

Los Padres National Forest Roads Inventory and Erosion Assessment



Final Report

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Los Padres National Forest

Roads Inventory and Erosion Assessment Project

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Prepared By:

Blue Tomorrow, LLC



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Authors: Eric Hopkins, Alex Dragos, Michael Paccassi, Annette Tran, Aarushi Jha, Sarah Sorensen

Surveyors: Aarushi Jha, Sarah Sorensen, Ann Marie Parkinson, Matthew Chan,
Michael Paccassi, Alex Ehrens

FOREWARD

This project was funded by the National Fish and Wildlife Foundation (NFWF) and Los Padres National Forest (LPNF) Wildfires Restoration Grant Program, which supports fire recovery efforts in watersheds impacted by the Zaca, Piru, and Jesusita Fires. All roads surveyed through this project are located around the Santa Ynez and Santa Maria Watersheds in areas of Santa Barbara and Ventura Counties affected by the 2007 Zaca Fire. These roads are an integral part of LPNF infrastructure for long term resource management, recreation, and fire-fighting needs. This report presents findings from a road network inventory conducted from June through October 2017.

ACRONYMS

GIS	Geographic Information Systems
GPS	Global Positioning System
GRAIP	Geomorphic Road Analysis and Inventory Package
LPNF	Los Padres National Forest
NAD	North American Datum
NAIP	National Agriculture Imagery Program
NFWF	National Fish and Wildlife Foundation
OHV	Off-Highway Vehicle
USDA	United States Department of Agriculture
USFS	United States Forest Service
UTM	Universal Transverse Mercator

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EXECUTIVE SUMMARY

This report presents results from a road inventory and erosion assessment project located in the Santa Lucia, Mt. Pinos, and Santa Barbara Ranger Districts of the Los Padres National Forest, California. All roads surveyed were affected by the 2007 Zaca Fire or identified as high priority roads for surveying. The method used for data collection and analysis was the Geomorphic Road Analysis and Inventory Package (GRAIP) developed by the Forest Service Rocky Mountain Research Station and Utah University.

Road inventorying, modeling, and data analyses were carried out for approximately 202 miles of forest roads. Field data were collected between June and October 2017. The GRAIP model was used to predict road-stream hydrologic connectivity, relative sediment production, and relative delivery to streams from road segments. The following presents a summary of the main results:

- Approximately 202 miles of road were surveyed within or near the Zaca Fire burned area.
- 3,370 drain points were inventoried, with the three most common types being broad based dips (46%), non-engineered drain points (29%), and stream crossings (12%).
- 167 active engineered drain points (5.0% of all drain points) exhibited problems with drain function.
- 101 drain points (2.9% of all drain points) were considered orphaned and were not observed to drain water from the road surface.
- 1,824 drain points (54% of all drain points) exhibited some level of fill erosion. Most fill erosion (40%) was from non-engineered drain points.
- 192 mass wasting events were observed, 24 of which were road-related.
- Approximately 7.1% of the inventoried road length (14.3 miles) was considered eroded (rilled, rutted, or gullied road surface).
- Approximately 9.8% of the inventoried road length (19.8 miles) was considered vegetated (grass, herbs, or large woody vegetation).
- 860 drain points (26% of all) are estimated to connect approximately 47.2 miles (23% of total road length) to the stream network.
- The top 168 drain points (5% of all drain points) are estimated to produce approximately 21% of all road-derived sediment. The roads with the greatest number of high sediment-producing drains were 6N03, 32S13.1, 32S13.2, and 8N02.
- Approximately 26% of all fine sediment produced from road surfaces is estimated to be delivered to the stream network.
- Treating the top 5% (168 drain points) of sediment-delivering drain points is estimated to reduce sediment delivery by as much as 52%. The roads with the greatest number of high sediment-delivering drain points were 9N11.3, 11N03, 8N19, and 11N04.3.

1.0 INTRODUCTION

The Los Padres National Forest (LPNF) Roads Inventory and Erosion Assessment project assessed the condition of approximately 202 miles of forest roads that were affected by the 2007 Zaca Fire. Survey activities and data analyses were based on the *GRAIP Volume 1: Data Collection Method* (Black et al., 2012), and *GRAIP Volume 2: Office Procedures* (Cissel et al., 2012). This report provides a summary of survey data and includes road improvement recommendations. Refer to Appendix A1 for a glossary of terms related to GRAIP and used throughout this report.

1.1 Background

In the LPNF, forest roads are an essential part of forest infrastructure and are used to access approximately 1,200 miles of trails, 65 camping locations, and ten federally designated Wilderness Areas that constitute nearly half (48%) of its acreage (NFWF, 2016). The proper design, use, and maintenance of the road network is critical to ensuring that recreational visitors are provided safe access to these public resources each year. Furthermore, these roads are an integral part of the LPNF infrastructure for long term resource management and fire-fighting needs.

The forest road network is a source of erosion and fine sediment delivery into the surrounding stream network. Roads collect water along their length and divert it onto hillslopes, resulting in the formation of gullies and landslides that affect the integrity of the road and stream networks. Fine sediment transported into streams can alter natural stream characteristics and create unsuitable habitat for sensitive aquatic species.

The erosive potential of road-related runoff is amplified by the effects of wildfire due to reduced vegetation and increased erodibility of the surrounding landscape. In 2007, the Zaca Fire burned over 240,000 acres in the LPNF (CalFIRE, 2017), making it the second largest recorded fire in California at the time (it is currently sixth largest). Much of the area burned by the Zaca Fire is drained by the Santa Ynez and Santa Maria River watersheds—including streams that are critical habitat for the federally endangered southern California Steelhead Distinct Population Segment (DPS). In 2015, the LPNF partnered with the National Fish and Wildlife Foundation (NFWF) to restore the watersheds and ecosystems affected by the Zaca, Jesusita, and Piru Fires. This partnership aims to invest in projects that provide sustainable and lasting ecological benefits, promote ecological resilience to future wildfire events, improve the LPNF's capacity to identify and address resource management issues stemming from these fires, and repair critical infrastructure such as trails and fuel breaks damaged by the fire, particularly where they have a discernable connection to the program's goals of ecological restoration (NFWF, 2015).

The LPNF Road Inventory and Erosion Assessment project was designed to support the goals of the LPNF and NFWF partnership through: (1) revealing restoration and road improvement opportunities that reduce sediment loading to streams and benefit aquatic habitat and (2) improving future firefighting efforts by identifying safety or integrity issues in the road network.

Although this project focuses on areas burned by Zaca Fire, it is be noted that other fires have affected and may continue to affect the integrity of roads within the study area. Since 1912, over 2.3 million acres have been burned by wildfire in the LPNF (USDA, 2018). Table 1 identifies the major wildfires that have affected a section of at least one surveyed road since 1990. A total of 10 large wildfires (including the Zaca Fire) have affected surveyed roads since 1990. Map 1 shows the number of times that these fires have burned land within the study area. Although some roads have been burned twice since 1990, most have only been burned once. There are some small areas in which three different fire scars overlap, but these are insignificant in size and may be due to small errors in mapping the fire extent. It is also important to note that Map 1 only shows fire perimeters and does not indicate burn severity.

Table 1 – Major fires affecting surveyed roads since 1990

The major fires (at least 1,000 acres) that have affected a section of at least one surveyed road since 1990.

Fire	Year
Marre	1993
Spanish	1999
Cachuma	2004
Perkins	2006
Bald – San Rafael Complex	2006
Zaca (program fire)	2007
La Brea	2009
White	2013
Rey	2016
Thomas	2017

1.2 Project Objective

This project aims to provide a current and comprehensive assessment of forest roads in and around watersheds affected by the 2007 Zaca Fire. This information can be used to prioritize road improvement projects that increase the accessibility and safety of the forest road network and reduce impacts to aquatic habitat and other forest resources. The objectives of this report are as follows:

- Provide a summary of data collected on LPNF forest roads from June to October 2017.
- Identify roads and areas with drainage, erosion, and road integrity issues.
- Identify primary areas for restoration or roadwork to improve road function.
- Identify roads with stream connectivity.
- Utilize the GRAIP model to assess the surveyed road network and identify areas of high sediment production.
- Provide recommendations for best management practices.

Map 1 – Zaca Fire and other overlapping fires since 1990

The major fires (at least 1,000 acres) that have affected surveyed roads in the study area since 1990. Yellow indicates areas that have been burned once since 1990, and orange indicates areas that have been burned twice since 1990. Zaca Fire is depicted using red diagonal hash marks.



2.0 SURVEY APPROACH

Data collection and analysis protocols were selected and modified from the *USFS Geomorphic Road Analysis and Inventory Package* (GRAIP; Black et al., 2012). Survey and data analysis protocols are specified in *GRAIP Volume 1: Data Collection Method* (Black et al., 2012), and *GRAIP Volume 2: Office Procedures* (Cissel et al., 2012). Modifications were made to adapt data collection protocols to the conditions observed in the LPNF and to ensure field crew safety.

Two survey crews comprised of two personnel each conducted the GRAIP surveys. Protocol training was conducted in the office and field to properly identify and measure road prism features as described in *GRAIP Volume 1: Data Collection Method* (Black et al., 2012). Crews were familiarized with all survey equipment, data collection methods, and safety devices. Field training was conducted over multiple days on 5N12.1 (East Camino Cielo), where crews were trained in feature identification, proper use of survey equipment, and survey documentation.

Surveys were conducted over 14 weeks between June and October 2017. The survey schedule was designed based on road priority, length, drivability, and ease of access. A list of 306 miles of forest roads, their known accessibility, and inventory priority was provided by the Forest Service at the onset of the project (see Table 17 in Appendix A2). Modifications to the initial schedule were made due to the Whittier Fire in July 2017, which caused the forest to shut down during the week of July 10. The inventory covered 86% of Priority 1 roads, 38% of Priority 2 roads and 58% of Priority 3 roads. The ability to survey remote backcountry roads was hindered by unsafe and inaccessible driving conditions, overgrown and eroded road surfaces, and blockage by landslides. Table 18 in Appendix A2 provides the final survey schedule for this project.

2.1 Targeted Survey Roads

All roads targeted for surveying were within the LPNF boundary and were either found within the Zaca Fire scar or were used during or impacted by fire suppression activities relating to these fires. Targeted survey roads were chosen based upon priorities that were identified by LPNF staff. A total of 202 miles of forest roads were surveyed, 99.4 miles of which are within the fire scar. Table 2 provides a summary of surveyed road length in relation to the Zaca Fire scar, and Map 2 shows the location of these road segments.

Table 2 – Approximate total surveyed road length

Summary of approximate total surveyed road length by road number and road name.

Road Number	Road Name	Road Length Surveyed (mi)
-	Bluff Campground	0.1
-	McKinley Campground	0.1
-	Arroyo Burro Trail	0.1
-	Miranda Pines Camp	0.4
10N06.1	La Brea Cyn. OHV	2.2
10N06A	Barrel Spring Campground	0.1
11N01.3	Bates Canyon	6.4
11N03	Miranda Pine	9.4
11N03A	-	0.3
11N04.3	La Brea OHV	11.7
11N04.4	Colson Cyn.	2.6
11N04B	Lazy Camp Campground	0.8
11N04C	Colson Cyn. Sta.	0.6
32S13.1	Sierra Madre	29
32S13.2	Sierra Madre	17.8
5N01	Pendola Jeep	2.9
5N01	Pendola Jeep	2.9
5N12.1	East Camino	8.8
5N12.2	East Camino	1.3
5N13.3	Murieta	7.7
5N15.2	Romero Camuesa Fdr.	4.3
5N16	Big Caliente	2.7
5N20	Arroyo Burro	5.7
6N03	Potrero Seco	22.1
6N11	Don Victor	2.4
6N17	Hildreth Pk.	4.0
7N04	Tinta Cyn. OHV	2.6
7N04A	-	0.8
8N02	Zaca Ridge Rd. OHV	9.0
8N02 Camp	-	0.04
8N08.1	McKinley	5.7
8N08.2	McKinley	1.8
8N19	West Dry	8.1
9N11.2	Buckhorn	5.0
9N11.3	Buckhorn	14.9
9N11.4	Buckhorn	7.9
Total Length (mi)		202.0

Map 2 – Surveyed Roads in the LPNF (June – October 2017)

LPNF forest roads inventoried from June to October 2017 for approximately 202 miles utilizing USFS GRAIP protocol.



2.2 Overview of Survey Methods

A Trimble Nomad GPS data logger was used to collect geo-referenced information on road lines, drain points, and other features encountered in the field. The Nomad GPS was equipped with Trimble TerraSync software and the INVENT 5.0 data dictionary developed for GRAIP. The Nomad has a real-time field accuracy of 2 to 5 meters, which can be further improved down to 1 meter by post-processing. Crews aimed to achieve a field accuracy of less than 8 meters. The GRAIP data dictionary is the interface through which information is collected according to the GRAIP protocol. The data dictionary was modified through the survey period to capture conditions and features specific to the LPNF. Data sheets and notebooks were used to log photos and document conditions that were difficult to capture using the data dictionary.

2.3 GRAIP Protocol

The GRAIP data collection and analysis methodology provides land managers with field-based geo-referenced data that can be used to estimate the extent of road-derived sediment delivery to the stream network. The GRAIP database provides a comprehensive inventory of the surveyed road network and offers valuable data concerning drain point location and condition, mass wasting events, gullies, and other important road-related features.

The GRAIP methodology examines three primary components of the road drainage network:

1. The road prism (cutslope, road surface, and fillslope) to identify road issues and assess where most of the water and sediment are generated.
2. Drain points, where the flow and sediment are diverted from the road prism, are identified to determine where and how they function.
3. Where the water is discharged below the drain point. Information regarding the hillslope flowpath below the drain point helps make inferences about sediment delivery to nearby streams.

2.4 GRAIP Protocol Additions & Modifications

Due to the unique conditions and topography of the LPNF, feature additions and modifications were included in the GRAIP data collection protocols.

