributes and Processes that Maximize Function and Habitat Value**
Riparian and Aquatic Habitat	▸ Significant contribution to local and regional biological diversity ▸ Provision of habitat for neotropical migrant bird and native fish communities ▸ Provision of wildlife movement and resting habitat ▸ Maintenance of movement, foraging, and breeding habitat for a variety of terrestrial and aquatic animal species ▸ Water quality maintenance in downstream areas	Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*)	Listed as threatened under the ESA. Rare species sensitive to presence of nonnative species, water quality, in-channel habitat and riparian condition.	▸ Absence or low abundance of, or isolation from, nonnative fish ▸ In-channel habitat structure (e.g., large woody debris, boulders, cobble, gravel) and diversity (combination of pools, riffles, etc.) ▸ Invertebrate productivity ▸ Riparian cover ▸ Stable bank/channel
		Mountain yellow-legged frog (*Rana muscosa*)	Candidate for listing under the ESA and designated as sensitive by the Regional Forester (USFS). Sensitive to water quality, riparian condition, and fish community composition; rare species of management concern; however, not known to occur in the Gray Creek watershed.	▸ Ponds, lakes, and bogs; or streams with deep pools and slow-moving water ▸ Absence of non-native fish predators
		Yellow Warbler (*Dendroica petechia brewsteri*)	Designated by DFG as a Species of Special Concern. Populations in California have declined due to loss of riparian habitat and nest parasitism by brown-headed cowbird (*Molothrus ater*).	▸ Native riparian vegetation, especially willow and aspen ▸ Vegetation structure with high foliar density ▸ Minimal conifer encroachment ▸ Hydrologic connectivity between stream channel and floodplain ▸ Absence of brown-headed cowbird
		Willow Flycatcher (*Empidonax traillii*)	Listed as endangered under CESA and designated as sensitive by the Regional Forester (USFS). Rare species associated with wet meadows in the Sierra Nevada; population declining and threatened.	▸ Meadows or wide riparian corridors with native riparian vegetation, especially willow (*Salix* spp.) ▸ Vegetation structure with high foliar density ▸ Hydrologic connectivity between stream

Table 4.1: Gray Creek Watershed Assessment Target Habitats and Special-status Animal Species Known to Occur in the Vicinity				
Target Habitat	Key Ecological Functions	Special-Status Species Associated with Target Habitat		
		Species	**Status**	**Important Attributes and Processes that Maximize Function and Habitat Value**
				channel and floodplain ► Saturated soils or standing water through July ► Minimal conifer encroachment ► Absence of brown-headed cowbird
		Mule Deer (*Odocoileus hemionus*)	No formal status; however, population declining and threatened. Regionally important and considered a species of management concern by local, state, and federal agencies. Gray Creek watershed is positioned within core migration range.	► Meadows or wide riparian corridors ► Aspen stands ► Moderate shrub cover near water ► Relatively undisturbed areas during fawning season
		Sierra Nevada Mountain Beaver (*Aplodontia rufa californica*)	Designated by DFG as a Species of Special Concern. Rare species associated with riparian corridors and wet meadows in the Sierra Nevada; occurs near the Gray Creek watershed	► Riparian corridors or wet meadows with dense riparian shrub cover ► Permanent water (e.g., perennial streams) ► Soft soil for burrowing

Table 4.2: Nomenclature Cross-reference between Nevada GAP Vegetation Classification, CALVEG-WHR Classification and Classification Developed for Vegetation Map of Gray Creek Watershed

Vegetation Type in Gray Creek Vegetation Classification	Corresponding Vegetation Types in:	
	Nevada GAP Classification	**CALVEG-WHR Classification**
Barren	Barren Lands, Non-specific; Sierra Nevada Cliff and Canyon; Mediterranean California Alpine Bedrock and Scree	Barren
Annual Grass	Invasive Annual Grassland	Annual Grass
Perennial Grass	Inter-Mountain Basins Semi-Desert Grassland	Perennial Grass
Sagebrush	Inter-Mountain Basins Montane Sagebrush Steppe; Inter-Mountain Basins Big Sagebrush Shrubland	Sagebrush
Montane Chaparral	Great Basin Semi-Desert Chaparral	Montane Chaparral; Bitterbrush
Juniper	Great Basin Pinyon-Juniper Woodland; Inter-Mountain Basins Mountain Mahogany Woodland and Shrubland	Juniper; Montane Hardwoods Conifer
Jeffrey Pine	Mediterranean California Ponderosa-Jeffrey Pine Forest and Woodland	Jeffrey Pine; Eastside Pine
Sierran Mixed Conifer	Mediterranean California Dry-Mesic Mixed Conifer Forest and Woodland	Sierran Mixed Conifer; White Fir
Red Fir	Mediterranean California Red Fir Forest and Woodland	Red Fir
Subalpine Conifer	Inter-Mountain Basins Subalpine Limber-Bristlecone Pine Woodland; Sierra Nevada Subalpine Lodgepole Pine Forest and Woodland; Northern Pacific Mesic Subalpine Woodland	Subalpine Conifer; Lodgepole
Fresh Emergent Wetland	Mediterranean California Subalpine-Montane Fen; North American Arid West Emergent Marsh	Fresh Emergent Wetland
Montane Riparian	Rocky Mountain Subalpine-Montane Riparian Shrubland; Rocky Mountain Subalpine-Montane Riparian Woodland; Great Basin Foothill and Lower Montane Riparian Woodland and Shrubland	Montane Riparian; Aspen
Other	Open Water; Agriculture; Blank	Lacustrine; Riverine

Table 4.3: Description of Vegetation Types in Gray Creek Vegetation Classification	
Vegetation Type	**Description**
Barren	Barren areas or lacking or have a low cover of trees or shrubs (i.e., <25% combined), and where exposed soil and rock is more extensive than herbaceous vegetation; these areas include cliffs, slopes covered in loose scree
Annual Grass	Annual grasses are the dominant species (in the Gray Creek watershed primarily cheatgrass [*Bromus tectorum*]); Tree cover < 10%, Shrub cover < 50% and herbaceous cover with greater cover than shrub layer
Perennial Grass	Perennial grasses are the dominant species; Tree cover < 10%, Shrub cover < 50% and herbaceous cover with greater cover than shrub layer
Sagebrush	Mountain sagebrush (*Artemisia tridentata* ssp. *vaseyana*) is the dominant species; Tree cover < 10%, Shrub cover > 50%, Herbaceous cover varies
Montane Chaparral	Tree cover is < 10%; Shrub cover is > 50% with important species including greenleaf manzanita (*Arctostaphylos patula*), pinemat manzanita (*Arctostaphylos nevadensis*), snowbrush ceanothus (*Ceanothus velutinus*), huckleberry oak (*Quercus vaccinifolia*), and Sierra gooseberry (*Ribes roezlii*); and herbaceous cover is < 25%
Juniper	Sierra juniper (*Juniperus occidentalis*) is the dominant tree species, and curlleaf mountain mahogany (*Cercocarpus ledifolius*) is an important associated species; Tree cover > 10% but low, and shrub and herb cover vary widely
Jeffrey Pine	Jeffrey pine (*Pinus jeffreyi*) is the dominant tree species; shrub cover and species composition varies widely; and, herbaceous cover is typically sparse (< 25%)
Sierran Mixed Conifer	Dominant species include Jeffrey pine and white fir (*Abies concolor*), and associated species include Sierra juniper, red fir (*Abies magnifica*), and lodgepole pine (*Pinus contorta*); Tree cover > 10%, shrub and herb cover varies widely
Red Fir	Red fir (*Abies magnifica*) is the dominant tree species; shrub cover and species composition varies widely; and, herbaceous cover is typically very sparse (< 10%)
Subalpine Conifer	Dominant and important tree species include whitebark pine (*Pinus albicaulis*), mountain hemlock (*Tsuga mertensiana*), lodgepole pine (*Pinus contorta*), and red fir; shrub cover and species composition varies, but is generally sparse; herbaceous cover is typically sparse (< 25%)
Fresh Emergent Wetland	Wetland dominated by herbaceous plants, which may include a variety of species.
Montane Riparian	Combined cover of tree and shrub layers is > 75%; herbaceous cover is > 25%; the predominant woody plants are black cottonwood (*Populus trichocarpa*), mountain alder (*Alnus incana ssp. tenuis*), Lemmon's willow (*Salix lemmonii*), and Scouler's willow (*Salix scouleriana*); except for black cottonwood, which is a large tree, these species grow as shrubs or small trees, in a typically dense layer; the herbaceous layer varies widely in cover and species composition.
Other	In the Gray Creek watershed, this category includes small areas mapped as agricultural, open water, or left blank in the Nevada GAP or CALVEG data layers.

4.2.4 Field Surveys

Riparian and Adjacent Upland Habitats

On August 29 and September 14, 2006, a rapid assessment of the Gray Creek watershed was conducted to assess existing habitat conditions and support the development of habitat enhancement or restoration concepts. The purpose of the assessment was to document the attributes of the mainstem, west fork, and north fork of Gray Creek and adjacent uplands. Attributes included the gradient, flow regime, and observations regarding the condition of the channel bed, channel banks, and adjacent riparian and upland areas.

The field assessment was stratified by stream reach to evaluate and geo-reference existing conditions on a reach-by-reach basis. The stream reach locations and nomenclature followed the reach delineation completed by USFS as part of its 2006 stream inventory of Gray Creek (Figure 2.9; USDA Forest Service, 2006a). The rapid assessment covered reaches MF1, MF2, and MF4 of the main stem of Gray Creek (lower Gray Creek); reaches WF1 and WF2 of the west fork, and a tributary of the west fork; and reach NF1 of the north fork. Although the GIS and aerial photo analysis covered the entire watershed, the field assessment focused on reaches outside the Mount Rose Wilderness boundary. It was assumed that potential restoration actions could be implemented only outside the Wilderness Area.

Riparian and aquatic habitat characteristics of each stream reach were recorded while walking the entire length of the reach and recording the presence or absence of key features, and overall characteristics of the reach. Stream features recorded included the reach type (e.g., perennial, ephemeral, seep, etc.), bankfull width and depth, substrates present, presence and characteristics of pools, barriers to fish movement, and evidence of floodplain. Characteristics of stream corridor and adjacent upland vegetation were also recorded. Riparian habitat attributes were characterized by plant community type and dominant species present, structure and cover classes of woody and herbaceous vegetation, corridor width, and evidence of conifer encroachment within the riparian vegetation zone. The same vegetation community characteristics were recorded for upland vegetation within 50 meters of the edge of the stream corridor. Also, where invasive plant species were observed, species, size and cover of infestation, and recruitment information were recorded. Appendix 4 includes an example field data form showing the specific variables recorded during field visits. Representative photographs were taken of each reach, and locations of breaks between reaches were recorded using a Thales MobileMapper CE GPS unit. All field-collected data were entered into the project's GIS database and will be provided to the TRWC as a separate submittal.

Overall reach condition and habitat restoration opportunities were assessed based primarily on 1) the presence or absence of significant stressors or limiting factors to habitat quality due to anthropogenic sources (e.g., land uses or other disturbances) or natural disturbances, and 2) the potential to substantially improve habitat conditions by implementing enhancement or restoration actions. Observed anthropogenic and natural sources that limit habitat quality were documented and mapped using a GPS unit, and representative photographs were taken (see Photos Section). Criteria used to preliminarily assess habitat restoration potential at these sources were the following.

- Is the observed disturbance or land use condition adversely affecting the distribution and productivity of native species or communities?
- Would restoration actions considerably improve habitat conditions for native flora or fauna over the long term, and are those actions likely to persist and succeed within the natural disturbance regime of the watershed?
- Are appropriate restoration actions feasible and cost-effective considering the location, access to, and physical setting of the problem area?

The TRWC uses a set of filter factors to identify and prioritize potential restoration projects. These factors were additionally applied to develop the list of recommended restoration projects, described in Chapter 5 (see Appendix 5 for the set of factors).

4.2.5 In-Stream Aquatic Habitat

The field survey described in the previous section also focused on a set of aquatic habitat features that could be rapidly estimated (see Appendix 4). During summer 2006, the USFS-Tahoe National Forest conducted a detailed aquatic habitat assessment of Gray Creek using the USFS Region 6 *Stream Inventory Handbook* (USDA Forest Service, 2002) protocol. Fisheries biologists from the Tahoe National Forest provided EDAW with initial summary reports of their stream inventory results (USDA Forest Service, 2006a). (The full USFS inventory reports were not available at the time of this writing.) To avoid duplication of effort and make the best use of available data, the aquatic component of this habitat assessment is based substantially on the summaries provided by USFS.

4.3 Ecological Processes

4.3.1 Terrestrial Ecological Processes

The following sections describe the vegetation dynamics (i.e., structural development, succession, and disturbances) of the major vegetation types in the Gray Creek watershed. The distribution and current condition of these vegetation types, and their related wildlife habitat functions and values, in the Gray Creek watershed are described under *Upland and Riparian Conditions.*

Change in the structure and species composition of vegetation (i.e., vegetation dynamics) results from disturbance, and the dispersal, establishment, and growth of plants. The major types of vegetation within the Gray Creek watershed differ in their dynamics, as described below for montane forests, juniper woodland, whitebark pine woodland, montane chaparral, sagebrush, and for montane riparian woodland and forest.

Montane Forests

In the Gray Creek watershed, montane forests account for a substantial portion of the vegetation (Figure 4.2, Table 4.4) and include stands dominated by Jeffrey pine (*Pinus jeffreyi*), white fir (*Abies concolor*), red fir (*Abies magnifica*), and lodgepole pine (*Pinus contorta*). These are large, long-lived tree species, and consequently, in the absence of a major disturbance, their dynamics are characterized by progressive structural changes resulting incrementally from the growth and death of canopy trees. The primary disturbances interrupting the development of late-seral stands (and removing late-seral stands) are fire, logging, and bark beetle outbreaks. The following sections describe the process of structural development in these forests and each of the major disturbance mechanisms.

Over time, as trees grow and die, the structure of a forest stand changes in a relatively predictable manner. The size of canopy trees, and of snags and downed wood, increases, and eventually canopy structure becomes more complex as younger (and smaller) cohorts of trees are recruited into the canopy. The rate of these changes and the stand structures that result differ among tree species, the resources available at a site for tree growth, and the major disturbances that occur at a site (such as fire, insect outbreaks, and logging) that may remove many, but not all, canopy trees.

In older (i.e., late-seral) stands, canopies of montane forests are dominated by trees 100–180 feet high. Jeffrey pine, and white and red fir, reach canopy size in 25–75 years, but may require another 50 years or more before reaching a large size (i.e., > 30 inches in DBH), and can often live for 200-400 years (Stuart and Sawyer, 2001). Thus, in the absence of major disturbances (e.g., insect outbreaks, catastrophic fires, timber harvests), only a small fraction (0.5–2%) of large canopy trees dies in a given year. These trees then become snags (if they remain standing after their death) or large pieces of woody debris on the forest floor.

Snags and large pieces of woody debris are eliminated through decay, fire, and removal during timber harvests. As a result of continual decay, snags eventually break apart and/or fall down, becoming downed wood (Harmon et al., 1986; Landram et al., 2002). In the absence of a major disturbance, the quantity of snags and downed wood gradually accumulate as a stand matures, eventually reaching an equilibrium level. This is one of the processes that produce the characteristic structure of late-seral stands.

Frequent fire has historically exerted a strong influence on forest structure in the Sierra Nevada, including the Gray Creek watershed. Historically, fires generally occurred at intervals of 2–20 years in Sierran conifer forests, with shorter average intervals in pine-dominated forests and longer intervals in fir forests and at higher elevations (Roy and Vankat, 1999; Taylor and Beaty, 2005). For example, in the nearby Lake Tahoe Basin, mixed conifer forests often burned at intervals of 10–15 years (Beaty, 2003), and these were fires of low to moderate intensity, which many larger trees survived. Annual variations in climate strongly influenced the likelihood of these fires (Taylor and Beaty, 2005).

During the 20th century, policies of fire exclusion were implemented throughout the region, reducing fire frequency and allowing the recruitment of large numbers of trees that would have been removed as saplings under a regime of frequent fire. As a result, many forest stands have become denser, and have higher loads of surface fuels. This change in stand structure has increased fire hazards because more intense fires, which may spread through the canopy and cause substantial tree mortality, are now much more likely.

Within the Gray Creek watershed, extensive mortality of canopy trees was caused by the Martis Fire. This fire occurred during June 2001, and burned about 12,727 acres, including two-thirds of the assessment area. Most of this acreage was classified as moderate to low intensity.

However, the fire moved into the tree canopy over large portions of the Gray Creek watershed (that were mapped as burning at moderate intensity); this removed canopy vegetation, and has had a substantial influence on the current structure of the vegetation. These effects are described in detail under *Upland and Riparian Conditions*.

Disturbance by logging shares some attributes in common with fire, including the partial or complete removal of canopy trees, and the subsequent recruitment of shrubs and tree saplings. It does not, however, provide the same seedbed and regeneration opportunities for species such as Jeffrey pine. Logging also creates a network of skid trails, landings, and roads that cause persistent effects on the movement of water and sediment. Section 2.5 describes the history of logging in the Gray Creek watershed.

Bark beetles are an important cause of tree mortality in conifer forests, including Jeffrey pine and white and red fir forests in the Gray Creek watershed. In white and red fir, fir engraver (*Scolytus ventralis*) excavates tunnels (i.e., galleries) in and feed on the living cells of the inner bark, impeding the movement of sugars and hormones from foliage to the roots. In Jeffrey pine, Jeffrey pine beetle (*Dendroctonus jeffreyi*) causes similar effects. This damages and often kills the tree (Furniss and Carolin, 1977; Wood et al., 2003).

In conifers, the tissues of the inner bark contain resin ducts, and in vigorously growing trees, resin flow inhibits bark beetle infestations. Major factors affecting tree growth include competition with other trees and annual rainfall. Slower-growing trees and trees with shorter and more ragged crowns (i.e., crowns with less live foliage) are more likely to die during bark beetle outbreaks (Ferrell et al., 1994). Stands with higher densities and basal areas contain numerous slower-growing and less vigorous trees, and mortality is concentrated in such stands (Negron and Poop, 2004; Olsen et al., 1996). Growth of white fir and Jeffrey pine is reduced during low rainfall years (Wensel and Turnbloom, 1998) making mortality more likely.

There is also a relationship between fire and bark beetle outbreaks (Geizler et al., 1980; Bradley and Tueller, 2001; Shaffer and Laudenslayer, 2006). Trees damaged by fire are more vulnerable to bark beetle infestation, and thus bark beetle infestations often increase following fire. The Martis fire damaged large numbers of trees throughout much of the watershed, and so elevated levels of bark beetle infestation are likely.

Juniper Woodlands

In the Gray Creek watershed, juniper woodlands are widely distributed (Figure 4.2, Table 4.4); they are primarily on steep rocky ground. These open woodlands are dominated by Sierra juniper (*Juniperus occidentalis*), and locally by curlleaf mountain mahogany (*Cercocarpus ledifolius*). Tree cover is generally low (< 20%) and cover in the shrub and herbaceous layers is generally discontinuous and often low.

The dynamics of woodlands dominated by Sierran juniper and mountain mahogany differ from montane forests in several important aspects. These include smaller tree sizes, slower growth of trees, greater tree longevity, and longer intervals between stand-replacing disturbances. These woodlands generally occur on rockier, shallower soils on which tree growth is slower and vegetation is relatively patchy. In addition to being slow-growing, the tree species that dominate these sites are very long-lived: curlleaf mountain mahogany can live for over 700 years and Sierra juniper can live for 2,000–3,000 years (Stuart and Sawyer, 2001; Gucker, 2006). Consequently, change in structure (and in species composition) is slow in the absence of major disturbance. And, because of the limited and discontinuous fuels in many of these woodlands, stand-replacing fire is a relatively rare event—despite these tree species being vulnerable to mortality from fire (Tirmenstein, 1999a; Gucker, 2006). Therefore, the dynamics of these woodlands tend to result in ancient stands with very stable structures.

Whitebark Pine Woodlands

In the Gray Creek watershed, whitebark pine (*Pinus albicaulis*) dominates woodlands at the highest elevations (in the subalpine zone), primarily in the West and Middle Fork subwatersheds (Figure 4.2, Table 4.4). In these woodlands, whitebark pine grows in clumps with multiple trunks; the cover of these clumps varies widely, and the height of the trunks ranges from about 20 to 40 feet in height.

Whitebark pine woodlands generally occur on rockier, shallower soils on which tree growth is slower and vegetation can be relatively patchy. In addition to being slow-growing, the species is very long-lived; whitebark pine can live for 400–700 years (Stuart and Sawyer, 2001). Consequently, change in structure is slow in the absence of major disturbance. And, because of the high elevation of, and often discontinuous distribution of fuels in, these woodlands, stand-replacing fire is a relatively rare event. Whitebark pine is vulnerable to mortality from fire, but also is a bird-dispersed species that colonizes recently burned sites (Tirmenstein, 1999a; Howard, 2002). Therefore, the dynamics of these woodlands involve very infrequent disturbances that can kill most trees in a stand, but after which whitebark pine tends to reestablish (rather than being replaced by other species). .

White pine blister rust is a fungal canker disease that can infect and kill large numbers of white pines, including whitebark pine (which forms extensive stands at high elevations in the Gray Creek watershed). The rust fungus which causes the disease (the introduced *Cronartium ribicola*) requires two hosts to complete its life cycle: a white pine species and a gooseberry or currant species (*Ribes* species). (*Ribes* species are abundant and widespread in the Gray Creek watershed.) In portions of the Cascades, northern Idaho, and western Montana severe white pine blister rust infections have prevented whitebark pine stands from developing in some timberline areas (Arno and Hoff, 1990). This has not occurred in the Gray Creek watershed or the surrounding region, but could occur in the future.

Montane Chaparral

In the Gray Creek watershed, montane chaparral varies from a closed to discontinuous canopy of shrubs and may be dominated by a variety of species (some of which are listed in Table 4.3). Montane chaparral is widespread in the Gray Creek watershed, but accounts for only a small portion of vegetation in the West and Middle Fork subwatersheds (Figure 4.2, Table 4.4).

The dynamics of montane chaparral are closely related to fire (Hanes, 1977, California Interagency Task Force Group, 2002). Because the crowns of chaparral shrubs are at or within several feet of the ground surface, they are killed by fire. However, many chaparral shrubs produce new shoots from their stem bases. These "sprouters" include tobacco brush (*Ceanothus velutinus*), huckleberry oak (*Quercus vaccinifolia*), choke cherry (*Prunus virginiana*), and bitter cherry (*Prunus emarginata*). Some sprouters and a number of non-sprouters also have a soil seedbank of dormant seed that are stimulated to germinate following fire. Species that develop a dormant seedbank include tobacco brush and other *Ceanothus* species, and manzanita (*Arctostaphylos*) species such as greenleaf (*Arctostaphylos patula*) and pinemat Manzanita (*Arctostaphylos nevadensis*).

Following fire, sprouts and seedlings rapidly restore the shrub layer. For example, in 2006, in areas where the shrub layer was consumed by the Martis Fire in 2001, it had already reformed in montane chaparral, with mature, reproducing shrubs up to 6 feet in height.

In the interval between fires, establishment of additional shrubs is limited, although additional shrubs do establish, as may tree species and a variety of herbaceous plants characteristic of forest understories as well. However, on many sites, most change during intervals between fires results from the continual growth of tree saplings that also establish following fire.

On many sites, montane chaparral is successional to woodland or forest vegetation. Chaparral shrub species are widespread in the understory of conifer forests. Thus, with their extensive post-fire recruitment from the seedbank and rapid growth, these shrubs dominate many forest sites following fires that remove most of the tree canopy. On these sites, the rates of establishment and growth of conifers determine the duration of chaparral between fires.

Crown fires that remove the tree layer and result in post-fire dominance of the site by chaparral shrubs also can reduce or practically eliminate post-fire establishment of trees by:

- Eliminating on-site seed sources if all trees are killed,
- Limiting dispersal of tree seeds onto the site if trees have been eliminated from a large area, and
- Competing with and reducing the growth and survival of tree seedlings that do become established.

If there is limited regeneration of conifers following a fire, or if a subsequent reburn eliminates conifer regeneration, the chaparral patches that originate post-fire can persist for decades. For example, in the nearby Griff Creek watershed, a large patch of chaparral developed on a previously forested site following a fire between 1952 and 1966 (EDAW, 2006). The patch has persisted largely unaltered to the present. In contrast, another chaparral patch that existed nearby in the Griff Creek watershed in 1966 had extensive conifer recruitment by the 1980s and by the 1990s it had largely filled in with conifer forest. Similarly, chaparral has replaced forest for up to sixty years at several sites in the southern Lake Tahoe Basin that experienced high intensity, stand-replacing fires between 1890 and 1987 (Russell et al., 1998).

In the Gray Creek watershed, patches of montane chaparral have formed in areas where the Martis Fire killed most conifers, and in some of these patches, conifer recruitment is very limited and the newly formed chaparral patches will likely persist for decades. These areas are described further in *Upland and Riparian Vegetation Conditions.*

Sagebrush

In the Gray Creek watershed, sagebrush occurs in all subwatersheds, although it accounts for very little of the vegetation in the Main Stem subwatershed (Figure 4.2, Table 4.4). This vegetation type is dominated by mountain sagebrush (*Artemesia tridentata* ssp. *vaseyana*), which is a shrub to 3 feet in height. Mountain sagebrush often lives to 40–50 years of age, and can establish in its own shade and in spaces between shrubs (Turminstein, 1999b). Thus, in the absence of fire, sagebrush may be self-perpetuating, or increase in density. Fire strongly influences the dynamics of sagebrush-dominated habitat. Sagebrush does not resprout after fire. Although some viable seed may survive a fire, sagebrush has relatively short-lived seed, and its wind dispersed seed generally do not travel far from the parent plant.

Consequently, frequent fires often convert sagebrush-dominated areas to other vegetation types. Invasion by cheatgrass (*Bromus tectorum*) increases the continuity and quantity of fuels within sagebrush-dominated vegetation, and thus increases fire-induced sagebrush mortality and fire frequency (Young, 2000). Both effects can substantially reduce the abundance of sagebrush. Cheatgrass is widespread and abundant within the Gray Creek watershed.

Montane Riparian Woodland and Forest

Along most reaches of Gray Creek and its tributaries, corridors of riparian vegetation are continuous but less than 100 feet wide, and often are less than 50 feet wide. (Although riparian vegetation is wider in some locations, most wide zones mapped by Nevada GAP and shown in Figure 4.2 are misclassifications of upland vegetation.) The riparian vegetation includes a tree layer dominated by black cottonwood (*Populus balsamifera* ssp. *trichocarpa*) or quaking aspen (*Populus tremuloides*), and a shrub layer dominated by mountain alder (*Alnus incana* ssp. *tenuis*), Lemmon's willow (*Salix lemmonii*), and Scouler's willow (*Salix scouleriana*). White fir and lodgepole pine are also locally important in the tree layer, and red osier dogwood (*Cornus sericea*) and thimbleberry (*Rubus parviflorus*) are widely distributed and locally dominant in the shrub layer. Patches may have both tree and shrub layers or the tree layer may be discontinuous or absent; the shrub layer is present almost throughout the riparian corridor.

The dynamics of this riparian vegetation are closely related to fires and floods. The shoots of the dominant angiosperms (black cottonwood, quaking aspen, willow species, red osier dogwood, and thimbleberry) are all killed by fires of even low intensity; however, these species all subsequently produce sprouts from their stem bases or roots. In contrast, the conifer species that occur in riparian zones have shoots that are not killed by light intensity fires, but if shoots are killed they do not produce new shoots from their stem base or roots. The shoots of many riparian trees and shrubs were killed by the Martis Fire, and many patches of riparian vegetation are dominated by post-fire sprouts (as described in *Upland and Riparian Vegetation Conditions*).

Flood events disturb vegetation by scour, burial, uprooting, and inundation (Malanson 1993; Mitsch and Gosselink, 1993; Freidman and Auble, 1999; Keddy, 2000). The frequency and magnitude of these disturbances are related to a stream's flow regime, and within a stream corridor, these disturbances are more frequent and intense at lower elevations (i.e., nearer the stream channel) than at higher elevations.

Plants differ in their vulnerability to mortality during flood events based on their size and species. Seedlings are readily uprooted, or killed by scour, burial, or prolonged inundation. In contrast, mature plants are rarely completely uprooted, and larger plants are difficult to bury completely or to completely inundate for prolonged periods during the growing season. Even mature plants of most species have shoots that are readily killed through abrasion by coarse sediment. However, many species (including black cottonwood and willow species) will produce new above-ground shoots from their stem bases or below-ground shoots (i.e., rhizomes).

Within the Gray Creek watershed, the large quantities of sediment transported through the stream network result in relatively frequent and intense scour and burial. Consequently, there are large areas of recent sediment deposits that are sparsely vegetated, and patches of young plants that established following recent flood flows.

For successful recruitment, many riparian-associated plants depend on specific hydrologic events before, during, and immediately following their seed release periods. Many species, especially species that are small-seeded and shade-intolerant, such as black cottonwood, require establishment sites that are largely free of competition from existing vegetation. The erosion and deposition of sediment along stream channels and on floodplains creates such surfaces.

After dispersal and germination, plant seedlings grow on surfaces ranging from immediately below peak-flow to immediately above low-flow elevations. Most seedlings do not survive their first year on these surfaces. Seedlings may desiccate on higher elevation surfaces, or be killed by flows during the following winter and spring. These flows may inundate all surfaces supporting seedlings, and seedlings may be scoured from those surfaces inundated with sufficient depth and velocity of water to mobilize the surface (Friedman and Auble, 1999). Such scouring is most likely on lower-elevation surfaces.

Once riparian trees and shrubs are established, shrubby thickets develop within several years, and black cottonwood can form a tree layer within a period of 10–20 years (DeBell, 1990). Black cottonwoods may live for over 100 years, and although shoots of quaking aspen and willow species are shorter-lived, these species regularly produce additional shoots from the base of their stems.

In the absence of fire and flood disturbance, conifers may establish within riparian areas. Conifers, in particular white fir, can tolerate and grow in the shade of riparian trees and shrubs, and have a narrower crown and can reach much greater heights than black cottonwood, quaking aspen, alder, or any of the willow species. Conifers can grow between or through the crowns of riparian trees and shrubs and overtop them. Because most riparian trees and shrubs are not shade-tolerant, their growth and survival are substantially reduced by over-topping conifers.

Consequently, encroachment by conifers not only results in increased conifer cover but also results in decreased cover of black cottonwood, quaking aspen, and willows in riparian areas. This process has recently been thoroughly evaluated for quaking aspen stands in the Sierra Nevada (Shepperd et al., 2006). In the Gray Creek watershed, conifer encroachment is widespread in riparian forests and woodlands that were not disturbed by the Martis Fire or recent floods.

4.3.2 Aquatic Ecosystem Processes

Environmental Patterns Affecting Processes

Like terrestrial environments, primary environmental patterns that influence aquatic ecosystems include hydrology, topography and geology, and soils. In the Gray Creek watershed, all of these patterns combine to support geomorphic processes that create, maintain, or change aquatic habitats, which in turn influence the types of aquatic communities present.

Streamflow patterns in particular play a significant role in aquatic habitats and are governed by precipitation, snow pack and runoff, temperature, and groundwater. The formation and maintenance of habitat types (e.g., pool, riffle, run) and substrate composition are directly influenced by streamflow patterns and associated fluvial geomorphic processes. In Gray Creek watershed streams, aquatic habitat is also heavily influenced by substantial inputs of sediments from upslope sources and large woody debris (LWD); the abundance of both appears to be largely a result of the Martis Fire (USDA Forest Service, 2006a).

Aquatic habitats resulting from streamflow patterns, topography, and LWD inputs dictate the abundance and types of organisms present in the watershed streams. Both the flow needs for sustaining fisheries and other aquatic life, and the amount, timing, and variability of flow are important in relation to the overall ecosystem function. Salmonids, such as Lahontan cutthroat trout (*Oncorhynchus clarki henshawi*) (LCT), require sufficient flows (and cold temperatures) to cue spawning and to provide spawning habitat. Eggs require clean gravel and sufficient flows during the incubation period to prevent egg exposure to freezing or desiccation, and to provide necessary water quality and temperature conditions. Rearing juveniles and adults both require flows necessary to maintain suitable water temperatures and dissolved oxygen concentrations. Aquatic macroinvertebrate communities, an important trophic link in aquatic ecosystems, require appropriate streamflows, water quality, and substrate conditions.

Groundwater connections in the form of springs and seeps are primary sources of hydrology supporting perennial streams and are vital to maintaining riparian ecosystems in the Gray Creek watershed. Fish populations in the watershed rely on these springs and seeps to provide cold baseline flows, especially during dry summer months. Aquatic invertebrates also are believed to rely on springs and seeps to provide habitat quantity and quality, and input of primary production. Changes in precipitation, snowpack, and groundwater quality and levels could have an effect on springs and seeps; however, the incidence and/or extent of this relationship are unclear.

Riparian and adjacent upland vegetation affect the types and quality of aquatic conditions within stream habitats along Gray Creek. Shade generated by large tree canopy decreases water temperatures, while low overhanging branches in the understory can provide sources of food by attracting terrestrial insects. As riparian areas mature or are physically disturbed (e.g., by fires or floods), vegetation falls into the streams, creating structurally complex habitat consisting of LWD that provides refugia from predators, creates water-velocity gradients, and provides habitat for aquatic invertebrates. Due to the steepness of and disturbance frequency in the Gray Creek watershed, aquatic habitat processes there are strongly affected by LWD and other physical inputs from the riparian corridor and adjacent uplands.

Fish and Aquatic Macroinvertebrate Community Structure

Fish and aquatic macroinvertebrate communities in Gray Creek and its tributaries are determined by several factors. The number and kinds of species present can be attributed to several ecological mechanisms: dispersal, physiological tolerances, biological interactions among species, and environmental disturbances. All of these mechanisms are affected by both natural and anthropogenic influences and have varying relationships with other factors. For example, a species ability to effectively disperse and colonize may be affected by passage barriers and localized habitat conditions. Physiological tolerances of sensitive species may exclude them from specific habitats including those that are degraded or altered. Biological interactions between species are heavily influenced by human introductions of nonnative species and habitat modifications that may favor one species over another. Individual species response to environmental disturbances may vary depending on several factors. Typically biological interactions (e.g., predation and competition) are important community structuring agents in physically stable and complex aquatic ecosystems, whereas the ability to disperse and colonize may be more important in aquatic environments subject to harsh recurrent disturbances (Schlosser, 1987). The latter condition is typical of the Gray Creek watershed.

The presence of nonnative salmonids greatly affects the viability of LCT populations in the Gray Creek watershed and throughout its entire range. Additionally, species tolerance to high elevation, high gradient, swift water conditions and ability to disperse and colonize are likely important ecological mechanisms that play a considerable role in structuring of the aquatic community in the watershed. For example, it is believed that throughout history localized, natural events caused the local extirpation of small populations of LCT in the Truckee River basin (TRIT, 2003). Those events included landslides and rock falls, fires, drought, and debris flows that restricted movement. LCT population persistence through those events was associated with the ability to maintain connectivity among populations (i.e., networked populations/systems), which allowed individuals to migrate, disperse, and/or recolonize into areas where fish had been locally extirpated (TRIT, 2003). This periodic recolonization by upstream or downstream sources enabled LCT to survive extreme circumstances and provided for genetic exchange (Ray et al., 2000; Neville-Arsenault, 2003). Because the Gray Creek watershed has numerous fish passage barriers (USDA Forest Service, 2006a) (see additional discussion below) and is especially prone to natural disturbance events, this is an important consideration for LCT recovery planning in the watershed. Additional discussion on these processes as they relate to conditions in the watershed is provided below.

4.4 Upland, Riparian, and Aquatic Habitat Conditions

This section first describes the habitat characteristics of each subwatershed based on the field assessment, GIS, and aerial photograph analysis, and data review; it then describes the distribution of observed invasive plant species, summarizes key riparian habitat functions with respect to wildlife communities in general and special-status animal species in particular, and describes aquatic ecosystem conditions throughout the watershed. Representative photographs taken of each stream reach evaluated during the field assessment are located in the *Photographs* section of this report. Several of these photos are referenced specifically in the following text.

