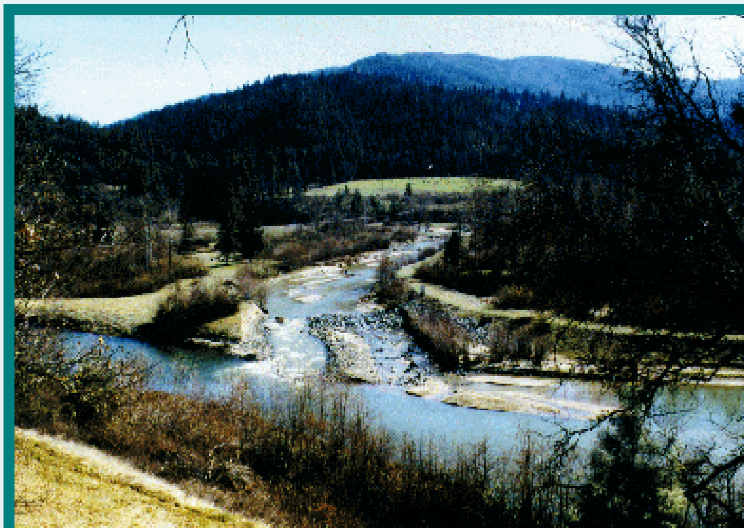
Grass Valley Creek Watershed Restoration Project:
Restoration in Decomposed Granite Soils



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Chapter 1
INTRODUCTION

The Purpose of the Report

The purpose of this report is to present technical design findings utilized in a large-scale restoration project undertaken in Grass Valley Creek watershed, a tributary historically known to deliver large amounts of sediment to the main stem of the Trinity River. The report also outlines a brief history of land uses in the watershed as well as an overview of the restoration project itself. In addition, some indicators of the overall success of the project are included.

Overview of the Report

This manual is divided into three sections: Part I presents the history of the Grass Valley Creek watershed and its relationship to the Trinity River, as well as an overview of the project as it unfolded; Part II presents restoration and monitoring techniques used in the watershed; and Part III presents tentative conclusions about the success of implemented restoration efforts, based on data obtained to date, as well as subjective assessments of the efficacy of the project overall and specific portions of the project. An appendix with documentation, maps, sample data sheets, a glossary of terms, and lists of sources is included at the back of the report.

Description of the Watershed

Regional Setting

Grass Valley Creek (GVC) is a tributary of the Trinity River situated in the southeastern portion of the Klamath River Basin. The GVC watershed comprises two percent of the area of the Trinity River basin. In 1963, the Central Valley Water Project diverted 90 percent of the upper basin natural flows of the Trinity River by construction of Trinity and Lewiston Dams, located about seven miles upstream of the confluence with GVC. The tributary component of total Trinity River basin runoff has increased because of this diversion. In the upper Trinity basin, historical tributary inflow of about 20 percent of the average monthly peak flow has increased about 450 percent because of this diversion. It is estimated that prior to restoration work GVC, because of its unstable soils, contributed about 65 percent of the average sediment load entering the Trinity River.

Location and Boundaries

The GVC watershed is located in eastern Trinity County, California. State Highway 299 bisects the area, and the county seat, Weaverville, lies about 5 air miles northwest of the watershed. The entire watershed extends from the headwaters at Shoemaker Bally to the confluence with the Trinity River (See Map, Appendix D1). Although they are not part of the GVC drainage basin, the restoration team extended the project area to include the Corral Creek watershed, a tributary of Indian Creek, and the south side of the Hoadley Gulch watershed; both these drainages consist also of highly erosive decomposed granite soils.

The community of Lewiston lies about one mile north and just west of the area. The GVC watershed includes about 200 privately owned parcels. The majority of the land base in private ownership is managed for industrial forest products. Residents in the watershed consist of year-round and summer residents. Valuable resources in the area include forest products; water, aquatic and terrestrial wildlife; scenery; clean air; wildlife habitat; and recreation opportunities.

Land uses in the area include: industrial timber production, homesite development, fishing, hunting, hiking, bicycling, utility transmission, and transportation.

Table 1-1 - GVC Watershed Ownership

Ownership	Acreage	Percent of Area
Private-Residential	5,000	18%
Private-Industrial	6,000	21%
Bureau of Land Management	16,500	59%
State of California	400	1%
Bureau of Reclamation	300	1%
TOTAL	28,200	100

Watershed Description

The GVC watershed constitutes steep, mountainous terrain, with elevations ranging from 1,740 to 5,950 feet. Vegetation is predominantly mixed conifer species, with hardwoods at the lower elevations and true fir stands at the upper elevations. About three quarters of the area is underlain by strongly weathered granitic rock and the remainder by metamorphic rock. The soils formed in granite are coarse textured, drought prone, and highly erosive.

Significant areas in the watershed have sparse vegetative cover and experience accelerated surface erosion. The remains of an extensive timber harvesting road and skid trail network created in the 1950's and 1960's continues to divert water flows from natural stream channels. This diverted water creates severe gully erosion problems in the area and sedimentation problems downstream in the Trinity River. Illegal motorcycle use in the northern portion of the Grass Valley Creek watershed destroys vegetation, soil structure, and consistency, and it channelizes water, creating severe gully and surface-erosion problems.

Climate

Climate in the watershed is characterized by warm, dry summers and cool, moist winters.. Precipitation ranges from 45 to 75 inches, most of which falls during the winter and spring months. Freezing temperatures occur throughout the area during the winter. Snowfall is common above 3,500 feet elevation and snow may persist on north facing slopes until the middle of May. Summer temperatures may exceed 100 degrees F. at the lower elevations.. The area is susceptible to intense summer thunderstorms which are capable of producing heavy precipitation for a short duration.

Geology

The watershed lies within the Klamath Mountains Geomorphic Province. This province is characterized by flat-topped ridges and glacial peaks. The major rocks in the watershed range from 330 to 125 million years in age (Devonian to Jurassic). The principal geologic features of the watershed include Copley Greenstone, the Bragdon formation, the Abrams formation, ultramafic rocks, the Shasta Bally batholith, the Weaverville formation, landslide deposits, and river terrace deposits.

The Copley Greenstone and Bragdon formation are the oldest rocks in the watershed. They occur in the northwest portion of the watershed. Copley Greenstone consists of metamorphosed, interlayered andesitic and basaltic volcanic flows, tuffs, and agglomerates. The Bragdon formation consists of interbedded shale, siltstone, and conglomerate. The sandstone grains consist chiefly of chert or quartz, but some may be tuffaceous. The conglomerates are mostly made up of chert, shale, or quartz.

The Abrams formation occurs over the western part of the GVC watershed. It is chiefly made up of quartz-mica schist consisting of quartz, biotite, muscovite, plagioclase, and garnet. Quartz-biotite and amphibolitic gneisses also occur in the western part of the GVC watershed. They are probably derived from the Bragdon formation and Copley Greenstone.

Ultramafic rocks occur as discontinuous chains in the western part of the GVC watershed. Peridotite is a common rock type, but most of it has been altered to serpentine. The Peridotite occurs in somewhat tubular bodies as sills or along highly sheared fault zones.

The granitic rocks of the Shasta Bally batholith make up the eastern three-fourths of the GVC watershed. They are the youngest of the rocks in the watershed and range in composition from granite to diorite. Several small areas of the Weaverville formation occur in the extreme western part of the watershed. These are continental sedimentary deposits consisting of sandstone, shale, lignite, tuff, and/or conglomerate.

Landslide and river terrace deposits are present in the western part of the GVC watershed. The landslide deposits are usually associated with shear zones in schist, Peridotite, or greenstone areas. The river terrace deposits are generally above the present stream channels.

The granitic rock in the watershed is part of the Shasta Bally batholith. This batholith is 127 million years old and is related to many other granitic intrusions in the Klamath Province (Murphy et al 1969). Of the numerous plutons in the Klamath Mountains, the Shasta Bally is thought to be the youngest of the granitic intrusions (Holtz 1971). This age difference explains why the batholith has a lower percentage of hydrothermal deposits such as quartz -veins.

The crystal size within the Shasta Bally Batholith is variable, but generally the batholith is coarse-grained, with crystals visible to the unaided eye. Compositionally, the batholith is a biotite-hornblende quartz diorite with extremes ranging from gabbro to granodiorite (Lydon and O'Brien, 1974). This quartz diorite contains quartz, hornblende, biotite, plagioclase, and some pyroxene. According to Hotz (1971), parts of the batholith are a trondjetinite (a high mica quartz diorite) with a biotite component of 13 percent. This biotite content is considered to be very high because accessory minerals, such as biotite, normally compose only two to five percent of a total igneous rock composition.

Numerous springs in the batholith are the result of a complex set of fractures and an abnormally high water table. Physical breakdown of the batholith because of unloading and fracturing has resulted in numerous fractures and joints which expose the inner pluton to water-induced chemical weathering. The water reacts with biotite to form hydrobiotite and hydrobiotite reacts with the water to form Vermiculite, chlorite, or kaolinite. Vermiculite is an expandable clay and in the presence of water will expand to twice its dry volume. This expansion causes the rock to break down into monocrystalline, coarse granular fragments. Therefore, granitic rocks in this batholith are highly susceptible to weathering and subsequent erosion when exposed to the air.

Soils and Erosion

The GVC watershed is mountainous, with steep slopes and narrow, V-shaped valleys. The upper three-fourths of the GVC watershed is underlain by granite of the Shasta Bally Batholith. The soils in these areas are derived from highly weathered granitic rocks. The western one-fourth of the GVC watershed consists of metamorphic rocks and landslide and river-terrace deposits. Recent alluvium is present along the narrow floodplains. The soils in this area are derived from metamorphic, sedimentary, and metavolcanic rocks.

Weathered granites are structurally weak and are easily broken down. However, weathering has not progressed to the point of clay formation. The result is coarse-textured, easily eroded soils and a predominance of weak bedrock that is easily broken down into sands with very little silts and clays.

Soils forming on granitic parent material generally have textures of gravely loamy coarse sand or gravely coarse sandy loam. Soil depths range from less than one foot on ridges and upper side slopes to five feet on the lower one third of side slopes and on toe slopes adjacent to stream channels. The granitic rock underlying these soils is highly weathered, erodes easily, and is fairly permeable. The coarse texture and variable depths yield very low or low available-water-holding capacity. The very low clay content, coarse texture, and steep slopes combine to create a high erosion hazard.

Soils in the western portion of the GVC watershed formed on the metasedimentary and metavolcanic rocks and landslides are generally three- to five-feet deep to bedrock, are medium to fine textured, having gravely clay loam textures, and have moderate available-water holding capacity. The moderate clay content of these soils creates adhesion between soil particles, resulting in a significantly lower erosion hazard and sediment production from this area.

In order to identify sediment sources in the watershed analysis area, United State Department of Agriculture (USDA) Soil Conservation Service (SCS, now the Natural Resources Conservation Service, NRCS) conducted a comprehensive inventory of sediment sources. A total of 1,164 problem areas were identified as significant sediment producers, capable of producing a total of 316,000 yards of sediment.

The major influence resulting in accelerated erosion in granitic soils is concentrated water flows. The primary causes of concentrated flows are roads and the alteration of hydrologic processes on upland slopes resulting from the removal of vegetative cover and rapid decomposition of forest litter.

Another significant source of sediment is from the surface of hill slopes. The NRCS inventory in 1992 (see also pg. 10) only evaluated severe surface-erosion sources and was not a complete inventory of all surface-erosion potential. Appendix D2 shows the locations of inventoried sites and the potential sediment yields of individual subwatersheds. Road-related erosion problems accounted for at least 59 percent of the total sediment potential.

Measurement of the results of erosion from GVC are available through sediment data collected at the Fawn Lodge stream gage. During the years 1977 through 1994, the highest recorded daily total was 65,000 tons, recorded in March, 1983.

Hydrology and Roads

A comparison of mean annual water flow between GVC and other interior coastal watersheds indicates that the predominantly granitic geology of this area produces less runoff and transmits more water to aquifers than watersheds of different lithology.

The topography is extremely dissected, with 23 miles of Order-1 streams, 68 miles of Order-2 streams, 211 miles of Order-3 streams. The many miles of channels create an efficient delivery system for sediment transport, and this results in short slope lengths between sediment sources and the delivery system. The steep slope gradients which predominate influence runoff, water energy, and sediment transport capability.

Climatic conditions that influence runoff amounts and flow volume are the frequency of high intensity storms and "rain on snow" events. High intensity storms have occurred in 1955, 1964, 1972, 1978, 1983, 1986 and 1995.

Channel inventories in GVC and some of its tributaries have provided information about hydrologic processes and existing conditions. "Preliminary inventory work along the mainstem revealed that GVC dominantly flows over competent bedrock or through long stretches of channel containing a relatively immobile lag of metamorphic cobbles and boulders. Extensive zones of fine sediment deposition are few and short, mainly being confined to temporary storage zones behind logjams, as well as in runs, pools and bedrock plunge pools. Thalweg elevations in the mainstem and the larger, perennial tributary channels are primarily controlled by bedrock, suggesting bed elevations are stable and changes in channel profile are not likely to occur" (Hagans and Weaver, PWA, 1994).

The dynamics of sediment transport and the past and potential sources of sediment can be inferred based on data collection and observations throughout the watershed. "The lack of substantial or widespread mainstem channel fill deposits reveals that stream gradients and flow velocities are sufficient to quickly transport the annual volume of introduced sand-sized sediment through GVC downstream to the Trinity River" (Hagans and Weaver, PWA, 1994). Similar results and conclusions were arrived at by Douglas Parkinson & Associates in a sediment assessment of Indian Creek in 1991.

Inventories of stream bank conditions in the mainstem of GVC and a few of the larger perennial tributaries suggest that 50 percent of the banks are stable and show little indication of past erosion. Approximately 32 percent of all stream banks surveyed were disturbed by past road construction activities. In connection with these inventories it should be noted that "no attempt was made to quantify volumes of past and future erosion and sediment yield within the study area." The report also states, "However, based on field evidence, the volumes are considerable and past yield appears closely connected to large floods (greater than 10-year recurrence interval) over the last 35 years." (Hagans and Weaver, PWA, 1994)

Attempts to trap sediment resulted in the construction of Buckhorn Sediment Dam approximately seven miles upstream of the confluence of GVC and the Trinity River. Sediment retention basins with a capacity of 45,000 cubic yards known, as the “Hamilton Ponds,” have also been constructed near the confluence.

The road and skid trail network has created numerous historic and potential diversions of surface and subsurface water flow. Roads intercept and transport rainfall to existing channels and can divert water out of stream channels onto road surfaces or hill slopes. An inventory of the past and potential erosion and diversion sites conducted by NRCS in 1992 identified, mapped and described 1,164 sites in the area.

Pacific Watershed Associates (PWA) conducted a roads inventory in a six-square-mile area between the Buckhorn Sediment Dam and the confluence of GVC and Little GVC. The results of this survey can be extrapolated to characterize conditions throughout most of the watershed area: "Based on air photo analysis, we estimate that approximately 75 percent of the 101 miles of inventoried roads and skid trails in the study area had already been built by 1957. While 22 percent of the network was constructed between 1957 and 1983, only 3 percent of the roads were built after 1983. A total of 113 stream crossings, 296 ravine crossings and 119 landings were also identified during the analysis. The most damaging road construction practice, building roads up the channel bottom of stream channels, was most common in the earliest construction period. Thus, of 21.4 miles of road and skid trail built in stream channels, 80 percent were constructed before 1957. Because of the early date of construction, most roads and landings built in stream channels have weathered the 1964 flood and other large storms. Field observations throughout the basin suggest that these roads have experienced severe erosion. Some of these roads may have been rebuilt one or more times since they were initially constructed." (PWA, 1994) In fact, observations during restoration planning indicate that many roads have been rebuilt three times.

PWA separated the road locations into five categories. Ridge roads dominate the transportation network in the study area. Approximately 35 percent of the roads were found in these locations. About 24 percent of the roads were built across hillslopes. Combining the last three categories, near channel, floodplain/terrace, and stream channel, reveals that 42 percent of the roads were constructed on these locations.

Roads initially built within the active stream channels appear to have been reconstructed on nearby sideslopes during successive timber harvests. This practice involved construction of many cuts and fills where fill may have been sidecast into or immediately adjacent to the active stream channel. These "near channel" roads cross numerous stream channels and ravines, creating many potential diversions. These roads represent a significant source of future sediment to the creek, especially from stream diversions and from failing stream crossings (PWA, 1994).

Relationship to the Trinity River Fishery

Numerous factors have contributed over the years to the serious decline of salmon and steelhead populations in the Trinity River system: mining, timber harvesting, dam construction, and water diversions. Although only a medium-sized sub-basin, the GVC watershed has played a greater role in the decline of the Trinity River fish resource than any other area. Two-thirds of GVC is underlain by the youngest (127 million years old) and most erosive batholith of decomposing granitic rock found within the entire Klamath River Basin. These predominantly granitic watersheds were intensively roaded and logged without proper erosion control for many decades. Subsequent storms have delivered excessive amounts of sand-sized sediment to one of the historically best spawning reaches of the Trinity River.

These granitic areas have likely been the most erosive terrain in the Trinity River Basin ever since the rising pluton became exposed at the surface. However, not until the Trinity Division (of the Central Valley Water Project) was completed (see pg. 9) did the coarse sand originating from its sideslopes seriously impact the Trinity River fish resources, as the river’s flushing capacity was severely reduced.

Nearly all of the granitic portion of the analysis area has been privately owned for decades and on three-fourths of it grows a vigorous coniferous forest. Most of this forest has been zoned for commercial timber harvesting, and, in the late 1940's, intensive logging began here as it did throughout the Trinity River Basin.

The privately owned forests in the GVC watershed were initially cut using a "heavy selection" type of harvest method. Logging was done with tractors but small trees were apparently left standing. Hundreds of miles of logging access roads were haphazardly constructed during this period. Neither the road construction nor timber harvest practices were conducted with any regard for (or legal requirement of) erosion-prevention practices.

A large storm in 1955 provided up to a 70,000 cubic feet per second (cfs) flow in the Trinity River at Lewiston. The enormous contribution of recently disturbed coarse sand sediment pouring forth from these three tributaries, however, apparently did little damage to the fishery for the remaining 35 miles of prime fish habitat down to the North Fork confluence. No evidence of reported impacts to fish habitat can be found in the literature following this storm, despite fish surveys conducted regularly after the event.

A completely different outcome resulted after the December, 1964 flood. Timber harvesting continued during the intervening decade between the two storms and the pace of cutting had actually slowed. The 1964 flood created a measured discharge into the newly created reservoir of 110,000 cfs. Uncontrolled spills never occurred below the dam; however, the reservoir was nearly empty before the storm event and could contain the equivalent of more than two normal winters of run-off. Hence, a maximum of only 240 cfs was released at the base of the dam in the wake of the storms when over 100,000 cfs would have been passing the site just two years earlier.

The tributaries throughout the Trinity Basin were of course flowing at unimpeded levels and the contrast was conspicuous just below the dam. GVC, entering the "placid" river just seven miles downstream from the dam, likely pumped over one million cubic yards of coarse granitic sand bedload into the slowly moving river. Nearly all of it settled out shortly after reaching the larger river course. The tributary has plagued this historically productive reach of river with sand deposits ever since, as numerous large but more frequent storms have replenished sediment supplies initiated by the 1964 flood.

The conspicuously white sand river bed downstream of GVC was noted after 1964 during salmon spawning surveys. Surveyors also noted during the late 1960's that spawning salmon shifted their emphasis to the area within two miles of the base of the dam and began to avoid the reach of river downstream of GVC.

Chapter 2
BACKGROUND OF THE GRASS VALLEY CREEK WATERSHED RESTORATION PROJECT

Trinity Dam Construction

Central Valley Project (1937)

The history of the Grass Valley Creek (GVC) Watershed Restoration Project cannot be considered apart from the historical effects of Trinity River management since the Central Valley Project (CVP) was mandated by congress in 1935 "to provide water and power to users within the State of California" (Frederiksen, Kamine, and Associates, pg. 199).

Trinity River Act--PL 86-386 (1955)

The Trinity River Act of 1955 (PL 86-386) established the creation of The Trinity River Division of the CVP. One aspect of the division was the construction of Trinity Dam--completed in 1963--to effect the diversion of "surplus" water from the Trinity River to the farms and homes of the Central Valley and for hydrologic power production (Figure 2-1). Even though the Trinity River Hatchery has been an integral part of dam planning from the outset, the construction of the dam has nevertheless led to "deterioration" of resources, in particular fisheries, since dam completion (Frederiksen, Kamine, and Associates, pg. 201). One major impact decreased flows has had on the river is the absence of spring flushing flows. Before the dam was constructed normal high flows in spring from snow melts flushed accumulated sediment in the river, restoring the anadromous fish habitat. Spawning fish require small cobbles to lay eggs, and deposition of decomposed granite soils in the river fills the interstices of the cobbles, preventing successful spawning. Thus, decreased flows have contributed to fishery deterioration, but the poor state of the watershed in tributaries has abetted the deterioration by the delivery of unusually high amounts of sediment to the main stem of the river. Even "extremely high" releases from Trinity Dam will not ameliorate damage caused by sediment from tributaries. Overfishing also causes damage. "Control of the anadromous fish harvests as well as sedimentation are unquestionably equal as important to a sound resource and management program as water releases in the river" (Frederiksen, Kamine, and Associates, pg. 201).

Figure 2-1. Trinity Dam

Sediment Dam Authorization--PL 96-335 (1980)

On September 4, 1980 Congress approved legislation that provided funding to construct sediment mitigation in GVC. PL 96-335 authorized the Commissioner of Reclamation to "design, construct, operate, and maintain, or to contract with the State of California for the design, construction , operation, or maintenance of, a sand dredging system on the Trinity River immediately downstream from Grass Valley Creek, a tributary of the Trinity River, and a debris dam and associated facilities on Grass Valley Creek, in Trinity County, California, in general conformity to the plan of development described and set forth in the Grass Valley Creek Sediment Control Study, April 1978." (Appendix A of Draft Environmental Impact Study for GVC Debris Dam; USDI BoR, 1986). The law and associated funding paved the way for the construction of both the Buckhorn Sediment Dam and Hamilton Ponds in 1984 and 1991, respectively (see also page 9).

Trinity River Fish and Wildlife Restoration Act--PL 98-541 (1984)

A noticeable impact on the fisheries in the wake of dam construction, despite the accommodations made for the fish by construction of the hatchery, led to the formation of the Trinity River Basin Fish and Wildlife Task Force in 1971 and the Trinity River Stream Rectification Act (PL 96-335) of 1980, which authorized the first steps toward mitigating sediment impact on the Trinity from GVC. Increased awareness of the problem of sediment entering the Trinity from tributaries, exacerbated by the loss of spring flushing flows, led to the passage of the Trinity River Fish and Wildlife Restoration Act of 1984 (PL 98-541), in which the Secretary of the Interior "was directed to implement a fish and wildlife management program to restore fish and wildlife populations to levels approximating those which existed immediately prior to the construction of the Trinity Division."

The Trinity River Basin Fish and Wildlife Restoration Act outlined an 11-point program for restoring the fish and wildlife habitat of the Trinity River. The 11 objectives of the project are to:

1. Establish The Institutional Infrastructure For Managing Restoration
2. Regulate Fish Harvests
3. Rehabilitate And Maintain Tributaries To The Trinity
4. Rehabilitate Mainstem Watersheds
5. Rehabilitate Grass Valley Creek Watershed
6. Establish Criteria For Roads And General Construction
7. Remove Sand From The Trinity River
8. Monitor The Fishery And Operations
9. Monitor Stream Conditions
10. Restrict Floodplain Development
11. Monitor Land Use.

Many of these objectives pertain to the GVC watershed, as well as the entire Trinity River Basin, but the GVC watershed in particular, because of the unstable nature of its soils and the extensive logging that has taken place in the watershed, has been targeted specifically for restoration by the task force (objective number 5, above).

Early Grass Valley Creek Sediment Reduction Efforts

Grass Valley Creek Sediment Ponds and Debris Dam (1984, 1991)

One of the first steps toward decreasing sediment delivery to the Trinity River was the construction, in 1984, of the Hamilton Ponds at the mouth of GVC near the confluence of the Trinity River and further upstream the construction of Buckhorn Sediment Dam (Figures 2-2 and 2-3). Both the sediment ponds and the debris dam were constructed as catchment sites for sediment before it enters the mainstem of the Trinity River. Because sediment from the watershed continues to enter the creek, the Hamilton ponds downstream from Buckhorn Sediment Dam need to be periodically dredged of sediment to retain their effectiveness.

Figure 2-2. Hamilton Ponds

Figure 2-3. Buckhorn Sediment Dam

Tree Planting (1980's)

Because the Hamilton Ponds have to be periodically dredged, particularly after high-flow storm events such as the winter of 1994-95, monitoring agencies realized that sediment capture was not a solution to the problem but an emergency measure set up to catch sediment before it reached the river itself. To effectively reduce sediment delivery to the river another approach had to be taken: reducing the amount of sediment entering GVC in the first place.

One early approach was to plant trees on the eroding sheet and rill slopes of the watershed, denuded of vegetation by logging. Removal of covering canopy on slopes exposed the steep slopes of the watershed to the direct impact of rain. Since the slopes had once been vegetated, and had plant communities to hold soils in place by their roots, it was reasoned that re-establishment of conifers on de-forested hillsides might mitigate erosion on the slopes and decrease sediment delivery to the creek. This practice met with only varying success. On many sites the low nutrient levels and poor water-holding capacity of the DG soils impeded success of tree planting. Later (1994-present), it was decided that conifers could only be successfully re-established on sheet and rill slopes by first re-establishing early successional vegetation (see pg. 80 for a discussion of sheet and rill treatments later implemented).

Sediment Inventories (1986, 1992)

In 1986 and again in 1992 the NRCS evaluated key areas of the Grass Valley Creek watershed in order to develop a sediment budget for the watershed. The 1986 study "identified and ranked critically eroding areas and sources of sediment" (USDA 1992, pg. 3). It also "evaluated various land treatment/land-use scenarios with respect to their overall cost effectiveness in sediment reduction." The 1986 study, which outlined general soil characteristics in the watershed, was supplemented by the 1992 study which sought to identify "critically eroding areas and sources" as well as "costs and effectiveness of the recommended land treatment measures..." (USDA 1992, pg. 3).

Reduction of Causes of Erosion and Sedimentation

Construction Improvement Standards for Roadways in Decomposed Granite Areas Ordinance (1981)

In 1981, as required by PL 96-335 (see page 9) the Trinity County Board of Supervisors approved an ordinance amending the Trinity County Code to improve and tighten the standards required for road development in decomposed granite areas. This ordinance called for a maximum road grade of 10 percent and road surfaces were to have a 6-inch, well-graded gravel or shale bed which is compacted with a road bed minimum width of 12 feet, with an outslope of 2 percent. This ordinance was intended to reduce the amount of erosion from new road construction (See Appendix J1 for a copy of the ordinance).

Off-Road Vehicle Usage Restriction Ordinance (1986)

In June of 1986, the Trinity County Board of Supervisors approved an ordinance amending the Trinity County Code to control the "Use of Motor Vehicles, Bicycles and Other Conveyances in the Grass Valley Decomposed Granite Shelter Area" (See Appendix J2 for a copy of the ordinance).

The Trinity County Resource Conservation District (RCD) acquired funds to educate bike clubs, students and others to the problem off-road vehicles (ORV's) cause in this fragile soil type as well as to install signage at locations of ORV entry which indicate that there is a $500 fine for breaking this law. This approach was effective in increasing awareness about the detrimental effects of ORV's.

Change in Land Management (1992)

Before 1992, GVC watershed was almost entirely in private ownership and had been intensively managed for timber production since the 1940's. Widespread land disturbance from commercial timber harvesting operations had occurred, adding significantly to the already high natural rates of erosion. Roads, skid trails, landings and other man-made features used in past timber operations were the primary source of sediment discharge into GVC.

A change in land management was the recommendation as the most effective solution to reduce the extreme rates of erosion from GVC watershed to the Trinity River (see National Heritage Institute, 1991). This recommendation resulted in the Trinity River Task Force procuring an additional $15 million to acquire and treat this land. $9.2 million of this amount went to purchase the nearly 17,000 acres owned by Champion International, in 1993. The remainder of the funds was allocated for uplands watershed restoration and erosion-control projects. This land buyout was facilitated by a third party, the Trust for Public Lands. Changing the primary use of GVC watershed from timber production to erosion control and watershed restoration through the acquisition of timberlands was an important step in improving the Trinity River fishery. The acquisition allowed for an extensive and comprehensive restoration program in this watershed to correct the most severe erosion sources.

Chapter 3
EVOLUTION OF THE GRASS VALLEY CREEK WATERSHED RESTORATION PROJECT

Introduction

The implementation of restoration projects in the Grass Valley Creek (GVC) watershed has evolved over the five-year span during which the major restoration effort unfolded, with changes in philosophy, strategies, and methods taking place at significant junctures along the way. Over this period of time many approaches to watershed restoration were attempted and a significant increase in knowledge was gained by all those involved in the work. There were many variables to account for in this watershed, and the Trinity County Resource Conservation District (RCD) was challenged with implementing different techniques, monitoring and assessing strategies over time, and changing practices as information and experience were gained.

The project evolved over roughly three phases from the beginning of the restoration work in the fall of 1992 to the fall of 1996, when physical treatments had been completed and a ten-year revegetation monitoring plan created. Two significant events along the way led to substantial changes in project philosophy and methods. The first of these events was the purchase of the land in the GVC watershed from Champion International in the early months of 1993; this cleared the way for an expanded scope to the project in the ensuing years. The second event was the severe storms of the winter of 1994-95, which substantially changed restoration strategies used in the GVC watershed; until the high flows from these storms impacted the watershed, the efficacy of treatments used had not been tested. Poor project performance during the storms substantially changed the way restoration work was implemented in the wake of storm damage to restoration sites.

The role of revegetation also underwent changes during this time, from primarily tree planting using traditional reforestation techniques, during the first phase of restoration; to critical-area treatments of mulch, seed and fertilizer, and planting trees, shrubs, and grasses, during the second phase of restoration; and finally to treating more upslope sheet and rill conditions using micro-site planting techniques, during the last phase of the project. The revegetation team also switched from the use of non-native species to natives over the course of the project. Various tests were developed to monitor treatments; at first monitoring was performed visually, but later monitoring was undertaken utilizing more scientific approaches to better assess the effectiveness of treatments over time.

Phase One: GVC Watershed Restoration, 1992-93

With the completion of the site-specific sediment-source inventory in February 1992, the GVC watershed restoration effort was ready to move into the implementation phase. The first and highest priority was to address projects identified in the highway 299 corridor, particularly Little Grass Valley Creek subwatershed, the largest tributary to GVC. These sites were chosen because they were below Buckhorn Sediment Dam and the sediment produced from these sites could markedly impact the Trinity River. Also, these sites were easy to reach, reducing potential logistical problems. Any sediment savings accrued from restoration efforts within Little Grass Valley Creek would reduce the sediment inputs to the Hamilton Ponds at the mouth of GVC and ultimately reduce the potential for any direct sediment delivery to the Trinity River.

The initial strategy for restoration was to begin within the upper part of the watershed, the headwaters area, and work downstream. The approach during this early stage of the project was to stabilize actively eroding features, such as gullies on roads and in stream channels, by building grade stabilization structures and revegetating to establish climax species, or conifers.

It was thought that revegetation would ultimately provide the long-term stability once the structures began to deteriorate. The participating agencies primarily relied on log grade stabilization structures and standard reforestation and revegetation techniques. During the fall of 1992, over 50 erosion-control projects were completed. This was followed by an extensive revegetation effort, with crews planting over 80,000 trees and shrubs.

Another focus of the initial restoration effort was on the existing permanent access roads in the watershed. The strategy for these roads was to reduce sediment production and delivery to stream channels as much as possible by improving road drainage. This was accomplished primarily by outsloping roads and surfacing them with gravel and increasing the numbers and capacities of road drainage-improvement structures such as culverts, waterbars, and rolling dips.

Through the winter of 1992/1993, preliminary evaluation and assessment of the log grade stabilization structures began. The cost-effectiveness and feasibility of building these types of structures for erosion control needs was evaluated. Log structures were found to be costly and difficult to build (Figure 3-1). Several factors contributed to this, such as the remoteness of the sites, the lack of available on-site logs with which to build structures, and the difficulty of keying them into unstable soils.

Figure 3-1. Log Grade-Stabilization Structure

Because of this, the participating agencies began to use soil/cement grade stabilization structures in place of the log structures (Figure 3-2). Soil/cement structures were found to be superior to the log structures because: 1) they were quicker and easier to construct and therefore more cost-effective; 2) they enabled the utilization of on-site sand (given the remoteness of most of the sites); and 3) the structures could be molded to the required shapes before they hardened. Monitoring results indicated that the sand/cement structures were more effective and required much less maintenance than the log structures.

Figure 3-2. Soil/Cement Grade Stabilization Structure.

The revegetation strategy also changed during this time. The need to quickly stabilize restoration sites initially led to the use of fast-growing exotics, but the team observed that exotics competed with conifers. Team members believed natives would do better than non-natives in the long run, as they were adapted to the site and conditions found in the GVC watershed. Native grass seeds and plugs were thus used to stabilize disturbed sites. Native grass seed and hay both demonstrated effectiveness for erosion control. Because of these positive initial results, the RCD developed a native seed collection program, with seed then sent to nearby nurseries for propagation of needed plants for future projects

Bioengineering methods utilizing native willow cuttings (willow wattles and willow stakes) from the watershed were used extensively for streambank stabilization and to re-establish riparian plant communities in stream channels (Figure 3-3). These bioengineering techniques were very effective when applied in the wetter channels.

Figure 3-3. Willow Wattles and Willow Stakes in Channel

Phase Two: GVC Watershed Restoration, 1993-94

During 1993 dramatic changes took place in the approach to restoration work. The purchase of Champion International Corporation's holdings in GVC watershed allowed a change in land use from resource extraction to rehabilitation. Emphasis thus shifted during this phase of the project from treating existing problems to treating *potential* problems, and a renewed emphasis was placed on identifying where the greatest potential for future sediment yield would occur within the watershed. The majority of roads, skid trails, and landings associated with recent logging were still intact and presented the greatest threat for future sediment production. The restoration team decided to treat potential erosion sources--particularly man-made fill in road crossings--by removing it, rather than by trying to check its progress once it had migrated into streams. This significantly broadened the scope of restoration work in the watershed.

The emphasis of the project then shifted from labor-intensive hand treatments to stop the flow of sediment to heavy-equipment use to remove fill from road crossings, recontour road prisms, and decommission roads no longer needed for vital transportation (Figure 3-4).

Figure 3-4. Heavy Equipment Removing a Road Crossing.

Phase Three: GVC Watershed Restoration, 1995-96

Because of an extended period of drought little was discovered about the viability of project methods during heavy rainfall. In early 1995 significant storm events provided this information. Some project sites, especially those in channels, underwent significant adjustments (Figure 3-5). The storms of early 1995 provided important information regarding the effectiveness of the various approaches and techniques attempted. This event taught much about the fragility and highly erosive nature of the watershed and the importance of channel protection in spite of the additional costs.

Figure 3-5. Gully Resulting from a Lack of Channel Proetection.

The impact of the storms resulted in a reduction in the scope and scale of the remaining work. Recontouring skid roads was virtually eliminated from the work as skids were found to deliver very little sediment, even during storms. Excavated sediment traps proved to be a very beneficial and highly efficient method of controlling sediment delivery from treated subwatersheds. Following the 1995 storms, the RCD constructed more sediment traps and utilized more channel protection, such as channel lining and grade stabilization structures (Figure 3-6). Rock for rocked crossings and for other road drainage improvement projects was also used to a greater extent. The use of heavy equipment was scaled back in the more remote locations that required opening access roads. Main channel excavations were also avoided to prevent destabilization of main stream channel beds. More handwork was utilized, such as headcut structures and checkdams in order to decrease the impact to the sites. During 1995 and 1996 a significant amount of maintenance and repair work was needed as a result of the storms on various sites.

Figure 3-6. Grade Stabilization Structures are Incorporated into most Road-Crossing Excavations

The construction phase of the restoration program lasted about four years, from the fall of 1992 through the fall of 1996 (Refer to the Table 3-1 below for extent of work and accomplishments during this period). As this phase of the program was completed, attention turned toward the upland hillslope erosion processes. Sheet and rill erosion on upland hillslopes is prevalent throughout much of the watershed (Figure 3-7). Although sediment delivery from this source is not as great as road-related sources, it is nonetheless a significant component of the overall sediment budget in the watershed. Stabilizing these hillslopes and restoring the forest plant community is also key to the long-term restoration of watershed health and function. As the GVC watershed heals, there is a high probability that the overall sedimentation rates within the watershed will move closer to background rates.

Figure 3-7 Planting in Sheet and Rill.

ACTIVITY	1992	1993	1994	1995	1996
Acres Treated	1,170	4,418	2,250	2,250	1,000
Number of Sites Treated	50	346	196	103	75
Road Reconstruction	2.4 miles	9 miles	3 miles	2.3 miles	2.2
Road Decommission	1.5 miles	22 miles	20 miles	1.4 miles	0.5
Revegetation-Trees, Shrubs & Grass Plugs	80,000	150,000	135,000	126,000	70,700
Total Expenditure	$380,000	$1,255,000	$1,784,000	$1,040,000	$456,000

Table 3-1. GVC Restoration Accomplishments and Costs.

In 1996 a revegetation/reforestation program was developed to treat 100 acres of upland areas over the next ten years. This has led to the development of a local native seedling nursery as a source of native plants. Many challenges and questions remain regarding implementation of this final phase of the restoration program within GVC watershed. However, a commitment to monitoring and innovation should provide the knowledge and tools necessary for this to be successful.