Added features include:

- “Road Ponding” to capture instances when water did not drain from the road surface and puddled in the road (differentiating it from sumps which were uncommon in the LPNF).
- “Road Line – Recently Graded” to record when a road surface had been recently graded.

- “Road Line – Rilled” to identify road segments where rilling of flow paths caused active fine sediment erosion.
- “Road Line – Gullied” to help characterize extreme erosion on road surfaces where gullying of flow paths caused active fine sediment erosion.
- “All drain points – Lead Off” to characterize how flows are conveyed from the road line to the drain point.

Modified features include:

- “Road Erosion” includes an average length, depth, and width of erosion.
- “Mass Wasting” includes additional types to differentiate between rockfalls, soil creeps, and earth slides.
- “Stream Connectivity” option for “Unknown” was added for use when it was not clear whether the drain point was connected to a stream and it was unsafe to leave the road surface to determine connectivity.
- “Photos” were included as an attribute to all point and line features. A paper photo log was also used to record photo numbers and descriptions of photographed features.
- “Road Fill” calculations were modified due to the frequent inaccessibility of the downstream end of culverts. The upstream and downstream lengths and gradients were estimated using a range finder and clinometer. The road width and fill length from valley edge to valley edge was measured by tape or range finder, and the gradient of the culvert was estimated using a clinometer.

2.5 Data Processing

Satellite position, topography, canopy, and cloud cover can influence the accuracy of GPS locations for point and line features, creating errors in the spatial representation of field data. Field data was corrected for accuracy through the following multi-step data processing method in accordance with *GRAIP Volume 2: Office Procedures* (Cissel et al., 2012):

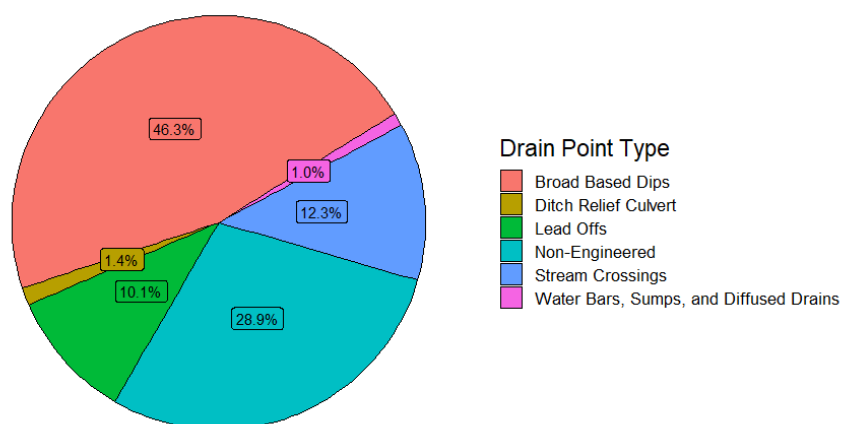
1. Field geo-referenced data was differentially corrected to improve inaccuracies from satellite orientation and positioning.
2. Corrected GPS data were projected to the UTM NAD 1983 Zone 11 projected coordinate system used by the USFS.
3. Data was corrected for topography and canopy cover interference. This may result in errors in the road line such as zig-zagging or clustered segments, which can create additional road length and may not be reflective of the actual road. Data was manually corrected by referencing field-collected road features against roads on aerial images of the survey area, collected by the National Agricultural Imagery Program (NAIP) between 2012 and 2014.

3.0 DRAIN POINT INVENTORY RESULTS

A total of 3,370 drain points were recorded throughout the inventoried road network. These included: broad based dips (1,561), diffused drains (22), ditch relief culverts (47), lead off ditches (341), non-engineered drains (973), stream crossings (414), sumps (9), and water bars (3). Figure 1 shows the relative distribution of all drain points. The most commonly encountered drain point types include broad based dips (46%), non-engineered drain point (29%), and lead stream crossings (12%). Because diffused drains, sumps, and water bars were so uncommon (1.0% combined), they are not discussed further in this report.

Figure 1 – Distribution of inventoried drain points by type

Distribution of inventoried drain points by type. Water bars, sumps, and diffused drains are combined.

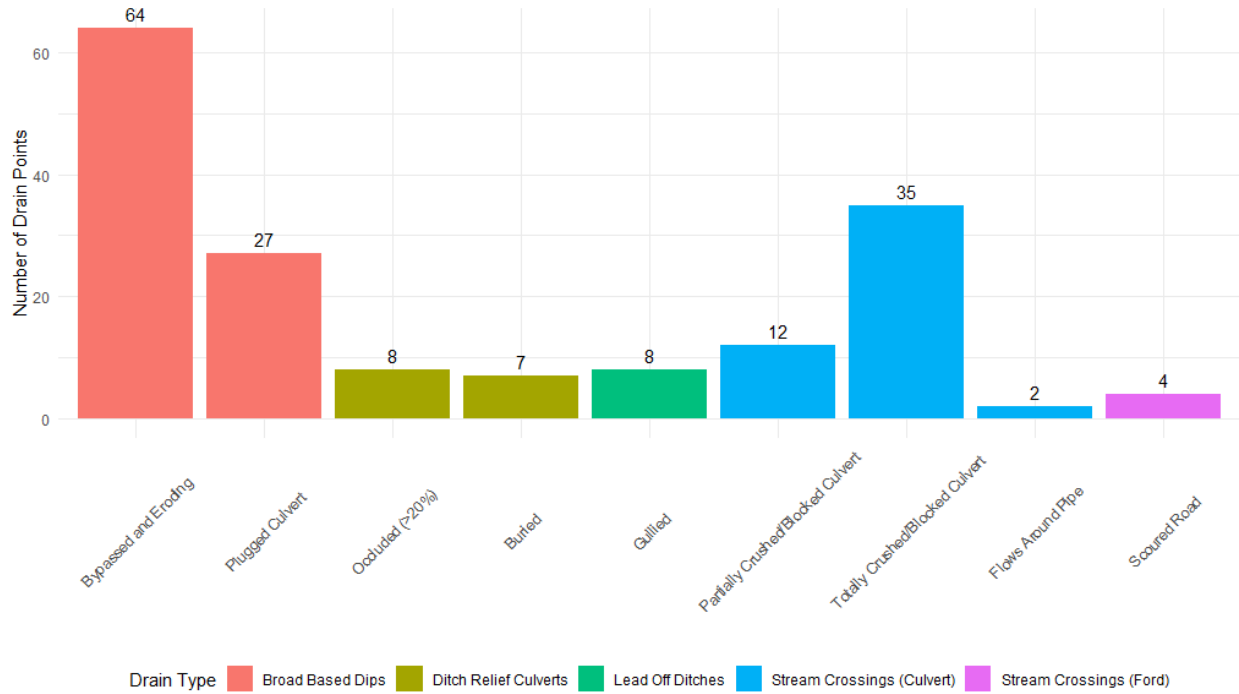


At the broadest level of drain function, drain points were either observed to drain water from the road surface or not. Drain points that were not observed to drain water from the road at the time of surveys are referred to as “orphaned.” While orphaned drains comprise only 2.9% (101) of all drain points, they are important to consider as they may create or exacerbate problems related to drain condition further down on the road network. Because orphaned drain points may be related to road condition (not necessarily drain point condition), they are considered separately in Section 6.3.

Table 4 provides an outline of the drain point conditions that are considered problematic in this analysis. It is important to note that a drain point may exhibit more than one of these conditions, but that only the most severe problem is recorded for that drain point. Approximately 5.0% (167) of all active (non-orphaned) engineered drain points exhibited problems related to their condition. All non-engineered drain points were considered problematic in this analysis. Figure 2 provides a breakdown of these problems by drain point type for active non-orphaned drains only. Broad based dips had the highest number of active problematic drain points (91), with 64 bypassed and eroding lead offs and 27 plugged culverts. Culvert stream crossings also had a high number of active problematic drain points (49), with 35 exhibiting a totally crushed or blocked culvert, 12 exhibiting a partially crushed or blocked culvert, and where flow was observed to go around the pipe inlet. A large portion of ditch relief culverts exhibited issues including occlusion greater than 20% (8) or were buried. In general, the number of active problematic drain points at lead off ditches (8) and ford stream crossings (4) was low.

Figure 2 – Problems associated with active engineered drain points

Drain point problems associated with active broad based dips, ditch relief culverts, lead off ditches, culvert stream crossings, and ford stream crossings. Orphaned drain points are excluded.



Fill erosion at a drain point may also indicate a broader issue dealing with drain point function. Table 3 summarizes the number of eroded drain points (including orphaned drains) and provides estimates for total, maximum, and average fill erosion. Non-engineered drain points contributed approximately 40% (1,330 m³) of all estimated fill erosion (3,299 m³), indicating a disproportionately large contribution. Broad based dips contributed 23% (766 m³) of total fill erosion despite constituting the largest percentage of inventoried drain points (46%).

Table 3 – Eroded drain point counts and fill erosion estimates

Eroded drain point counts and summary statistics for fill erosion estimates.

Drain Type	Total Count	Drain Points with Fill Erosion		Fill Erosion (m ³)		
		Count	Percent	Total	Max	Avg*
Broad Based Dip	1,561	804	52%	766	53	0.98
Ditch Relief Culvert	47	11	23%	22	10	1.98
Lead Off	341	105	31%	231	104	2.20
Culvert Stream Crossing	111	16	14%	507	145	31.68
Ford Stream Crossing	303	58	19%	443	185	7.65
Non-Engineered	973	830	85%	1,330	251	1.63
Total	3,336	1,824	54%	3,299	-	-

* Average fill erosion calculation only includes drain points with fill erosion greater than zero.

Table 4 – Explanation of problematic drain point conditions

Drain point conditions that are considered problematic for this analysis. Condition is listed in order from most to least severe (top to bottom) for each drain point type. A drain may exhibit more than one of these conditions, but only the most severe was recorded in the GRAIP database.

Drain Point Type	Condition	Problem
Broad Based Dips	Bypassed and eroding	Indicates active erosion of the drain point and increased sediment production below the drain point. May lead to gullyng of the hill and fill slope and increase sediment delivery to the stream channel.
	Plugged culvert	Prevents water from flowing into the culvert as intended. May indicate excess sediment being routed to the drain point and may cause drain point to be orphaned.
Ditch Relief Culvert	Buried	Prevents water from flowing into or out of the ditch relief culvert and under the road surface as intended. Drain point may be orphaned and water is forced to drain to the next drain point (see “Orphaned”).
	Occlusion > 20%	Reduces the capacity and functionality of the culvert to move water under the road surface. May lead to buried inlet if not addressed (see “Buried inlet”).
Lead Off	Gullied	Indicates active erosion of the drain point and increased sediment production. May lead to gullyng of the hill and fill slope and increase sediment delivery to the stream channel.
Stream Crossing (Culvert)	Totally crushed or blocked	Prevents water from flowing under the road surface as intended. May lead to capture of the stream channel by the road, the creation of non-engineered drain points, or catastrophic failure of the crossing and delivery of a large sediment pulse to the stream channel.
	Partially crushed or blocked	Reduces the capacity and functionality of the culvert to move water under the road surface. May become totally blocked if not addressed (see “Totally blocked”).
	Flows around pipe	Prevents water from flowing under the road surface as intended. May lead to capture of the stream channel by the road, the creation of non-engineered drain points, or catastrophic failure of the crossing and delivery of a large sediment pulse to the stream channel.
Stream Crossing (Ford)	Scoured road surface	Indicates active erosion of the drain point and increased sediment delivery to the stream channel.

3.1 Broad Based Dips

A broad based dip is a large grade reversal in the road that is either constructed into the road grade or is the result of two hillslopes meeting. Properly located and installed, broad based dips provide a relatively cheap and low maintenance way to divert water off the road surface, disperse water flows, and reduce erosion.

Broad based dips were the most common drain point observed on surveyed roads. A total of 1,561 broad based dips were recorded during the survey, comprising approximately 46% of all surveyed drain points. The most commonly encountered problem with broad based dips was bypassed and eroding lead offs (approximately 4% of all broad-based dips). At these drain points, water was observed to drain around the culvert, which normally carries (leads off) down the fill slope and protects it from erosion, causing erosion of the road surface, fillslope, and hillslope to occur. Bypassed and eroding lead offs may occur due to inadequate road drainage above the drain point, or may be due to plugged, crushed, or displaced lead off culverts (such as McCarthy drains).

Broad based dips with fill erosion greater than or equal to 20 m³ are shown in Table 5. Seven out of the eleven broad based dips have bypassed and eroding lead offs. Out of the broad based dips presented in Table 5, four are located on 6N03 and four are located on 9N11. The distribution of all broad based dips is shown on Map 3, highlighting ones with the highest fill erosion and that are bypassed and eroding. Two bypassed and eroding lead offs with a large amount of fill erosion on 6N03 are shown in Photo 1.

Table 5 – Broad based dips with fill erosion greater than 20 m³

Broad based dips with fill erosion greater than 20 m³ by road number, point ID from the geodatabase, total fill erosion (m³), and whether they are bypassed and eroding.