4.4.1 Upland and Riparian Vegetation Conditions

In the Gray Creek watershed, there are many rocky, sparsely vegetated areas and a large portion of the watershed was burned by the Martis Fire (Figures 2.13 and 4.1). Consequently, vegetation varies extensively in its cover, structure and species composition (Figure 4.2).

Most of the watershed is covered by subalpine and montane woodlands and forests. Subalpine woodlands and forests include stands of whitebark pine (Photo 4-33), mountain hemlock, and lodgepole pine. Montane forests and woodlands include Jeffrey pine forests and woodlands, mixed conifer forests, juniper woodlands, and red fir forests (which are in the upper montane and transitional to the subalpine forests).

Other upland vegetation includes montane chaparral, sagebrush, and grasslands (Table 4.4). Riparian vegetation consists primarily of stands of black cottonwood and shrub-dominated riparian scrub with mountain alder, willow species, red osier dogwood, thimbleberry. Some quaking aspen and lodgepole pine stands are also present within riparian areas, and at high elevations some wetlands have been mapped by the Southwestern GAP (USGS, 2004) along tributary streams.

The following sections provide a summary by subwatershed of vegetation structure prior to and following the Martis Fire both in uplands and along streams. All subwatersheds, however, share several attributes that have significance for habitat values. These attributes include:

- Extensive areas of steep, rocky terrain where fire fuels are discontinuous (Photo 4-10). In these areas, fires will tend to be patchy skipping some areas and burning others with variable intensity. The combination of varied (but generally stressful) environmental conditions and heterogeneous patterns of disturbance causes these sites to have diverse, slowly changing vegetation. These also tend to be actively eroding sites.
- Stream corridors bordered by steep terrain and large quantities of coarse sediment are being transported by the streams (Photo 4- 8). The width of riparian vegetation is limited to a narrow band 10–100 feet wide because of these physical constraints. Furthermore, the disturbances created by both flood flows (especially scour and burial) and fire repeatedly affect the riparian vegetation, and mature stands of large black cottonwoods are largely absent.
- Extensive areas within which most or all trees were killed by the Martis Fire, and within which there is little or no conifer regeneration (Photo 4- 22). As indicated in the section describing the dynamics of montane chaparral, shrubs may continue to dominate these sites for at least several decades. (These sites also have dense concentrations of snags and downed coarse woody debris.)
- Many stands of upper montane and subalpine forest that were not affected by the Martis Fire and many of these also were not affected by other recent fires or previous logging.

North Fork

Prior to the Martis Fire, most of the North Fork subwatershed was occupied by Jeffrey pine and juniper woodlands, montane chaparral, and sagebrush (Table 4.4). Subalpine conifer forests and upper montane forests of red fir occupied only about a quarter of the watershed. A conspicuous feature of this watershed is the sparsely vegetated ridge of hydrothermally-altered, acidic andesite along its boundary with the subwatershed of the Middle Fork. Along the North Fork of Gray Creek, adjacent upland vegetation was primarily a mosaic of Jeffrey pine forest and woodland, juniper woodland, and montane chaparral. However, along the eastern, higher elevation, section of the stream was red fir forest, subalpine conifer forest, and some perennial grassland (Figure 4.2).

Table 4.4: Percentage of Subwatershed Area in Each Vegetation Type

Vegetation Type	Subwatershed			
	West Fork	**Middle Fork**	**North Fork**	**Main Stem**
Barren	2	7	1	4
Annual Grass	0	0	0	12
Perennial Grass	0	0	1	0
Sagebrush	6	8	8	1
Montane Chaparral	5	4	13	38
Juniper	10	21	14	21
Jeffrey Pine	20	17	31	19
Sierran Mixed Conifer	0	0	0	2
Red Fir	27	16	21	3
Subalpine Conifer	27	25	5	0
Fresh Emergent Wetland	1	0	0	0
Montane Riparian	2	2	6	0
Other	0	0	0	1
Total	**100**	**100**	**100**	**100**
Subwatershed Acres	**5,120**	**3,136**	**1,536**	**1,600**

The Nevada GAP data layer maps several large areas of montane riparian vegetation along the North Fork of Gray Creek. Review of aerial photographs indicates that, although some of these polygons do represent wider areas of riparian vegetation, several areas are erroneously mapped uplands and others contain both riparian and upland vegetation. In the North Fork subwatershed, most streams are bordered by a narrow corridor, less than 15 feet wide, of shrub-dominated riparian vegetation.

The Martis Fire burned over 80% of the North Fork subwatershed. In the northern portion of this subwatershed, the fire created moderately severely burned areas; in the southern portion, areas of low severity burn (Tetra Tech, 2005). Within many burned areas the fires effects were variable because of steep topography, frequent rock outcrops and cliffs, and sparse and discontinuous vegetation. Burned areas were primarily below about 8,000 feet in elevation. Therefore, red fir and subalpine conifer forests were less affected by the fire than other vegetation types.

Within its perimeter, the Martis Fire burned most riparian vegetation, but willows, mountain alder, black cottonwood and quaking aspen have produced abundant sprouts from their stem bases, and a wide variety of perennial forbs, grasses, sedges and rushes have produced abundant new growth. As a result, a narrow band of shrub-dominated riparian scrub has developed along the stream channel, and continued growth of black cottonwood sprouts should create some riparian woodland in the next few years. The adjacent uplands also were burned, but where fuels were sparse and discontinuous, as in woodlands of juniper and mountain mahogany, many trees and shrubs survived the fire.

At higher elevations, outside of the fire's perimeter, tree cover along the North Fork remained low. Riparian vegetation had little tree cover, and was dominated by dense patches of shrubs (alder, willows, and red osier dogwood) that formed a riparian scrub. The adjacent uplands consisted of comparable acreages of open forests, shrub lands, and areas that were barren or dominated by herbaceous vegetation.

Main Stem

Prior to the Martis Fire, most of the Main Stem subwatershed was occupied by montane chaparral, juniper woodland, and Jeffrey pine forest. Unlike the other subwatersheds of Gray Creek, the lower elevation Main Stem subwatershed virtually lacks upper montane red fir forest and subalpine conifer forest (Table 4.4, Figure 4.2). This subwatershed also is the only subwatershed with extensive annual grassland, within which the invasive species cheatgrass is abundant.

Along the Main Stem of Gray Creek, prior to the Martis Fire, the adjacent upland vegetation was relatively open, and consisted of a mosaic of Jeffrey pine forest and woodland, juniper woodland, montane chaparral, and rock outcrops. In the downstream reaches of the Main Stem (Reaches MF1 and MF2), the riparian corridor, which is up to 200 feet wide, but typically about 65–80 feet wide, consisted primarily of patches of black cottonwood and sparsely vegetated gravel bars. In the upper Reaches (Reaches MS3 and MS4), the stream becomes narrower, with a deeper channel bordered by narrow (< 10-foot wide) bands of riparian vegetation consisting of mountain alder, black cottonwood, and willow species.

The Martis Fire effectively burned this entire subwatershed at a moderate or low severity level (Tetra Tech, 2005). However, many stands of uplands were severely burned while other areas escaped the fire. Much of this subwatershed is extremely steep, with many rock outcrops and cliffs, which create breaks in fuels, and fuels were variable and discontinuous in most vegetation types. Consequently, numerous small pockets of vegetation were not burned, and in some lightly burned areas, trees and even some shrubs were not killed by the fire, which apparently was a surface fire of less intensity and/or duration in some areas. In addition to the disturbance by fire, large quantities of coarse sediment have buried or scoured extensive areas of riparian vegetation.

Nonetheless, in the stream corridor, some riparian vegetation was not directly affected by these disturbances. Riparian vegetation still includes a number of black cottonwood stands dominated by mature trees 1–2 feet in DBH. Other black cottonwood stands have been partially or completely top-killed (i.e., stems were killed but the root system survived to produce new shoots), but already have tree-sized sprouts 1–6 inches in DBH forming a new tree canopy. In the understory of these stands, and throughout the riparian area there is a patchy shrub layer with several willow species, mountain alder, and red osier dogwood.

In addition to a mosaic of mature and recently disturbed black cottonwood stands, a distinctive feature of the Main Fork's stream corridor is extensive gravel bars and recent deposits of sediment. These sparsely vegetated areas occupy nearly half of the stream corridor, and are thicker and more extensive than in the upstream subwatersheds. A variety of upland and riparian shrubs and herbs have established on these surfaces including sand bar willow (*Salix hindsii*), mountain alder, bitterbrush (*Purshia tridentata*), mountain mahogany, rabbitbrush (*Chrysothamnus nauseosus*), willow herb (*Epilobium ciliatum*), common monkeyflower (*Mimulus guttatus*), and common horsetail (*Equisetum arvense*).

Even after the Martis Fire, the upland vegetation adjacent to the Main Stem of Gray Creek still consisted of Jeffrey pine woodland, rock outcrops, and montane chaparral/scrub. The Jeffrey pine woodland had a very sparse cover of trees (some of which were killed by the fire) over a discontinuous cover of shrubs (a 10 to 25% cover of bitterbrush and sagebrush), and grasses and perennial forbs. Much of the existing montane chaparral was Jeffrey pine woodland or forest prior to the fire, but the fire killed most trees, and a dense shrub layer has developed from seedlings that established after the fire and post-fire sprouts. This shrub layer is dominated by choke cherry and bitter cherry, but also contains greenleaf manzanita, tobacco brush, bitterbrush, and a variety of shrubs, many of which are also common in the discontinuous shrub layer of rock outcrops and cliffs, and in the shrub layer of Jeffrey pine woodlands.

Middle Fork

Prior to the Martis Fire, most of the Middle Fork subwatershed was occupied by upper montane forests of red fir, subalpine conifer forests, and montane Jeffrey pine and juniper woodlands (Table 4.4). At lower elevations (below 8,000 feet), riparian vegetation formed a discontinuous narrow corridor along streams. At higher elevations, riparian vegetation varied from a 100-foot wide corridor to a narrow band of willows (or even was absent). Along the Middle Fork, and its tributaries, juniper woodland accounted for much of the adjacent vegetation; Jeffrey pine, montane chaparral, and sage also were widespread. At higher elevations (above 8,000 feet), conifer forest (particularly lodgepole pine) accounted for much of the adjacent vegetation.

Conspicuous features of this watershed include the sparsely vegetated ridge of hydrothermally-altered, acidic andesite along its boundary with the subwatershed of the North Fork, and extensive areas of sparsely vegetated subalpine/alpine scree-covered slopes.

The Martis Fire burned about half of the Middle Fork subwatershed (Figure 4.1). In the northern portion of the subwatershed most areas were low severity burned; in the southern portion, most areas were moderately severely burned. A small severely burned area occurred at the junction with the Main Stem of Gray Creek (Tetra Tech, 2005). Much riparian vegetation was top-killed by the fire, and a shrub-dominated scrub is the primary vegetation along streams. Sparsely vegetated areas (including sediment deposits) are frequent along stream channels. The adjacent uplands still include areas of Jeffrey pine and juniper woodlands, but also include more extensive areas of montane chaparral and sparsely vegetated barrens.

Although the Martis Fire burned up to 9,000 feet in elevation in some areas, most areas over 8,000 feet were not burned. Therefore, higher elevation forests and woodlands were less affected by the fire than other vegetation types in this subwatershed. At the highest elevations, subalpine forests are dominated by whitebark pine; hemlock (*Tsuga heterophylla*) and lodgepole pine are important as well. The upper montane forests are dominated by red fir or lodgepole pine. Some of the red fir forests are late-seral, with large snags and trees (i.e., > 30 inches in DBH).

West Fork

In the West Fork subwatershed, most areas burned by the Martis Fire were below 8,000 feet in elevation; consequently, the upper montane and subalpine vegetation that occupy over half of this subwatershed were mostly unaffected by the fire (Table 4.4). These higher elevation forests are concentrated in the southern portion of the subwatershed (Figure 4.2). The uppermost sections of tributaries to the West Fork of Gray Creek include extensive areas of lodgepole pine forest, a narrow corridor of riparian scrub with several areas where riparian vegetation was much wider (over 50 feet in width), and some wetlands that have been mapped as fens (USGS, 2004). Several areas of perennial grassland also were mapped at high elevations in this and in other subwatersheds; most of these areas are relatively open (and sometimes rocky) areas up to several hundred feet across within juniper or subalpine woodlands, and some appear to be dominated by low scattered shrubs and forbs.

The northern (and lower elevation) portion of the West Fork subwatershed contained primarily Jeffrey pine forests and woodlands, with lesser amounts of juniper woodlands, montane chaparral, and sagebrush (Figure 4.2). Prior to the Martis Fire, Jeffrey pine forest and juniper woodland were adjacent to most of the West Fork's length below 8,000 feet. Riparian vegetation along reaches WF1 and WF2 was dominated by black cottonwood or mountain alder; conifers also were important and some quaking aspen were present. The width of the stream corridor (i.e., stream channel plus adjacent riparian vegetation) ranged from 10 to 80 feet but was typically 15 to 25 feet.

The Martis Fire burned a substantial portion (about 39%) of this subwatershed and most of the area below 7,500 feet in elevation. Most of the northeast portion of the watershed was mapped as moderately burned and most of the northwest portion was mapped as a burned area of low severity (Tetra Tech, 2005). These mapped severities are inaccurate, because in this subwatershed, large areas of Jeffrey pine forest were severely burned. In areas of 10 to 100 acres, every canopy tree was killed by fire that burned through the canopy and consumed all but the larger lateral branches.

Within the burned area in the uplands adjacent to the West Fork, almost all trees (most of which were Jeffrey pine or white fir) were killed, and only widely scattered conifers remain. There has been little recruitment of conifer seedlings and saplings in these areas. (Along Reach WF2, there were, however, some areas where fire burned under but did not kill canopy trees.) Throughout the burned area, seedlings and sprouts that originated post-fire have grown into a relatively dense shrub layer (mostly 40–80% cover and 2–4 feet in height). This layer is dominated by chokecherry and tobacco bush.

Within the fire perimeter, some patches of riparian vegetation have not been burned (primarily along Reach WF2). These areas were dominated by a mixture of white fir and black cottonwood trees 1–2 feet in DBH, and a well-developed shrub layer with 60–80% cover. Most riparian vegetation, however, was shrub-dominated riparian scrub with mountain alder, thimbleberry, red osier dogwood, and sprouts of black cottonwood and willow species. Most of this riparian scrub was tree-dominated prior to the Martis Fire, and as tree sprouts continue to increase in size, patches of tree canopy are reforming.

Noteworthy vegetation along the lower reaches of the West Fork of Gray Creek (Reaches WF1 and WF2) includes:

- A distinctive feature along Reach WF1 was a large perennial seep covered by patches of willow and by diverse herbaceous vegetation (including a small floating mat of mosses).
- A distinctive feature along the western tributary of the West Fork was stands of mid- to late-seral conifer forest on the slope to the east. These stands were dominated by white fire with red fir, Jeffrey and lodgepole pine, and juniper. Some of these stands had been partially cut by logging in recent decades; others, however, do not appear to have had any trees removed for at least fifty years. These less disturbed stands had a multi-layered canopy structure with most canopy trees only 1–2 feet in DBH but also with many larger trees.
- A distinctive feature at the junction of the western tributary with the West Fork was several acres of mature black cottonwood forest with white fir and some lodgepole pine. This stand had canopy trees 1–2 feet in DBH (many of which were decadent and had crowns with broken tops, dead limbs, or cavities) and a dense understory of mountain alder and tree saplings (mostly white fir but some cottonwood root sprouts).

The higher elevation reaches within the Wilderness area were not assessed as part of the field survey. However, USFS included these reaches in their stream assessment (USDA Forest Service, unpublished data). They noted a diverse riparian corridor along Reach WF3 that included areas dominated by black cottonwood, red fir, and aspen, including a large aspen stand (with Basque tree carvings) along the upper portion of the reach. Along Reach WF4, the lower portion included areas dominated by aspen, and in the upper portion of the reach, lodgepole pine dominated the riparian vegetation.

4.4.2 Invasive Plant Species

Through human transport, thousands of plant species have established populations beyond their prior range. Of these, some have become invasive, and their rapid expansion in range and local abundance has caused substantial ecological change. Invasive species may reduce the cover and diversity of native species, alter water or nutrient availability, increase fire hazards, or alter wildlife habitats (D'Antonio and Vitousek, 1992; Mack et al., 2000).

In general, infestations of invasive plants initiate where soil and vegetation has been disturbed. Seeds and fragments of invasive plants frequently are introduced into these areas, and the removal of vegetation creates opportunities for these introduced propagules to develop into established plants. Through growth and reproduction, these plants may subsequently spread throughout the disturbed area, and some invasive species may spread into adjacent, undisturbed vegetation as well.

In the Gray Creek watershed, riparian areas and upland areas that were severely burned are particularly susceptible to invasion. Riparian areas are frequently invaded because their high levels of resource availability and frequent natural disturbance provides opportunities for a wide variety of invasive species to establish, and their linear and connected nature facilitates the spread of invasive species. Catastrophic wildfires also create opportunities for invasive species to establish and spread in areas previously occupied by a high biomass of native vegetation that would not have been invaded by most species. Efforts to contain wildfire, prevent post-fire erosion, and salvage timber often introduce invasive species to disturbed sites where they are likely to establish and spread.

Several invasive species have been documented in comparable habitats in the vicinity of the Gray Creek watershed (Table 4.5); these species could be present in the watershed or become established in the near future. Many of these species invade riparian areas, and several species of these nonnative invasive plants were observed during the field assessment (Table 4.6). Observed species were cheatgrass, musk thistle (*Carduus nutans*), bull thistle (*Cirsium vulgare*), woolly mullein (*Verbascum thapsus*), and Russian thistle (*Salsola tragus*).

Cheatgrass can alter fire regimes and interfere with establishment of native species from seed (Young, 2000). It alters fire regimes by creating continuous fine fuels in sagebrush and woodland habitats that previously lacked an even distribution of such fuels, and where the dominant trees and shrubs are vulnerable to mortality from fire. Thus, vegetation types can be converted by its invasion. It was abundant and widespread along the lower elevation reaches, and could cause substantial effects in much of the watershed.

The other observed species have less potential to alter ecosystems. Both musk thistle and bull thistle can become locally abundant and displace native species (Randall, 2000; Kadrmas and Johnson, 2003). Woolly mullein and Russian thistle are considered to cause only limited adverse effects on ecosystems (Cal-IPC, 2006). Both occurred as scattered individuals and did not dominate the vegetation in local areas; woolly mullein, however, occurred over large areas in both upland and riparian habitats.

The distribution and abundance of nonnative invasive species within each subwatershed is described further in the following sections; and included in the GIS data layers by stream reach (and the location of some discrete infestations is also included in the GIS data layers).

Main Stem of Gray Creek

Throughout this subwatershed, including the stream corridor (the riparian area and adjacent uplands), cheatgrass was widely distributed and generally abundant. Other invasive species observed during the field assessment were woolly mullein, Russian thistle, musk thistle, and bull thistle. Widely scattered individuals of woolly mullein occurred on gravel bars, in riparian vegetation, and adjacent uplands. Widely scattered individuals of Russian thistle occurred on gravel bars and sparsely vegetated stream banks near the downstream end of Reach MF1. Musk thistle was observed at just one site that consisted of several individuals in an area of $< 500\ ft^2$ in a disturbed black cottonwood stand. Bull thistle occurred in widely scattered infestations along the entire length of the Main Stem, typically consisting of just several individuals.

North Fork

Throughout the uplands adjacent to reach NF1, cheatgrass was widespread and abundant. It also was present, but less abundant, within the riparian area of this stream reach. (The upstream distribution of cheatgrass is not known because the field assessment did not extend further up the North Fork.) Scattered individuals of woolly mullein and bull thistle also were widely distributed in riparian vegetation along this reach.

Table 4.5: Nonnative, Invasive Plant Species Potentially Occurring in the Gray Creek Watershed[1]

Species	Observed	Growth Form	Habitat(s)
Russian knapweed *Acroptilon repens*	No	Clonal, perennial forb	Riparian areas
Cheatgrass *Bromus tectorum*	Yes	Annual grass	Grasslands, sagebrush, open areas in forests and woodlands
Musk thistle *Carduus nutans*	Yes	Biennial forb	Riparian areas
Whitetop/Hoary cress *Cardaria draba*	No	Clonal, perennial forb	Riparian areas, wetlands
Canada thistle *Cirsium arvense*	No	Clonal perennial forb	Grasslands
Bull thistle *Cirsium vulgare*	Yes	Biennial forb	Riparian areas, grasslands
Diffuse knapweed *Centaurea diffusa*	No	Annual forb	Grasslands, open shrublands and woodlands
Spotted knapweed *Centaurea maculosa*	No	Non-clonal, perennial forb	Grasslands
Yellow starthistle *Centaurea solstitialis*	No	Annual forb	Grasslands
Poison hemlock *Conium maculatum*	No	Biennial forb	Riparian areas, seasonal wetlands, moist grasslands
Klamathweed *Hypericum perforatum*	No	Perennial forb	Riparian areas, grasslands
Tall whitetop/Perennial pepperweed *Lepidium latifolium*	No	Clonal, perennial forb	Riparian areas, wetlands, montane meadows
Oxeye daisy *Leucanthemum vulgare*	No	Non-clonal, perennial forb	Montane meadows
Dalmatian toadflax *Linaria genistifolia* ssp. *Dalmatica*	No	Non-clonal, perennial forb	Grasslands, forest openings
Purple loosestrife *Lythrum salicaria*	No	Non-clonal, perennial forb	Wetlands, riparian areas
White sweetclover *Melilotus alba*	No[3]	Biennial forb	Riparian areas
Scotch thistle *Onopordum acanthium*	No	Biennial forb	Grasslands, riparian areas, sagebrush
Medusahead grass *Taeniatherum caputmedusae*	No	Annual grass	Grasslands, Juniper woodland

Notes:
[1] – Based on Donaldson et al. 2004, Tetra Tech 2005
[2] – Observed during 2006 field surveys of Main Stem reaches 1,2, and 4; West Fork reaches 1, 2; West Fork Tributary 1; and North Fork Reach 1.
[3] – Observed just outside of the watershed along the Truckee River.

Middle Fork
The field assessment did not include stream reaches within the Middle Fork subwatershed. Therefore, the distribution and abundance of nonnative invasive plants in this subwatershed is not known.

Table 4.6: Nonnative, Invasive Plant Species Observed During the Field Assessment in Riparian Corridor of the Gray Creek Watershed

Species	Impact on Ecosystems[1]	Abundance	Reaches Observed[2,3]	Habitat(s) Observed
Cheatgrass *Bromus tectorum*	High	Ubiquitous	MS1, MS2, MS4, NF1, WF1	Uplands, riparian areas (gravel bars, dry banks)
Bull thistle *Cirsium vulgare*	Moderate	Small infestations	MS1, MS2, MS4, NF1, WF-T1, WF1	Riparian areas, perennial seep
Musk thistle *Carduus nutans*	Moderate	Small infestations	MS1, NF1, WF2,	Riparian areas
Woolly mullein *Verbascum thapsus*	Limited	Scattered individuals	MS1, MS2, MS4, NF1, WF1	Uplands, riparian areas
Russian thistle *Salsola tragus*	Limited	Scattered individuals	MS1	Gravel bars and banks in riparian area

Notes:
1 – Based on Cal-IPC 2006
2 – Reach codes are: MS = Main Stem, NF = North Fork, WF = West Fork, and WF-T = West Fork tributary
3 – Field assessment included MS1, MS2, MS4, NF1, WF1, WF2, and WF-T1.

West Fork
Several invasive plant species occurred along the West Fork, including: cheatgrass, woolly mullein, bull thistle, and musk thistle. Cheatgrass was widespread and abundant in all vegetation types in the northern third of Reach WF1, but was largely absent from stream corridors and adjacent uplands further upstream. Woolly mullein occurred as occasional individuals in open riparian and upland areas. Both bull thistle and musk thistle occurred in small infestations of several individuals, the largest of which was about half an acre in size.

4.4.3 Riparian Habitat Functions

This section first provides an overview of riparian habitat functions and values in the Sierra Nevada bioregion, which includes the Gray Creek watershed, to establish a general reference of potential conditions and factors that affect habitat quality for wildlife; then summarizes the riparian habitat conditions and functions of the Gray Creek watershed. Aquatic habitat conditions and functions are described in section 4.4.4 (*Aquatic Resources Conditions*). Environmental patterns and ecological processes that affect or shape these functions are discussed separately in previous sections. Although upland habitats are important components of the Gray Creek watershed, and their overall conditions are described in the previous sections of this chapter, riparian habitats are the focus of this section based on the project's scope.

Riparian Functions in the Sierra Nevada Bioregion

Riparian habitats are transitional between an aquatic source (e.g., stream, pond, subsurface water) and terrestrial uplands. They are distinguished by unique ecological processes and biological communities, a biophysical linkage between surface or subsurface hydrology and surrounding uplands, sharp ecological gradients, and high primary productivity and biological diversity (Keddy, 2000, Brinson et al., 2002 *cited in* Jones & Stokes, 2004; USDA Forest Service, 2001b; RHJV, 2004). In the Sierra Nevada, important forms of riparian habitat include linear riparian corridors along streams and deciduous shrub components of wet meadows. Specific functions of riparian habitat in this region include the following:

- Biological functions, including maintenance of native aquatic and terrestrial vegetation communities; maintenance of movement, foraging, and breeding habitat for a variety of aquatic and terrestrial wildlife species; contribution to local and regional biological diversity; provision of habitat for neotropical migrant bird communities; and provision of habitat linkages between locations within and across watersheds.

- Biogeochemical functions, including primary production; carbon storage; and phosphorus, nitrogen, and micronutrient cycling.

- Hydrologic and geomorphic functions, including ground water recharge, surface water storage, sediment and organic matter transport, sediment storage, and maintenance of channel and floodplain landforms. (Keddy, 2000 and Brinson et al., 2002 *cited in* Jones & Stokes 2004.)

Many of the wildlife species found in the Sierra Nevada near the Gray Creek watershed are dependent on aquatic or riparian communities or use riparian environments for some aspect of their life history. In this portion of the Sierra Nevada, which is transitional between the relatively dry Great Basin and wetter Sierra Nevada biomes, wildlife species diversity and abundance are greater in riparian and stream environments than any other habitat type (Sands and Howe, 1977; Thomas et al., 1979). Many of these species are entirely dependant on the riparian corridor or adjacent aquatic environments for all or part of their life histories. Of approximately 400 terrestrial vertebrate species in the Sierra Nevada, approximately one-fifth (84 species) are dependent on riparian areas (Graber, 1996). In the Sagehen Creek basin, a tributary of the Little Truckee River near the Gray Creek watershed, around 40 percent of vertebrate species are strongly dependent on riparian habitat (Morrison et al., 1985). Similarly, a large proportion of vascular plants are strongly associated with riparian areas (Graber, 1996).

Riparian areas provide habitat for aquatic and terrestrial organisms such as aquatic insects, insectivorous birds, aquatic reptiles, amphibians, and mammals. Riparian habitats are among the most productive and species-rich areas in the Sierra Nevada bioregion, and support a high proportion of neotropical migrant landbird species (i.e., birds that breed in North America and winter in the neotropics). Riparian areas provide some of the most important habitat for neotropical migrants that breed in or migrate through the western United States. These areas function as breeding habitat, as well as important stopover areas during spring and fall migration. Riparian habitat degradation and loss may be the most important cause of landbird population declines in western North America (RHJV, 2004). Conservation of neotropical migrants and other riparian biota has received considerable attention over the past 15 years due to local and widespread population declines of species within these groups (see Hagen and Johnston, 1992).

Riparian zones influence the habitat value of associated streams and uplands. Many of the species associated with or using riparian habitats also use upland habitats, and uplands immediately adjacent to riparian zones also influence conditions in riparian zones and streams, particularly in mountainous terrain such as the Gray Creek watershed, where riparian corridors are narrow. Therefore, stream corridors, riparian zones, and adjacent uplands are integrated landscape units in the Gray Creek watershed.

Although some riparian-associated or aquatic species that occur in the Sierra Nevada, such as mountain yellow-legged frog (*Rana muscosa*) and willow flycatcher, are practically restricted to riparian and stream corridors or wet meadows, other species use adjacent upland vegetation as well. For example, many amphibian and reptile species, although strongly associated with streams and adjacent riparian vegetation, use adjacent uplands for foraging or refugia. Similarly, many bird species that breed in riparian areas, such as Macgillivray's warber (*Oporonis tolmiei*) and yellow warbler (*Dendroica petechia*), also forage in adjacent upland vegetation.

Conversely, streams and their associated riparian areas are important to many wide-ranging and upland species, including bats (such as Yuma Myotis [*Myotis yumanensis*]) and mule deer. Generally, riparian scrub and woodlands are important for migratory mule deer that forage, breed, and take cover there. Optimal deer fawning habitat has been described as having moderate to dense shrub cover near forest cover and water, such as riparian zones (Leckenby et al., 1982; Wood et al., 1999 *citing* Thomas, 1979 and Hall, 1985). A source of surface water (e.g., creek or river) is especially important to mule deer (Leckenby et al., 1982, Zeiner et al., 1990a) and many other mammals. (Mule deer use of the Gray Creek watershed is addressed separately in *Special-status Species* below.)

Adjacent uplands shade riparian areas and streams, and are a source of coarse woody debris. In settings similar to the Gray Creek watershed, with steep terrain and narrow riparian vegetation zones, relatively large snags and trees in adjacent uplands can cast important shade that maintains cool, moist conditions in stream and riparian corridors. Snags and coarse woody debris provide necessary habitat elements for a variety of species. For example, western toads (*Bufo boreas*) and Pacific treefrogs (*Pseudacris regilla*) seek cover under rotting logs, and some bird species (e.g., some woodpeckers, owls, swallows and flycatchers) require large snags for nesting (Morey, 2002 a, b; Zeiner et al., 1990b; RHJV, 2004). Large pieces of woody debris are also important components of aquatic habitats (Harmon et al., 1986; Brinson et al., 2002). Because small trees and shrubs dominate most riparian vegetation, large woody debris primarily originates from snags and trees in adjacent uplands.

The species associated with riparian habitats vary considerably in their requirements for riparian vegetation structure, home range or territory sizes, and use of upland habitats. Consequently, more diverse assemblages of wildlife are associated with heterogeneous, wide, and contiguous riparian corridors bordered by natural upland vegetation. Amphibian and reptile species use a variety of microhabitats including both sunny and shaded conditions. Mammal species often require dense vegetation close to the ground for cover. Many breeding bird species use primarily early successional and shrub-dominated vegetation; other bird species prefer late-successional vegetation with taller trees and snags.

Overall, the species richness of riparian and stream corridors increases with their width, continuity, and presence of surface water or saturated soils in the stream channel and adjacent floodplain. For birds, this has been demonstrated by numerous studies in a variety of riparian ecosystems including studies in California (Keller et al., 1993; Dickson et al., 1995; Sanders and Edge, 1998; Kilgo et al., 1998; Rottenborn, 1999; Hagar, 1999; Hannon et al., 2002; Heath and Ballard, 2003; Jones & Stokes, 2004). The importance of wide, contiguous corridors may be related to increased habitat heterogeneity in larger corridors, absence of interior habitats in narrower, fragmented corridors, and corridors of greater area supporting species with larger home ranges.

Width and continuity also affect the use of riparian and adjacent uplands as movement corridors. Very narrow corridors or corridors fragmented by development or lacking dense cover, may not be used by some species. In particular, if riparian and adjacent upland does not meet a species' habitat requirements, it may not be used for dispersal and hence will not provide a suitable corridor connecting habitat patches, particularly for smaller, less mobile animals (Noss et al., 1996; Rosenberg et al., 1997; Brinson et al., 2002).

In addition to riparian vegetation characteristics, habitat suitability for some riparian-associated bird species is a function of hydrologic conditions. For example, important characteristics of meadows and riparian corridors suitable for breeding willow flycatchers include a high water table that results in standing or slow-moving water, or saturated soils (e.g., "swampy" conditions), during the breeding season; abundant riparian deciduous shrub cover (particularly willow); and riparian shrub structure with moderate to high foliar density that is uniform from the ground to the shrub canopy (Sanders and Flett, 1989, Bombay, 1999, Green et al., 2003). More complete reviews of biophysical characteristics, ecological functions, status, and trends of riparian and aquatic habitats are included in Keddy (2000), USDA Forest Service (2001), Brinson et al. (2002), and RHJV (2004).

Gray Creek Riparian Habitat Overall Condition and Functions

Within the Gray Creek watershed, riparian (including aspen stands) and aquatic habitats are among the most ecologically significant resources. These habitats are sensitive and key biological resources to be considered in watershed management. Riparian habitats in the study area include montane riparian woodland and forest comprised primarily of stands of black cottonwood, and shrub-dominated riparian scrub with mountain alder, willow species, dogwood, and thimbleberry. Some quaking aspen and lodgepole pine stands are also present within riparian areas. These vegetation types were described in a previous section of this chapter.

The quality and value of these habitats for native wildlife communities and sensitive or special-status species vary considerably over the watershed. The environmental patterns and ecological processes described in section 4.3 (*Ecological Processes*) strongly affect habitat distribution, composition, and quality, as well as riparian corridor width and continuity, in all subwatersheds and reaches.

Wildlife habitats in the study area are shaped primarily by a range of sharp environmental gradients, particularly variation in topography and geomorphology, soils, and natural disturbances. Natural disturbances that strongly influence wildlife habitats in the watershed include fire, frequent landslides, and other types of mass soil movements due to steep terrain. There are many steep, rocky, sparsely vegetated areas, and a large portion of the watershed was burned by the 2001 Martis Fire (Figure 4.1). The effects of the Martis Fire were extensive and are described in detail under *Upland and Riparian Conditions*. Importantly, the existing habitat conditions within much of the Gray Creek watershed are in a recovery or successional period following recent fire; and their functions and values overall and for particular species will change through time.

Overall, riparian habitats in the watershed are characterized by stream corridors with discontinuous vegetation cover bordered by steep, rocky terrain (Photos 4-8 and 4-10); and within which large quantities of coarse sediment are being transported. The width of riparian vegetation in all subwatersheds and reaches is limited to a narrow band 10–100 feet wide by these physical constraints, which substantially limits the habitat value for wildlife (see discussion of riparian corridor width in the previous section). Furthermore, both flood flows and fire repeatedly disturb most of this riparian vegetation, and mature stands of large riparian trees (e.g., black cottonwood, aspen) are very limited in extent.

In the Lake Tahoe-Truckee region, riparian habitats generally support an exceptionally rich avian and mammal community and contribute a disproportionately high amount to landscape-level species diversity. However, most riparian habitat in the Gray Creek watershed is narrow and patchy, with fast-moving water mostly confined in the stream channel, and its overall value is limited. Generally, the riparian corridors in most of the Gray Creek watershed provide low to moderate overall habitat value for avian communities relative to other montane riparian areas in the Lower Truckee River watershed (e.g., Sagehen Creek, Martis Creek, Schaffer Creek). This is a very general characterization based on observed corridor widths and continuity, vegetation structure, and frequency of standing or slow-moving water or saturated soils in the stream channel and adjacent floodplain. Avian species richness and population abundance generally increase as a function of these variables. Additionally, only a small amount of potential amphibian habitat was observed by USFS biologists during their surveys (see *Aquatic Resources Conditions*, below).

