Lagunitas Creek Watershed Sediment Reduction and Enhancement Project – Final Report

Presented:

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To:

Marin Municipal Water District
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Corte Madera, CA 94925

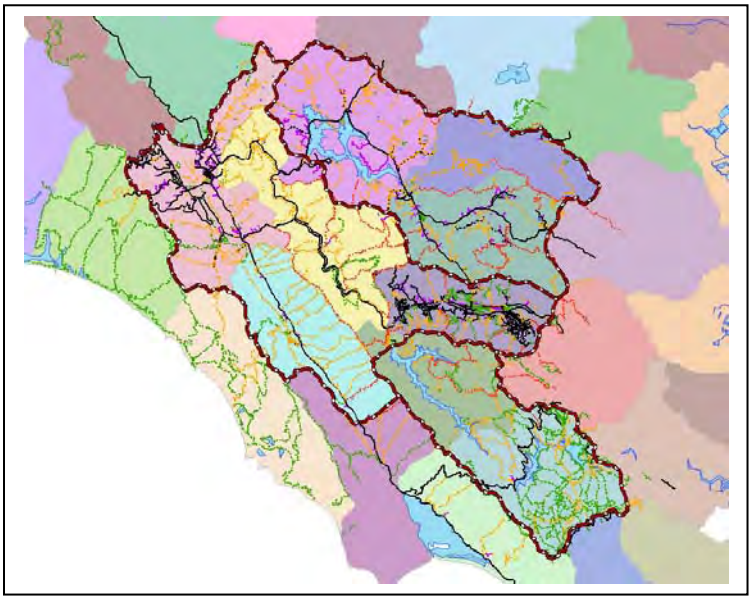

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Table of Contents

Executive Summary

The Lagunitas Creek Watershed spans 70,598 acres of relatively pristine land in Marin County California. The watershed comprises three resource areas, two secondary (31,669 acres) basins that feed into one primary (38,929 acres) basin. These resource areas are further classified into 9 sub-basins as defined by California Interagency Watershed Map of 1999 (CalWater version 2.2.1). The watershed serves many disparate and often competing uses from recreational to residential, and natural habitat to agricultural and ranch uses. Protecting this land is one of the core missions of all stakeholders in the region, and particularly of this endeavor.

This project had two goals: 1) utilize Geographic Information System (GIS) technology to develop a comprehensive road and trail network within the watershed, and 2) apply these same tools in a series of analyses that could evaluate the potential road run-off infiltrating the local drainage system. The first objective involved many tasks and consumed 90% of the project's resources. Five different existing data sets were ultimately employed to compile the existing road systems. These were rectified to fit the Marin County's digital orthophotography; general horizontal accuracy was improved from approximately 30 feet to approximately 5 feet. New roads were added to the compiled network focusing on unpaved roads but including all roads with a width of 4 feet or more and at least 3 meters in length. All features in the project area were classified through photo-interpretation, field verification and peer review work sessions. Classification included: road type, surface type, use, and ownership characteristics.

The completed road data was summarized based on feature length, and characterized by primary/secondary resource area, and sub-basin. Including trails, the network comprises 598 miles; 327 miles are unpaved roads. These unpaved roads are roughly proportional across all 9 sub-basins with typical patterns based on land use. For example, sub-basins such as San Geronimo Creek has a high percentage of paved and unpaved roads due the relatively high density of residential use while Upper Lagunitas Creek which is used, in part, for recreation has a high percentage of trails, and the ranch/agricultural land in Nicasio Reservoir has a high percentage of secondary unpaved road surface.

There is roughly an equal distribution of unpaved road surface between publicly held land and large landowners. The watershed supports important and relatively stable populations of several threatened and endangered species, including coho salmon and steelhead, California freshwater shrimp, northern spotted owls, and California red-legged frogs. This suggests a favorable resource when applying for grant monies to employ road rehabilitation and sediment infiltration prevention practices.

Road crossings, slope, and creek proximity were analyzed to try and constrain the unpaved roads and focus on the most likely and largest contributing portions of the network. There are 271 unpaved, creek crossings, and 26 miles of unpaved road falling along relatively steep slopes within 200 feet of a creek. These areas should be considered the highest priority and the highest contributors of sediment into the drainage system.