Road	Point ID	Fill Erosion (m ³)	Bypassed and Eroding?
9N11.4	236	53	No lead off
11N04.3	764	50	No lead off
9N11.4	318	46	Yes
6N03	474	35	Yes
6N03	492	35	Yes
6N03	484	25	Yes
11N04.3	659	24	Yes
9N11.3	32	24	No
5N15.2	30	24	Yes
9N11.4	325	20	No lead off
6N03	208	20	Yes

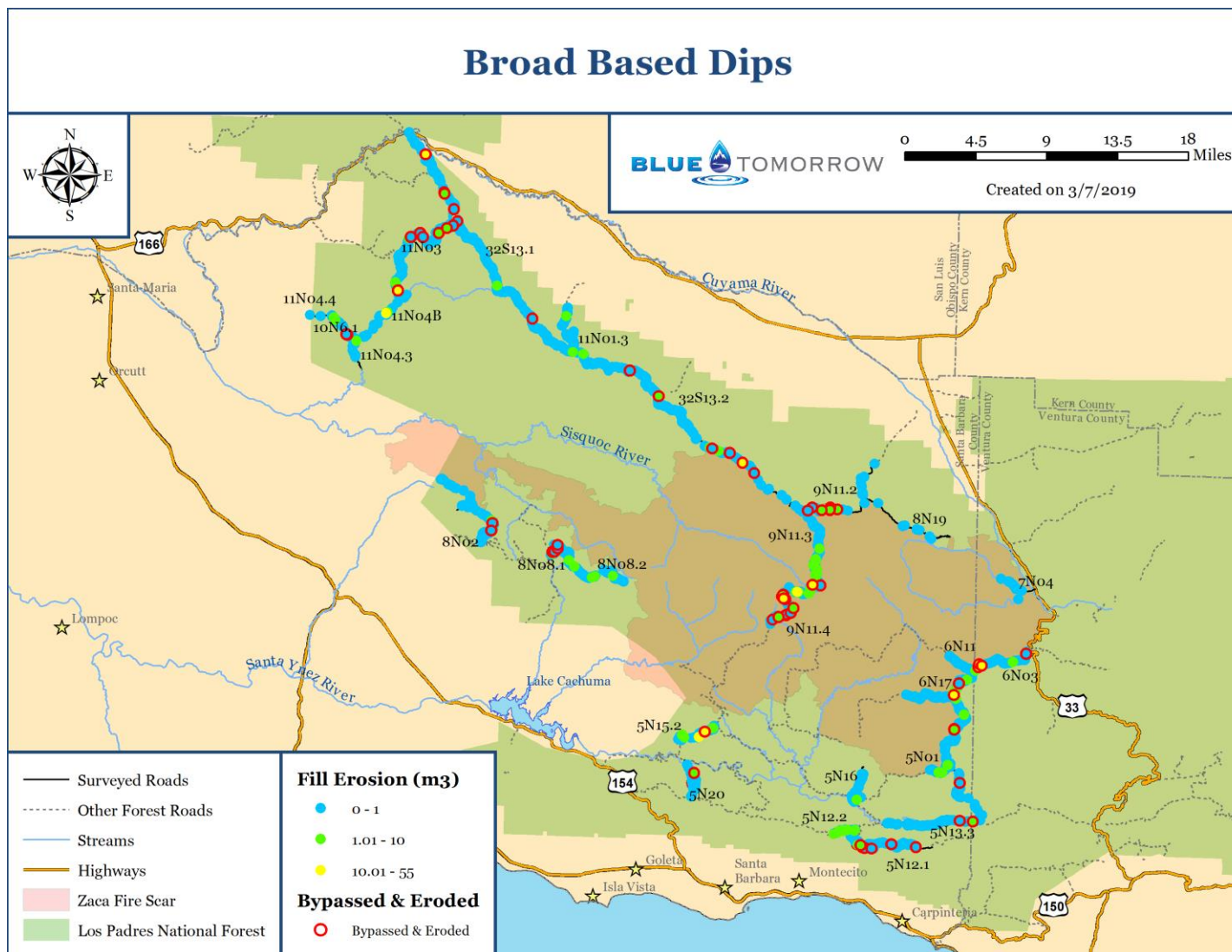
Photo 1 – Bypassed and eroding McCarthy drains at broad based dips on 6N03

Two bypassed and eroding broad based dips located on 6N03 (Potrero Seco). From top to bottom: a broad based dip with 35 m³ of fill erosion (Point ID: 474), and a broad based dip with 25 m³ of fill erosion (Point ID: 484).



Map 3 – Broad based dips

All broad based dips inventoried within the study area. Broad based dips are symbolized by the estimated volume of fill erosion and the presence of a bypassed and eroding metal lead off such as a McCarthy drains or other similar flume.



3.2 Lead Off Ditches

Lead offs for ditches were documented as a distinct point when flow from the side of the road was diverted (or led) off the road onto the hillslope. Use of frequently spaced lead off ditches helps prevent accumulation of excessive water in roadway ditches.

A total of 341 lead off ditch drain points were recorded in the survey area (Map 4). Out of these, 9 were gullied, 7 were rilled or eroded, and 4 exhibited excess deposition (Table 6). At gullied lead offs, gully erosion was observed to concentrate surface flows, extend flow paths, and increase the amount of erosion caused by the road. A total of 34 lead offs discharged runoff into gullies on the hillslope. Fill erosion associated with lead offs is generally low (2.20 m³ average). Two examples of gullied lead offs are shown on 11N03 (Photo 2) and 9N11.4 (Photo 3).

Table 6 – Counts of lead off ditch condition

Summary of lead off condition by road number, total number of lead offs, number with excess deposition, number with rilling or erosion, and the number that are gullied.

Road	Total Number	Number Excess Deposition	Number Rilled/Eroded	Number Gullied
5N12.1	13	3	2	3
9N11.4	6	0	0	2
5N15.2	15	0	0	2
11N03	11	0	0	1
8N19	51	1	0	0
6N03	55	0	0	1
8N08.2	5	0	5	0

Photo 2 – Gullied lead off ditch on 11N03

Gullied lead off located on 11N03 (Point ID: 589).



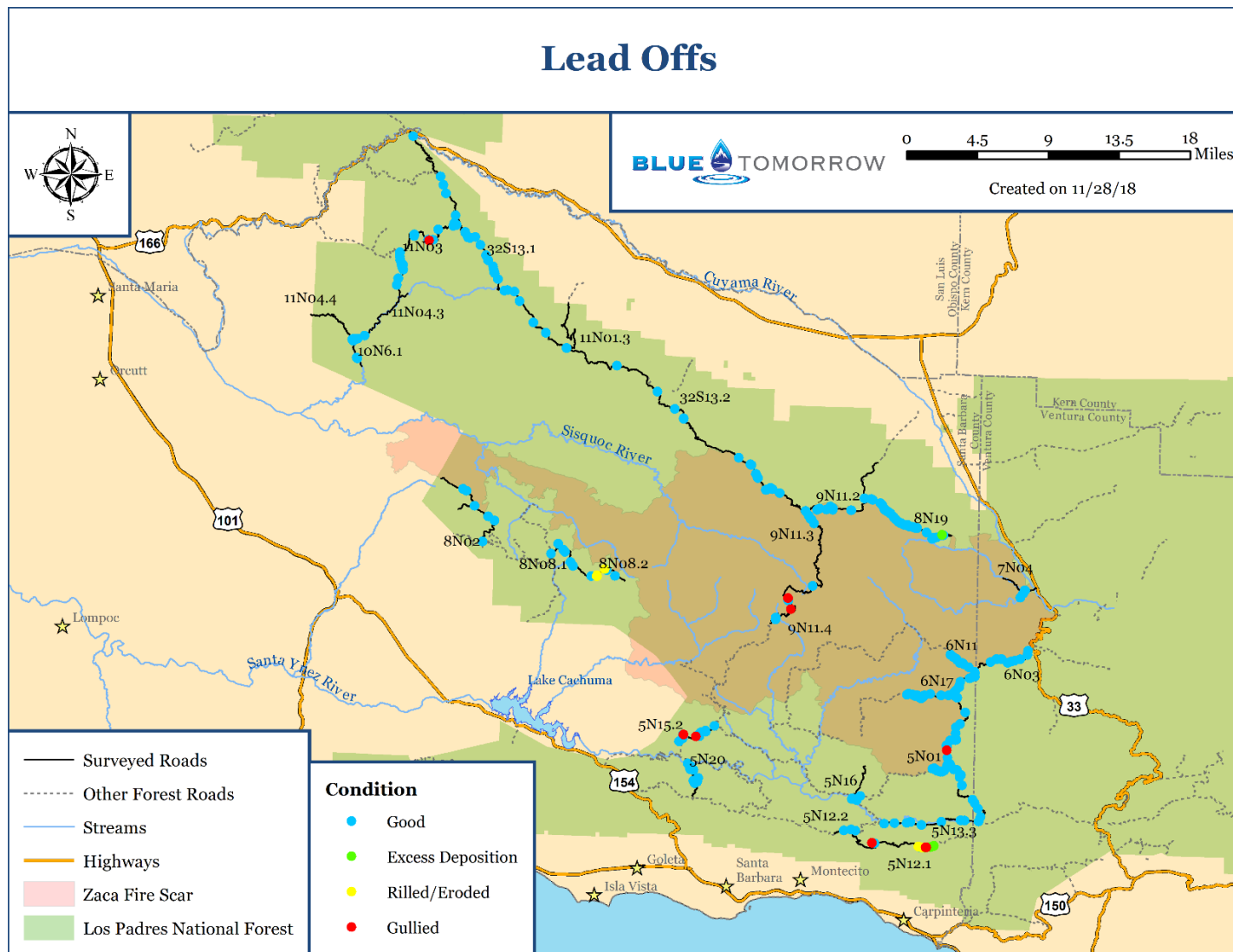
Photo 3 – Gullied lead off ditch on 9N11.4

Gullied lead off located on 9N11.4 (Point ID: 313).



Map 4 – Lead off ditches

All lead offs inventoried within the study area symbolized by condition (good, excess deposition, rilled/eroded, and gullied).



3.3 Ditch Relief Culverts

Ditch relief culverts are conduits buried beneath the road surface to drain water from an inboard ditch under the road onto the hillslope. They drain water from the cutslope and the road (if the road is in-sloped).

A total of 47 ditch relief culverts were recorded within the survey area on just seven of the surveyed roads. These were primarily located on the northwestern part of 32S13.1 (near Highway 166) and the western edge of 6N03 (near Highway 33). Table 7 provides a summary of all ditch relief culverts. The most common issue with ditch relief culverts was occlusion or buried culverts. Occlusion refers to blockage at the inlet, outlet, or within a culvert due to sediment or other obstructions which prevents water from efficiently flowing through the culvert. Approximately 34% (16) of ditch relief culverts exhibited greater than 20% occlusion. In instances where culverts were completely buried by sediment, the ditch relief culvert no longer functioned and was considered orphaned. Completely buried ditch relief culverts were encountered twice during the surveys.

The distribution of ditch relief culverts throughout the surveyed road network is shown on Map 5. 6N03 and 11N04.3 appeared to have the most issues with ditch relief culverts. An example of a ditch relief culvert buried by a landslide on 5N15.2 is shown in Photo 4 and a ditch relief culvert buried by grading on 11N04.3 is shown in Photo 5.

Table 7 – Counts of occluded ditch relief culverts

Counts of occluded ditch relief culverts summarized by the total number of ditch relief culverts and the number in each percent occlusion category (20-80%, 80-100%, and Buried).

Road	Total Number	Percent Occluded (Count)		
		20 – 80%	80 - 100%	Buried
6N03	20	5	5	0
32S13.1	13	0	1	0
11N04.3	6	1	2	1
5N15.2	4	0	1	1
32S13.2	2	2	0	0
5N20	1	0	0	0
9N11.4	1	0	0	0
Total	47	8	6	2

Photo 4 – Buried ditch relief culvert on 5N15.2

Buried ditch relief culvert located on 5N15.2 (Point ID: 431).



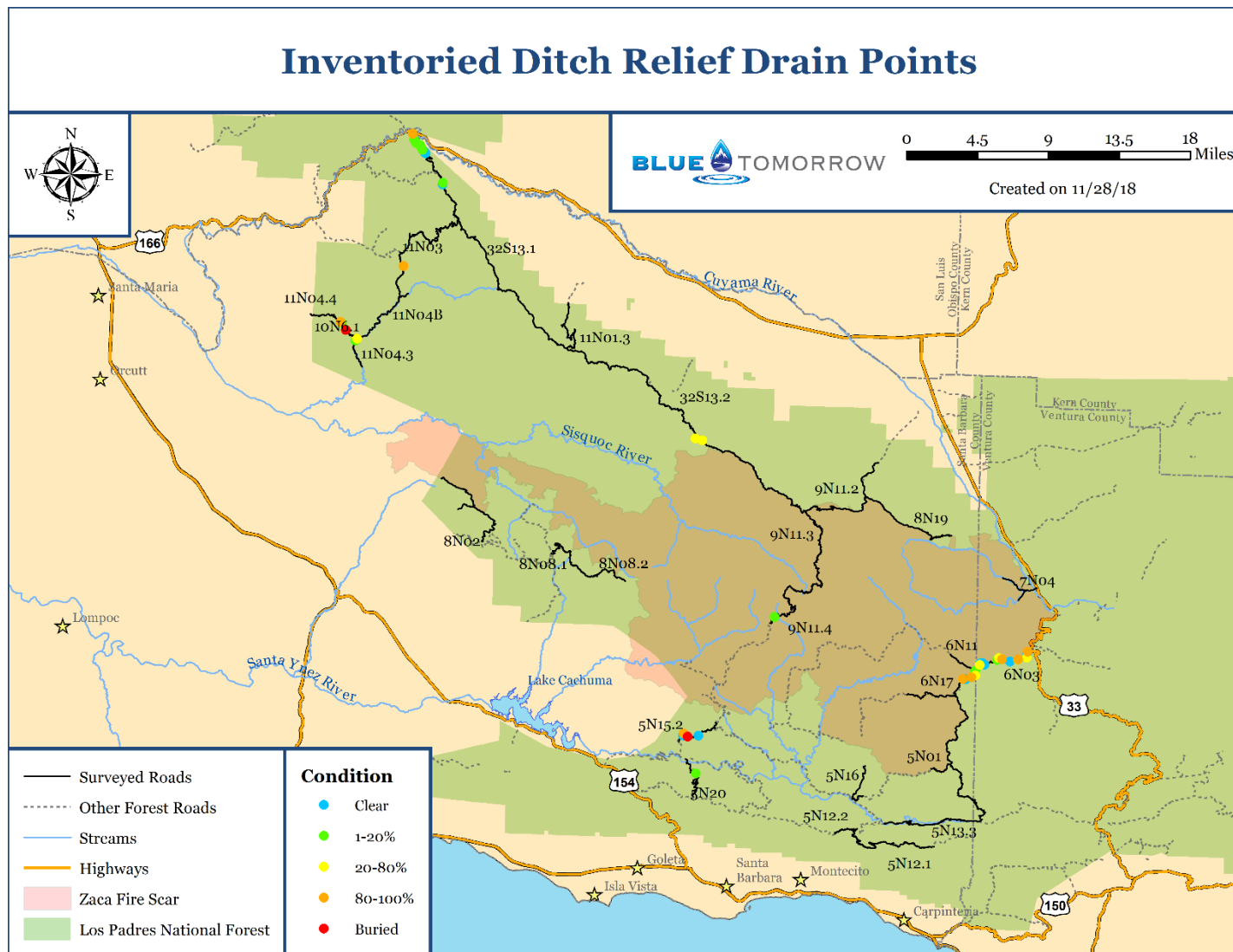
Photo 5 – Buried ditch relief culvert on 11N04.3

Buried ditch relief culvert located on 11N04.3 (Point ID: 92).