Despite this overall characterization relative to other nearby watersheds that are more biologically diverse, the Gray Creek watershed provides valuable habitat for a variety of wildlife species. Due to the watershed's steep topography, the more mesic conditions provided by the riparian zone are restricted to narrow corridors along seasonal and perennial streams. Although Gray Creek's North Fork, West Fork, and Main Stem riparian corridors represent a small proportion of the landscape, they provide important habitats and affect the habitat values of adjacent uplands. For example, in some locations, these areas provide the primary water source for important upland species such as mule deer and black bear (*Ursus americanus*). During the EDAW and USFS field surveys, several mule deer and signs of their presence (e.g., tracks, scat), and signs of black bears, were observed within or immediately adjacent to the riparian corridor in all subwatersheds. Several common riparian-associated bird species are known or likely to use portions of the Gray Creek riparian corridors during the breeding and migration seasons, including Wilson's warbler (*Wilsonia pusilla*), song sparrow (*Melospiza melodia*), warbling vireo (*Vireo gilvus*), and MacGillivray's warbler (*Oporornis tolmiei*). Also, American dipper (*Cinclus mexicanus*), a regionally uncommon species associated with high-gradient montane streams, was observed using the stream channel regularly by EDAW and USFS biologists.

Table 4.7 summarizes key points about existing physical habitat conditions by each stream reach evaluated by EDAW, as well as anthropogenic sources of disturbance, identified during the field survey. The following section discusses habitat functions specifically for special-status species.

Special-status Species

Based on the results of this habitat assessment, the historic and present potential for occurrence of several special-status animal species known to occur near Gray Creek were found to be naturally low due to the biophysical characteristics of the watershed, and not primarily limited by land uses. Therefore, managing the watershed or enhancing habitat specifically for those species may not be an appropriate or feasible objective. Table 4.8 summarizes the relevant habitat associations and ecology of special-status wildlife species, known or potential for their occurrence, suitability of the Gray Creek watershed for these species, and potential land use effects on habitat. Special-status fish species (Lahontan cutthroat trout) are addressed in the following section (*Aquatic Resources Conditions*).

Land Use Constraints to Habitat Functions

Several natural and anthropogenic disturbances have been documented in the Gray Creek watershed. However, nearly all existing constraints to riparian habitat functions for common and special-status wildlife species within the Gray Creek watershed are caused by natural environmental patterns and disturbances rather than anthropogenic sources. Table 4.7 summarizes potential land use effects on the riparian corridor in general; Table 4.8 summarizes potential land use effects or constraints on habitat specifically for special-status wildlife species.

4.4.4 Aquatic Resources Conditions

Aquatic Habitat

Aquatic resource conditions in the Gray Creek watershed include flow-related habitat types, instream cover (e.g., boulders and LWD), and riparian elements (e.g., vegetation and instream tree and shrub debris). Generally, all of these habitat components provide structure and complexity that benefit the diversity and abundance of aquatic species.

The structure and complexity of aquatic habitat varies throughout the Gray Creek watershed. The following sections provide a summary by subwatershed of aquatic habitat conditions in streams. All subwatersheds, however, share several attributes that have significance for habitat values. These attributes include:

- The general streamflow patterns in the Gray Creek watershed streams are typical of high Sierra tributaries and are influenced by winter snow storms and snow pack accumulation followed by spring warming and runoff. Occasionally the winter snow pack is greatly reduced by warm storms (rain on snow events) in mid-winter that rapidly melt the snow pack and cause flooding.

Table 4.7: Summary of Riparian Corridor Habitat Conditions by Subwatershed and Stream Reach			
Reach ID	Summary of Riparian Corridor Condition	Photographs of Reach	Anthropogenic Effects or Constraints on Habitat Function
Main Stem Gray Creek			
MF1	Lowest reach in watershed, located almost entirely on private property. Reach has been heavily to severely affected by fire and flooding. The January 2006 floods in particular moved large sediment, altered streambed location, and transported large woody debris (LWD) and sediment throughout the reach. Abundant post-fire cottonwood regeneration. Gravel bars dominate the channel/canyon (60%), followed by recovering black cottonwood. No amphibian breeding habitat found by USFS. Estimated stream corridor width (feet): typical = 65, minimum = 35, maximum = 150.	Photos 4-1, 4-2, 4-3, 4-4, 4-5, 4-6	One low-water (road) crossing to access private home in the main canyon was altering streamflow (Photos 4-4 and 4-5), and could block fish passage. Numerous constraints for restoration include property ownership and potential for flooding.
MF2	Typical of the Main Fork, this reach is located at the bottom of a very steep canyon with numerous major sediment sources including landslides and side drainages, damage from fire, and channel alterations from major flood events (e.g., January 2006). More dense and abundant riparian cover than reach MS1. Excellent cottonwood and shrub regeneration; shrubs, especially *Prunus* spp., abundant. High levels of black bear (*Ursus americana*) activity and deer sign observed. No amphibian breeding habitat found by USFS. Pacific treefrog (*Hyla regilla*) was observed by EDAW biologists during field surveys. Estimated stream corridor width (feet): typical = 80, minimum = 30, maximum = 200.	Photos 4-7, 4-8, 4-9, 4-10	No significant sources identified.
MF4	Short reach located between the confluence of the West and North Forks at the upper burn perimeter of the 2001 Martis Fire. Adjacent forests were intact, with evidence of a less severe underburn present in most locations except for near the mouth of the West Fork. Near the West Fork mouth, fire severity was high and stand-replacing. The channel was deeply incised (> 3 meters [10 feet]) above and below a 50-meter (164-foot) section of bedrock-confined "narrows." Abundant riparian vegetation, dominated by alder and willow, with many rock outcrops and LWD. No amphibian breeding habitat found by USFS. Estimated stream corridor width (feet): typical = 10, minimum = 3, maximum = 40.	Photos 4-29, 4-31	No significant sources identified.

West Fork Gray Creek			
WF1	Lowest reach of West Fork, located in very steep canyon with severe, stand-replacing fire damage in most areas. Very little conifer tree regeneration observed, but excellent cottonwood/riparian regeneration. Stream corridor generally narrow (7.5 meter [25 feet]), but widens in a few locations, and has greater abundance of cottonwoods in those wide locations. A seep/spring on the south/east slope provides some wet meadow-type habitat. Small amount of amphibian habitat found by USFS, limited to side channel pools, perennial tributaries. Estimated stream corridor width (feet): typical = 25, minimum = 10, maximum = 80.	Photos 4-26, 4-27, 4-28	No significant sources identified.
WF2	Stream corridor is similar to WF1, with abundant cottonwood/riparian regeneration, although stream channel is less steep than in WF1. Very little, if any, conifer tree regeneration in severely burned areas. Alder-dominated riparian vegetation in most locations. Beaver (*Castor candadensis*) sign noted in this reach; deer sign abundant. Very small amount of amphibian habitat found by USFS, limited to pools in small side channels or tributaries. Estimated stream corridor width (feet): typical = 20, minimum = 10, maximum = 60.	Photos 4-20, 4-21, 4-22, 4-23, 4-24, 4-25	One blown-out road may be a minor sediment source (Photo 4-20).
WF-T1	Tributary to West Fork; confluence is at the top of WF2 and just below Wilderness boundary. Reach is perennial, with willow/alder riparian, and cottonwood stands. Not affected by fire, but had signs of recent logging in adjacent forests. Small amount of potential amphibian habitat associated with seep/tributary. Estimated stream corridor width (feet): typical = 15, minimum = 10, maximum = 30.	Photos 4-11, 4-12, 4-13, 4-14, 4-15, 4-16, 4-17, 4-18	At the upper edge of the surveyed reach, an old road diverts a seep/tributary that joins WF-T1, causing some erosion and altering stream function in that location (Photos 4-11 through 16). A second blown-out road crossing is present through a portion of the reach and may be degrading stream function (Photo 4-18).
North Fork Gray Creek			
NF1	Narrow, densely vegetated riparian corridor. Reach showed signs of underburn only; no evidence of severe or stand-replacing fire. No human disturbance observed. Steep canyon, remote location. No amphibian breeding habitat noted by USFS. Estimated stream corridor width (feet): typical = 15, minimum = 4, maximum = 30.	Photo 4-32	No significant sources identified.

Table 4.8: Habitat Associations and Existing Conditions for Special-status Wildlife Species

Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
Mountain yellow-legged frog (*Rana muscosa*)	Mountain yellow-legged frogs (MYLFs) are found in upper elevation lakes, ponds, tarns, and slow moving alpine streams (Zeiner et al., 1988). While some populations have been located at elevations as low as 4,500 ft or lower, the majority of Sierra Nevada populations are found between 6,000 and 12,000 feet (Zweifel, 1955). Mountain yellow-legged frogs are almost always found within one meter of water, and are associated with montane riparian habitats in lodgepole pine, ponderosa pine, jeffery pine, sugar pine, white fir, whitebark pine, and wet meadow vegetation types (Zweifel, 1955; Zeiner et al., 1988; Bradford et al., 1993). Alpine lakes inhabited by mountain yellow-legged frogs generally have grassy or muddy margin habitat, although below treeline sandy and rocky shores may be preferred (Zweifel, 1955). Adult frogs are typically found on rocks or in open shoreline with little or no vegetation. A variety of shoreline habitats may be used by MYLFs, but shorelines with shallow regions near the shore margin may be preferred due to warmer water temperatures, and for predator avoidance (Bradford et al., 1993; Jennings and Hayes, 1994). Suitable stream habitat can be highly variable, from high gradient streams with plunge pools and waterfalls, to low gradient sections through alpine meadows (Center for Biological Diversity and Pacific Rivers Council 2000). Low gradient streams are preferred, since breeding and tadpole development cannot occur in streams with fast-moving water. All substrate types, including sand, gravel, and cobbles are used. Stream margin can also be highly variable, from wet meadow margin to willow riparian corridor. Small streams are generally unoccupied and have no potential breeding locations due to the lack of depth for overwintering and refuge (Jennings and Hayes, 1994). While mountain yellow-legged frogs have been observed successfully breeding in shallow locations less than two meters deep (Pope, 1999), typically depth is an important factor for breeding locations since MYLF adults and larvae require overwintering habitat. For up to nine months, MYLF adults and larvae will live/hibernate below ice, or in non-frozen portions of ponds or lakes, so adequate depth (>2m) is necessary to avoid having the pond or lake freeze through. Mountain yellow-legged frog tadpoles must overwinter for at least one year, and may spend up to three years, before metamorphosis takes place. Eggs are usually deposited on rocks, gravel, under banks, or attached to vegetation immediately following snowmelt and breaking up of surface ice. Mountain yellow-legged frog movement is generally confined to within close proximity of breeding locations, although some frogs may migrate away from breeding sites. Typically, MYLF will regulate body temperature by moving between sunny basking sites and underwater refuges. Similarly, tadpoles will congregate in shallow water near the shoreline of lakes and ponds, and will move to deeper water when disturbed. In winter, tadpoles will remain in warmer water below the thermocline (thermally stratified water) in lakes (Bradford, 1983).	**Occurrence:** The Museum of Vertebrate Zoology collections database (MVZ 2001) includes one record of MYLF collected by H. Fitch on 7 August 1935, from 0.5 mile of the mouth of Gray Creek. The specimen location was written as "0.5 mi. above mouth Gray Creek." The geographic coordinates provided in the MVZ database place the occurrence outside the Gray Creek watershed, above the stream mouth but on the north (opposite) side of the Truckee River and Interstate 80. An interpretation by CNDDB (2006) of the original description places the occurrence in the Gray Creek canyon 0.5 mile upstream of the mouth (in reach MS1). There is considerable error/uncertainty in both locations. Although MYLF could occur seasonally in portions of the watershed, this species is not known or likely to breed in most reaches evaluated during this assessment. Because tadpoles require slack water, breeding does not occur in high-gradient streams. There is some potential for breeding in portions of the upper watershed (see *Habitat Conditions* below). **Habitat Conditions:** All locations evaluated by EDAW during the riparian and aquatic assessment were not considered suitable breeding habitat. Although Gray Creek provides aquatic habitat, it is not considered suitable breeding habitat for MYLF or other amphibian species due to its high gradient and fast flow. USFS biologists documented a limited amount of amphibian habitat in the following upper watershed reaches: MS5 (pond in side channel), MS 8 (meadow), and WF1, WF2, WF3, and WF4 (side channel pools, seeps, tributaries). In addition to WF1 and WF2, EDAW found a small amount of potential amphibian habitat associated with seep/tributary along WF-T1. Whether the locations documented by USFS could sustain MYLF populations was not specified. Based on EDAW's assessment of aquatic conditions in WF1, WF2, and WF-T1, MYLF breeding populations are not likely to persist there due to the lack of still or slow-moving water with size and depth sufficient to remain non-frozen

Table 4.8: Habitat Associations and Existing Conditions for Special-status Wildlife Species		
Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
		during winter. **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Some. Primary limitations to habitat suitability are natural hydrology (high-gradient) and topography. However, the following were potential sources of aquatic habitat degradation: 1) in WF2 a blown-out road may be a minor sediment source; 2) in WF-T1, the upper edge of the surveyed reach, an old road diverts a seep/tributary that joins WF-T1, causing some erosion and altering stream function in that location; and a second blown-out road crossing is present through a portion of the reach and may be degrading aquatic habitat; and 3) In WF3 an historic road runs along the right bank of this stream with some recent OHV activity noted. While the road is predominantly in the uplands, it is influencing the West Fork by trapping and diverting some tributaries. The stream is entrenched and downcut with many occurrences of erosion.

Table 4.8: Habitat Associations and Existing Conditions for Special-status Wildlife Species		
Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
Yellow Warbler (*Dendroica petechia brewsteri*)	In the Sierra Nevada, yellow warblers typically breed in wet areas with dense riparian vegetation. Breeding habitats primarily include willow patches in montane meadows, and riparian scrub and woodland dominated by willow, cottonwood, aspen, or alder with dense understory cover. Localized breeding has been documented recently in more xeric sites, including chaparral, wild rose (*Rosa* spp.) thickets, and young conifer stands (Sisegel and DeSante 1999, RHJV 2004).	**Occurrence:** Unknown; however, species could occur in low abundance where riparian understory vegetation is relatively contiguous and dense. **Habitat Conditions:** Most riparian habitat in the study area is patchy, and relatively narrow and limited in extent. No high-quality breeding habitat was observed. However, a limited amount of moderate-quality breeding habitat occurs where riparian vegetation is relatively contiguous and dense. **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Some land uses and anthropogenic disturbances (e.g., a low water road crossing in reach MS-1) have affected the riparian corridor in localized areas. Also, non-native, invasive plant infestations (e.g., bull thistle, musk thistle) are present in the riparian zone in several reaches (see Table 4.10 for details). However, the primary limitations to habitat distribution and suitability are fire effects, natural hydrology and regular flooding, soils, and topography.
Mule Deer (*Odocoileus hemionus*)	Mule deer in California generally migrate out of high elevation areas in the fall to valleys and other low-elevation areas that receive less than two feet of snow, and then return to mountainous areas as snow melts in the spring. Mule deer browse and graze, preferring the new growth of shrub vegetation, forbs, and grasses. Forage preferences vary by availability, quality, and season. In the Sierra Nevada, early to mid-successional forests, woodlands, and riparian and brush habitats are preferred due to the greater diversity of shrubby vegetation and woody cover. In addition to forage, vegetative cover is critical for thermoregulation. Suitable habitat includes a mosaic of vegetation including forest or meadow openings, dense woody thickets and brush, edge habitat, and riparian areas. Fawning habitat, used by does during birth and by newborn fawns is of critical importance for reproductive success. A diversity of thermal cover, hiding cover, succulent forage, and water are needed during fawning (Sheehy, 1978; Stuth, 1975). Optimal deer fawning habitat has been described as having moderate to dense shrub cover near forest cover and water, such as riparian zones (Leckenby et al., 1982; Wood et al., 1999 *citing* Thomas, 1979 and Hall, 1985). A source of surface water (e.g., creek or river) is especially important to mule deer (Leckenby et al., 1982; Zeiner et al., 1990a). Typical fawning habitat varies in size, but an area of 5-26 acres is adequate, with optimal fawn-rearing habitat of around 400 acres (Leckenby et al., 1982).	**Occurrence:** Mule deer summer range occurs throughout the Gray Creek watershed; critical winter range is located nearby at lower elevations. The watershed is positioned within core migration range of the Loyalton-Truckee deer herd. Several mule deer were observed during field assessments conducted in August and September 2006. There are no known fawning areas (Tetra Tech 2005). **Habitat Conditions:** Upland and riparian habitats throughout the watershed provides suitable migration and foraging habitat. Mule deer forage preferentially in sagebrush/ bitterbrush communities and in aspen/riparian habitats (Tetra Tech, 2005). A high proportion of mule deer foraging habitat was initially removed by the Martis Fire. However, post-fire recovery and productivity of shrub forage appears vigorous in many locations, and foraging habitat may be improving over much of

Table 4.8: Habitat Associations and Existing Conditions for Special-status Wildlife Species		
Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
		the watershed. **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Primary factors affecting habitat suitability are the watershed's natural hydrology and regular flooding, soils, topography, and fire. The 2001 Martis Fire initially caused mortality of shrub, herbaceous, and tree cover used by mule deer for foraging and hiding. However, vigorous post-fire recruitment of shrub and herbaceous vegetation may have recently increased foraging habitat quality. Cheatgrass, a nonnative and invasive species, is widespread and abundant throughout much of the upland and riparian vegetation along some stream reaches (see Table 4.10 for details). This species alters fires regimes, and affects regeneration of native species, including vegetation used as browse by mule deer.
Willow Flycatcher (*Empidonax traillii*)	In the Sierra Nevada, willow flycatcher habitat typically consists of montane meadows that support riparian deciduous shrubs (particularly willows [*Salix*]) and remain wet through the willow flycatcher nesting season (i.e., mid-summer). Important characteristics of meadows suitable for breeding willow flycatchers include a high water table that results in standing or slow-moving water, or saturated soils (e.g., "swampy" conditions), during the breeding season; abundant riparian deciduous shrub cover (particularly willow [Salix]); and riparian shrub structure with moderate to high foliar density that is uniform from the ground to the shrub canopy (Sanders and Flett, 1989; Bombay, 1999; Green et al., 2003). Although willow flycatchers have nested in meadows less than one acre in size, Serena (1982) and Harris et al. (1987; 1988) reported that more than 80% of occurrences were in meadows larger than 19.8 acres. A recent summary of willow flycatcher occurrence data for the Sierra Nevada indicates that occupied meadows range in size from 1 to 716 acres, and average approximately 80 acres (USDA Forest Service, 2001c). Although less common in the Sierra Nevada, riparian habitat along streams can also function as suitable habitat for willow flycatcher. However, those areas must support the hydrologic and vegetation characteristics described for suitable meadows (e.g., standing or slow-moving water, abundant and dense riparian vegetation). Stream channels that are high-gradient, deeply incised and lacking a flood plain (e.g., potential for saturated soils or standing water), and characterized by a sparse or narrow riparian vegetation corridor are not suitable for breeding willow flycatchers.	**Occurrence:** Not known to occur in the watershed; occurs nearby in the Lake Tahoe Basin and at Perazzo Meadows near Truckee. **Habitat Conditions:** Suitable nesting habitat for this species was not observed in the watershed. Gray Creek is a high-gradient stream with dry, rocky banks in most locations. The riparian vegetation distributed along Gray Creek is narrow and patchy. **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** No. Lack of suitable habitat is due to hydrology, topography, and environmental patterns.

Table 4.8: Habitat Associations and Existing Conditions for Special-status Wildlife Species

Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
Sierra Nevada Mountain Beaver (*Aplodontia rufa californica*)	Sierra Nevada mountain beavers use riparian habitats with soft, deep soils for burrowing, lush growth of preferred food sources such as willow and alder, and a variety of herbaceous species for bedding material. Vegetation types include wet meadows and willow-alder dominated riparian corridors, typically near water sources. Mountain beavers are generally solitary except during their short breeding system, and spend a high proportion of their time in extensive underground burrow systems with multiple openings, tunnels, and food caches. (Carraway and Verts, 1993; Steele, 1982; Steele and Litman, 1998).	**Occurrence:** Not known to occur in the Gray Creek watershed; populations are known to occur in riparian corridors and meadows nearby (e.g., Schaffer Creek). **Habitat Conditions:** Most riparian habitat in the Gray Creek watershed is not considered suitable, due to lack of soft, deep soils and a dense herbaceous understory within the riparian zone. Much of the substrate there is steep, rocky, and dry. Some locations in the upper portion of the watershed could support habitat for this species; but none was observed during field surveys. **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** No. Primary limitations to habitat distribution and suitability appear to be soils, topography, and the composition and structure of riparian vegetation associated with those conditions.

All subwatersheds are relatively steep (channel and upslope terrain) and aquatic habitat is influenced by heavy sediment inflows from several tributaries (from upslope sediment sources), and channel erosion and deposition. Channel activity and movement (i.e., sediment transport and deposition, and channel incision and erosion) appeared to be substantial throughout all subwatersheds. Channel movement is likely the result of sediment inputs from upslope areas. Sediment inputs have the potential to degrade aquatic habitat through several mechanisms including:

- filling of pools – pool habitat is important because pools provide habitat and thermal refugia during the summer low flow period and during periodic droughts;
- embedding cobble and gravel – degrades conditions required for salmonid spawning and macroinvertebrate production;
- increases in turbidity – prolonged exposure to high levels of suspended sediment could create a loss of visual capability in fish, leading to a reduction in feeding and growth rates; a thickening of the gill epithelia, potentially causing the loss of respiratory function; clogging and abrasion of gill filaments; and increases in stress levels, reducing the tolerance of fish to disease and toxicants (Waters, 1995); and
- episodic disturbance – sudden and heavy inputs of sediment can result in substantial episodic disturbance such that a small, isolated population of fish could be lost.

- Aquatic habitat throughout all subwatersheds consisted of steep step-pools formed by large boulders, bedrock, and LWD jams that may act as potential fish passage barriers under different flows. Potential passage barriers by subwatershed are as follows:
  - Main Stem (including Middle Fork) – total of 16 barriers (13 seasonal) ranging in height from 3 to 9 feet;
  - North Fork – total of 17 barriers (4 seasonal) ranging in height from 3 to 12.5 feet; and
  - West Fork – total of 39 barriers (9 seasonal) ranging in height from 3 to 35 feet.

  Many of these potential barriers are seasonal and/or temporary due to ongoing dynamic physical processes (e.g., movement of boulders and LWD). An abundance of log snags and upslope sources of sediment (result of Martis Fire) will continue to provide an instream recruitment source of LWD and boulders in the future.

- Most reaches evaluated during this habitat assessment and the USFS stream inventory provided low-value breeding habitat for amphibian communities, due to fast flows and lack of backwaters and calm pools. Only a small amount of suitable habitat was identified by USFS and/or EDAW biologists. This habitat was limited to the upper watershed in reaches MS5, MS8, WF1, WF2, WF3, WF 4, and WF-T1, where small pools associated with side channels/tributaries and seeps occur.

Main Stem - The Main Stem subwatershed includes reaches MF1, MF2, MF3, and MF4. The aquatic habitat in the Main Stem of Gray Creek can be characterized as having sparse riparian canopy cover and stream banks that are composed mainly of large cobbles and loose sediment with some herbaceous and woody plant species. Most of the reaches have large gravel/cobble bars on alternating banks (Photos 2-1 to 2-6). There were several natural potential fish passage barriers noted throughout the subwatershed that were formed by large boulders and LWD jams.

There were several seasonal side channels throughout all reaches of the subwatershed. Seasonal side channels can provide important winter and spring (high flow) refugia for small, young-of-year fish and can also be important areas for aquatic macroinvertebrate production. As noted above, there were many ephemeral and intermittent tributaries throughout the Main Stem subwatershed that contribute significant amounts of sediment to Gray Creek. Reach MF4 appears to contribute considerably less sediment than other reaches.

In Reach MF1 there are two private residences under construction; one near the confluence with the Truckee River, the other approximately one-half mile upstream. A bridge near the mouth provides access to the lower residence; a low water crossing to the home further upstream (Photo 2-5). The low water crossing is a potential fish passage barrier and widens the channel. There is also a historic low water crossing between the confluence of the Truckee and the bridge that is rarely used and was washed out by the New Years 2006 flood.

<u>North Fork</u> - The North Fork subwatershed had sparse to no canopy cover along all of its reaches, with the exception of the uppermost portion of Reach NF4. This part of Reach 4 did not burn as intensely as the rest of the subwatershed. The understory consisted mainly of alder with some willow, cottonwood, and dogwood. Stream banks consisted primarily of cobbles with some grasses and nettles. There were some cut banks in Reaches NF3 and NF4; however, in Reach NF4, these banks appeared to be largely revegetated.

The first 650 feet of Reach NF1 was very steep and dominated by bedrock and falls. Seasonal side channels were absent throughout the subwatershed. There were several natural potential fish passage barriers noted throughout that were formed by large boulders, bedrock chutes and falls, and LWD jams.

<u>Middle Fork</u> - The Middle Fork subwatershed includes stream reaches MF5, MF6, MF7, and MF8. The aquatic habitat in the Middle Fork subwatershed can be characterized as having sparse riparian canopy cover and stream banks composed mainly of large cobbles and loose sediment with some herbaceous and woody plant species. Most of the reaches in the subwatershed have large gravel/cobble bars on alternating banks. There were several natural potential fish passage barriers noted throughout the subwatershed formed by large boulders, bedrock chutes, and LWD jams.

There were several seasonal side channels in the subwatershed. As noted above, there were many ephemeral and intermittent tributaries in the Middle Fork subwatershed that contribute significant amounts of sediment to Gray Creek. Reach MF6 however, appeared to contribute considerably less sediment than the other reaches.

A small amount of potential amphibian habitat was identified by USFS biologists in the upper Middle Fork subwatershed along reaches MF5 (pond in side channel) and MF8 (meadow).

West Fork - The West Fork subwatershed can be characterized as having varying riparian canopy cover (sparser in the lower reaches) and an understory that consisted of alders with some willows, cottonwood, and dogwood. There was little stream bank vegetation with loose soil and cobbles in Reach WF1, whereas, Reaches WF2 through WF4 had banks that were armored with stable cobble and vegetation. There were several natural potential fish passage barriers noted throughout the subwatershed that were formed by large boulders, bedrock, and LWD jams. There were several seasonal side channels throughout the subwatershed.

Reach 3 of the West Fork appeared to provide limited fish habitat value (relative to other subwatershed reaches) due to steep gradients, high water velocities, low number of pools, and high number of potential barriers. A small amount of potential amphibian habitat was identified in the West Fork along WF-T1 (seep/tributary), and WF1, WF2, WF3, and WF4 (side channel pools, seeps, tributaries) by EDAW and/or USFS biologists.

Fisheries Resources
Based on known occurrences in the Truckee River basin, a total of seven native fish species occur or have the potential to occur in the Gray Creek watershed (Table 4.9). The overall abundance of the native fish community has declined considerably since the arrival of Euro-Americans to the region. It is believed that several factors (e.g., logging, grazing, and introduction of nonnative fish species) have contributed to the decline or extinction of native fish and the degradation of fish habitat (Sierra Nevada Ecosystem Project, 1996). Beginning in the late 1800s, many nonnative fish species were introduced into the Truckee River basin which greatly influenced the native fish community (Sigler and Sigler, 1987). Discussions of special-status, native, and nonnative fish species are provided below. Table 4.9 summarizes the relevant habitat associations and ecology of these species, known or potential for their occurrence, and suitability of the Gray Creek watershed for these species. Table 4.9 also summarizes potential land use effects or constraints on habitat for these fish species.

Special-status Fish Species: Lahontan cutthroat trout is the only salmonid native to the Gray Creek watershed. Of all the native fish species, LCT were especially revered by Native Americans because they provided ample food for their people. In the late 1800s and early 1900s the LCT supported a commercial fishery that supplied markets as far away as San Francisco. The fishery was in decline during the 1920s and finally collapsed in the early 1930s (Cordone and Frantz, 1966). The failure of this fishery and its extirpation were the result of overharvesting, habitat degradation, and the introduction of nonnative fishes (Moyle, 2002). Numerous attempts have been made to reintroduce this native trout into the Truckee River basin. In 1970, LCT was federally listed as endangered, but in 1975 it was reclassified as threatened (40 Federal Register [FR] 29864, July 16, 1975) to facilitate its management and allow angling (Benke, 1992). Approximately 100 LCT individuals were stocked in the West Fork of Gray Creek in 1983, and 66 were stocked in 1987 (USDA Forest Service, 2001a; USFWS, 1995; Kling, pers. comm., 2006). Surveys conducted in 1990 recorded 6 LCT individuals present; however no LCT were found during surveys conducted in 1998 and 2001 (Kling, pers. comm., 2006). While unlikely, it is possible that LCT may still be present in physically isolated reaches where nonnatives have not been able to become established; however, any potential presence is vulnerable to extirpation as a result of isolation (i.e., numerous passage barriers) and potential disturbances.

Other Native Fish Species: Headwaters with fast, shallow water usually contain only trout. However, the only trout native to the Gray Creek watershed – Lahontan cutthroat trout – was not found during surveys conducted in 1998 and 2001 (see previous discussion of this species). In general, moving downstream of headwaters, the first species other than trout likely to occur is Paiute sculpin (*Cottus beldingi*). As gradients decrease and pools and runs become more common, Tahoe sucker (*Catostomus tahoensis*) and speckled dace (*Rhinichthyes osculus*) can become more abundant, with Lahontan redside (*Richardsonius egregious*) in deeper pools (Moyle, 2002). The Gray Creek watershed appears to provide suitable biophysical conditions for these species. However, the ability to disperse and recolonize areas of the watershed (i.e., individual tributaries and/or segments of streams) is an important factor in the local distribution, diversity, and abundance of species throughout the watershed streams. Because the Gray Creek watershed is especially subject to natural disturbance events and streams contain numerous passage barriers, the distribution of native fish species may be patchy over the watershed.

Nonnative Fish Species: Several nonnative fish species probably occur in the Gray Creek watershed (Table 4.9). Nonnative brook trout (*Salvelinus fontinalis*) are most commonly found in high-gradient streams and headwaters, and are typically replaced by brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*) at lower elevations. Rainbow, brown, and brook trout have similar habitat requirements to native LCT and therefore are suited to similar aquatic habitats. The similar habitat requirements for both native and nonnative species presents challenges in evaluating and implementing management strategies aimed at restoring native Lahontan cutthroats and discouraging nonnatives. As stated above, a primary cause of LCT decline is due to interactions (i.e., predation, competition, and hybridization) with nonnative trout (Moyle, 2002). Cutthroat trout and rainbow trout are both spring spawners and are capable of hybridization, which can degrade genetic integrity of populations.

Aquatic Macroinvertebrates

Aquatic macroinvertebrates are common and important components of aquatic environments in the Gray Creek watershed. Insects are the main types typically present and commonly include mayflies (Ephemeroptera), stoneflies (Plecoptera), caddisflies (Trichoptera), and true flies (Diptera). Non-insect invertebrates include snails, leeches, worms, and scuds.

Aquatic macroinvertebrates are essential to the ecological function of all types of aquatic systems. Aquatic macroinvertebrates can have an important influence on nutrient cycles, primary productivity, decomposition, and translocation of materials. Aquatic macroinvertebrates constitute an important source of food for numerous fish, and unless outside energy subsidies are greater than in-stream food resources for fish, fish-invertebrate linkages and invertebrate linkages with resources and habitats can play important roles. Interactions among aquatic macroinvertebrates and their food resources vary among functional groups. Five functional groups are frequently identified based on feeding behavior: scrapers, shredders, collectors, filterers, and predators. These are described further in the bullets on the pages following Table 4.9.

Table 4.9: Habitat Associations and Existing Conditions for Native and Nonnative Fish Species

Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
Native Fish Species		
Lahontan cutthroat trout *(Oncorhynchus clarki henshawi)*	LCT is endemic to the physiographic Lahontan basin of northern Nevada, eastern California, and southern Oregon. LCT were once widespread throughout the basins of Pleistocene Lake Lahontan (USFWS, 1995). Self-sustaining LCT populations occur in a small percentage of the historic stream and lake habitats (USFWS, 1995). LCT, like other trout species, are found in a wide variety of cold-water habitats including small headwater tributary streams (USFWS, 1995). In streams, LCT generally occur in cool flowing water with available cover, velocity breaks, well-vegetated and stable stream banks, and relatively silt free, rocky substrate in riffle-run areas. LCT are stream spawners and spawn from April to July (spring) depending upon stream flow, elevation, and water temperature. Spawning behavior of LCT is similar to other stream-spawning trout (Gerstung, 1988). They pair up, display courtship, and lay eggs in redds dug by females. Eggs are deposited in gravels with flowing water (Gerstung, 1988; USDA Forest Service 1993). Good egg survival requires that spawning beds be relatively silt-free and well oxygenated (Gerstung, 1988; USDA Forest Service, 1993). Water temperatures of less than 57^{o}F are required from April through July for successful reproduction (Gerstung, 1988). Optimum temperatures include averages of 55^{o}F, with maximums less than 72^{o}F (Gerstung, 1988; USDA Forest Service, 1993). LCT are opportunistic feeders, preying primarily on aquatic and terrestrial invertebrates that occur in the drift (USFWS, 1995; Moyle 2002). Terrestrial prey items may make up a significant portion of the diet of trout in small headwater streams and meadows during the summer months (USDA Forest Service, 1993). Cover is an important habitat component. LCT occupy areas with overhanging banks, vegetation, or woody debris, and within stream cover (e.g., brush, aquatic vegetation, and rocks) is very important for juvenile survival (USDA Forest Service, 1993). LCT evolved in the absence of other trout species and, consequently, do not compete effectively with other trout (Gerstung, 1988). In addition, genetic purity is lost from hybridization with rainbow trout. Presently, barriers separate most viable LCT populations from other trout species to ensure their continued viability.	**Occurrence:** Approximately 100 LCT individuals were stocked in the West Fork Gray Creek in 1983, and 66 were stocked in 1987 (USDA Forest Service, 2001a; USFWS, 1995; Kling, pers. comm., 2006). Surveys conducted in 1990 recorded 6 LCT individuals present; however no LCT were found during surveys conducted in 1998 and 2001 (Kling, pers. comm., 2006). While unlikely, it is possible that LCT may still be present in physically isolated reaches where nonnatives have not been able to become established; however, any potential presence is vulnerable to extirpation as a result of isolation (i.e., numerous passage barriers) and potential disturbance events. ► ► **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. While the passage barriers may provide potential benefits (i.e., isolating LCT from nonnative salmonids), they also present problems associated with population recolonization if extirpation were to occur due to a substantial disturbance event. ► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. The primary limitations to LCT are habitat degradation from sediment inputs (resulting primarily from the Martis Fire), the potential presence of nonnative salmonids (i.e., rainbow, brook, and brown trout), and small, isolated population vulnerability to substantial disturbance events. However, the following were potential sources of aquatic habitat degradation: 1) in WF2 a blown-out road may be a minor sediment source; 2) in WF-T1, the upper edge of the surveyed reach, an old road diverts a seep/tributary that joins WF-T1, causing some erosion and altering stream function in that location; and a second blown-out

Table 4.9: Habitat Associations and Existing Conditions for Native and Nonnative Fish Species		
Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
		road crossing is present through a portion of the reach and may be degrading aquatic habitat; and 3) In WF3 an historic road runs along the right bank of this stream with some recent OHV activity noted. While the road is predominantly in the uplands, it is influencing the West Fork by trapping and diverting some tributaries. The stream is entrenched and downcut with many occurrences of erosion.
Mountain whitefish *(Prosopium williamsoni)*	Mountain whitefish is native to lakes and streams of western North America, including streams tributary to the Truckee River. Adults are typically 10–16 inches in length and spawn in the fall or early winter. Whitefish may spawn among gravel, cobble, and boulders in riffles of tributary streams. Mountain whitefish spend much of their time near the bottom of streams and feed mainly on aquatic insect larvae. These fish were an important food fish for Native Americans (Moyle, 2002). Their current distribution in the region is poorly documented and they are generally believed to be less abundant and less widely distributed relative to historic levels. The reasons for decline are unclear; however, predation on whitefish fry by nonnative trout species is believed to be a possible cause (Moyle, 2002).	**Occurrence:** There is no known documentation of mountain whitefish in the Gray Creek watershed; however, they are likely present. ► **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. Lower reaches and stream segments with lower gradient conditions are more favorable. ► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. The primary limitations are habitat degradation from sediment inputs (resulting primarily from the Martis Fire), the potential presence of nonnative salmonids (i.e., rainbow, brook, and brown trout), and small, isolated population vulnerability to substantial disturbance events. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.
Paiute sculpin *(Cottus beldingi)*	Paiute sculpin is the only sculpin native to the Gray Creek watershed. This species inhabits streams with slight to moderate current and is found in riffle areas among rubble or large gravel. They also occur in lakes, including Lake Tahoe. Paiute sculpin's food consists of a variety of aquatic invertebrates. This sculpin is an important prey item for some species of trout (Moyle, 2002).	**Occurrence:** There is no known documentation of Paiute sculpin in the Gray Creek watershed; however, they are likely present. ► **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. Lower reaches and stream segments with lower gradient conditions are more favorable.