Background

The Lagunitas Creek Watershed is located about one hour's drive north of San Francisco Bay in California. Its relatively pristine hilly countryside holds and conveys water for nearly 190,000 customers of the Marin Municipal Water District (MMWD). As stewards of the land MMWD has taken a progressive approach to preserving the land and wildlife habitats as well as providing a balance for recreational activities and general access within the Watershed.

While MMWD is one of the largest landowners within the watershed it is not alone. Other important constituents have banded together, not only for this study, but for other preservation and forward-thinking activities to care for the land. These include many public agencies and as many as 47 large private landowners. The other principal public agencies include: the Marin County Open Space District (MCOSD), California Department of Parks and Recreation, Marin County Resource Conservation District, Marin County, and the National Park Service (Golden Gate National Recreation Area and Point Reyes National Seashore).

Human activity impacts the land, and the Lagunitas Creek watershed is not immune. The watershed has seen the effect of the San Francisco Bay Area's population expansion, and development means more people, more roads, and more impact on the terrain. The Lagunitas Creek watershed's road and trail system is extensive, stretching easily over 600 miles. This road network increases the potential for landslides by over steepened slopes, and the amount of sediment runoff which concentrates in the drainage system. These process' impact on fish and wildlife is measurable and the coho salmon is one example. Their numbers have dropped steadily over the past 30 years and now are listed as an endangered species. The coho are known to inhabit a few of the streams within Lagunitas Creek and its tributaries, and measuring the causes for their decline is one goal of this study. More tangibly, this project will look at the road and trail system within the Lagunitas Creek watershed as it relates to the drainage system to try and identify potential mitigation sites.

Geographic Information Systems (GIS) provide an important contribution towards mapping and analysis that would otherwise make this project cumbersome and much more expensive and time consuming. This technology not only provides the technician the ability to combine disparate data types and sources into one cartographic presentation, it also enables the analyst to interpret these data, draw conclusions and present the results. Many agencies have employed GIS for individual efforts within there respective disciplines for the past 10 years. The road and trail system is one class of layers captured, and in many cases, several times. Moreover, the methods, level of accuracy and information about the roads and trails is inconsistent with each agency, GIS, or new project. Therefore, a second, and perhaps principal goal of this project is to develop a single comprehensive road and trail system. Further, it is hoped that the project can present a design and series of recommendations that will enable all agencies to use and maintain a common dataset that can be extended to the entire county.

Statement of Purpose

Road and Trail Inventory
The initial and primary purpose of this project is to develop a comprehensive inventory of roads and trails within the Lagunitas Creek watershed. This will be accomplished using a variety of methods.

First, there are several *existing* street and trail systems that are developed in a GIS (ESRI) format. These include: 1) Marin County, 2) MMWD, 3) MCOSD, 4) GGNRA, and 5) Pt. Reyes National Seashore. In addition, several topical projects conducted in the past have created smaller road data sets that contain valuable and pertinent data. Finally, there are several published map series of roads and trails of the area that will be garnered for pertinent information. The map published by the Department of Parks and Recreation for Samuel P Taylor State Park, and the commercial maps offered by Tom Harrison are examples that will serve the project well. Each data set offers something but each varies in spatial extent and accuracy, and typically have similar attributes with a mixture of potential values. For example, some roads have street names parsed while others are combined, some have functional class but use different definitions, and some have created new and valuable data such as trail width or condition. The first challenge to even start using this resource is to combine the disparate data sets and migrate or conflate the attributes into one table or series of tables referenced back to a single spatial feature i.e. one road or trail segment.

A second method will identify and digitize *new* road and trail features from recent digital orthophotography. This photography was flown in early 2004, is very high resolution (4 inch and 12 inch pixels), and high accuracy (± 2' horizontal). Any observed, navigable feature longer that about 10 feet and wider than about 4 feet will be digitized and incorporated into the final road and trail network. In addition, this resource will be used to rectify *existing* roads and trails. There are many cases where existing features are displaced tens of feet from the true ground position when compared to this imagery; these will be corrected.

Third, we will conduct a series of field reconnaissance surveys of the combined methods described above to verify this information, confirm areas where tree cover obscured visibility, and confirm or capture additional data such as road surface type that may be difficult to discern from the aerial photography.

Finally, the compiled data will be subjected to a series of peer review sessions in which staff from each of the participating agencies will contribute. This will not only serve as a formal review of the data captured, but it will also grant an opportunity to provide valuable institutional knowledge that only experienced field staff can offer.