Map 5 – Ditch relief culverts

All ditch relief culverts inventoried within the study area symbolized by percent occlusion (clear, 1-20%, 20-80%, 80-100%, and buried).



3.4 Stream Crossings

Stream crossings and the section of road leading to the crossing have great potential for sediment delivery to streams because of frequent direct hydrologic connectivity between the road and stream (Aust et al., 2011; Lane & Sheridan, 2002; Wear et al., 2013). A total of 414 stream crossings were inventoried on surveyed roads. Of these, 111 were culvert stream crossings, 285 were natural fords, and 18 were concrete fords.

Culvert stream crossings were found to have issues due to the culvert being blocked or crushed. A total of 12 culvert stream crossings were either partially blocked or partially crushed. Complete blockage or crushing of culverts occurred at 35 culvert stream crossings, inhibiting stream flow from moving through the culvert. This causes the stream channel to flow around the pipe, leading to fill erosion and capturing of the stream channel by the road surface. A blocked culvert can also present a hazard during a storm and could cause destruction to the road. This could also cause high sediment impact to the stream if the road fill is blown out. Table 8 provides a summary of roads with at least one culvert stream crossing that was found to be totally blocked or crushed. The distribution of stream crossings is shown in Map 6, highlighting culverts that were crushed or blocked at the time of surveying. Photo 6 shows an example of a large volume of fill erosion created by a totally blocked culvert stream crossing on 9N11.3.

Table 8 – Counts of stream crossing condition

Counts of stream crossing condition on roads with at least one totally blocked or crushed culvert summarized by the total number of stream crossings, the number that were open and sound, the number that were partially crushed or blocked, and the number that were totally crushed or blocked.

Road	Total	Open and Sound	Partially Crushed/Blocked	Totally Crushed/Blocked
5N15.2	10	2	2	6
11N04.3	9	3	1	5
8N19	8	4	0	4
9N11.2	8	4	0	4
11N04.4	11	7	1	3
6N03	8	5	0	3
5N12.1	7	4	1	2
5N20	8	4	2	2
9N11.4	6	4	0	2
32S13.1	6	5	0	1
32S13.2	3	2	0	1
5N16	2	0	1	1
9N11.3	1	0	0	1

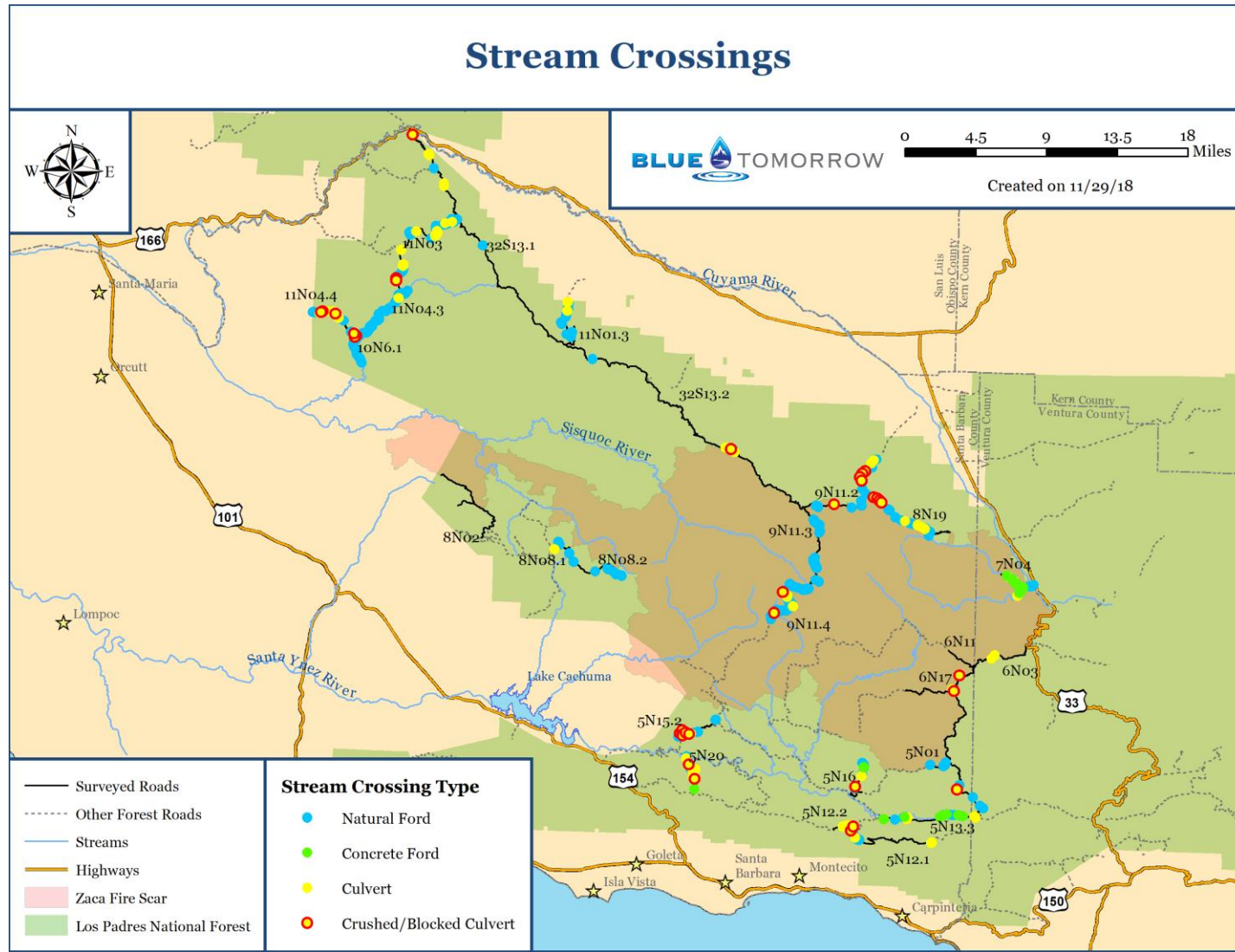
Photo 6 – Example of erosion at outlet of blocked culvert stream crossing on 9N11.3

Erosion at the outlet of a blocked culvert stream crossing on 9N11.3 (Point ID: 26). From top to bottom: as viewed from the road looking down at the channel, and from mid-channel looking up at the road. The fill and gully erosion was estimated at about 43 m³.



Map 6 – Stream crossings

All stream crossings inventoried within the study area symbolized by stream crossing type (natural ford, concrete ford, culvert) and the presence of crushed or blocked culverts (only totally crushed or blocked).



3.5 Non-Engineered Drain Points

Non-engineered drain points may increase sediment delivery into the stream network and may form when engineered drain points inadequately drain water off the road surface or road maintenance is not regularly conducted. A total of 973 non-engineered drain points were observed on surveyed roads and accounted for roughly 29% of all drain points, second only to broad-based dips.

Diverted flow paths and broken berms caused most non-engineered drain points (93%). As shown on Map 7, non-engineered drain points were abundant on nearly every road throughout the survey area. Table 9 summarizes the top ten roads with non-engineered drain points as a percentage of total drain points. Non-engineered drain points account for over half of all drain points observed at 11N01.3 (Bates Canyon; 57%). Photo 7 shows an example of a non-engineered drain caused by a diverted flow path on 8N08.2. Map 7 also highlights non-engineered drain points with the greatest fill erosion. The largest recorded fill erosion from a non-engineered drain (251 m³) occurred on the southern end of 9N11.4 and was linked to a landslide (Photo 8).

Table 9 – Roads with more than 30% non-engineered drain points

Roads with non-engineered drain points accounting for over 30% of the total drain points. Roads with a surveyed length less than one mile or with fewer than 50 total drain points were not included.

Road	Engineered	Non-Engineered	Total	Percent Non-Engineered
11N01.3	44	58	102	57%
9N11.4	93	90	183	49%
6N03	264	215	479	45%
5N01	63	49	112	44%
8N19	82	50	132	38%
9N11.2	32	19	51	37%
32S13.2	127	68	195	35%
8N08.2	73	60	133	35%
9N11.3	211	109	320	34%
6N11	37	18	55	33%
Total	2374	933	3307	39%

Photo 7 – Non-engineered drain caused by a diverted flow path on 8N08.2

Non-engineered drain point and associated fill erosion caused by a diverted flow path on 8N08.2 (Point ID: 266).



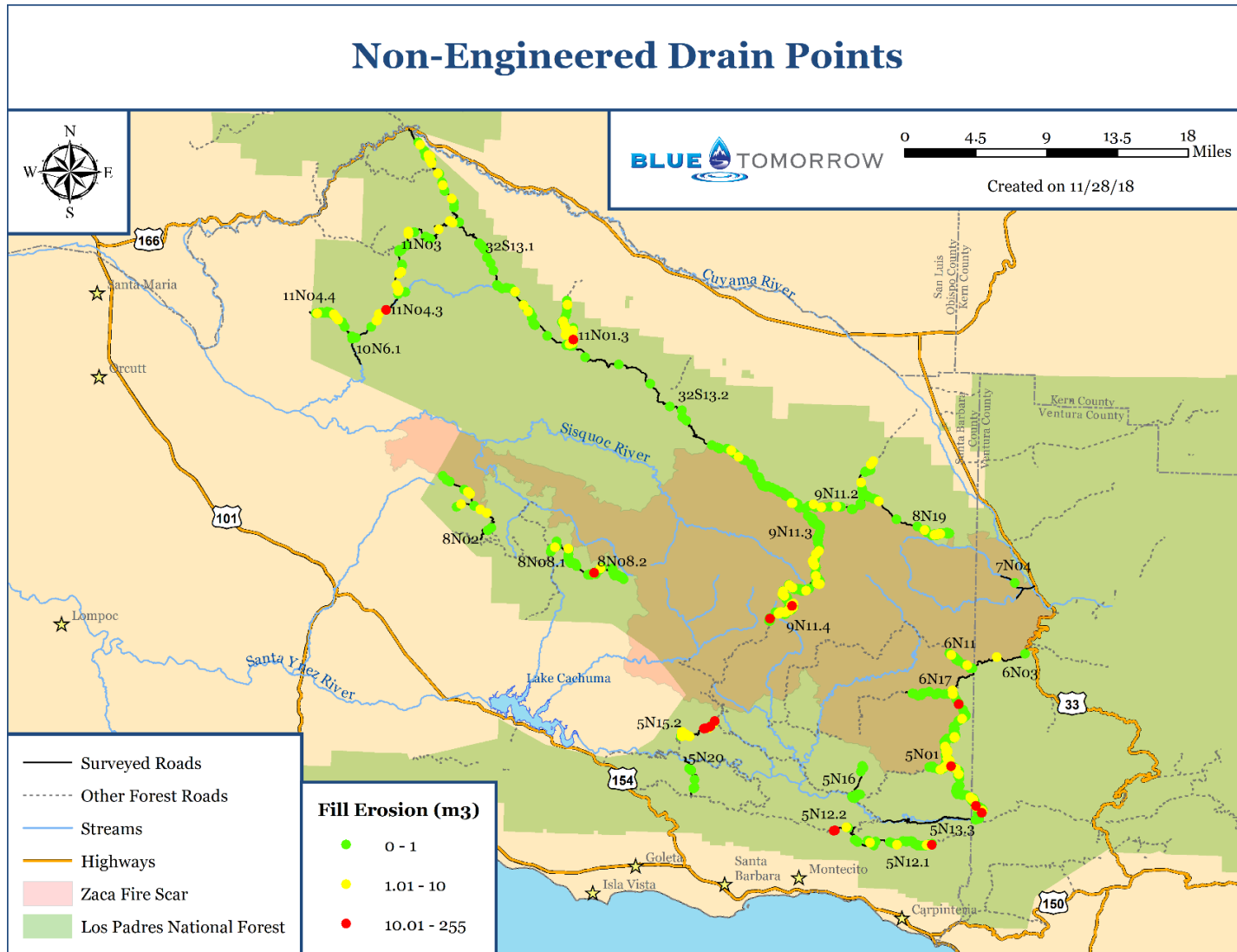
Photo 8 – Erosion associated with non-engineered drain point on 9N11.4

Non-engineered drain point and associated landslide on 9N11.4 (Point ID: 5).



Map 7 – Non-engineered drain points

All non-engineered drain points inventoried within study area symbolized by volume of fill erosion.



4.0 ROAD LINE INVENTORY RESULTS

A total of 202 miles of forest roads were inventoried in the LPNF. This section provides a summary of the drainage and surface conditions of the inventoried road network and highlights the most commonly observed issues. Road issues presented in this section are a point-in-time representation and may have changed since surveys were conducted.