Table 4.9: Habitat Associations and Existing Conditions for Native and Nonnative Fish Species

Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
		► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. The primary limitations are habitat degradation from sediment inputs (resulting primarily from the Martis Fire) and small, isolated population vulnerability to substantial disturbance events. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.
Lahontan redside *(Richardsonius egregious)*	Lahontan redside is native to streams and lakes in the Lahontan Basin, including the Truckee River basin. Spawning occurs among gravel and cobble substrate in streams. In small streams, adults associate with high-velocity water along the stream margin or in backwater areas (Moyle, 2002).	**Occurrence:** There is no known documentation of Lahontan redside in the Gray Creek watershed; however, they are likely present. **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. Lower reaches and stream segments with lower gradient conditions are more favorable. ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. The primary limitations are habitat degradation from sediment inputs (resulting primarily from the Martis Fire) and small, isolated population vulnerability to substantial disturbance events. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.

Table 4.9: Habitat Associations and Existing Conditions for Native and Nonnative Fish Species		
Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
Speckled dace *(Rhinichthyes osculus)*	Speckled dace is the most widely distributed fish in western North America. Lahontan speckled dace (*R. o. robustus*) occurs throughout streams and lakes in the Lahontan Basin and is the only subspecies native to the Truckee River basin. Speckled dace may spawn among gravel areas in stream riffles. Fry concentrate in warm shallows, particularly between large rocks or among emergent vegetation. Adults prefer large substrates with interstitial spaces, shallow rocky riffles and runs, and submerged vegetation or tree roots (Moyle, 2002).	**Occurrence:** There is no known documentation of Lahontan speckled dace in the Gray Creek watershed; however, they are likely present. ► **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. Lower reaches and stream segments with lower gradient conditions are more favorable. ► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. The primary limitations are habitat degradation from sediment inputs (resulting primarily from the Martis Fire), the potential presence of nonnative salmonids (i.e., rainbow, brook, and brown trout), and small, isolated population vulnerability to substantial disturbance events. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.
Tahoe sucker *(Catostomus tahoensis)*	Tahoe sucker is native to lakes and streams in the Lahontan Basin, including the Truckee River basin. Suckers can spawn in streams or lakes. In streams, spawning generally occurs in runs or areas of small gravel in pools. Juveniles prefer pools and deep runs with abundant cover (Moyle, 2002).	**Occurrence:** There is no known documentation of Tahoe sucker in the Gray Creek watershed; however, they are likely present. ► **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. Lower reaches and stream segments with lower gradient conditions are more favorable. ► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.

Table 4.9: Habitat Associations and Existing Conditions for Native and Nonnative Fish Species		
Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
Mountain sucker *(Catostomus platyrhynchus)*	Mountain sucker is native to lakes and streams in the Lahontan Basin, including the Truckee River. Spawning usually takes place between June and July on gravel riffles. Mountain suckers feed mostly on algae and diatoms as well as small quantities of aquatic insects and other invertebrates (Moyle, 2002).	**Occurrence:** There is no known documentation of mountain sucker in the Gray Creek watershed; however, they are likely present. ► **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. Lower reaches and stream segments with lower gradient conditions are more favorable. ► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.
Important Nonnative Fish Species		
Rainbow trout *(Oncorhynchus mykiss)*	Rainbow trout was first introduced into the Truckee River basin in the late 1800s. Until recently, large numbers of domestic hatchery-raised rainbow trout have been planted annually into the Truckee River between Tahoe City and Truckee. Rainbow trout have similar habitat associations and ecology as LCT. They have the potential to affect LCT through competition, predation, and hybridization.	► **Occurrence:** There is no known documentation of rainbow trout in the Gray Creek watershed; however, they are likely present to some extent. ► ► **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. Lower reaches and stream segments with lower gradient conditions are more favorable. ► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.

Table 4.9: Habitat Associations and Existing Conditions for Native and Nonnative Fish Species		
Species	Habitat Associations and Ecology	Species Occurrence, Habitat Conditions, and Land Use Effects Summary
Brown trout *(Salmo trutta)*	Brown trout was introduced into eastern North America from Europe and from there into California in 1893 (Dill and Cordone, 1997). It is likely that this fish was introduced into the Truckee River shortly after its first planting in other parts of California. Brown trout have similar habitat associations and ecology as LCT with the exception of being fall spawners and slightly more favored towards larger, lower gradient creeks and rivers. Brown trout have the potential to affect LCT through predation and competition.	► **Occurrence:** There is no known documentation of brown trout in the Gray Creek watershed; however, they may be present in the lower reaches of the main stem. ► ► **Habitat Conditions:** Lower reaches and stream segments with lower gradient conditions may provide suitable habitat. ► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.
Brook trout *(Salvelinus fontinalis)*	Brook trout is native to eastern North America and were first brought to California in 1871 (Dill and Cordone, 1997). They were soon planted in numerous streams and lakes throughout California. The timing of the first introduction of brook trout into the Truckee River is undocumented. Brook trout introductions can fundamentally change alpine lake and stream ecosystems. Brook trout have eliminated yellow-legged frogs, other amphibians, and large invertebrates through predation. Brook trout have also been documented to contribute to elimination of native cutthroat trout through competitive interactions (Moyle, 2002). Brook trout have similar habitat associations and ecology as LCT with the exception of being fall spawners. They are extremely prolific and commonly associated with small headwater streams. Brook trout have the potential to affect LCT through predation and competition.	► **Occurrence:** There is no known documentation of brook trout in the Gray Creek watershed; however, they may be present in the lower reaches of the main stem. ► ► **Habitat Conditions:** All streams in the watershed are considered to provide suitable habitat. ► ► **Evidence of Land Use or other Anthropogenic Constraints on Habitat Suitability?** Limited. Potential anthropogenic sources of aquatic habitat degradation are the same as those described for Lahontan cutthroat trout.

- ***Scrapers*** are animals adapted to graze or scrape materials (periphyton, or attached algae, and its associated microbiota) from mineral and organic substrates;
- ***Shredders*** are organisms that comminute primarily large pieces of decomposing vascular plant tissue (>1 mm diameter) along with the associated microflora and fauna, feed directly on living vascular macrophytes, or gouge decomposing wood;
- ***Collectors*** are animals that feed primarily on fine particulate organic matter (FPOM; <1 mm diameter) deposited in streams;
- ***Filterers*** are animals with specialized anatomical structures (e.g. setae, mouth brushes, fans, etc) or silk and silk-like secretions that act as sieves to remove particulate matter from suspension; and
- ***Predators*** are organisms that feed primarily on animal tissue by either engulfing their prey or piercing prey and sucking body contents.

Aquatic invertebrate communities are sensitive and informative indicators of stream ecosystem condition, degradation, and water quality (Herbst, 2001), and have been used to monitor anthropogenic effects on aquatic and terrestrial habitats (bioassessment). Each aquatic invertebrate species has a different tolerance level to habitat degradation. Some species have narrow and specific habitat requirements and are therefore restricted to certain habitat conditions, while others can survive in a wide variety of habitat conditions (Erman, 1996). It is possible to use different invertebrate species and assemblages as indicators of water quality and habitat quality. The principal behind bioassessment is to determine the biological integrity of a site by comparing its biotic community to that of a known relatively undisturbed or reference site. Aquatic invertebrates are an important component of bioassessment, land use evaluation, and restoration assessment because they are more diverse, ubiquitous, and abundant than fish; and these organisms are in contact with both the water and bottom substrate in streams.

Gray Creek's invertebrate community was not sampled as part of this habitat assessment. However, benthic macroinvertebrates have been sampled in Gray Creek by the Truckee River Aquatic Monitors (TRAM) in 2001, 2002, 2005, and 2006 (Christman, pers. comm., 2006). TRAM is a committee of TRWC. TRAM follows a protocol for citizen monitors developed by DFG. Samples from 2001 and 2002 showed a stream community dominated by sediment-affiliated taxa such as midges in the family Chironomidae and mayflies in the family Baetidae. Insects in these families are categorized as collectors. In 2005, both Chironomid midges and Baetid mayflies were abundant but did not dominate the stream community to the extent they had in previous sampling years. Samples from 2006 have not yet been analyzed. Bioasssessment data are available from TRWC.

Land Use Constraints to Habitat Functions

As discussed above for riparian habitat functions, nearly all existing constraints to aquatic habitat function within the Gray Creek watershed result from natural environmental patterns and disturbances rather than anthropogenic sources. The few observed potential anthropogenic effects on aquatic habitat functions are primarily in the West Fork subwatershed, where forest roads are contributing to erosion and sedimentation.

4.5 Key Findings

The following bullets summarize the main findings of this habitat assessment:

Riparian and Upland Habitat

- The riparian zones in the watershed are characterized by stream corridors with discontinuous vegetation cover bordered by steep, rocky hillslopes. The riparian vegetation in all reaches is limited to a narrow band (10 to100 feet wide) because of these physical constraints. Furthermore, both flood flows and fire repeatedly disturb most of this riparian vegetation, and so mature stands of large riparian trees (e.g., black cottonwood, aspen) are very limited in extent.

- Because most riparian habitat in the Gray Creek watershed is narrow and patchy, with fast-moving water confined to the channel, its overall habitat value for wildlife communities is limited. Generally, the riparian corridors in most of the watershed presently provide low to moderate overall habitat value relative to other montane riparian areas in the Lower Truckee River watershed (e.g., Sagehen, Martis, and Schaffer Creeks). This is a very general comparison based on observed corridor widths and continuity, vegetation structure, and frequency of standing or slow-moving water in the stream channelor saturated soils in the adjacent floodplain.

- Despite the low to moderate habitat values relative to nearby watersheds, the study area provides valuable habitat for a variety of wildlife species. Although Gray Creek's North Fork, West Fork, and Main Stem riparian corridors represent a small proportion of the landscape, they provide important habitats and affect the habitat values of adjacent uplands. For example, in some locations, these areas provide the primary water source for important upland species such as mule deer and black bear (individuals or signs of these species were frequently observed in or adjacent to the riparian corridor during surveys). Several common riparian-associated bird species are known or likely to use portions of the Gray Creek riparian corridors during the breeding and migration seasons, including Wilson's warbler, song sparrow, warbling vireo, and MacGillivray's warbler. Also, American dipper, a regionally uncommon species associated with high-gradient montane streams, was observed using the stream channel in several locations.

- Ecologically significant habitat features were observed, particularly in the West Fork of Gray Creek. These are summarized below.

    - Along Reach WF1: a large perennial seep covered by patches of willow and by diverse herbaceous vegetation (including a small floating mat of mosses).

    - Along the western tributary of the West Fork (WF-T1): stands of mid- to late-seral conifer forest on the slope to the east. Some of these stands had been partially cut by logging in recent decades; others, however, do not appear to have had any trees removed for at least fifty years. These less disturbed stands had a multi-layered canopy structure with most canopy trees only 1–2 feet in DBH but also with many larger trees.

  - At the junction of the western tributary with the West Fork: several acres of mature black cottonwood forest with white fir and some lodgepole pine. This stand had canopy trees 1–2 feet in DBH (many of which were decadent and had crowns with broken tops, dead limbs, or cavities) and a dense understory of mountain alder and tree saplings (mostly white fir but some cottonwood root sprouts).

  - During their stream inventory work during summer 2006, USFS biologists noted a diverse riparian corridor along Reach WF3 that included areas dominated by black cottonwood, red fir, and aspen, including a large aspen stand (with Basque tree carvings) along the upper portion of the reach. Along Reach WF4, the lower portion included areas dominated by aspen, and in the upper portion of the reach, lodgepole pine dominated the riparian vegetation.

- A detailed assessment of upland conditions throughout the Gray Creek watershed was not conducted as part of the field survey. However, based on observations from the stream corridor and adjacent uplands, mule deer foraging habitat availability and quality may have improved as a result of the 2001 Martis Fire. In much of the watershed that burned, a dense shrub layer has developed from seedlings that established after the fire and post-fire sprouts. This shrub layer is dominated by choke cherry and bitter cherry, but also contains greenleaf manzanita, tobacco brush, bitterbrush, and a variety of shrubs. During the field survey, several mule deer or signs of their presence (e.g., tracks, scat) were observed within or immediately adjacent to the riparian corridor in all subwatersheds. The long-term foraging habitat quality for mule deer will depend on the change in shrub species composition over time.

- There are extensive areas where most or all trees were killed by the Martis Fire. These areas have little or no conifer regeneration; shrubs may dominate these sites for several decades or more (i.e., widespread, long-term conversion of conifer forest to montane chapparal is likely). These sites also have dense concentrations of snags and downed coarse woody debris, which provide valuable habitat elements for several bird species.

- Five species of nonnative invasive plants were observed during the field assessment: cheatgrass, musk thistle, bull thistle, woolly mullein, and Russian thistle (see *Implications for Restoration* below for further discussion).

Aquatic Habitat

- In all subwatersheds, aquatic habitat is influenced by steep channels and large sediment inflows from some tributaries (from upslope sediment sources), and channel erosion and deposition. Sediment inputs have the potential to degrade aquatic habitat through filling of pools; embedding of cobble and gravel substrate; increasing turbidity; and channel erosion and incision.

- Aquatic habitat throughout all reaches consists of step-pools formed by large boulders, bedrock, and large woody debris jams that may act as potential fish passage barriers under different flows. Potential fish passage barriers by subwatershed are as follows: Main Stem (including Middle Fork) – total of 16 barriers (13 seasonal) ranging in height from 3 to 9 feet; North Fork – total of 17 barriers (4 seasonal) ranging in height from 3 to 12.5 feet; and West Fork – total of 39 barriers (9 seasonal) ranging in height from 3 to 35 feet. Many of these potential fish barriers are seasonal and/or temporary due to varying flows and ongoing dynamic physical processes (e.g., movement of boulders and LWD). An abundance of log snags and upslope sediment sources (resulting from the Martis Fire) will continue to provide recruitment of LWD and boulders in the future.

- Most reaches evaluated during this habitat assessment and the USFS stream inventory provided low-value breeding habitat for amphibian communities, due to fast flows and lack of backwaters and calm pools. Only a small amount of suitable habitat was identified by USFS and/or EDAW biologists, limited to the upper watershed in reaches MS5, MS8, WF1, WF2, WF3, WF 4, and WF-T1, where small pools associated with side channels/tributaries and seeps occur.

Special-Status Species

- The Gray Creek watershed provides valuable mule deer foraging habitat and cover. Also, a limited amount of moderate-quality breeding habitat for yellow warbler occurs where riparian vegetation is relatively contiguous and dense. The watershed's historic and present potential to support viable populations of other special-status wildlife species known to occur in the vicinity were found to be naturally low due to the characteristics of the watershed, and not land use. For example, no breeding habitat for willow flycatcher or Sierra Nevada mountain beaver was observed. (Some locations in the upper portion of the watershed could support habitat for mountain beaver, but none was observed during field surveys.)

- Gray Creek is generally not considered suitable breeding habitat for mountain yellow-legged frog due to its steep gradients and fast flows. A limited amount of potential amphibian habitat was observed by EDAW and USFS biologists along Gray Creek, particularly in side channels and seeps in the upper watershed (see *Aquatic Habitat* above). Based on the rapid assessment completed for this report (Reaches MF1, MF2, MF4, WF1, WF2, WF-T1, and NF1), breeding populations of mountain yellow-legged frog are not likely to persist due to the lack of still or slow-moving water with sufficient depth not to freeze during winter. Although unlikely, breeding habitat could occur in other reaches not surveyed for this report.

- All streams in the watershed are considered to provide suitable habitat for Lahontan cutthroat trout. While the observed passage barriers may provide some potential benefits by isolating LCT from nonnative salmonids, they also present problems for population recolonization if extirpation were to occur. Approximately 100 LCT individuals were stocked in the West Fork Gray Creek in 1983, and 66 were stocked in 1987 (USDA Forest Service, 2001a; USFWS, 1995; Kling, pers. comm., 2006). Surveys conducted in 1990 recorded 6 LCT individuals present; however no LCT were found during surveys conducted in 1998 and 2001 (Kling, pers. comm., 2006). While unlikely, LCT may still be present in physically isolated reaches where nonnative fish have not been able to become established. However, any potential presence is vulnerable to extirpation as a result of isolation (i.e., numerous passage barriers) and disturbance. Nearly 40% of the West Fork subwatershed burned in 2001 during the Martis Fire along the lower reaches, likely degrading habitat for LCT in areas adjacent to and downstream of the burn near WF1 and WF2.

Implications for Restoration

- Nearly all existing constraints to riparian and aquatic habitat functions for common and special-status species within the Gray Creek watershed are caused by natural environmental patterns and disturbances rather than anthropogenic sources. Where land use disturbances were found, they were concentrated in the West Fork subwatershed where forest roads contribute to erosion and sedimentation and potentially to aquatic habitat degradation. The West Fork subwatershed is also where most of the ecologically significant habitat features summarized above (e.g., potential amphibian habitat, a large perennial seep, stream reaches where LCT were stocked) are located. Therefore, potential restoration actions focused on erosion control and sediment reduction would likely have the greatest benefits to aquatic and riparian habitat in the West Fork.

- Of the five nonnative invasive plant species documented in the watershed during this assessment, eradication is most feasible for three of them – bull thistle, musk thistle, and Russian thistle – because their infestations are still small (bull thistle, musk thistle) or they occur as scattered individuals within small areas (Russian thistle). Invasive plant removal projects could be implemented using volunteer efforts.

- Overall, the incremental effects of historic and current land uses or other anthropogenic sources on riparian and aquatic habitat quality in the Gray Creek watershed appear relatively small compared to the effects of environmental gradients and the natural disturbance regime. Also, feasible and cost-effective restoration activities are limited throughout much of the watershed due to steep topography, lack of existing road access, and regular flooding and mass soil movements. However, several issues that affect habitat functions, and that could be addressed by restoration activities, were identified based on this habitat assessment. Table 5.3 in Chapter 5 (*Erosion Control and Restoration*) summarizes these key habitat issues by stream reach and the potential restoration actions and their feasibility and benefits.

5. EROSION CONTROL AND RESTORATION

5.1 General Considerations

The options or opportunities for erosion control and habitat restoration are discussed under separate headings in this chapter and then combined in the Restoration Strategy in the following chapter. Erosion control and sediment management are discussed for roads, slopes, and the stream corridor, followed by a discussion of habitat restoration opportunities. The options are based on the results of the sediment source and aquatic habitat investigations described earlier. Note that for some options, further investigations or analysis are required in order to develop a project that can be constructed. Consequently, the options discussed in the following sections are roughly equivalent to "concepts".

To the extent practical, we discuss the feasibility and benefits of the various erosion control and restoration options. This discussion emphasizes factors such as accessibility, cost, impacts on other resources, and benefits and roughly reflects the criteria included in the TRWC's "Project Filter Factors" (see Appendix 5).

5.2 Erosion Control along Roads

5.2.1 Background

As discussed earlier, roads are the main anthropogenic source of sediment in Gray Creek watershed. There are about 19.5 miles of road, with 14 of those in the West Fork subwatershed. A brief field reconnaissance indicates that the roads are surfaced with native materials and that water bars and other water control features were added to some of the roads before they were abandoned. As described in Table 2.6, about 2.5 miles of road have low gradients and are on ridge tops or cross flat terrain. These have the lowest sediment production and erosion risk. However, much of the road network has the potential for erosion. About 3.5 miles of road leading into and from the valley are steep (greater than 15%) and surface erosion has the potential to deliver sediment to streams, particularly where the road leads to a drainage course. Also, about 9.2 miles of road cross steep hill sides (steeper than 50%) and often have high, unstable cut banks (Figures 2.12 and 2.13). The roads appear to be half-benched, with the outboard side of the road constructed on a fill prism placed on the hill slope. Cross drains are infrequent and some drainage structures at gullies and small watercourses were observed to be blocked by sediment and debris. These roads have the potential to fail, resulting in slope instability or landsliding on the steep hill sides.

The field reconnaissance and GIS analysis indicates the following current and potential sources of sediment from the road network:

- Surface erosion from steep road segments near streams appears to directly enter into watercourses
- Inboard ditches that erode where they intercept and channel subsurface drainage, such as on the road leading to Juniper Ridge
- Failure of the road prism or diversion of flow along the road at culverts or other drainage structures that are blocked

- Failure of the road prism and initiation of a landslide where half-benched roads cross steep slopes

5.2.2 Access Management and Erosion Treatments

Generally, erosion control treatments are developed after a watershed road management plan has been completed. These plans typically review access requirements, inventory the road system, and identify actions needed for environmental protection and mitigation. The plans also establish the requirements and standards for road use during wet weather, re-construction or improvement, maintenance and abandonment. The California Code of Regulations (Title 14 Chapter 4 California Forest Practice Rules) describes the general requirements for such a plan.

The Forest Service recently proposed the Martis Travel Management Plan (USDA Forest Service, 2006b) which would close the roads entering the West and North Forks to public motorized travel. This plan does not recommended particular treatments for the road network in the watershed.

We recommend developing a road management plan for the Gray Creek watershed that will guide erosion treatments. The plan would be a cooperative effort between the Forest Service, TDLT, TRWC and other interested parties. Such a plan would consider whether any roads are to remain open to traffic, whether they are to be removed or abandoned or converted to trail, and the timing of closure to allow for restoration works, if access along the road network is needed for their construction. Such a plan would direct appropriate road rehabilitation measures, inspection and maintenance and, if necessary, the development of new roads that meet current standards. The GIS database developed in this study, combined with previous recommendations for road restoration and decommissioning, are an appropriate starting point for this process (McGraw et al., 2001; Tetra Tech, 2005).

5.2.3 Erosion Treatment Objectives and Practices

The goals of the road management plan for erosion control or of any plan for sediment control on the road network are as follows:

- Prevent initiation of gully erosion and landslides
- Prevent road-related sediment from entering streams
- Prevent alteration of the natural drainage network and its hydrology
- Prevent barriers to fish movement and maintain fluvial processes at crossings of major streams

General guidance on road decommissioning can be obtained from the "Handbook for Forest and Ranch Roads: A guide for planning, designing, constructing, reconstructing, maintaining and closing wildland roads" (Pacific Watershed Associates, 1994), which is recommended by the Southwest Regional Office of the National Marine Fisheries Service for forestry practices in California despite its age. Specific, local guidance for the northern Sierra Nevada Mountains does not seem to be available, but a number of other sources provide advice on field techniques and best management practices.

California State Parks provides a general guide or primer for construction practices for road removal (Merrill and Casaday 2001) and guidance on best management practices (BMP) for road rehabilitation (Merrill and Casaday 2003). Their guidance is specific to the North Coast of California, but covers the following topics:

- Road-stream crossing removal
- Partial road recontouring
- Full road recontouring (road removal or obliteration)
- Road-to-trail conversion

The implementation of any of these particular road treatments should be based on the road management plan, but the guidance on road-to-trail conversion may be particularly useful for Gray Creek, once access requirements and the purpose for the road network are established.

Other road erosion treatments (ripping of road surface and re-planting, erosion treatments for cut slopes, culvert removal, etc) are described in Pacific Watershed Associates (1994) or in various other publications available from County Public Works Departments or other sources.

5.2.4 Next Steps

In the long-term, the treatment of the road network should be based on a road management plan. However, given that it may take some time to prepare this plan, we have identified treatment options for the most significant road erosion sites, as identified in the sediment source assessment. Figure 5.1 shows the location of these 24 sites and Table 5.1 provides site information, problem identification, habitat implications and suitable treatments. Projects are listed by erosion site number (see Figure 5.1) and prioritized based on property ownership, proximity to stream channels, accessibility, and feasibility for site restoration. Erosion sites more than 250 ft away from stream channels are not considered to have a significant impact on stream habitat and are noted as such in Table 5.1. Access was interpreted from air photos; onsite field inspection may reveal obstacles in the roadway that were not visible in air photos. Most of the high priority sites are landings that can be treated by re-vegetation. These projects are suitable for volunteer labor as Truckee River Day projects.

Rough costs for the treatments are also provided in Table 5.1. We have assumed a cost of about $3,000 to $5,000 for re-vegetation of landing sites and about $20,000 to $40,000 for sediment removal and re-contouring of road fills where slopes are unstable. The unit cost for the removal and re-contouring is derived from the average cost per erosion site for road rehabilitation in the Pescadero/Memorial/San McDonald County Park Complex in San Mateo County (Pacific Watershed Associates 2003) and may vary considerably depending on site size, conditions, access and other factors. The assumptions underlying the costs are documented in their report. Typically, the repairs require heavy equipment and are not suitable for volunteer labor.

Table 5.1 Recommended Restoration Projects for Road Erosion Sites in the Gray Creek Watershed

Erosion Site ID	Priority	Property Ownership	Erosion Type	Problem Description	Aquatic and Riparian Habitat Implications	Accessibility	Suitable Treatments or Prescriptions	Rough Cost $000
2	2	Private	Road Erosion	Upslope landslide runout intersects a 30 ft long section of road. This is a potentially active source of future landslides and subsequent road erosion.	Site is within 100 ft of stream, potential for direct supply of sediment to stream	Good but private land	Maintenance - remove and haul future landslide material from road site before it enters the stream. Do not sidecast loose material downslope.	20 to 40
3	2	Private	Road Erosion	Stream ford constructed as a low water road crossing; large boulders and fill form the crossing, providing an additional source of sediment and turbidity.	Ford crossing in stream is a barrier to fish and removes stream bed habitat	Good but private land	Remove existing ford. Engineer and construct a new bridge that minimally impacts aquatic habitat and does not impede fish passage.	Unknown
8	1	TDLT	Road Erosion	Unvegetated landing on old forest road acts as a sediment source; surface area is approximately 3000 sq. ft.	None - no stream corridor in proximity to this location	Good	Rip ground surface, seed and mulch	3 to 5
9	1	TDLT	Road Erosion	Unvegetated landing on old forest road acts as a sediment source; surface area is approximately 5600 sq. ft.	None – no stream corridor in proximity to this location	Good	Rip ground surface, seed and mulch	3 to 5
10	1	TDLT	Road Erosion	Large, poorly vegetated landing on old forest road acts as a sediment source; surface area is approximately 45,000 sq. ft.	None - no stream corridor in proximity to this location	Good	Rip ground surface, seed and mulch	3 to 5
11	2	Private	Road Erosion	Unvegetated landing on old forest road acts as a sediment source; surface area is approximately 30,000 sq. ft.	None - no stream corridor in proximity to this location	Good but private land	Rip ground surface, seed and mulch	3 to 5
16	1	TDLT	Road Erosion	Series of narrow switchbacks up steep mountain slope; possibly used for yarding?	None - no stream corridor in proximity to this location	Accessible from below on forest road	Remove erodible sidecast or spoil piles (if any), recontour hillslope, seed, and mulch	20 to 40
17	1	TDLT	Road Erosion	Unvegetated landing on old forest road acts as a sediment source; surface area is approximately 3,750 sq. ft.	None - no stream corridor in proximity to this location	Good	Rip ground surface, seed, and mulch	3 to 5
18	1	TLDT	Road Erosion	Unvegetated landing on old forest road acts as a sediment source; surface area is approximately 15,000 sq. ft.	None - no stream corridor in proximity to this location	Good	Rip ground surface, seed, and mulch	3 to 5
21	2	USFS	Road Erosion	Unvegetated landing on old forest road acts as a sediment source; surface area is approximately 15,000 sq. ft.	None - no stream corridor in proximity to this location	Good	Rip ground surface, seed, and mulch	3 to 5
22	2	USFS	Mass Movement	Denuded area indicating slope failure upslope of road cut; failure site is approximately 150 ft by 100 ft.	None -no stream corridor in proximity to this location	Poor – air photo shows narrow road in unknown condition	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
25	1	TDLT	Road Erosion	Drainage concentration and erosion along downslope side of roadway; area of eroded site is approximately 8,000 sq. ft.	None - no stream corridor in proximity to this location	Good	Recontour road drainage away from runout, recontour hillslope, seed and mulch	20 to 40
27	3	USFS	Road Erosion	Debris flow path intersects road; affected area is approximately 50 ft long by 15 ft wide.	Low – direct flow path from eroded road material to stream 1,000 ft downslope	Poor - air photo shows narrow road in unknown condition	Excavate any remaining road fill that may be eroded by future debris flows; recontour, seed and mulch	20 to 40
36	2	USFS	Road Erosion	Unstable slope on upslope side of road cut; surface area is approximately 35,000 sq. ft.	None -no stream corridor in proximity to this location	Poor - air photo shows narrow road in unknown condition	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
39	3	USFS	Road Erosion	Slope failure upslope and downslope of road cut; surface area is approximately 17,500 sq. ft.	None -no stream corridor in proximity to this location	Poor - air photo shows overgrown road, likely impassable by 4WD	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
48	3	USFS	Road Erosion	Unstable slope on upslope side of road cut; surface area is approximately 4,000 sq. ft.	None -no stream corridor in proximity to this location	Poor - air photo shows overgrown road, likely impassable by 4WD	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
49	3	USFS	Road Erosion	Unstable slope on upslope side of road cut; surface area is approximately 5,000 sq. ft.	None -no stream corridor in proximity to this location	Poor - air photo shows overgrown road, likely impassable by 4WD	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
56	3	USFS	Mass Movement	Small slope failure on upslope side of dirt road; surface area is approximately 5,000 sq. ft.	None -no stream corridor in proximity to this location	Poor - air photo shows overgrown road, likely impassable by 4WD	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
59	3	USFS	Road Erosion	Unstable slope on upslope and downslope side of roadcut; surface area is approximately 17,500 sq. ft.	None -no stream corridor in proximity to this location	Poor - air photo shows narrow road in unknown condition	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
60	3	USFS	Road Erosion	Unstable slope on upslope and downslope side of roadcut; surface area is approximately 23,000 sq. ft.	None -no stream corridor in proximity to this location	Poor - air photo shows narrow road in unknown condition	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
61	3	USFS	Road Erosion	Unstable slope on upslope side of road cut; surface area is approximately 3,000 sq. ft.	None -no stream corridor in proximity to this location	Poor - air photo shows narrow road in unknown condition	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
62	3	USFS	Road Erosion	Landslide path on upslope and downslope side of road cut; affected length of road is approximately 80 ft.	None -no stream corridor in proximity to this location	Poor - air photo shows narrow road in unknown condition	Remove unstable sediment deposits on road (if any), recontour hillslope, seed and mulch.	20 to 40
86	2	USFS	Rilling and Gullying	Gully erosion through road berm	Low – direct flow path from eroded road material to stream 1,500 ft downslope	Poor - air photo shows narrow road in unknown condition	Excavate any remaining road fill that may be eroded by future gully flows; recontour, seed and mulch.	20 to 40
87	2	USFS	Road Erosion	Construction site adjacent to stream; surface area is approximately 7,500 sq. ft.	Site is within 100 ft of stream, potential for direct supply of sediment to stream	Good but private land	Identify rills and recontour if necessary, seed and mulch.	20 to 40

Table 5.2 Recommended Sites for Treatment of Natural Erosion Sites in the Gray Creek Watershed

Erosion Site ID	Priority	Property Ownership	Erosion Type	Problem Description	Aquatic and Riparian Habitat Implications	Accessibility	Suitable Treatments or Prescriptions
1	1	Private	Mass Movement	Active landslide area; landslide source area is approximately 25 ft wide by 75 ft long.	Landslide is approximately 400 ft upslope from Gray Creek, sediment is supplied directly to stream	Good but private land	Conduct site visit of landslide and assess erosion control options.
6	1	Private	Mass Movement	Active landslide area adjacent to site 1; landslide source area is approximately 25 ft wide by 75 ft long.	Landslide shares same runout as site 1; sediment is supplied directly to stream	Good but private land	Conduct site visit of landslide and assess erosion control options.
19	2	TDLT	Mass Movement	Potentially active landslide area; landslide source area is approximately 20 ft wide by 50 ft long.	None - no stream corridor in proximity to this location	Good	Stabilize base of source area; seed and mulch.
24	2	USFS	Mass Movement	Denuded area indicating recent slope failure; surface area is approximately 400 ft wide by 575 ft long or about 230,000 sq. ft.	None - no stream corridor in proximity to this location	Poor - available access along narrow road in unknown condition that comes within 300 ft of site	Seed and mulch, assess possible opportunity for soil bioengineering or planting.
26	3	USFS	Stream bank Erosion / Mass Movement	Landslide into stream channel precipitated by toe erosion of steep slope; eroding area is approximately 200 ft wide by 250 ft long.	Sediment is supplied directly into the stream channel	Poor - air photo shows narrow road in unknown condition that comes within 300 ft of site	Possibly construct bank stabilization works to protection toe of slide; requires road construction

* Priority 1 is the highest priority; Priority 3 the lowest.

5.3 Erosion Control on Unstable Hillslopes

5.3.1 Background

As described earlier, steep slopes combined with highly erodible soils and geologic material create conditions conducive to frequent, natural erosion. The sediment source assessment identified sixty-five natural erosion sites in Gray Creek watershed, primarily in the Middle Fork subwatershed. Fifty-five of these sites are mass movements, usually landslides located on steep slopes, whereas the remaining are stream bank and rill and gully erosion sites (see Appendix 2).

5.3.2 Erosion Control Objectives and Treatments

Treatments and best management practices for landslides and hillslope instability are described in a variety of publications. Atkins et al (2001) and Chatwin et al (1991) describe practices in British Columbia for management of landslides and for hillslope restoration. A wide variety of publications are available for other jurisdictions. In California, the previously referenced report by Pacific Watershed Associates (1994) provides a brief description of some hillslope stabilization techniques.

The goals of landslide or hillslope instability treatments can be to prevent future slope failure at an unstable site or to treat failed sites to reduce surface erosion and allow establishment of vegetation. Generally, geotechnical methods for slope stabilization (unloading the slope, drainage, loading the toe or shifting the position of the failure surface) are appropriate where the goal is to prevent future failure of an unstable slope (Chatwin et al 1991). Application of such methods requires road access, heavy equipment and is generally very expensive. Such an approach is generally not practical unless needed to protect a valuable resource or constructed feature from future slope failure. We see no need for geotechnical treatment of any of the landslides we identified in Gray Creek.

Soil bioengineering or vegetative treatments of a landslide track after failure can reduce subsequent surface erosion and help restore vegetation (Atkins et al 2001). Typical techniques include seeding, planting, live staking, wattle fences, modified brush layers or other approaches, but the applicability and success of these techniques for stabilization of the steep slopes in the Gray Creek watershed is not well known. Note that bioengineering or vegetative treatments do little to prevent another failure from the same unstable terrain.

Lack of road access is another difficulty in erosion control treatments for existing landslide sites. Most of the natural erosion sites are in remote areas with no road access, particularly in the Middle Fork subwatershed (Figure 5.2). However, five erosion sites are located within 300 ft of an access road; three in the West Fork and two along lower Gray Creek. These sites present the best potential for soil bioengineering or vegetative rehabilitation work other than seeding conducted by helicopter or on foot.

5.3.3 Next Steps

Table 5.2 describes the five erosion sites with road access, where bioengineering or vegetative treatments might be tried. We recommend developing prescriptions for bioengineering or vegetative treatments at these sites, as a general trial for the success of such approaches to sediment management in the Gray Creek watershed or in this part of the northern Sierra Mountains. Overall, we view these sites as a low priority for treatment but work might be combined with road de-activation or other activities in the watershed to make it cost-effective.