Feature Attributes

The first objective will be mixed with a second project goal to develop a set of attributes for each road or trail segment. The project will collect new data related to road condition and use. It will also attempt to consolidate certain, existing attributes shared by all contributing agencies and data sets. Keeping in mind that the ultimate project goal is, "… identification of road-related sediment inputs… and not for transportation uses.", this aspect, i.e. the street feature attribute table (FAT) will not be comprehensive. However, the project will provide a *recommendation* to use the network for other purposes and to maintain the data for the long term. The attributes to be collected as a minimum are:

- Name
- Ownership Class
- Secondary Owner
- Other Owner (if any)
- Surface Type
- Data Origin
- Use Type
- Status (Open Year Round)
- Management Resource Area
- Sub-watershed
- Feature Length

Analysis and Reporting

The third purpose of this project is to summarize the data and present the results in the form of 1) presentation quality maps, 2) tables and reports of the feature attributes, and 3) a pilot analysis of two sub-watershed areas: San Geronimo and Devil's Gulch. This analysis will evaluate the roads and trails in terms of other criteria such as proximity to creeks and slope by using readily available GIS processing algorithms. The application of this analysis will be established in a manner so that it can be applied to other sub-watersheds within the project area and possibly to other watersheds throughout California.

Methodology

Definition of Terms

It is important to clarify several terms used throughout this report because many of the terms must be considered in its context rather than some other. For example, the term 'trail' is used in this report as a path that is generally less than 4 feet and therefore should be considered as having lower sediment contribution, but in the context of recreational use a trail could be any width including an old road that is used for hiking or horse-back riding.

Road Type

1. **Primary Road** Defined as named roads, generally paved, within a public right-of-way as defined by Marin County; serves as public access traveled ways to support two directions of traffic, usually 20 feet wide or more.

2. **Secondary Road** Generally unpaved and unnamed roads but with sufficiently wide traveled ways to permit one direction of travel. May or may not be maintained as a road. Note that many roads designated hereto are NOT currently used for roads but *were* old logging roads or have road-cuts that may contribute significant sediment run-off.

3. **Fire Road** Usually unpaved, well maintained, named or unnamed roads, generally following ridgelines and crests.

4. **Driveway** A traveled way supporting one direction of travel, usually less than 15 feet wide and intended for minimal traffic patterns; single to a few residential passenger cars or light trucks.

5. **Trail** Narrow, generally < 4 feet wide, foot, horse or bicycle traffic only.

Surface Types

1. **Paved** Any asphalt or concrete road surface (regardless of condition).

2. **Dirt** Unpaved traveled ways that may include various materials i.e. can include unimproved 'native' surface or maintained dirt.

3. **Gravel** Unpaved traveled ways in which the base rock is constructed of 1-2 inch road construction grade material.

4. **Other** For the purposes of this study, this classification reflects a bridge that may include wood, concrete or asphalt over steel.

Ownership Contains 3 columns in the Roads database table: Class, Primary and Secondary:

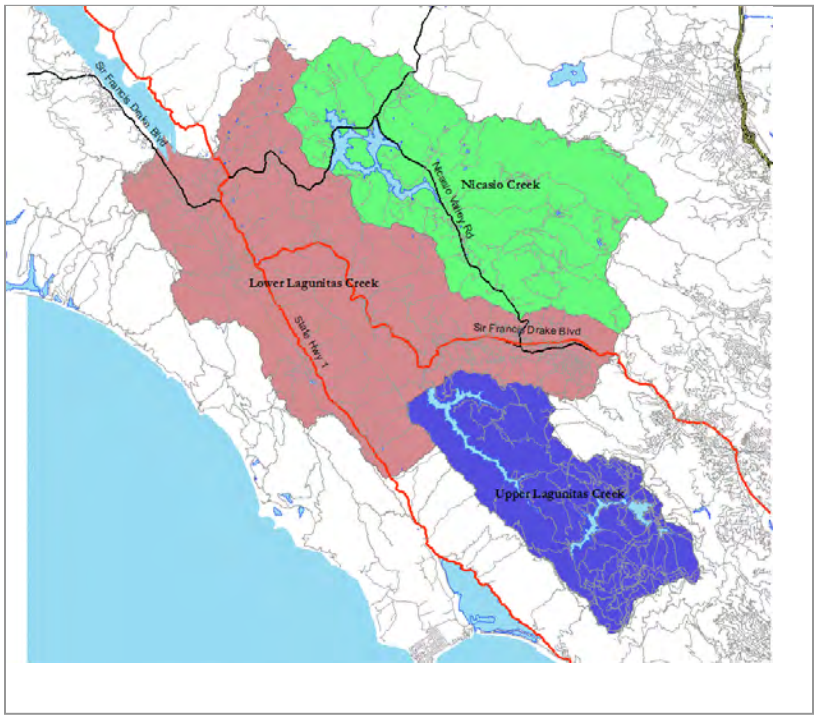
1. **Class** May be Public or Private; public includes NPS, State, MCOS, MMWD etc.