Chapter 4
RESTORATION IMPLEMENTATION ASPECTS

Restoration Philosophy

With any watershed restoration project, it is important to understand and identify the predominant processes at work that are primarily responsible for the erosion and sedimentation occurring within that watershed. Within the Grass Valley Creek (GVC) watershed, it has been well documented that the combination of past land use practices (primarily associated with timber harvesting) and the highly erosive decomposed granite soil types, which occur throughout the majority of the watershed, have led to the accelerated rates of erosion and sedimentation which are evident today.

The 1986 Soil Conservation Service (SCS) Sediment Study stated that 65% of the erosion and sediment yield within the GVC watershed originated from roads. Roads intercept surface and subsurface flows resulting in concentrated water on the road itself. This interception and concentration of water on roads is the dominant process associated with accelerated erosion and sediment yield from the road network in the watershed. The placement of fill at stream crossings without proper drainage structures is another significant contributor to the overall sediment budget throughout the watershed. Many of these stream crossings or landings were constructed without culverts or utilized under-sized culverts, setting the stage for these crossings to fail altogether or divert stream flows down roads. Roads were also constructed adjacent to stream courses, resulting in extensive erosion of road fill due to scouring during high-flow storm events.

Road construction and design play a significant role in the behavior of water once it reaches the road. Prior to any restoration activities in the watershed, the majority of roads were “in-sloped”: the road surface was sloped inward towards the cutslope (see Figure 5-4, page 35). These in-sloped roads drain all water intercepted from upland areas and capture it in the inboard ditch, concentrating this water and creating a highly efficient sediment delivery system. Additionally, this often results in gullies, as concentrated water from the inboard ditch is unloaded onto fillslopes, natural hillslopes, or into small-order drainages. Commonly, the drainage from several small subwatersheds is diverted via an inboard ditch and unloaded into one small-order channel, resulting in large gullies.

Based on these erosional processes associated with roads, the restoration philosophy of the GVC Watershed Restoration Project encompassed two main objectives:

1) to eliminate or substantially reduce the concentration of water on road fill, and

2) to restore the hydrologic integrity of the watershed.

These objectives were met primarily by decommissioning roads and pulling fillslopes to outslope or recontour roads when necessary. These practices are discussed in much more detail in chapter 5. Road decommissioning was only practiced on roads no longer needed for long-term management. For roads which were necessary for access or other management needs, similar practices were employed to achieve restoration objectives. Road improvement practices such as outsloping, surfacing, or adding rolling dips, rocked crossings, and larger culverts were designed to work in concert with one another to significantly reduce erosion potential and sediment delivery to nearby stream courses.

Planning Process

Obtaining Required Permits

Each year it was necessary to obtain all required permits for work prior to implementation. The Bureau of Land Management was instrumental in obtaining these documents which ultimately enabled the restoration work to proceed. These permits include:

1. Environmental Assessment and the Finding of No Significant Impact;

2. Memorandum of Understanding Between the Bureau of Land Management and Trinity County Resource Conservation District Regarding Conditions and Procedures For Restoration Activities in the Grass Valley Creek Watershed;

3. Fish and Game Permit 1603-Agreement Regarding Proposed Stream or Lake Alteration;

4. Army Corps of Engineers (Section 404);

5. Notice of Intent (NOI) to Comply with the terms of the General Permit to Discharge Storm Water Associated With Construction Activity.

Compilation of Erosion Control Work Plan

Staff compiled all data sheets, maps, design cards with survey information, and site drawings into an Erosion Control Work Plan for each subwatershed. The information included in these plans is a listing of the erosion problem and prescribed treatment, estimated costs, sediment savings analysis, project drawings, an environmental assessment, and all of the necessary permits and other agreements. These plans were distributed to all parties involved for review, comment, and approval. Appendix F includes copies of the data sheets, design cards, and other forms that were utilized for this work.

Implementation

On-the-ground work focused on mitigating sediment delivery problems through primary and secondary treatments. Primary treatments included the removal of crossings and landings; road repair, outsloping, and removal; recontouring skids; re-creation of the original channel systems; headcut stabilization. Secondary treatments included mulching and revegetation of physically treated sites. A pre-work walk-through was conducted for each sub-watershed for final approval. Heavy equipment work was supervised by a “Responsible Design Person.” The restoration technicians (the hand crew) constructed necessary structures, delivered straw, and implemented revegetation work and critical area treatments as called for in the Work Plan.

Revegetation

The revegetation coordinators were responsible for prescribing vegetative treatments at each treated site, utilizing all the knowledge obtained from other specialists in this field as well as the results of the variety of tests they prepared in 1993 and 1994. The revegetation coordinators analyzed the conditions at each site, assessing slope, aspect, soil type and depth, amount of disturbance, and cover. They wrote their prescriptions on design cards (see Appendix F4), and this information is included in the subwatershed work plans, so the success of the treatments can be effectively monitored over time. The information they have and will continue to gather is important to the success of erosion control efforts in the GVC watershed. Getting the disturbed soil covered has proven to be one of the most critical elements in providing effective erosion control in this decomposed granite watershed.

As the physical work was being completed, it was necessary to plan for long-term revegetation needs in the watershed, and, in 1996, a ten-year revegetation plan was developed. The emphasis of restoration in GVC watershed has since shifted to revegetation as a primary rather than secondary treatment. This long-term plan provides focus and direction to the program, detailing on a yearly basis restoration work through 2007.

Documentation and Monitoring

Photo points were established at most sites, where “before,” “during,” and “after” photos were taken to document the work. These photo points were located and tagged in the field and located on hand-drawn maps for the work plans. The photo slides from these locations have proved to be an excellent tool to reference changes as they occur and have been used for presentations to various interested groups.

Supervisor summary sheets and heavy equipment summary sheets (see Appendix F) were utilized to document the work implemented in the watershed. The crew supervisor tracked hours and type of work accomplished by the crew as well as the materials utilized for each site. The RDP recorded heavy equipment hours by site in order to track cost-effectiveness. During 1993 and 1994, equipment operators were billed for their services at an hourly rate. In 1995 and 1996 the majority of the heavy equipment work performed was put out to competitive bidding and operators were paid either by the amount of sediment moved or in a lump sum, rather than on an hourly basis (see page 16 for contracting process).

Several sites have been selected to be closely monitored in order to establish a scientific measurement of the effectiveness of various experimental treatments attempted. Surveys are taken before and after work and again in following years to see what impacts occurred each winter. Sediment catchment basins have been constructed in small ephemeral drainages. These sites are surveyed every year to measure the annual sediment yield from these sub-basins. Cross sections of the mouth of the Buckhorn Sediment Dam and Hamilton Ponds have been established to determine amount and changes in sediment input from GVC above and below the project sites over time (see chapter 7, Monitoring at the Watershed Level, for more detail and results to date). Various costs (labor, materials, planning, equipment, etc.) were compared to determine the cost-effectiveness of the various treatments utilized. Monitoring the work has provided the feedback necessary for revising and refining the restoration techniques utilized in GVC watershed as the project has progressed.

Monitoring was undertaken extensively during 1995, following the significant storm events. A monitoring technician was hired to review each of the nearly 1,000 sites that had been implemented. This project resulted in a database of information (See Appendix E for the database forms) which was attached to the GIS map of the watershed for future reference, analysis, and monitoring.

Interagency Project Review, Approval, and Evaluation (Peer Review)

In all phases of the planning and implementation process, peer review was an important component of restoration work. The RCD scheduled tours and information sessions with agencies, consultants, and other interested parties to review the work, both prior to and after implementation, which provided an opportunity to obtain feedback and hear other points of view. The US Fish and Wildlife Service, Bureau of Reclamation, Bureau of Land Management, Natural Resource Conservation Service, US Forest Service, Redwood National Park geologists, and Pacific Watershed Associates were all actively involved in this part of the process.

Contracting Process

The RCD Board of Directors has adopted the California Uniform Public Construction Cost Accounting Act (CUPCCAA) and its *Cost Accounting Policies and Procedures Manual* (CAPPM).

The CAPPM guidelines the RCD must follow when putting construction projects out to bid are as follows:

> During November each year, each Public Agency which has elected to become subject to the Uniform Public Construction Cost Accounting Procedures shall mail a written notice to all construction trade journals (Builders' Exchanges) designated for that agency under Section 22036, inviting all licensed contractors to submit the name of their firm to the Agency for inclusion on the Agency's list of qualified bidders for the following calendar year.
>
> These Builders' Exchanges are business that local contractors pay yearly dues to for the purpose of supplying the contractors with potential projects in the form of bid packages. The bid packages (containing design plans and specifications) can be reviewed and bid upon by the contractor. If the contractor is interested in bidding the project, they fill out a contractors information form that supplies the RCD with information regarding type of contractor's license(s) held, contractor's license number and the type of work the contractor is interested in. The RCD then receives this form and sends the contractor the plans and specification at a nominal fee. The contractor is then put on a list of qualified bidders (holding a valid Class A General Engineering Contractor License and possessing applicable insurance required by the RCD). The contractor will then receive future notification from the RCD of future projects that they can bid on. This list of qualified bidders is established yearly in the month of January and is valid for one year.

Projects put out to bid by the RCD are broken down into three classifications:

1. Projects that are estimated to cost more than $75,000.00 must be put out to a Formal bid process. The RCD must advertise the project in the Builders' Exchanges not less than 10 calendar days, and local newspapers for at least 30 calendar days, prior to the deadline of the bid opening. Bids are sealed and are opened at special board meetings with at least two of the five board members present.

2. Projects that are estimated to cost more than $25,000.00 but less than $75,000.00 are put out to an Informal bid process. The RCD must advertise in the Builders' Exchange not less than 10 calendar days, and in the local newspaper at least 14 calendar days, prior to the deadline of the bid opening. Bids are sealed and are opened at special board meetings with at least two of the five board members present.

3. Projects that are estimated to cost less than $25,000.00 are considered to be implemented using a Force Account. In this process , the RCD chooses from the list of qualified bidders, contractors who can perform the work at a lump sum cost or by a negotiated hourly rate. The RCD chooses the contractor to perform the work under the Force Account Agreement based on restoration experience, overall construction experience, availability, and cost.

The contractor chosen to perform the work is based solely on the discretion of the RCD Project Manager.

By adopting the CUPCCA, the RCD is allowed more leeway in the execution of public works projects by speeding up the award process and improving timeliness of project completion. By eliminating considerable financial constraints, such as not requiring the contractor to have bonding or not utilizing the Davis-Bacon Prevailing Wage Act, the RCD eliminates red tape and cumbersome paperwork relative to advertising and contracts.

Chapter 5
PHYSICAL TREATMENTS AND MONITORING

Introduction

The Grass Valley Creek (GVC) watershed restoration program has been regularly monitored and subjected to peer review to improve program efficiency and effectiveness. Every year more knowledge has been gained, which has changed aspects of inventory, planning, design, and implementation. The January and March storms of 1995, in particular, provided a wealth of knowledge, putting to the test many of the assumptions made before that time. That January, the highest monthly precipitation total in 82 years of record was recorded at the Weaverville Ranger Station: the 24-inch monthly total eclipsed the old record of 18 inches recorded in December 1964. A rain gauge located in the GVC watershed recorded 34 inches of precipitation for the month of January, with 7 inches of rain recorded in a 24-hour period on January 9, 1995 and 15 inches of rain in four days between January 9 and 13. On January 9, the GVC stream gauging station at Fawn Lodge recorded the second highest mean daily discharge in 20 years of record (1700 cfs). This storm event was the "big storm" that the GVC program was designed to protect against.

The following recommendations represent the current methodology and technology which have been used in the GVC watershed restoration program. Although this section is not intended to be a complete list of all operating procedures, it does summarize the most widely implemented practices used in the GVC watershed restoration program. Monitoring of physical treatments differed from revegetation treatments in that treatments were monitored only for success relative to other treatments. In contrast to revegetation, a quantitative system of monitoring physical treatments, was not developed. Results of physical treatments are therefore incorporated into the discussion of each treatment in this chapter and are not presented in a separate section as is done with revegetation treatments (Chapter 6).

Inventory

Mapping

An accurate map should be the first step of the inventory process. A mapping system should be devised using either good aerial photography or a United States Geological Survey (USGS) 1:24,000 topographic map. Because all roads and drainages are not shown on a USGS map, additional mapping is required to accurately identify erosion sites. Accurate mapping is essential for future design, implementation, maintenance, and monitoring purposes. Accurate site locations enable correct drainage area measurements, which are used to prescribe treatments, design structures, and identify needed culvert sizes.

Data Collection and Management

A standard data sheet should be developed prior to the field inventory of sites. The data sheet should be structured to be a "fill in the blank" form, which captures all relevant site information and organizes the data in a format which can be readily input into a database. Standard terminology should be adopted for site descriptions so that the data may be easily queried in a database. Inventoried sites should be given unique identifiers or site numbers so that each site may be tracked from inventory through design, implementation, and future monitoring (see Appendix F3 for example of a data sheet).

Erosion Potential

Existing erosional features should be evaluated to determine the potential for future erosion. The age of erosional features can be determined from the existing vegetation. For example, if vegetation is well established in a gully, it can be assumed that the gully has been stable for the storm frequencies experienced during the life of the vegetation. A higher priority should be given to potential sites associated with recent disturbances rather than old features which are not actively eroding.

Sediment Delivery

Eroding decomposed granite (DG) breaks down into sand-sized particles, which, because of their large size, are not easily transported and do not travel far. This means that whereas smaller, silt-sized particles delivered to creeks get flushed downstream, having little impact on habitat, larger particles, once deposited in streamcourses, do not get flushed as easily, and migrate slowly, seriously impacting aquatic habitat. This characteristic of DG to move slowly, however, means sediment often does not reach watercourses in the first place. For example, a road may be severely eroding, but the sediment may be deposited onto a hillslope away from a stream course. Some small headwater drainages may exhibit high erosion rates but may deposit sediment onto natural or man-made basins, resulting in little to no sediment delivery downstream. On the other hand, if a defined waterway exists (for example, a gully or inboard ditch), which can transport sediment directly to a stream channel, sediment delivery can be very high. Also, drainages which have steep gradients and well-defined stream courses may have a 100 percent sediment delivery potential. The entire stream network between the source of erosion to the impacted stream should be evaluated for delivery potential.

In order to get good estimates for erosion rates and sediment delivery, all available sediment yield data should be analyzed. Examples of potential data sources are:

1. USGS stream gaging stations
2. Sediment basins, ponds, dams, where sediment may be captured and measured.
3. Silt fences installed on hillslopes to measure sheet and rill erosion.

Having accurate sediment yield quantities measured for a basin or sub-basin is very useful for calibrating and validating sediment yield estimates for an individual site.

Prioritization

The extensive timber harvest road network created in GVC watershed has had the greatest erosional impact on the watershed. Haul roads and skid trails were found in nearly every subwatershed in the GVC watershed. Some roads, most of these along ridges, were still needed for fire suppression, but the remainder could be decommissioned and treated to eliminate or decrease erosional potential and sediment delivery to streams within the watershed. Such treatments included road crossing and landing removal as well as road prism removal (see pg. 32 for prescriptions for Road Removal).

The largest sources of sediment have been where roads came into direct contact with streams--at road crossings. Of these sites, those which exhibited high erosion and sediment delivery potential were considered highest priority for treatment. These sites included:

1. Stream Diversions onto Road. The largest contributors of sediment--and the easiest to repair--occur when streamcourses divert onto road surfaces and flow down the roads themselves, causing gullies. By eliminating the diversion potential, hundreds or thousands of cubic yards of road fill may be prevented from entering streams.

2. Road Crossings. Another problem associated with road crossings through streams is when high flows wash out the crossings, depositing fill, often all of it, into streams. Removing fill from road crossings is one way to prevent diversion of streams onto road surfaces or washouts of road fill. However, the volume of fill to be removed should be weighed against the disturbance caused by excavation: if only a small amount of fill is to be excavated it may not justify the disturbance.

In some cases roads were decommissioned but otherwise left in place because they provide essential long-term access. In these cases, road drainage was improved to eliminate or decrease erosion potential from the road surfaces. On decommissioned roads, drainage was improved by the installation of waterbars and rolling dips. On roads intended to be kept open, drainage was improved by outsloping road prisms, rocking road crossings, installing waterbars and rolling dips, installing aggregate surfaces, installing or upgrading culverts, and dissipating flow energy at outlet points, such as culverts, rolling dips, and waterbars (see pg. 35 for prescriptions for Road Drainage Improvement).

On roads intended to be kept open, priority was given to sites where sediment from roads would be delivered directly into streams. Among such sediment sources the following cases were seen as particularly pervasive or problematic:

Cutbanks with Inboard Ditches. Cutbanks generally have very high rates of erosion and sediment delivery can be 100 percent if the inboard ditch discharges directly into a stream channel. However, if the road is outsloped and does not have an inboard ditch, sediment delivery from the cutbank will be very low.

Road Surface Erosion. Road surfaces potentially deliver large amounts of sediment to streams, particularly in cases where roads are insloped and drainage from an inboard ditch flows directly into streams.

Eliminating sediment sources in the watershed, in particular those associated with roads, is now seen as the most important restoration work undertaken in the GVC watershed. As a backup measure, the restoration team also expanded the use of sediment capture as a means of preventing sediment from entering the the Trinity River from GVC. In addition to the Buckhorn Sediment Dam and sediment capture basins constructed near the confluence of GVC and the Trinity River (known as the “Hamilton Ponds”), the restoration team also installed numerous small sediment traps in various subwatersheds to prevent sediment entering streams from migrating downstream. The sediment traps are monitored for sediment accummulation and excavated as needed. Although such measures were considered a backup, they are very instrumental in keeping sediment from migrating downstream, particularly during large storms such as those of 1995 (see pg. 45 for prescriptions for Sediment Capture).

The original restoration work in GVC was undertaken in stream channels themselves, before the team understood fully how sediment migrated throught the stream network of the GVC watershed. This in-stream work, is now seen to be the least effective method for controlling sediment, since it does not necessarily take into consideration the causes of stream channel erosion, which may be due to upland problems associated with roads. What was seen as central to GVC restoration in 1992--stream channel stabilization--is now seen as a “Band-Aid” approach, since it does not necessarily address the *causes* of stream bank erosion. Such treatments are discussed in Chapter 3, Evolution of the Grass Valley Creek Restoration Project, and they include the installation of grade stabilization structures and channel lining as well as stream bank excavation, which was undertaken in a few cases where stream banks had become over-steepened through natural or human-induced erosional processes (see pg. 49 for prescriptions for Stream Channel Stabilization).

Prescriptions for Physical Treatments

Road Removal

Road removal typically involves excavation of all stream crossing fill and in rare cases the total removal of road prism fill. Although it is generally essential to remove all fill from stream crossings, it may not be necessary to remove all road prism fill from hill slopes to achieve the desired objective. The length of road prism fill to be removed is based on the sections of road which have been identified for removal in the inventory process and the sections of road on which excavated crossing fill is to be placed. The volume of fill to be excavated within each section is determined by balancing cut and fill cross sections to achieve the desired finished grade (Figure 5-1). It may not always be possible or desirable to achieve a "full recontour" by removing all of the old fill slope and filling the road bench to the top of the cut bank. It is generally not possible to achieve a balance of cut and fill to recreate precisely the pre-road cross section due to:

- Decrease in soil volume due to erosion
- Increase in soil volume due to sedimentation
- Inability to achieve pre-road soil density.

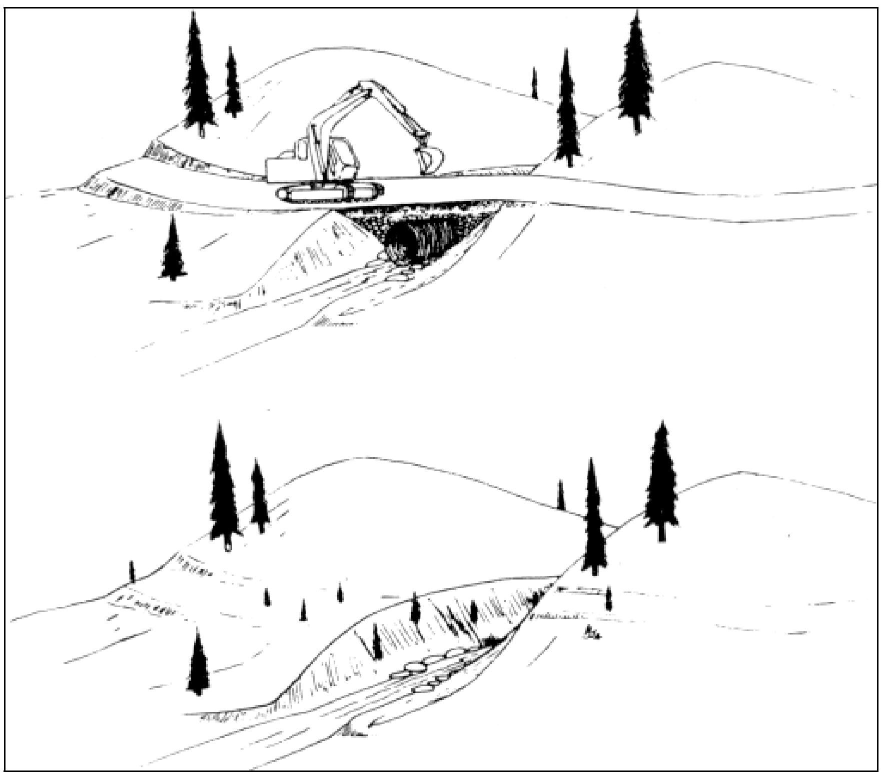

Figure 5-1. Removing a Road Crossing

However, if none of these factors are excessive or if the combined effects of the factors are fairly balanced, a reasonably close approximation of the pre-road cross section can be achieved. However, it should be noted that although the original dimensions may be very closely restored, the structure of the soil profile has been altered from its original matrix. Therefore the water holding capacity, infiltration rate, subsurface flow patterns, shear strength, and other soil properties will be different from the original soil profile.

It may not be desirable to achieve a full recontour if:

- The slope grade required to achieve full recontour exceeds the stable slope limit of the compacted fill.

- The volume of fill excavated from the lower reaches of the fill slope does not justify the additional length of excavation. In other words, if only a thin veneer of fill is removed from the lower slope there is more potential erosion caused by removing the vegetation than could be potentially saved by removing the fill.

- The additional cost of total fill removal is not justified by the additional benefits.

After consideration of all these factors, the overall design of road removal can begin. Different designs may be considered for different sections of the road as long as the feasibility of the individual road segment designs is considered in the context of the overall road removal plan (for example, can the same construction equipment be used for all designs?).

Road removal is performed most efficiently using a combination of dozer and track-excavator. Generally, the first step is for the dozer to open the road for the delivery of construction materials. The materials should be stockpiled in areas that won't interfere with construction activities but are readily accessible. Excavation then begins at the furthest point from entry with the dozer and excavator working in tandem on both crossing and road prism removal. Post-excavation treatments may begin as the equipment works its way out of the project area.

On most crossings, dozers can perform the bulk of the excavation by pushing the fill from the crossing onto the road bench on either side of excavation. An excavator can then be used to finish the channel excavation, placing the fill where the dozer can efficiently move the material onto the road bench, which should be ripped by equipment prior to placement of road fill. The excavator can also be used to move and place materials used for channel stabilization (i.e. rocks, logs and rootwads).

When excavating the road prism, the dozer can be used to push fill from the outside berm onto the road bench. The excavator then removes the remaining fill slope to achieve the desired outslope grade and surface. The finished surface may include placing trees removed during excavation.

End-Hauling. If the volume of excavated fill exceeds the available storage capacity of the adjacent road, material may need to be transported off-site by dump trucks (end-hauled). Generally, the existing road bench has sufficient storage simply because fill used in road crossing construction came from the road cut directly adjacent to the site. However, it may not always be possible to return all of the fill to its pre-road construction location. If large volumes of material need to be moved long distances, end-hauling may be a more efficient means of transport than pushing with a dozer. End-hauling may be necessary where:

- The road bench is determined to be unsuitable for spoil placement due to springs, seeps, landslides, proximity to stream channels, etc.
- The material to be excavated includes large amounts of sediment deposited from upslope sources.
- Steep terrain in which the road cut cannot be filled to the top due to fillslope stability considerations.

Road Crossing/Landing Removal

Definition:

Excavation of road and landing fill from stream channel crossings and stabilization of excavated and filled areas. Usually performed in conjunction with road prism removal.

Purpose:

To prevent erosion of road crossing fill and/or to prevent diversion from the stream channel onto the road surface.

Conditions Where Practice Applies:

Roads for which access is to be temporarily or permanently removed.

Planning Considerations:

- Accessibility of site by equipment and vehicles.
- Disturbance caused by accessing site.
- Availability of suitable spoil locations on-site and feasibility off-site spoil location (end-hauling).
- Temporary stream flow diversion away from work area if operating in a perennial stream.
- Potential of uncovering springs or seeps.
- Moisture content and compactability of excavated fill.
- Removal and placement of trees, stumps, rocks, and boulders.
- Delivery and storage of equipment and materials required for post-excavation treatments (mulch, rock, etc.).
- Future access for planting and O and M.
- Culvert salvage or disposal.

Design Criteria:

The design of a crossing excavation involves determining:

- The dimensions of the crossing fill to be removed to restore the stream channel to its pre-road configuration.
- The placement, compaction, and grading of the excavated fill.
- Post-excavation treatments for stream-channel stability and slope stabilization.

The design criteria for these components includes:

- The stream channel above and below the proposed excavation should be generally stable.
- The excavated channel cross section should be based on stable channel cross sections immediately above and below the proposed excavation.
- A stream profile survey and cross sections through the proposed excavation shall be done to determine limits of excavation, depth of cut, and excavation volume.
- Excavated channel grade should be uniform or concave through the excavation.
- Excavated side slopes should not exceed 2:1. If the existing topography dictates a steeper side slope, slope stabilization measures should be incorporated into the design.
- The excavated channel shall be stable for a 10-year, 24-hour storm for the as-built condition and a 25-year, 24-hour storm for the aged condition. The necessary stability can be achieved with the aid of channel stabilization measures including grade control structures and channel lining.

- Trees removed during excavation may be cut into manageable lengths to be placed cross-slope on the excavated slope to protect from overland flow and along the toe of excavation to protect from design flow. Logs placed cross slope should be keyed-in by excavating a trench prior to placement or by pushing the logs into the soil with the bucket of the excavator.

Construction Specifications:

- Adjustments to the original design may need to be made as the excavation proceeds. The excavation should be monitored closely to look for indicators of original channel and side slope location. Indicators such as lag deposits, buried tree stumps, and logging debris can be used to determine the final configuration of the excavated channel and side slopes.
- The finished channel should be without abrupt changes in alignment and should conform to natural contours above and below excavation.
- The finished excavated and fill *surfaces* should be rough and uncompacted, with no ridges, depressions, or gaps that may act to concentrate or pond water. The transition from finished slopes to undisturbed ground shall be smooth and free from ridges and gaps.
- As a general rule, channel protection measures should be used when excavating road crossings in DG when:

    1. Length of channel excavation exceeds 100 feet;
    2. Drainage area above the site exceeds 10 acres;
    3. The stream channel above the excavation is “well defined,” indicating a relatively high frequency of surface flow;
    4. Competent bedrock is not encountered at the channel surface.

Operation and Maintenance:

- Monitoring of completed site for erosion and the condition of vegetation for all disturbed areas;
- Repair of grade structures or channel lining as needed;
- Removal of obstructions which may divert stream flow.

Conclusions to Date:

When excavating a road crossing from a stream channel the goal has been to remove all the road fill while taking great care not to excavate below the pre-road channel grade. Because of the increased risk for channel instability, if the crossing is not completely excavated or if the excavation goes below the pre-road channel grade, much effort has been placed on refining design and implementation procedures to achieve the most stable long-term channel configuration.

The first step of design is to survey the stream profile and hill slopes above, below, and through the crossing. This survey can be used to project the existing hillslopes and stream channel through the crossing to estimate the pre-road channel elevation and location. In addition to the design survey, the excavation should be monitored for indicators of the pre-road ground surface. Indicators such as buried tree stumps and logging debris can be used to distinguish between road fill and the original ground surface. Although these indicators can give a very good clue as to the approximate channel location, the exact pre-road channel elevation is generally not as readily apparent.

Most crossing excavations took place in small ephemeral drainages in DG where water-lain rock, riparian vegetation, and other channel bottom indicators are generally non-existent. The channel bottom in these drainages is most often comprised of unconsolidated DG overlying granite bedrock. Occasionally bedrock outcrops may be found at the surface of the channel, but the depth to bedrock is commonly 2 to 3 feet, with much greater depths in alluvial reaches. Because indicators of original channel elevation are very subtle, the distinction between road fill and unconsolidated channel material may be very difficult to determine and somewhat irrelevant due to the highly erosive nature of both. Therefore, more reliance is placed on excavating the stream channel to conform to the channel profile above and below the crossing rather then on uncovering a distinct, well-defined channel bottom with the original properties still intact.

Although removal of the road crossing may successfully restore the original channel elevation and configuration, the original channel structure has been highly disturbed as a result of crossing construction and removal. The excavated channel lacks the natural complexity and resistance to erosion, which, in the original channel, was provided by woody debris, vegetation, and the natural channel forming and sorting processes. The excavated channel bottom is essentially comprised of loose, granular, unconsolidated DG, which is extremely erosive. This was recognized early in the program as a concern when considering channel excavations in DG. It was concluded at this time that either channel stabilization measures would have to be incorporated into the design or some risk would be assumed regarding post-excavation erosion. It was decided initially that post-excavation erosion would be acceptable if it did not exceed 20 percent of the volume of the estimated sediment yield of the site. Consequently, this risk was accepted and no channel protection measures were incorporated into crossing excavation designs.

As a result of the January and March Storms of 1995 some very large adjustments were observed that exceeded the definition of acceptable erosion (Figures 5-2 and 5-3). In some cases the volume of erosion exceeded the original sediment yield estimate of the site. In order to quantify the impacts of the storms, all the large adjustments were surveyed to determine the volume of erosion from each site. This data was analyzed to determine the contributing factors which led to the unacceptable level of erosion recorded at these sites. From this analysis it was determined that the most relevant factors contributing to excessive erosion were: length of stream channel excavation, drainage area, and the underlying soil and geology of the site. Because of the complexity and interdependence of the variables involved, a statistical model could not be derived to quantify the relative weight of these factors.

Figure 5-2. Unprotected Channel on 6/15/94.

Figure 5-3. Same Channel on 2/14/95 after Major Storm

<u>Geology/Soils</u>:

The majority of road crossings were excavated in stream channels where the entire channel matrix was comprised solely of DG. In this setting the underlying material consisted of unconsolidated DG (alluvium, colluvium, residuum) grading to bedrock. The competency of the bedrock varied depending on mineralogy, fracturing, and weathering.

Stream channels in which metamorphic rock was present, adjusted differently than did channels comprised solely of DG. These channels were able to develop an armor layer with the native rock in the channel matrix. As fine sediment was washed from the matrix, the rock sorted itself to form a rock lined channel. Consequently, the erosion resistance of the channel material increased in response to increasing stream flows. In no case where metamorphic rock was present in the channel matrix did post-excavation erosion exceed the acceptable tolerance (20 percent of estimated sediment yield).

This process did not occur in channels comprised solely of DG. In this setting the stream downcut through the unconsolidated material and sometimes well into the bedrock. In channels with deep unconsolidated material and/or highly fractured and weathered bedrock, the depth of down cutting was much greater than where more competent bedrock occurred near the surface. However, the existence of competent bedrock near the surface was rare and occurred mainly in steep headwater drainages. Consequently, the largest adjustments occurred at channel confluences where the depth of unconsolidated material was generally the greatest. All of the sites which exceeded the accepted erosion tolerance occurred at channel confluences with channel material composed solely of DG (i.e., no metamorphic rock).

Excavated Channel Length:

The largest crossing excavations were landings constructed at channel confluences. As discussed above, the stream channel at these locations was generally comprised of deep unconsolidated DG. As this material eroded a headcut or series of headcuts formed and migrated through the excavation. However, in almost every case the headcut did not migrate beyond the top of excavation. The headcuts at the top of excavations exposed a dense rootmass in the layer of unconsolidated material which has checked gully migration (this has been a very good indicator of the importance of vegetation to channel stability). The length of the gully was generally equal to the length of excavation while the depth and width of gullying increased in relation to watershed discharge, channel grade, length of excavation and erosiveness of the channel material.

Based on the knowledge gained from the 1995 storms and a reevaluation of the remaining work in the watershed, the philosophy regarding crossing excavations has changed. Due to the extremely erosive nature of DG, it has been decided to design crossing excavations with channel protection if potential for post-excavation erosion is significant.

See also: Road Prism Removal (below), Stream Channel Stabilization (49), Channel Lining (53), Critical Area Treatments (58).

Road Prism Removal

Definition:

Excavation of part or all of road fill to restore natural drainage patterns. Usually performed in conjunction with crossing removal.

Purpose:

To prevent erosion caused by:

- Concentration of flow on road surface or inboard ditch.
- Stream channel encroachment.
- Unstable fill slopes.

Conditions Where Practice Applies:

Roads for which access is to be temporarily or permanently removed.

Planning Considerations:

- Accessibility of site by equipment and vehicles.
- Disturbance caused by accessing site.
- Availability of suitable spoil locations on-site and feasibility off-site spoil location (end-hauling).
- Moisture content and compactability of excavated fill.
- Removal and placement of trees, stumps, rocks and boulders.
- Delivery and storage of equipment and materials required for post-excavation treatments (mulch, seed, etc.).
- Future access for planting and operation and maintenance.

Design Criteria:

- If road bench is to receive spoil from a crossing excavation, the finished outslope cross section must be balanced with crossing and road fill spoil.
- The volume of fillslope to be excavated should be calculated by determining the limits of excavation based on topography, vegetation, and proximity to stream channel.
- If the design outslope grade does not exceed the road grade, waterbars should be installed as required to prevent water flow down the outsloped road.
- Compacted road surfaces should be decompacted by mechanical ripping prior to placing fill. Typically two passes by a dozer with ripper shanks to a depth of at least 18 inches is sufficient.
- Finished slopes of the compacted fill should be limited based on the level of compaction provided. Compacted slopes should be no steeper than 2:1. Uncompacted slopes should be no steeper than 2.5:1. The required level of compaction can normally be achieved by the dozer if spoiling in lifts of 12 inches or less. When removing a road using only an excavator, compaction is difficult to achieve, thus 2.5:1 slopes are recommended.

Construction Specifications:

- Excavation shall be limited to existing road fill.
- No material shall be side cast into the stream corridor as a result of construction operations.
- The finished excavated and fill *surfaces* shall be rough and uncompacted, with no ridges, depressions, or gaps that may act to concentrate or pond water. The transition from finished slopes to undisturbed ground shall be smooth and free from ridges and gaps.
- Trees removed during road removal should be placed on the finished surface. Trees larger than 6 inches in diameter may be placed cross-slope to aid in slope stability.

Operation and Maintenance:

Monitoring of completed site for erosion and the condition of vegetation for all disturbed areas.

Conclusions to Date:

This practice performed very well by eliminating the sources of erosion from roads (cutbanks, surfaces, and fill slopes). The only post-excavation erosion observed from these sites was some minor surface erosion and slumping of the regraded fills. However, very little surface erosion occurred where adequate mulching was done and little to no slumping occurred when fills did not exceed 2.5:1 slope grade. Even where erosion did occur, very little sediment was delivered off site due to removal of the delivery system (concentrated flow).

Significant erosion was observed at a few sites where removal of the road fill slope extended to the bottom of a stream channel. With the freshly excavated slope left unprotected, the stream found a “soft spot” and cut into the stream bank. In future work when fill slopes encroach into a stream channel, the excavation will be limited to the slope above the anticipated high water mark or the excavated bank will be protected by placing logs or other streambank protection at the toe of the slope.

See also: Road Crossing Removal (page 29), Critical Area Treatments (page 58).

Road Decommissioning

Definition:

Decompaction and disruption of the road surface for restoring infiltration and cross-slope drainage. Usually performed in conjunction with road crossing removal.

Purpose:

To prevent erosion caused by concentration of flow on road surface or inboard ditch.

Conditions Where Practice Applies:

Roads for which access is to be temporarily or permanently removed and road prism removal is not necessary or feasible.

Planning Considerations:

Road decommissioning can be accomplished most efficiently by a dozer with a six-way blade and mechanical rippers. The dozer constructs large water bars (berms) at frequent intervals and decompacts the road surface.

Design Criteria:

- Berms should be installed as required to prevent water flow down the road. The berms should be a minimum of 3-feet high when compacted.
- Compacted road surfaces should be decompacted by mechanical ripping. Typically two passes by a dozer with ripper shanks to a depth of at least 18 inches is sufficient.
- No material shall be side cast into the stream corridor as a result of construction operations.

Operation and Maintenance:

Monitoring of completed site for erosion and the condition of vegetation for all disturbed areas.

Conclusions to Date:

In many cases this practice may be much less expensive and just as effective as road removal. In particular if the road is very old and has been stable for many years it may be more desirable to build large water bars and perform only selected fill slope excavation to eliminate any potential for water diversion down the road. This would require much less disturbance to existing vegetation and would require less critical area treatments.

See also: Critical Area Treatments (page 58).

Road Drainage Improvement

Road drainage design can be grouped into four basic categories, defined by road cross section: level, crowned, insloped, and outsloped (Figure 5-2).