5.3.4 Landslide Hazard Reduction

The existing natural erosion sites correspond well with high hazard areas shown in the erosion hazard map (see Figure 3.2). We anticipate the majority of new natural erosion sites to occur in these high erosion hazard areas, which are located mainly in steeply sloping parts of the middle and lower basin. Conversely, we expect few natural erosion sites in low hazard areas, which are mainly located in the basin headwaters where slopes are generally less steep, there are few roads, and the area is unaffected by the 2001 Martis Fire.

Avoidance of high hazard areas or unstable slopes is one of the best approaches to managing future sediment contributions to Gray Creek. As such, the erosion hazard map is a useful planning tool for evaluating potential impacts of disturbances such as road de-activation, new roads, trails, grazing or other activities.

5.4 Erosion Control along Streams

5.4.1 Background

The large but infrequent sediment contributions from tributaries and slopes into the main streams in the watershed, the narrow and steep stream corridors, and the succession of large floods over the past decade or so have resulted in instability and erosion over large parts of the stream network that has increased sediment contributions to the Truckee River (see Tables 2-4 and accompanying discussion). Field inspection and previous reports show erosion of banks and floodplains, filling of the channel with tributary fans or deposits, and incision or downcutting, as indicated by knickpoints in the Middle Fork and the lowering of the bed of lower Gray Creek below recent flood deposits. In general it appears that the Middle Fork is the least stable and the West Fork is the most stable of the streams. However, all the streams have the potential for extensive erosion during moderate and large floods (Sections 2 and 3).

5.4.2 Potential Erosion Control Treatments

Given the steep channel slopes and the potential for contributions of large volumes of material from slope failures, there are few suitable options for erosion control along streams. Typically, large rock (quarry stone or riprap) would be needed to re-construct or protect stream banks, prevent future erosion, and significantly reduce sediment from this source. Given the lack of roads along the stream, the narrow stream corridor, the expense of rock construction, and potential impacts on aquatic and other habitats, such an approach is not likely to be cost-effective, particularly when it appears that stream bank erosion is a much less significant sediment source than landslides.

Local or limited erosion protection might be provided as part of aquatic habitat restoration, through re-construction of banks and floodplains or addition of woody structures or other habitat features. As discussed in the section, restoration of aquatic habitat is not a high priority and it is unlikely that significant erosion control will be provided through this approach.

An alternative approach might be to apply bar stabilization techniques to the floodplain. Such an approach would consist of partial burial of whole trees in the floodplain recent gravel deposits or anchoring portions of trees or root wads (see Soto et al 1997). These techniques have been successful in stabilizing bars and the woody structures would act to roughen the floodplain and trap or capture some of the fine sediment carried in suspension during floods, which generally promotes growth or riparian vegetation. The sediment trapping on the floodplain would also reduce the overall sediment supply from Gray Creek to the Truckee River, although the net reduction would be small.

One of the weaknesses of this approach is the failure of the structures during large floods when the bank and floodplains are eroded. This is particularly a problem in a steep, narrow stream like Gray Creek, where large forces are exerted on stream banks during floods. Large anchors are required to stabilize the structures; as a result, they are best constructed where the valley bottom is reasonably wide and a road lies close to the stream. There are few places in the Gray Creek watershed where this occurs, most notably on the private land along Reach MF1. One other weakness is the lack of suitable trees or root wads in the area near Gray Creek.

5.4.3 Next Steps

It is our view that most approaches to reducing or preventing stream erosion are not feasible in the Gray Creek watershed. The most suitable approach is likely to be floodplain stabilization with woody structures. We see this as a low priority, but such structures could be installed along Reach MF1, combined with riparian treatments, where road access is available. The structures might consist of two or three logs and anchors and cost around $5,000 to $10,000 to install. Given a spacing of about 100 feet, the net cost would be around $250,000 to $500,000 per mile.

5.5 Habitat Restoration Opportunities

5.5.1 Background

The habitat assessment identified problem areas in the watershed and, if appropriate, feasible restoration opportunities and constraints.

5.5.2 Restoration Treatments

The incremental effects of historic and current land uses or other anthropogenic sources on riparian and aquatic habitat quality appear relatively small compared to the effects of the natural disturbance regime of the watershed. Also, feasible and cost-effective restoration activities are limited throughout much of the watershed due to steep topography, lack of existing road access, and regular flooding and mass soil movements.

However, several issues that affect habitat functions, and that could be addressed by restoration activities, were identified in Section 4 and summarized in Section 4.5, Key Findings. Table 5.3 summarizes the issues related to invasive species, riparian and upland habitat and aquatic habitat, identifies stream reaches where they are significant and discusses potential restoration actions and their feasibility and benefits.

Table 5.3: Primary Habitat Issues, Potential Restoration Actions, and Feasibility Considerations			
Issue	Stream Reach	Potential Actions	Factors Affecting Feasibility, Costs and Benefits
Bull Thistle Invasion of Riparian Areas. Bull thistle infestations are present within riparian areas and are likely to be expanding, which will displace native vegetation and alter ecosystem functions and recreational values.	MS1 MS2 MS3 MS4 NF1 WF1 WF2	**Eradication of Infestations.** Infestations can be removed through application of herbicides or manually by cutting plants at least 2 inches below the ground surface. Cut plants or all flowering branches should be removed to prevent seed dispersal. Follow up visits are necessary to remove any recruits, resprouts, or previously overlooked plants. See *The weed worker's handbook: a guide to techniques for removing Bay Area invasive plants* (The Watershed Project and Cal-IPC, 2004) for guidance for volunteer-based eradication efforts. Note: The native thistle *Cirsium andersonii* is widespread in the Gray Creek watershed, and thus volunteers should be briefed on their distinguishing features. See Donaldson (2004) or Donaldson et al. (2003) for this information.	Because infestations are still small, eradication is still feasible; infestations can expand rapidly, however, and feasibility of control may diminish substantially within several years. In the absence of successful eradication, a moderate impact on riparian areas could occur. Infestations are primarily on USFS land, but in reach MS1, some plants also occur on adjacent private property; coordination with and permission from these property owners would be necessary. Although access is limited, only hand equipment would be necessary, along with volunteer labor. Using volunteers, costs would be minimal.
Musk Thistle Invasion of Riparian Areas. Musk thistle infestations are present within riparian areas and are likely expanding, with consequences similar to those described for bull thistle.	MS1 NF1 WF2	**Eradication of Infestations.** Musk thistle infestations can be eradicated through actions similar to those described for bull thistle.	The factors affecting feasibility, costs, and benefits are the same as described for bull thistle in these stream reaches.

Table 5.3: Primary Habitat Issues, Potential Restoration Actions, and Feasibility Considerations

Issue	Stream Reach	Potential Actions	Factors Affecting Feasibility, Costs and Benefits
Woolly Mullein Invasion of Riparian and Upland Areas. Woolly mullein is scattered throughout riparian and upland areas and is likely increasing in abundance, which will displace native vegetation and alter ecosystem functions.	MS1 MS2 MS3 MS4 NF1 WF1	**Eradication of Infestation.** The infestation can be removed through application of herbicides, on manually by uprooting plants or cutting plants at least 2 inches below the ground surface. (Reproductive plants or all fruits and flowers should be removed from the site.) Follow up visits are necessary to remove any recruits, resprouts, or previously overlooked plants. For guidance regarding volunteer-based eradication efforts, see *The weed worker's handbook: a guide to techniques for removing Bay Area invasive plants* (The Watershed Project and Cal-IPC, 2004).	The benefits of this action may be limited. Although the abundance of woolly mullein is likely to increase and will displace native vegetation, the species is considered to cause limited impacts on ecosystems. (There are concerns, however, that abundant woolly mullein can inhibit regeneration of trees and shrubs after major disturbances.) The factors affecting the feasibility and costs of this action are the same as those described for bull thistle along this stream reach.
Russian Thistle Invasion of Riparian Areas. Russian thistle is scattered in open sites within the riparian areas in reach MS1.	MS1	**Eradication of Infestation.** The infestation can be removed through application of herbicides or by uprooting plants. (Reproductive plants or all fruits and flowers should be removed from the site.) Follow up visits are necessary to remove any recruits or previously overlooked plants. For guidance regarding volunteer-based eradication efforts, see *The weed worker's handbook: a guide to techniques for removing Bay Area invasive plants* (The Watershed Project and Cal-IPC, 2004).	The benefits of this action may be limited. The abundance of Russian thistle may not increase, and the species is considered to cause only limited impacts on ecosystems.
Cheatgrass Invasion of Native-dominated Vegetation. Cheatgrass is widespread and abundant through out much of the upland and riparian vegetation along several stream reaches. This species alters fires regimes, and affects regeneration of native species	MS1 MS2 MS3 MS4 NF1 WF1 WF2	**Eradication of Infestation.** The infestation could possibly be eradicated through repeated herbicide applications (see Young 2000) over a relatively large portion of the riparian and upland vegetation along this stream reach. Repeated prescribed fires in spring could reduce the abundance of cheatgrass (Young 2000).	Although cheatgrass infestations cause substantial alterations of ecosystems, it probably is not feasible to eradicate cheatgrass from the upland and riparian areas along these stream reaches. In addition to the large material and labor costs of repeatedly applying herbicide over large areas, and the potential adverse effects of these applications, numerous plants would survive in relatively inaccessible locations (e.g., cliff faces), and could recolonize treated areas.

Table 5.3: Primary Habitat Issues, Potential Restoration Actions, and Feasibility Considerations			
Issue	Stream Reach	Potential Actions	Factors Affecting Feasibility, Costs and Benefits
Fish passage (natural barriers). Several fish passage barriers were noted throughout all areas of the watershed. These passage barriers are formed by large boulders, high water velocities/chutes, and large woody debris that appears to be a product of the Martis Fire.	All reaches	**Removal of barriers.** Barriers can be removed by using heavy equipment, blasting, and other techniques. Construction areas may require restoration to some extent following barrier removal.	Passage barriers formed naturally are numerous throughout the watershed. Most of these barriers are formed by large woody debris and boulders and there is an abundance of upslope sources of log snags and coarse sediment (resulting from the Martis Fire) that will continue to provide recruitment of new woody debris and boulders into the channels in the future. The large woody debris and boulders that forms many of the barriers serves as a beneficial habitat component for the native fish community (e.g., cover and structure). Because feasibility is limited and the barriers are natural features that provide habitat function, removal of natural fish barriers is not recommended.
Fish passage (anthropogenic barriers). A low water crossing was identified as a potential fish passage barrier.	MS1	**Removal of barriers.** Barriers can be removed (or modified) by using heavy equipment, blasting, and/or other techniques. Construction areas would likely have to be restored to some extent following removal.	The low water crossing that is a potential passage barrier could be accessible by large equipment and could be removed at relatively low cost. However, nearly all land above high-water mark of Gray Creek (i.e., the access route) is privately owned. In addition to forming a potential barrier, this structure appears to be a source of excess sediment and may also negatively affect channel morphology (i.e., causing channel widening); therefore, removal and restoration would achieve multiple benefits. Removing the low water crossing is feasible, if landowner partnership is achieved. However, maintaining access across the creek and the potential subsequent requirement to construct a bridge crossing would increase costs substantially. If maintaining access and bridge construction is a requirement, removal of these barriers would likely become infeasible as a result of the high costs of a bridge replacement.

Table 5.3: Primary Habitat Issues, Potential Restoration Actions, and Feasibility Considerations

Issue	Stream Reach	Potential Actions	Factors Affecting Feasibility, Costs and Benefits
Sediment inputs to creek (bank source). Left bank is highly eroded and supplying a substantial amount of sediment into creek resulting in instream habitat degradation.	NF2	**Bank stabilization.** Eroding banks can be stabilized through conventional and bio-engineering techniques to reduce sediment inputs into the creeks.	The site is remote and not accessible by heavy equipment and stabilization of the bank without equipment would be labor intensive and difficult. Additionally, the benefits of this action may be limited.
Lack of Conifer Regeneration Following Crown Fire. Areas of 10–100+ acres along this reach had few surviving conifers and little or no regeneration of conifers from seed. Consequently, these areas will likely remain shrub-dominated for several decades.	WF1 WF2	**Planting Conifers.** Conifers could be planted in areas lacking natural regeneration. For guidance regarding planting techniques see Hobbs et al. 1992.	The potential benefit of this action would be to reestablish conifers and the habitat elements they provide near this stream, where post-fire conifer regeneration has not occurred and is unlikely to occur for several decades. Planting conifers may not be feasible, unless shrub clearing occurs first. Several years have elapsed since the Martis Fire and a dense shrub layer has developed. Planted conifers are unlikely to survive in such shrub-dominated areas. Clearing shrubs from the vicinity of existing post-fire seedlings could increase the conifer seedlings survival and growth of these seedlings, and thereby increase conifer recovery. To evaluate potential unforeseen adverse effects (e.g., increased summer heat stress, increased herbivory), this selective clearing should first be applied experimentally on a pilot-scale. Selective clearing of shrubs would need to be coordinated with USFS. It could be performed with volunteer labor and hand tools.

Table 5.3: Primary Habitat Issues, Potential Restoration Actions, and Feasibility Considerations

Issue	Stream Reach	Potential Actions	Factors Affecting Feasibility, Costs and Benefits
Conifer encroachment of Black Cottonwood and Aspen Stands. Conifers have encroached extensively into a mature black cottonwood-dominated stand at the junction of West Fork Reaches 2 and 3. This encroachment is reducing reproduction and increasing mortality in this stand, when the extent of mature riparian forest has been reduced by the Martis Fire. The USFS assessment documented aspen stands in this stream reach (including one with Basque carvings). Conifers may have encroached into these stands.	WF2 WF3	**Removal of Conifers from Black Cottonwood and Aspen Stands.** Conifers can be removed from cottonwood and aspen stands through a variety of techniques, including girdling, felling (and in some cases prescribed fire). These techniques have recently been reviewed by Shepperd et al. 2006. Because of the lack of road access, it probably would be necessary to remove conifers with hand equipment.	The benefits of this action may be limited by the retention of larger encroaching conifers. Large conifers provide important habitat functions, and like mature black cottonwood and aspen, their abundance has also been reduced by the Martis Fire. Also, there are restrictions on tree removals from riparian areas. Therefore, possibly just smaller conifers, perhaps only saplings, would be removed by this action. This would reduce additional encroachment, but would not undo most effects of current encroachment. This action would need to be coordinated with USFS, who manages this land. USFS has been treating conifer encroachment as a regionally significant conservation issue. Costs would largely result from coordination with USFS and obtaining necessary permissions and approvals, and to a lesser extent from the labor cost for several days time for a small crew (2–4 individuals) to perform the removals.
Sediment inputs to creek (tributary source). Intermittent tributaries are supplying a substantial amount of sediment into creek resulting in instream habitat degradation.	All reaches	**Channel and slope stabilization.** Intermittent channels and adjacent slopes can be stabilized through conventional and bio-engineering techniques to reduce sediment inputs into the creeks.	The size, location, and nature of the sediment sources are all factors that affect feasibility, costs, and benefits. Refer to discussion on sediment source actions.

Table 5.3: Primary Habitat Issues, Potential Restoration Actions, and Feasibility Considerations

Issue	Stream Reach	Potential Actions	Factors Affecting Feasibility, Costs and Benefits
Lahontan cutthroat trout. While not optimal conditions, the Gray Creek watershed provides suitable habitat for LCT. Fish passage barriers offer both opportunities and constraints for LCT reintroduction in the watershed.	All reaches	**Consult with Resource Management Agencies regarding Gray Creek Watershed as a Potential LCT Reintroduction Site.** In consultation with Nevada Department of Wildlife, USFWS, and Forest Service, evaluate watershed streams as possible location for LCT reintroduction / recovery efforts.	The *Recovery Plan for LCT* identifies Gray Creek as a possible reintroduction site for LCT (USFWS, 1995). The *Short-term Action Plan for LCT in the Truckee River Basin* (TRIT, 2003) states that establishing and maintaining a networked population may provide the ability to recover LCT without having to establish fish in every tributary in the Truckee River basin. The Gray Creek watershed serves as a potential reintroduction site for LCT that, if successful, could contribute (through population networking) to recovery in the larger Truckee River basin. The numerous fish passage barriers present throughout the watershed offer both opportunities and constraints for LCT reintroduction and recovery. On one hand, the barriers provide an opportunity as they present a means to isolate potential LCT populations from nonnative salmonids. On the other hand, they serve as a constraint because they would limit LCT ability to disperse and recolonize following a potential substantial disturbance event.
Note: no invasive plant-related actions were identified for the middle fork, the portion of the North Fork upstream from NF1, and the portion of the west fork upstream from WF2 because those areas were not assessed during the field surveys.			

5.6 Potential for Expansion of the Mt. Rose Wilderness

The western boundary of the Mt. Rose Wilderness intersects the Gray Creek watershed; much of the upper watershed lies within the Wilderness Area. Although not a specific objective of this assessment, potential opportunities for and benefits of expanding the existing Wilderness Area to include more of the Gray Creek watershed were identified during this analysis.

The Wilderness Act of 1964 (Public Law 88-577 88th Congress, S. 4 September 3, 1964) established an effective mechanism for protecting in perpetuity areas designated as Wilderness, which are roadless areas that are highly restricted in the types of management and recreational activities that can occur there. Restrictions and uses vary among individual Wilderness Areas, but the possession or use of motor vehicles, motorboats, or any other motorized equipment are prohibited in all wilderness areas. This essentially means that access is restricted to foot and horse travel, and that no mechanized equipment for travel or management can be used.

In addition to the portions of the Gray Creek watershed that are currently part of the Mt. Rose Wilderness, there is additional acreage within the canyons west of and continuous with the existing Wilderness Area that presently or could meet this definition. Specifically, the areas around the confluence of the Main and West Forks are particularly remote and relatively undisturbed by anthropogenic sources. The Main Fork and North Fork canyons are also steep, remote, and relatively undisturbed. Some of these portions of the Gray Creek watershed are identified within the USFS Rare2 boundaries, an inventory of roadless areas, which increases their potential for Wilderness designation. While Wilderness designation is not a surrogate or replacement for restoration, it could provide an opportunity to protect federal lands in perpetuity. Benefits to expanding the Mt. Rose Wilderness Area farther west include protecting more of the upper Gray Creek watershed from potential future degradation as a result of commercial or salvage logging, road development, or other land uses; and maintaining the remoteness of the Gray Creek watershed landscape.

Wilderness designation would require a number of actions, beginning with detailed resource mapping and inventory with the specific goal of evaluating the area's potential for addition to the Mt. Rose Wilderness. Identification of potential additions to the Mt. Rose Wilderness would include an evaluation of roads within the watershed. Portions of the watershed, such as the West Fork, that have existing unmaintained or decommissioned roads would be evaluated for consistency with the Wilderness Act and Forest Service plans; these areas could potentially qualify for an addition to the Mt. Rose Wilderness. Wilderness additions must be approved through Congress. Bills that propose potential Wilderness additions and new Wilderness areas have recently been sponsored by California representatives. For example, in May 2006, Senators Barbara Boxer (D-CA) and Dianne Feinstein (D-CA), and Representative Howard (Buck) McKeon (R-Santa Clarita), introduced the Eastern Sierra Rural Heritage and Economic Enhancement Act (HR 5149/S 2567), which proposed additions to existing wilderness areas.

6. RESTORATION STRATEGY RECOMMENDATIONS

6.1 Revised Objectives

The overall goals of the Truckee River Watershed Council for Gray Creek are to reduce sediment contributions to the Truckee River and improve riparian and aquatic habitat throughout the watershed. It is worth re-visiting and refining these goals, given the results of the sediment and habitat assessment completed for this report.

Recent sediment contributions from Gray Creek to the Truckee River are thought to be greater than if the watershed was "pristine", both because of accelerated erosion from the 2001 Martis Fire and because human impacts have altered watershed processes and created sediment sources. However, it appears that much of the sediment carried to the Truckee River is from naturally occurring landslides and other erosion sources on steep slopes in the watershed and that there is little potential to effectively control these sources. Treatment is unlikely to be successful because the sediment sources are on steep and inaccessible slopes, there are a very large number of erosion sites and erosion areas to treat, and new sections of the slope may fail and contribute sediment during any particular flood.

The large but infrequent sediment contributions into the main channels in the watershed, and the erosion and instability that have resulted from recent floods, are also likely to reduce the success of stream corridor (riparian and aquatic) habitat restoration. Field inspections, previous reports, and air photo analysis (see Section 2.3) indicate that the Middle Fork and lower Gray Creek are currently unstable and, as a result, may not be well suited for such restoration. On the other hand, the North Fork and the West Fork appear considerably more stable and likely provide better opportunities for successful stream corridor restoration projects.

Given the above considerations, we recommend the following goals for the TRWC in the Gray Creek watershed:

- Develop erosion control projects that eliminate or reduce human-caused erosion, particularly where this improves riparian and aquatic habitat value.
- Develop erosion control projects on lands owned by the Truckee-Donner Land Trust.
- Improve riparian and aquatic habitat where sediment contributions are least (or can be reduced) and channel and floodplains are most stable.

We also recommend assigning priorities for restoration to the individual subwatersheds, based on the likelihood of achieving these goals. These would be:

- The West Fork has an extensive network of roads, reasonable access, and a low concentration of natural erosion sites and erosion areas. We see the West Fork as the highest priority subwatershed, where erosion control works have the potential to significantly reduce sediment supply to this stream and habitat improvements are most likely to be successful and beneficial.
- The North Fork has a low to moderate priority for road treatments and habitat restoration

- The Main Stem (Lower Gray Creek) is a low to moderate priority for erosion control and habitat restoration given the channel instability, significant sediment contributions, and private land in this subwatershed
- The Middle Fork has a high concentration of natural erosion sites and erosion areas, an unstable main channel, no road access, and little or no human impact. Consequently, we view the Middle Fork as the lowest priority for restoration.

6.2 Recommended Initial Actions

6.2.1 Roads

A detailed assessment and erosion control program is required for the roads in Gray Creek watershed, as part of an overall road management plan. Such a program would include:

- Inventory, inspection and maintenance of stream crossings and drainage structures along the road network (see Figure 2.12 for crossing sites). If roads are to remain open, then maintenance or replacement of some structures may be necessary to reduce the risk of erosion. If roads are to be decommissioned, then removal of such structures and re-construction of the drainage channel may be the appropriate prescription.
- Inventory of ditches and road surfaces that contribute sediment to streams and inspection of the road prism for stability. The GIS analysis identified a number of steep road segments that lead to streams and are potential sediment sources; the analysis and field inspection also identified half-benched roads with fill prisms placed on steep side slopes that may potentially fail.
- Development of prescriptions and costs for rehabilitation of drainage structures and roads consistent with access requirements and recreation use
- BMP (prescriptions) for road and trail erosion management

We recommend development of such a program for the West Fork subwatershed as the highest priority, with the North Fork and lower Gray Creek as moderate priorities. As noted earlier, the development of the road management plan will require a cooperative effort between various state and federal agencies and other interested parties. Given that it may take a considerable period to develop such a plan, restoration could proceed by treating the significant road sediment sources described in Table 5.1. This table identifies the general nature of the erosion sites but prescriptions and costs for remediation will require detailed field assessment.

It may also be cost-effective to treat the sediment sources listed in Table 5.2 as part of the overall road erosion treatment program, depending on the nature of the work and the equipment and other resources available in the watershed. As discussed earlier, soil bioengineering or vegetative treatments might be developed for these sites as part of a program or project to test their effectiveness in this part of the northern Sierra Nevada mountains.

6.2.2 Habitat Restoration

We recommend undertaking the following restoration options in Gray Creek:

- Invasive plant control, focusing on eradication of bull and thistle in all reaches of the watershed. These projects are suitable for volunteer labor and may be appropriate for

Truckee River Day projects where access is suitable. Further information can be found in Table 5.3.

- Control of conifer encroachment into black cottonwood and aspen stands along the West Fork. The project would consist of removing conifer saplings and could potentially be appropriate for a Truckee River Day project. Further information can be found in Table 5.3.

Projects to address other habitat issues (lack of conifer regeneration in riparian zones in the West Fork) are of lower priority, given the likely lack of success of conifer plantings in shrub-dominated areas. However, after the higher priority programs listed above are completed, the TRWC may wish to continue with some of the less feasible or less effective programs that are listed in Table 5.3.

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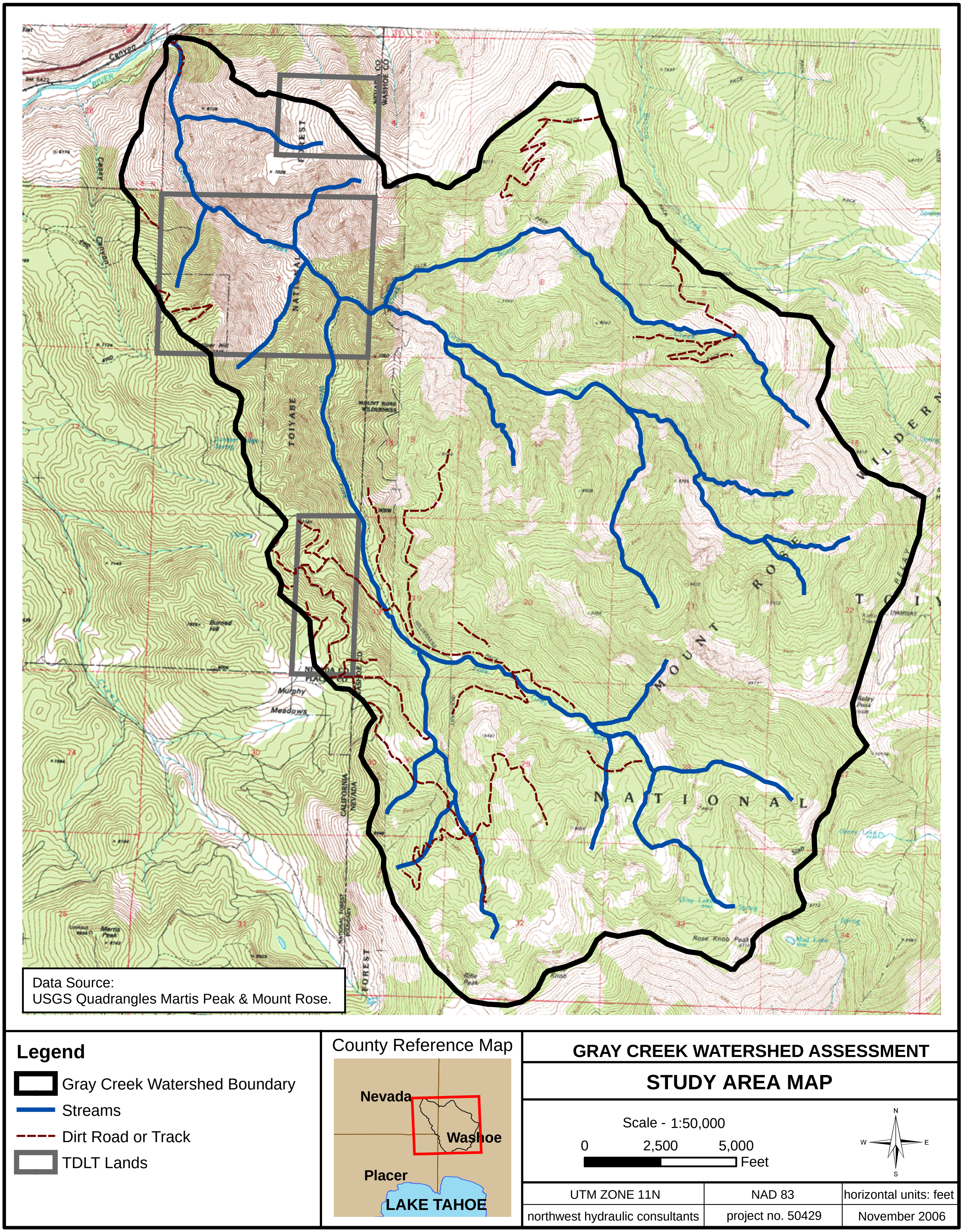
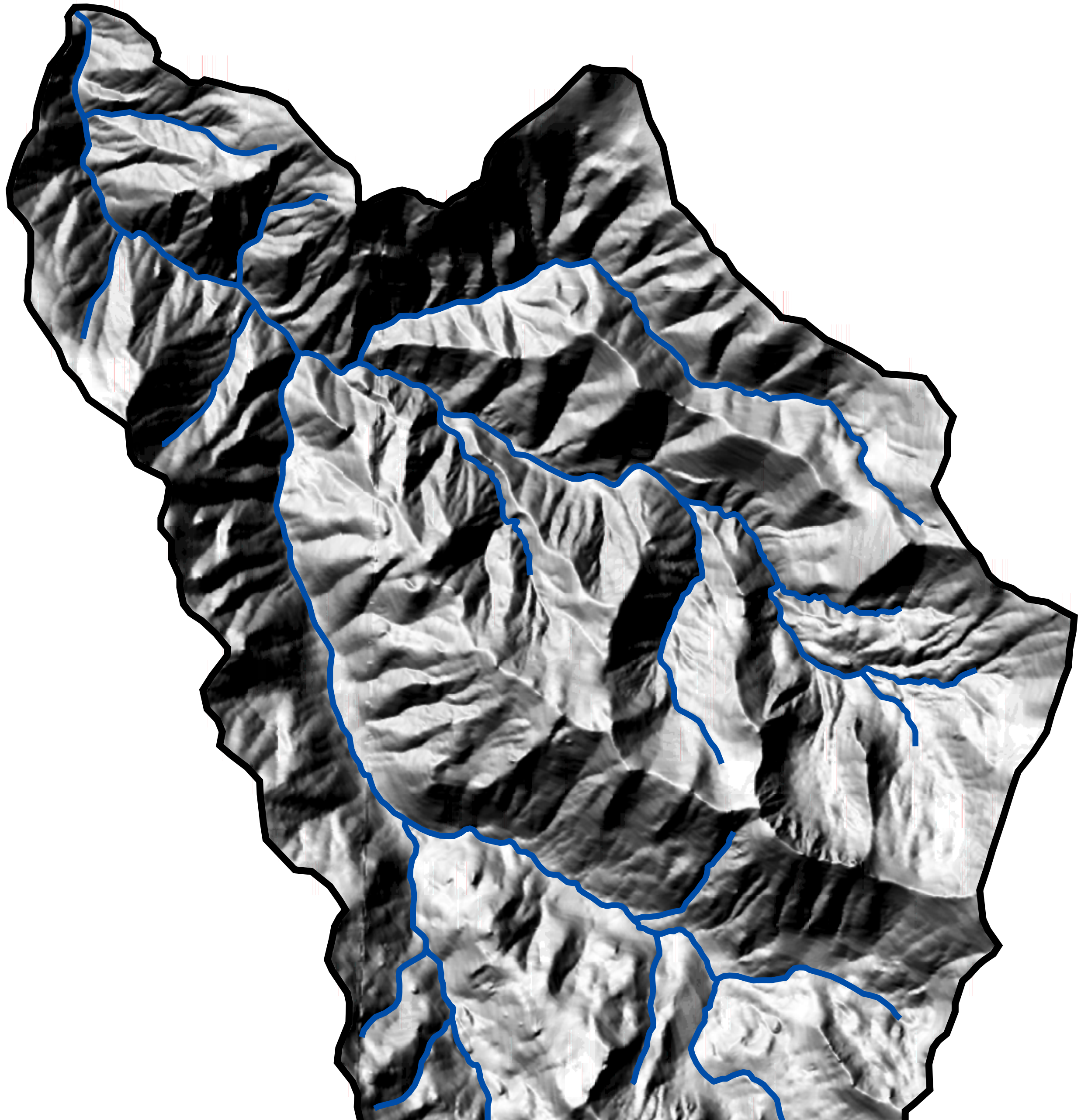


FIGURE 2.1 STUDY AREA MAP



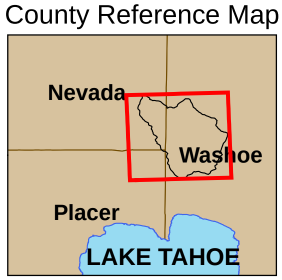
Data Source: USGS National Elevation Dataset

Legend

Gray Creek Watershed Boundary

Streams

County Reference Map



GRAY CREEK WATERSHED ASSESSMENT

HILLSHADE MAP

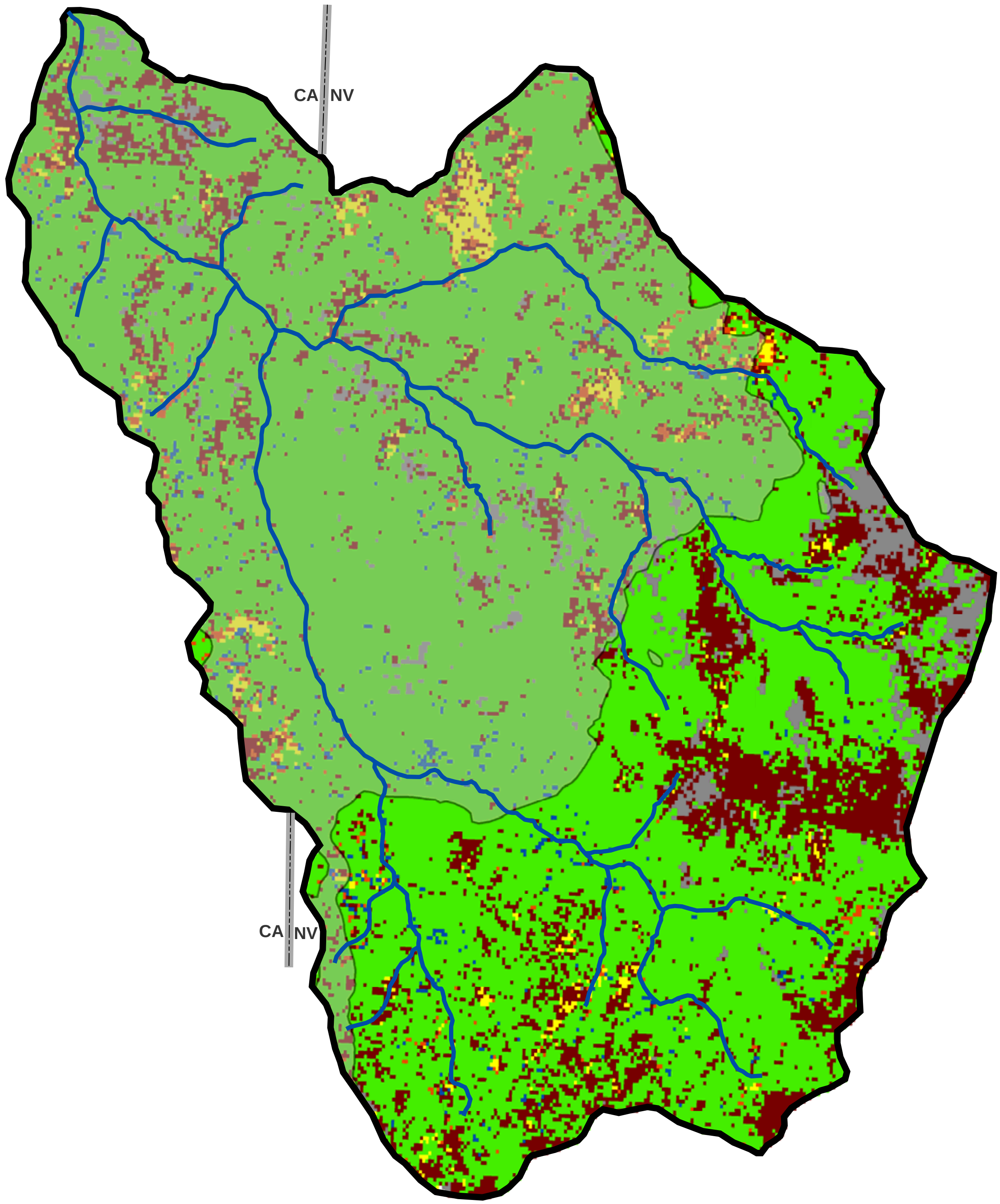
Scale - 1:50,000

0 2,500 5,000 Feet

N W E S

UTM ZONE 11N	NAD 83	horizontal units: feet
northwest hydraulic consultants	project no. 50429	November 2006