2. **Primary** Restricted to public entities: Marin County, MMWD, NPS, State Parks, MCOSD and cities.

3. **Secondary** Restricted to large private land owners with holdings greater than 40 acres.

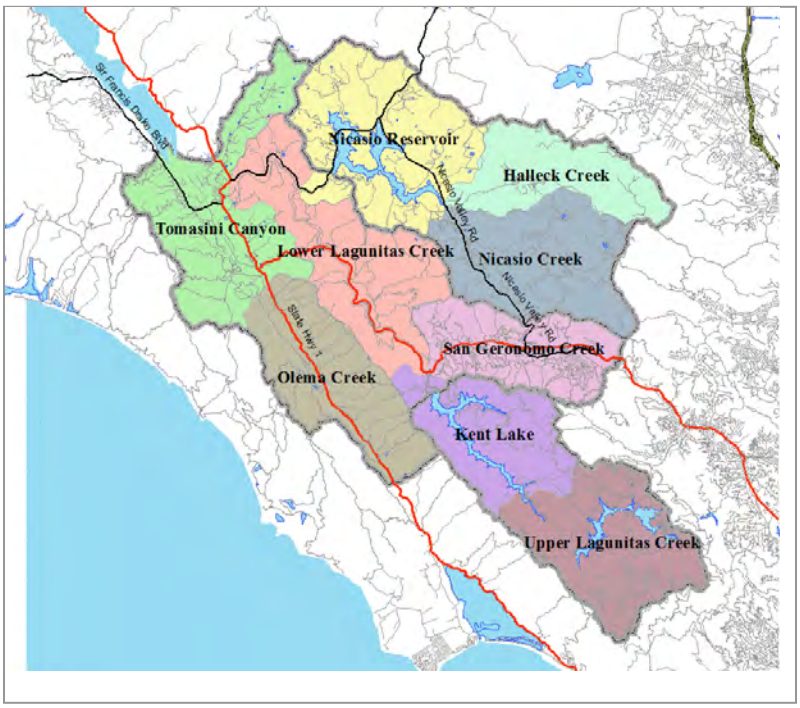
Project Area and Watershed Basins

Figure 1: Lagunitas Creek Watershed



The project area is defined as the Lagunitas Creek Watershed and is generally delineated by the ridgelines north of Nicasio Reservoir, east of San Geronimo Valley and the Mt. Tamalpais watershed, west of the Olema Valley and north of Mt. Tamalpais and Bolinas Ridge, as shown in Figure 1. The watershed includes Lagunitas, Nicasio, and Olema Creeks and hundreds of tributaries. It is also cut by the San Andreas Fault which defines the drainage pattern in the southwest corner of the watershed. The watershed is defined by three basins and 9 sub-basins. The Lower Lagunitas Creek is considered a Primary basin for this study as it has unrestricted drainage and is fed by the two secondary basins: Upper Lagunitas Creek and Nicasio Reservoir. These latter two contain 5 reservoirs forming the Nicasio, Kent, Alpine, Bon Tempe and Lagunitas lakes. The California Interagency Watershed Map of 1999 (CalWater version 2.2.1) defines 9 sub-basins within the watershed and were adopted for this study (Figure 2).