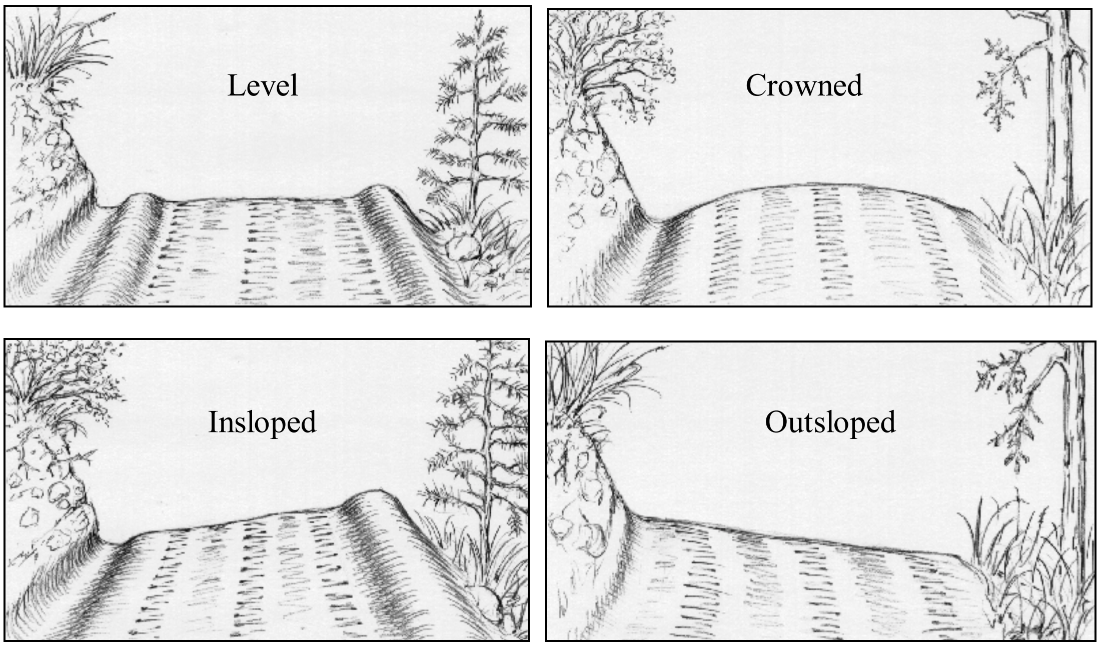

Figure 5-4. Road Drainage Designs

Insloped and crowned roads generally have a defined inboard ditch to convey drainage to a discharge point which is most often a stream channel. Level roads generally have waterbars or rolling dips to divert drainage from the road and sometimes have an inboard ditch. Outsloped roads generally do not have inboard ditches, but may have dips and/or outside berms to direct drainage away from unstable areas.

In decomposed granite the guiding principle in road design is to minimize the concentration of road drainage. Not only can erosion from the cut bank, road surface, and fill slope be reduced, but the sediment delivery potential of any future erosion can be minimized by eliminating direct discharge of road drainage to the stream channel.

Road outsloping is the most effective design for dispersing road drainage. However due to safety concerns or cost constraints, outsloping may not always be feasible. Road drainage dispersion can be achieved to a lesser extent by creating rocked crossings, installing water bars and rolling dips, resurfacing road bases, or installing culverts. By reducing the accumulation of road drainage, erosion and sediment delivery can be greatly reduced or even eliminated.

Off-site effects from road drainage can be further minimized by providing adequate energy dissipation at discharge points. If the flow of water can be interrupted to allow infiltration into the hill slope, down-slope erosion and sedimentation can be eliminated.

Road Outsloping

Definition:

Reconstruction of the road surface, changing the cross-slope grade to drain water away from the cutbank (Figure 5-5).

Purpose:

To prevent erosion caused by concentration of flow on road surfaces or inboard ditches.

Conditions Where Practice Applies:

Roads which are to be maintained for vehicle access.

Figure 5-5. Outsloping Reduces Concentrated Flow on Road Surface

Planning Considerations:

- Safety consideration for winter travel.
- Road use (seasonal, residential, fire, etc.).
- Road surfacing - present and future.
- Traffic control and dust abatement during construction.

Design Criteria:

- Degree of outslope should be based on the road grade and safety considerations for desired use. A maximum outslope grade of 2 to 5 percent is common for year-round residential roads, while 5 to 10 percent outslope may be acceptable for seasonal utility roads.
- If the road grade exceeds maximum allowable outslope grade, rolling dips or waterbars should be included in the design.
- Cut and fill x-sections need to be balanced for the entire length of road.
- Conventional outslope can be constructed solely with a grader or dozer. This outslope results in a wider road surface with more original road fill left in place.

- Contoured outslope requires an excavator or backhoe, in addition to a grader or dozer. This type of outslope involves excavating more of the fill slope and placing it along the cutbank or on the road surface.

Construction Specifications:

- No material shall be side cast from the road as a result of construction operations.
- Trees, stumps, roots, brush, and rocks (6 inches and larger) removed during excavation shall be placed on the excavated slope below the road or at designated locations off the roadway. No organic material should be incorporated into the earthfill used on the road surface.
- Earthfill should be compacted in layers not to exceed 6 inches. Compaction can be achieved by a road grader or dozer passing over 90 percent of the surface area of each lift.
- The moisture content of fill materials shall be adequate to achieve the desired compaction. A water truck is commonly required on-site to maintain adequate moisture control.
- Road bench segments on which fill is placed should be decompacted by mechanical ripping to a minimum depth of 12 inches. Ripping may be performed by a dozer or grader with ripper shanks.
- All cut and fill slopes shall be made smooth and continuous with no ridges, gaps, or depressions which may act to concentrate water.

Operation and Maintenance:

Grading of the road surface as needed to eliminate rills and tire tracks which may concentrate water on the road surface.

Conclusions to Date:

This practice performed well for its intended purpose. Although some minor surface erosion was observed on outsloped road surfaces and fill slopes, the sediment delivery off site was very low due to dispersion of the road drainage. Some fill slope failures did occur on newly outsloped roads. In these cases it appears that water concentrated along the outside edge of the road due to ruts, ridges, or insufficient outslope grade. When the concentrated water discharged onto saturated fills gullying and/or mass wasting occurred. Based on these observations the following additions were made to design criteria:

1. Roads which are used for winter access will need to be graded on a regular basis to eliminate ruts, which may concentrate road drainage.
2. The outside edge of the road should be sloped at a steeper grade than the road surface or slightly rounded to allow for rapid drainage off the fill surface.
3. Additional rolling dips may need to be installed to capture concentrated runoff from tire tracks and to direct drainage away from potentially unstable fill areas.
4. Even with these modifications some fill failures still occurred. It appears that removing the outside berm and existing vegetation may destabilize the remaining fill and make it susceptible to mass movement. Therefore outsloping *should be avoided* in areas with potentially unstable fill slopes.

See also: Road Surfacing (page 40), Waterbars and Rolling Dips (page 39).

Rocked Crossing

Definition:

This treatment includes the partial or total excavation of road crossing fill and the placement of rock riprap in the crossing.

Purpose:

To prevent erosion of road crossing fill due to culvert failure and/or to prevent diversion from stream channel onto road surface.

Conditions Where Practice Applies:

Roads which are to remain open to vehicle access, but are not traveled or maintained on a regular basis.

Planning Considerations:

- Road use (seasonal, residential, fire, etc.).
- Availability of suitable spoil locations on-site and feasibility off-site spoil location (end-hauling).
- Temporary stream-flow diversion away from work area if operating in a perennial stream.
- Removal and placement of trees, stumps, rocks, and boulders.
- Culvert salvage or disposal.
- Traffic control and dust abatement during construction.

Design Criteria:

- This practice is limited to stream crossings with shallow fill.
- The stream channel above and below the proposed excavation should be generally stable.
- The excavated channel cross section should be made driveable by the vehicles for which the road is designed.
- Generally, 3- to 6-inch diameter rock is the largest size which can be safely driven across by automobiles. Larger rock may need to be placed downstream of the travelway to slow the velocity of the water across the travelway and to protect steeper channel grades at the outlet.
- A coarser aggregate road base may be needed on the approaches due to the increased road grade.

Construction Specifications:

- No material shall be side cast into the stream corridor as a result of construction operations.
- The subgrade should be excavated to the design depth of riprap so that the riprap surface conforms to the road surface.
- Road base material excavated from the crossing may be stockpiled and placed on the finished road surface according to the design specifications.

Operation and Maintenance:

- Repair and replacement of riprap as needed.
- Monitoring of completed site for erosion and the condition of vegetation for all disturbed areas.

Conclusions to Date:

This practice should only be considered when most or all of the road crossing fill can be removed while still maintaining adequate vehicle access. It is best suited for unmaintained limited access roads where a diversion potential exists.

See also: Channel Lining (page 53), Road Surfacing (page 40), Critical Area Treatments (page 58).

Waterbars and Rolling Dips

Definition:

Dips in the road surface which diffuse water from the road and/or inboard ditch (Figure 5-6).

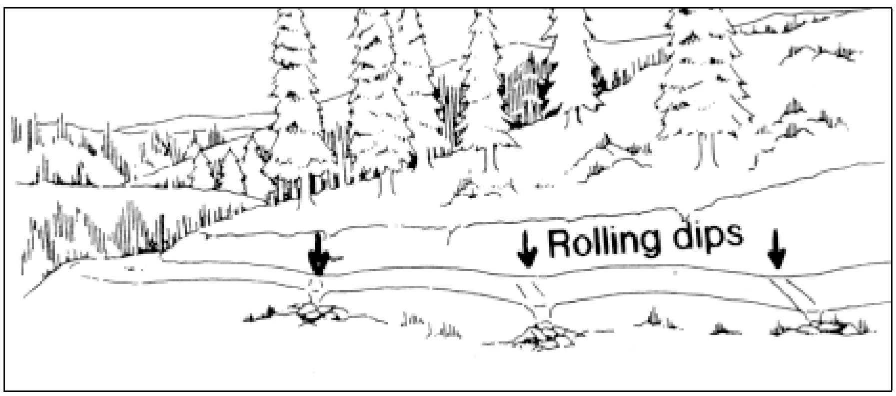

Figure 5-6. Rolling Dips.

Purpose:

To prevent erosion caused by concentration of flow on road surface or inboard ditch.

Conditions Where Practice Applies:

Roads which are to be maintained for vehicle access.

Planning Considerations:

- Potential off-site impacts from outlet discharge.
- Road use (seasonal, residential, fire, etc.).
- Traffic control and dust abatement during construction.
- Since rolling dips have longer approaches than water bars, they are gentler to drive over; however, more road surface is disturbed during construction.

Design Criteria:

- Drainage outlets should be located at stable discharge points or outlet protection should be provided.

- Placement of excavated road fill must be incorporated into the design, either spread on the road surface or placed off-site.
- When the road grade exceeds 10 percent, a rolling dip cannot be constructed adequately, therefore waterbars are generally required.
- The outlet grade of the dip should be equal to or greater than the road grade to prevent sedimentation in the dip.
- Spacing of dips is based on road grade, road surface material, hillslope drainage and suitable outlet locations.

Construction Specifications:

- No material shall be side cast from the road as a result of construction operations.
- Earthfill should be compacted in layers not to exceed 6 inches. Compaction can be achieved by a road grader or dozer passing over 90 percent of the surface area of each lift.
- The moisture content of fill materials shall be adequate to achieve the desired compaction. A water truck is commonly required on-site to maintain adequate moisture control.
- Road bench segments on which fill is placed should be decompacted by mechanical ripping to a minimum depth of 12 inches. Ripping may be performed by a dozer or grader with ripper shanks.
- All cut and fill slopes shall be made smooth and continuous, with no ridges, gaps, or depressions which may concentrate water.

Operation and Maintenance:

- Grading of the road surface to eliminate rills and tire tracks and to maintain original design dimensions.
- Addition of road base material as required.

Conclusions to Date:

This practice has been very effective on road grades less than about 5 percent. On road grades steeper than this, rolling dips and/or water bars are more difficult to construct and maintain as vehicle traffic wears down the crest of the dip. As tire tracks or ruts develop across the dip, road drainage will follow the track through the dip.

See also: Outlet Protection (page 43, Road Outsloping (page 36), Road Surfacing-Road Base (below)

Road Surfacing - Road Base

Definition:

A compacted layer of road-base material applied to the road surface.

Purpose:

To prevent erosion of the road surface and to protect the structural integrity of the road design. Surfacing helps to prevent the formation of rills and tire ruts, to protect waterbars from wear, and to reduce the potential for dips filling with sediment.

Conditions Where Practice Applies:

Roads which are to be maintained for vehicle access.

Planning Considerations:

- Road use (seasonal, residential, fire, etc.).
- Traffic control and dust abatement during construction.
- Availability of road-base material and impact to access roads from rock trucks.

Design Criteria:

- The road base material and placement shall conform to local grading ordinances and agency specifications.
- The base material should be crushed rock with enough fine material to hold the rock in place and provide for good compaction.
- The typical road base layer is 6 to 10 inches of base material spread and compacted to achieve a final thickness of 4 to 6 inches.
- Moisture control and compaction are generally required for most road base material applications. Road-base compaction is best achieved with a vibratory roller.

Construction Specifications:

- No material shall be side cast from the road as a result of construction operations.
- Road base material should be spread in uniform layers and rolled to achieve the desired compaction.

Operation and Maintenance:

- Grading of the road surface to eliminate rills and tire tracks.
- Addition of road base material as required.

Conclusions to Date:

As a practice, road surfacing by itself may reduce some road-surface erosion but should be considered a *secondary* treatment to road drainage improvements. Road surfacing improves the effectiveness of other road drainage practices by protecting the structural integrity of the road design. Surfacing helps to prevent the formation of rills and tire ruts, protects water bars from wear, and reduces the potential of dips filling with sediment.

See also: Road Outsloping (page 36)

Culvert Installation

Definition:

This treatment includes the installation or replacement of a culvert in a stream crossing or for drainage of an inboard ditch.

Purposes:

1. To prevent erosion of road-crossing fill due to culvert failure and/or to prevent diversion from stream channel on to road surface.
2. To reduce the erosive force and sediment carrying capacity of inboard ditch flow by dispersing the drainage at stable locations.

Conditions Where Practice Applies:

Roads which are to remain open to vehicle access, and *are to be maintained* on a regular basis.

Planning Considerations:

- Temporary stream flow diversion away from work area if operating in a perennial stream,
- Traffic control and dust abatement during construction.
- Culvert salvage or disposal.

Design Criteria:

- The stream channel above and below the road crossing should be generally stable.
- The culvert should be sized to convey the design water and sediment flow from the watershed above.
- The crossing should be constructed with an overflow route (critical dip) which will prevent water from running down the road should the culvert become plugged.
- Stream-crossing culverts should be installed at or slightly below natural channel grade.
- Ditch-relief culverts should be installed at a grade of one or two percent greater than the inboard ditch, with a minimum grade of 2 percent to daylight.
- The minimum fill over the culvert should be at least 1/2 the pipe diameter but never less than 1 foot.
- Adequate inlet and outlet protection should be provided for full pipe flow (See Outlet Protection, page 43).
- Where there is a potential for plugging from debris in the channel, a trash rack should be installed upstream of the culvert.

Construction Specifications:

- Follow manufacturer's specifications for installation of pipe.
- The trench should be excavated with a uniform grade from the inlet to outlet. Any trench excavation exceeding 4 feet shall be supported or the slopes laid back to a stable angle.
- A firm bed of clean compacted fill, free from rocks and organic material, should be prepared for the pipe.
- All sections of pipe should be placed in the trench and joined with standard coupling bands.
- Backfill shall be placed in uniform layers on each side of the pipe with suitable material from the crossing excavation. The backfill should be wetted and mixed well to achieve the desired moisture content (usually such that it will form a ball when squeezed by hand).
- When backfilling along the sides, the pipe shall be loaded sufficiently to prevent it from being lifted from the bedding.
- The thickness of each layer should not exceed 8 inches and should be compacted to the same density as adjacent undisturbed earth. Compaction is best achieved with manually directed tampers.

Operation and Maintenance:

- Removal of obstructions which may plug culvert.
- Repair and replacement of inlet and outlet protection materials.

Conclusions to Date:

There is always a potential for any size culvert to become plugged with debris or sediment, even though the culvert may be designed for a “100-year storm.” (Figure 5-7). Therefore, a “critical dip” should be incorporated into the design of the crossing. A critical dip is a rolling dip at a road crossing to ensure that if the culvert plugs water will remain in the stream channel and not divert onto the road surface. In addition, maintenance should always be performed to minimize the potential for plugging.

See also: Outlet Protection (below)

Figure 5-7. Culverts Will Inevitably Plug With Debris. Critical Dips At Crossings Will Ensure That Flows Remain In Stream Channels.

Outlet Protection (Energy Dissipation)

Definition:

Material used to protect road drainage discharge points from the erosive forces of water.

Purposes:

1. To prevent erosion at the point of discharge.
2. To minimize downslope and downstream impacts of discharge by reducing water velocity.

Conditions Where Practice Applies:

Outlets of waterbars and rolling dips, culverts.

Planning Considerations:

- Availability of on-site materials (rock, brush, etc.).

Design Criteria:

- Overside drains with flumes may be required to convey discharge across unstable slopes.
- Culvert inlets should be designed to protect road fill from backwater turbulence and piping around the culvert.
- Culvert outlets should be designed to dissipate energy from the outfall and to conform to the channel downstream.
- Outlet protection material shall be designed to withstand design flow with minimal displacement.

Construction Specifications:

- The subgrade should be excavated to allow for the design depth of channel lining.
- Outlet protection at rolling dips and water bars should not cause ponding of water, which may result in sedimentation.

Operation and Maintenance:

Repair and replacement of inlet and outlet protection materials.

Conclusions to Date:

Due to accelerated water velocities at drainage outlets, scour protection should always be considered.

See also: Channel Lining (page 53), Grade Stabilization Structures (page 50).

Turbidity Control and Sediment Capture

The practices described thus far deal with the prevention of erosion at the source. The practices listed in this section deal specifically with the capture of sediment once it has left the site. The primary objectives for implementing sediment capture practices were to:

1. Prevent turbidity in perennial streams as a result of construction activities.
2. Provide long-term sediment capture and storage for the purpose of reducing sediment yield from upland areas.

Turbidity Control

Before doing any work in a stream channel the necessary permits must be obtained from the appropriate regulatory agencies. Special measures may be required to reduce short-term impacts on water quality as a result of construction operations. Beyond the need to comply with regulations it is important to consider the potential impact on water quality downstream. Turbidity resulting from construction operations may not be detrimental to fisheries or wildlife but it may be a concern to fishermen and other recreational and domestic users downstream. Because construction projects in California are generally limited to the dry season (summer and fall) when background turbidity is generally very low, any increase in turbidity will be very noticeable.

Turbidity is a measure of the clarity of water. Although there is a standard procedure for measurement, turbidity is most often described by visual observation of the “cloudiness” of water. Turbidity in streams is usually due to the presence of suspended silt and clay particles. Once in suspension these particles are difficult to remove from solution. The particles can be settled out of suspension by very large detention basins or filtered from suspension by natural vegetation or filter fabrics.

The most effective way of controlling turbidity during construction operations is *to avoid getting sediment in the stream altogether*. This can be achieved by constructing a temporary diversion around the work area. If work is limited to the stream banks or parts of the channel, flow may be diverted away from the work area by means of sand bags or straw bales placed in the channel. However, when excavating a road crossing from a perennial stream channel it may be necessary to divert water from the channel above the crossing, around the work area, to the channel below the crossing. Flexible plastic pipe works very well for this purpose. The pipe is laid and secured at the desired location and then a small checkdam or headwall is constructed at the inlet of the pipe using sand bags. The inlet should be located far enough upstream so that the elevation at the top of the headwall is greater than highest elevation along the pipe.

Whenever work is to be performed in a flowing stream channel a temporary diversion should be constructed. Even a very small amount of flow can make a big mess during a crossing excavation. *Even if surface flow is not evident above and below a crossing, diversion pipe should be available in case subsurface flow is encountered during excavation.*

If the crossing has a culvert in place, the excavation should be completed to the extent possible before removing or displacing the culvert. If more channel excavation is required after removing the culvert or if grade structures or channel lining is to be installed, flow should be diverted from the channel before removing the culvert. The diversion pipe should be placed far enough upslope from the channel to ensure that it will not be disturbed during remaining construction activities.

If the crossing does not have a culvert in place, the diversion pipe should be installed several days prior to excavation to allow the crossing to dry out. If possible the pipe should be laid completely around the work area to avoid the need to move the pipe during excavation. *However, if this is not possible a plan for moving or replacing the pipe should be made before the excavation begins.*

If causing turbidity during construction is unavoidable, measures can be implemented downstream of the work area to minimize turbidity leaving the site. When working in natural stream channels, large settling basins constructed in the channel are generally not feasible or desirable. The disturbance caused by this activity would generally outweigh any potential benefits. Most commonly, small checkdams constructed with straw bales or welded wire panels lined with geotextile fabric are built in the channel downstream of the work area. These small structures will generally not pond enough water to settle clay and silt particles in suspension but will capture particles as water flows through the structure. Therefore these structures will only be effective under very low flows and should be designed to pass the entire flow of the channel through the structure.

The limited effectiveness of this practice should be evaluated against natural filtering of the water by vegetation downstream. Also, if the stream flow goes subsurface at any point downstream, additional filtering is not required.

Sediment Capture

The most important factor to consider in basin design is the minimum particle size to be captured by the basin for the design flows considered. Although many factors affect the time required for a particle to settle in a basin, generally the larger the size of the particle the quicker it will settle. Sand particles will settle quickest, followed by silt and then clay particles. Therefore much smaller basins are required to capture sand particles then would be required to capture silt and clay particles.

The design of a sediment basin can be a very complex process depending on the desired function of the basin. Basin design can be greatly simplified, however, if the main function of the basin is to capture bedload and sand-sized suspended sediment. For this purpose an *excavated sediment*, or *sand, trap* may be adequate (Figure 5-8). This type of basin is very low risk for failure, as sediment storage is below the natural grade of the channel. Upon filling, the basin will approach the pre-excavation channel grade.

The other basic design of a sediment capture basin can be categorized as an *impoundment basin*. This design requires the construction of a dam to impound water above the natural grade of the channel. This type of design has a higher risk of failure due to the increase in potential energy of the water. This design also requires much more engineering and may require special permits to construct.

Impoundment basins may be constructed at existing road crossings by installing a slotted riser onto the existing culvert. However the existing crossing must be evaluated for suitability of ponding water. If it is determined that a potential for soil piping and/or fill slope saturation and failure exists, additional measures to protect the fill slope will need to be incorporated into the design. The riser should generally not be greater than 3 feet from bottom of culvert to top of riser and should be slotted to allow for drainage of the basin. In addition to providing sediment storage, the addition of an over-sized riser will also reduce the potential of the culvert from plugging with debris.

Excavated Sediment Trap

Definition:

A basin excavated below original ground surface.

Figure 5-8. Excavated Sediment Traps Have Proven To Be Very Effective In GVC.

Purpose:

To capture sand-sized sediment from upland sources.

Conditions Where Practice Applies:

Basins should be located in natural deposition areas as evidenced by sediment deposits or an abrupt change in grade.

Planning Considerations:

- Impacts of ponded water (child safety, mosquito abatement laws, potential down-slope seepage, etc.).
- Accessibility of site by equipment and vehicles.
- Disturbance caused by accessing site.
- Availability of suitable spoil locations on-site or feasibility of off-site spoil location (end-hauling).
- Temporary stream-flow diversion away from work area if operating in a perennial stream.
- Potential of uncovering springs or seeps.
- Removal and placement of trees, stumps, rocks, and boulders.
- Delivery and storage of equipment and materials required for post-excavation treatments (mulch, rock, etc.).
- Future access for sediment removal.

Design Criteria:

- The stream channel above and below the proposed excavation should be generally stable.
- A stream profile survey and cross sections through the proposed excavation shall be done to determine limits of excavation, depth of cut, and excavation volume.
- The storage capacity of the basin should be sized according to anticipated rate of sediment accumulation and frequency of maintenance. The desired capacity of the basin should be balanced with the need to conform the basin to the surrounding topography.
- Excavated channel grade should not exceed channel grade immediately above excavation.
- The outlet elevation should not be greater than the original channel elevation. If the outlet elevation is to be raised, refer to the design for Impoundment Basin (see Page 48).
- Excavated side slopes should be stable under ponded conditions.
- The basin inlet and outlet shall be stable for a 50-year, 24-hour storm. The necessary stability can be achieved with the aid of channel stabilization measures, including grade control structures, and channel lining.

Construction Specifications:

See appropriate specifications for inlet and outlet protection.

Operation and Maintenance:

- Repair of grade structures or channel lining as needed.
- Removal of obstructions which may divert stream flow.

Conclusions to Date:

Excavated sediment traps have worked well for capturing sand-sized particles and will continue to be used at appropriate locations. These basins are constructed only in natural deposition areas that have previously been disturbed by road construction and for which future access will be maintained. The basins shall be relatively shallow (2 to 3 feet) to avoid ponding a lot of water and to avoid oversteepening of the upstream channel grade. The inlet and outlet of the basin shall be protected against erosion of the excavated channel.

See also: Grade Stabilization Structures (page 50), Channel Lining (page 53), Critical Area Treatments (page 58).

Sediment Basin - Impoundment

Definition:

A basin constructed above original ground surface.

Purpose:

To capture sediment from upland sources.

Conditions Where Practice Applies:

Basins should be located in low-gradient reaches of stream.

Planning Considerations:

- Impacts of ponded water (child safety, mosquito abatement laws, potential-down slope seepage, etc.).
- Potential impacts of dam failure.
- Obtaining necessary permits from regulatory agencies.
- Accessibility of site by equipment and vehicles.
- Disturbance caused by accessing site.
- Availability of suitable spoil locations on-site and feasibility off-site spoil location (end-hauling).
- Temporary stream flow diversion away from work area if operating in a perennial stream.
- Removal and placement of trees, stumps, rocks and boulders.
- Delivery and storage of equipment and materials required for post-excavation treatments (mulch, rock, etc.).
- Future access for sediment removal.

Design Criteria:

Due to the complexity involved in sediment basin design it is beyond the scope of this manual to provide design criteria. The reader is referred to NRCS or other related agencies (refer to list of Participating Agencies in the front portion of this manual).

Operation and Maintenance:

- Excavation of accumulated sediment.
- Repair of grade structures or channel lining as needed.
- Removal of obstructions which may plug outlet.

Conclusions to Date:

Most of the impoundment basins were constructed at existing road crossings where a slotted riser was installed on the end of an existing culvert. Generally the barrel of the riser should be 1.5 times the diameter of the culvert so as not to restrict flow into the pipe. The base of the riser needs to be designed to offset the buoyant force of the ponded water; generally the base should be set in concrete. The riser should be slotted to allow drainage under low flow conditions. However it has been observed that when water is not ponded and is allowed to flow directly into the slots, sand-sized particles can enter the riser. For this reason we now wrap the lower 2 feet of the riser with geotextile fabric to ensure that sand does not enter the slots. These risers have been very effective for capturing sand-sized particles.

Stream Channel Stabilization

Stream channel instability is commonly a result of increased flows due to runoff from roads and upland disturbances. All sources contributing to channel instability should be identified before considering channel treatment. Road drainage is commonly a direct cause of channel scour and instability, and in most cases it is easier to correct than broad-scale disturbances. Road drainage problems may result from both maintained and unmaintained roads.

The most common problems associated with unmaintained roads are road crossing diversions and failed drainage structures such as waterbars and culverts. Drainage from several adjoining sub-basins may be intercepted by the road or inboard ditch for several hundred feet, discharging into a different sub-basin. This results in increased sediment flow rates for the channel receiving the discharge.

The main problems associated with maintained roads are inboard ditches, inter-basin diversions, and culvert discharges (Figure 5-9). Maintained roads are commonly highly compacted and capped with an semi-impermeable or impermeable surface layer. This results in increased surface runoff from the road surface. An insloped road intercepts lateral hill slope surface and subsurface flows and, combined with road surface runoff, concentrates the flow to a discharge point. The more widely spaced the discharge points are, the greater the concentration of flow. Culvert discharges, whether from road drainage or road crossings, can cause stream channel scour for several hundred feet below the point of discharge if adequate energy dissipation is not provided.

Figure 5-9. Road Drainage Issues Affecting Stream Channel Stability

If road drainage is determined to be a probable cause of stream channel instability, practices that deal with road drainage problems should be evaluated before proceeding with stream stabilization practices (see Road Drainage Improvement, pg. 35).

Stream channel instability is characterized by head-cutting, down-cutting, and stream bank erosion. Because all of these occur in the formation of a gully, and since these processes are interdependent, it takes some investigation to determine how active each of these processes are. The history of gully migration can be determined from the age of vegetation growing at different locations along the gully. If there is well established vegetation in the channel, the bottom has remained stable for the life of the vegetation, and if the channel has been through both normal and high-flow events, stream channel stabilization is probably not necessary.

The rate of headcut migration can be determined from the vegetation on the gully walls immediately below the headcut. If vegetation is well established, it can be assumed that the headcut is stable for the range of flow it has experienced during the life of the vegetation. If the channel bottom below the headcut appears to be stable but the headcut is actively migrating, a headcut structure without additional grade stabilization should be adequate.

Grade Stabilization Structures

Definition:

Structures used to control grade erosion and headcutting in natural and excavated channels.

Purpose:

To stabilize the grade and control erosion in stream channels and to prevent the formation or advance of gullies.

Conditions Where Practice Applies:

- Stream channels that are actively headcutting or downcutting.
- Excavated road crossings.
- Inlets/outlets of excavated sediment basins.
- Incorporated into design of road crossing excavations when they exceed 50 feet in length.
-

Planning Considerations:

- Stream channel instability is usually a result of increased runoff from roads and upland disturbances. Therefore, the source of the problem should be addressed before considering treatment of the channel.
- Accessibility of site by equipment, vehicles, or crew.
- Availability of on-site building materials (wood for log structures, water and sand for soil/cement structures).
- Temporary stream flow diversion away from work area if operating in a perennial stream.
- Life expectancy of structure.

Design Considerations:

<u>*Grade Check Structures*</u>

- The spillway should be as wide as the channel outlet protection will allow (typically equal to downstream channel width). Spillway depth should be designed to convey the design discharge, with the given spillway width.
- Spillway height and spacing of structures will be designed to achieve the desired channel grade between structures. Smaller, more closely spaced structures are generally cheaper and easier to construct than a few large structures. Smaller structures (less than a 2-foot spillway height) have less potential for failure and more closely mimic the stepped profile of natural forested headwater streams.
- Structures should be well keyed into the channel bottom and banks to prevent water from piping under or around structures. Geotextile fabric should be used in the keyways of log structures.

- Adequate outlet protection should be provided for all structures.

Headcut Structures

- Headcuts should be shaped to a stable angle for the placement of materials (2.5:1 for rock, 2:1 for soil/cement bags).
- When using rock rip-rap, it is recommended that a rock filter be used rather than geotextile fabric. A rock filter conforms to the ground surface and fills the spaces in the riprap, holding it in place better than fabric.
- If subsurface flow is a concern, drainage through the structure should be provided.
- The structure should extend far enough up the bank to protect against the design flow.

Construction Specifications:

Soil/Cement Checkdams

- Cement shall be Type II Portland Cement, proportioned 4:1, soil to cement.
- Soil shall contain no sod, grass, roots, or other unsuitable material.
- Soil and cement must be thoroughly mixed, water should not be added during mixing.
- Bags should be made of at least 10 oz. burlap and should be 18 X 36 inches.
- The bags should be 1/2 filled with soil/cement, to leave room for folding. When placing bags, the folded end should be on the bottom and facing downstream. Tamp each bag firmly into place, ensuring that there are no gaps between bags.
- Bags should be placed one layer at a time with a minimum overlap of 1/3 bag between layers. The seams of each course should be staggered.
- Number 4 18-inch rebar should be driven through *each*.
- After placing each layer, bags should be thoroughly wetted, but not saturated.

Log Checkdams

- Logs used in construction should be sound wood, free from decay, and straight for easy placement.
- Logs should be stripped of bark before construction to reduce potential of insect infestation.
- Logs should be wired or spiked together firmly.
- Logs should be keyed into bank at least 2 feet, with geotextile fabric lining the keyway. The keyway is then backfilled and compacted to native soil density. Water may need to be added for compaction. Soil/cement or geotextile bags may also be used to backfill keyway.

Conclusions to Date:

When considering treatment of an eroding stream channel, the cause of the erosion must be identified. If it is suspected that the erosion is occurring as a result of increased peak flows from roads or logged areas, the treatment of these areas should be considered before attempting channel stabilization measures.

Soil/Cement Checkdams (Figure 5-11) have proven to be very effective in DG when designed and built adequately. The life expectancy of these structures is 3 to 5 years, after which some degradation can be expected. Ideally the degradation will continue for several years before the structure losses all effectiveness, during which time vegetation will provide an increasing amount of stability. This practice is well suited to DG soils which is ideal for use in soil cement mixtures. The structures themselves are relatively easy to construct and may be built wherever cement can be delivered. Unlike rigid structures, soil cement structures conform very well to the existing topography. This requires less sub-grade preparation and decreases the likelihood of piping under and around structures. Because of their relative low cost, ease of construction, and high effectiveness, soil/cement structures will continue to be the practice of choice when short-term stream channel stabilization is required in small ephemeral drainages. The most important factors to the success of grade stabilization structures are adequate: soil-cement mixture, spillway capacity, outlet protection, spacing, and keyways in the channel bottom and sides.

Log Checkdams (Figure 5-11) are generally more difficult to construct and have a higher potential for failure than soil/cement checkdams. This practice is currently being used only when cement or rock cannot be feasibly transported to a site. Life expectancy of these structures is generally 5 to 10 years. When log structures fail they typically lose all effectiveness rather than degrading incrementally as soil/cement structures. The most common cause for failure has been piping around the structure. This is difficult to avoid due to the nature of DG and the rigidness of the structure. However, the risk can be minimized by: keying the logs well into the bank (2 feet minimum), using geotextile fabric in keyways, well compacting the keyway, and by keeping spillway height less than 3 feet.

Figure 5-10. Soil/Cement Checkdam

Figure 5-11. Log Checkdam

Stream Bank Excavation

Definition:

This treatment is used along stream channels with near-vertical banks of easily erodible material. These slopes are not able to support vegetation, and sediment delivery to the stream system is immediate. Excavation is performed by a backhoe or excavator working along the top of the bank.

Purpose:

To remove potential sediment from the stream system and reconstruct the bank to a stable slope on which vegetation can be established.

Conditions Where Practice Applies:

- Road crossings and landings which have "blown out," eroding through the road fill to the original channel grade while leaving vertical columns of fill adjacent to the channel.
- Stream channels, which have down-cut due to past disturbances, in which the grade has since stabilized but has left vertical stream banks of easily erodible material.
- Stream channels which are actively downcutting and for which grade stabilization will also be installed.

Planning Considerations:

- Accessibility of *both* sides of the stream bank by equipment. Is a temporary crossing required?
- Disturbance caused by accessing site.
- Availability of suitable spoil locations on-site and feasibility off-site spoil location (end-hauling)
- Removal and placement of trees, stumps, rocks, and boulders.
- Future access for planting and operation and maintenance.

Design Considerations:

- It may not be possible to slope the entire bank to the desired grade due to hill slope constraints. Therefore, consideration must be given to either sloping less of the bank or increasing the excavated slope grade and providing for slope protection.
- Excavation should be above the anticipated high water mark. If excavation does extend into the design flow channel, armoring of the excavated bank should be considered. The stream channel bottom should not be disturbed unless grade stabilization is included in the design.
- Trees removed during excavation may be cut into manageable lengths to be placed cross-slope on excavated slopes to protect from overland flow and along the toe of excavation to protect from design flow. Logs placed cross slope should be keyed-in by excavating a trench prior to placement or by pushing the logs into the soil with the bucket of the excavator.

Construction Specifications:

- No material shall be side cast downslope of the excavation area.
- The finished excavated and fill *surfaces* shall be rough and uncompacted, with no ridges, depressions, or gaps that may act to concentrate or pond water. The transition from finished slopes to undisturbed ground shall be smooth and free from ridges and gaps.

Conclusions to Date:

It is very important not to disturb the streambank of the active channel. If the excavation must extend into the active channel, streambank protection measures must be incorporated.

Channel Lining

Definition:

Material used to protect excavated stream channels from the erosive forces of water.

Purpose:

To stabilize excavated stream channels for the purpose of controlling erosion and establishing vegetation.

Conditions Where Practice Applies:

- Excavated road crossings.
- Inlets/outlets of excavated sediment basins.

Planning Considerations:

- Can rock be delivered to the site?
- What is the desired future channel vegetation condition? Is the lining to be temporary protection to aid in re-establishment of vegetation?

Design Considerations:

- Design flow velocity.
- Resistance to erosion of the lining under present and future conditions.

Construction Specifications:

Rock Riprap

- Rock Riprap should be angular, not rounded. This usually requires that the rock be quarried. River rock and cobble is generally rounded and is not suitable for riprap.

- The rock shall have a specific gravity not less than 2.5 and an absorption of not more than 2 percent. Individual fragments shall be dense, sound, and free from cracks, seams, and defects which may accelerate weathering. The rock should be inspected at the quarry by a geologist for hardness, angularity, and durability. The rock should be able to withstand a fall of 3 feet from the bucket of an excavator with minimal fracturing.

Nylon Filament Matting

- The matting shall be three-dimensional nylon matting designed for use as channel lining. The tensile properties shall conform to ASTM D-1682. The strength along the length shall be 54 pounds per foot or greater. The strength along the width shall be 27 pounds per foot or greater. The matting shall be a minimum of .35 inches in thickness.