4.1 Eroded Road Surfaces

The most common issue with road condition was eroded road surfaces, which may create unsafe driving conditions, inhibit road access, and indicates sediment production. For this analysis, the road surface was considered eroded when it was observed to be rilled, rutted, or gullied. As shown in Table 10, a total of 14.3 miles (7.1%) of surveyed roads were identified as eroded. The longest total length of road surface erosion was recorded on 6N03 (Potrero Seco), which totaled to 3.8 miles. As shown in Map 8, erosion was documented throughout the entirety of 6N03 and was particularly bad near the connected roads of 5N01 (Pendola Jeep) and 6N17 (Hildreth Peak). Other roads with a large amount of eroded road surface include 32S13.1 (1.7 miles) and 8N08.1 (1.5 miles; Table 10). Photo 9 shows eroded road surfaces on 6N03.

Table 10 – Length and percentage of eroded road surface

Approximate length and percentage of eroded road surface (gullied, rilled, or rutted). Only roads with at least 1% percent erosion are included.

Road	Surveyed Road Length (mi)	Eroded Road Length (mi)	Percent Eroded
Miranda Pines Camp	0.4	0.3	84%
11N04C	0.6	0.4	78%
8N08.2	1.8	0.6	33%
6N11	2.4	0.8	33%
11N04.4	2.6	0.6	23%
8N08.1	7.4	1.5	21%
5N01	2.9	0.6	20%
6N03	22.2	3.8	17%
11N03A	0.3	0.05	15%
5N12.1	9.8	1.3	13%
8N02	9.0	1.2	13%
6N17	4.0	0.4	9%
32S13.1	29.0	1.7	6%
5N12.2	1.3	0.06	5%
9N11.4	7.9	0.3	4%
11N01.3	6.4	0.2	3%
11N04.3	11.7	0.3	3%

Map 8 – Road surface condition (erosion and vegetation)

Road surface erosion condition (eroded, not eroded) and vegetation condition (vegetated, not vegetated) for all surveyed roads.

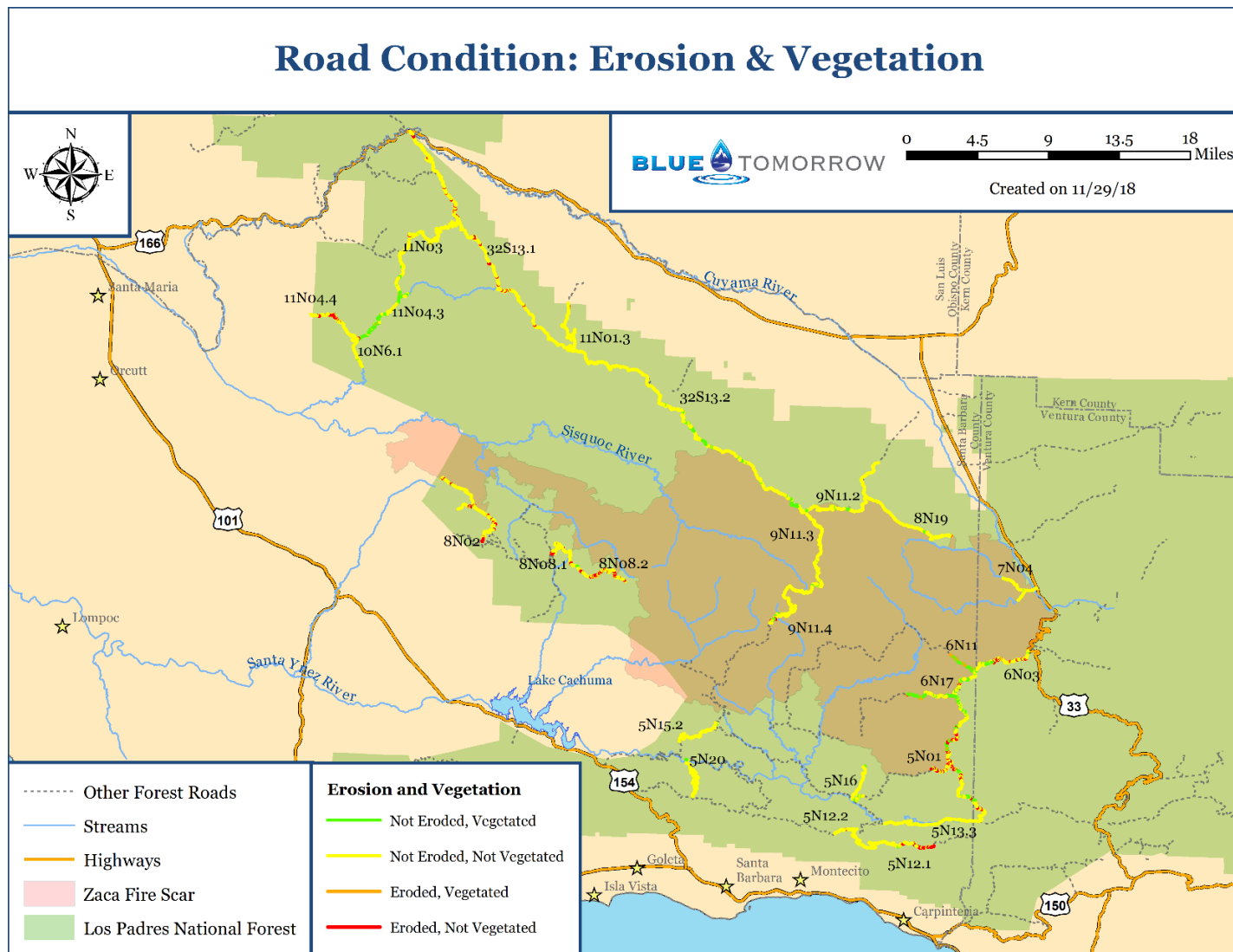


Photo 9 – Road 6N03 eroded road surface
Eroded road surfaces on 6N03 (top and bottom).



4.2 Vegetated Road Surfaces

Road surfaces were documented as being overgrown or vegetated when the surface was more than 25% covered in grass, herbs, or live woody vegetation. Vegetation helps reduce erosion and increase road stability but can be overgrown and inhibit drivability and access. Approximately 19.8 miles of the road network were observed to be overgrown (Table 11). Roads with the greatest vegetated length include 6N03 (4.8 miles), 11N04.3 (3.8 miles), and 32S13.2 (3.1 miles). The entire surveyed length of 6N11 was vegetated (2.36 miles). Map 8 shows the distribution of vegetation on surveyed roads. Photo 10 shows an example of vegetated road surface on 6N17.

Table 11 – Length and percentage of vegetated road surface

Approximate length and percentage of surveyed road by surface vegetation class (grass, herbs, or large woody vegetation). Only roads with at least 1% percent vegetated are included.

Road	Surveyed Road Length (mi)	Vegetated Road Length (mi)	Percent Vegetated
6N11	2.4	2.4	100%
11N04B	0.8	0.6	71%
6N17	34.0	2.3	58%
10N06A	0.09	0.05	51%
11N04.3	11.7	3.8	32%
6N03	22.2	4.8	21%
32S13.2	17.8	3.1	17%
5N01	2.9	0.4	15%
10N6.1	2.2	0.2	9%
Miranda Pines Camp	0.4	0.03	8%
5N16	2.7	0.2	7%
9N11.3	14.9	0.9	6%
9N11.4	7.9	0.4	5%
11N04C	0.6	0.02	3%
8N08.1	7.4	0.2	2%
5N20	5.7	0.1	2%
7N04	2.6	0.05	2%
5N15.2	4.3	0.07	2%
8N19	8.0	0.1	2%
5N12.1	9.8	0.08	1%

Photo 10 – Road 6N17 overgrown with grasses and herbs, woody vegetation

Vegetated road surfaces on 6N17. From top to bottom: road surface vegetated with grasses and herbs, road surface vegetated with woody vegetation.



4.3 Road-Stream Connectivity

Unpaved forest roads that discharge to streams can degrade water quality by routing overland flow and sediment into the stream network. In total, 860 drain points (26%) connected 47.2 miles of road (23% of all surveyed roads) to the stream network (Map 9). Additionally, 217 (6%) drain points had unknown stream connectivity, due to inability to safely assess connectivity. Including “unknown” drain points would connect an additional 13.5 miles of the surveyed road network to streams. For this analysis, only road segments where stream connectivity was certain are included.

Roads that are more than 25% stream-connected are summarized in Table 12. The greatest stream-connected road length was found on 11N04.3 (6.9 miles), which runs along La Brea Creek and had multiple washed out road segments and creek crossings (Photo 11). 9N11.3 had approximately 4.9 miles (33%) of stream-connected road, but it should be noted that a large percentage has unknown stream connectivity (32%). While road surface erosion on this road was minimal due to recent grading, the potential for high rates of erosion exists. The entire length of 11N04.4 was connected to stream channels, with most of the road less than 50 feet away from a stream channel, and non-engineered drain points commonly encountering drain points (Photo 12).

Table 12 – Length and percentage of stream connectivity

Stream-connected road length summarized by road number, stream connected road length, and percent connected. Only roads with more than 25% stream connectivity are included.

Road	Surveyed Road Length (mi)	Stream Connected Road Length (mi)	Percent Stream Connected
11N04.4	2.6	2.6	100%
10N6.1	2.2	1.9	86%
7N04	2.6	2.2	82%
11N04B	0.8	0.6	75%
9N11.2	5.0	3.4	69%
11N03A	0.3	0.2	64%
11N04.3	11.7	6.9	59%
5N16	2.7	1.3	47%
8N19	8.0	3.5	44%
5N20	5.7	2.4	43%
7N04A	0.8	0.3	38%
11N03	9.4	3.1	33%
9N11.3	14.9	4.9	33%
5N13.3	7.7	2.5	32%
McKinley Campground	0.1	0.03	32%
9N11.4	7.9	2.2	28%
11N01.3	6.4	1.8	28%
5N15.2	4.3	1.2	27%
5N01	2.9	0.8	25%

Map 9 – Road-stream connectivity

Stream connectivity (not connected, connected, unknown) for all surveyed roads.

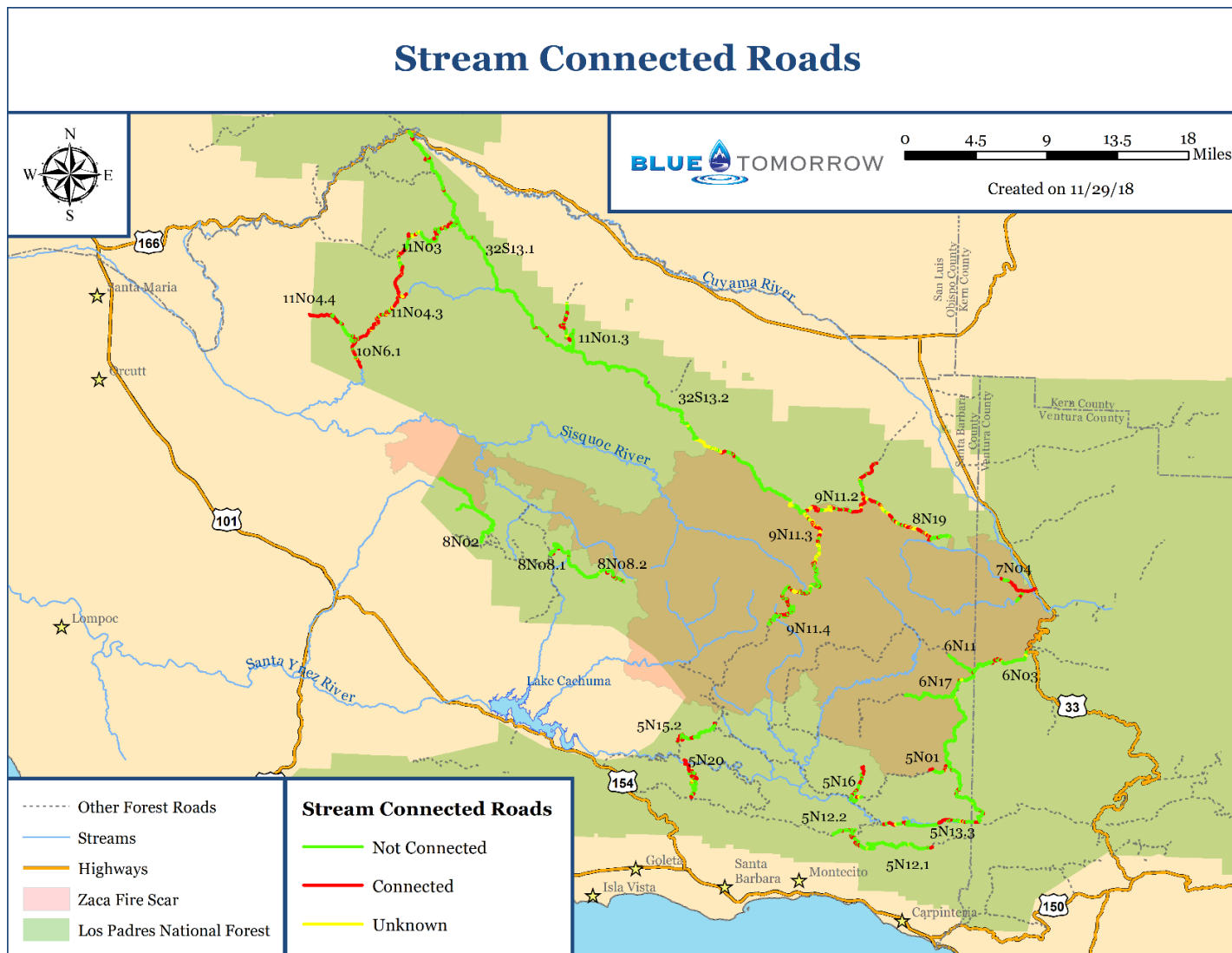


Photo 11 – Stream crossing on 11N04.3
Stream crossing on 11N04.3 in La Brea Creek (Point ID: 2083).



Photo 12 – Non-engineered drain point located next to a culvert stream crossing on 11N04.4
One of multiple non-engineered drain points contributing to stream connectivity on 11N04.4 (Point ID: 169).