Figure 2: CalWater Sub-Basins



Road Construction

Existing Digital Data

Existing road centerline GIS datasets were supplied for the project. Each carried its own set of attributes, overlapping geographic coverage, and degrees of accuracy. The principal digital data sets used for the project were from the following agencies:

Agency	*File*
Marin Municipal Water District	Trans_RdsnTls_MtTam_all
County of Marin (MarinMap), as modified and renamed by MMWD SkyOaks GIS.	Trans_rds_marin
Marin County Open Space	Trails22.shp Fireroads16.shp
National Park Service (Pt. Reyes National Seashore/GGNRA)	Poretrails.shp

Digital Orthophotography

Approximately 250 hours was invested in the road and trail system using the County's 2004 4"/1' pixel resolution digital orthophotography. We corrected roads or trails that did not match the orthophotography; in other words, existing roads or trails that fell outside the traveled way or path were redigitized. In many cases roads were off by more than 30 feet or so crudely shaped that we replaced the entire section. If a road was obscured by

tree cover it was left as-is. New road features were digitized focusing on unpaved features. All discernable road features greater than 3 feet wide were digitized within the watershed. This included unpaved or paved driveways, and recognizable paths in which we could trace a feature for some noteworthy distance. In many cases, particularly in the Olema Valley and Nicasio areas where agricultural and ranch land is the dominant land use, it was difficult to tell truck tracks from graded maintained roads, or even well used cow paths. This lead to many 'hanging' features which we wanted to avoid, and after some discussion, we settled on any feature that was at least 4' wide.

One area, the Upper Lagunitas Creek Area, all within the Marin Municipal Water District lands was considered complete and therefore very little time was spent proofing or checking these roads and trails.

Photo-interpretation was employed to classify all road and surface types.

Hard Copy Sources

Hard copy maps proved extremely helpful particularly for trail and gate locations in the San Geronimo and Lower Lagunitas Creek basin areas. Two primary sources: Tom Harrison Maps and the California Department of Parks and Recreation, Samuel P. Taylor State Park Trail map. These maps were scanned, geo-rectified and placed under the existing roads to fill in areas obscured by trees and not captured by other existing sources.

Field Work

Two staff spent 6 days in the field verifying existing road locations and surface classification. All of that time was spent in the Lower Lagunitas and Nicasio Creek basin areas with the final 30 hours focused on unpaved roads in the San Geronimo Creek sub-basin and Devils Gulch areas.

The field work was critical. It uncovered many features that could not be interpreted from the orthophotography and determined what roads were actually navigable. For example, it was virtually impossible to discern gravel road surface types from the imagery however, unpaved versus paved roads were proven correct in most cases. The field study validated the work we had accomplished up to this point and we believe that within the San Geronimo Valley and Nicasio Creek/Reservoir areas, we captured and verified over 90% of the road and trail system. This effort was quite valuable in two additional ways. First, it generally confirmed the viability of road and surface type classification based on photo interpretation, and secondly it clarified many features from the original digital data that were questionable. Specifically many road centerlines were created because they represent a right-of-way but were never actually constructed; these were removed from the data set.

The field work was also slow and exhausting. Navigating the road system with just one person hindered our effort and probably would have been better with a second staff. We recommend that more time be spent in the field, up to 50% of the total data gathering phase of the project could be spent in field study.

Peer Review

Ten 1" = 100' scale maps of the project area were prepared and submitted for peer review. Different meetings were held for MMWD staff only, and the larger community of participating agencies. The peer review phase occurred in the middle of the field work portion of the project.

Two staff members from MMWD spent several hours reviewing both the road/trail and creek networks within the project area. Several errors to local creek names and flow patterns, based on the current orthophotography, and local knowledge were identified and subsequently corrected.

Five staff from the Marin Open Space district and MMWD thoroughly reviewed the trail system, particularly in the San Geronimo and Nicasio basin areas. Many corrections and additions to trails or remote access roads were identified, particularly based on institutional knowledge of the area. In addition several hillside erosion sites were identified on the maps.

The project manager, Nicholas Salcedo spent many hours reviewing the data set and offered many corrections and updates to the road system. Two separate review periods were conducted to validate the road features. Road features attributes were also checked however, the attribute validation focused on the following fields only:

- Road Type
- Surface Type
- Use Type *
- Ownership Class (Public vs Private)
- Primary Owner
- Resource Area

* Note: Use Type was based on several factors: photo-interpretation, existing classification by others, and land use classification for agricultural lands based on the Marin County parcel data set.