- Manufacturer's recommendations for placing and staking the matting should be followed. A very important aspect of installation is keying the matting into the channel bed. Keyways are excavated at the top, bottom, and at intervals along the length of the mat. The keyway at the top of the mat is the most critical to the success of the matting. It should keyed in at least 2 feet, to prevent water from flowing under the matting, and to keep the matting in place. If the top of the matting were to come loose, the entire length of matting could roll up in a ball and end up downstream. The maximum spacing between the keyways along the length of the matting shall be 25 feet. These keyways are essential to prevent water from flowing under the matting. It is generally recommended that the trenches be backfilled and compacted with "erosion-resistant soil." For installation in decomposed granite it is recommended to backfill the trenches with soil/cement.

Conclusions to Date:

Rock riprap is by far the most effective and durable channel lining used in channel excavations. However, it is generally the most expensive option and may not be feasible if a local source is not available. Generally, the cost of rock is the same no matter what size you get. To ensure that riprap stays in place, the larger rock is better. However, when the rock is greater than 2 feet in diameter, the cost of handling increases as hand placement becomes impossible and specialized equipment may be required for placement. Also it becomes more difficult to get well-graded rock and to avoid sorting during placement. As a general rule, well-graded, 14-inch (maximum diameter) riprap or 24-inch riprap with a 3- to 6-inch rock filter work well for channel lining and headcuts. If it is determined that a filter is required to be placed under the riprap, it is recommended to use a gravel or rock filter rather than geotextile fabric. Rock can slide off the fabric at high-energy reaches of channel (in particular culvert outlets).

Nylon filament matting is relatively easy to install in excavated channels. The cost of materials is high, but is generally cheaper than the cost of hauling and placing rock. Channel matting is a good option to consider if long-term protection is required but access is a problem for delivery of rock. If the channel grade exceeds 15 percent, grade stabilization structures should be added along with the channel matting. The most important factor for the success of this practice is that the matting be very well keyed into the channel bottom. Although most manufacturers' specifications call for compacted soil to be used in the keyways, DG is too erosive to maintain the structure of the keyway. Therefore it is recommended that a soil/cement mixture, using the same proportion and procedure used in soil/cement structures be used in place of compacted DG soil (see Grade Stabilization Structures, pg. 55).

Chapter 6
REVEGETATION TREATMENTS AND MONITORING

Revegetation Treatments

Introduction

The primary focus of restoration in the Grass Valley Creek (GVC) watershed has been on physical work, such as road obliteration, slope recontouring, and reshaping channels and crossings. Because of this emphasis on mechanical work, revegetation has been used as secondary treatment--referred to as "critical area treatment"--after completion of the physical work.

The majority of this revegetation work consisted of a three-phase process of fertilizer, seed mix, and straw mulch application, using a wide variety of materials. The main goal of implementing these treatments was to reduce both short- and long-term soil erosion; the former by protecting bare soil with a protective mulch, and the latter by establishing a dense stand of herbaceous vegetation. Additional treatments have consisted of bioengineering techniques, such as the installation of willow wattles and stakes in channels and gullies. Planting has also been used extensively, with approximately 65 acres a year planted within the watershed, utilizing conifers, hardwoods, shrubs, and native grass plugs.

In addition to the critical area treatments, attempts have been made to revegetate steep slopes of decomposed granite where sheet (overland flow of suspended particles) and rill (small gullies) erosion is a severe problem. Numerous techniques have been tested for revegetating areas experiencing sheet and rill erosion, such as fertilizer, seed mix, and mulch combinations, erosion blankets, and chemical tackifers. The success of these treatments has varied widely, yielding information from both failures and successes.

To ensure that appropriate and successful revegetation treatments are prescribed for sites, we have developed a four phase process for revegetation work, consisting of vegetation inventory, prescription, implementation, and monitoring. Each of these phases is described below in detail.

Vegetation Inventory

The critical first step in the revegetation process is collecting information on restoration sites so that appropriate treatments and plant species can be selected. In order to select plants that are ecologically adapted to the project site, it is necessary to inventory the to assess conditions that may limit plant growth (See Prescription Process, below.)

The inventory consists of measuring those factors on the site that are pertinent to vegetation establishment. (See Appendix F4 for inventory form) The most important of these factors is the listing of existing vegetation at the site. This information indicates which species naturally occur and have been re-establishing on their own. The GVC watershed has not been so severely disturbed that native vegetation has been completely altered. Existing vegetation is listed in order by dominance (i.e., most prevalent) in the following groups: trees, shrub, grasses, and forbs.

Other important factors consist of site area (in square feet or acres), aspect (in direction and degrees), elevation (in feet), slope (%), overstory (%), ground cover (%), soil depth (in inches or feet), and litter cover (%). Some specialized equipment is required for this inventory such as a compass (aspect), altimeter (elevation), clinometer (slope), and densiometer (cover). Qualitative observations are also listed, such as site characteristics, previous disturbance, logging history, plantability, and access to the site.

Once completed, all data from the inventory sheets are entered by field site number into a data base.

Prescription Process

Revegetation coordinators use information from the inventory sheets to prescribe specific treatments for restoration sites. The criteria listed below was created by the revegetation coordinators through the process of trial and error over a period of three years. Although this criteria is specific to the GVC watershed, there are many attributes of this prescription process that can be applied to other restoration projects.

The components of the inventory form are used as follows in creating planting prescriptions:

Area: The area of the site (sq. ft.) is used to determine the amount of materials required for a site. (See individual treatments beginning on pg. 58 for recommended quantities.)

Species: The plant species used on a site are based on the predominate species already existing, or in the vicinity, of the restoration site. Seed mixes are based primarily on the native grasses at the site, while stock for planting is based on the existing shrubs, hardwoods, and conifers.

Elevation: An important consideration in the planning process is the elevation of the site. Differences in elevation are usually a problem when an ecotype (species inherent to a specific area) is taken from a low elevation and planted at a higher elevation. Physiologically the plant will not complete its typical cycle before the frost comes to the higher elevation. Plants brought down from a higher elevation to a lower elevation will often loose their leaves in the fall well before plants that are adapted to the lower elevation area. The growing season in the higher elevation is much shorter, so establishment of low elevation plants at high elevation sites will probably give poor results.

Soil: Soil depth is especially critical in determining where stock can be planted, since a minimum of 8 inches of topsoil is needed for planting trees and shrubs. For seed mix application, a minimum of 1 inch of topsoil is needed.

Aspect: Aspect is important in determining what species to plant and the probable survival rate of those planted. Plants which normally grow on north- or east-facing slopes will not do well on west- or south-facing slopes. Plants such as these are adapted for less direct sunlight, richer soil, and more moisture-supplying capacity from the soil. In the GVC watershed in particular, with its harsh, white, bare south- and south-west facing slopes, even species that are adapted to these aspects often have a difficult time establishing when planted as seedlings.

Canopy cover: Canopy cover is an important element in the GVC watershed, especially on sheet and rill slopes. The canopy from trees moderates temperature extremes, provides shade, duff, moisture, and seed-- elements that are crucial for the long-term sustainability of these sites.

Ground cover: In order to know what to plant, it is important to know what types of vegetation already exist on a site, and at what density each species occurs. The more conifers on a site, for example, the better off the site will be in the future. If shrubs are the main component, there is a high probability that planted conifers will have a high survival rate due to the many microsites available. If grasses and forbs are the dominant species, it is likely that the site is in an early stage of recovery and will require additional treatment.

Slope: The slope of a site is measured by percentage and is an important factor in treating a site much in the way that access to the site (below) is. If a site is too steep to walk on or to hold seed and/or mulch, the site will not receive any treatment, regardless of the need. Generally, we will not treat sites that have greater than 70 percent slope.

Plantability: Plantability of a site is determined primarily by the depth of soil and percent slope (see above). The depth of soil will also determine what type of species can be planted at the site. Grasses would be more suitable at sites with shallow soils (3-4 inches). Shrubs and trees (container stock) would require more soil depth (8-10 inches). Some bareroot stock may require up to 12 inches of soil depth.

Access: Access to revegetation sites should be taken into consideration when planning a revegetation treatment. Access will affect planting method and logistics, species selection, and the stock type that is most appropriate.

Revegetation Treatments and Seed Collection

The following revegetation techniques have been utilized in the GVC watershed. (For a list of the costs associated with each treatment, refer to Appendix H1.)

Critical-Area Treatments:	***Sheet and Rill Treatments*:**	***Seed Collection:***
Seeding	Contour Furrows	Native Forb/Grass/Shrub Collection
Straw Mulch	Straw Wattles	Conifer Cone Collection
Fertilizer	Microsite Planting	Acorn Collection
Grass/Shrub/Tree/Acorn Planting	Cross Slope with Logs	Native Plant Nursery
Bioengineering	Lop and Scatter (Slash)	
Lop & Scatter (Slash)	Erosion Blanket	
Flake and Stake	Mulch Pellets	
	Seed/Mulch/Fertilizer	
	Fertilizer	

These treatments/collection techniques are described in detail in the discussion that follows, indicating conditions where the practice applies, planning considerations, design criteria, and advantages and disadvantages of each treatment.

Critical-Area Treatments

Seed/Mulch/Fertilizer

The main treatments used in the GVC watershed consisted of a three-step process of first applying fertilizer, followed by seeding with native or non-native seed mixes, and lastly, covering with a straw mulch. Although these treatments were generally used in conjunction with each other, each treatment will be described individually.

Seeding

Although the GVC watershed restoration project originally used more conventional, non-native sed mixes, emphasis has shifted to using native seed collected in the watershed nd propigated in various nururies. (see Cone, Seed, and Acorn Collection, pg. 80). Native seed mixes used in the GVC watershed are composed of native species found within the watershed, and they are a combination of perennial bunch grasses and forbs (Table 6-1). Native grasses may be used for multiple goals in revegetation projects. Native grasses are adapted to the soil and climatic conditions in any given area. Grasses are known to encourage the

Seed Mix	Species	Percentage
Hot/Dry	*Hordeum brachyantherum* ssp. *californicum* (California barley)	15
	Elymus elymoides (squirreltail)	15
	Poa secunda (pine blue grass)	10
	Bromus carinatus (California brome)	20
	Festuca idahoensis (Idaho fescue)	15
	Elymus glaucus (blue wildrye)	15
	Lupinus succulentus (arroyo lupine)	10
Warm/Moist	*Deschampsia elongata* (slender hairgrass)	20
	Poa secunda	10
	Bromus carinatus	20
	Festuca idahoensis	20
	Elymus glaucus	25
	Lupinus succulentus	5
Channel	*Festuca rubra* (red fescue)	40
	Deschampsia elongata	30
	Deschampsia ceaspitosa (tufted hairgrass)	30
Quick	*Bromus carinatus*	50
	Elymus glaucus	50
RCD	*Bromus carinatus*	34
	Festuca idahoensis	24
	Elymus glaucus	30
	Deschampsia elongata	12
Non-native	*Agropyron trichophorum* ('Luna' pubescent wheatgrass)	60
	Trifolium spp. (rose clover)	20
	Vulpia myuros (annual fescue)	10
	Dactylis glomerata ('Berber's orchardgrass)	10

Table 6-1. Seed Mixes in GVC Watershed Revegetation

development of a good "crumb" structure in soil by developing an extensive root mat that enmeshes and separates soil particles (Killham 1994). Also, grass cover may act to keep soil pH from dropping (Barbour et al 1987). During periods of water stress, many grasses are extremely adept at producing new root biomass when the soil is re-wetted (Killham 1994). Native grass species may allow other native plants (e.g. shrubs and trees) to grow and do not outcompete various species of plants as some non-natives tend to do (Figure 6-1). Native grasses are used to achieve the more long-term goals of revegetation as well as provide short-term erosion control.

A non-native seed mix of perennial bunch grasses, annual grass, and forbs was initially used in the GVC watershed. Non-natives are less expensive than natives, and have been proven to provide effective erosion control in the watershed. The high degree of survival characteristic of many exotic grasses has made them practical for fullfilling short-term management objectives, but their invasiveness and long-term effect on both the biological and genetic diversity of ecosystems is an increasing concern (Knapp and Rice 1996). Field observations have indicated that the non-natives do not stay on slopes very well and tend to migrate to a low gradient portion of the treated slope with a more stable, protected environment.

Figure 6-1. Landing Seeded with Hot/Dry Native Seed Mix

Conditions Where Practice Applies:

Native grass seed is used on places that have been mechanically treated or on sheet and rill slopes. It is used primarily on critical areas that are more exposed. Areas with more ground and/or canopy cover may not require the application of seed. Typically, native seed is used in conjunction with mulch.

Planning Considerations:

Initially, the RCD purchased non-local native seed for revegetation work in the GVC watershed. (i.e., seed from native species that originated from areas outside the watershed). The exception to this was the use of blue wild rye (*Elymus glaucus*), a native grass species that was grown from seed collected from the GVC watershed.

Since 1994, the RCD has been collecting local seed from the GVC watershed. There are few sources from which to purchase large quantities of native seed. It is preferable to collect seed from the area and have the seed grown by a nursery; that way you are using seed that is genetically adapted to the area that will be treated. After the seed is collected, the seed should be sent to nurseries for propagation one year in advance. By following this procedure, large quantities of seed may be procured for future restoration work.

Design Considerations:

Canopy cover, slope gradient, soil content (nutrient availability), aspect, moisture availability, and elevation.

Design Criteria:

Rate of application:
1993-94- 40 lbs./ acre or 1 lb. per 1000 sq. ft.
1994-96- 20 lbs./acre or 1/2 lb. per 1000 sq. ft. or more if site conditions are very poor (e.g., sheet and rill slopes).

Application Method**:** hand or “belly roller”

Cost:

The native seed mix ranges in price between $6-$13.50 (1993-95 prices) per pound compared to the non-native mix at ~ $3.00 per pound (1993 price). A greater demand for native seed would result in more nurseries producing such seed, potentially leading to an eventual reduction in price.

Advantages/Disadvantages:

Native grasses are well suited to local decomposed granite soils and thrive in weather conditions inherent to the area. These grasses are perennials and can be long-lived. Natives may also control weed encroachment. We have had successful short-term results from the mixes used on mechanically treated sites.

Native grasses have not yet been proven to provide long-term erosion control support on severely disturbed soils or sheet and rill slopes. It is difficult to obtain a steady supply of native grass seed and native seed is more expensive than non-native seed.

Straw Mulch

Mulch has four basic purposes in the GVC watershed: to protect bare soil from raindrop impact and surface run-off, to increase water holding capacity (field capacity), to add organic matter to soil (which enhances the intrasystem cycling of nutrients and improves soil structure, pore space, and water storage), and to provide a microclimate for germinating seeds. Mulches are usually made of materials that have a short lifespan, and they begin to decompose immediately but typically last one to three years. Mulches should be applied soon after planting before soil moisture is depleted and before the sown seed is consumed by wildlife (Figures 6-2 and 6-3).

Figure 6-2. RCD Crew Spreading Mulch

Figure 6-3. RCD and CCC Crews Spreading Mulch on Mechanically Treated Site.

Conditions where practice applies:

Used on every site if possible, unless slope gradient exceeds 70 percent or access is limited.

Planning considerations:

Slope gradient, access to site, mulch type, sources for mulch and species of native hay mulch most suited for each site.

Design Criteria:

> Rate of Application: 87 bales per acre or two bales per thousand square feet. A thicker (at least 2 inches) application of straw mulch is preferred on decomposed granite soils because of the erosive nature of these soils and the eccellerated rate at which mulch decomposes on exposed sites with little or no canopy cover.
>
> Slope Gradient: not recommended for use on slopes with over 70 percent gradient.
>
> Access to Site: bales are very difficult to transport, as they are heavy and bulky. Other practices should be applied when access is limited.
>
> Application Method: straw mulch should be applied evenly with good contact with soil by hand or by blower. Apply with as little disturbance to the site as possible.

Cost:

Straw bales range from $4.50 to $8.00 per bale or $374.00-$664.00 (not including labor) per acre depending on the type and amount ordered.

Types Used - Advantages and Disadvantages:

Native Blue Wild Rye (*Elymus glaucus*): best germinator of any native type used. Good cover; easy to spread.

Native California Brome (*Bromus carinatus*): good cover, easy to spread, good germination of native seed contained in the bales.

Native California Barley (*Hordeum californicum*): good cover; easy to spread, but very little germination of seed contained in the bales; however, it does not inhibit the germination of sown seed underneath.

Barley: good cover and germination of sown seed, easy to spread.

Wheat: same as for barley.

Rice: very dirty, difficult to spread, very poor germination of seed underneath. We no longer use this type of straw in GVC watershed.

Other Types Used: *Vulpia myuros* (Zorro fescue), *Stipa cernua* (nodding needlegrass), *Achnatherum lemmonii* (Lemmon's needlegrass), *Melica californica* (California melicgrass), *Deschampsia caespitosa* (tufted hairgrass), *Deschampsia elongata* (slender hairgrass), *Festuca idahoensis* (Idaho fescue), *Festuca californica* (Californica fescue) and *Stipa pulchra* (purple needlegrass).

Fertilizer

The emphasis of fertilization used in the GVC watershed is placed on nitrogen amendments. Soil tests were conducted by Vic Claassen, Soil Scientist from UC Davis. He came to the conclusion that DG soils in GVC watershed are not lacking in phosphorus but in nitrogen availability. In the GVC watershed several types of fertilizer amendments were used: ammonium phosphate fertilizers,16-20-0, 11-52-0-2, 38-0-0 (slow release); and organic fertilizers: Milorganite, Biosol, and compost. Field observations indicated that there were no significant observable differences between areas that were fertilized and areas that were not, although positive results were gained from the use of Milorganite and Biosol (both organic fertilizers) on sheet and rill slopes.

Conditions Where Practice Applies:

Fertilizer is used primarily on the harsh sites, such as exposed areas or sheet and rill sites. Fertilizer is not applied in riparian areas with more favorable site conditions or other areas in proximity to water.

Planning Considerations:

The condition of the site to be treated determines the use of fertilizer amendments. Canopy and ground cover and existing vegetation determine whether amendments are necessary.

Design Criteria:

Application Rate: 80-180 lbs. per acre depending on conditions and location of the site. Typically, 180 lbs. per acre is used on harsh sites such as sheet and rill sites.

Access to Site: areas that are inaccessible for hauling may not be treated with fertilizer.

Application: fertilizer is generally spread by hand (wearing gloves) or by "belly-roller."

Time of Year Applied: fall application favors exotic species and spring application favors native species.

Cost:

Average Costs Per Acre (ranging from 80-180 lb./acre):

11-52-0-2:	\$14.00-\$31.00	(1993 prices)
16-20-0:	\$12.00-\$27.00	(1994 prices)
38-0-0:	\$51.00-\$115.00	(1994 prices)
Biosol/Milorganite:	\$53.00-\$120.00	(1995 prices)

Advantages/Disadvantages:

Fertilizers may increase a plant's ability to absorb mineralized nitrogen in decomposed granite soils, especially on harsh sites, thereby increasing plant growth (Claassen 1994). However, evidence from GVC revegetation indicates that fertilizer tends to favor exotic species; after the first year exotics are the primary species showing up on treated sites. Fertilized plants are more palatable and may suffer increased animal damage. Care must be taken not to fertilize with greater amounts than young plants can utilize or to allow contact of the fertilizer and the transplant roots (Young et al 1981).

According to nurseryman Tom Jopson (personal communication 1993), fertilizer tends to stress native tree species and facilitates mortalities. Most fertilizers are chemically based and may cause allergic reactions in some people. Nitrogen usually increases shoot growth over root growth, creating surface cover but less underground biomass. A scientific advisory group comprised of botanists, horticulturists, soil scientists, and agency representatives attended a spring 1994 tour of the GVC watershed one year after revegetation treatments were implemented. Several in the group commented that on the fertilized sites, the energy that goes into shoot growth may exhaust a plant's resources, shortening its lifespan. This may not be good for the long term, unless recruitment of other species to the site takes place soon after treatment.

Grass/Shrub/Tree/Acorn Planting

Definition and Purpose:

Planting is done on areas that have been mechanically treated and on exposed slopes affected by sheet and rill erosion. Grasses, shrubs, and trees are planted in these areas. Linear planting has been the method used primarily on mechanically treated roads and landings to decrease the time needed for regeneration; "micrositing" is practiced on sheet and rill slopes, and consists of planting adjacent to and underneath existing vegetation and downed woody material to increase vegetative cover, especially canopy cover (provided by trees). Natural regeneration has been observed in these places.

In the GVC watershed, pines naturally and frequently emerge from canopies of shrubs. Saplings are usually found growing a few inches from the root collars of older shrubs, indicating that shrubs provide a favorable environment for conifer establishment. Existing brush and trees may increase survival of planted conifer species on extreme sites by providing a milder microenvironment. Microsite planting is used to close the gaps between existing vegetation. If the plants survive and mature they will ultimately provide shade, moisture, and duff to harsh sites.

According to nurseryman Tom Jopson (personal communication 1993), long-needle pine species, especially ponderosa and Jeffrey pine, are potentially the best choice for many sites in the GVC watershed. They occur naturally on decomposed granitic soils and the long needles form an effective mulch which resists wind and downslope movement even on steep and exposed roadcuts. Also, pine seedlings have been produced in large quantities for many years by many nurseries and are readily available. If grown from seed collected for a particular area, seedlings can easily be ready for planting the following year. Potential long-term benefits are a deeply penetrating root system and permanent needle mulch cover that will effectively control erosion.

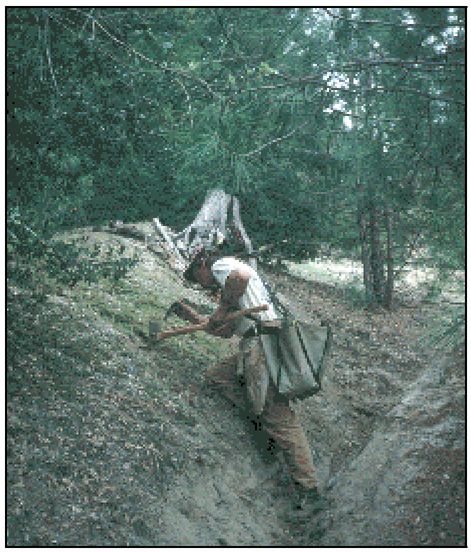

Figure 6-4. Planting to Stabilize Gully Banks

Conditions Where Practice Applies:

Areas such as slopes with reduced vegetative cover from logging or mulched and seeded areas that need further enhancement can usually be given a quicker start at recovering when planted. Several types of species are planted to maintain diversity and increase survival.

Planning Considerations:

For trees, shrubs, and grasses, planting stock should be procured 1.5 to 2 years prior to planting. This allows enough time for seed to be collected, to find a nursery to propagate the seed, and allow time for the stock to grow to a plantable size. For conifers, cone collection is dependent on having suffiecient cone crop (enough cones to make hiring a professional cone collector cost effective—usually every 7 years). For acorn planting, acorns need to be collected early in fall and planted within thre months. Seed zone, soil type, and elevation are important considerations when collecting seed and cuttings, and purchasing nursery stock. Tree seed zones are delineated on the basis of collection criteria designated by Fowells (1946). Fowells specified that seed should be collected within 100 miles north or south of the planting site and differ in elevation by less than 1,000 feet. Also, careful consideration should be given to areas having unusual climatic, topographic, or soil conditions that might greatly affect tree growth (Buck et al 1970). GVC watershed is located in the 300 series (North Coast Interior) zone.

There are four granitic soil complexes mapped in the watershed: **177** (Minersville sandy loam: 50-75 percent slope), **198** (Tallowbox-Minersville Complex: 30-50 percent slope), **199** (Tallowbox-Minersville Complex: 50-75 percent slope), and **204** (Valcreek-Minersville-Choop Complex: 30-75 percent slope). Some plant species found in the watershed are site-specific according to soil type. For example, birchleaf mountain mahogany (*Cercocarpus betuloides*), grey pine (*Pinus sabiniana*) and creeping sage (*Salvia sonomensis*) are found in soil type 177 (where soil conditions are more favorable for their growth) and usually do not occur in soil type 204. Care must be taken that these species are planted in the soil type that is suitable for their growth requirements.

Elevation in the GVC watershed ranges from 1,740 to 5,950 feet. To increase long-term survival, stock from a particular elevation is planted within 500 feet of the elevation from which the seed was originally collected. For example, stock originating from a 2,700 foot elevation would be planted in an area ranging in elevation between 2,500 and 3,000 feet.

Arrangements can be made to have cuttings of shrub species and seed collected from the watershed propagated for future use. It is extremely important to use local materials whenever possible, in order to preserve ecotypes within the restoration area. Ecotypes are collections of species that are in a specific ecological area. This area or range is defined as having similar physical and biological characteristics, such as vegetation, climate, soils, fauna, and topography (USDA Forest Service 1978). When information is not available on ecotypes or cultivars that are adapted to the project area, it is best to purchase and plant the same species from a seed zone and elevation as close to the planting site conditions as possible.

Sites should be inventoried prior to planting to determine quantities and suitable species needed for a particular area. Factors to consider and use when planning include: soil profile (depth, organic material present), elevation, canopy cover, aspect, plant community, vegetation currently growing on-site, moisture conditions, plantability (microsites), area size, and accessibility.

<u>Suitable Species Selection</u>: Good root and above ground structure, soil building characteristics (nitrogen-fixing capability), species permanence (perennials over annuals), biodiversity, and succession. Acorns should have a root just beginning to emerge, with a healthy, white tip. Although, even if the tip has begun to brown, it should still be all right to plant as long as the remainder is white and fleshy (McCreary 1996).

<u>Stock Type</u>: Plug, bareroot, styros (grown in styrofoam containers). Bareroot plants have been the preferred stock for GVC watershed planting. The free root system allows for healthy growth and good survival. Often when plants are grown in containers (usually 6- to 8-inch plastic cells)--even if removed from the containers before shipping--the roots grow to the bottom then bind up. When this occurs, the roots need to be separated or clipped before put into the ground. This is much more tedious and time consuming for mass-plantings, and crews then need to be properly instructed and carefully supervised. Because no containers or extra soil surround the root system with bareroot stock, more plants may be carried at one time and the time to plant is approximately cut in half.

<u>Spring Planting vs. Fall Planting</u>: For GVC watershed work, spring planting is scheduled as early in the season as possible, preferably when root growth capacity is high (February and March). Hot and dry conditions can come on very rapidly. Fall planting allows a longer period of time for establishment before the hot, dry summer months. Also, plants can more easily compete with weeds that may inhabit the site when planted in fall. Fall has a much shorter window of time to plant and its been found that more plantings can be done in the spring (120,000 plants in spring as compared to 20,000-60,000 in fall). There is not yet enough comparable data to determine whether survival is higher for fall or spring plantings. Additional monitoring data will have to be collected to make valid comparisons.

Design Criteria:

Proper Planting Technique

Grasses/Shrubs/Trees: For the GVC watershed, hoedads are the primary tool used to open the planting hole (Figure 6-5). Dibbles have also been used, but these tend to not create a wide enough or deep enough hole for the 6 inch, 8 inch, and bareroot stock used in plantings. The hole must be made deep enough for the roots to be fully extended. The plant should not be taken out of the planting bag until after the hole is made to ensure that the roots do not dry out. On dry days, water should be added periodically to the bottom of the planting bag, to ensure that roots stay moist. (It takes less than one minute for roots to become too dry to keep the plant alive.) The roots must be checked to ensure they are not curled or bunched up; if roots are in such a condition, they should be gently separated by hand. The plant should be held in place in the hole to ensure the roots are straight and not turned up ("J-rooted"). Seedlings must not be planted too shallow (top of root mass showing above ground) or too deep (buried up to lower branches). The soil should be firmly tamped around the roots to prevent air pockets that can dry out roots. Finally, a slight tug should be given to the seedling to ensure that it is firmly anchored.

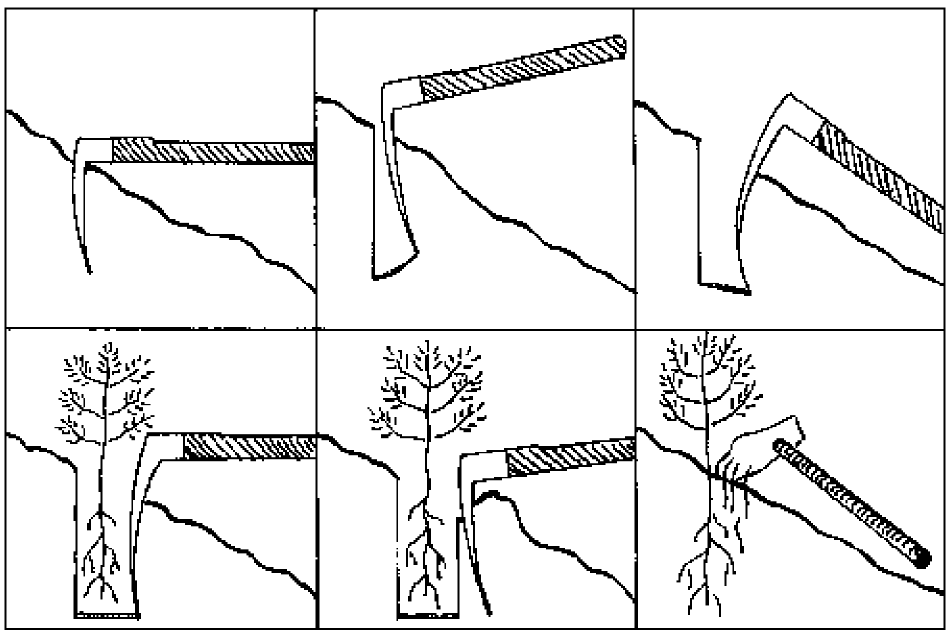

Figure 6-5. Proper Planting Technique

Acorns: In the fall of 1996 acorn planting on bare sheet and rill slopes was initiated in the GVC watershed, with acorns planted as soon as the initial roots began to emerge. (Stored acorns were periodically checked for root emergence.) Because the germination rate of the acorn stock was unknown, *Quercus chrysolepis* (live oak) and *Q. garryana* (Oregon white oak) acorns were planted at three acorns per hole to increase the likelihood that one would germinate. A hand trowel, back end of a hammer, or hoedad was used to dig a hole approximately 2 inches deep. The acorns were placed next to each other, lying on their sides in the hole, then covered with soil. The results of acorn planting were very poor, with less than 10 percent germination. These results show that direct planting of acorns on shet and rill slopes is not an effective way to revegetation sheet and rill slopes.

Landings, Roads, Crossings: Linear planting, the most common method used, is done on 3- x 3-foot to 10- x 10-foot centers, depending on the condition of the site.

Sheet and Rill: In early trials, entire slopes were planted, regardless of existing canopy or lack of microsites, resulting in very poor survival. Microsite planting is the preferred method used on these harsh sites. If a microenvironment--which provides more of what a plant requires, such as protected zones with more moisture and nutrients--can be utilized by seedlings, then survival may be increased for planted species. North-facing sides of slopes or underneath existing vegetation or in existing woody debris (in the shade zone) should be planted. Conifers should be planted only on sites with soil depth of at least 8 inches, with existing vegetation and surface organic material present.

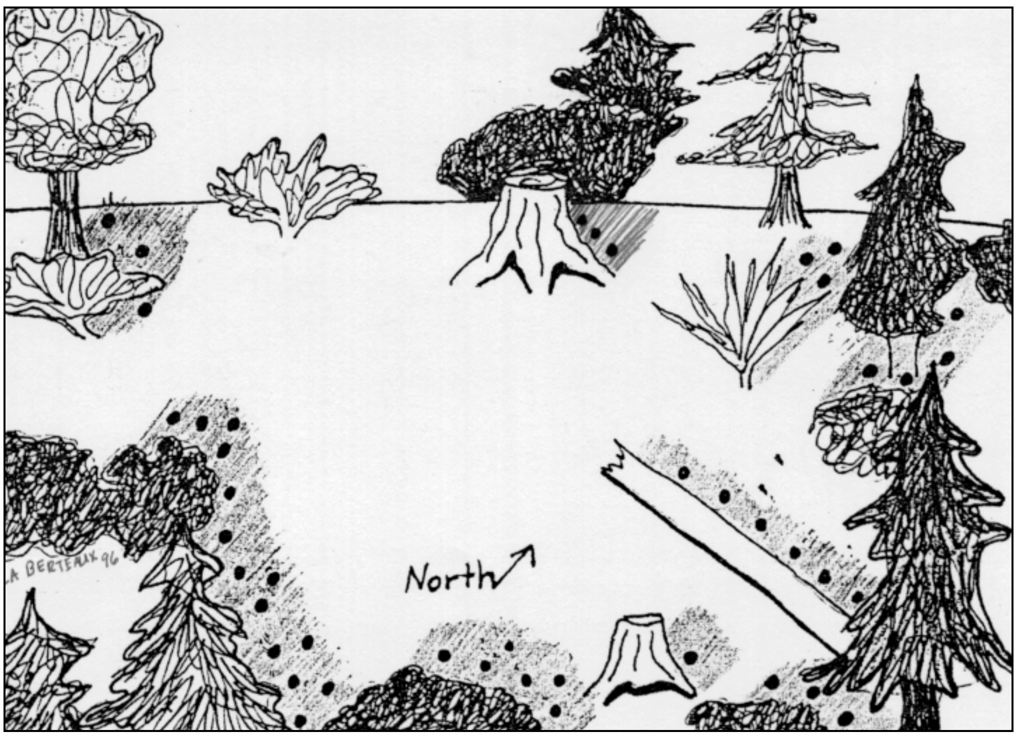

Figure 6-6. Planting Shaded Areas (North Sides) on Sheet and Rill (Dots Represent Planting Sites)

Cost:

<u>Cost of Planting Per Acre (Materials and Labor)</u>: $500.00-$1,000.00

Operation and Maintenance:

Planting can enhance sites that have been previously worked. Planting of willows and other riparian species has proved useful in controlling further erosion along stream banks. The typical stock used is non-rooted woody cuttings (discussed in more detail in bioengineering section). On upper banks behind the cuttings, conifers and/or hardwoods can be planted to strengthen the wall for protection.

Advantages/Disadvantages:

Micrositing is crucial on sheet and rill sites, although it takes a little more time and consideration to plant in the more favorable areas on a harsh site, when the practice is first introduced. Linear planting can be done more quickly and easily, although survival may be poor on harsher sites.

Acorns are prone to being unearthed and eaten during fall and winter by rodents and other animals, because they are an important food source. In spring, the new shoots are easily and often browsed by deer. Protective devices may be purchased or built to protect the acorns and/or seedlings, but these will be time-consuming to install and may add quite an extra cost to the planting. Whether or not protective devices are used should be decided by the importance of seedling establishment and overall goals of the restoration project.

Finding proper storage for plants can be a problem. We have used storage sheds insulated with bales of straw to maintain cooler temperatures in spring and to prevent freezing in fall. It is best to have storage available which is kept at a constant temperature (35 to 40 degrees F), but we have not always been able to use proper storage facilities due to inaccessibility or cost and logistics of renting space.

Bioengineering

Definition and Purpose:

Willows have been planted in the GVC watershed since 1980. Live staking of willows and willow wattles ("bioengineering") began to be used extensively throughout the GVC watershed starting in 1992. Willow and other riparian species such as cottonwood, alder, maple, hazelnut and equisetum have been used for both riparian vegetation enhancement and for bank stabilization.

Conditions Where Practice Applies:

Non-rooted woody cuttings are installed in areas with sufficient year-round moisture, such as along creeks or wet draws.

Planning Considerations:

- Sites to be planted should be inventoried prior to installation to select the right species type and amount needed for each site.

- Willow, cottonwood and other riparian species should be collected while dormant, generally from December through March or prior to bud break.

- Soaking the cuttings prior to installation (5 to 7 days) increases their survival. This initiates the root growth process within the inner layer of bark.

Design Criteria:

> <u>Site Conditions for Installation</u>: If inventory and analysis suggest willows are a treatment option, usually the entire problem area is planted, not just parts of a curve in the stream channel. A continuous line of willows through the curve is important so that water is not channeled behind the cuttings. Some guidelines for planting willows should be followed: **1)** Creeping-type willows are found and should be planted on the inside curves of a stream channel. **2)** Shrubby types would normally be planted on the outside curves of a streamchannel as a continuous barrier. **3)** Tree-type willows should be installed up the bank from the shrubby type or right on top of the bank or floodplain (USDA Soil Conservation Service, 1993).

For stakes: Stakes 3 to 4-foot in length and 3/4 to 2 inches in diameter are used in the GVC watershed for ease of transport and installation. 2/3 of the cutting should be planted in the ground with one to three buds remaining above ground level. The stakes are installed using an auger or digging bar. It is essential to have good contact between the cutting and the soil. Air pockets around the cutting can kill the roots, so soil should be tamped around the cutting firmly several times as the hole is filled. If bank stabilization is the goal of the planting, the cutting should extend more above the ground (1 to 2 feet) at a 45-degree angle from the channel bottom to provide immediate protection as it leafs out. Stakes should be planted close together (1 to 3 feet apart) to form a “wall” of protection.

Figure 6-7. Willow Stakes Installed Along an Excavated Channel

For Wattles: Primarily willow species are used for wattle material. The lengths vary from 3 to 6 feet depending on accessibility to the site and size of area treated. Bundle diameters are made small (4 to 6 inches) in order to allow ease of transporting them to the site. The cuttings are put together in specially built troughs designed to hold several cuttings in place in order to tie the ends of the bundles together. Cuttings are placed in the troughs with the top ends sticking out each end of the bundle.

When installing the bundles, a trench 4 to 6 inches deep is dug with a trenching shovel. The trench may be dug parallel to the stream or perpendicular to the stream, depending on the type of protection needed. The wattle is placed in the trench with the ends exposed, and the rest of the wattle is then covered with soil and packed down. The buried section will sprout roots and the exposed ends will leaf out to quickly form shrubby growth.