4.4 Mass Wasting Events

Mass wasting events can be exacerbated by forest roads. Construction of the road prism can create steep gradients and a loss of deep-rooted vegetation above and below the road, which increases slope instability and susceptibility to mass wasting events. This section highlights roads where mass wasting events were documented as affecting road integrity or where clusters of mass wasting indicated a higher susceptibility to such events.

A total of 189 mass wasting events (24 road-related) were observed on 22 of the 30 inventoried roads (Map 10; Table 13). The number of mass wasting events was highest on 11N04.3, 9N11.4, and 11N01. (Table 10). 9N11.4 had a total of 27 mass wasting events in 7.9 miles, with ten occurring within a 0.2-mile stretch. This section of road was made inaccessible to vehicles due to multiple rockfalls (Photo 13). The largest documented road-related mass wasting event (893 m³) was also observed on 9N11.4 (Photo 14). The road with the largest total volume of landslides is 9N11.4, with a total of 2188 m³.

Table 13 – Counts of mass wasting events and total volume

Counts of road-related mass wasting summarized by road number, number of road-related mass wasting events, number of mass wasting events that are not road-related, total number, and total mass wasting volume (m³).

Road	Road Related	Not Road Related	Total	Volume (m ³)
11N04.3	0	34	34	1,751
9N11.4	5	22	27	2,188
11N01.3	5	18	23	1,509
6N03	1	13	14	1,037
9N11.3	0	10	10	841
5N12.1	1	9	10	486
32S13.1	0	10	10	325
5N12.2	1	8	9	1,299
11N03	0	9	9	362
5N20	1	7	8	271
8N08.1	5	3	8	136
32S13.2	2	3	5	63
5N15.2	2	3	5	354
5N16	0	4	4	292
6N17	0	3	3	74
8N02	1	2	3	53
6N11	0	2	2	48
11N03A	0	2	2	14
11N04.4	0	1	1	38
8N19	0	1	1	31
9N11.2	0	1	1	45

Map 10 – Mass wasting events

Mass wasting events symbolized by road-related events and not road-related events.

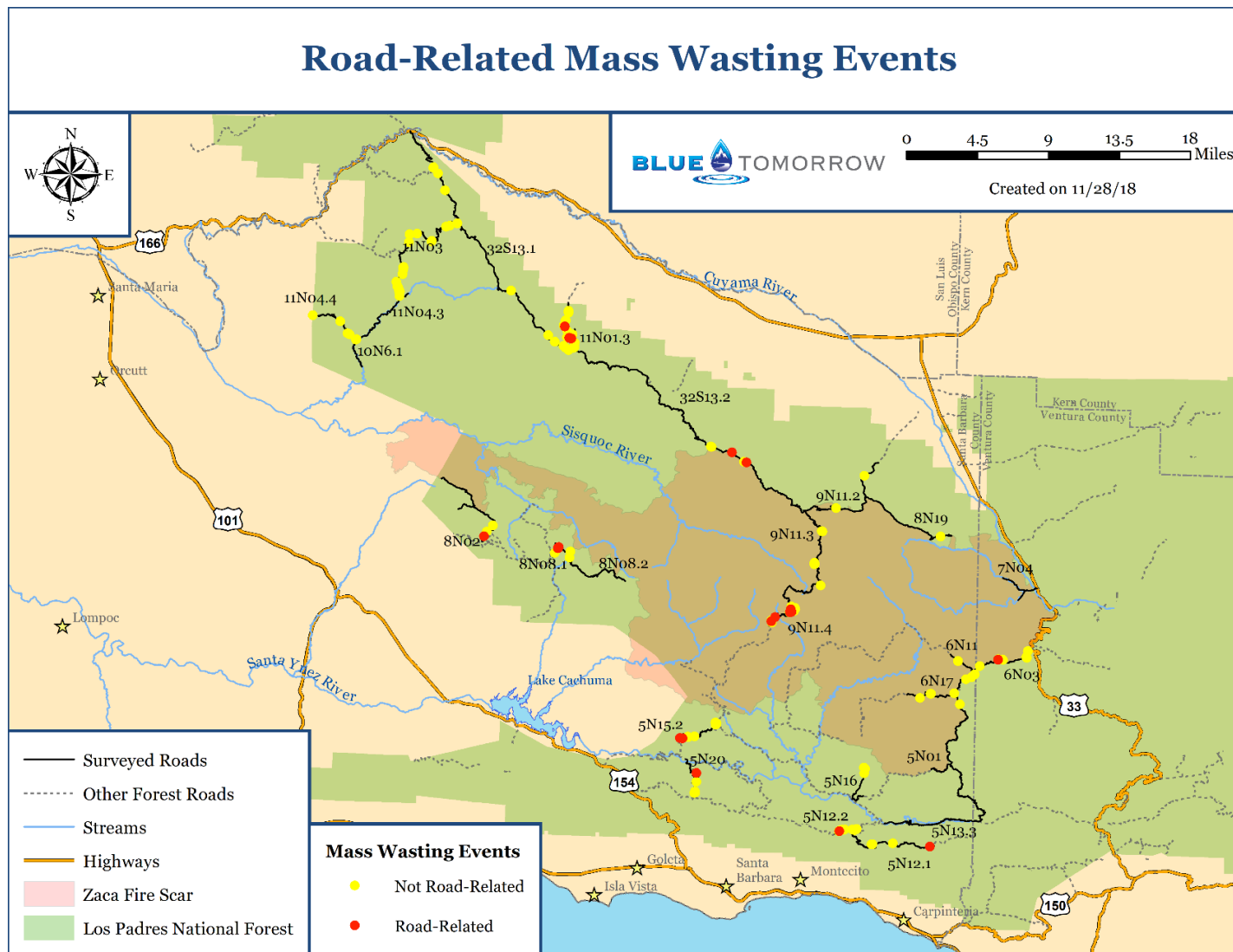


Photo 13 – Rockfall blocking access to 9N11.4

Mass wasting event on 9N11.4 which blocked access to the road (Point ID: 143).



Photo 14 – Largest mass wasting event located on 9N11.4

Mass wasting event on 9N11.4 which was the largest road-related event at 893 m³ (Point ID: 14).



5.0 GRAIP ANALYSIS

GRAIP is used to assess the impacts of the forest road network by estimating: (1) the potential amount and source of sediment or runoff generated and intercepted by the road network, and (2) the location where water and sediment are transported off of the road network. Corrected field data was spatially analyzed in ArcGIS 10.3.1 using the GRAIP-2 toolbox (Tarboton & Dash, 2016) and the TauDEM 5.3 toolbox (Tarboton et al., 2015) to evaluate road related sediment production and road-stream hydrologic connectivity.

5.1 Model Parameters

Fine sediment production (kg/yr) for a road segment (E) is estimated based upon a base erosion rate and other properties of the road, as shown below.

$$E = \frac{aLSrv}{2}$$

a is the annual base erosion rate (kg/yr/m of elevation change)

L is the road length (m) contributing to the drain point

S is the slope (m/m) of the road segment

v is the vegetation cover factor for the flow path

r is the road surfacing factor

This analysis was conducted with an annual base erosion rate of 79 kg/yr, which is based on data collected from forest roads in western Oregon (Luce & Black, 1999). While this may not accurately reflect erosion rates in the ANF, it can be used to compare relative potential sediment production between drain points or road segments. The variable r changes depending on the road surface type. Roads with a surface of “crushed rock” are given a multiplier of 1 (default), “native” are given a multiplier of 5 (higher erosivity), and “paved” are given a multiplier of 0.2 (lower erosivity). The variable v is the flow path vegetation multiplier which depends on the density of vegetation along the flow path. Road segments that are less than 25% vegetated are given a multiplier of 1 (default), while roads with greater than 25% vegetation are given a multiplier of 0.14 (lower erosivity).

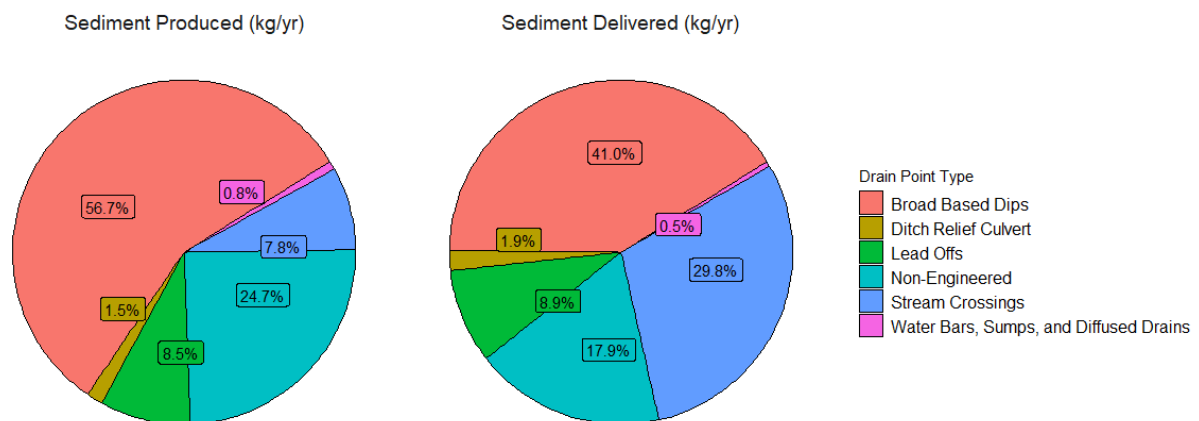
Fine sediment delivery to the stream channel network was determined by observations at each drain point. When possible, evidence of a visible flow path under each drain point was followed until the flow path was no longer visible or it entered the stream channel. Due to the steep terrain and dense chaparral vegetation, following flow paths until their termination was not always possible. In these instances, drain points were considered to have unknown stream connectivity. For the GRAIP model, drain points with unknown connectivity were considered disconnected from the stream network. Estimates of partial delivery to the stream network were not made.

5.2 Sediment Production and Delivery by Drain Type

Figure 3 provides the relative distribution of total sediment produced and delivered by drain type, as estimated by the GRAIP model. Broad based dips had the largest impact on sediment production and delivery, comprising 57% of all sediment produced and 41% of sediment delivered. This is not surprising as broad based dips were the most common drain point type (46% of all drain points). Non-engineered drain points—representing around 29% of all drain points—comprised approximately 25% of all sediment produced and 18% of sediment delivered. Stream crossings (12% of all drain points) produced just 7.8% of all sediment but comprised nearly one-third of all sediment delivered to the stream network (30%).

Figure 3 – Distribution of total sediment produced and delivered by drain type

Relative distribution of the sediment produced and the sediment delivered to the stream network by drain point type. Water bars, sumps, and diffused drains are considered cumulatively due to their low occurrence.



5.3 Areas of High Sediment Production

GRAIP model results indicate that 5% (168) of all drain points (3,370) are responsible for 21% of all sediment produced (Figure 4). Map 11 shows the distribution of the top 5% sediment-producing drain points throughout the road network. These drain points are found throughout most of the road network, with exceptions on 11N04.3, 32S13.2 near its intersection with 9N11, and the western portion of 8N19. Out of the top 20 sediment-producing drain points, five are located on 8N02, and three each are on 5N20 and 6N03 (Map 11). Figure 4 – Percent of total sediment production by percent of all drain points

The percent of total sediment production as a function of the percent of all drain points.

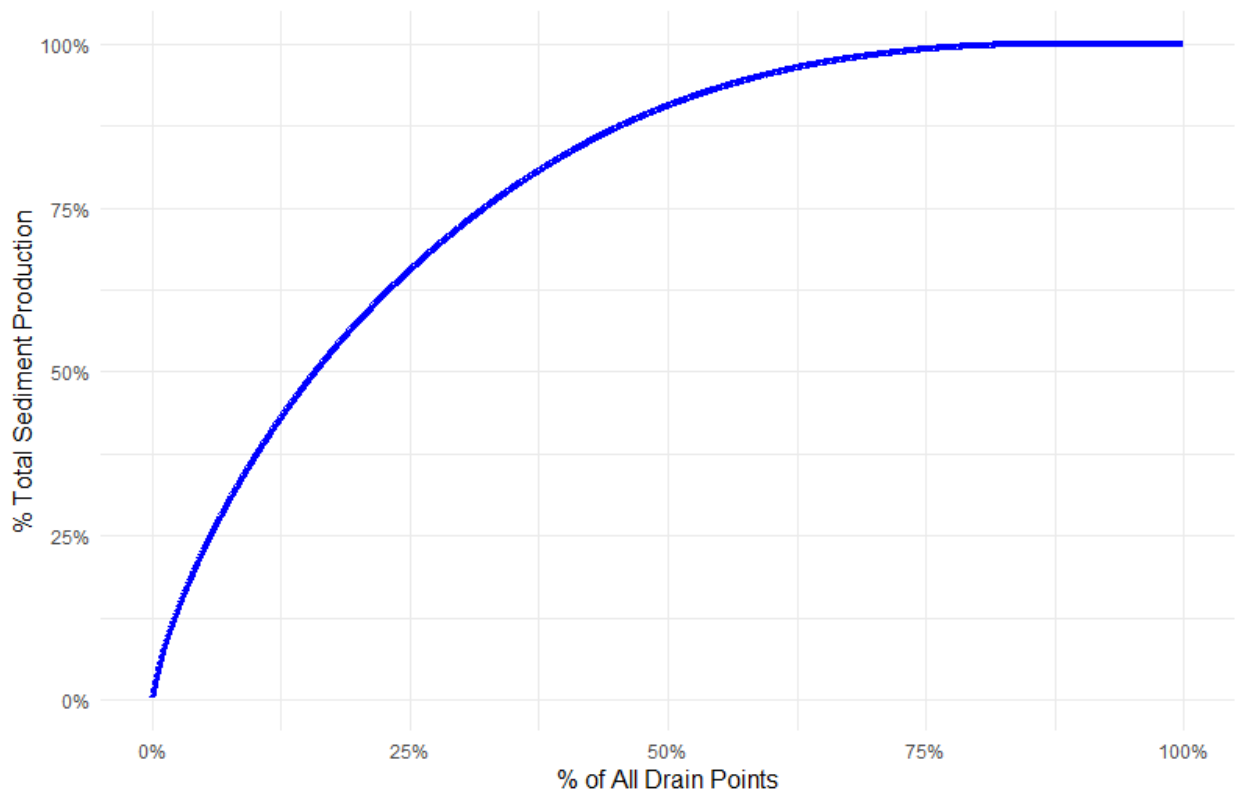


Table 14 provides a summary of the top 5% sediment-producing drain points by road number. Roads with the highest amount include 6N03 (26), 32S13.1 (23), and 32S13.2 (18). However, these are also the three longest road segments. Greater insight can be gained by looking at the average distance between these high sediment-producing drain points for each road (Figure 4 – Percent of total sediment production by percent of all drain points)

The percent of total sediment production as a function of the percent of all drain points.