FIGURE 2.2 HILLSHADE MAP



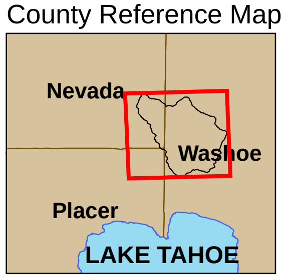
Data Source: National Land Cover Dataset 1992

Legend

- Streams
- Perennial Ice/Snow
- Deciduous Forest
- Evergreen Forest
- Grasslands/Herbaceous
- Mixed Forest
- Shrubland
- Bare Rock

Note: Shading denotes Martis Fire burn area

County Reference Map



GRAY CREEK WATERSHED ASSESSMENT

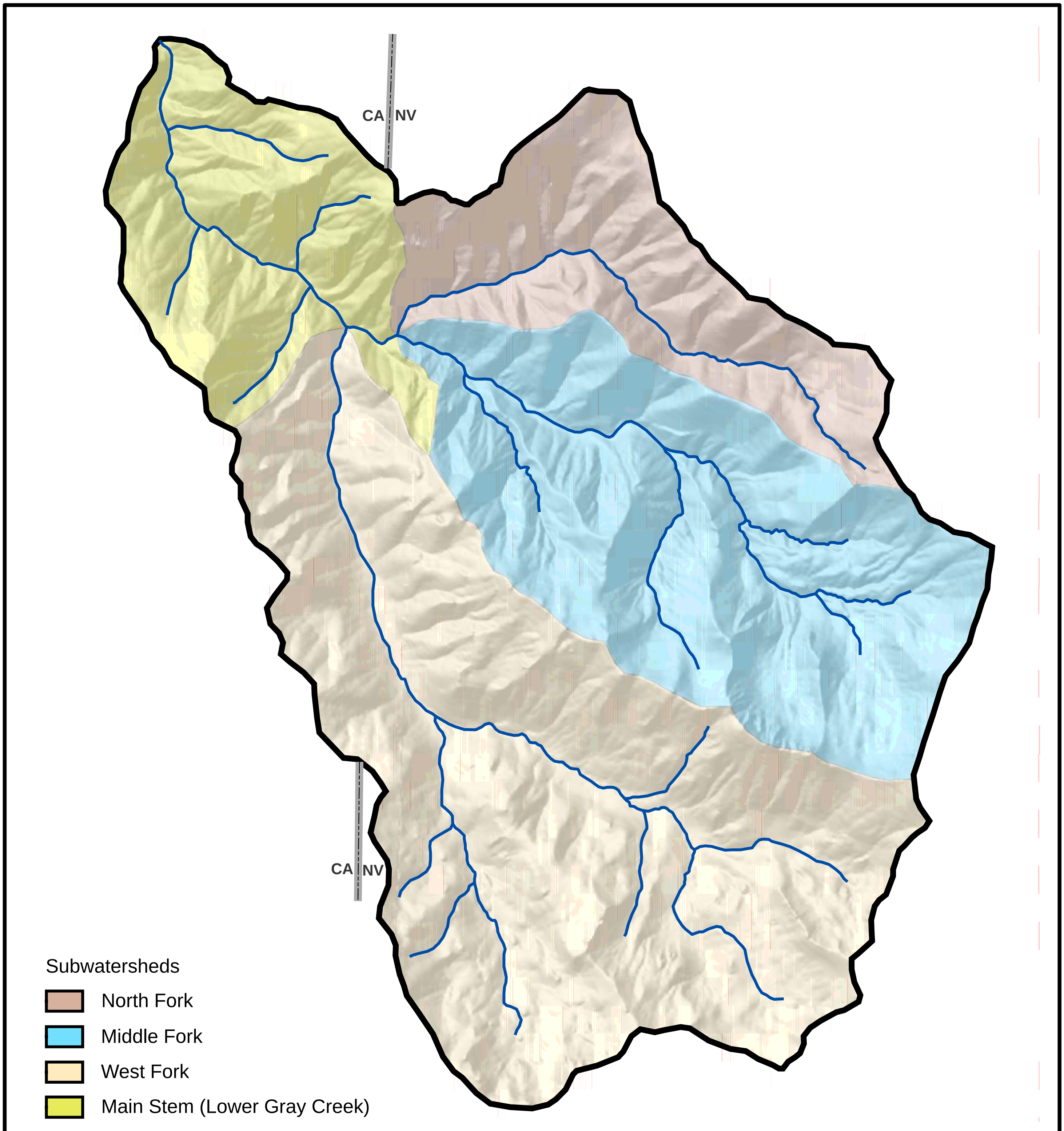
LAND COVER MAP

Scale - 1:50,000

0 2,500 5,000 Feet

UTM ZONE 11N	NAD 83	horizontal units: feet
northwest hydraulic consultants	project no. 50429	November 2006

FIGURE 2.3 LAND COVER MAP

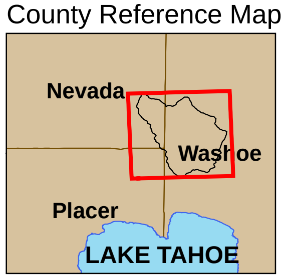


Legend

Watershed Boundary

Streams

County Reference Map



GRAY CREEK WATERSHED ASSESSMENT

SUBWATERSHED MAP

Scale - 1:50,000

0 2,500 5,000 Feet

UTM ZONE 11N	NAD 83	horizontal units: feet
northwest hydraulic consultants	project no. 50429	November 2006

FIGURE 2.4 SUBWATERSHED MAP

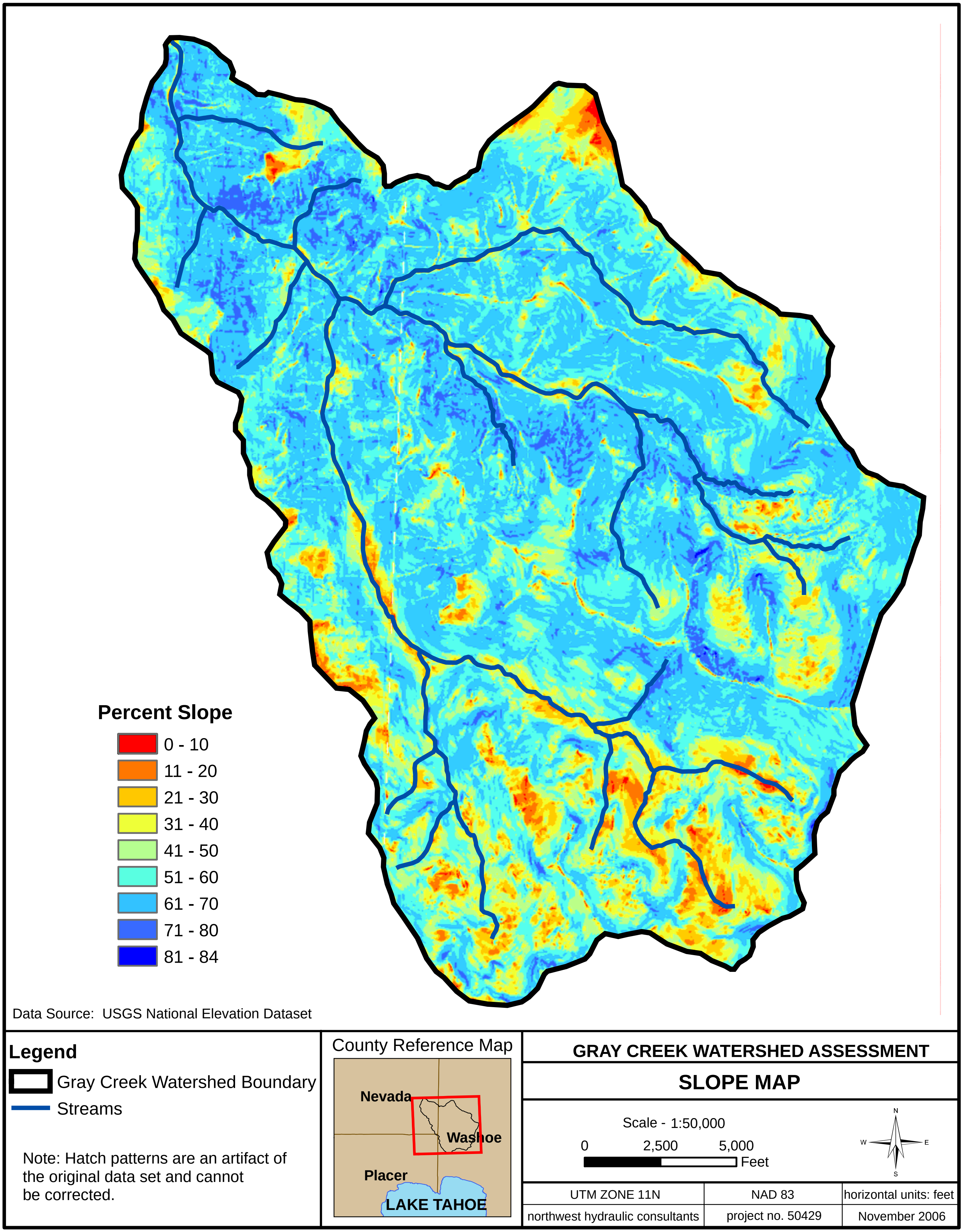


FIGURE 2.5 SLOPE MAP

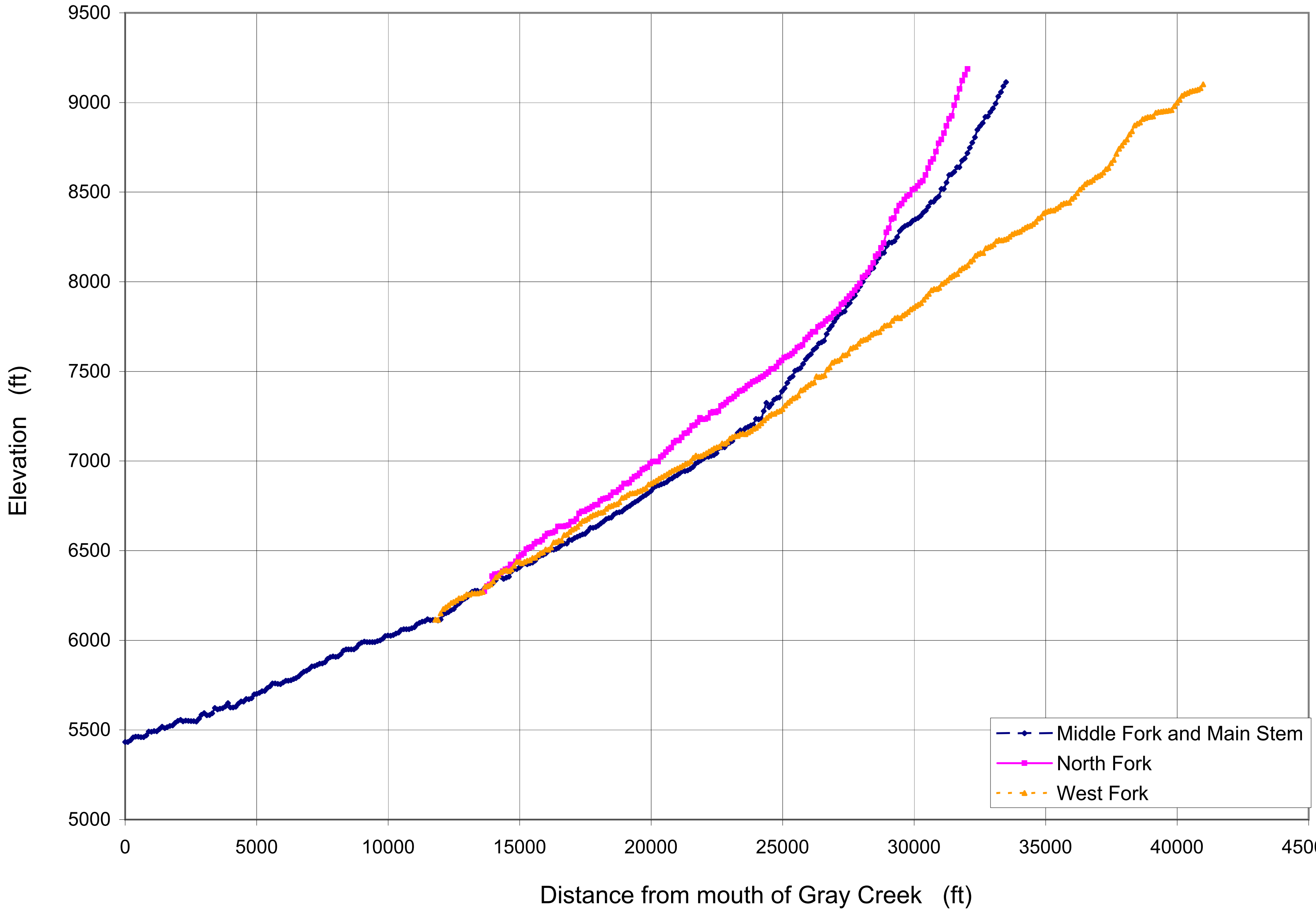


Figure 2.6 Longitudinal profiles of Gray Creek and main tributaries

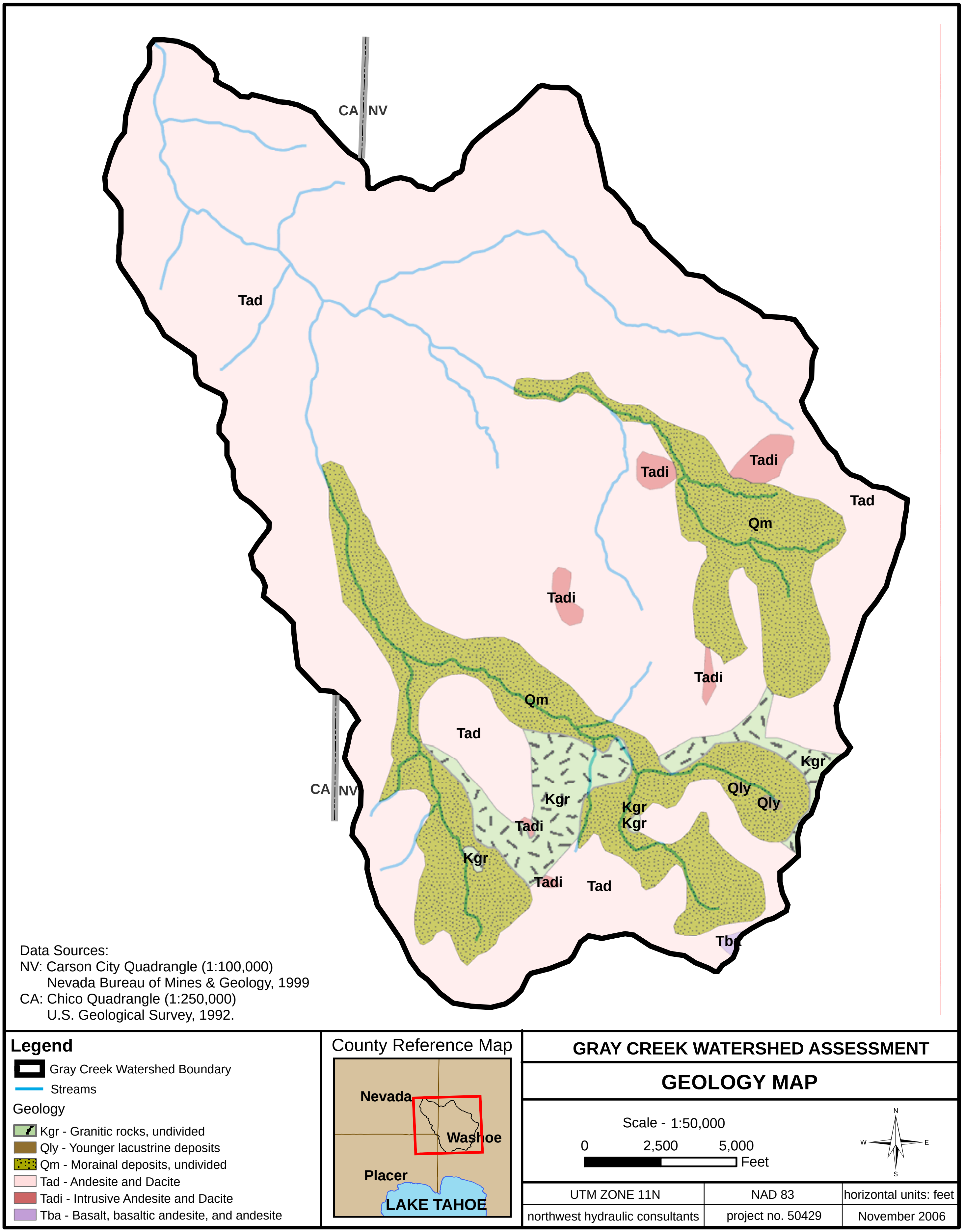
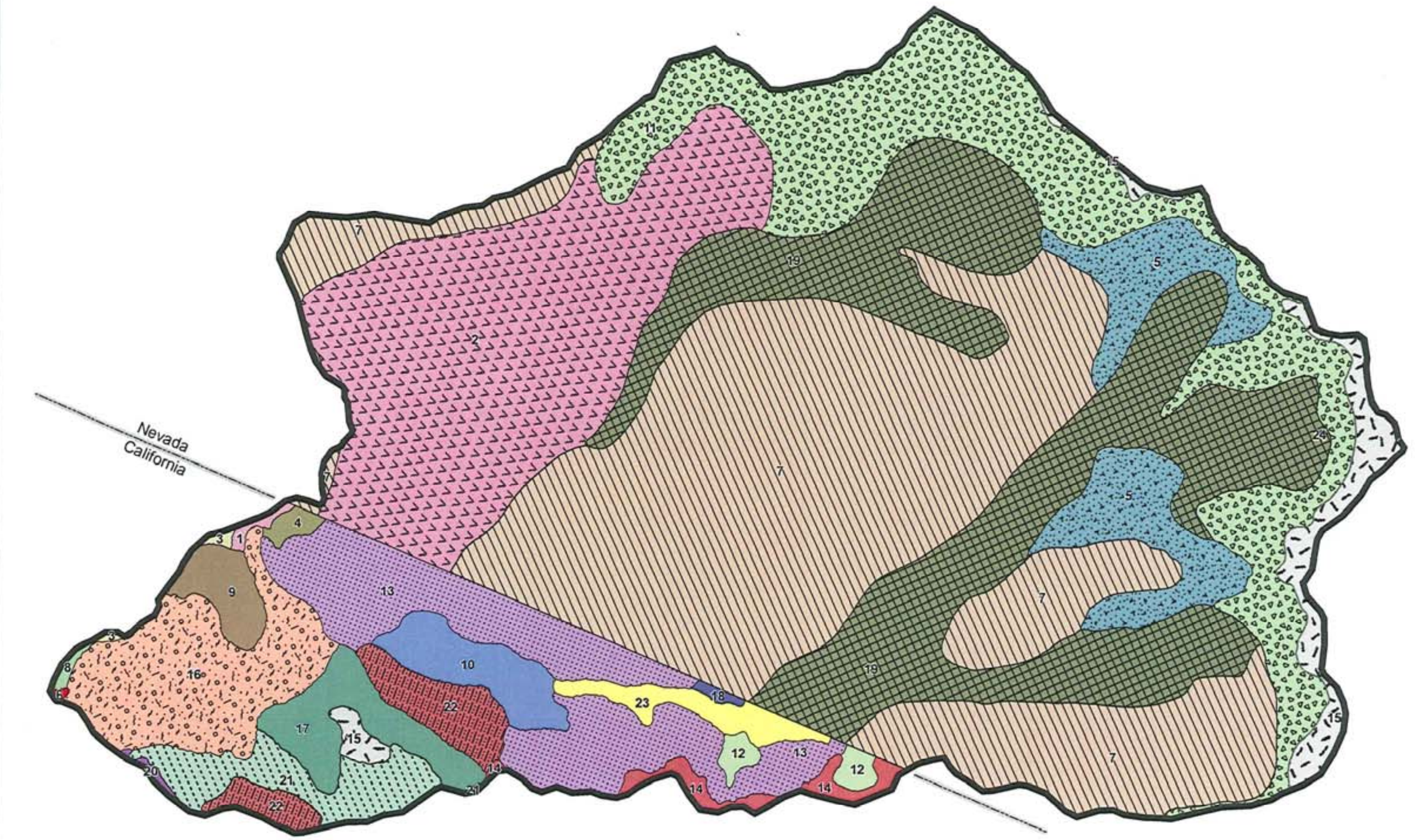


FIGURE 2.7 GEOLOGY MAP



Data Source: NRCS Soil Surveys

GRAY CREEK WATERSHED ASSESSMENT

SOILS MAP

Scale - 1:36,000
1 inch = 3000 feet

UTM Zone 11 N	horz. datum: NAD 83	horz. units: meters
northwest hydraulic consultants	project no. 50429	November 2006

REFERENCE MAP

LEGEND

Gray Creek Watershed Boundary

Soils

- 1 - ALDI-KYBURZ-ROCK OUTCROP COMPLEX, 30 TO 75 PERCENT SLOPES - COBBLY LOAM TO GRAVELLY SANDY LOAM
- 2 - DUCKHILL-HIRSCHDALE-FRAVAL ASSOCIATION - GRAVELLY STONY LOAM
- 3 - FUGAWEE-ROCK OUTCROP-TAHOMA COMPLEX, 30 TO 50 PERCENT SLOPES - VERY STONY AND COBBLY SANDY LOAM
- 4 - FUGAWEE VARIANT-FUGAWEE-ROCK OUTCROP COMPLEX, 30 TO 75 PERCENT SLOPES - VERY STONY SANDY LOAM
- 5 - GRAYLOCK-TEMO-ROCK OUTCROP COMPLEX, 30 TO 70 PERCENT SLOPES - GRAVELLY LOAMY COARSE SAND
- 6 - INVILLE-RIVERWASH-AQUOLLS COMPLEX, 2 TO 5 PERCENT SLOPES - GRAVELLY COARSE SANDY LOAM
- 7 - JORGE-BOOMTOWN-FUGAWEE ASSOCIATION - VERY STONY AND STONY SANDY LOAM
- 8 - KYBURZ-ALDI COMPLEX, 30 TO 50 PERCENT SLOPES - GRAVELLY SANDY AND COBBLY LOAM
- 9 - KYBURZ-TROJAN COMPLEX, 9 TO 30 PERCENT SLOPES - GRAVELLY SANDY LOAM
- 10 - MEISS-GULLIED LAND-ROCK OUTCROP COMPLEX, 30 TO 75 PERCENT SLOPES - GRAVELLY ASHY LOAM
- 15 - ROCK OUTCROP
- 24 - WATER

Soils Continued

- 11 - MEISS-SIBELIA-ROCK OUTCROP ASSOCIATION - GRAVELLY ASHY LOAM AND VERY COBBLY SANDY LOAM
- 12 - MEISS-WACA-CRYUMBREPTS, WET COMPLEX, 2 TO 30 PERCENT SLOPES - GRAVELLY ASHY LOAM AND VERY GRAVELLY COARSE SANDY LOAM
- 13 - MEISS-WACA-ROCK OUTCROP COMPLEX, 30 TO 50 PERCENT SLOPES, SEVERELY ERODED - GRAVELLY ASHY LOAM AND VERY GRAVELLY COARSE SANDY LOAM
- 14 - MEISS-WACA COMPLEX, 2 TO 30 PERCENT SLOPES - GRAVELLY ASHY LOAM AND VERY GRAVELLY COARSE SANDY LOAM
- 16 - ROCK OUTCROP-FRANKTOWN-KYBURZ COMPLEX, 50 TO 75 PERCENT SLOPES - VERY STONY TO GRAVELLY SANDY LOAM
- 17 - ROCK OUTCROP-WOODSEYE VARIANT-UMPA COMPLEX, 30 TO 75 PERCENT SLO PES - STONY TO VERY GRAVELLY SANDY LOAM
- 18 - TALLAC-CRYUMBREPTS, WET COMPLEX, 2 TO 30 PERCENT SLOPES - GRAVELLY COARSE SANDY LOAM
- 19 - TALLAC SERIES, 4 TO 30 PERCENT SLOPES - VERY BOULDERY SANDY LOAM
- 20 - UMPA-ROCK OUTCROP COMPLEX, 2 TO 30 PERCENT SLOPES - STONY SANDY LOAM, ROCKY
- 21 - UMPA-ROCK OUTCROP COMPLEX, 30 TO 75 PERCENT SLOPES - STONY SANDY LOAM, ROCKY
- 22 - UMPA SERIES, 30 TO 50 PERCENT SLOPES - STONY SANDY LOAM
- 23 - WACA-CRYUMBREPTS, WET-WINDY COMPLEX, 30 TO 50 PERCENT SLOPES - VERY GRAVELLY COARSE SANDY LOAM

FIGURE 2.8 SOILS MAP

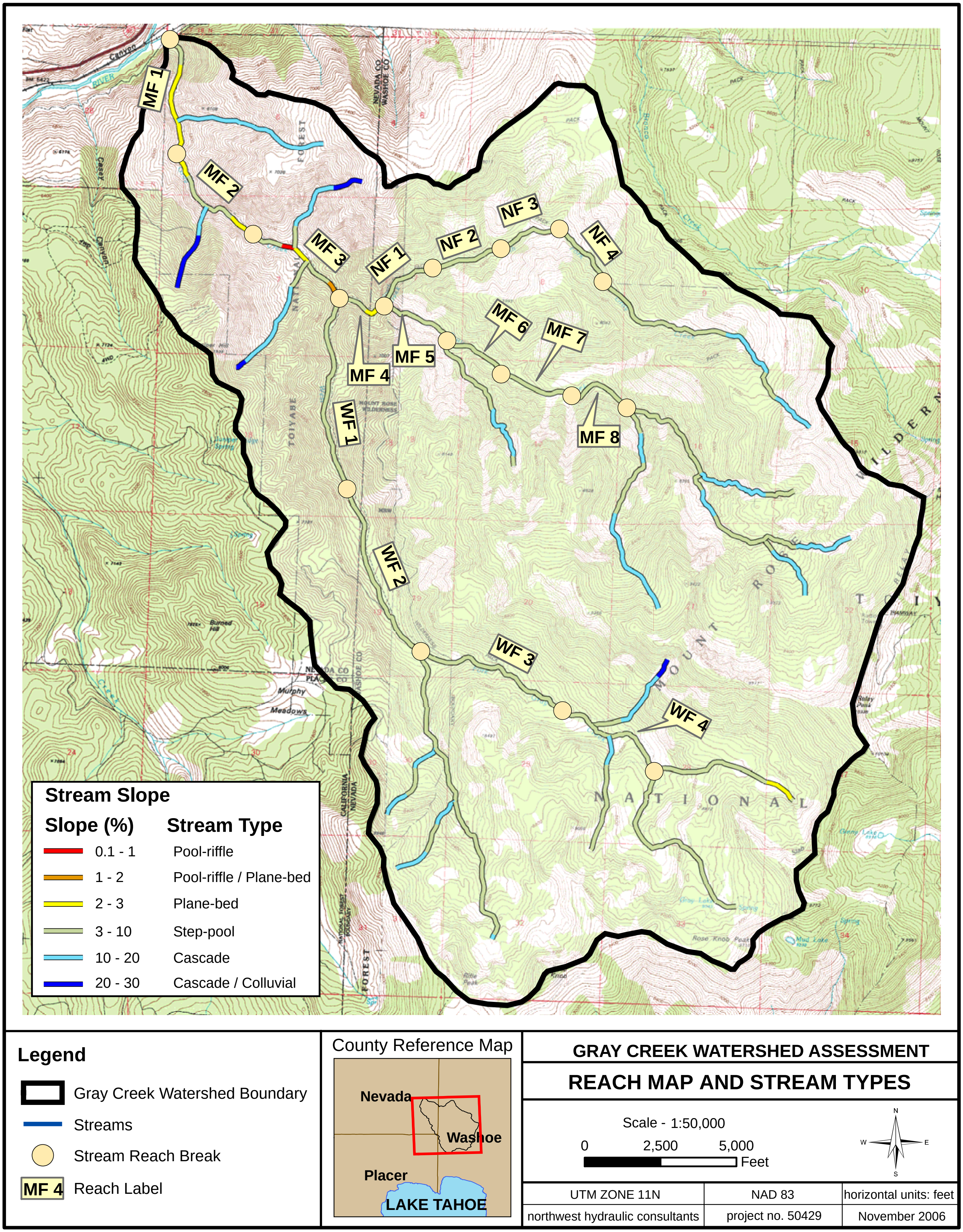


FIGURE 2.9 REACH MAP AND STREAM TYPES

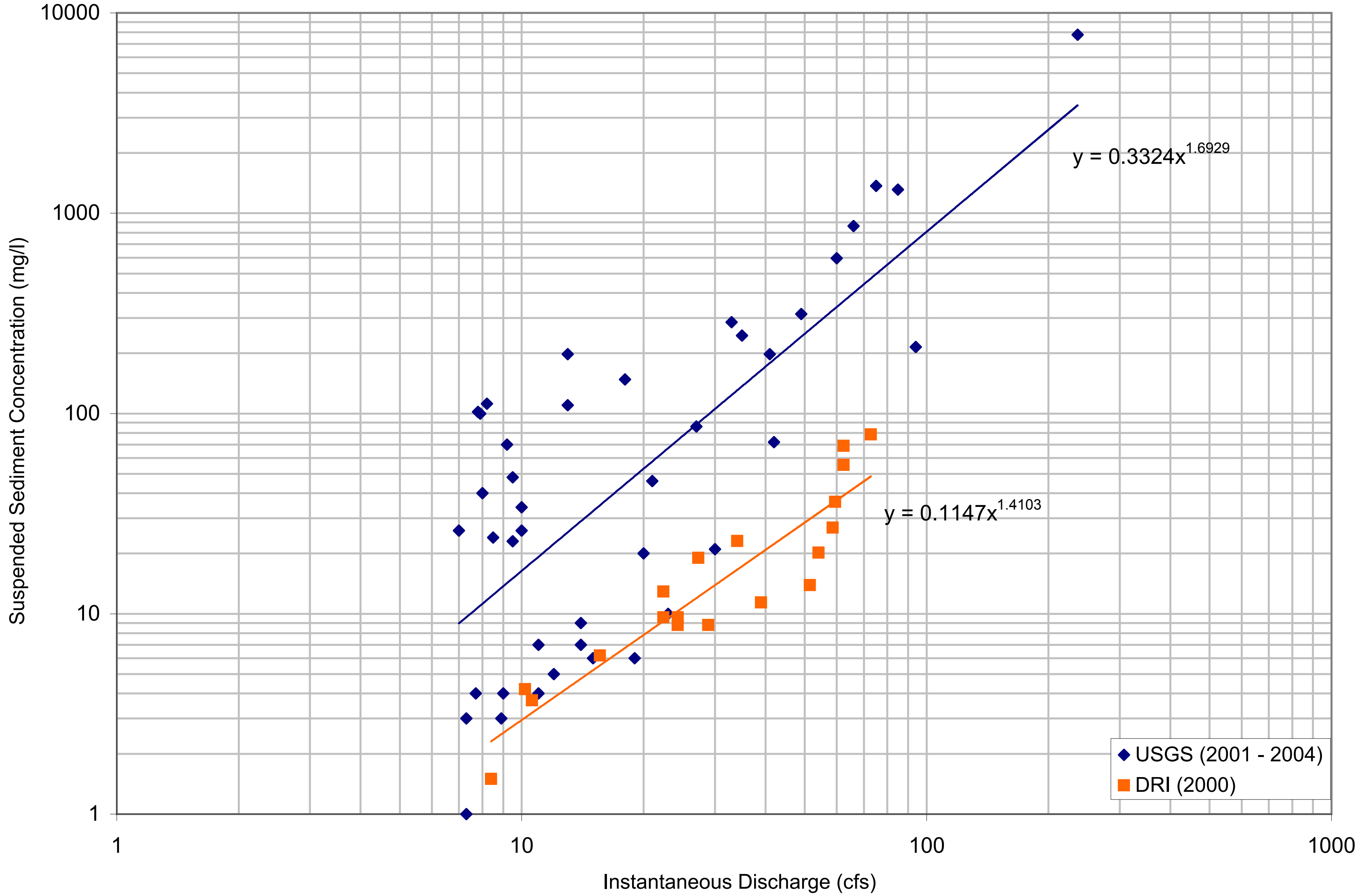


Figure 2.10 Gray Creek suspended sediment concentrations.