Figure 6-8. Sprouted Willow Wattles

Cost:

Labor per 1,500 stakes/wattles (collection and installation): approximately $2,800.00

Operation and Maintenance:

Wattles are used extensively for operation and maintenance. They are frequently used in conjunction with planting of nursery stock. Conifers can be planted just upslope from the cuttings to increase bank protection and enhance the riparian buffer zones. Wattles and stakes will stabilize the banks so that conifers and riparian hardwoods can establish themselves, eventually shading out the willows, by creating an overstory canopy. Later, woody debris will be recruited to the streams, providing habitat for fish.

Advantages/Disadvantages:

The advantage of using stakes and wattles is their ability to speed up regeneration and create a fast-growing cover for bank protection. Cuttings are cost effective and easy to collect and install.

If cuttings are not taken at the appropriate time (spring and summer, while in the budding stage), their chances for survival are greatly reduced. Sometimes weather conditions are not conducive to installation of cuttings as the best time to install them is while they are dormant, in winter. Willows may need constant managing to control invasiveness. Improperly installed willows may divert the flow of water.

Lop and Scatter (Slash)

Definition and Purpose:

"Lop and scatter" treatment utilizes a technique using material (slash) derived from branches of live trees and shrubs and dead material on the ground which is then spread on soil surfaces as mulch. Slash is used as a substitute to straw mulch on areas where access to sites is a problem. It is used primarily in the GVC watershed to create microenvironments (areas specifically meeting the germinating requirements of a species) or "safe sites" for sown and planted species and to add detritus in the form of woody material, which, with the process of decomposition, will add nutrients to the soil. Lop and scatter also creates surface roughness and complexity.

Figure 6-9. Slash Spread on a Sheet and Rill Slope

Conditions where practice applies:

Used in areas where access is limited and there is a good supply of material on or near the site being treated.

Planning Considerations:

Slope gradient, materials available (caution should be taken not to deplete resources used).

Design Criteria:

Contact with Soil: when spreading material, care should be taken to ensure that the material has good contact with the ground to protect the soil and retain moisture.

Direct Seeding: seed can be sown in areas that are slashed.

Amount Used: cover as much soil as possible, leaving a minimum amount of exposed areas.

Types of Materials Used: woody debris from limbs of hardwoods and conifers are typically used, or piles of woody debris existing nearby can be spread without depleting an area.

Slope Gradient: slash may more easily adhere to steeper slopes and may be used on slopes with gradients over 70 percent.

Cost:

Labor (Collection, Installation): approximately $600.00 per acre.

Advantages/Disadvantages:

Cover from Slash: surface coverage is less when this practice is used. 40 to 50 percent coverage as opposed to 85 to 100 percent for straw mulch.

Germination of Seed: lower germination, but it will provide some protection ("safe sites") for species planted in slash.

Site Specific: materials are obtained from sources close to treated sites. These materials contain microorganisms indigenous to the area and may provide nutrients to sown or planted species.

Flake and Stake

Flake and stake is a mulching method used on steep banks with poor soils. It prevents surface erosion, but more importantly, it applies a thick layer of mulch that eventually decomposes into organic material which can support species planted at a later time. This form of mulching differs from most because planting is done two years after the mulch is applied rather than at the same time. The heavy layer of mulch is left to decompose for one to two years, during which time decomposing organisms move into the mulch layer and begin the soil building process. Decomposition of mulch will initially reduce soil nitrogen (N). Once this decomposition has occurred, there is theorectically enough organic material on the ground to support planted species. The time frame is a bit longer, but on severely denuded sites it is worth prolonging the process of treatment in order to have a higher survival rate. The immediate problem is addressed by covering the soil with mulch and the long-term problem addressed by assisting the process of soil regeneration.

Conditions Where Practice Applies:

This practice is used primarily on the slopes of channels but it can be used on any slope to enhance as well as protect the soil.

Planning Considerations:

Depth of soil is important for installation of flakes. Usually the flakes will require some staking to adhere them to the slope. Access to the site should be considered as bales will have to be hauled onto the site. This practice may be useful on slopes greater than 70 percent.

Design Criteria:

1. Break the bales apart into flakes about 3 inches thick (most straw species when unbound will naturally split apart into rectangular pieces.)
2. Proceed to cover the slope as if you were shingling a roof. Start at the bottom of the slope laying a row of flakes across the slope, staking the flakes onto the soil with a willow stake up to 3 feet long and 1 to 2 inches in diameter, or use long (24 inch) metal staples.

3. Overlap the second row over the first row approximately 4 inches. Stake each flake as you proceed. Continue layering the flakes until the entire site is covered.

Cost:

<u>Materials and Labor:</u> approximately $12,000.00 per acre

Advantages and Disadvantages:

This technique is more time consuming and more costly than regular mulch treatments, so evaluating where it can best be applied is an important consideration.

Sheet and Rill Treatments

Definition and Purpose:

Treatment of harsh sheet and rill (surface erosion) sites have taken place since 1994 on a small scale with the establishment of several test plots using various revegetation techniques. These sheet and rill slopes have lost canopy cover which provided duff to protect the soil from rain drop impact and created "safe sites" for seeds to germinate. The duff layer essential for the health of soils is absent on sheet and rill sites in DG soils.

Figure 6-10. Typical Sheet and Rill Slope

Conditions Where Practices Apply:

Areas lacking canopy cover have lost or are in the process of loosing the duff layer created by needles, leaves, and branches of trees. Creating a duff layer or "safe" area may help build a soil base which can sustain forb and grass species and, eventually, create enough soil depth, water-holding capactiy, and soil nutrients to sustain shrub and tree species.

Based on successional theory, we may be able to enhance the microbial recruitment during the initial weathering phases of the parent material. This may be accomplished by mulching the bare area, allowing mosses and other soil-subculture species to establish. If this is possible, then we can at least begin the re-creation of soil on sheet and rill areas. We have had a few years of observing plant trials on harsh sites that indicate very poor success when trying to accelerate succession too quickly.

Planning Considerations:

When evaluating a sheet and rill site, an important factor to assess is the length of time since trees were harvested from the site. Sites where trees were harvested less than 10 years ago may have deeper soil, better soil structure (water holding capacity), and existing vegetation. These factors will make the site more suitable for planting and/or seeding and mulching for long-term sustainability. Sites logged 30 to 50 years ago have been in the process of decline much longer and have lost most of the topsoil and organic matter (duff), which protected the soil and reduced erosion. These sites have little soil structure or soil depth. The site has no "real" soil to sustain plants, especially shrubs and trees. This type of site will probably not be suitable for planting and may be a site to seed, mulch, fertilize, or leave alone.

Design Criteria:

Inventory: conditions to look for when assessing a site are: site characteristics (what is the current status of the site), soil profile (depth, horizons, organic material), slope (steeper than 70 percent slope may not be treatable), elevation, aspect, existing plant community, soil moisture and pH, and accessibility.

Prioritize: areas that are most likely to be stabilized or enhanced by vegetation are given higher priority. The site is given a rating for plantability based on the aforementioned information. The site is rated on a scale from low to high, high being the best conditions for successful seeding and mulching and/or planting.

Advantages and Disadvantages (various sheet and rill treatments):

Contour Furrows: Trenches are dug along the contour of the slope approximately three feet apart. Seed is sown in the trenches and sometimes covered with mulch such as straw or pine needle duff. This is a cost-effective but labor-intensive treatment. Also, trenches tend to fill in, burying seed (Figure 6-11).

Figure 6-11. Contour Furrows

Figure 6-12. Straw Wattles

Straw wattles: 20- to 25-foot-long trenches are dug along the contour of the slope for each wattle. Wattles are placed in the trench and wooden stakes are used every few feet to hold the wattles in place (Figure 6-12). Seed is sometimes sown behind the wattles where needles, leaves, and other organic material is deposited. Wattles are very difficult to install properly, especially on sheet and rill slopes with little soil depth. They are expensive to purchase and install (very labor intensive). In the GVC watershed, they have been pulled out and eaten by wildlife. Rilling frequently occurs underneath the wattles.

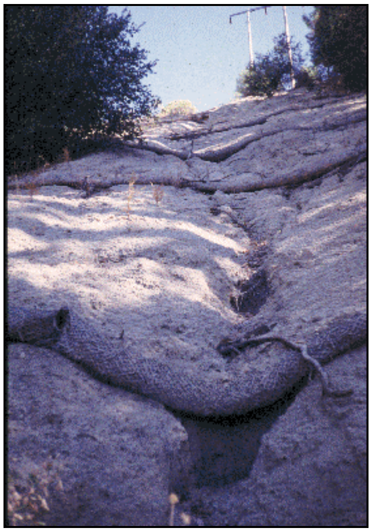

Figure 6-13. Straw Wattle on ORV-Damaged Site

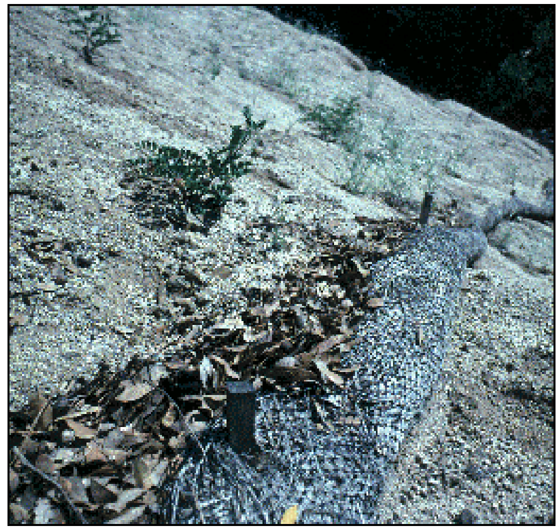

Figure 6-14. Straw Wattles Collecting Debris.

Microsite Planting: Sites with particularly severe micro-environments such as found on sheet and rill slopes may not support succession. The few scattered "pioneer" species able to colonize the habitat constitute the climax species as well, although succession on a very local scale may occur in "safe sites" (microclimates) (Barbour et al 1987). For this reason, planting on sheet and rill sites is usually done in these microclimates where conditions are more favorable for growth.

Species most frequently planted on sheet and rill are Ceanothus, manzanita, grasses such as Achnatherum, and Pinus species, generally ponderosa and sugar pine.

Cross-slope (X-slope) with Logs: When material is available, logs can be installed in much the same way as straw wattles. This technique is much more cost effective, but can be very labor intensive. Transportation of materials and shallow soils (which makes the digging of trenches more difficult) contribute to the increase in labor. Germinated seedlings are usually found behind or underneath the logs where there is better soil and cover. Decomposing logs will establish organic matter on the site, increasing soil nutrients to the site. Results will probably take some time to achieve.

Figure 6-15. Cross Slope with Logs

Lop and Scatter (Slash): This technique should be used only when there is enough material available on or near the site to avoid depleting the existing resources. This technique is cost effective when materials are in proximity to the site. Spreading slash (woody material) creates "safe" areas and increases moisture availability with the cover it provides. Native slash may contain microorganisms necessary to increase soil health, and when decomposed will add organic material. From field monitoring observations, shrubs and trees do significantly better when planted in slashed areas.

Erosion Blanket: Germination of seeds sown under erosion blankets has shown very poor results. Wildlife use the blankets for bedding. Blankets are expensive and labor intensive to install. Some moisture is retained under the blanket, but the weave of the material may be too close to allow germination of seed.

Figure 6-16. Erosion Blankets

Mulch Pellets: Organic mulch pellets, consisting of dried plant material, were used as a combination of both fertilizer and protective mulch. As a mulch these pellets were ineffective; the pellets tended to roll down steep slopes and were browsed upon by deer. However, where pellets did remain on the site, there was a slight increase in the amount of herbaceous growth. This suggests that the pellets were somewhat effective as a soil amendment.

Lime-Based Tackifier: This is a product that when combined with water forms a slurry. It is composed of hydrated lime, sodium sulfate, brucite, limestone, periclase, and quartz. When sprayed on the surface of soil it binds with the soil to form a crust, which provides a microclimate to enhance the germination of seeds. It can be used in place of straw mulch. The brand name used by the RCD is Poz-O-Cap.

Sprayed from a Truck: This slurry has been sprayed from a truck on test sites where access was available. When dry, the slurry forms a protective crust about 1/4-inch thick, which adheres to the slope and creates a base for seeds to germinate. Native grass and collected forb seed was spread on test sites prior to application. Milorganite, an organic fertilizer, was mixed in with the slurry. After one year we observed very good results from this technique. Accessibility, however, is a problem, as most sheet and rill sites are located too far to access by truck. The cost of this treatment is comparable to seed/mulch/fertilizer treatments.

By Helicopter: A helicopter was employed to apply lime-based tackifier to areas inaccessible by truck. The slurry, plus seed and fertilizer, was mixed in a tank, and smaller amounts were transferred to a bucket, which was attached to the helicopter and carried to each site. The slurry came out of the bucket very quickly; each site had to be

Figure 6-17. Lime-Based Tackifier Being Applied

visited three or four times. The helicopter operator was not able to access sites more than one mile from the staging area and was not able or willing to treat all of the sites that were inventoried. The expense of this technique was not as cost effective as originally estimated due to several equipment breakdowns. The application by helicopter was very thin and spotty. It was doubtful at first whether this would be an effective treatment, although field observations have indicated that germination of seed has taken place on areas treated by helicopter. Careful planning must be done when using a helicopter, and the staging area should be close to the sites. Make sure that the operator has done this type of work before and knows what to expect.

<u>Seed/Mulch/Fertilizer (SMF)</u>: This technique has been the preferred treatment used in the GVC watershed. This type of treatment is discussed in more detail in previous sections (see pg. 58). We have established the importance of cover on harsh sites to create a better soil base for germinating seeds.

Bales of straw are difficult to transport long distances, and mulch will not adhere well if the slope gradient is too steep. This treatment is fairly cost effective; however, native straw bales are nearly twice the cost of cereal grain straw such as barley or wheat, though there is a substantial amount of seed contained in the native bales (up to 2 lbs.). Several test sites were treated in 1995 using this technique. The mulch was spread by hand and by blower.

By Blower: It was very difficult to get the blower to the sites as the areas were very steep. A wench and several technicians were employed to haul the blower up skid roads to the tops of ridges where the straw was sprayed on the slopes. Twice as many bales must be used when applying the straw by blower. The straw is broken up into finer particles. Most of the sites were not accessible by blower.

Figure 6-18. Using Straw Blower to Apply Mulch

By Hand: The majority of the sites were treated by hand which is less expensive and more controllable. The native straws used on these sites were Bromus carinatus and Elymus glaucus (2 bales per 1000 sq. ft. by hand, 4 bales per 1000 sq. ft. by blower). The RCD native grass seed mix (see Table 6-1. pg. 66, for species) was used (40 lbs./acre) with Biosol organic fertilizer, at a rate of 180 lbs. per acre. Results are not yet available for this type of treatment on sheet and rill.

Fertilizer: Organic fertilizers, Biosol (a by-product of penicillin production) and Milorganite (derived from animal waste), and native seed applications were tested alongside ammonium phosphate fertilizers (16-20-0, 11-52-0-2, 38-0-0) with native seed. We have observed some promising results from trials (implemented in fall 1994) using a combination of Biosol or Milorganite organic fertilizers and native seed. However, very low germination rates occurred on sites fertilized with ammonium phosphate fertilizers. (See Monitoring Results and Discussion section, pg. 86).

Cone, Seed, and Acorn Collection

Definition and purpose:

Collection of seed from species indigenous to the GVC watershed has been done to create a seedbank for catastrophic events (such as fire), for direct sowing onto sites, and for propagation at nurseries in the form of plug or bareroot stock for planting. The advantages of collecting seed indigenous to an area are the ability to use native stock for revegetating, creating a seedbank for future use, and maintaining genetically correct species that are adapted to an area. A restoration site containing genetically diverse, adapted individuals runs a lower risk of developing inbreeding depression, or falling victim to pathogens or severe climatic conditions than a genetically homogeneous population (Glass 1989).

Conditions Where Practice Applies:

Cones, seeds, and acorns are used on areas originally vegetated with naturally occurring plant species that have been changed by human activity--such as logging and road building--or vegetatively altered by the introduction of non-native species to “restore” disturbed lands.

Collecting seed stock from areas to be enhanced by revegetating creates the opportunity for diversity of species and a healthier genetic base.

A survey prior to seed collecting is necessary to locate populations from which to collect. During this survey, a seed collection inventory form (Appendix F9, pg. A-26) is used to record information needed for collecting, such as species, location, number of plants, and estimated ripening date. This information is used to plan the collection process so that sufficient quantities of seed are obtained for the appropriate elevation and site conditions.

Planning Considerations:

Plants should be chosen, broadly, from the same seed zone as the project area, and more specifically, from an area within the watershed being treated. Plants have the best chance of survival if they are from ecotypes growing on or near the area to be treated (Wiese 1996). Seeds for a specific site should also be collected within 500-foot elevational increments. For example, if an area being treated is at 3000-foot elevation, seeds collected for later planting or direct seeding should come from 2500- to 3500-foot elevation. Other important factors used to determine which species to collect are aspect and soil type. When collecting, seeds should come from a broad genetic base. This includes collecting from a number of different stands, avoiding plants with disease, isolated plants, and plants with lower branches, which are often self pollinated. Choose species that have moderate to heavy seed production; choose dominant species seen throughout the watershed; and choose species most suitable for your specific revegetation efforts. Gather no more than 1/3 of the ripened fruit in any stand of species so as not to deplete their natural regenerative capabilities. It is also important to keep in mind that many species do not produce seed or produce healthy seed every year; thus, it may be necessary to collect seed over a number of years.

Design Criteria:

<u>Native Forb/Grass/Shrub Collection</u>**:** Different gathering techniques were employed (refer to *Seed Propagation* by Dara Emery for more information), since the seeds of some species ripen all at once, and others such as *Erigonum* (buckwheat) ripen throughout the growing season. Other factors, such as elevation, influence the ripening of seed as well. Usually, the lower the elevation, the sooner the seed will be ready for collecting. Therefore, if seed of one particular species is being collected from different elevational zones, the seeds will not be ready and collected all at once. The collectors begin at the lower elevations, periodically checking the seed at higher elevations for readiness. Another factor affecting maturity of seed is aspect. Seeds of the same plant at the same elevation, but at different aspects, will most likely not be ready at the same time. Seeds on south and southwest aspects will ripen sooner than seeds on other aspects, especially if sites are in a harsh area with little canopy.

Species such as lupine (*Lupinus* sp.) and ceanothus (*Ceanothus* sp.) were gathered before the fruit was fully ripe because the fruiting body bursts open when mature, making it difficult to obtain any seed. Immediately after collecting, the seed was laid out in racks covered with screens in order for it to dry, mature, then dehisce (split open). It is important that seed is set out to dry as soon as possible if this method is used, otherwise molds may develop and damage it. Other harvesting techniques, such as tying paper bags over maturing seed clumps or laying out ground tarps below individual plants or stands may be employed for species such as *Lupinus* and *Ceanothus*. Once the seed has matured, dried, and dehisced, it should be separated from the chaff using various sizes of screens, relative to the various sizes of seeds. Separating the seed is not entirely necessary. However, if the seed is going to be sent to a professional seed cleaning service, it cuts down on costs if excess material is removed.

As seeds are collected it is important that information is gathered. Both the scientific and common names of the plant should be recorded, the location of collection (seed zone at a minimum), elevation, aspect, and the date collected. When transferring the seeds to storage containers or when sending to cleaning facilities, it is important to label packages with information from the seed collection forms. The seed collection inventory form (Appendix F-9, pg. A-26) can be converted to a label that attaches to the seed envelopes or bags. If the project is detailed, and extensive monitoring is to be done of the later planted species, it is good to record the township, range, and section of collection sites, the plant community of the site from which the seeds were collected, the number of individual plants from which seed was collected, time spent collecting, and gross amount of material collected before cleaning.

Species such as lupine or *Chrysothamnus* (rabbitbrush) mature and produce seed over several weeks, on any given plant. These species can be gathered more than once during the season--every week or so--as new, ripened seed is apparent. Care should be taken not to gather fruit too early if it is gathered on the stalk then set out to dry. If unsure, it may be wise to do several collections to ensure that viable seed is collected. The method of gathering seed all at once when it is ripe requires intensive gathering by a large crew.

Figure 6-19. Seed Drying

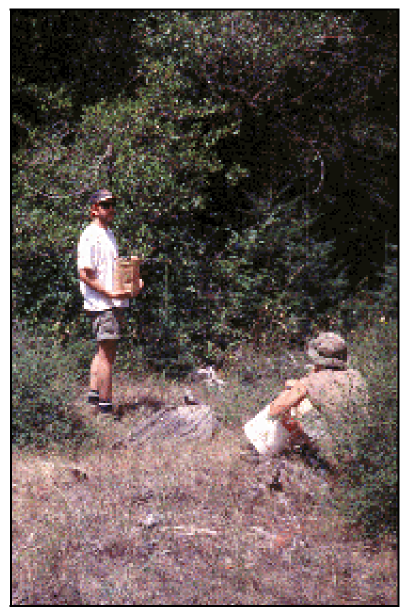

Figure 6-20. RCD Crew Collecting Seed

<u>Conifer Cone Collection</u>: In collecting seed cones, it is wise to canvass the forest area to find healthy specimens of the species desired, preferably growing in a stand of five or more trees of the same type. Trees selected should have no defects and should be producing a good crop of seed cones. This process should begin when cones first develop. Very important in this selection is the terrain beneath the tree. When the cones are picked, they will be thrown to the ground by the cone picker and harvested by ground crews. If the tree is located in an area where undergrowth or steepness of banks make recovery rates questionable, the tree should not be selected. When trees have

been chosen and it is time to collect, we enlist the help of a professional cone collector to ensure that the cones are properly collected.

Acorn Collection: Acorns ripen and are usually ready to collect during late summer and early fall (September/October). Good indicators are: when the shells begin to change color from olive-green to light brown, acorns begin falling to the ground, and/or acorns are easily removed from their caps. Acorns can be knocked out of trees and collected from the ground, picked directly off the tree, or collected from tarps placed under the tree canopy. Acorns should not be collected off the ground, unless first knocked or shaken out or a tarp is placed underneath to catch those that fall. (Acorns lying on the ground are prone to insect predation and desiccation.) Our primary method of collection was picking directly off the tree, sometimes knocking down acorns too high to collect. Tarping under trees is very time consuming and not very effective, if collecting from more than just a few trees. In addition, trees must be located on flat ground, near a road for accessibility, and acorns must be collected early in the morning before the tarp becomes too warm, which damages acorns.

While collecting, one can check for and discard acorns that have soft, weak, or split shells, weevil holes, or any other damage. Immediately as possible after collection, acorns need to be soaked in buckets of water to cool down. Unhealthy acorns will float to the top and should be discarded. After soaking, acorns should be dried and placed in sealable plastic bags. Peat can be added to absorb excess moisture and to help prevent damage to radicles as they emerge. If not planted or sent to a nursery right away, acorns should be refrigerated, with caution not to let the temperature get to freezing. We stored our acorns at approximately 40° F.

Acorns cannot be stored longer than the time at which radicles emerge, when they become ready for planting. If acorns are wanted for successive plantings, they will have to be collected every year.

Costs:

Seeds from thirty-five species were collected with a gross weight of 230 lbs. Total collection costs for 1996: $9,842.00

Advantages/Disadvantages:

Not every year is suitable for collection of native species. Conditions such as drought or flooding can drastically alter genetics and effect the reproducing capabilities of certain species. Disease and insect infestation can curb collection efforts, also. If seeds are not to be propagated right away, there may be a problem with seed viability over time. For instance, seeds of *Ceanothus* can remain viable for up to twenty-four years, if properly cleaned and stored, but seeds of riparian species such as *Acer* (maple) and *Populus* remain viable for only a few hours after they have fallen or been taken from the tree (Wiese 1996).

The advantages of collecting seed indigenous to the area are the ability to use native stock for revegetating, creating a seedbank for future use, and maintaining genetically correct species that are adapted to the area.

Often a large number of people are needed for a short period of time for collecting specific plants in a given area. Collection can be costly if large crews are needed and there may be impacts to the area from foot traffic.

Native Seed Species Collected:

<u>Shrubs</u>: *Arctostaphylos patula* (greenleaf manzanita), *Arctostaphylos viscida* (whiteleaf manzanita), *Cercis occidentalis* (Western redbud), *Ceanothus cuneatus* (buckbrush), *C. integerramus* (deerbrush), *C. lemmonnii* (Lemon's ceanothus), *C. pumilus* (dwarf ceanothus), *Chrysothamnus nauseosus* (green rabbitbrush), *Holodiscus* species (oceanspray).

<u>Grasses</u>: *Achnatherum lemmonii* (Lemmon's needlegrass), *Achnatherum occidentalis* (Western needlegrass), *Achnatherum stillmanii* (Stillman's stipa), *Bromus carinatus* (California brome), *Elymus elymoides* (squirreltail), *Elymus glaucus* (blue wild rye), *Elymus trachycaulus* (slender wheatgrass), *Festuca californica* (California fescue), *Festuca idahoensis* (Idaho fescue), *Poa secunda* (pine blue grass).

<u>Forbs</u>: *Annaphalis margaritacea* (pearly everlasting), *Angelica arguta* (angelica), *Brodiaea* species (brodiaea), *Cynoglossum* species (hound's tongue), *Eriogonum nudum* (naked-stem buckwheat), *Eriogonum umbellatum* (sulfur flower buckwheat), *Eriophyllum lanatum* (woolly sunflower), *Gnaphalium* species (cudweed), *Helianthella californica* (California sunflower), *Lotus crassifolius* (broad-leaf lotus), *Lotus purshianus* (Spanish lotus), *Lupinus albicaulis* (sickle-keel lupine), *Lupinus albifrons* (silver lupine), *Lupinus bicolor* (bicolor lupine), *Lupinus brewerii* (mat lupine), *Lupinus latifolius* (broad-leaf lupine), *Madia elegans* (common madia), *Monardella* species (mountain pennyroyal), *Pedicularis densiflora* (Indian warhead), *Phacelia mutabilis* (caterpillar plant), *Salvia sonomensis* (creeping sage), *Streptanthus* species (jewelflower), *Wyethia angustifolia* (mule's ear).

<u>Hardwood Trees</u>: *Alnus rhombifolia* (white alder), *Cornus nuttallii* (Pacific dogwood), *Cornus sessilis* (blackfruit dogwood), *Quercus chrysolepis* (live oak), *Quercus garryana* (Oregon white oak).

<u>Conifers</u>: *Pinus ponderosa* (ponderosa pine), *Pinus lambertiana* (sugar pine), *Calocedrus decurrens* (incense cedar).

Native Plant Nursery

Purpose:

The RCD nursery was initially established to propagate native grass plugs in similar soil and climate conditions of that of the watershed. It is hoped that propagating seed in similar site conditions as it was collected will result in more vigorous, acclimated plants and will reduce the possibility of disease or other weaknesses resulting from propagation in a nursery with a completely different climate and elevation. The nursery may also be used in the future to experiment with growing species that are specific to the GVC watershed and are not yet available from commercial forest nurseries.

Planning Considerations:

In considering establishing a nursery in a rural area, the main concern was finding suitable land that was level, easily accessed, and had irrigation. The RCD was fortunate to have the use of private land, including an irrigation system, donated for the nursery.

Design Criteria:

The area of the nursery is approximately 1,500 square feet. (30 x 50 feet), and is located in a pasture normally occupied by either llama or cattle. A fence consisting of barbless wire and metal posts was first erected around the nursery to protect the plants from livestock. The area was first mowed to remove existing vegetation; black felt erosion blanket was then laid down to reduce regrowth under the nursery plants. An additional three-inch layer of decomposed granite (DG) was spread over the blanket to reduce the amount of heat absorbed.

Racks to hold the plant containers were built out of wood pallets donated from local businesses. Each pallet was converted into a “box” by removing the crossbeams from one side of the pallet. Each pallet was then placed on the ground with the open side facing upwards, with plastic netting stretched across the top of each pallet and nailed in placed. The netting consisted of donated CalTrans emergency fencing, with a mesh size of one inch by two inches. This netting was used to hold the individual plug containers. Each rack varied in size, holding from 200 to 700 containers each.

For planting containers, both 6- and 8-inch plastic plugs (i.e., tubes) are used. The smaller tubes are used primarily for slower growing species such as *Achnatherum*, and the larger tubes for faster growing species such as *Elymus.*

In developing a soil mixture for the nursery, the idea was to grow the plants in soil similar to that in which they grow in naturally and will be transplanted into. Initially the soil mixture consisted of five parts DG to one part peat moss. However, due to the lack of mineral content and soil structure, there were a few problems with this first mixture, such as soil streaming out the holes in the bottom of the tubes. To remedy this, the bottom one inch of the tubes were first filled with peat moss, with remainder of the tube filled with the soil mixture. With this mixture the plants grew well, but when it came time to plant, the DG semi-cemented the plugs, making them difficult to remove from the container. The plugs were also extremely heavy compared to other plugs, which made them cumbersome to pack into sites. The soil mixture was then changed to a 3:1 (DG to peat) for the second sowing. Seeds were sown at three to five per tube.

The irrigation system for the nursery consists of one Rainbird sprinkler, which draws water pumped directly from the creek. The sprinkler is set up in the middle of the nursery and is turned on and off manually. (This is in part due to the need to share water privileges with the landowners and also because timers cannot be used much of the year because of freezing temperatures.) Plants are watered for at least one half hour every day in the summer and once a week during dry spells in the spring and fall. No irrigation is needed during the winter.

Currently, half of the nursery space is being used and approximately 15,000 plants are being grown.

Cost:

The total cost for the construction of the nursery and initial sowing was $8,659.00. This translates into a per plug cost of $0.50. Now that the nursery has been established, the cost per plug should be $0.20.

Figure 6-21. Native Plant Nursery

Monitoring and Results of Revegetation Treatments

Introduction

The monitoring of revegetation treatments has become an integral component of the watershed revegetation program. Such monitoring is important in documenting the results of treatments and evaluating the relative success or failures of these treatments over time. Long-term data collection will provide valuable information on the changes of species composition over time.

Methods

All 100 treated sites were evaluated over a period of four months during the summer of 1995. All vegetative treatments were evaluated separately, although most sites had multiple treatments.

A monitoring form was created based on those attributes that were to be evaluated in the field (Appendix G, pg. A-27).

Plantings

Monitoring method:

The effectiveness of plantings was determined by evaluating the survivability of tree and shrub outplantings. Although grass plugs were also evaluated, it was later found that it was impossible to distinguish between plug plantings and naturally occurring grasses, so that data was not used. For small sites, all living and dead seedlings were recorded, with the dead or dying seedlings subtracted from the total. For larger sites, a representative sample of the area (as determined by the field technician) was counted and this applied to the entire site. The amount of live materials was then compared with the known quantities planted at the site, with an estimate of survivability recorded by the technician.

For willow stakes and wattles, the percentage of survivability was determined by counting the number of surviving stakes and wattles and comparing the total with the quantity installed.

Results:

Several difficulties were encountered in attempting to assess survival for planted species, such as inadequate documentation in the first phase of the project and evolving monitoring techniques. For many sites planted in 1993, there is no record of the number of species and planting date for each site, which makes it impossible to quantify species survival. There were also problems with data collection, with conifer species not individually identified on several sites. Because monitoring consisted of visual estimates of species numbers at each site, there is a wide margin for human error and bias. Because of such factors, some of the data is not congruent with field observations, and requires additional explanation.

> *Note*: *All survival data presented here are for those species planted in 1993 and 1994.*
>
> <u>Conifers</u>
>
> Among the conifers, sugar pine had the highest survival (90 percent), although this value was obtained from observations at only one site (Table 6-2). Additional sites were planted with sugar pine, but information is lacking on the exact numbers. Field observations indicate that planted sugar pine has a high survival rate, especially on dry, south-facing slopes. This was seen with natural regeneration in the watershed, where sugar pine was observed to produce more seedlings and saplings than other pine species.

For several sites the conifers were grouped together and not counted by species. This mixed conifer group, consisting of Jeffrey, sugar, and ponderosa pine, also had a high survival rate (53 percent). Although no data is available on the individual species, it is assumed that sugar pine comprised the majority of this group and accounts for the high survival rate. Ponderosa pine was also planted extensively, and, like sugar pine, appears to have moderate-to-high survival rate (>50 percent) on dry, south-facing slopes. In reforestation projects, ponderosa pine tends to be planted on south and west aspects due to its drought tolerance. Long-needled pines, especially ponderosa and Jeffrey pine have been specifically recommended for revegetation work, mainly because they occur naturally on decomposed granite (Jopson 1992). Other benefits of pines include their long needles, which provide a protective and nutritive mulch.

Species	**50-100% Survival**
Sugar pine (*Pinus lambertiana*)*	90
Willow wattles	74.2
Mixed conifers (Jeffrey, sugar, and ponderosa pines)	52.7
Needlegrass (*Stipa pulchra)**	50
Horsetail (*Equisetum* sp.)*	50
Big leaf maple (*Acer macrophyllum*)*	50
Incense cedar (*Calocedrus decurrens*)	48.3
Species	**20-50% Survival**
California fescue (*Fetuca californica*)	34.5
Greenleaf manzanita (*Arctostaphylos patula*)	28.7
California wild grape (*Vitis californica*)	26.7
Blue wild rye (*Elymus glaucus*)	25.5
Deerbrush *(Ceanothus integerrimus*)	25.2
Rush (*Juncus* sp.)*	25
Willow (*Salix* sp.)*	24.0
Jeffrey pine (*Pinus jeffreyi*)	22.5
Evergreen blackberry (*Rubus laciniatus*)*	20.0
Species	**<20% Survival**
Douglas-fir (*Pseudotsuga menziesii*)	18.4
Ponderosa pine (*Pinus ponderosa*)	17.5
Willow stakes	15.0
Mock orange (*Philadelphus lewisii*)	13.7
Redbud (*Cercis occidentalis*)	11.8
Pacific dogwood (*Cornus nutallii*)*	8.2
Dwarf ceanothus (*Ceanothus pumilis*)	6.0
Lemon ceanothus (*Ceanothus lemmonii*)	6.0
Palmer ceanothus (*Ceanothus palmeri)**	6
Mountain mahogany (*Cercocarpus betuloides*)	5.5
Snowberry (*Symphoricarpos albus*)*	5.2
White leaf manazanita (*A. viscida*)*	5
Cream bush (*Holodiscus discolor*)*	3
Rush (*Juncus castaneus*)*	3
Needlegrass (*Stipa* sp.)*	1
White alder (*Alnus rhombifolia*)*	1
Dogwood wattles*	0
Bicolor lupine (*Lupinus bicolor*)	0
Squawcarpet (*Ceanothus prostratus*)	0
Blue elderberry (*Sambucus cerulea*)	0

Table 6-2. Percentage of survival of shrub, tree, and grass species following one and two years of growth. Those species marked with a star (*) indicate that survival is based on only one or two sites, suggesting that caution must used in interpreting such results on a larger scale. (All other data represents mean survival based on several sites.) Data is for bare root, container, and plug stock planted during the spring and fall of 1993 and 1994, respectively.

Of tree plantings, incense cedar had moderate survival rate (48 percent), which was probably a result of the favorable conditions where it was planted. Within the GVC watershed, incense cedar occurs naturally in Klamath mixed conifer and Douglas-fir communities, where greater canopy cover provides lower temperatures and greater soil moisture. Because cedar occurs in more hospitable sites, this species was planted on north-facing aspects, valley bottoms, and adjacent to riparian zones. These areas have greater available moisture than steep, south-facing slopes, so planted species endured less drought stress, resulting in greater survival.

Although mixed conifers had a high survival rate, data for ponderosa pine showed survival was less than 20 percent. This was also the case for Douglas-fir, which also had survival rate less than 20 percent. It is suspected that these low values are a result of poor planting techniques (and an inexperienced crew) during the initial stages of restoration. During the 1993 planting season, trees were planted without respect for aspect and site condition. Douglas-fir was planted on south aspects, and both firs and conifers were planted on bare, exposed slopes.

During the 1994 season, steps were taken to rectify these unsuccessful approaches to planting. Because Douglas-fir occurs naturally in the watershed on north aspects where temperatures are cooler and soil moisture is greater, this species is now only planted on north and east aspects (USDI BLM 1995). Ponderosa and sugar pine are planted on south and west aspects, and are generally not planted on bare, exposed slopes. Instead, the trees are microsite planted in the shade of existing trees and shrubs, or within piles of woody debris. An RCD field study currently is evaluating the effectiveness of microsite planting.

Proper planting technique is crucial for survival of stock, so planting requires a trained and supervised crew. The RCD now has an experienced, highly motivated crew that is supervised by both a crew leader and a revegetation specialist. The revegetation specialist selects sites, determines species and numbers to be planted, and keeps detailed records of this information. The crew leader ensures that designated sites are planted as specified by the revegetation specialist, and that planting techniques are correct. With better site selection and planting techniques, it is expected that survival rates will be higher for current plantings. It will also be easier to determine survival of species with detailed records of sites and the amount of each species planted.

Future plantings should also have higher survival rates through the use of locally adapted species. During the first year of restoration, plant materials were obtained from numerous sources, so species were not necessarily adapted to local soils and climate. A seed and cone collection was initiated in 1994, with materials sent to local nurseries for propagation. This has ensured that a portion of stock material used for revegetation is from plants that have adapted to the granitic soils and local precipitation regimes of the watershed. It is hoped that the seed and cone collection will be expanded in future years so that most stock material will have originated from the GVC basin.

Future planting work in the watershed may require supplemental treatments to increase survival, especially on harsh, south-aspect slopes. Previous research on granitic soils indicates that the use of straw mulch with netting reduces surface erosion and results in high ponderosa pine survival rates (Megahan 1974), while large stock (2 year-old seedlings) and fertilizer improve growth (but not survival) of Douglas-fir (Strothmann 1980). A review of mulching techniques used in California and Oregon found that conifer seedlings benefited most from mulching on soils with low water-holding capacity such as decomposed granite (McDonald and Helgerson 1990). Although mulching with planting involves more labor and expense, it may be cost effective if seedling survival rates are increased.