Feature Topology

Topology rules were created and tested twice; once after the initial data creation phase (digitizing and field work) and at the end of the project during the QC period. All road and trail dangles, gaps, and overlaps were tested and removed for the entire project area. In addition, the following characteristics should be considered when using the road and trail network:

- Roads were split (planarized) at all intersections including trails. The only exception is when a driveway intersects another road type.
- Roads were not tested for direction.
- Address ranges were not reapportioned due to planarization.

Creeks

The creeks feature class was largely adopted from the data supplied by MMWD. However, some additional effort was applied to improve the layer and overall results of the project:

- Portions of creeks were re-digitized when gross positional errors were spotted while working with the orthophotography,
- Some minor drainage systems were digitized north of the Nicasio Reservoir Basin (this was aborted when it became obvious that it would exceed the scope and project's budget),
- Locally known creek names were added to the layer's features based on peer review of the network,
- The drainage system for the Devil's Gulch and San Geronimo Creek areas were studied by Stillwater Sciences. This data set was much more complete for this area and included many minor creeks. We incorporated this data into the creeks layer that is part of the geodatabase by overlaying the two and cutting and pasting and then edge matching the new features into the feature class.
- Topology rules were created for creeks and dangles and overlaps cleaned for the entire project area.
- Creeks were tested for flow direction and approximately 35% of the creeks were flipped to follow the correct drainage patterns.

Findings and Recommendations

1. More field time would help clarify road definition and surface classification. Focus on unpaved roads. We recommend future projects restrict the scope or area of coverage to one sub-basin (~ 7,500 acres), and that field work is increased to approximately 50% of the total budget.

2. Clarify the distinction between a road and a trail. In other words, many features currently viewed as trails are actually old roads that should be classified as a road even though its use is a trail. I think that this interpretation was somewhat lost during the peer review phase so that many trails could be classified as roads.

3. Creeks and drainage are severely under-represented using the existing creek data set. This is demonstrated in all phases of the project: photo interpretation, field study, and by comparing the hydrologic modeling by Stillwater Sciences in the San Geronimo Valley. This suggests that these results should be considered a *minimum* potential risk of sediment intrusion by unpaved roads. In other words, the actual creek crossings and length of roadways in close (< 200') proximity to creeks is likely to be much higher with a more complete creek drainage representation.

Analysis

Overall, we considered the analysis of the Lagunitas Creek watershed by considering several factors that will likely identify potential sediment intrusion and mitigating factors:

- Length of roads by road and surface types, and detailed by resource area and sub-basin
- Ownership
- Direct infiltration into creeks i.e. where are the creek crossing points
- Proximity to creeks
- Slope

Road Length

The road and trail data set is summarized for the watershed in Tables 1 and 2 of Appendix A. Additional detailed summary of the road data is in an Excel file accompanying this report. This file will allow the user to look at road and surface type for each resource area and by sub-basin.

Overall the Lagunitas Creek watershed includes almost 600 miles of roads and trails. Approximately 112 miles or about 19% of the network is trail (which is not the focus of this report but is included in all data summaries). The overall ratio of unpaved to paved road surface is 2:1, or about 327 miles of unpaved roads compared to 159 paved roads. Dirt surfaces accommodates for almost all (97%) of the unpaved surface types. Looking at the overall inventory by resource area and surface type, there is a proportional balance for all surface types. For example, there are roughly equal proportions of secondary dirt roads (~ 112 miles) in both primary and secondary resource areas. The one exception seems to be primary roads; there is approximately 3 times more paved and 3 times less unpaved road in the primary resource area than the secondary resource areas. Similarly, looking at road feature length based on the sub-basin seems to reflect the overall use or degree of study. For example, the dominance of road features in the San Geronimo Creek basin reflects the density of residential development; the Upper Lagunitas Creek basin is used primarily for water collection but also for recreational purposes has a correspondingly high linear miles of trails.

Ownership

Land ownership is relevant to this project when considering the resources and permissions required to minimize potential road-related sediment contribution into the drainage system. For this report we only considered public land owners: MMWD, County Open Space, State Parks, and the National Park Service, and private landowners that owned more than 40 contiguous acres. Road distribution based on principal landholdings is illustrated in Plate 6 of this report. There are approximately 180 miles of unpaved road on public lands compared to 144 miles on large private landholdings. Note that these numbers do not reflect roads that fall within a public right-of-way. Also note that these numbers (and the values on Plate 6) are approximate based on an averaged weight (length) to assigning ownership to road segments.