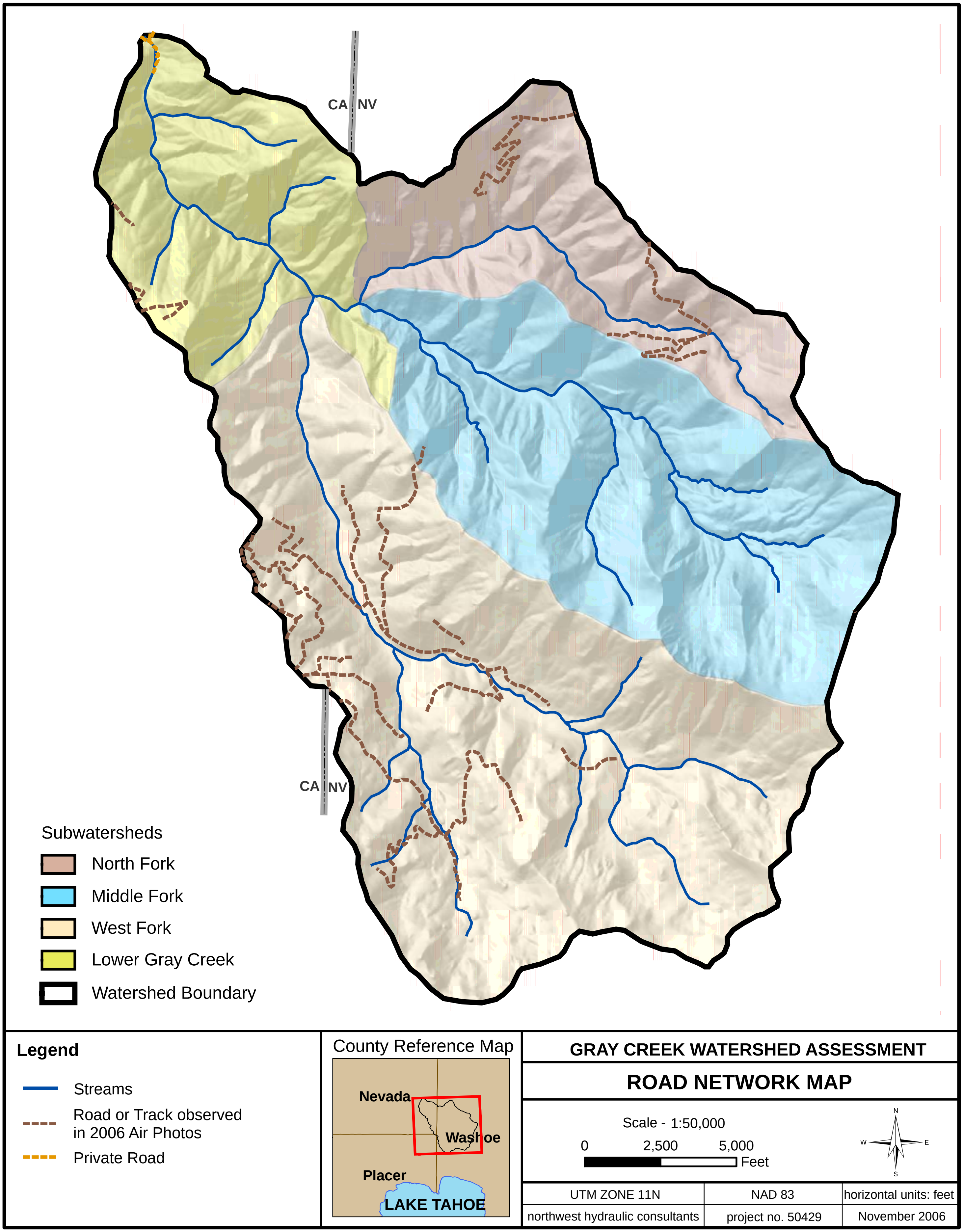


FIGURE 2.11 ROAD NETWORK MAP

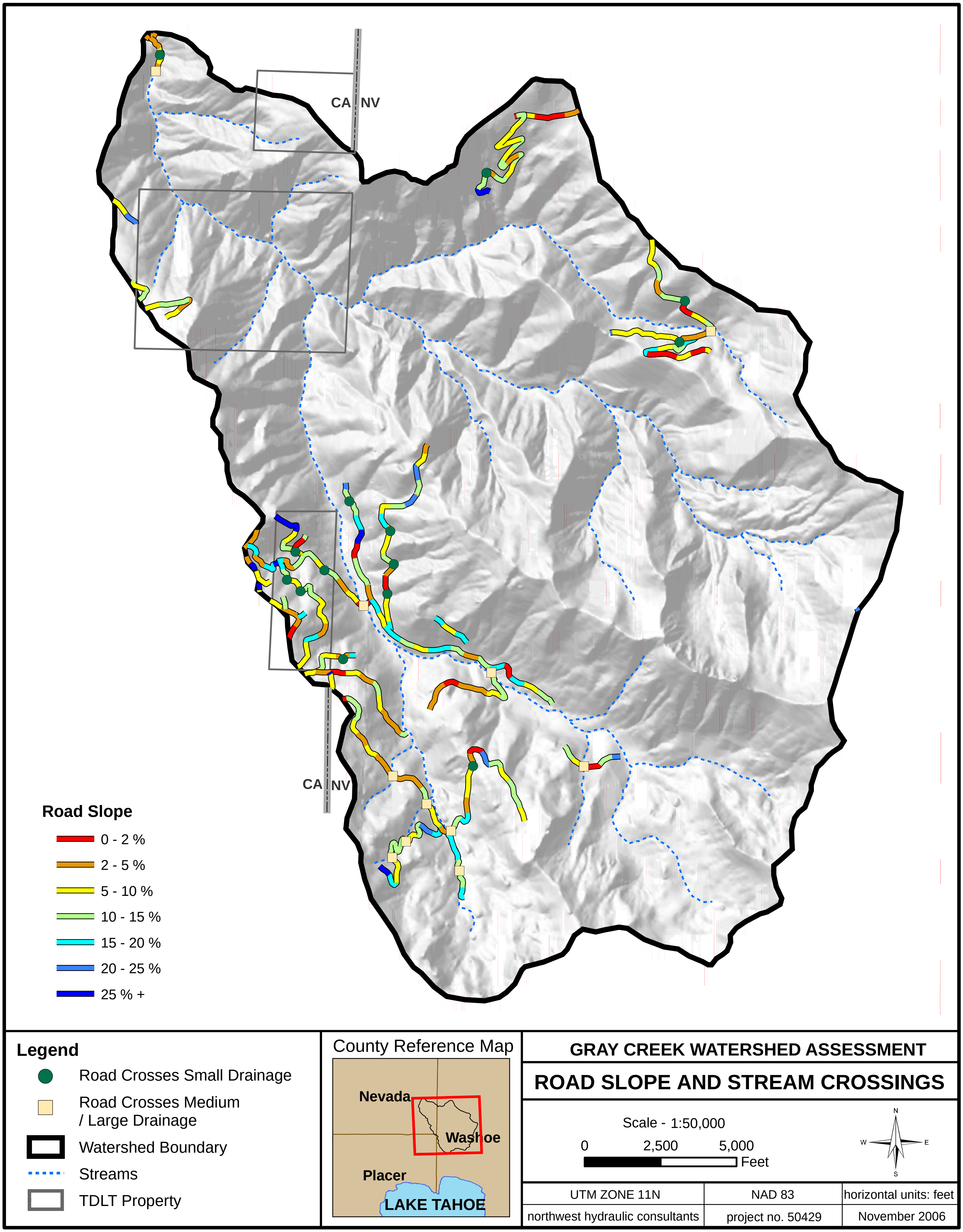
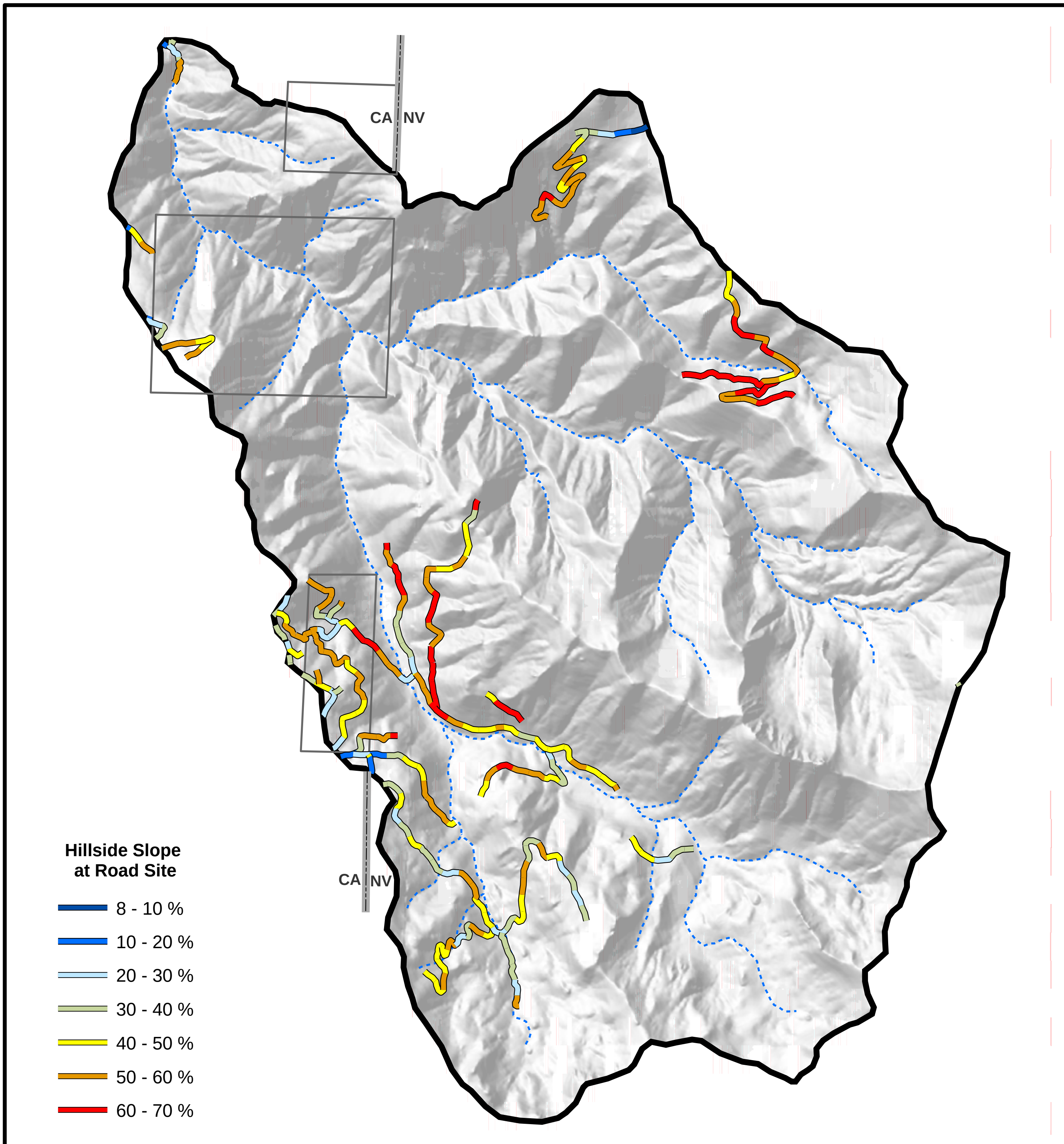


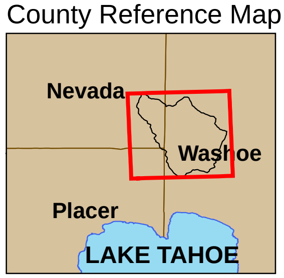
FIGURE 2.12 ROAD SLOPE AND STREAM CROSSINGS



Legend

- Watershed Boundary
- Streams
- TDLT Property

County Reference Map



GRAY CREEK WATERSHED ASSESSMENT

HILLSIDE SLOPE AT ROAD SITES

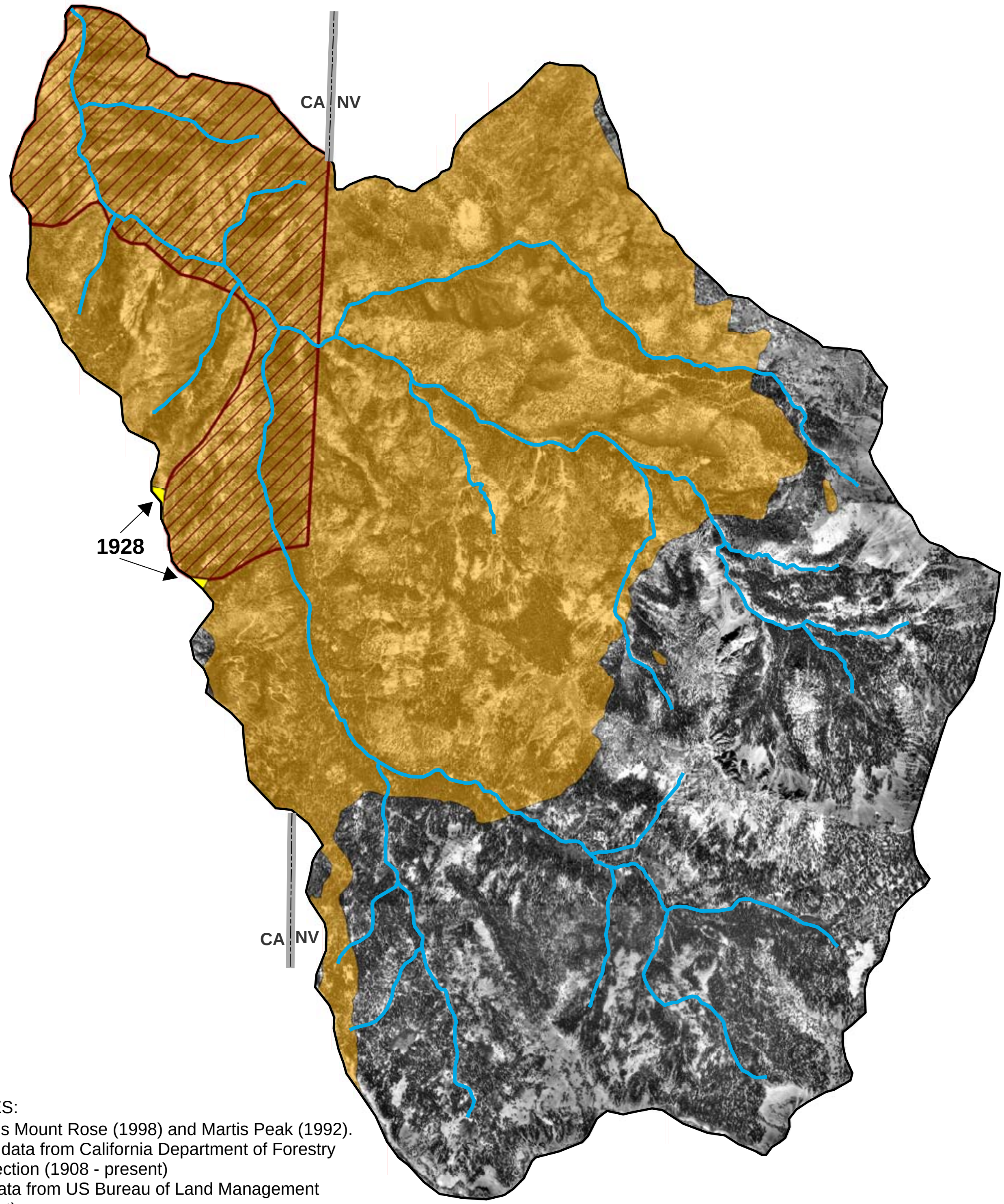
Scale - 1:50,000

0 2,500 5,000 Feet

N W E S

UTM ZONE 11N	NAD 83	horizontal units: feet
northwest hydraulic consultants	project no. 50429	November 2006

FIGURE 2.13 HILLSIDE SLOPE AT ROAD SITE



DATA SOURCES:
- USGS DOQQs Mount Rose (1998) and Martis Peak (1992).
- California fire data from California Department of Forestry and Fire Protection (1908 - present)
- Nevada fire data from US Bureau of Land Management (1941 - present)

Legend

Gray Creek Watershed Boundary

Streams

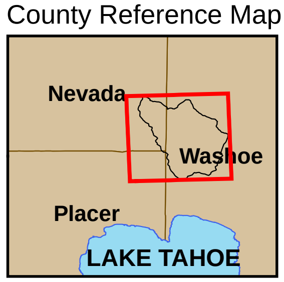
Fire History

1926 (CA data only; no NV data)

1928 (CA data only; no NV data)

2001 - Martis Fire

County Reference Map



GRAY CREEK WATERSHED ASSESSMENT

FIRE HISTORY MAP

Scale - 1:50,000

0 2,500 5,000 Feet

UTM ZONE 11N	NAD 83	horizontal units: feet
northwest hydraulic consultants	project no. 50429	November 2006

FIGURE 2.14 FIRE HISTORY MAP

GRAY CREEK WATERSHED ASSESSMENT

nhc
DECEMBER 2006

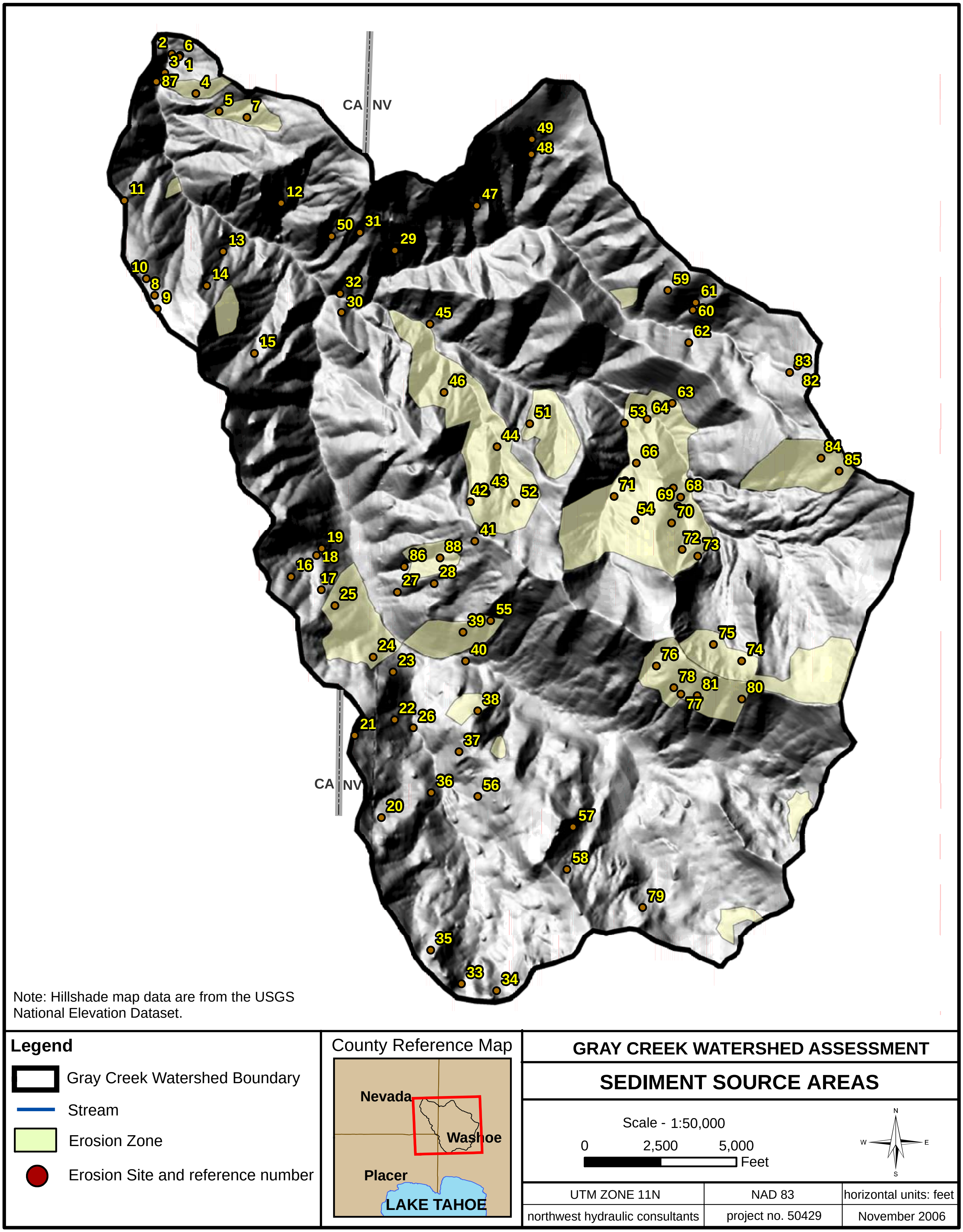


FIGURE 3.1 SEDIMENT SOURCE AREAS

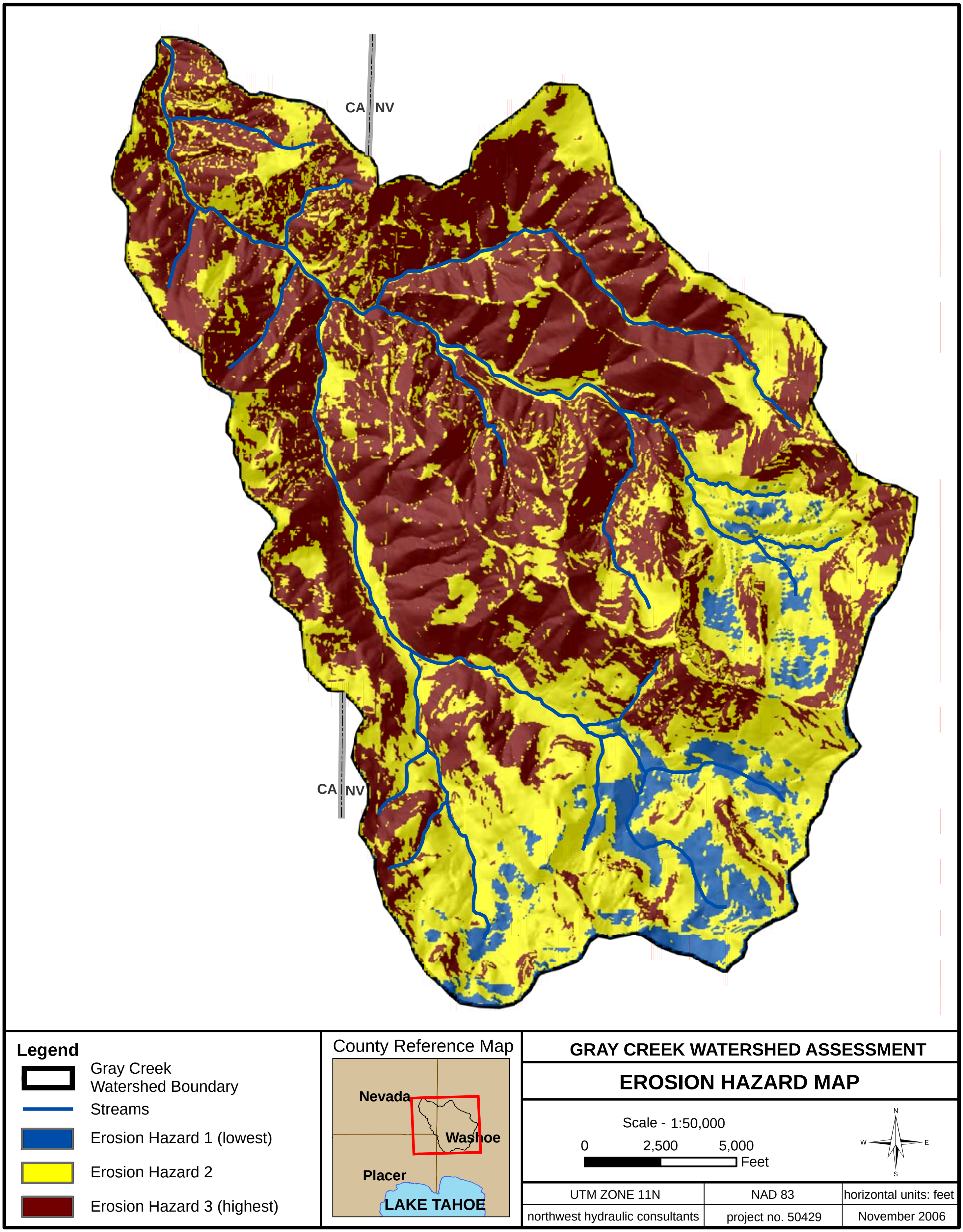


FIGURE 3.2 EROSION HAZARD MAP

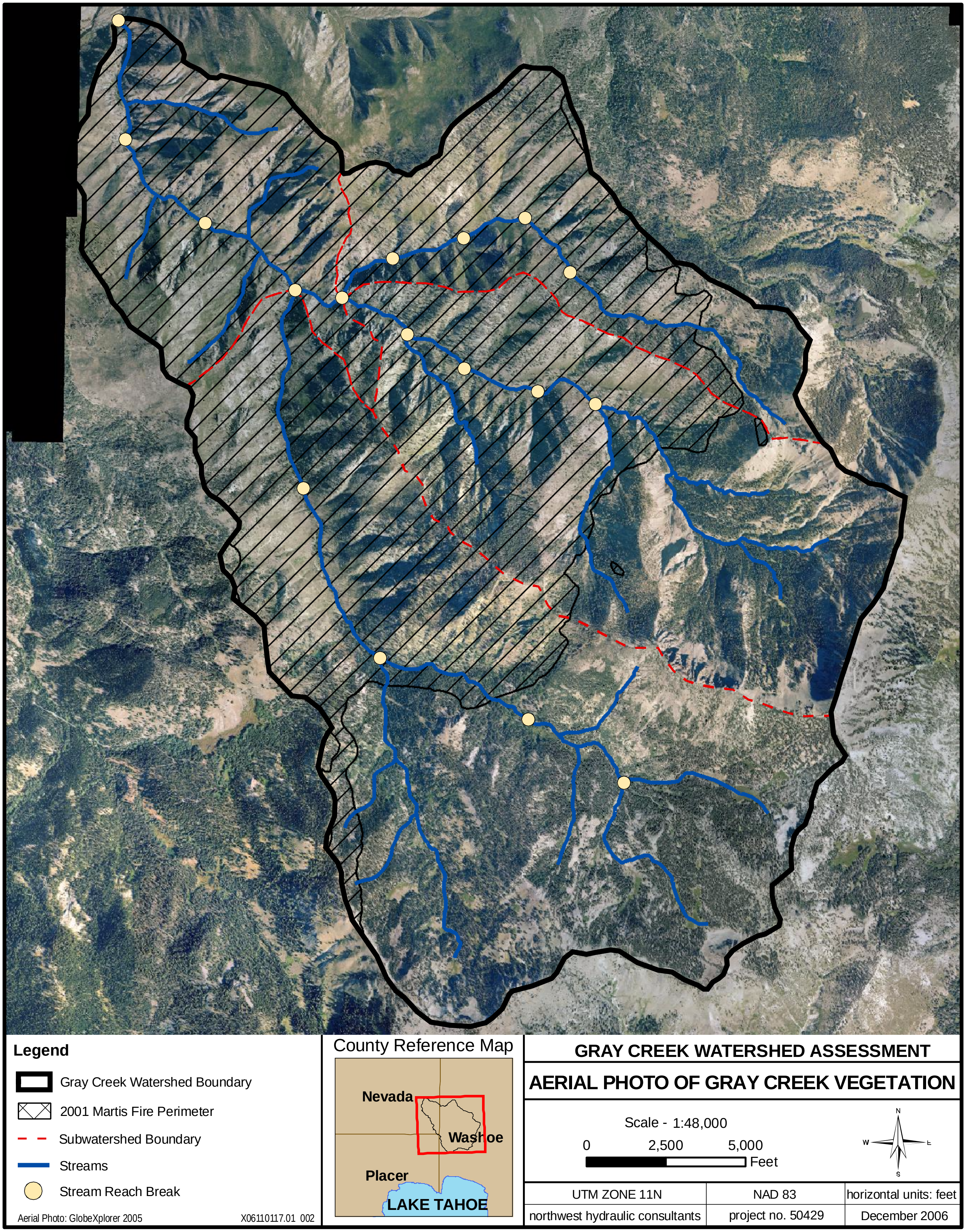


FIGURE 4.1 AERIAL PHOTO OF GRAY CREEK VEGETATION

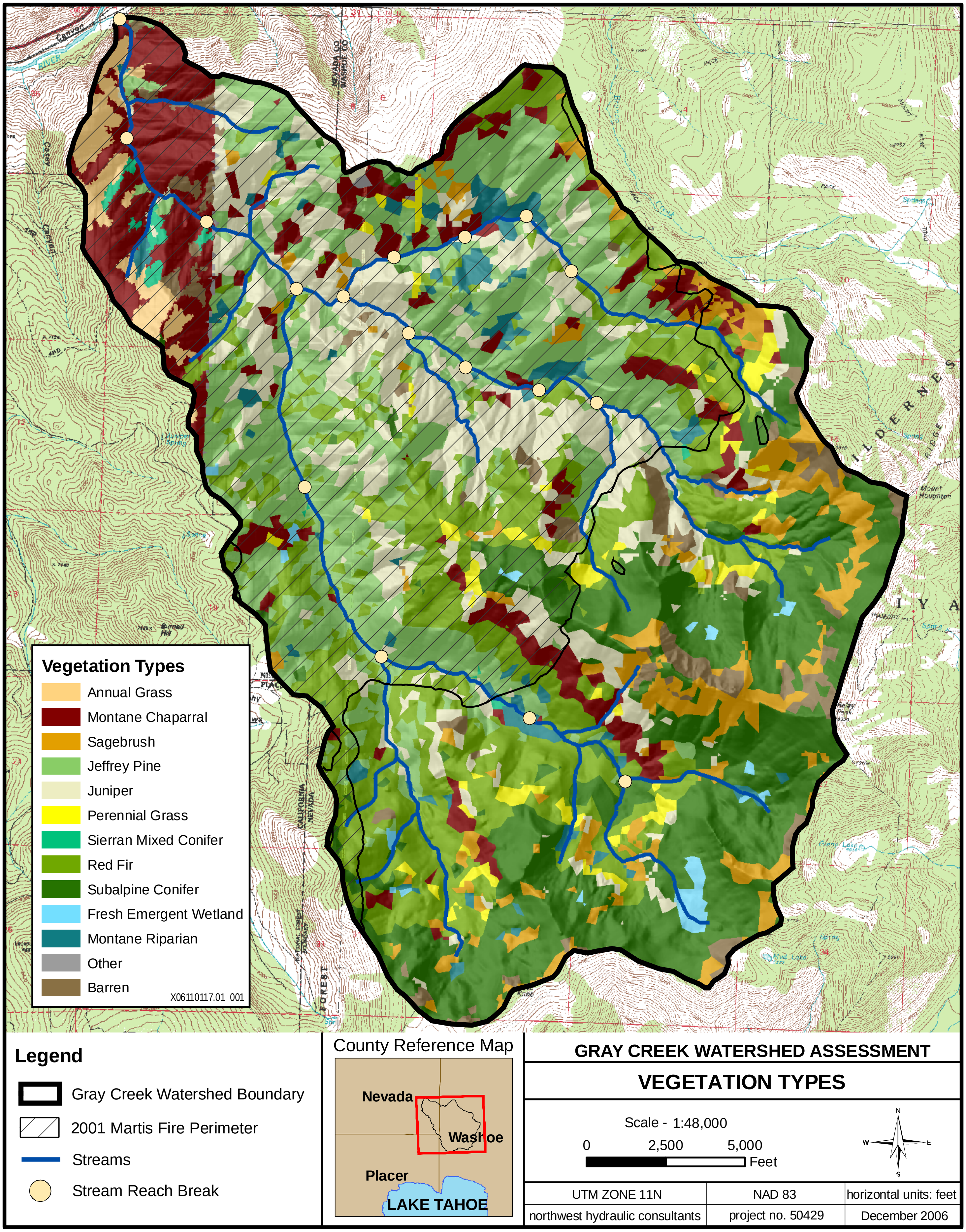
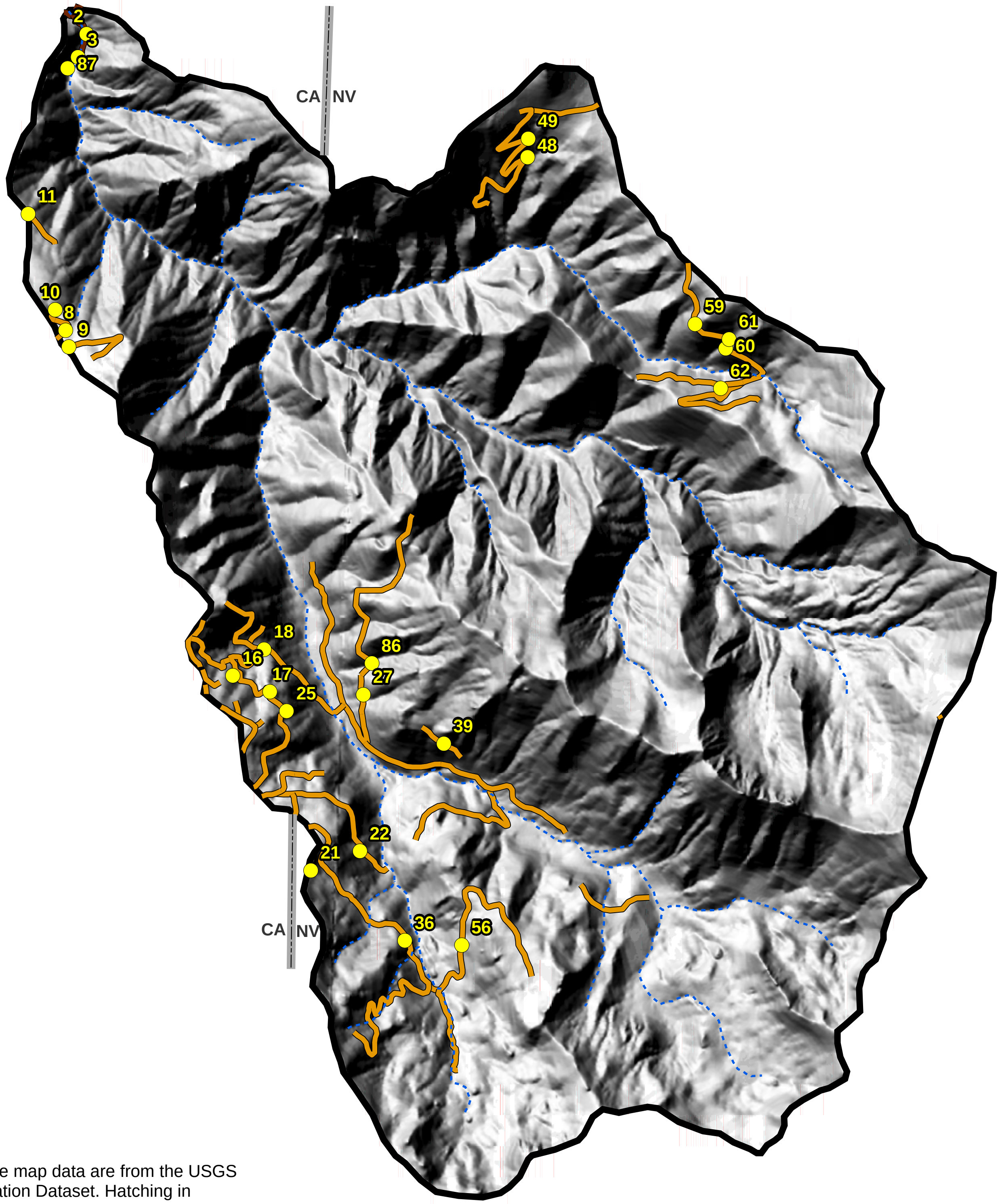


FIGURE 4.2 VEGETATION TYPES

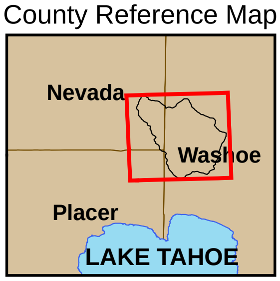


Note: Hillshade map data are from the USGS National Elevation Dataset. Hatching in California data are an artifact of the dataset.

Legend

- Gray Creek Watershed Boundary
- Stream
- Road
- Erosion Site and reference number

County Reference Map



GRAY CREEK WATERSHED ASSESSMENT

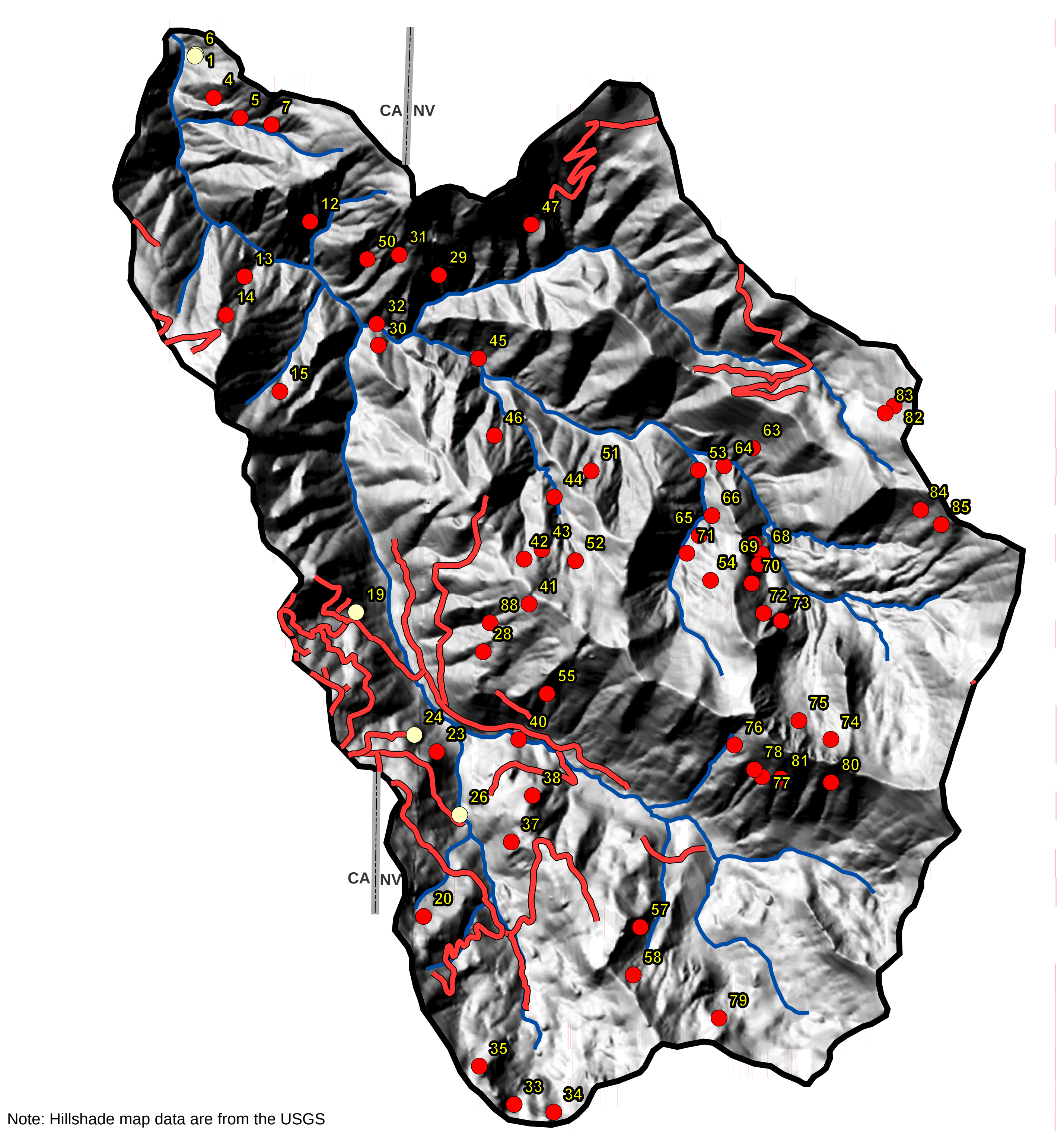
ROAD EROSION SITES

Scale - 1:50,000

0 2,500 5,000 Feet

UTM ZONE 11N	NAD 83	horizontal units: feet
northwest hydraulic consultants	project no. 50429	November 2006

FIGURE 5.1 ROAD EROSION SITES



Note: Hillshade map data are from the USGS National Elevation Dataset.