Riparian Species

Among riparian species, the willow wattles had the highest survival rate (74 percent). The success of these was a result of proper timing for installation of the wattles. Wattles need to be installed when the young willows are dormant: fall to early spring. Use of willow cuttings is quite common in riparian restoration, due to the ease in obtaining material and the high success rate of cuttings forming roots and sprouting. Big leaf maple had 50-percent survival rates on the one site where data was collected, but it is believed that the actual survival of all maple plantings is much higher. This is also true of white alder, dogwood, willow, and snowberry plantings, although limited data was available for these species. Because these are some of the more common species that occur in the watershed, they are the preferred species to use. It is apparent that more thorough documentation and monitoring will be needed to accurately assess the survival of these species.

Those species with low survival rates included willow stakes, which was a result of incorrect handling, storage, and planting time: stakes were planted in late spring and early summer and were subject to desiccation. It is expected that mortality of willow stakes will be much lower now that they are installed while dormant (late fall through early spring). Dogwood wattles also had low survival, which may have been due also to incorrect planting time. Data for other riparian species are based on one or two sites, and therefore may not reflect actual survival rates.

Shrubs

Among the shrubs, greenleaf manzanita and deerbrush had the highest survival rates, which is promising for revegetation work. Manzanita naturally occurs on steep, dry slopes, and may be useful in revegetating sites experiencing severe sheet and rill erosion. Deerbrush (*Ceanothus integerrimus*) is common throughout the watershed, and is important for enriching soils, as are other ceanothus species. Although ceanothus shrubs are not leguminous, they have the capability of fixing nitrogen and therefore influence nitrogen content in forest systems (Vlamis et al 1958, Hellmers and Kelleher 1959, Youngberg and Dyrness 1964). Because of this ability to add nitrogen to the soils, ceanothus species may prove useful in improving degraded granitic soils. (Because *Ceanothus* is among the most wide-spread genera of nodulated non-legumes, it has applications in restoration projects throughout the U.S.) Survival was low for other ceanothus species (dwarf, lemon, and Palmer), which was probably due to the harsh condition of the sites on which they were planted. Both lemon and dwarf ceanothus naturally grow on harsh sheet and rill sites, so it would be beneficial if these species could be used for revegetating such sites. Some additional treatment or techniques may be needed to enhance shrub survival, such as microsite planting, shade cards, mulch, or organic fertilizers.

Shrubs may also be used as nurse crops for other plantings on harsh slopes, by planting shrubs the first year and conifers a few years later. The shrubs would provide shade for the tree seedlings, and at the same time, the trees would grow with the shrubs and eventually form a second canopy over the shrubs. This is the natural pattern of succession that occurs in forest systems after disturbance. While conventional forestry practice eradicates shrubs before conifer planting, some research suggests that brush can be beneficial for conifer establishment (Zavitkovski 1970). Such research points to higher soil moisture around root collars, which results from the brush canopy intercepting rain and funneling it down the main stem (Wahlenberg 1930, Rowe 1947, Youngberg 1966). Air and soil temperatures were found to be cooler under brush (Wahlenberg 1930, Youngberg 1966), which may also lead to increased moisture in the upper soil surface.

Grass Plugs

It was difficult to obtain an accurate estimate of the number of surviving grass plugs because grass plugs looked identical to naturally occurring bunchgrasses. Although California fescue and blue wild rye had moderate survival rates (35 percent and 26 percent, respectively), it is suspected that actual plug survival was even higher, based on field observations. In the future a sample of planted plugs will be marked in order to determine survival rate.

In comparing grass plugs with native seeding, a high degree of cover is provided by native seed mixes (see "Native vs. Non-native," pg. 93), however, there are areas where the use of plugs may be more desirable than seeding. Such areas may be where structures have been placed to halt gullying, or in riparian zones where eroding streambanks need to be stabilized. In these situations one wants to quickly have vegetation establish abundant roots to stabilize the soil, so it may be more expedient to plant grass plugs and other stock that already have initiated root growth. This is especially true for perennial bunchgrasses, which take two years to reach maturity when started from seed.

Seed Mixes

Monitoring method:

The percentage of cover of both naturally occurring and sown plant species was determined by visual estimation at seeded site.

Results:

There was some contention after 1993 as to which provided greater cover: native or non-native seed mixes. The monitoring data shows that after two years of growth, the native mixes (channel mix, quick mix, hot/dry mix have greater cover than the non-natives (SCS mix, rose clover, Zorro fescue, and clover) (Figure 6-22). The quick mix and the warm/moist mixes had the highest cover among the natives, while the Zorro fescue and the SCS mix had the highest cover among non-natives. This difference may be explained by species composition within the native and non-native mixes. The native mixes contained perennial

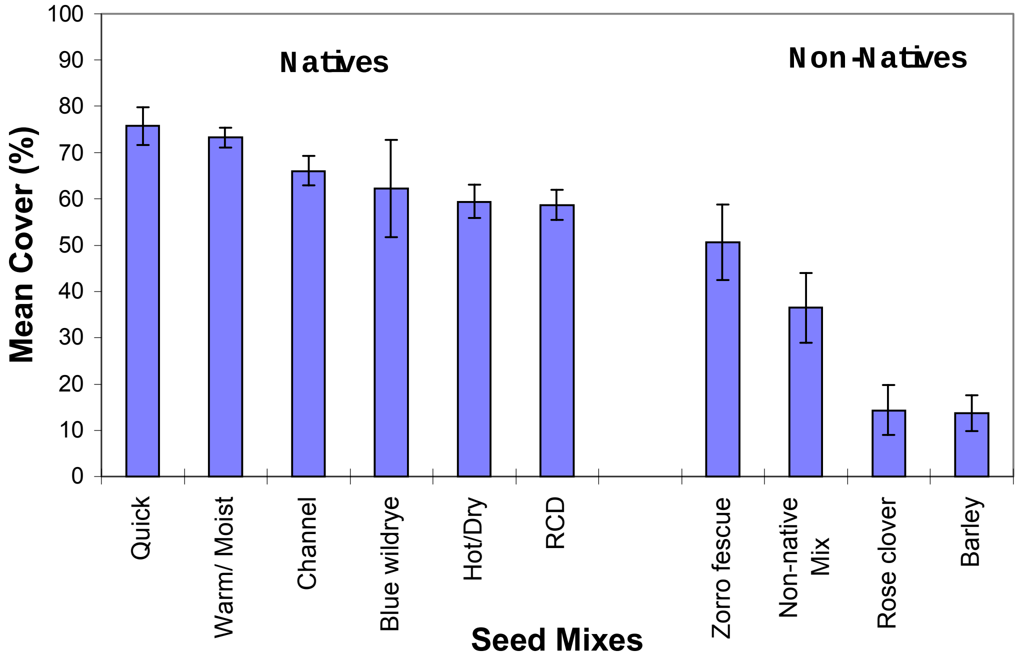

Figure 6-22. Comparison of the vegetative cover of native and non-native seed mixes after two years of growth. Error bars represent ± 1 SE (standard error).

grasses, while the non-native mixes had perennial and annual grasses, as well as some annual forbs. Annuals have only one season to mature and reproduce, so they must grow rapidly after planting, while perennial bunchgrasses grow more slowly, and often take two seasons to reach maturity (Barbour et al 1987). With faster growth, annuals tend to dominate a site the first year after planting. This has been seen in some prairie restorations, where weedy annuals dominate the first year, with perennials grasses emerging the second year and becoming well established by the third year (Sutton 1985). It is possible that the annual components of the SCS and other non-native mixes germinated rapidly to provide dense cover the first year, while the perennial grasses required two seasons of growth to reach full height and provide dense cover. This may explain the greater cover of native perennial grasses seen in the monitoring data.

The first-year cover of natives can be seen in the RCD native mix, which was sown in 1994 and monitored in 1995. This mix was composed of the more prolific species that were seen emerging from the native mixes: *Bromus carinatus, Elymus glaucus, Deschampsia elongata,* and *Festuca idahoensis*. Although the RCD mix was composed of these dominant grasses, it had the lowest mean cover (59 percent) of any of the native mixes. This is probably a result of the RCD mix having only one year to establish, while the other mixes have had two years. In the future monitoring the cover of the RCD mix may reveal that it increases over that of the other native mixes.

The non-native mixes may have also provided more cover the first year because they were composed of species that germinate quickly and grow rapidly. This makes exotics useful in stabilizing severely disturbed sites, such as road cuts, burns, and mining sites (USFS 1994).

Such cover is intended to be dense, so it is rather surprising that the non-natives had such low cover (12 to 51 percent) after two years. This poor response may be due to the exotics being ill-adapted to the conditions of the watershed, especially to the granitic soils and precipitation regime. Exotic species not adapted to sites can have low survival, slow growth, and may be more susceptible to environmental fluctuations. Such problems reinforce the advantages of using native species.

The grasses used in the native mixes were all species that occur naturally in the watershed, indicating that they have adapted to the soils, climate, and fauna of the area. From observations within the watershed it was seen how native grasses provided cover on slopes, stabilized banks, added organic matter to the soil, and provided habitat for endemic insects and soil microorganisms. Native grasses are an integral part of the complex forest systems of the watershed that are habitat components for wildlife.

Native and Non-Native Mulches

Monitoring method:

The percentage of cover of sown and naturally occurring grasses and forbs was determined by visual estimation at each site where mulched was used.

Results:

Mulching after mechanical work on roads has proved to be highly effective in reducing erosion and establishing a cover of vegetation. Both native mulches and wheat and barley create a hospitable microenvironment for seed germination by protecting the soil from direct sunlight, which results in lower soil temperature and increased moisture retention. Straw is an especially effective mulch because of its low heat conductivity, so that little incoming solar radiation is trapped within the straw and is not conducted to the ground. Mulching also decreases splash erosion by reducing impact of rainfall on the soil. Also, through its decomposition, mulch adds organic material to the soil.

In comparing the cover of seeded species, it was found that native straws and non-native barley and wheat produced similar coverage (Figure 6-23). Native blue wildrye, California brome, and needlegrass straw produced the highest cover, which ranged from 64 to 69 percent. Cover of barley and wheat was 59 percent, with rice straw producing low cover of seeded species. Also, rice straw was dirty and difficult to spread, so its use was discontinued. Because it appears that results of native and non-native mulch cover is very similar, there are some factors to consider in deciding which to use. The main factor may be cost, with barley and wheat ranging from $4.00 to $5.00 a bale, while native grasses can range from $5.00 to $8.00. Native straws may cost more now, but with increased demand encouraging suppliers to produce native material, there may be a reduction in price over time (Craig Dremann, personal communication, Native Grass Workshop, 1995). The primary advantage of native straw is that bunchgrasses germinate from the bales, which was seen in field observations. Applying native mulches would be a native seed source without any additional seeding, depending on the desired amount of ground cover. One must be careful in obtaining “any” wheat or barley straw, for it can be contaminated with exotic species such as clover and annual grasses. *This caution should be used in obtaining native straw also: the RCD has received native bales that could not be used due to contamination with exotics.*

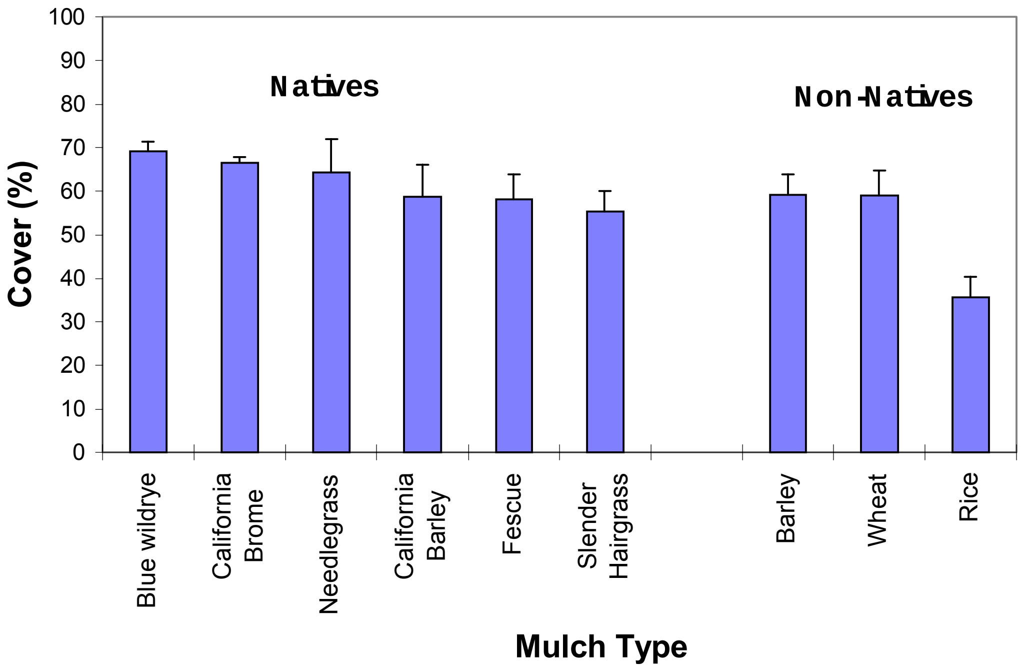

Figure 6-23. Comparison of Vegetative Cover from Seed Mixes Using Native and Non-Native Straw Mulches.

Fertilizer

Monitoring methods:

The percentage of cover of grasses and forbs was determined by visual estimation at each fertilized site.

Results

As shown by Figure 6-24, vegetation growth was greatest in the high nitrogen fertilizer (38-0-0). With this fertilizer, the cover of seeded species was 24 percent greater than in the other fertilizers, indicating that a slow-releasing nitrogen amendment was beneficial for increasing plant growth.

The similar amount of cover seen in the other fertilizers is most likely a result of the type of chemical fertilizers that were used. Three of the fertilizers (11-52-0-2, 16-2-0-0, and a combination of 11-52-0-2 and 38-0-0) were not slow-releasing, so that all minerals were released into the soil over a period of days and weeks. Considering the course texture of granitic soils and associated low capacity for holding nutrients (USDI BLM, 1994*)*, it is likely that most of the fertilizer leached away before it could be utilized by the plants. The high phosphate fertilizer (11-52-0-2) may not have been necessary, for the GVC granitic soils are known to be deficient in nitrogen, not phosphorus (Claassen 1994).

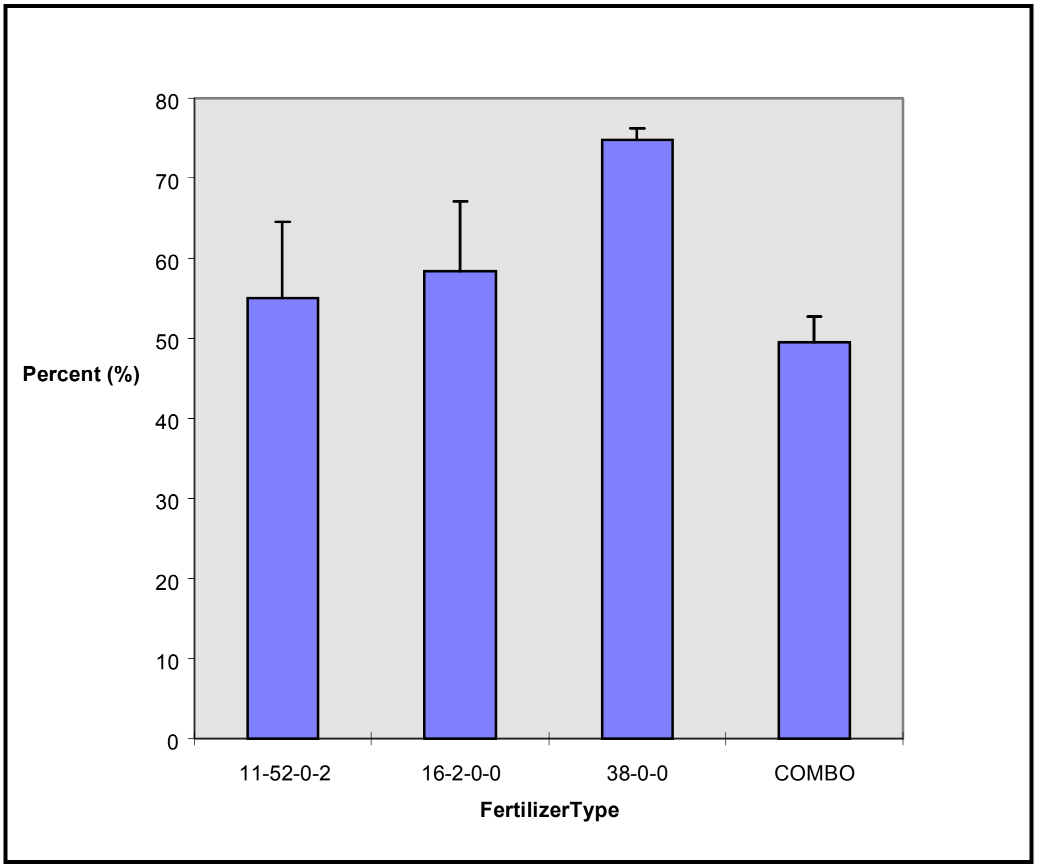

Figure 6-24. Percenatage of Cover of Seeded Species with Fertilizer Treatments

Other Treatments

A variety of other techniques was used during revegetation work, including the use of erosion blankets, contour furrows, straw wattles and lop and scatter. Although no quantified data is available on these treatments, subjective assessments on the effectiveness of these treatments have been made based on field observations.

Erosion Blankets.

Erosion blankets slowed erosion and had extensive vegetative cover when they were placed in mechanically treated areas, such as steep banks where a culvert was placed. Because erosion blankets were designed for such sites, they were effective in stabilizing the soil and promoting plant growth. Erosion blankets were also tested on bare sheet and rill slopes, but with poor results. Plant cover was sparse, and rilling was found underneath the blanket. Temperatures under the blanket were higher than on surrounding bare ground, indicating that heat under the blankets retarded any plant growth. The blankets were difficult to install on the slopes and required non-degradable materials, such as plastic netting and metal pins. Erosion blankets are not specifically designed for natural hillslopes where the soil has not been mechanically disturbed, which can explain the poor results of erosion blankets on sheet and rill. It may be that the blankets are ineffective on harsh slopes, where there is little topsoil left to support vegetation, and the blankets are exposed to increased solar radiation from the expanse of bare ground. The erosion blanket may prove useful on less harsh sites where there is more topsoil and greater canopy cover, but where a steep slope needs to be quickly stabilized.

Lop and Scatter

Lop and scatter also had mixed results. It was found that scattering woody debris across slopes without straw mulch resulted in continued rill and gully formation. However, it was seen that soil did collect behind stem sections that were in contact with the ground, and that some plants were establishing in these areas. Lop and scatter was also helpful in holding straw mulches in place and possibly increased the surface protection of the mulches. While lop and scatter alone may not offer sufficient cover for erosion control, it may provide microsites for seed germination when it is used in conjunction with straw mulch.

Contour Furrows

Contour Furrows used on steep slopes were one of the least effective treatments. The furrows were labor intensive to install, and after two years, the furrows had completely filled with eroding soil, and little vegetation had established in the furrows.

Straw Wattles

Straw wattles were also ineffective on steep slopes, with rills and gullies formed beneath the wattles. The wattles tended to bow out from the weight of accumulating sediment, and sometimes broke apart completely. Also, deer tended to browse on the wattles. Wattles were difficult to install properly, due to the inconsistency of soil depth and hardness. Considering the labor and expense required for wattle installation, it is not a recommended technique for granitic slopes.

Chapter 7
MONITORING AT THE WATERSHED LEVEL

Introduction

The ultimate measure of success for the Grass Valley Creek (GVC) Project is reduction of sediment delivered to the Trinity River. To measure the effectiveness of the program both sediment discharge and steam flow are being monitored on a watershed scale. The effectiveness of the program can only be determined through analysis of the long-term trend of sediment discharge in relation to stream discharge under a wide range of flow conditions.

Stream Gauging Station

The U.S. Geological Survey (USGS) has operated a stream gauging station on GVC since November 1975. The station is located at Fawn Lodge, approximately three miles above the confluence with the Trinity River, and captures 84 percent of the GVC watershed. At this site the USGS maintains a continuous stream stage recorder and samples suspended and bedload sediment during peak storm events. From this data the USGS publishes daily mean flow, peak flows from storm events, and an estimate of daily sediment discharge.

Hamilton Ponds

The Department of Water Resources (DWR) has constructed three sediment ponds at the mouth of GVC. The lower pond was constructed in 1984 on private property right at the confluence with the Trinity River. The upper and lower ponds--constructed in 1988 and 1989, respectively--are located on DWR property. These ponds capture 100 percent of flow from the GVC watershed and have a storage capacity of 42,000 cubic yards.

An analysis of the sediment capture efficiency of the ponds has shown that the capture efficiency of the ponds will decrease as stream flow increases. Generally, under all flow conditions, the heavier sand particles will settle into the pond while the lighter clay particles will stay in suspension and be carried through the pond. The varying efficiency is due to the percentage of silt and fine sand particles which settle under different flows. The overall efficiency of the ponds was estimated to be between 70 to 80 percent for all peak flows experienced during the life of the ponds. This efficiency assumes that the ponds are not full and that ponded water conditions do exist.

A baseline survey of the upper two ponds was completed after the ponds were dredged in 1995. The ponds were re-surveyed again in 1996 and 1997 to monitor yearly sediment accumulations.

Buckhorn Sediment Dam

Constructed by the Bureau of Reclamation in 1990, the Buckhorn Sediment Dam captures the upper 25 percent of the GVC watershed and has an storage capacity of 1.8 million cubic yards. Given the very large surface area in relation to flow rate, it is assumed that 100 percent of all sand and silt particles will settle into the reservoir. However, some of the clay will most likely stay in suspension under very high flow rates. This was evident during the peak of the 1995 storms when it was observed that the water flowing over the spillway was “chocolate brown” in color. Therefore, the overall capture efficiency is estimated at 95 to 100 percent depending on flow rate and sediment concentration.

A baseline survey of the upper part of the reservoir was completed prior to filling the lake. The reservoir was re-surveyed again in 1995, 1996, and 1997 to monitor yearly sediment accumulations.

Findings

The best measure of effectiveness that can be made to date is comparing the sediment accumulation in Buckhorn Sediment Dam and Hamilton Ponds after the 1995 and 1997 storm events (Figure 7-1). Because no restoration work has been undertaken upstream of the dam, the sediment accumulation in the reservoir will serve as a good measure of erosion from untreated areas. Because the 1995 storm occurred during the middle of the program, many sites had not been treated. Also many of the sites which involved stream crossing excavations experienced a great deal of erosion (see road removal section). The storm did occur at a good time, however, as it proved without a doubt that large channel excavations should not be undertaken in decomposed granite (DG) without including stabilization measures in the excavated channel. Since the 1995 storm, channel stabilization measures have been incorporated into all stream crossing excavations. No significant erosion was observed from any of the stream crossing excavations with channel stabilization after the 1997 storm.

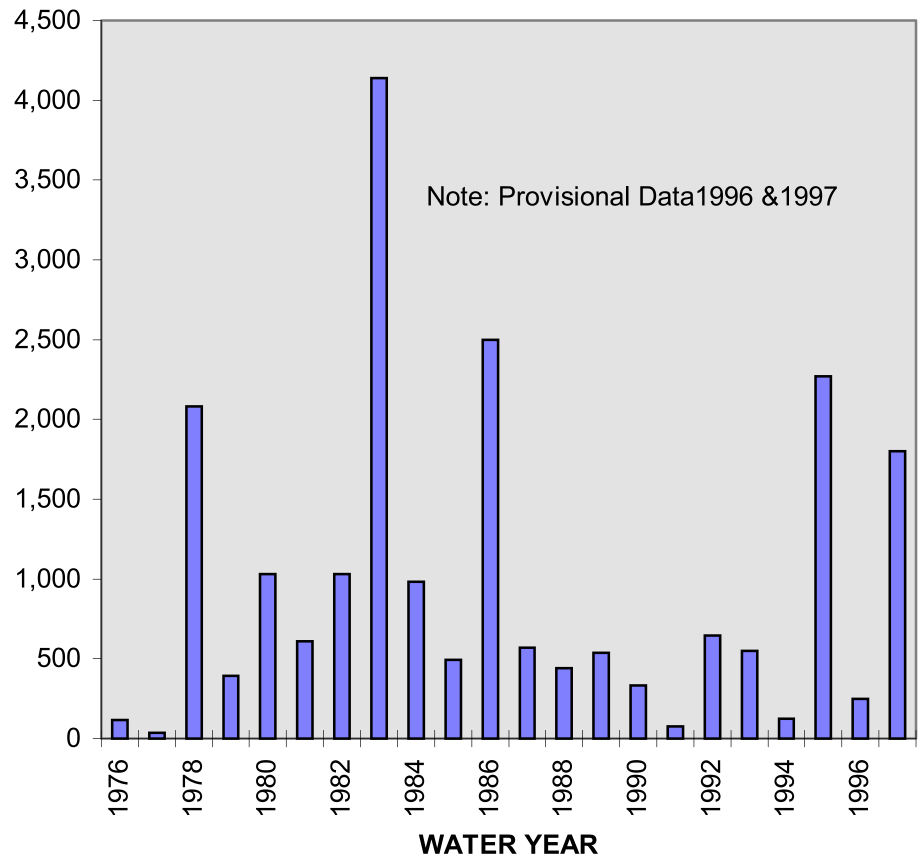

Figure 7-1. Maximum Instantaneous Peak Discharge from Grass Valley Creek at Fawn Lodge (1976-1997).

Although a baseline survey of Hamilton Ponds was not taken prior to 1995, the upper pond had just been dredged and the middle pond had no observable deposition. The lower pond had been reported to be “partially filled” prior to construction of the upper two ponds.

During the January 9, 1995 storm, all three ponds filled with sediment. The upper pond captured a lot of woody debris, large boulders, cobble, and gravel, while the lower two ponds were filled primarily with DG. Because the ponds were full, sediment from the January 24 and March 10 storms flowed directly into the river. A total of 42,000 cubic yards was dredged from all three ponds in the summer of 1995. Assuming that the lower pond was about half full, as reported by observations, approximately 35,000 cubic yards of sediment was captured in the ponds.

The 1995 survey of Buckhorn Sediment Dam shows that approximately 15,000 cubic yards of sediment had accumulated at the upper end of the reservoir in the first five years of operation. It is assumed that most of this accumulation had occurred in 1995, as no noticeable deposition had been observed prior to 1995. The plume observed in 1995 formed the classic depositional fan which occurs as sand particles settle quickly from suspension when water is ponded. The plume was comprised almost entirely of DG with no cobble or gravel visible.

In 1996 no peak flows over 300 cfs were recorded at Fawn Lodge gage. Although it was a wetter than average winter, no “large” storm events occurred. The upper Hamilton Pond captured approximately 3,000 cubic yards of sediment while no measurable accumulation was found in Buckhorn Sediment Dam (some accumulation may have occurred, but the plume did not migrate far enough to intersect the next cross section).

In 1997, a 1,800 cfs (USGS provisional data) peak flow was recorded at Fawn Lodge on January 1. This peak flow nearly approached the 2,270 cfs peak recorded during the January 9, 1995 storm event; however, only about 12,000 cubic yards of sediment reached Hamilton ponds. As in 1995, a significant percentage of this total volume was comprised of woody debris, boulders and cobble (10 percent, est.). Buckhorn Sediment Dam, on the other hand, had accumulated approximately 16,000 cubic yards since the 1995 survey. Therefore the combined sediment accumulation for 1996 & 1997 was nearly equal for Buckhorn Sediment Dam and Hamilton Ponds (16,000 versus 15,000 cubic yards). Considering that Buckhorn Sediment Dam captures the upper 25 percent of the watershed while Hamilton Ponds captures the remaining 75 percent, and that well over two times the amount of sediment came into the ponds versus the Sediment Dam in 1995 (because the ponds had filled, it could be much more than this) this is a positive trend.

The differences between the two years may also be in part to the differences in the storm events. The 1995 peak was caused by mainly by rainfall intensity and duration (7 inches in 24 hours) whereas the 1997 peak was more a result of warm rain on an existing snowcap and saturated soils (3.5 inches in 24 hours, 20 inches of rain in month proceeding).

Both the Buckhorn Sediment Dam and Hamilton Ponds will continue to be surveyed annually. It will take five to ten years of data with a couple more large storms before more definite conclusions can be drawn from the data.

Chapter 8
CONCLUSIONS TO DATE

Introduction

The Grass Valley Creek (GVC) restoration program has continually been monitored and subjected to peer review for the purpose of improving program efficiency and effectiveness. Each year more knowledge has been gained which has changed aspects of inventory, planning, design and implementation. The January and March storms of 1995 provided a wealth of knowledge, putting to the test many of the assumptions made to date. That January, the highest monthly total precipitation in 82 years of record was recorded at the Weaverville Ranger Station. The 24-inch monthly total eclipsed the old record of 18 inches recorded in December 1964. A rain gage located in the GVC watershed recorded 34 inches of precipitation for the month of January with 7 inches of rain recorded in a 24 hr period on January 9, 1995 and 15 inches of rain in 4 days between January 9-13. On January 9, the GVC stream gauging station at Fawn Lodge recorded the second highest mean daily discharge in 20 years of record (1700 cfs). This storm event was the “big storm” that the GVC program was designed to protect against.

The following recommendations represent the current methodology and technology which is being used in the GVC watershed restoration program at this time. Although this section is not intended to be a complete list of all current operating procedures, it does attempt to summarize some of the most relevant concepts which may be applied to sediment reduction projects in Decomposed Granite (DG) watersheds.

Physical Treatments

Inventory

Erosion Potential: Existing erosional features should be evaluated to determine the potential for future erosion. The age of an erosional feature can be determined from the existing vegetation. For example, if vegetation is well established in a gully, it can be assumed that the gully has been stable for the storm frequencies experienced during the life of the vegetation. A higher priority should be given to potential sites associated with recent disturbances rather than old features which are not actively eroding.

Sediment Delivery: Since sand-sized particles are not easily transported, sediment delivery potential is very important to consider in DG watersheds. For example, a road may be severely eroding, but the sediment may be deposited onto a hillslope away from a stream course. On the other hand, if a defined waterway exists, (i.e. gully or inboard ditch) which can transport sediment directly to a stream channel, sediment delivery can be very high. The entire stream network between the source of erosion to the impacted stream should be evaluated for delivery potential. Some small headwater drainages may exhibit high erosion rates but may deposit sediment onto a natural or man-made basin resulting in low to no sediment delivery downstream. Conversely, drainages which have steep gradients and well defined stream courses may have a 100 percent sediment delivery potential.

In order to get good estimates for erosion rates and sediment delivery all available sediment yield data should be analyzed. Examples of potential data sources are:

1. USGS stream gaging stations.
2. Sediment basins, ponds, dams, etc., where sediment may be captured and measured.
3. Silt Fences installed on hillslopes to measure sheet & rill erosion.

Having accurate sediment yield quantities measured for a basin or sub-basin is very useful for calibrating and validating sediment yield estimates for an individual site.

Mapping: An accurate map should be the first step of the inventory process. A mapping system should be devised using either good aerial photography or a digitized copy of a United States Geologic Survey (USGS) 1:24000 topographic map. Because all roads and drainages are not shown on a USGS map, additional mapping is required to accurately identify erosion sites. Accurate mapping is essential for future design, implementation, maintenance, and monitoring purposes. Misplaced site locations will lead to incorrect drainage area measurements, which are used to prescribe treatments, design structures, and prescribe culvert sizes.

Data Collection and Management: A standard data sheet should be developed prior to the field inventory of sites. The data sheet should be structured to be a "fill-in-the-blank form" which captures all relevant site information and organizes the data in a format which can be readily input into a spreadsheet or database. Standard terminology should be adopted for site descriptions so that the data may be queriable in a data base. Inventoried sites should be given a unique identifier or site number so that each site may be tracked from inventory through design, implementation, and future monitoring.

Planning

Prioritization: Sites which exhibited high erosion and sediment delivery potential should be considered highest priority for treatment. In DG these sites include:

> *Stream Diversions onto Roads:* In this instance by excavating a relatively small amount of fill from a stream crossing, hundreds or thousands of cubic yards of road fill may be prevented from entering the stream.
>
> *Road Fill in Stream Channels*: These features have a very high potential for erosion and are 100 percent deliverable to the stream. However, the volume of fill to be removed should be evaluated against the disturbance caused by excavation (i.e. if 20 cubic yards of fill is removed from 50 feet of channel length, the benefit-to-cost ratio would be much less than if 200 cubic yards of material were to be removed from the same length of channel).
>
> *Cutbanks with Inboard Ditches:* Cutbanks generally have very high rates of erosion and sediment delivery can be 100 percent if the inboard ditch discharges directly into a stream channel.

Logistics: Grouping sites into families or sub-watersheds can be helpful in organizing a timeline for delivery of materials and treatment. All materials should be "on-site" before road access is limited or removed. Heavy equipment, if needed, should be the appropriate size and type for the project. Undersized, oversized, or the wrong type of equipment for the project can lead respectively to: the project taking too long, damage to the environment, or a compromise in project quality.

Temporary Stream Diversions: When working in a flowing stream, a diversion around the project area should be in place before work begins. An effective diversion can reduce construction time and cost, improve quality of construction, and eliminate potential of causing turbidity in the stream. If a diversion is not practical, measures designed to reduce turbidity should be constructed downstream of the work area. Conventional "checkdams" which are built to pond water are generally not sufficient to settle the fine soil particles which cause turbidity. Rather, specially designed filters or "turbidity curtains" should be used to retain and filter the water. Notification of water quality officials or local landowners may be needed, as well as appreciated.

Design

Grade Stabilization

Soil/Cement Grade Stabilization Structures: These have proven to be very effective in DG when designed and built adequately. The first structures built four years ago have shown some erosion of the concrete but are still functioning as designed. However, it remains to be seen if the life of the structures will be adequate to stabilize the stream channels until vegetation necessary to provide long-term stability can become established. These structures have been used effectively in drainages up to 170 acres in size but are generally limited drainages less than 100 acres. Because of their relative low cost, ease of construction, and high effectiveness, soil/cement structures will continue to be the practice of choice when short term stream channel stabilization is required in small, ephemeral drainages. The most important factors to the success of the structure are adequate: soil-cement mixture, spillway capacity, outlet protection, spacing, and keyways in the channel bottom and sides.

Log Checkdams: These are generally more difficult to construct and have a higher potential for failure than soil/cement checkdams. This practice is currently being used only when cement or rock cannot be feasibly transported to a site. The most common cause for failure has been piping around the structure. This is difficult to avoid due to the nature of DG and the rigidness of the structure. However the risk can be minimized by: keying the logs well into the bank (2 feet minimum), using geotextile fabric in the keyway, well compacting the keyway, and by keeping spillway height less than 3 feet.

Nylon Filament Matting: This has not been used extensively due to material expense and environmental and aesthetic concerns regarding the use of synthetic materials in the restoration of natural stream channels. However, this practice has been very effective and will continue to be used where rock riprap would normally be required but is not feasible or accessible. The most important factor for the success of this practice is that the matting be very well keyed into the channel bottom. Although most manufacturers' specifications call for compacted soil to be used in the keyways, DG is too erosive to maintain the structure of the keyway. Therefore, it is recommended that a soil/cement mixture, using the same proportion and procedure used in soil/cement structures, be used in place of compacted soil.

Rock Riprap: Rock riprap is the most effective channel protection practice, but due to the expense has been limited to sites where maximum protection is required. If it is determined that a filter is required to be placed under the riprap, it is recommended to use a gravel or rock filter rather than geotextile fabric. It has been observed at high energy reaches of channel (in particular, culvert outlets) that rock can slide off the fabric.

When considering treatment of an eroding stream channel the cause of the erosion must be identified. If it is suspected that the erosion is occurring as a result of increased peak flows from roads or logged areas, the treatment of these areas should be considered before attempting channel stabilization measures.

Road Crossing Removal

When excavating a road crossing from a stream channel the goal has been to remove all the road fill while taking great care not to excavate below the pre-road channel grade. Because of the increased risk for channel instability if the crossing is not completely excavated or if the excavation goes below the pre-road channel grade, much effort has been placed on refining design and implementation procedures to achieve the most stable long-term channel configuration.

The first step of design is to survey the stream profile and hill slopes above, below, and through the crossing. This survey can be used to project the existing hillslopes and stream channel through the crossing to estimate the pre-road channel elevation and location. In addition to the design survey, the excavation should be monitored for indicators of the pre-road ground surface. Indicators such as buried tree stumps and logging debris can be used to distinguish between road fill and the original ground surface. Although these indicators can give a very good clue as to the approximate channel location, the exact pre-road channel elevation is generally not as readily apparent.

In the GVC watershed, most crossing excavations took place in small ephemeral drainages in DG where water-lain rock, riparian vegetation, and other channel-bottom indicators were generally non-existent. The channel bottom in these drainages is most often comprised of unconsolidated DG overlying granite bedrock. Occasionally bedrock outcrops may be found at the surface of the channel, but the depth to bedrock is commonly two to three feet, with much greater depths in alluvial reaches. Because indicators of original channel elevation are very subtle, the distinction between road fill and unconsolidated channel material may be very difficult to determine and somewhat irrelevant due to the highly erosive nature of both. Therefore, more reliance was placed on excavating the stream channel to conform to the channel profile above and below the crossing rather than on uncovering a distinct, well-defined channel bottom with the original properties still in tact.