Creek Crossings
There are 858 creek crossings in the Lagunitas Creek watershed including those intersecting trails. Excluding trails there are 271 unpaved road crossings and 256 paved crossings; these crossings are shown on Plate 7; this is also charted in figure 4 of Appendix A accompanying this report. However, we believe that this number is compromised by the creek feature class and that the number would increase dramatically if a similar inventory as that performed by Stillwater Sciences group were applied to the entire watershed.

Proximity to Creeks
Equally compelling is the map shown in Plate 8 which shows the distribution of road features (paved and unpaved, no trails) that fall near creeks. We selected two criteria: roads within 100 feet and within 200 feet and the results are proportionally reflected in the number of miles of roads. There are 198 miles of unpaved road and 129 miles of paved road falling within 60 yards of creeks within the watershed. This high number may reflect the nature of the steep terrain.

Slope
Plates 9 and 10 illustrate road/creek crossings and road proximity to creeks as a function of slope. Both illustrations reflect the steep terrain of the watershed. For this analysis, we focused on roads near creeks on slopes greater than about 8%; these are illustrated in the solid color, and there are about 26 miles of unpaved roads within 200 feet of creeks on relatively steep terrain.

Summary and Conclusions

The Lagunitas Creek watershed is a diverse landscape with almost 600 miles of roads, trails and private travel ways. The land and its roads are used for access to private residences, emergency access, recreational uses, maintenance, and agriculture and cattle grazing. All of these impact the land and, for the purposes of this project, contribute sediment into the neighboring drainage system. Of the 4,000+ segments in the network, over half, 327 miles are unpaved, crossing creeks directly 271 times, and of these, 26 miles of unpaved road fall along slopes within 200 feet of a creek. These areas should be considered the highest priority for assessment of potential road-related sediment contribution into the drainage system.

Other considerations and more detailed analyses of the data would help to analyze the potential of sediment contribution and identify sensitive areas. One such measure is to collect more complete drainage information. As discussed above, the San Geronimo Creek and Devils Gulch are two examples where the number of creek crossings increased significantly because of the more detailed drainage system contributed by Stillwater Sciences' work. Another factor that we did not test in this study and did not collect data on was the proximity of roads and creeks to known erosion sites and landslides. These are areas where their intersection would indicate a perfect combination of unstable, unconsolidated material and a transport mechanism to the drainage system. A third opportunity for further study would be to compare the roads, and soils and geomorphology of the sub-basins to look at potential instability i.e. which rock types and surface conditions are prone to slippage, and have unpaved roads in canyons or on steep slopes.

Appendix A: Maps, Figures, Tables

Table 1: Total Distribution of Roads and Trails within the Lagunitas Watershed

Road Type	Surface Type	Use Type	Width	Length (Feet)	Miles
Trail	Dirt			542,475	102.74
	Paved			49,148	9.31
	Other			240	0.05
Total				**591,863**	**112.10**
Fire	Dirt			343,265	65.01
	Gravel			293	0.06
	Paved			17,779	3.37
Total				**361,337**	**68.44**
Primary	Dirt			66,066	12.51
	Gravel			16,799	3.18
	Other			163	0.03
	Paved			614,193	116.32
Total				**697,221**	**132.04**
Secondary	Dirt			1,204,943	228.21
	Gravel			34,289	6.49
	Other			542	.10
	Paved			41,242	7.81
Total				**1,281,016**	**242.61**
Driveway	Dirt			52,202	9.89
	Gravel			7,437	1.41
	Other			257	.05
	Paved			165,485	31.34
Total				**225,381**	**42.69**
Grand Total				**3,156,821**	**597.88**

Table 2: Distribution of Road Surfaces within Lagunitas Watershed

Surface Type	Length	Miles
Trail	542,476	102.74
Fire	343,265	65.01
Driveway	52,202	9.89
Secondary	1,204,943	228.21
Primary	66,066	12.51
Dirt	**2,208,952**	**418.36**
Trail	0	0.00
Fire	293	.05
Driveway	7,437	1.41
Secondary	34,289	6.49
Primary	16,799	3.18
Gravel	**58,818**	**11.13**
Trail	240	.05
Fire	0	.00
Driveway	257	.05
Secondary	542	.10
Primary	163	.03
Other	**1,202**	**0.23**
Trail	49,148	9.31
Fire	17,779	3.67
Driveway	165,485	31.34
Secondary	41,242	7.81
Primary	614,193	116.32
Paved	**887,847**	**168.45**
Grand Total	**3,156,821**	**597.88**[1]