Legend

Gray Creek Watershed Boundary

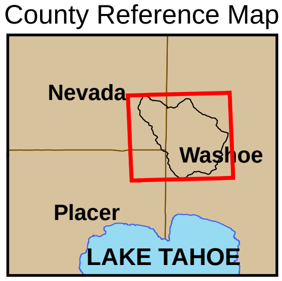
Stream

Road

Erosion Site and reference number

Erosion site is located within 300 ft of a road

County Reference Map



GRAY CREEK WATERSHED ASSESSMENT

NATURAL EROSION SITES

Scale - 1:50,000

0 2,500 5,000 Feet

UTM ZONE 11N	NAD 83	horizontal units: feet
northwest hydraulic consultants	project no. 50429	November 2006

FIGURE 5.2 NATURAL EROSION SITES

Photos

Photo 2-1. Looking downstream in Reach MF-1 near the mouth of Gray Creek.

Photo 2-2. Looking upstream in Reach MF-1, upstream of the Andresen bridge.

Photo 2-3. Walking upstream on a partially eroded gravel bar in Reach MF-1.

Photo 2-4. Typical example of small bank failure of coarse material in Reach MF-1.

Photo 2-5. Looking north across the Andresen low water crossing in Reach MF-1. Flow is to the left of the photo.

Photo 2-6. Walking upstream in Reach MF-1, downstream of the first main tributary.

Photo 2-7. Looking upstream at a small side feeder channel to Gray Creek in Reach MF-1.

Photo 2-8. This notch is a side tributary to Gray Creek that has incised through volcanic flow deposits in Reach MF-1.

Photo 2-9. Typical forest road near the entrance to Gray Creek watershed via Murphy Meadows.

Photo 2-10. Looking north across burned area of West Fork subwatershed.

Photo 2-11. Old forestry loading area with virtually no vegetation regrowth near Murphy Meadows in West Fork subwatershed.

Photo 2-12. Close up of road erosion caused by small drainage just downslope of Murphy Meadows in West Fork subwatershed.

Photo 2-13. Severe erosion along abandoned road cut in West Fork subwatershed.

Photo 2-14. Abandoned forest road leading to Reach WF-2 in West Fork subwatershed.

Photo 2-15. Looking upstream a short distance upstream of a washed out road crossing in Reach WF-2 in West Fork subwatershed.

Photo 2-16. Typical appearance of burned slope in West Fork subwatershed.

Photo 2-17. Looking downstream at typical step-pool stream morphology in Reach WF-2 in West Fork subwatershed.

Photo 2-18. Looking downslope at trail in West Fork subwatershed adjacent Reach WF-2. Fresh motorcycle tracks were observed here.

Photo 4-1. View looking downstream towards I-80 and the Truckee River corridor at the lower end of Main Stem Reach 1 (MF-1).

Photo 4-2. Remnants of a dam structure in the lower end of Main Stem Reach 1 (MF-1).

Photo 4-3. Old water diversion-type structures in the lower end of Main Stem Reach 1 (MF-1).

Photo 4-4. Road crossing, Main Stem Reach 1 (MF-1).

Photo 4-5. View looking upstream at a step in the channel created by road crossing, Main Stem Reach 1 (MF-1)

Photo 4-6. View looking downstream at wooden dam/diversion materials just above road crossing shown in Photo 4-5, Main Stem Reach 1 (MF-1).

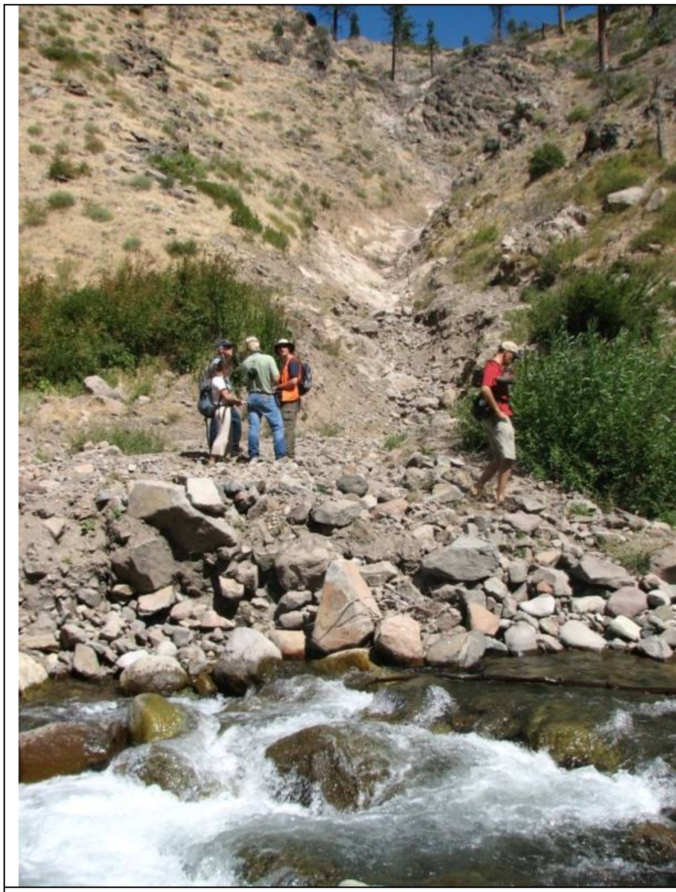


Photo 4-7. Natural debris flow, typical of side drainages in the lower Main Stem, Main Stem Reach 2 (MF-2).

Photo 4-8. View looking downstream at typical riparian vegetation in the lower portions of the Main Stem, Main Stem Reach 2 (MF-2).

Photo 4-9. Typical steep hillside with rock outcrops intermixed with upland vegetation, above Main Stem Reach 2 (MF-2).

Photo 4-10. Typical steep hillside with rock outcrops and discontinuous vegetation, left side (if facing downstream) above Main Stem Reach 2 (MF-2).

Photo 4-11. View looking up at road (left side of photo) above the left side of upper West Fork Tributary 1 (WF-T1).

Photo 4-12. View looking down at erosion into Gray Creek from the same road shown in Photo 4-11, left side of upper West Fork Tributary 1 (WF-T1).

Photo 4-13. View of the same road shown in Photo 4-11, upper West Fork Tributary 1 (WF-T1).

Photo 4-14. View of the same road shown in Photo 4-11, where road intersects with seep, upper West Fork Tributary 1 (WF-T1).

Photo 4-15. Montane riparian vegetation associated with seep, and road edge (lower right section of photo), upper portion of West Fork Tributary 1 (WF-T1). Road conveys flow where seep is crossed.

Photo 4-16. View looking west across West Fork Tributary 1 (WF-T1) at eroded slope above the tributary. Barely visible here, the road pictured in Photo 4-11 traverses this slope just above the non-vegetated feature in the lower left of photo.

Photo 4-17. View looking downstream, upper West Fork Tributary 1 (WF-T1).

Photo 4-18. Road crossing, West Fork Tributary 1 (WF-T1).

Photo 4-19. Post-fire conditions where the Martis Fire was patchy, near the confluence of West Fork Reach 2 (WF-2) and West Fork Tributary 1 (WF-T1).

Photo 4-20. Road crossing near the upper end of West Fork Reach 2 (WF-2).

Photo 4-21. Typical view of riparian corridor along West Fork Reach 2 (WF-2).

Photo 4-22. Conditions five years after stand-replacing fire in forest upland, West Fork Reach 2 (WF-2).

Photo 4-23. Erosion control structure in severely burned forest, West Fork Reach 2 (WF-2).

Photo 4-24. Thistle infestation, West Fork Reach 2 (WF-2).

Photo 4-25. Evidence of beaver (*Castor canadensis*) activity along West Fork Reach 2 (WF-2).

Photo 4-26. View looking downstream of West Fork Reach 1 (WF-1) towards the confluence of the West Fork and Main Stem.

Photo 4-27. Spring and associated meadow/riparian vegetation, from east side West Fork Reach 1 (WF-1).

Photo 4-28. Typical view of riparian corridor, looking downstream, West Fork Reach 1 (WF-1).

Photo 4-29. Typical view of channel, Main Stem Reach 4 (MF-4), above confluence with the West Fork.

Photo 4-30. Typical canyon view near the confluence of the Main Stem and North Forks.

Photo 4-31. View of the upper Main Stem (Main Stem Reach 4 [MF-4]), looking downstream from its confluence with the North Fork.

Photo 4-32. Typical view of the narrow, densely-vegetated North Fork corridor, North Fork Reach 1 (NF-1).

Photo 4-33. Subalpine forest in the Middle Fork subwatershed.

Appendix 1

GIS Data Files

Appendix 2

Erosion Site Data Table

Erosion Zone Data Table

Erosion Site Data Table

Site Id	Land Cover	Erosion Class	Erosion Type	Erosion Sub-type	Erosion Width	Erosion Length	Erosion Area	Visible in 1998	Erosion Status	Sediment Delivery Zone	Stream Proximity	Road Proximity	Habitat Type	Habitat Implications	Priority
1	Martis Fire burn area	Natural	Mass Movement	Landslide	25	75	1875	X	Active	Stream	370	271			
2	Martis Fire burn area	Anthropogenic	Road Erosion	Landslide induced erosion of road bed	20	30	600	X	Potentially Active	Stream	103	0			
3	Martis Fire burn area	Anthropogenic	Road Erosion	River crossing susceptible to erosion	20	80	1600		Potentially Active	Stream	0	0			
4	Martis Fire burn area	Natural	Rilling and Gullying	2 gullies below small landslide source	10	500	5000		Active	Stream	1370	1152			
5	Martis Fire burn area	Natural	Mass Movement	Landslide	50	250	12500		Active	Stream	178	2125			
6	Martis Fire burn area	Natural	Mass Movement	Landslide	25	75	1875	X	Active	Stream	345	260			
7	Martis Fire burn area	Natural	Mass Movement	Landslide with minor gullying along the landslide runout	50	125	6250		Active	Stream	390	3005			
8	Martis Fire burn area	Anthropogenic	Road Erosion	Staging area / turnaround on roadway (bare ground)	30	100	3000	X	Potentially Active	Hillslope	515	0			
9	Martis Fire burn area	Anthropogenic	Road Erosion	Staging area / turnaround on roadway (bare ground)	40	140	5600	X	Potentially Active	Hillslope	872	0			
10	Martis Fire burn area	Anthropogenic	Road Erosion	Staging area / turnaround on roadway (bare ground)	150	300	45000	X	Potentially Active	Hillslope	621	0			
11	Martis Fire burn area	Anthropogenic	Road Erosion	Staging area / turnaround on roadway (bare ground)	150	200	30000	X	Potentially Active	Hillslope	2203	0			
12	Martis Fire burn area	Natural	Mass Movement / Gullying	2 small landslides flowing into single large gully downslope	15	200	3000	X	Potentially Active	Stream	433	4210			
13	Martis Fire burn area	Natural	Mass Movement	Landslide source area	650	400	260000	X	Active	Stream	890	1805			
14	Martis Fire burn area	Natural	Mass Movement	Landslide source area	500	900	450000	X	Potentially Active	Stream	2142	564			
15	Martis Fire burn area	Natural	Mass Movement	Landslide source area	350	500	175000	X	Active	Stream	330	2454			
16	Martis Fire burn area	Anthropogenic	Road Erosion	Series of switchbacks up mountain slope	10	2500	25000	X	Potentially Active	Hillslope	2803	0			
17	Martis Fire burn area	Anthropogenic	Road Erosion	Staging area / turnaround on roadway (bare ground)	50	75	3750	X	Potentially Active	Hillslope	1540	0			
18	Martis Fire burn area	Anthropogenic	Road Erosion	Staging area / turnaround on roadway (bare ground)	100	150	15000	X	Potentially Active	Hillslope	1501	0			
19	Martis Fire burn area	Natural	Mass Movement	Landslide	20	50	1000		Potentially Active	Stream	1215	215			
20	Martis Fire burn area	Natural / Anthropogenic	Mass Movement	Rockfall area? / Related to anthropogenic activity?	250	450	112500	X	Potentially Active	Stream	341	1536			
21	Evergreen Forest	Anthropogenic	Road Erosion	Staging area / turnaround on roadway (bare ground)	100	150	15000		Potentially Active	Hillslope	1960	0			
22	Evergreen Forest	Anthropogenic	Mass Movement	Denuded area indicating slope failure upslope of road cut	150	100	15000	X	Potentially Active	Hillslope	640	0			
23	Martis Fire burn area	Natural	Mass Movement	Denuded area indicating recent slope failure	400	500	200000	X	Potentially Active	Hillslope	670	493			
24	Martis Fire burn area	Natural	Mass Movement	Denuded area indicating recent slope failure	400	575	230000	X	Potentially Active	Hillslope	1082	270			
25	Martis Fire burn area	Anthropogenic	Road Erosion	Drainage concentration along downslope roadway	10	775	7750	X	Potentially Active	Hillslope	1150	0			
26	Evergreen Forest	Natural	Stream Bank Erosion / Mass Movement	Landslide into stream channel precipitated by toe erosion	200	250	50000	X	Active	Stream	0	226			
27	Martis Fire burn area	Anthropogenic	Road Erosion	Debris flow path intersects road	20	30	600	X	Potentially Active	Stream	1067	0			
28	Martis Fire burn area	Natural	Mass Movement	Debris flow source area	150	300	45000	X	Pontentially Active	Stream	2260	1131			
29	Martis Fire burn area	Natural	Mass Movement	Landslide source area	400	300	120000	X	Active	Stream	640	3642			
30	Martis Fire burn area	Natural	Mass Movement	Landslide source area	100	200	20000	X	Potentially Active	Stream	465	4701			
31	Martis Fire burn area	Natural	Mass Movement	Landslide source area	100	200	20000	X	Potentially Active	Stream	2170	4448			
32	Martis Fire burn area	Natural	Stream Bank Erosion / Mass Movement	Landslide into stream channel precipitated by toe erosion	30	100	3000	X	Potentially Active	Stream	0	4644			
33	Shrubland	Natural	Mass Movement	Landslide source area	350	300	105000	X	Potentially Active	Hillslope	1730	2850			
34	Shrubland	Natural	Mass Movement	Landslide source area / Scree slope	400	400	160000	X	Potentially Active	Hillslope	1920	3140			
35	Evergreen Forest	Natural	Mass Movement	Large scree slope	250	250	62500	X	Potentially Active	Hillslope	2409	2200			
36	Evergreen Forest	Anthropogenic	Road Erosion	Unstable slope on upslope side of road cut	100	350	35000	X	Active	Hillslope	370	0			
37	Evergreen Forest	Natural	Mass Movement	Debris flow source area	200	200	40000	X	Active	Stream	832	730			
38	Shrubland	Natural	Mass Movement	Landslide source area / Scree slope	150	150	22500	X	Active	Stream	1570	720			
39	Martis Fire burn area	Anthropogenic	Road Erosion	Slope failure upslope and downslope of road cut	50	350	17500		Active	Hillslope	785	0			
40	Martis Fire burn area	Natural	Stream Bank Erosion / Mass Movement	Landslide into stream channel precipitated by toe erosion	100	100	10000	X	Potentially Active	Stream	0	333			
41	Martis Fire burn area	Natural	Mass Movement	Debris flow source area	125	125	15625	X	Potentially Active	Stream	4000	2140			
42	Martis Fire burn area	Natural	Rilling and Gullying	Gullying in unvegetated area of hillslope	30	1500	45000	X	Active	Stream	2825	1400			
43	Martis Fire burn area	Natural	Mass Movement	Landslide and slope failure source area	400	255	102000	X	Active	Stream	1210	2050			
44	Martis Fire burn area	Natural	Stream Bank Erosion / Mass Movement	Landslide and slope failure source area precipitated by stream	275	275	75625	X	Active	Stream	0	1957			
45	Martis Fire burn area	Natural	Stream Bank Erosion / Mass Movement	Landslide into stream channel precipitated by toe erosion	25	50	1250	X	Potentially Active	Stream	0	4710			
46	Martis Fire burn area	Natural	Mass Movement	Landslide source area	100	200	20000	X	Potentially Active	Stream	673	1780			
47	Martis Fire burn area	Natural	Mass Movement	Landslide source area	400	400	160000	X	Potentially Active	Stream	1370	580			
48	Martis Fire burn area	Anthropogenic	Road Erosion	Unstable slope on upslope side of road cut	30	130	3900	X	Potentially Active	Hillslope	2564	0			
49	Martis Fire burn area	Anthropogenic	Road Erosion	Unstable slope on upslope side of road cut	50	100	5000	X	Potentially Active	Hillslope	3063	0			
50	Martis Fire burn area	Natural	Mass Movement	Scree slopes of loose material	350	200	70000	X	Potentially Active	Stream	1581	4840			
51	Martis Fire burn area	Natural	Mass Movement	Large landslide	150	600	90000	X	Active	Stream	1130	3130			
52	Martis Fire burn area	Natural	Rilling and Gullying	Active gullying in upper part of this subdrainage	20	2000	40000	X	Active	Stream	1111	3060			
53	Martis Fire burn area	Natural	Stream Bank Erosion / Mass Movement	Landslide into stream channel precipitated by toe erosion	250	115	28750	X	Active	Stream	0	2492			
54	Evergreen Forest	Natural	Mass Movement	Landslide	100	400	40000	X	Active	Stream	1195	1226			
55	Martis Fire burn area	Natural	Mass Movement	Landslide source area	60	200	12000	X	Potentially Active	Stream	1720	807			
56	Evergreen Forest	Anthropogenic	Mass Movement	Small slope failure on upslope side of dirt road	20	250	5000	X	Potentially Active	Stream	1325	0			
57	Shrubland	Natural	Mass Movement	Rockfall	225	250	56250	X	Potentially Active	Hillslope	372	1256			
58	Evergreen Forest	Natural	Mass Movement	Landslide / slope failure source area	100	200	20000	X	Potentially Active	Hillslope	871	1880			
59	Martis Fire burn area	Anthropogenic	Road Erosion	Unstable slope on upslope and downslope side of road cut	80	220	17600	X	Potentially Active	Hillslope	1115	0			
60	Martis Fire burn area	Anthropogenic	Road Erosion	Unstablie slope on upslope and downslope side of road cut	150	150	22500	X	Potentially Active	Hillslope	857	0			
61	Martis Fire burn area	Anthropogenic	Road Erosion	Unstable slope on upslope side of road cut	60	50	300	X	Potentially Active	Hillslope	1100	0			
62	Martis Fire burn area	Anthropogenic	Road Erosion	Landslide path on upslope and downslope side of road cut	150	200	30000	X	Active	Stream	442	0			
63	Martis Fire burn area	Natural	Mass Movement	Landslide	175	300	52500	X	Active	Stream	703	1580			
64	Martis Fire burn area	Natural	Stream Bank Erosion / Mass Movement	Landslide into stream channel precipitated by toe erosion	200	150	30000	X	Potentially Active	Stream	0	2141			

65	Martis Fire burn area	Natural	Mass Movement	Landslide source area	150	250	37500	X	Active	Stream	235	4260			
66	Martis Fire burn area	Natural	Mass Movement	Landslide source area	150	350	52500	X	Active	Stream	186	3613			
67	Shrubland	Natural	Mass Movement	Landslide	60	100	6000	X	Active	Stream	430	4254			
68	Shrubland	Natural	Mass Movement	Landslide	50	100	5000	X	Active	Stream	314	4526			
69	Shrubland	Natural	Mass Movement	Landslide	75	150	11250	X	Active	Stream	643	4830			
70	Shrubland	Natural	Mass Movement	Landslide	50	150	7500	X	Active	Stream	1160	5380			
71	Evergreen Forest	Natural	Mass Movement	Landslide	150	200	30000	X	Active	Stream	150	4856			
72	Shrubland	Natural	Mass Movement	Landslide source area	100	250	25000	X	Potentially Active	Stream	1863	6240			
73	Shrubland	Natural	Mass Movement	Landslide source area	150	700	105000	X	Active	Stream	1205	5830			
74	Shrubland	Natural	Rilling and Gullying	Scree slope with rill development	1100	650	715000	X	Active	Hillslope	4102	4462			
75	Shrubland	Natural	Mass Movement	Scree slope with several small landslides	1000	750	750000	X	Active	Hillslope	3918	5208			
76	Shrubland	Natural	Mass Movement	Landslide source area	120	80	9600	X	Potentially Active	Stream / Hillslope	180	3362			
77	Shrubland	Natural	Rilling and Gullying	Gullying with rill development on upper slopes	200	450	90000	X	Active	Stream	2421	2707			
78	Shrubland	Natural	Rilling and Gullying	Gullying with rill development on upper slopes	250	400	100000	X	Active	Stream	2436	2732			
79	Evergreen Forest	Natural	Mass Movement	Debris flow source area	100	300	30000	X	Potentially Active	Hillslope (meadow)	2256	4567			
80	Shrubland	Natural	Rilling and Gullying	Gullying with rill development on upper slopes	150	400	60000	X	Potentially Active	Hillslope	2290	5105			
81	Shrubland	Natural	Rilling and Gullying	Gullying with rill development on upper slopes	75	350	26250	X	Active	Stream	3270	3030			
82	Shrubland	Natural	Mass Movement	Landslide	125	200	25000	X	Potentially Active	Hillslope	2277	2600			
83	Bare Rock	Natural	Mass Movement	Landslide	150	250	37500	X	Potentially Active	Hillslope	1580	2378			
84	Bare Rock	Natural	Rilling and Gullying	Gullying with rill development on unvegetated slope	500	800	400000	X	Active	Stream	1812	5188			
85	Bare Rock	Natural	Rilling and Gullying	Gullying with rill development on unvegetated slope	300	600	180000	X	Active	Stream	2171	4683			
86	Martis Fire burn area	Anthropogenic	Rilling and Gullying	Gully erosion through road berm	30	30	900	X	Potentially Active	Stream	1500	0			
87	Martis Fire burn area	Anthropogenic	Road Erosion	Construction site adjacent to stream	75	100	7500		Active	Stream	175	490			
88	Martis Fire burn area	Natural	Mass Movement	Landslide	50	75	3750		Active	Stream	2765	1230			

Erosion Zone Data Table

Id	Area (sq. miles)	Erosion Class	Erosion Zone Description
1	0.033	Natural	a few small landslides
2	0.055	Natural	several small to medium landslides / some rill and gully formation
3	0.008	Natural	several small to medium landslides / rill formation
4	0.184	Natural	numerous slope failures on burned slope / rill and gully formation
5	0.060	Natural	several small to large landslides / rill and gully formation
6	0.449	Natural	numerous slope failures / rill and gully formation
7	0.033	Natural	numerous slope failures / scree slope
8	0.103	Natural	Rilling and gullying on recently burned slope
9	0.035	Natural	numerous slope failures / rill formation
10	0.128	Natural	abundant slope failures / rill and gully formation
11	0.010	Natural	gullying and minor slope failures
12	0.015	Natural	numerous small slope failures / rill formation
13	0.248	Natural	scree slopes / numerous slope failures / rill and gully formation
14	0.192	Natural	numerous slope failures / abundant rill and gully formation
15	0.032	Natural	large scree slopes
16	0.027	Natural	large scree slopes / rock falls
17	0.170	Natural	abundant slope failures / rill and gully formation
18	0.641	Natural	abundant slope failures

Appendix 3

Erosion Hazard Assessment
Data Layer Ratings

Erosion Hazard Analysis
Data Layer Ratings

Data Layer: Slope

Slope Range	Hazard Rating
0 – 40%	0
40% - 50%	1
50% - 60%	2
60% - 70%	3
70%+	1

Data Layer: Geology

Geologic Unit	Name	Hazard Rating
Kgr	Granitic Rocks, undivided	0
MPva	Miocene-Pliocene volcanic rocks (andesite)	1
Tad	Andesite and Dacite	1
Tadi	Intrusive Andesite and Dacite	1
Tba	Basalt, basaltic andesite, and andesite	1
Qm	Morainal deposits, undivided	1
Qly	Younger lacustrine deposits	0

Data Layer: Soils

Soil Thickness (inches)	Hazard Rating
0” – 10”	-1
10” – 20”	0
20”+	1

Note: Soil thickness information obtained from NRCS Soil Surveys.

Data Layer: Martis Fire

	Hazard Rating
Within Martis Fire Burn Area	1
Outside Martis Fire Burn Area	0

Data Layer: Roads

	Hazard Rating
Road in Vicinity	1
No Roads in Vicinity	0

Note: Polygons were drawn around areas with roads and converted to a raster dataset.

Erosion Hazard Analysis Ranking

Summation of Hazard Ratings from all Data Layers	Erosion Hazard
-1 to 1	1 (lowest)
2 to 4	2
5 to 7	3 (highest)

Appendix 4

Habitat Assessment Field Form

EDAW

Gray Creek Riparian and Aquatic Habitat Assessment

Reach ID: ___________ Date: __________ Data Collectors: ___________ Page ______ of _______

Stream Corridor Vegetation

Vegetation Type 1:_____________	Vegetation Type 2:______________	Vegetation Type 3:______________	Invasive Plant Infestations
% of riparian corridor ____	**% of riparian corridor ____**	**% of riparian corridor ____**	**Infestation ID:**
Total % vegetated cover ____	**Total % vegetated cover ____**	**Total % vegetated cover ____**	**Species**:_________________
Tree cover (%)	**Tree cover (%)**	**Tree cover (%)**	**Infestation size**
0 0–10 10–25 25–40 40–60 60–80 >80	0 0–10 10–25 25–40 40–60 60–80 >80	0 0–10 10–25 25–40 40–60 60–80 >80	Length _____ ft width_______ ft
Canopy size class	**Canopy size class**	**Canopy size class**	**cover (%)**
1–6 6–11 11–24 >24 Multi-layered	1–6 6–11 11–24 >24 Multi-layered	1–6 6–11 11–24 >24 Multi-layered	0 0–10 10–25 25–40 40–60 60–80 >80
Snag density per 1,000 m^2	**Snag density per 1,000 m^2**	**Snag density per 1,000 m^2**	**recruits**: None Few Many
0 1 2 3 4 5 >5	0 1 2 3 4 5 >5	0 1 2 3 4 5 >5	**veg. type**_____________________
Dominant tree species:	**Dominant tree species:**	**Dominant tree species:**	**GPS ID**_______________________
_____________________	_____________________	_____________________	**Infestation ID:**
_____________________	_____________________	_____________________	**Species**:_________________
Shrub cover (%)	**Shrub cover (%)**	**Shrub cover (%)**	**Infestation size**
0 0–10 10–25 25–40 40–60 60–80 >80	0 0–10 10–25 25–40 40–60 60–80 >80	0 0–10 10–25 25–40 40–60 60–80 >80	Length _____ ft width_______ ft
Shrub Height (ft)	**Shrub Height (ft)**	**Shrub Height (ft)**	**cover (%)**
0 0–1 1–2 2–4 4–6 6–8 >8	0 0–1 1–2 2–4 4–6 6–8 >8	0 0–1 1–2 2–4 4–6 6–8 >8	0 0–10 10–25 25–40 40–60 60–80 >80
Crown decadence (%)	**Crown decadence (%)**	**Crown decadence (%)**	**recruits**: None Few Many
<1 1–25 >25	<1 1–25 >25	<1 1–25 >25	**veg. type**_____________________
Dominant shrub species:	**Dominant shrub species:**	**Dominant shrub species:**	**GPS ID**_______________________
_____________________	_____________________	_____________________	**Infestation ID:**
_____________________	_____________________	_____________________	**Species**:_________________
Herb cover (%)	**Herb cover (%)**	**Herb cover (%)**	**Infestation size**
0 0–10 10–25 25–40 40–60 60–80 >80	0 0–10 10–25 25–40 40–60 60–80 >80	0 0–10 10–25 25–40 40–60 60–80 >80	Length _____ ft width_______ ft
Herb layer height (ft)	**Herb layer height (ft)**	**Herb layer height (ft)**	**cover (%)**
<1 >1	<1 >1	<1 >1	0 0–10 10–25 25–40 40–60 60–80 >80
Dominant herb species:	**Dominant herb species:**	**Dominant herb species:**	**recruits**: None Few Many
_____________________	_____________________	_____________________	**veg. type**_____________________
_____________________	_____________________	_____________________	**GPS ID**_______________________
Evidence of Conifer Encroachment?	**Evidence of Conifer Encroachment?**	**Evidence of Conifer Encroachment?**	
Yes No	Yes No	Yes No	

EDAW

Gray Creek Riparian and Aquatic Habitat Assessment

Reach ID: ___________ **Date: __________** **Data Collectors: ___________** **Page ______ of _______**

Adjacent Upland Vegetation

Vegetation Type 1:_______________

% of Adjacent Zone ____

Total % vegetated cover ____

Tree cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Canopy size class

1–6 6–11 11–24 >24 Multi-layered

Snag density per 1,000 m^2

0 1 2 3 4 5 >5

Dominant tree species:

____

____

Shrub cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Shrub Height (ft)

0 0–1 1–2 2–4 4–6 6–8 >8

Crown decadence (%)

<1 1–25 >25

Dominant shrub species:

____

____

Herb cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Herb layer height (ft)

<1 >1

Dominant herb species:

____

____

Vegetation Type 2:_______________

% of Adjacent Zone ____

Total % vegetated cover ____

Tree cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Canopy size class

1–6 6–11 11–24 >24 Multi-layered

Snag density per 1,000 m^2

0 1 2 3 4 5 >5

Dominant tree species:

____

____

Shrub cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Shrub Height (ft)

0 0–1 1–2 2–4 4–6 6–8 >8

Crown decadence (%)

<1 1–25 >25

Dominant shrub species:

____

____

Herb cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Herb layer height (ft)

<1 >1

Dominant herb species:

____

____

Vegetation Type 3:_______________

% of Adjacent Zone ____

Total % vegetated cover ____

Tree cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Canopy size class

1–6 6–11 11–24 >24 Multi-layered

Snag density per 1,000 m^2

0 1 2 3 4 5 >5

Dominant tree species:

____

____

Shrub cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Shrub Height (ft)

0 0–1 1–2 2–4 4–6 6–8 >8

Crown decadence (%)

<1 1–25 >25

Dominant shrub species:

____

____

Herb cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

Herb layer height (ft)

<1 >1

Dominant herb species:

____

____

Invasive Plant Infestations

Infestation ID:

Species:_________________

Infestation size

Length _____ ft width_______ ft

cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

recruits: None Few Many

veg. type_____________________

GPS ID_______________________

Infestation ID:

Species:_________________

Infestation size

Length _____ ft width_______ ft

cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

recruits: None Few Many

veg. type_____________________

GPS ID_______________________

Infestation ID:

Species:_________________

Infestation size

Length _____ ft width_______ ft

cover (%)

0 0–10 10–25 25–40 40–60 60–80 >80

recruits: None Few Many

veg. type_____________________

GPS ID_______________________

EDAW

Gray Creek Riparian and Aquatic Habitat Assessment

Reach ID: ___________ **Date:** __________ **Data Collectors:** ___________ **Page** ______ **of** _______

Stream Features

Reach type: ☐ephemeral ☐ perennial stream ☐ other: **Water present?** ☐ No ☐ Yes

Bankfull width (ft): ☐ 0-3 ☐ 3-10 ☐ 10-20 ☐ >20 **Depth at bankfull**______ ft

Pools present? ☐ No ☐ Yes **Size (ft):** ☐ < 2 ☐ 2-6 ☐ >6 **Max. depth (ft):** ☐ <3 ☐ >3

Describe type & abundance:

Dominant non-pool habitat: ☐ run ☐ riffle ☐ glide ☐ other:

Substrate: ☐ mud ☐ sand ☐ gravel ☐ cobble ☐ boulder ☐ bedrock ☐ duff/detritus

Bank stability: ☐ stable ☐ vulnerable ☐ unstable

Large woody debris (> 30 cm diameter): ☐ present ☐ absent **Pieces per 100 m:** ☐ 1 ☐ 2-5 ☐ >5

Potential barriers to fish movement: ☐ present ☐ absent ***Describe***:

Floodplain, evidence of overbank flows/hydrologic connectivity: ☐ present ☐ absent

Stream corridor width: min_______(ft) max ________(ft) typical_______ (ft) ***Describe***:

REACH MAP:

Restoration Opportunities:

Opportunity ID:________________ **GPS ID:**_____________ *Describe:*

Opportunity ID:________________ **GPS ID:**_____________ *Describe:*

Opportunity ID:________________ **GPS ID:**_____________ *Describe:*

Overall Condition of Reach:

PHOTO POINTS

Photo #	GPS ID/Notes

EDAW

Gray Creek Riparian and Aquatic Habitat Assessment

Reach ID: ___________ Date: __________ Data Collectors: ___________ Page ______ of _______

Land Use and Disturbance					
Land Use/Disturbance Type	**In Stream Corridor (Y, N)**	**In Adjacent Upland (Y, N)**	**Photo ID**	**GPS ID**	**Notes**
Fire					
Erosion/landslides					
Active permanent roads					
Decommissioned/abandoned roads					
Skid trails/temporary logging roads					
OHV trails or disturbance					
Recreational trails (non-OHV)					
Bridges/culverts/other road crossings					
Levees/berms					
Bank protection					
Dams					
Diversions					
Buildings/landscaping					
Mine tailings/pits					
Trash dumping					
Tree-cutting					
Brush removal					
Other disturbance					

Appendix 5

TRWC Filter Factors

TRUCKEE RIVER WATERSHED COUNCIL

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PROJECT FILTER FACTORS

Updated: April 11, 2001 (content)
Updated: January 09, 2002 (format only)

The Truckee River Watershed Council (TRWC) uses the following list of questions as a means of helping identify projects suitable for collaborative support and pursuit of funding. Those projects that rate well against a large number of these questions will be likely candidates for TRWC support.

PROJECT FOCUS—ADDRESSES THREATS TO WATERSHED HEALTH

1. Does the project address biological and physical functions? Does the project address a key resource need?
2. Will it improve water quality?
3. Will it improve biological resources?
4. Will it protect/conserve key resources that are particularly vulnerable?
5. Does the project address the cause rather than the symptom?
6. How severe is the problem the project will correct? What will be the extent of the benefit?
7. Are there future projects that may build on this project?
8. Does the project enhance the safety local and downstream residents of the watershed?
9. Will the project increase our knowledge and understanding of biological and physical function in the watershed? (Needs more discussion)
10. Will the project enhance understanding of the value and importance of preserving and restoring the watershed? Is there a recreational element that will enhance public education on the value and importance of watershed health? (Needs more discussion)

ENHANCES PARTNERSHIPS

11. Are there multiple partners/beneficiaries?
12. Does the project build the credibility of the TRWC?
13. Will it go forward without TRWC involvement?

PROJECT READINESS/PROCEDURAL ISSUES

15. Is a funding source readily available?
16. Will the project require seeking the appropriate funding source?
17. Does the project have a sponsor who has the capacity to implement the project?
15. Is the project practical and will it solve the problem?
16. Does the proponent/CRMP/partnership have the capacity to implement the project?
17. How quantifiable is the outcome?
18. Is there a monitoring component?
19. Is the project designed to be self-maintaining within 2-3 years?
20. Does the project use methods proven to be successful? Does it point out similar projects that have been successful?
21. Has the project met all regulatory compliance requirements/necessary approvals?
22. Is there a passionate proponent willing to develop a detailed outline of the project?
23. Is there an educational element built into the project?