Although removal of the road crossing may successfully restore the original channel elevation and configuration, the original channel structure has been highly disturbed as a result of crossing construction and removal. Excavated channels lack the resistance to erosion, which in the original channel, was provided by vegetation and the natural channel forming and sorting processes. Excavated channel bottoms were essentially comprised of loose, granular, unconsolidated DG, which is extremely erosive. This was recognized early in the program as a concern when considering channel excavations in DG. It was concluded at this time that either channel stabilization measures would have to be incorporated into the design or some risk would be assumed regarding post-excavation erosion.

The experience of other restoration programs has shown the greatest economy comes from the excavation of crossings and that post-excavation treatments are generally not as cost effective for the additional potential sediment savings. For example, if 200 cubic yards of sediment can be saved at a cost of $1000 by excavating the crossing with no channel stabilization the cost-to-benefit (C/B) ratio is $1000 for 200 cubic yards, which equals $5 per cubic yard of sediment saved. However, if 50 cubic yards of sediment will be lost by not providing channel protection a total of 250 cubic yards of sediment can be saved by excavating the crossing and providing channel protection. If the additional cost for the channel protection is $1000, the total project cost would be $2000 with a C/B ratio of $2000 for 250 cubic yards, which equals $8 per cubic yard. The C/B Ratio of the channel protection portion of the project would be $1000 for 50 cubic yards, which equals $20 per cubic yard. With a threshold C/B ratio of $10 per cubic yard, the crossing excavation with channel protection project would be feasible at $8 per cubic yard, however it would not be as cost effective as doing only the crossing excavation at $5 per cubic yard. Also, considering the channel-protection portion of the project alone, the C/B ratio of $20 per cubic yard exceeds the threshold C/B ratio of $10 per cubic yard.

Based on this economic evaluation, the focus of the GVC program became to perform crossing excavations without channel protection measures if the C/B ratio of the proposed project was less than $10 per cubic yard. The likelihood that the excavation would experience some “adjustment” (i.e., erosion) was determined to be acceptable as long as the volume of erosion did not exceed 20 percent of the original sediment yield estimate of the site. Although it was not certain under what circumstances that this level of adjustment may be exceeded. Work began in 1993 based on the philosophy that such methods be tried and the results monitored. That year, many stream crossings were excavated with only some having post-excavation channel protection installed. These sites were monitored through the winter of 1992-93 and were observed to experience little or no erosion. Unfortunately, that winter turned out to be extremely mild (the Fawn Lodge gauging station recorded the fourth lowest mean annual discharge in 20 years of record). Therefore, some uncertainty remained as to the amount of erosion that might occur under average or above-average stream flows. Work proceeded the following year (1994) under the same philosophy, of removing road fill from the channel and allowing for some post-excavation adjustment. The true test finally came in January 1995 with the “big storm”.

As a result of the January and March storms of 1995 some very large adjustments were observed that exceeded the definition of acceptable erosion. In order to quantify the impacts of the storms, all the large adjustments were surveyed to determine the volume of erosion from each site. This data was analyzed to determine the contributing factors which led to the unacceptable level of erosion recorded at these sites. From this analysis it was determined that the most relevant factors contributing to excessive erosion were: length of stream channel excavation, drainage area, and the underlying soil and geology of the site. Because of the vast amount, complexity, and interdependence of the variables involved, a statistical model could not be derived to quantify the relative weight of these factors. However, these factors did stand out as the most relevant. In addition to the surveyed sites a total of 150 crossings were evaluated from which the following results were obtained.

Geology/Soils: The majority of crossings were excavated in stream courses where the entire channel matrix was comprised solely of DG. In this setting the underlying material consists of unconsolidated DG (alluvium, colluvium, residuum) grading to bedrock. The competency of the bedrock varies depending on mineralogy, fracturing, and weathering. However, the western one third of the watershed has a different geology. In this area the granitic pluton is capped by a metamorphic layer through which the pluton has intruded. This has resulted in a mixture of metamorphic rock and DG in the channel matrix.

Stream channels in which metamorphic rock was present adjusted differently than did channels comprised solely of DG. These channels were able to armor themselves with the native rock in the channel matrix. As fine sediment was washed from the matrix, the rock sorted itself to form a rock lined channel. Consequently, the erosion resistance of the channel material increased in response to increasing stream flows. In no case where metamorphic rock was present in the channel matrix did post excavation erosion exceed the acceptable tolerance (i.e., 20 percent of pre-work estimated sediment yield).

This process did not occur in channels comprised solely of DG. In this setting the stream downcut through the unconsolidated material and sometimes well into the bedrock. In channels with deep unconsolidated material and/or highly fractured and weathered bedrock, the depth of downcutting was much greater than where more competent bedrock occurred near the surface. However, the existence of competent bedrock near the surface was rare and occurred mainly in steep headwater drainages. Consequently, the largest adjustments occurred at channel confluences where the depth of unconsolidated material was generally the greatest. All of the sites which exceeded the accepted erosion tolerance occurred at channel confluences with channel material composed solely of DG (i.e., no metamorphic rock).

Excavated Channel Length: Less than 10 percent of all crossings evaluated exceeded the acceptable erosion tolerance. However, less than 5 percent of sites with excavation lengths under 100 feet exceeded the tolerance while nearly 30 percent (seven) of the sites with excavation length over 200 feet exceeded the tolerance. Moreover, the erosion volume at two of these sites *exceeded* the original estimate of sediment yield volume of the site. The effect that the length of excavation had on the volume of adjustment was due to a combination of factors.

The largest crossing excavations were landings constructed at channel confluences. As discussed above, stream channels at these locations in DG were generally comprised of deep unconsolidated material. As this material eroded a headcut or series of headcuts formed and migrated through the excavation. However, in almost every case the headcut did not migrate beyond the top of excavation. The headcut at the top of excavation had exposed a dense rootmass in the layer of unconsolidated material which has checked gully migration (this has been a very good indicator of the importance of vegetation to channel stability). The length of the gully was generally equal to the length of excavation while the depth and width of gullying increased in relation to watershed discharge, channel grade, length of excavation and erosiveness of the channel material.

Based on the knowledge gained from the 1995 storms and a reevaluation of the remaining work in the watershed, the philosophy regarding crossing excavations has changed. Due to the extremely erosive nature of DG and the relatively few crossings identified for future excavation, it was decided to design crossing excavations with channel protection if potential for post-excavation erosion was significant. Although this increased project costs, increased efficiency in design and construction of temporary channel stabilization measures made it possible to complete most projects under the $10-per-cubic-yard target. Therefore, all of the remaining crossing excavations can be completed feasibly, with more potential sediment savings expected from these sites, by more effectively reducing over-all erosion.

As a general rule, channel protection measures should be used when excavating road crossings in DG when:

1. Length of channel excavation exceeds 50 feet;
2. Drainage area above the site exceeds 10 acres;
3. The stream channel above the excavation is “well defined,” indicating a relatively high frequency of surface flow;
4. Competent bedrock is not encountered at the channel surface.

Road Removal

This practice performed very well by eliminating the sources of erosion from a road (i.e., cut bank, surface, and fillslope). The only post-excavation erosion observed from these sites was some minor surface erosion and slumping of the regraded fills. However, very little surface erosion occurred where adequate mulching was done, and little to no slumping occurred when fills did not exceed 2.5:1 slope grade. Even where erosion did occur, very little sediment was delivered off site due to removal of the delivery system (concentrated flow).

Significant erosion was observed at a few sites where removal of the road fillslope extended to the bottom of a stream channel. With the freshly excavated slope left unprotected, the stream found a “soft spot” and cut into the streambank. In future work, when fill slopes encroach into a stream channel, the excavation will be limited to the slope above the anticipated high-water mark or the excavated bank will be protected by placing logs at the toe of the slope.

Outsloping

This practice also performed very well for its intended purpose. Although some minor surface erosion was observed on outsloped road surfaces and fillslopes, the sediment delivery off site was very low due to dispersion the road drainage. Some fillslope failures did occur on newly outsloped roads. It appears that water concentrated along the outside edge of the road due to ruts, ridges, or insufficient outslope grade. When the concentrated water discharged onto saturated fills, gullying and/or mass wasting occurred. Based on these observations the following additions were made to design criteria:

- Roads used for winter access needed to be graded on a regular basis to eliminate ruts, which may concentrate road drainage.
- The outside edge of the road should be sloped at a steeper grade than the road surface or slightly rounded to allow for rapid drainage off the fill surface.
- Additional rolling dips need to be installed to capture concentrated runoff from tire tracks and to direct drainage away from potentially unstable fill areas.

Sediment Traps

Excavated sediment traps have worked well for capturing sand-sized particles and will continue to be used at appropriate locations. These basins are constructed only in natural deposition areas that have previously been disturbed by road construction, and for which future access will be required. The basins shall be relatively shallow (2 to 3 feet) to avoid ponding a lot of water and to avoid oversteepening of the upstream channel grade. The inlets and outlets of basins shall be protected against erosion of excavated channels.

Implementation

Staff

- Project implementers should have knowledge or experience in heavy equipment supervision, earth science, ability to interpret plans, and possess basic survey skills.
- Implementation staff should be involved, whenever possible, during the design process, prior to commencement of work.
- Skilled labor may be more expensive but it enables a higher degree of quality control in the project.

Contracting

Contracting involves more planning and design but may cut costs involved with equipment, staff, and crew time.

Revegetation Treatments

Planning, Inventorying, and Monitoring

The key to an organized and successful revegetation project is a detailed plan that describes sites, lists materials and labor needs, and provides for monitoring once revegetation treatments have been implemented. Site inventorying is crucial in determining appropriate revegetation treatments, especially for selecting plant species. A monitoring program is also crucial for any long-term revegetation project, so that treatments can be evaluated for effectiveness over time.

Use of Native Plant Materials

In any revegetation project, the use of native species is crucial to re-establish or enhance the natural vegetation communities of the restoration site. Not only is it important to use those native plants found within the restoration area, but to use local ecotypes that have evolved specifically in that area. The best means of obtaining local materials is to collect seed from the restoration project area.

The use of native grass has been an effective means of revegetating roads, skids, and landings. The combination of fertilizing, seeding, and mulching a site after completion of equipment work has resulted in dense stands of grasses that require no additional maintenance. Such stands of native grasses can be used as harvest sites for native straw and seed.

Use of Native Straw Mulches

Both native and non-native straws are effective mulches and will produce dense herbaceous cover of native grasses if used in conjunction with a seed mix. Due to the higher cost of native straw, the use of wheat and barley straw is more economical and the preferred mulching straw.

Willow Wattling and Staking

The use of willow wattles and stakes were found to be a simple and inexpensive means of revegetating riparian areas and in helping to stabilize channels and gullies. To ensure success, however, proper techniques must be used in the timing and placement of materials.

Sheet and Rill Treatments

Although numerous materials and techniques were tested for revegetating sheet and rill slopes, no single treatment was found to be both economical and effective in establishing vegetation on such harsh sites. The current approach in the GVC revegetation program is to plant in and around sheet and rill areas in an attempt to establish vegetation.

APPENDICES

Appendix A
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Appendix B
ABBREVIATIONS AND ACRONYMS

Abbreviation/Acronym	Definition
BoR	Bureau of Reclamation
BLM	Bureau of Land Management
CAPPM	Cost Accounting Policies and Procedures Manual
CAT	Critical-Area Treatment(s)
C/B	Cost-to-Benefit (Ratio)
CCC	California Conservation Corps
CDF	California Department of Forestry
cfs	Cubic feet per second
CUPCCAA	California Uniform Public Construction Cost Accounting Act
CVP	Central Valley Project
DG	Decomposed Granite
DWR	Department of Water Resources
GIS	Geographic Information System
GVC	Grass Valley Creek
Lbs	Pounds
NoI	Notice of Intent
NRCS	Natural Resources Conservation Service
O&M	Operation and Maintenance
ORV	Off-road Vehicle
PWA	Pacific Watershed Associates
RCD	Trinity County Resource Conservation District
RDP	Responsible Design Person
SAG	Scientific Advisory Group
SCS	USDA Soil Conservation Service
UC	University of California
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geologic Survey

Appendix C
GLOSSARY OF TERMS

Aspect	Compass direction (North, South, East, West) toward which a hillside faces.
Batholith	Literally, "Deep rocks." A body of intrusive rock at least 40 square miles in area.
Cutslope	The road-cut, hillslope side of a road.
Diversion (intentional)	Re-routing of stream flow around a work site while work is undertaken in a stream channel.
Diversion (unintentional)	Re-routing of streamflow down a road surface due to failure of a road crossing.
End-hauling	Transporting excavated fill or sediment off-site for spoiling at another location.
Excavated Sediment Basin	In-stream structure that captures sediment in small, ephemeral drainages (same as Sediment Catchment Basin).
In-Slope	Road surface graded so that the lowest point on the road surface is near the cutbank, rather than the outer edge (see also Cutslope).
Landing	Wide, flat ground surface used to load timber onto logging trucks.
Out-Slope	Road surface graded so that the lowest point on the road surface is near the outer edge, opposite the cutbank (see also In-Slope).
Rip-rap	Large, angular rocks used to dissipate flow energy in stream channels and outlet points.
Sediment Catchment Basin	In-stream structure that captures sediment in small, ephemeral drainages (same as Excavated Sediment Trap).
Sediment Dam	A large reservoir meant to capture sediment. Buckhorn Sediment Dam was designed to capture sediment flowing from the headwaters of GVC

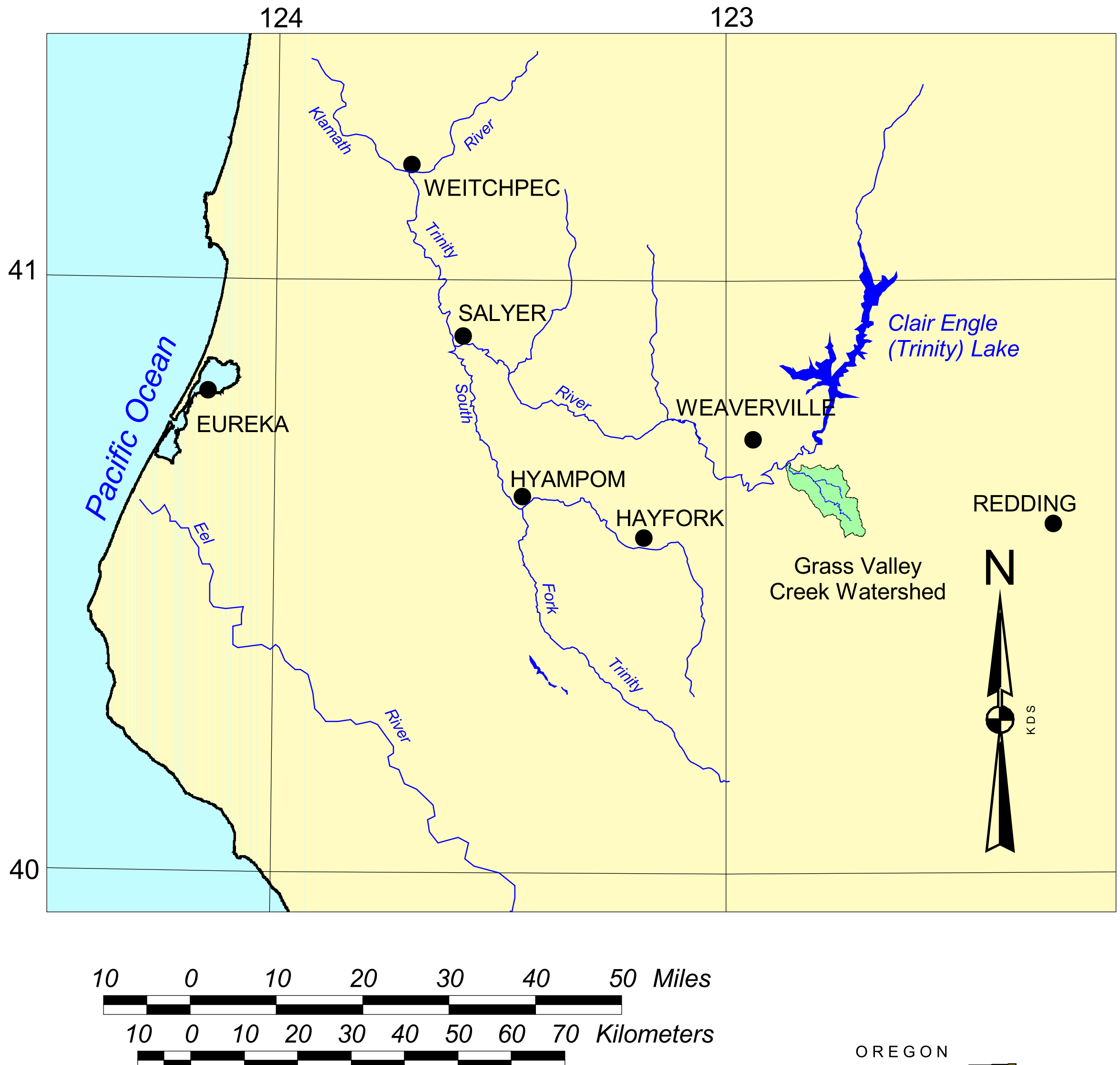
	for a period of 50 years, after which time it would no longer be effective. Unlike the sediment ponds, the sediment dam is not periodically dredged.
Sediment Pond	Pools constructed at the mouth of GVC meant to capture sediment that has migrated downstream as far as the mouth of the stream. The three ponds at the confluence of GVC and the Trinity River are known as “Hamilton Ponds.” The ponds are periodically dredged of sediment to restore their effectiveness.
Skid (trails, roads)	Rough roads used to extract timber and transport it to landings to be loaded. typically occur at tectonic plate boundaries.
Spoiling	Deposition of excavated materials (road fill or sediment) in a safe (not subject to erosion) location.
Turbidity	A measure of water clarity. Water is more or less turbid depending on the amount of suspended material (particularly silt or clay) it contains.
Ultramafic	Ferro-magnesian silicate-type rocks occurring widely in western portions of the U.S. Ultramafics typically occur at tectonic plate boundaries between oceanic and continental crust layers.
X-Section	Cross-section.
X-Slope	Cross-slope. A design that places logs or other treatments along the contour of a hillside.

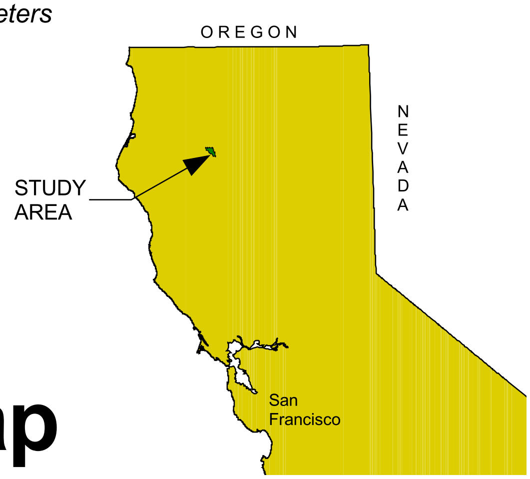
Appendix D
MAPS

1. Location of the GVC Watershed

2. GVC Restoration Work Sites

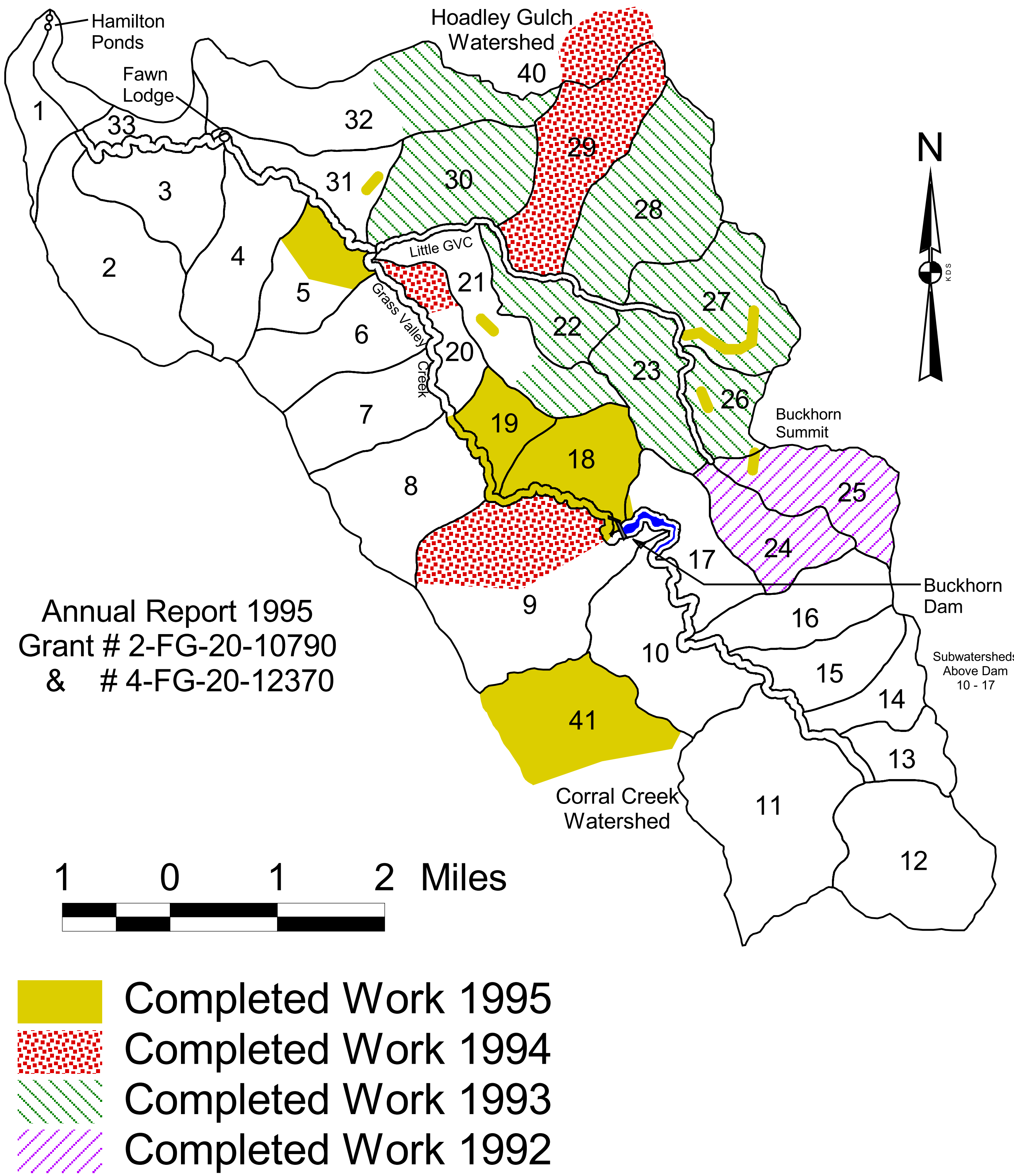
3. GVC Plant Communities



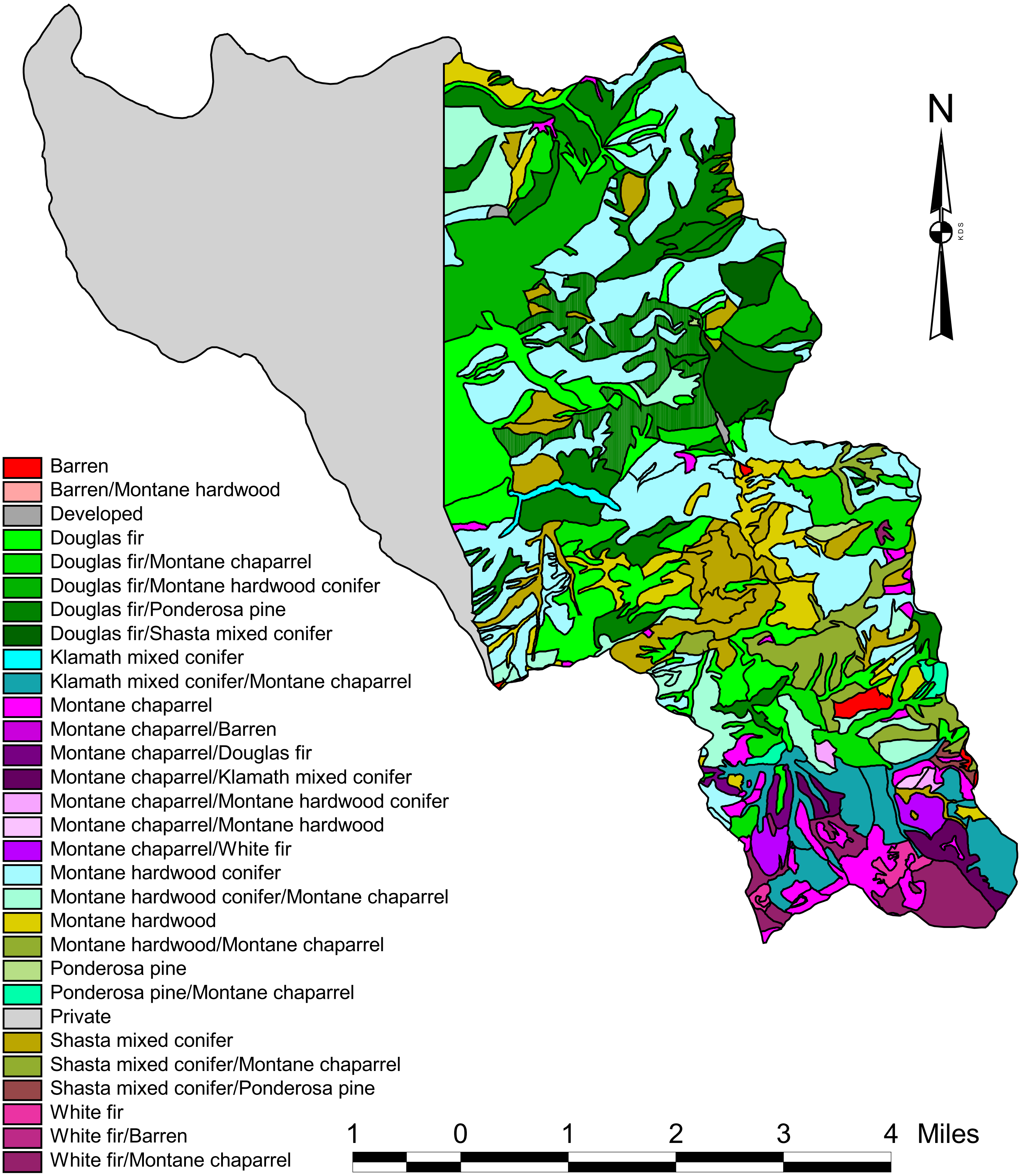


Location Map
Grass Valley Creek Watershed

Grass Valley Creek Watershed Restoration Work (with Hoadley and Indian Creek Watersheds) Figure 1



Grass Valley Creek
Plant communities



Appendix E
DATA BASE FORMS

1. Terms

2. Format

3. Erosion Site identification

4. Treatment Site Identification

Glossary for Erosion Site Moniloring Terminology for Data Base

Standard Terminology	Abbreviations	Definition	Example
Road (Location)	none	Associated with current or past vehicle use.	Mainline, Dam, CLRN, CLRS, Odd fellows
"Highway (Type)	HWY	Hwy 299, Lewiston	
'Main (Type)	none	A maintained road with a paved or rock surface.	
'Haul (Type)	none	An unpaved road used primarily for logging trucks.	
'Ridge Skid (Type)	RSkid	An unmaintained road on a ridge used for heavy equipment.	
Side Slope Skid (Type)	SSSkid	An unmaintained road on a slope used for heavy equipment.	
Skid (Type)	non0	An unmaintained road in a channel.	
'Fill Slope (Source)	none	Where road cut material Is dumped, downslope of road.	
"Cut bank (Source)	none	Where slope was removed to create road width, upslope of road.	
'Surface (Source)	none	The "road" surface.	
'Sheet and Rill (Cause)	S&R	Uniform shallow erosion (sheet), irregular grooves usually narrow and long (rills).	
'Road Drainage (Cause)	Road Drain	Water concentrated by compacted road surface runs onto road fill.	
'Diversion (Cause)	none	Stream diverted by blocked culvert, road fill in channel, fallen tree in channel.	
'Mass Movement (Cause)	Mass Move	Large failures, rotational slides, slumps, earth flows.	
'Inboard ditch (Cause)	Inbd Ditch	Concentrated flow from the road surface causes ditch to form at the toe of the cut bank..	
Channel (Location)	none	Associated with permenant or ephemeral streams, creeks, and tributaries.	
Watershed Area (Type)	WSHDA	Area calculated from CAD map, in acres.	
'Road Fill (Source)	none	Road fill entering channel from fill slope, stream crossing, or landing.	
'Channel Fill (Source)	none	Alluvium entering channel from stream bank erosion, road construction, road drainage, or deforestation	
'Road Construction (Cause)	Road Const	Road construction in or near the channel or where fill has been deposited in the channel.	
'Log Jam (Cause)	none	Where logs have fallen into the channel pooling, and diverting water into toes of stream banks.	
Deforestation (Cause)	Deforest	Removal of dominant vegetation, loss of canopy protection, binding strength of root mass, felling and skidding of trees.	
'Sedimentation (Cause)	Sediment	Process of sediment delivery to the stream channel, causes channel aggredation.	
'Stream Bank (Cause)	none	Streambank collapsing, oversteepened channels (stream cutting at toe of banks), widening of channel.	
'Unknown	none	Should be rare if at all, most likely sheet erosion on channel banks.	
'Crossing (Cause)	none	Road fill pushed into the channel for road construction.	
Landing (Cause)	none	Landing built in the stream corridor, for loading of raw timber.	
'Fill Slope (Cause)	none	Where fill slope is eroding into channel.	
Hill Slope ***(Location)***	none	A mountainside, forest or medow.	
'Soil (Type)	Either DG or non DG	Decomposed Granite or not decomposed Granite	
'Gully (Source)	none	A hiltslopo gully caused by road drainage.	
'Off Road Vehicle (Cause)	ORV	Two, three and four wheel gas poworcd **vehicles with big tires that toar up soil and protective duff, repeated use especiallyon DG results in severe S&R, and** gully	
Equipment (Treatment Class)	none	Restoration **work was** primarily **done with equipment.**	
'Hand (Treatment Class)	none	Restoration **work was** primarily **dono by hand.**	
Treatment Descriptions			
'Excavation (Practice)	none	Sediment and alluvium was removed and placed clscwhere.	
Crossing (Description)	non0	Removal of stream or ephemeral **channel crossing. accompanied by channel contouring and mulching and planting.**	
'Landing (Description)	non0	**Landing excavated from the stream channel.**	
'Landing Pullback (Description)	Landing PB	**Landing pulled back to countour with the site topography.**	
'Road (Description)	non0	**Outsloping, or excavation aro the possible treatments.**	
Stroam Bank (Description)	none	**Where streambank has failed or is overstecpened or undercut,** has **been re-contourad, mulched and planted possibly accompanied by oroslon blankot.**	
'Sediment Basin (Description)	Sed Basin	**Constructed to capture upslopo sediment sources.**	
'Rock Crossing (Description)	non0	**Where stream crossing has** been excavated, and armored with rock.	
'Alluvium (Description)	none	Channel excavated to remove potentially mobile sediment.	
Sediment Removal (Descripti	Scd Removal	Where a sediment basin was cleaned out.	
'Road Drainage (Practice)	Road Drain	Addressing water concentrated by compacted road surface causing erosion.	
Water Bars (Description)	none	Directs road concentrated water off road at intervals to an oncrgy dissipation **site.**	
Rolling Dip (Description)	none	Dip in road to allow drainage, usually w/ energy dissipation sometimes just brush or thick vegetation.	
Culvert (Description)	none	Unplugging, replaclng or romoving completely the culvert and crossing.	
Outslope (Description)	none	Road sloped to avoid concentration of water on inside or surface of road, gentle outslope usually 2-3 %.	
Rock surface (Description)	Rock Surf	Protection of road surface with aggregato to protect from rain drop impact, used as maintinence for roads under heavy use.	
Grading (Description)	non0	Grading to eliminate rills and gullies that concentrate road drainage.	
Outlet Protection (Description	Outlet Protect	Energy dissipation structure to handle concentrated road drainago.	

Head Cut (Practice)	none	Active portion of gully eroding "headward" (into ungullyed area upslope)
'Geotech Bag (Description)	Gco Bag-L, or M, or S	Geotextile bags filled with DG/cement mixture or just DG. placed at the eroding head cut.
'Cement Bag (Description)	Cem Bag-L, or M, or S	Burlap Bag filled with DG/ cement mixture, placed at the eroding headcut.
Log (Description)	none	Log structure built into the slope at the toe of the cut bank, can be re-enforced with geo-textile material.
'Grade stabilization (Practice)	Grade Stab	Attempt to prevent furthur downcutting of gullies and stabilize slope by retaining sediment behind structures.
'Gcotcch Bag (Description)	Gco Bag-L, or M, or S	Geotextile bags filled with cement/ DG mixture and made into a checkdam.
Cement Bag(Dcscription)	Cem Bag-C, or M, or S	Burlap bags filled with cement/DG mixture and made into a checkdam.
'Log Checkdam (Description)	Log Ckdam-L, or M. or S	Log structure sometimes with wing walls, and a spillway, used in combination with geotextile material and cement or geotech bags.
'Log Step (Description)	none	Log structure built into a steep gully, can be re-enforced with geo-textile material.
Rock Riprap (Description)	none	8-12 inch angular rock placed in order to prevent furthur degrading of slope.
'Channel Mat (Description)	none	Geotextile material laid in channel to prevent scour and downcutting, staked in'or used w/ rock.
'Straw Dam (Description)	none	Bates of straw placed, dug in or staked into the base of the streambank or hillslope to retain sediment.
'Slope Stabilization (Practice)	Slope Stab	Attempt to stop, slow and restore slopes suffering from sheet and rill erosion caused by road building and deforestation.
X-Slope Log (Description)	none	Logs staked into hillslope along contour to recruit sediment and establish good microsite conditions for vegetation establishment.
'Straw Wattle(Descriplion)	Straw Watt	Geotech mesh tube stuffed with straw staked in along contour to retain sediment and provide microsite for vegetation establishment.
'Mulch (Description)	none	Straw spread over ground surface to protect soil from rain drop impact, establish protective duff layer, and to provide sites ***for grass*** and forb regeneration.
'Contour Furrow (Description)	none	Shallow ditches built along contour of slope to reduce slope area exposed to overland flow, and to provide microsite for vegetation establishment.
'Erosion Blanket (Description)	none	Geotextile mesh mat filled with straw, coconut fiber, or shredded wood laid on slope to protect the soil surface and encourage vegetative establishment.
'Lop and Scatter (Description)	Lop & Scttr	Branches and logging slash, scattered across slope surface to trap sediment, provide microsites, and reduce effects of overland flow.
'Vegetative (Practice)	none	Planting, seeding and bio-engineering efforts aimed at long term stabilization
'Pine (Description)	none	Pondorosa Pine, Sugar Pine, Knobcone Pine, Jeffery Pine, 8 inch plug stalk.
'Fir (Description)	none	Douglas Fir, 8 inch plug stalk.
'SCS Seed (Description)	none	Berber Orchardgrass, Luna Pubescent Wheatgrass, Zorro Fescue (annual), and Rose Clover. See Susan for more info on vegetation monitoring.
'Native Seed (Description)	none	Elymus glaucus, Festuca californica.
Willow Stakes (Description)	none	Willow cuttings aprox. 12 inches in length used for staking geotech material to hillslopes and streambanks, attempt to establish longer term stability in structures.
Willow Wattles (Description)	Willow Watt	Bunch of willow cuttings bound and woven together, held in the channel with willow stakes, used to stabilize stream banks.
'Shrubs (Description)	none	Deerbrush, Snowbrush, Curleaf Mt. Mahogany, Manzanita.

Access Database Tables are named and described as follows;

Site Info: All site information specific to each unique site (one record per site).

SITE	LOCAT	TYPE	WSA	SOURCE	CAUSE	EP	PE	FE	DR	SY	EFF	SS.	GRD	CAN	ASP	ELEV	OLD NUM
091201	Channl	E	9	RdFill	Lnding		60	1332	100	1332	90	1199	30	65	IO	2750	12L
091501	Road	SSSkid		Surfce	RdDrn			43	75	32	90	29	15	30	315	2800	15-2/15S
091503	Road	SSSkid		Surfce	RdDrn								45	35	70		15R
091504	Channl	E	2'	RdFill	'Xing			153	100	153	90	138	25	35	70		15-1X
091505	Channl	E	1	RdFill				100	100	100	90		35				15-3X

SITE: a number that identifies eachfromuothersthat tis usedto tle retogether.
LOCXT: lowtron of site.
TYPE: type
WSA: watershed area (behind site - usually only used with Channel sites).
source of erosion from site.
CAUSE: cause of erosion from site.
EP: Erosion Potential of site.
PE: Past Erosion of site.
FE: Future Erosion of site.
DR: Delivery Ratio of site.
SY: Sediment Yield of site.
EFF: Project Effectiveness of treatment.
SS: Sediment Saved after treatment.
CRD: grade or slope of site.
CAN: canopy of site.
ASP: aspect of site (facing direction).
ELEV: elevation of site.
OLD_NUM: old number of site (if applicable - often a number used by field crew that may not be usable in database).

PhysTrt: Physical treatments (each treatment for a single site has it's own record).