Note: Ratio of Unpaved to Paved Surface = 2.6 (Incl. Trails)

[1] Totals of Tables 1 and 2 (and subsequent references includes trails as defined above)

Figure 3: Road Surface by Resource Area

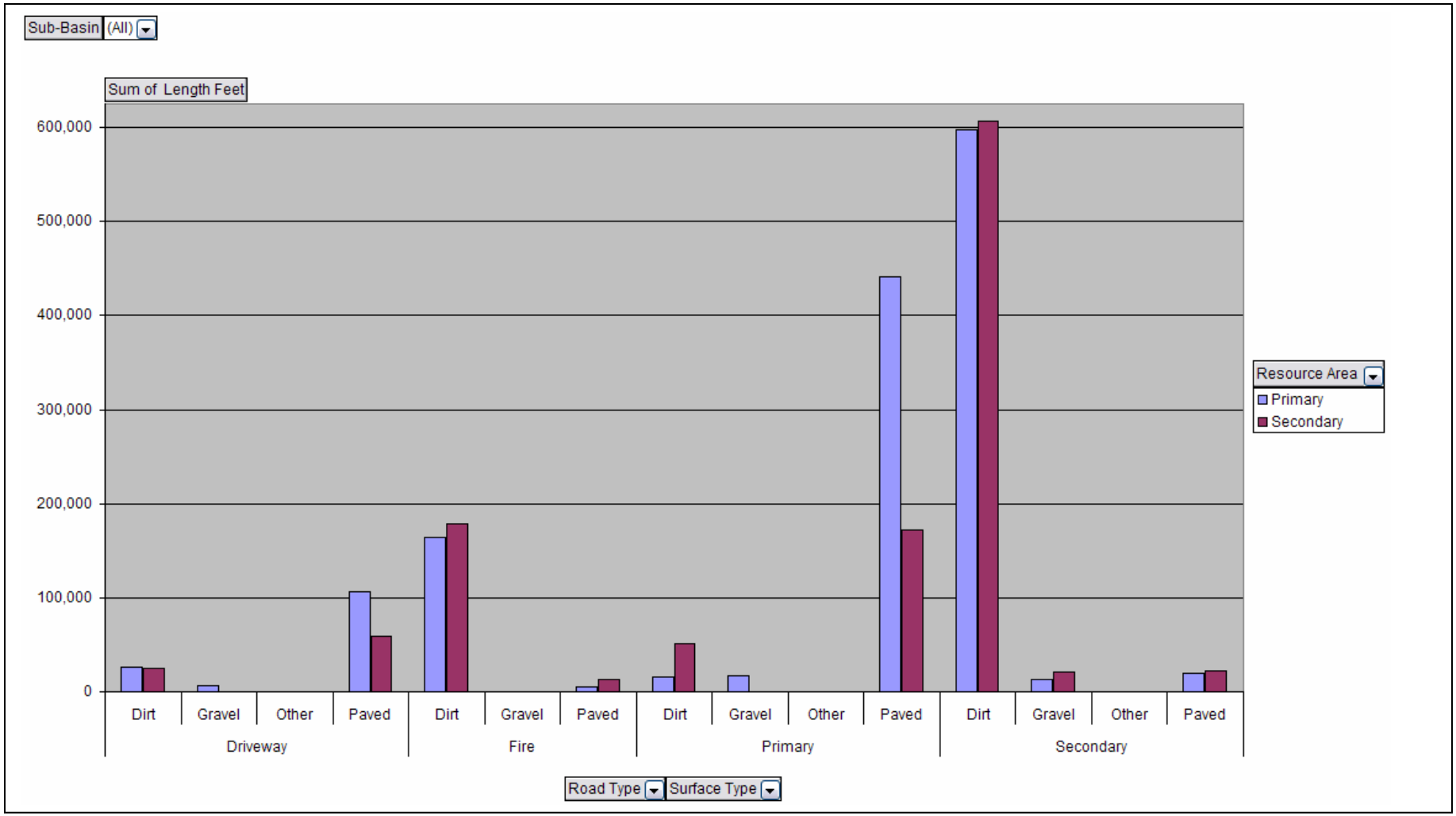


Figure 4: Creek Crossings