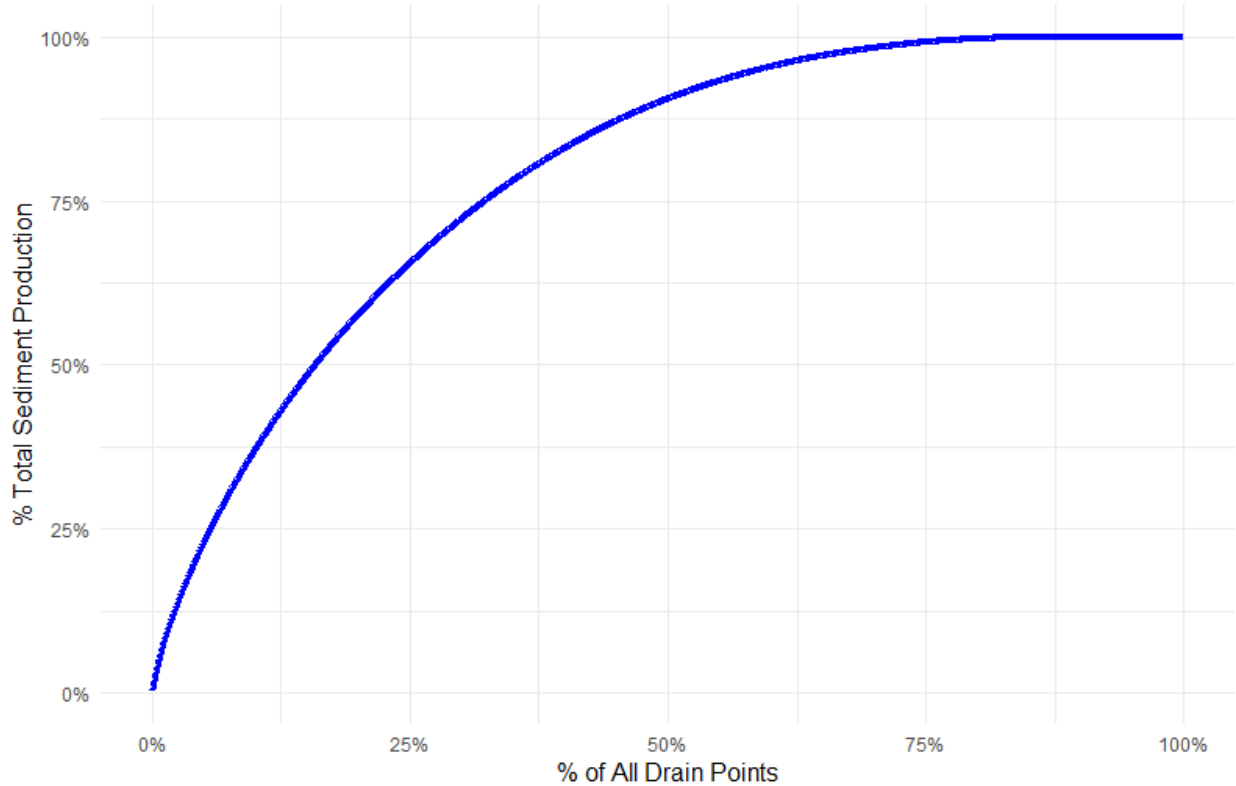


Table 14). When doing so, 8N02 again stands out as one of the most impactful road segments with an average distance of 0.6 miles between high sediment-producing drains. Some roads, such as 11N04.3, 32S13.2, and 8N19, have several heavily impacted segments, but because of their long road length, have a low average distance between high sediment-producing drains.

Figure 4 – Percent of total sediment production by percent of all drain points

The percent of total sediment production as a function of the percent of all drain points.

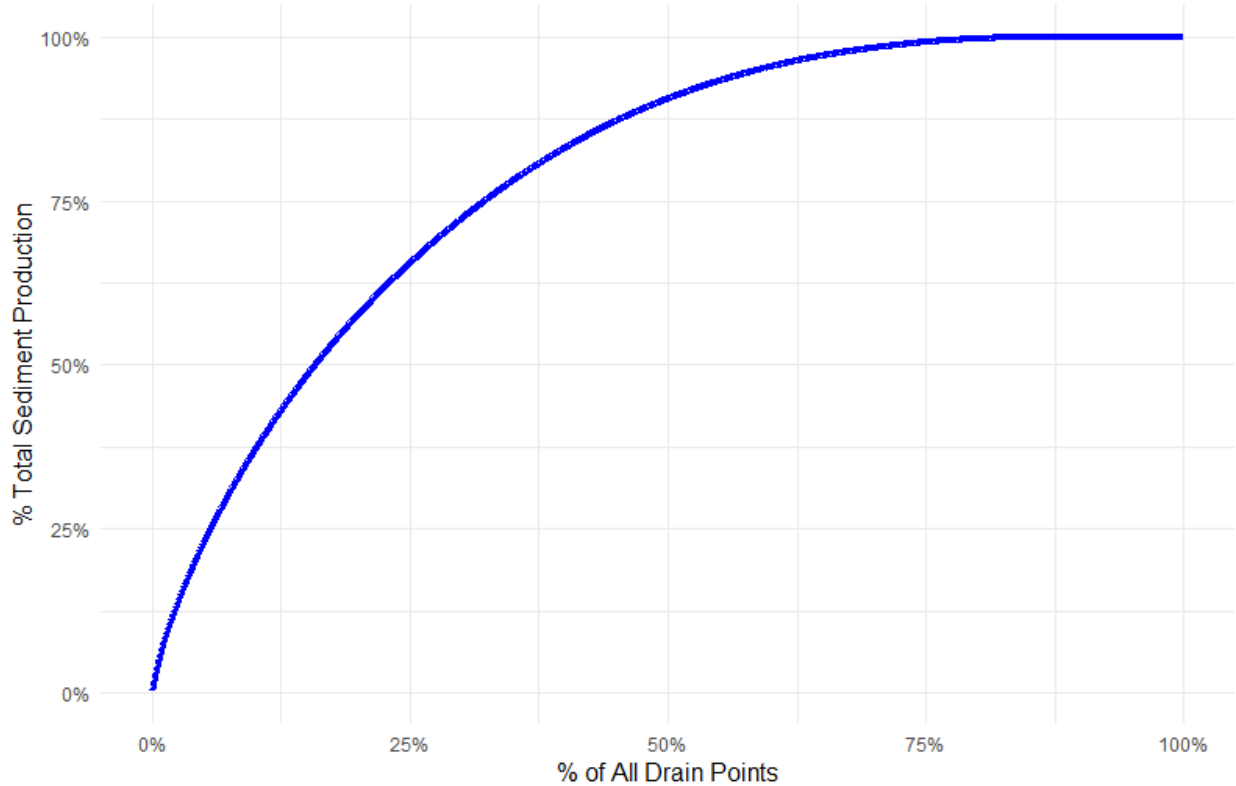


Table 14 – Counts of the top 5% sediment-producing drain points by road

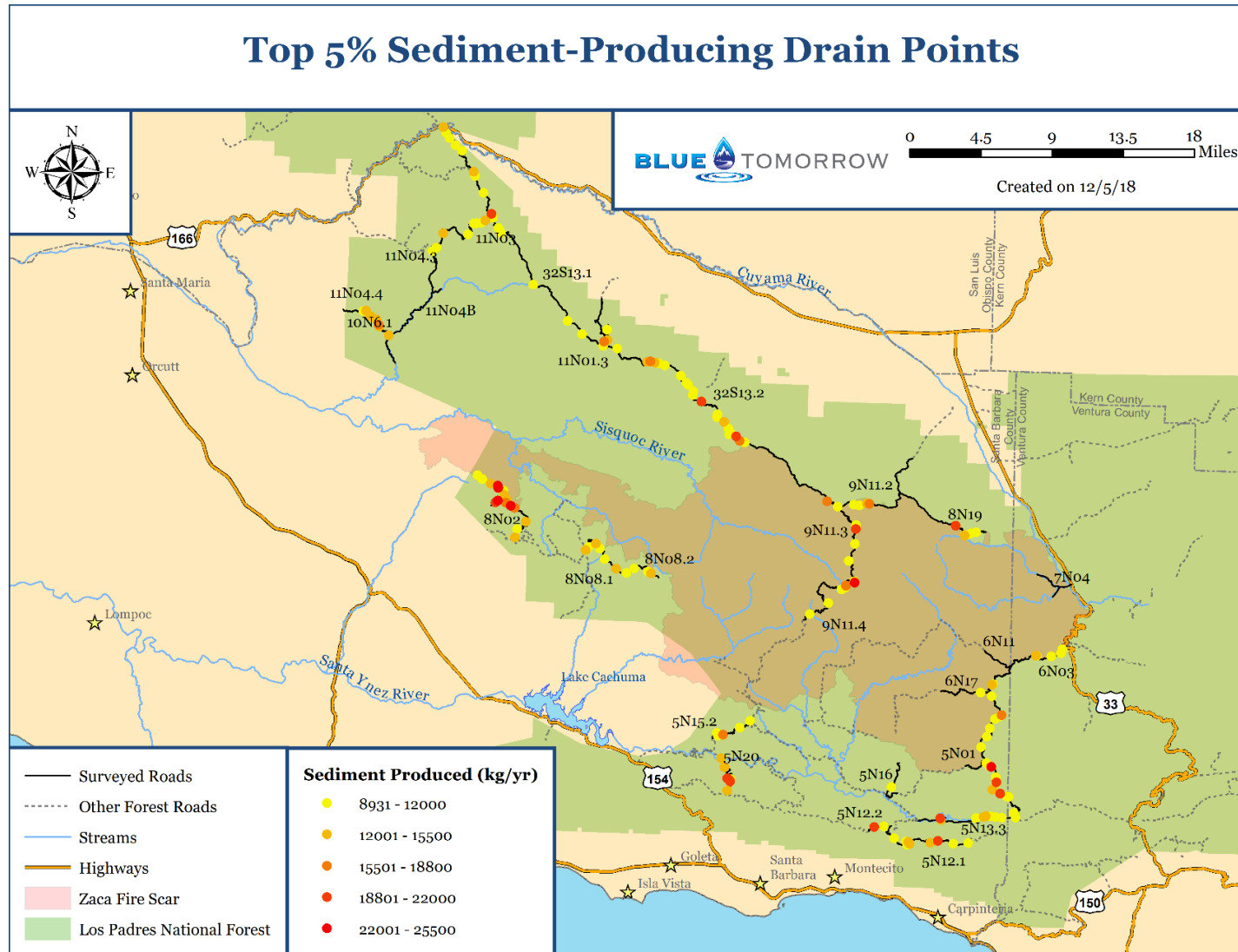
Counts of the top 5% sediment-producing drains by road number, road length, count, and average distance.

Road	Surveyed Road Length (mi)	Number of High Sediment-Producing Drains	Average Distance Between High Sediment-Producing Drains (mi)
6N03	22.2	26	0.9
32S13.1	29.0	23	1.3
32S13.2	17.8	18	1.0
8N02	9.0	16	0.6
9N11.3	14.9	13	1.1
8N08.1	7.4	9	0.8
11N03	9.4	9	1.0
5N12.1	9.8	9	1.1
5N13.3	7.7	8	1.0
5N20	5.7	7	0.8
8N19	8.0	6	1.3
11N04.3	11.7	5	2.4
5N15.2	1.3	4	0.3
11N01.3	6.4	3	2.1

9N11.4	7.9	3	2.6
5N12.2	1.3	2	0.6
8N08.2	1.8	2	0.9
11N04.4	2.6	2	1.3
11N04C	0.6	1	0.6
5N16	2.7	1	2.7
6N17	4.0	1	4.0

Map 11 – GRAIP model, top 5% sediment-producing drain points

The top 5% sediment-producing drain points, as determined by the GRAIP model.



5.4 Areas of High Sediment Delivery to Streams

As noted in Section 4.3, 863 drain points (26% of all surveyed drain points) connected 47.2 miles of road (23% of all surveyed roads) to the stream network (Map 9). These roads delivered around 26% of the total sediment produced by the surveyed road network. The GRAIP model results indicate that the top 5% sediment-delivering drain points (168) are responsible for 52% of all sediment delivered to the stream network (Figure 5). Out of the top 20 sediment-delivering drain points, four are located on 9N11.3, and three each are on 8N19 and 32S13.2 (Map 12). Figure 5 – Percent of total sediment delivery by percent of all drain points

The percent of total sediment delivered as a function of the percent of all drain points.