SITE	CLASS	PRACT	DESCRI	NUM	OBS	QUANT	UNT	GRD	OS	IMPD	RVWD	0 M	NOTE
091201	Equip	Excav	Lnding		""""	100	ft			9/94	10/95		No
091201	Equip	Excav	Road		""""	310	ft	15	30	9/94	10/95		No
091501	Equip	Excav	Road		""""	175	ft	15	30	6/94	10/95		No
091503	Equip	RdDrn	OutSlp		""""	300	ft	40	50	8/94	10/95		No
091504	Equip	Excav	Xing		""""	40	ft	--		8/94	10/95		No
091505	Equip	Excav	Xing		""""	40	ft			8/94	10/95		-x0-

SITE: a number that identifies each unique site that is used to tie records from others tables together.
CLASS: treatment classification (Equipment or Hand).
PRACT: treatment practice.
DESCRI: treatment description.
NUM: number (of Waterbars. Rolling Dips. or Structures).
OBS: observational evaluation (we will be discontinuing the collection of this data).
QUANT: quantity (in linear feet or cubic yards).
UNT: units of measure for QUANT.
GRD: grade or slope of road treatments
OS: outslope grade of road treatments.
IMPD: implementation date.
RVWD: monitored review date.
O_M: operation and maintenance date (if applicable).
NOTE: pertinent information found on data sheets (Yes or No field).

VegTrt: Vegetative treatments (each treatment for a single site has it's own record).

SITE	PRACT	DESCRI	IMPD	QTY	SUPP	AREA	OBS	GRD	CAN	ASP	COV	CON	SWN	NAT	RVWD	O_M
091201	Plant	PIPO	11/94	450	LOPA	24310	5	30	65	IO	85	H	70	15	10/95	
091201	Seed	RCD	9/94	4.5	COSE	9310	70	30	65	IO	85	H	70	15	10/95	
091201	SlpSt	L&S	9/94			7000	75	30	65	IO	85				10/95	
091201	SlpStM	DEEL	9/94	21	COSE	9310	80	30	65	IO	85	H	70	15	10/95	

Most fields have the same description as in Tables above. The differences are as follow;

QTY: numeric quantity of treatment (i.e.: 450 trees [Ponderosa Pine], 4.5 pounds [of RCD grass seed], 2 1 bales [of Deschampsia Elongata]. etc.).
SUPP: supplier of treatment.
AREA: area of treatment (in square feet).
COV: observed ground coverage.
CON: consistency of ground coverage.
SWN: sown species in ground coverage.
NAT: naturally occurring species in ground coverage.

Erosion Site Identification

Site #	Location	Type	Source	Cause
	Road	Haul		
		Ridge Skid		
		Side Slope Skid		
		Main		
		Skid		
		Highway		
			Fill Slope	Sheet & Rill
				Road Drainage
				Diversion
				Mass Movement
			Cut Bank	Inboard Ditch
				Sheet & Rill
				Mass Movement
			Surface	Sheet & Rill
				Road Drainage
				Diversion
				Gully
	Channel	Perrenial		
		Intermittent		
		Ephemeral		
			Road Fill	Crossing
				Landing
				Fill Slope
			Channel Fill	Road Constructior
				Road Drainage
				Log Jam
				Deforestation
				Sediment
				Stream Bank
				Unknown
	Hill Slope	Soil		
			Gully	Road Drainage
				Diversion
				Off-Road Vehicle
			Sheet & Rill	Deforestation
				Off-Road Vehicle
			Mass Movement	Road Constructior
				Road Drainage
				Deforestation
				Unknown

Treatment Site Identification

Trt Class	Practice	Description	Number	Observ.	Quantity	Unit	Grade	Out Slope	Imp_Date	Review_Dt	O_M_Dt
Equip											
-land											
	Channel Armor	Cement Bag	#	#					#	#	#
		Logs	#	#					#	#	#
	Excavation	Alluvium		#	#	ft			#	#	#
		Crossing		#	#	ft			#	#	#
		Landing		#	#	ft			#	#	#
		Landing Pullback		#	#	ft			#	#	#
		Rock Crossing		#	#	ft			#	#	#
		Road		#	#	ft	#	#	#	#	#
		Sediment Basin		#	#	yrd3			#	#	#
		Sediment Removal		#	#	yrd3			#	#	#
		Stream Bank		#	#	ft			#	#	#
	Grade Stabilization	Cement Bag	#	#			#		#	#	#
		Channel Mat		#	#	ft			#	#	#
		Geotech Bag	#	#			#		#	#	#
		Log Checkdam	#	#			#		#	#	#
		Log Step	#	#			#		#	#	#
		Rock Riprap		#	#	ft	#		#	#	#
		Straw Dam	#	#			#		#	#	#
	Head Cut	Cement Bag	#	#			#		#	#	#
		Geotech Bag	#	#			#		#	#	#
		Log	#	#			#		#	#	#
	Road Drainage	Culvert	#	#					#	#	#
		Drop Inlet	#	#					#	#	#
		Grading		#	#	ft			#	#	#
		I nslope		#	#	ft	#	#	#	#	#
		Outlet Protection	#	#			#	#	#	#	#
		Outslope		#	#	ft	#	#	#	#	#
		Ripped		#	#	ft	#	#	#	#	#
		Rock Surface		#	#	ft	#	#	#	#	#
		Rolling Dip	#	#			#	#	#	#	#
		Water Bar	#	#			#	#	#	#	#
	Slope Stabilization	Contour#Furrow		#	#	ft2	#	#			#
		Cross-S#pe Log	#	#	#	ft2	#	#			#
		Erosion Blanket		#	#	ft2	#	#			#
		Straw Bales	#	#	#	ft2	#	#			#
		Straw Wattle		#	#	ft2	#	#			#

Appendix F

FORMS UTILIZED IN THE PLANNING AND IMPLEMENTATION PROCESS

1. Erosion Site Identification
2. Treatment Site Identification
3. Erosion Site Inventory Worksheet
4. Revegetation Form
5. Project Implementation Worksheet
6. Erosion Volume Calculation
7. Sediment Delivery Ratio for Erosion Sites
8. GVC Watershed Inventory Data Sheet
9. GVC Seed Collection Inventory

TABLE 1: EROSION SITE IDENTIFICATION

3/1 5/96

STANDARD TERMINOLOGY FOR DATA BASE

Location: Road

Type: Skid | Haul | Maintained | Paved

Source:	Cut Bank	Road Surface	Fill Slope	Stream Crossina
Cause:	Inboard Ditch	Road Drainage	S&R	No Culvert
		Stream Diversion	Road Drainage	Unmaint. Culvert
			Stream Diversion	Undersized Culvert
			Stream Channel	Humboldt
			Mass Movement	

Location: Channel

Type: Watershed Area (ac)

Source:	Head Cut	Stream Bank
Cause:	Road Drainage	Road Drainage
	Road Construction	Road Construction
	Mining	Log Jam
	Logging	Sedimentation
	Unknown	Mining
		Logging
		Unknown

Location: Hill Slope

Type: Soil (DG or Non-DG)

Source:	Gully	S&R	Mass Movement
Cause:	Road Drainage	Logging	Road Construction
	Stream Diversion	ORV	Road Drainage
	ORV		Logging
	Mining		Unknown

TABLE 2: TREATMENT SITE IDENTIFICATION

Trt Class: Equipment | Hand

Practice:	Excavation	Road Drainage	Head Cut	Grade Stab (ft)	Slope Stab.(sq ft)
Description:	Crcssing(yd3)	Water Bar(ft)	Rock	Cement Bag	X-Slope Log
	Road(ft)	Rolling Dip(ft)	Cement Bag	Log Chkdam	Willow-Wattle
	Stream Bank(ft)	Outslope (ft)		Rock Riprap	Erosion Blanket
	Sed Basin(yd3)	Rock Surface		Channel Mat	
	Sed Removal(yd3)	Rock Crossing(yd3)		Willow dam	
	Lndg Pullback(yd3)	Culvert(Dia.)			
		Outlet Prot.(yd3)			

EROSION SITE INVENTORY WORKSHEET

3/15/96

Watershed ____________________ Evaluated By: __________

Site# ____________________ Date: __________

EROSION SITE DATA

Location: ROAD CHANNEL HILL SLOPE

Type: __________ Source: __________ Cause: __________

Erosion Potential: HIGH MODERATE LOW

Volume Method: ____________________ Dimensions: __________

Past Erosion: __________ (cu. yds.) Future Erosion: __________ (cu. yds.)

SEDIMENT DELIVERY DATA

Distance to Channel: < 100' 100-200' > 200'

Hillslope Grade to Channel: O-30% 30-50% > 50%

Sediment Delivery Ratio __________ %

Sediment Yield = Future Erosion X Sediment Delivery Ratio = __________ (cu. yds.)

TREATMENT DATA

TRT Class: EQUIPMENT HAND COMBINATION

Practice: ____________________ Description: ____________________

CAT? Y/N Veg? Y/N Project Effectiveness: __________ %

IMPLEMENTATION DATA

Equipment Type: BACKHOE EXCAVATOR DOZER

Equipment Hours: __________ (hrs)

Crew Time: __________ (h rs)

Materials:

Comments: (see sketch on back)

GRASS VALLEY CREEK WATERSHED RESTORATION
REVEGETATION FORM

Subwatershed#__________ Field Site#____________________ Database+____________________
Location: __________________Township: _______Range:__________Section:______________________
Revegetation Person:________________ Inventoried By:_________________Date Inventoried:_______________

SITE DATA:

Area:___________________
Aspect:_________________
Elevation:_________,_____
Slope:__________________
Overstory Canopy:_______
Vegetative Ground Cover: ________
Surface Organic Material: ________
Soil Depth:___________

Site Characteristics:____
Previous Disturbance:____
Logging History:____
Access to Site:____
Plantability: High__________Medium__________Low_________
Existing Vegetation

Critical AREA Treatment:

Seed	Amount	Fertilizer	Amount	Mulch	Amount	Date Treated	Crew Hours

Planting:

Species	Amount	Zone/Elev	Stock	Nurseyr	Date Planted	Crew Hours

Plant Prescription: Comments: Photos:

PROJECT IMPLEMENTATION WORKSHEET

3/15/96

Watershed ________________ Supervised By: ________

Site# ________________ Implementation Date: ________

Treatment Class: EQUIPMENT HAND

EXCAVATION DATA

Practice Description: ________________

QUANTITY (Enter 1)

Excavation Volume:	________	(yd3)	(Crossing, Sed Basin, Sed Removal, Lndg Pullback)
Excavation Length:	________	(ft)	(Road, Stream Bank)
Channel Grade:	________	(%)	(Crossing)

ROAD DRAINAGE DATA

Practice Description: ________________ Number: ________
(Water Bars or Rolling Dips)

QUANTITY (Enter 1)

Road Length:	________	(ft)	(Water Bar, Roiling Dip, Outslope, Rock Surface)
Rock Volume:	________	(yd3)	(Rock Crossing, Outlet Protection)
Culvert Diameter:	________	(in)	(Culvert)
Channel Grade:	________	(%)	(Rock Crossing, Culvert)
Outslope Grade:	________	(%)	(Outslope, Rock Surface)

STREAM STABILIZATION DATA

Practice Description: ________________ Number: ________
(Number of Structures)

QUANTITY (Enter 1)

Channel Length:	________	(ft)	(All Grade Stab. Practices - N/A for Headcut Structure)
Channel Grade:	________	(%)	(All)

EQUIPMENT DATA

Equipment Type: BACKHOE EXCAVATOR DOZER

Equipment Hours: ________ (hrs)

Estimated Project Effectiveness: ________ (%)

Sediment Savings = Sediment Yield X Project Effectiveness = ________ (cu. yds.)

EROSION VOLUME CALCULATION

Source	Volume Method
Road	
Cut Bank	Prism (Lateral Recession)
Surface	Gully or S&R
Fill Slope	Gully, Prism, S&R
Stream Crossing	Crossing Worksheet
Stream Channel	
Stream Bank	Prism
Stream Headcut	Gully
Hillslope	Gully, S&R

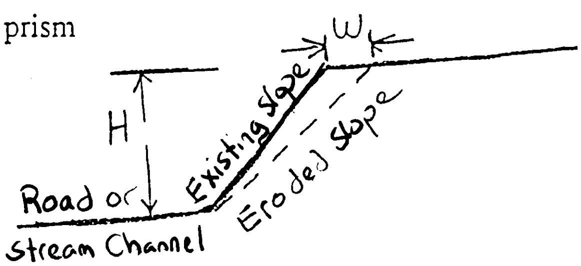
Prism: $\frac{\text{(H)eight * (Width * (L)ength}}{54}$ = Erosion Volume (cu. yds.)

where:

H = Vertical height of prism measured from the toe to top of slope (ft)

W = Horizontal width of prism measured from existing edge to estimated edge of the eroded slope. (ft)

L = Total length of prism (ft)



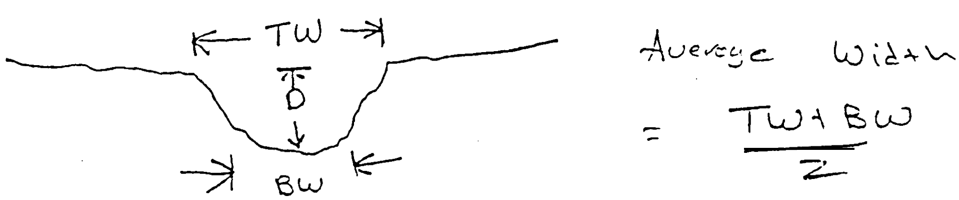
Gu $\frac{\text{\{D)epth * (Width * (L)ength}}{27}$ = Erosion Volume (cu. yds.)

where:

D = Depth of gully, usually measured from existing gully (ft)

W = Average of top & bottom widths usually measured from existing gully. (ft)

L = Total length of gully (ft)



SEDIMENT DELIVERY RATIO FOR EROSION SITES

DELIVERY RATIO FOR EROSION SITES LOCATED IN A STREAM CHANNEL = 100%

NOTE: However this should be field verified to see if natural deposition areas or sediment basins are located in the stream channel downstream.

DELIVERY RATIO FOR HILLSLOPE AND ROAD EROSION SITES

Dist to Channel (ft)	Hillslope Grade Between Erosion Site & Channel		
	0-30%	30-50%	> 50%
< 100	**20%**	**50%**	**80%**
100-200	**10%**	**30%**	**50%**
> 200	**0%**	**10%**	**20%**

NOTE: If sediment can be tranported from the site directly to the stream channel by way of inboard ditch or gully, the delivery is 100% to that channel.

GRASS VALLEY CREEK WATERSHED INVENTORY DATA SHEET

Is there more than one problem at this site (circle): **Yes** **No**

Site number: ____________ Date mapped ________ by ______.
Land Ownership: ____________ Photos ________ roll ______.

SITE INFORMATION AND ACCESS:

Location: longitude ____________ latitude ____________ *Loran or Topo?*
Air Photos Used: ____________
Road Classification(circle) : H C P T S A Road Gradient ______%
Ease of access (choose 1): driveable in *2wd* _. *4wd* *walk?* (mi) ______.
Eqpmt only? Y__ N__ *MINOR or MAJOR* rebuild required for access
Comment on access: ____________.

Site info: slope above slope below% | springs present? Y / N
'Aspect '(degrees) : ______ 'depth to bedrock (in.) ________.
Soil type: DG ________ Non-DG ________ Colluvial ________.
hillslope position (enter what applies): ____________.
Channel Type: peren. ____ intermit. ____ ephem. Gradient: ______.
Comment on site: ____________.

PROBLEM DATA
Cause: natural ________ man-induced ________ combo ________.
Status: Active ______ Inactive ______ Potential ______.
For active features - change appears ______ gradual or ______ fast
Most recent activity (list in order of volumetric importance):
S&R ______ gully ______ ravel ______ sliding ______ bankcutting ______.
Comment on problem: ____________.

NATURE OF PROBLEM:
Source:
A: Road check: surface __ ditch cut fill __ gully
B: Skid trail check: __ surface ditch __ cut __ fill __ gully
C: Landing check: __ surface - ditch __ cut __ fill __ gully
D: Stream Erosion type: log - jam bank slough ____ headcut
E: Gully
F: Sheet and Rill Surface erosion
G: Debris slide ____ existing potential
____ H: Landslide ____ existing potential
I: Stream Crossing

FOR ALL STREAM CROSSING PROBLEMS: (use 1 if not applicable)

type of problem: ______ diversion ______ failure ______ Humboldt
1. Xing Width (ft) ______ Est. Drainage area above Xing (ac) ______.
2. CMP size (in): ____ Sized properly? Y/N If no, what size? ____.
3. est. diversion distance (ft): ________.
4. Potential for CMP to plug: *High or Low*
5. Plug cause: woody debris sediment ___ vegetation ___ combo ___
6. H20 source: Ditch ____ Stream ____ road runoff - D + S ____.
7. If Road Shaping required, what length (ft): ________.
Comment on XING: ____________.

PAST EROSION AND FUTURE EROSION **POTENTIAL:**

A. **Est. volume** of **past erosion:** LxWxD (ft) ____x- x - =________ft3
OR estimate Tons per Acre: _______over ______ acres
Comment:____.

B. Estimated potential for additional erosion: High Low
C. **Est.** volume of future erosion: Length **(ft)** = _____. Width ____(ft).
height (ft) = _____. IRR **class:** L M S VS .
D. **Will** future erosion **enter** a channel? *Yes / No*
E. **Distance to channel** which sediment will enter (ft):___________.
Comment on future erosion: ______________________________________.
____.

TREATMENT DATA (choose from list up to '4 treatments **per** alternative):

Treatment Alternative 1 (best):__________________ and ______
Extent of **Area** ______________ # ______.
Comments on Treatment 1: ______________________________________.
____.

Treatment Alternative 2 (next): ______and______and______and______.
Extent of 'Area to **be** treated: ______________ &/or # Of TRT **areas:** ____.
Comments **on** Treatment 2: ______________________________________.
____.

Treatment Alternative 3 (next): ______and______and______and______.
Extent **of Area to be** treated: ______________ &/or# of TRT areas:_____.
comments on Treatment 3: ______________________________________.
____.

Treatment Alternative 4 (next): ______and______and______and______.
Extent of **Area to be** treated: ______________ &/or# of TRT areas:_____.
Comments on Treatment 4: ______________________________________.
____.

Is **Energy Dissipation** available near site? Yes or No

SKETCH:

1/17/91 version

GVC Seed Collection Inventory Form

Date Inventoried: ______________
Date Collected: _______________
Collector: ____________________

Scientific Name: ___________________________________
Common Name: ___________________________________

Elevation: _____________

Soil Type: _____________

Slope: ________________

Aspect: _______________

Subwatershed: _________

Location: T_____ R______ S________ SS____________________

____
____
____

Habitat: ____

Plants Growing In Association With: ____
____
____

Plant Type (circle one): Grass Legume Vine Forb Shrub T r C C

No. of Plants (circle one): 1 2-6 6 or mot-c

Estimated Ripening Date: _______________

Comments/Remarks:

Appendix G
MONITORING FORMS

1. GVC Site Monitoring Form

2. Erosion Monitoring Dams
   (Site Establishment)

3. Erosion Monitoring Dams
   (Deposition Monitoring)

4. GVC Site Monitoring Form for Vegetation Treatments

GVC SITE MONITORING FORM 7/5/95

WS# ____________ Site# ____________ Date: ____________

Roll # ____________ Photo# ____________

Evaluated By: ____________ Checked By ____________

Access ____

Location ____________ Type ____________

Source ____________ Cause ____________

Trt Class ____________

	Practice	Description	Qty	Effective(%)	Notes / Cause of Failure
1					
2					
3					
4					
5					
6					
7					
8					

Road Drainage

WB Spacing ________ (ft) (OS Grade ________ (%)

Road Grade ________ %

Head Cut/Grade Stab.

Ht of Drop ________ (ft)

Cause of Failure?

Slope Stabilization

Slope Grade ________ % Gmd Cover ________ %

Canopy ________ % Aspect ________ (deg)

Sediment Retention/Germination?

Vegetatative

Survival

Erosion Monitoring Dams
(Site Establishment)

Structure No. ____________ Date Established ____________
District ____________ Crew ____________

. Structure type ____________

Location:

Legal Description: ______ Section ______ T ______ R ______

U.S.G.S. Quad: ______ Compartment No.: ______ Stand #: ______

Timber Sale: ______ Harvest Unit #: ______

Directions: ____

Site Inventory:

Topography

Slope ______ %

'Aspect ______ °

Elevation ______ it:

Rock Type ______

Erodibilitv/EHR

USFS ______ / ______

Inter-Agency ______

Soil Classification ______

Management Practices

Logged/Conversion Date ______

No Burn/Piled/Broadcast Date ______

Soil Name ______

Summery of Monitoring Frequency:

Measurement Date

1. ______
2. ______
3. ______

Date

4. ______
5. ______
6. ______

Hydrophobicity:

Rating System Key

1. <1 0 sec...... Not Hydrophobic
2. 10 sec. to 1 min. Low Hydrophobicity
3 - 1 min. to 2 min........ Moderate Hydrophobicity
4. >2 min...................... High Hydrophobicity

% Catagories:

3

On Surface:

0.5" depth ______

1.0" depth ______

'2.0" depth ______

3.0" depth

Erosion Monitoring Dams
(Deposition Monitoring Form)

Structure No. ________________ Crew ________________________________

Date ______________________ Establishment ☐ Re-Measurement ☐

Stake Measurements:

Grid Post #	Measurement (tenth ft.)	Grid Post #	Measurement (tenth ft.)	Grid Post #	Measurement (tenth ft.)
1.		34.		67.	
2.		35.		68.	
3.		36.		69.	
4.		37.		70.	
5.		38.		71.	
6.		39.		72.	
7.		40.		73.	
8.		41.		74.	
9.		42.		75.	
10.		43.		76.	
11.		44.		77.	
12.		45.		78.	
13.		46.		79.	
14.		47.		80.	
15.		48.		81.	
16.		49.		82.	
17.		50.		83.	
18.		51.		84.	
19.		52.		85.	
20.		53.		86.	
21.		54.		87.	
22.		55.		88.	
23.		56.		89.	
24.		57.		90.	
25.		58.		91.	
26.		59.		92.	
27.		60.		93.	
28.		61.		94.	
29.		62.		95.	
30;		63.		96.	
31.		64.		97.	
32.		65.		98.	
33.		66.		99.	

Precipitation Data:

Rainfall / Intensity: ____

Snowfall: ____

Grass Valley Creek Site Monitoring Form for Vegetation Treatments 7/27/95

WS# ________ **Site#** ________ **Date:** ________

Evaluated By ________ Checked By ________

Access ______________________________

Location ________ Type ________

Source ________ Cause ________

Site Characteristics:

Mix Hardwood/conifer ____ Mixed conifer ____ Chaparral (Shrub): ____ Riparian: ____ Sheet & Rill ____

Woody Debris: present ____ not present ____

Trt Class	Practice	Description	QTY # planted	Area Trtd (ft2)	Effective (%)	Slope Grade (%)	Canopy (%)	Aspect (Deg)	Ground Cover (%)	Planted Spp. (%)	Sown Spp. (%)	Nat Occur (%)
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												

Consistency of % of Coverage:

low ____ **low-med** ____ **medium:** ____ medium-high ____ high ____ very **high:** ____

Photos: # ____ **Description:**

____ **Description:**

____ **Description:**

____ **Description:**

Appendix H
RESTORATION COSTS

1. TCRCD Restoration Cost Information

2. TCRCD Equipment Work Costs

TCRCD RESTORATION COST INFORMATION

Labor includes benefits

RCD Crew (avg. for 8 person crew)	$13.30/person/hour

Plant materials

trees, shrubs & grass plugs	$0.21 each
fertilizer (2 lbs / 1000 sq ft)	$1.34 per 1000 sq ft
11-52-o 80# bag	$13.5O/bag
38-O-O 50# bag	$32.OOlbag
We use 80 lbs/acre	
seed (0.5 lb/1000 sq ft, except for barley and sterile wheat 2.5 lb/1000 sq ft)	
s c s	$2.40 per 1000 sq ft
Quick Mix (native)	$6.92 / lb
native seed	$5.50 per 1000 sq ft
sterile wheat	*$2.25/lb*

Erosion blanket	$ 0.10 per ft^2
Straw wattles	$20.00 per 25ft wattle
Enkamat-channel protection	$ 4.35/cu.yd
Straw bales	$ 5.OO/bale
organic fertilizer	$ 0.40/lb.
Native seed	$13.50/lb

SMF materials

w/ non-native seed	$15.74 per 1000 sq ft
w/ native seed	18.84 per 1000 sq ft
plus labor (45 min per 1000 sq ft)	10.00 per 1000 sq ft.

Mulching

1 person 1 bale per *500* sq ft takes *20* mins, 45 mins/ **1000** sq ft

straw bales (2 bales per 1000)	$6.00 each avg. range from $5/bale to $7.50/bale
native (Cal Brome straw, blue wild rye, barley)	$6.25/bale
rice	$4.OO/bale

Planting

(1 person 1000 ft2 per hour)

3x3 and *5x5*	*$1* ,OOO.OO-$1,500.00 per acre
microsite planting (sheet & rill)	$895/acre: 1750 plants/acre, and 4 crew hours/acre
Live staking	$1.50 to $3.50 per stake

100 bag headcut structure (4 people, 8 hrs)= $500 all inclusive

TCRCD Equipment Work Costs

Equipment		
Dozer (D7, D8)	$110.00 per hour	
Small Dozer (TD8)	$ 65.00 per hour	
Excavator (1.2 cu yd bucket)	$110.00 per hour	50-75 cu.yds/hr-stream Xing 35-50 cu.yds/hr-humboldt Xing 100- 120 cu.yds/hr-sidecast
Backhoe	$ 6O.OO/hr	
Dump truck	$ 55.00/hr	
Water truck	$ 6O.OO/hr	
Front loader	$ 75.OO/hr	
End haul	$ 3.00 per cu. yd.	$5.OO/cu. yd. over 2500'

Dozer spoils (DG) 5 cu. vd. each push
lOO'/min on 15% slope
50'/min on 30% slope
25'/min on 60% slope
lOOyds/hr max D6H

Outsloping road — $1.50- 1.79 per linear foot

Skid removal	75' of rd/hr	Excavator O/S rate = lOO'/hr
Ridge skid removal	100' of rd/hr	
Partial outslope	250' of rd/hr	

Maintained road outslope

Mobilization	$l,OOO-$1,300 per piece of equipment round trip
Road construction and grading-rip existing road and rough outslope	$1.50-$2.22/LF
Rough grading-5 % outslope	$0.55-$l.O2/LF
Aggregate Road Base Material-class 2	$14.44-$16.OO/ton

Actual Cost for CLRS: $82.850 to treat 5.755' of road

Culvert costs

18" cmp	$ 6.45/ft
24" cmp	$ 8.60/ft
30" cmp	$10.76/ft
36" cmp	$13.OO/ft

Typical sediment riser for 24" culvert 6' high — $300.00

Rock (various quality) rough cost per cubic yard

Tyler pit (shale)	$15.00
bought from Redding	30.00
Yingling (CLRN) class 2	13.3 1
Tatonka (shale)	9.00

Appendix J

TRINITY COUNTY ORDINANCES FOR DECOMPOSED GRANITE

1. Construction Improvement Standards for Roadways in Decomposed Granite

2. Restriction of Use of Vehicles, Bicycles, and Other Conveyances in GVC Decomposed Granite Shelter Area

CONSTRUCTION IMPROVEMENT STANDARDS FOR ROADWAYS IN DECOMPOSED GRANITE AREAS

Sections:

12.12.010 Title. This chapter shall be known and cited as the "construction improvement standards for roadways in decomposed granite areas of the county of Trinity." (Ord. 379 §1, 1981)

12.12.020 Purpose. This chapter is adopted to promote and protect ***the*** public health, safety and general welfare, and to promote and protect the soil, water, and fishery resources of the county. (Ord. 379 52, 1981)

12.12.030 Definitions. For the purpose of this chapter certain terms are defined as follows:

A. "Decomposed granite areas" are those areas identified on the most current Soil Conservation Service map(s) of Trinity County, and/or Geologic Map of California, that depict all decomposed granite soils. It shall be the responsibility of any operator within the county to conform to this chapter where decomposed granite soils are located outside of these maps.

B. "Roadways" are those routes, both public and private, constructed for purposes of providing access to a subdivision; or to individuzl parcels, or as a means of access for purposes of removing forest products. For purposes of this chapter, a roadway shall include roadbed, shoulders, slopes, culverts, drainage structures, ditches and all other elements constructed for the purpose of providing access to lands. A roadway shall also include driveways providing access from a main road to individual dwellings, structures or other sites, and parking areas at those dwellings, structures, or sites.

C. "Subdivision" is any division of land regardless of the method of division, including but not limited to gift deed, grant deed, parcel map, subdivision map, or quarter-quarter division. (Ord. 1100 §1, 1987; Ord. 379 §3, 1981)

12.12.040 Construction 'and improvement standards. The following standards
to all roadways constructed* in decomposed granite areas of

Maximum road grades in decomposed granite shall be' ten percent, except where grades up to fifteen percent can be shown to result in less impact than a ten percent slope will create.._._ Road surfaces shall have a six-inch, well-graded gravel or shale bed 'and -be -suitably-compacted:

B. Road beds shall have a minimum width of twelve feet;'; and shall be outsloped at two percent except for short inslopes immediately above culverts and/or where outsloping will result in diverting runoff onto fill slopes or nonvegetated soils. Rolling dips shall be placed as follows:

Gradient of Roadway, Percent	Spacing Between Rolling Dips, Maximum
1 -- 3	250'
3 -- 8	150'
8 -- 10	100'

C. Runoff from rolling dips shall discharge onto selected areas where protection from erosion is afforded by rocky ground, slash or vegetative cover. Rolling dips shall be constructed as per Exhibit "A" attached to Ordinance 379. Cut slopes shall be 1-½:1 and fill slopes shall be 1-½:1 or flatter. Exceptions to these ratios shall be supported. by determinations of a civil engineer.

D. Drain culverts shall be installed in all drainageways. Culvert size shall be determined by a civil engineer or equivalent, or by using the following table:

Watershed Area	Minimum Culvert Size (Inside Diameter)
0 -- 3 acres	18 inches
3 -- 25 acres	24 inches
20 -- 40 acres	30 inches
40 -- 60 acres	36 inches
60 -- 100 acres	48 inches
100 -- 160 acres	60 inches
160 -- 230 acres	72 inches
over 230 acres	Bridge or Ford

E. Culvert outlets shall terminate on energy dissipating surfaces, adequate, in the judgment of a civil engineer, to minimize erosive processes arising from any flows carried by said culverts.

F. The road alignment in most cases will be determined by land slope. In general, slope greater than forty percent will not meet road standards for Granite soils.

G. All cut-and-fill slopes shall be seeded and fertilized with seed, fertilizer and mulch as approved by the Soil Conservation Service for the site under consideration. This shall be accomplished prior to the first growing season following completion of construction. 'The objective is to achieve 2 vegetative cover sufficient, in the judgment of the county's designated representative, to prevent soil loss from the slopes within two growing seasons following completion of construction. If, in the judgment of said county's representative, this is not physically possible, some other acceptable slope stabilization method may be recommended by the Soil conservation Service and approved by the county

E. When a parcel of land is divided, it shall be the responsibility of the owner to construct the main access road. Such road shall touch each piece of property in such a manner as to allow the new owner access to his property.

I. The landowner or controlling agent shall be re-sponsible for construction and continued maintenance of such roadways, to comply with the intent of this chapter. (Ord. 1100 §2, 1987; Ord. 379 §4, 1981)

12.12.050 Exemptions. Roadways constructed and maintained for purposes of removincj forest products and which are regulated by the California Department of Forestry shall be exempt from the provisions 0f this chapter. (Ord. 379 §5, 1981)

12.12.060 Permit requirements. A. Issuance, The county public works department is given authority and direction to establish additional stanards and conditions to nest the intent of this chapter, to issue permits for the construction and/or improvement of roadways in decomposed granite areas of the county, and to act as the county's representative in the carrying out of all provions of this chapter.

B. Application, Application for a road ccnstruction permit, made to the public works department in writing in a form approved by that agency, shall contain statements, plans and elevations necessary to show all necessary details of the proposed roadway.

C. Responsible Applicant. It shall be the responsibility of the principal contractor or, in the event that roadway is constructed by other than a licensed contractor, it shall be the responsibility of the on-site representative of the owner to secure the permit described in this section. Further, it shall be the responsibility of said on-site representative or owner to have such permit available for work at all times that work is being performed as described by this section. (Ord. 1100 §3, 1987)

12.12.070 Enforcement. It shall be the duty of the county road commissioner to enforce the provisions of this chapter pertaining to the construction or reconstruction of roadways in decomposed granite areas. It shall be the duty of the sheriff of the county, and all officers of the county herein and/or otherwise charged by law with the enforcement of this chapter, to assist the county road commissioner as necessary in the enforcement of this chapter. (Ord. 379 §7(a), 1981)

12.12.080 Violation--Penalty. Any person, firm or corporation, whether as principal, agent, employee, or otherwise, violating or causing or permitting the violation of any of the provisions of this chapter, shall be guilty of an infraction and upon conviction thereof shall be punishable by a fine of not more than five hundred dollars. Such persons, firm or corporation shall be deemed to be guilty of a **separate** offense for each and **every** day during any portion of which any violation of this chapter is committee or permitted by such person, firm or corporation. (Ord. 1100 §4, 1987)

Chapter 12.14

USE Or" VEHICLES, BICYCLES, AND OTHER CONVEYANCES IN THE GRASS VALLEY CREEK DECOMPOSED GRANITE SHELTER AREA

Sections:

12.14.030 Violation--Penalties.
12.14.040 Installation of signs--Promulgation of entry permit standards and conditions.

12.14.010 Definitions. For the purpose of this chap-, ter, certain terms are defined as follows:

A. "Bicycle" means any -two-wheeled device having fully operative pedals for propulsion by human power.

B. "Conveyances" means any means of travel across the ground or water which may be utilized by human beings and makes actual contact with either the ground or the water crossed,

C. "Grass Valley Creek Decomposed Granite Shelter. Area" means all that real property located within the following described boundaries, and being situated in the county of Trinity, state of California, more'particularly described as follows:

All that real estate located in Township, 33N, Range 8W, M.D.B &M, Trinity County, State of California, described as follows:

S/2 of Section 19;
S/2 of -N/2 and S/2 of Section 20;
S/2 of N/2 and S/2 of Section 21;
W/2 of Section 22;
All that portion of Section 27 in Trinitv County;
Section 28;
Section 29
Section 30;
E/2 of Section 31;
Section 32;
Section 33;
Section 34;
All that portion of Section 35 in Trinity County;

All that real estate located in Township 32N, Range 8W, M.D.B. &M., Trinity County, State of California, described as follows:

All that portion of Section 2 in Trinity County;
Section 3;
Section 4;
Section 5;
E/2 of Section 6;
E/2 of Section 7;
Section 8;
Section 9;
Section 10;
All that portion of Section 11 in Trinity County;
All that portion of Section 13 in Trinity County;
All that portion of Section 14 in Trinity County;
Section 15;
Section 16;

Section 17;
E/2 of Section 20;
Section 21;
Section 22;
Section 23;
All that portion of Section 24 in Trinity County;
Section 25;
Section 26;
Section 27;
Section 28;
E/2 of Section 33;
Section 34;
Section 35;
Section 36;

All that real estate located in Township 32N, Range 7W, M.D.B &M., Trinity County, State of California, described as follows:

All that portion of Section 30 in Trinity County;
All that portion of Section 31 in Trinity County;

All that portion of the N/2 of Section 6, T31N, R7W, M.D.B. &M., Trinity County, State of California;

All that real estate located in Township 31N, R8W, M.D.B.&M., Trinity County, State of California, described as follows:

All that portion of Section 1 in Trinity County;
All that portion of Section 2 in Trinity County;
Section 3;
All that portion of Section 10 in Trinity County.

D. "Motor vehicle" means a vehicle which is self-propelled. This definition specifically includes all types of motorcycles, motorscooters and motorized tricycles.

E. "Motorcycle" means any motor vehicle other than a tractor having a seat or saddle for use of the rider and designed to travel on not more than three wheels in contact with the ground, weighing less than one thousand five hundred pounds, except that four wheels may be in contact with the ground when two of the wheels are a functional part of the sidecar. (Ord. 1083 §1(part), 1986)

12.14.020 Closure of ares. to all off-road travel by vehicles. A. The Grass Valley Creek Decomposed Granite Shelter Area is hereafter closed to off-road travel by any motor vehicle, bicycle, motorcycle or other conveyance.

B. Certain exceptions to the terms of this chapter exist. They are as follows:

1. Off-road travel by persons, firms, and corporations working within the terms of a valid timber harvest plan covering any part of the Grass Valley Creek Decomposed Granite Shelter Area is allowed, only to the extent that such travel is necessary as a part of such timber harvest plan.

2. Off road travel by any person, firm or corporation having a valid entry permit authorized, and issued by the department of public works for the county is authorized.

3. Off road. travel by police, fire, anbulance and U.S. Forest Service vehicles and personnel engaged in the lawful performance of their duties is authorized. (Ord. 1083 §l(part), 1986)

12.14.030 Violation--Penalties. Operation of 2 motor vehicle, bicycle, motorcycle or other conveyance in the Grass Valley Creek Decomposed Granite Shelter Area in a manner not authorized by the provisions of this chapter shall be punishable by a fine of up to five hundred dollars for each violation. (Ord. 1083 §l-(part), 1986)

12.14.040 Installation of signs--Promulgation of entry permit standards and conditions. A. The public works department is directed to install along all county road entrances to the shelter area, signs indicating the existence of the ordinance codified in this chapter by its ordinance number, the activities proscribed by this chapter, and the penalties and consequences for violations of this chapter.

B. The department of public works for the county is further authorized and directed to promulgate standards and conditions for the issuance of the entry permits mentioned in this section. Further, the department of public works shall be directed and authorized to issue such permits as seen proper in the discretion of the department. (Ord. 1083 §1, (part), 1986).

Appendix K
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Appendix L
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