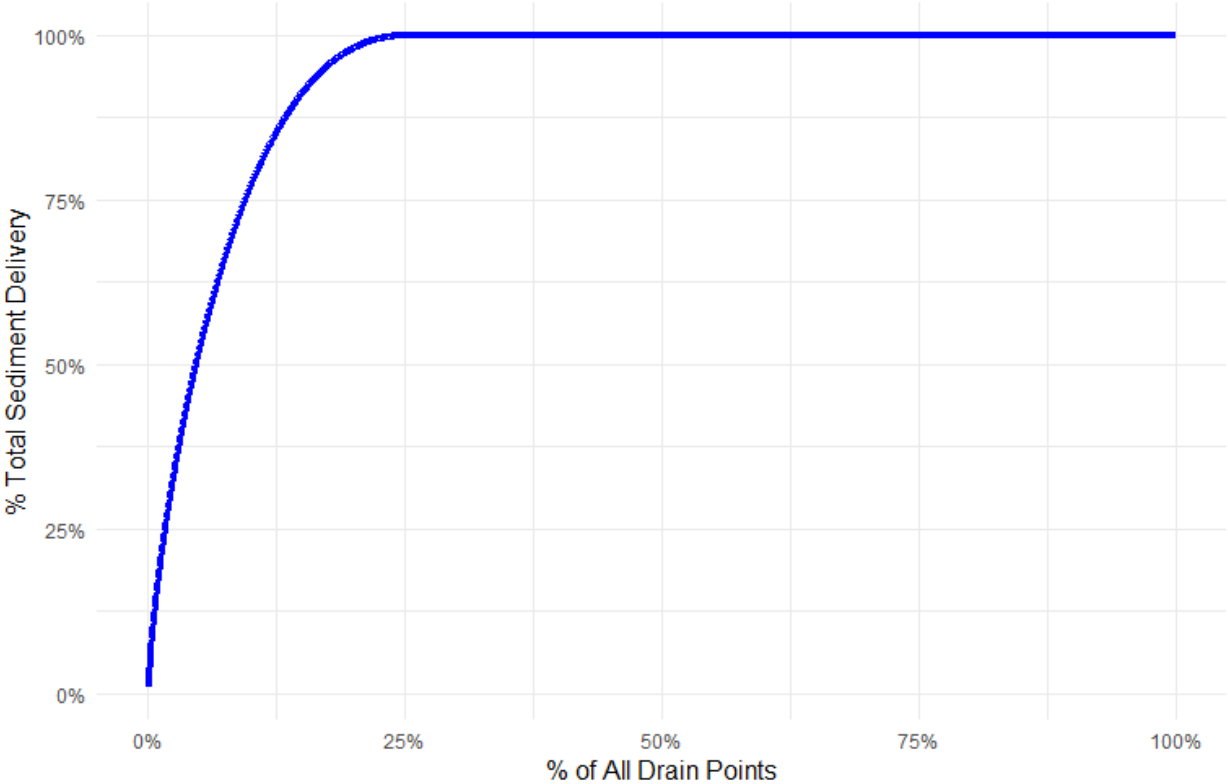


Table 15 provides a summary of the top 5% sediment-delivering drain points by road number. Roads with the highest number of sediment-delivering drain points include 9N11.3 (34), 11N03 (21), and 8N19 (16). When looking at the average distance between these high sediment-delivering drain points for each road, the following roads are shown to have a high impact due to the short distance between drain points: 11N03A, 8N08.2, and 11N04.4.

Figure 5 – Percent of total sediment delivery by percent of all drain points

The percent of total sediment delivered as a function of the percent of all drain points.

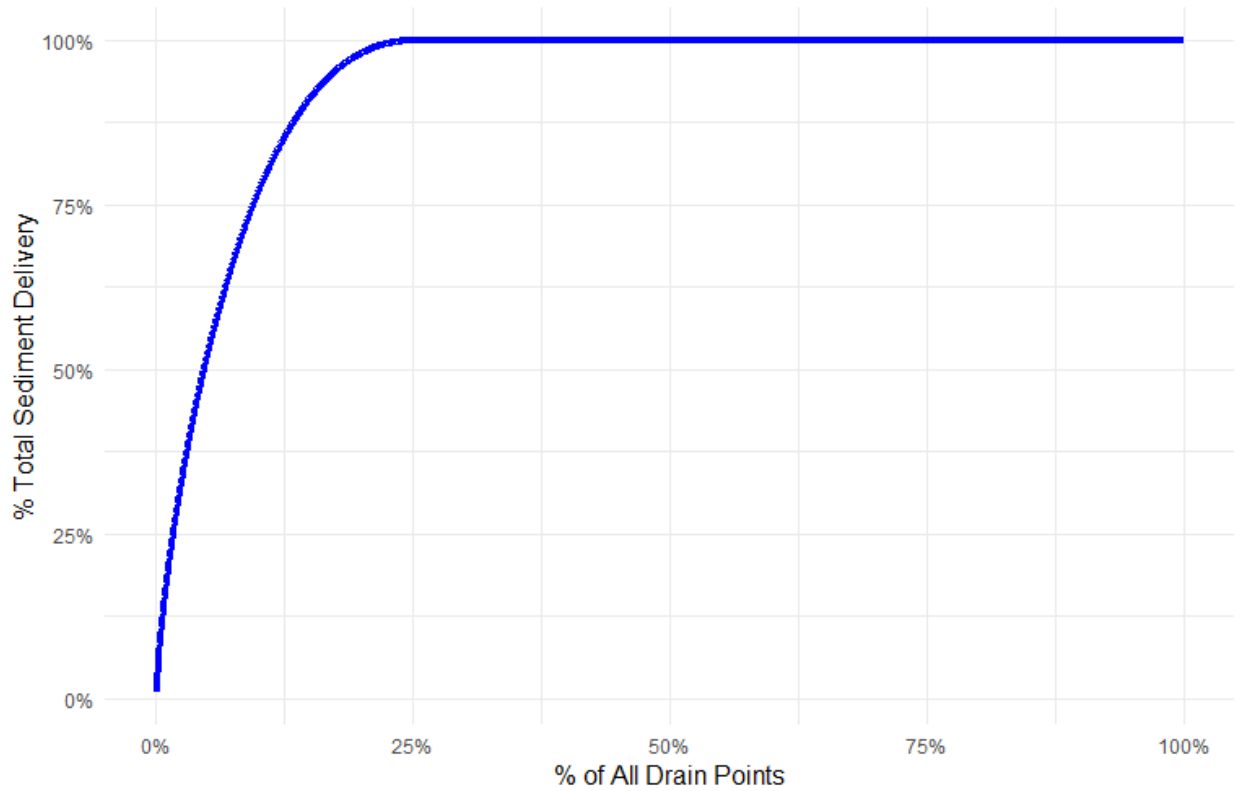


Table 15 – Counts of the top 5% of sediment-delivering drain points by road

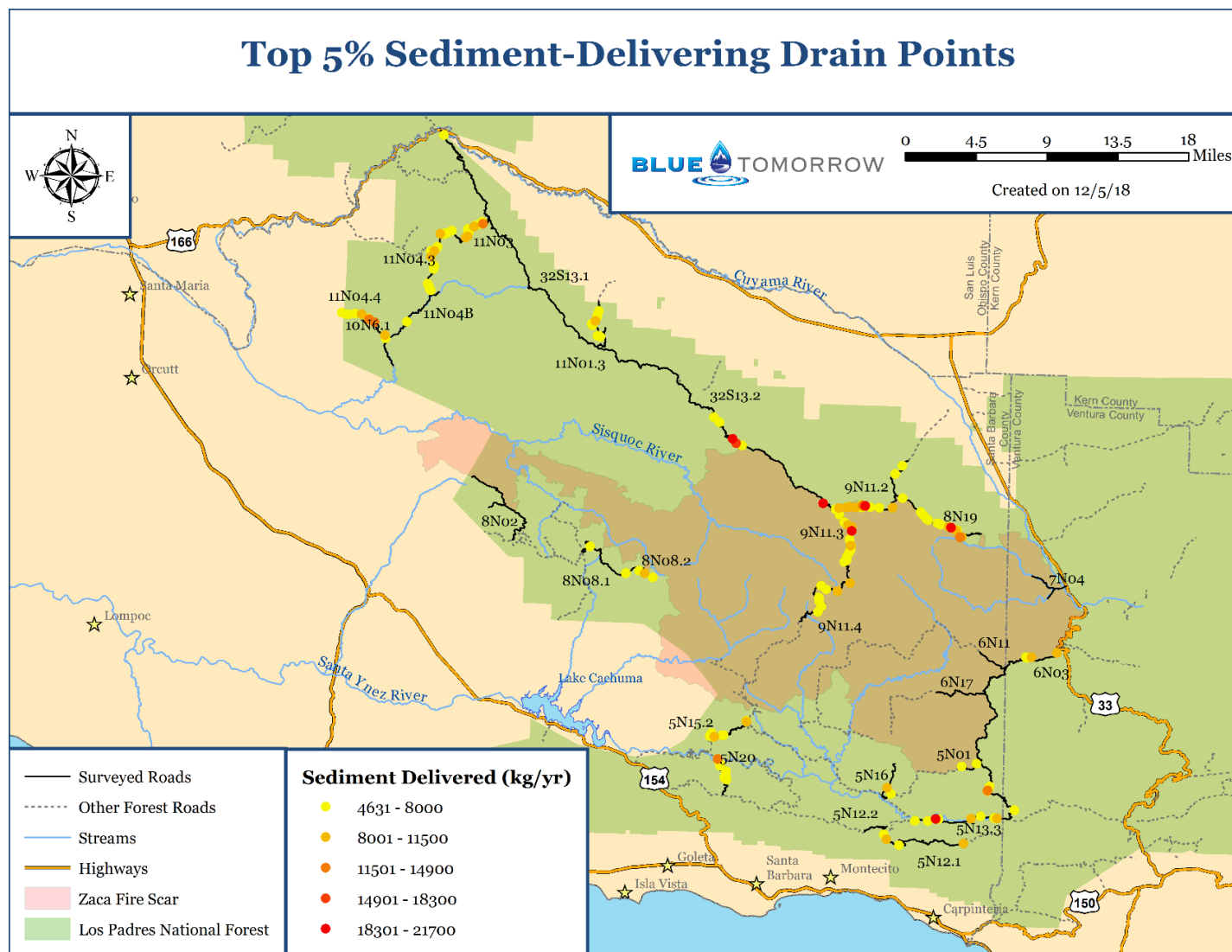
Counts of the top 5% sediment-delivering drains organized by road number, road length, and average distance.

Road	Surveyed Road Length (mi)	Number of High Sediment-Delivering Drains	Average Distance Between High Sediment-Delivering Drains (mi)
9N11.3	14.9	34	0.4
11N03	9.4	21	0.5
8N19	8.0	16	0.5
11N04.3	11.7	13	0.9
11N01.3	6.4	10	0.6
5N20	5.7	9	0.6
5N13.3	7.7	9	0.9
6N03	22.2	9	2.5
9N11.4	7.9	8	1.0
11N04.4	2.6	7	0.4

5N15.2	4.3	7	0.6
32S13.2	17.8	6	3.0
8N08.2	1.8	5	0.4
5N12.1	9.8	4	2.5
9N11.2	5.0	3	1.7
5N16	2.7	2	1.4
5N01	2.9	2	1.5
11N03A	0.3	1	0.3
8N08.1	7.4	1	7.4
32S13.1	29.0	1	29.0

Map 12 – GRAIP model, top 5% sediment-delivering drain points

The top 5% of drain points delivering sediment to the stream network, as determined by the GRAIP model.



6.0 RECOMMENDATIONS

Throughout road surveys, common issues were identified that affected the functionality of drain points and sedimentation into the stream network. Observed issues included: (1) drain points orphaned by berms, (2) bypassed and eroding lead offs at broad based dips, (3) the formation of gullies at drain points, (4) buried and sediment-filled stream crossings, and (5) non-engineered drain points. Table 16 at the end of this section provides a summary of major issues observed on surveyed road segments and recommendations for how to mitigate their effect.

6.1 Bypassed and Eroding Metal Lead Offs at Broad Based Dips

McCarthy drains, other similar functioning culverts, and dirt lead offs at broad based dips are designed to move water from the road surface down to the hillslope below. Due to the proximity of moving water, the fillslope around these drain points is prone to erosion—especially if a culvert is too small, is not correctly installed, the fillslope is not reinforced, or obstructions are present. In instances where this occurs, water will drain around the culvert instead of through it, causing fill erosion. If eroding lead offs are not fixed, the fillslope will continue to erode and eventually bypass the drain completely, potentially leading to culvert displacement and (or) gullying.

Roads to Consider for Repair

Bypassed and eroding broad based dips were recorded throughout the entire road network. However, there were clusters on 6N03 (Potrero Seco), 9N11.4, and 9N11.3 (Buckhorn). Three of the bypassed and eroding broad based dips with the most fill erosion were clustered together on 6N03. This area had a significant amount of total erosion and each of the culverts was completely separated from the fillslope.

Recommendations

- Replace eroded fill and reinstall displaced McCarthy drains or culverts.
- Armor (or re-armor) slope adjacent to the dips using small boulders, asphalt, or concrete.
- Where appropriate, increase drain size to ensure high volume flow can pass through.
- Perform regularly scheduled drain maintenance to ensure that all culverts are free of debris and that water can easily pass through.

6.2 Crushed or Blocked Culvert Stream Crossings

Culvert stream crossings are constructed to divert stream water underneath the road. Buried and blocked culverts are unable to transport water, resulting in water being diverted around the culvert. This can cause erosion of the road surface, and in some cases, may result in the road capturing the stream channel. This can cause surface erosion on the road segment and overload subsequent drain points. During rain events, buried and blocked culvert stream crossings can severely impact road integrity.

Roads to Consider for Repair

Six out of 10 culvert stream crossings on a two-mile stretch along 5N15.2 (Romero Camuesa) were entirely crushed or blocked by sediment. This made 5N15.2 contain the greatest number of entirely blocked/crushed culvert stream crossings of all surveyed roads. They all occurred within two miles and were likely due to recent road grading. Two more stream crossings on 5N15.2 were partially crushed or blocked. There was evidence that due to the fully blocked culverts, the stream crossings became natural fords and were capturing road runoff and sediment. Furthermore, about two miles away south of 5N15.2, on 5N20, there were two totally blocked culverts and another two that were partially blocked.

A total of nine (9) culvert stream crossings were completely buried by debris flow on 8N19 (4), 9N11.2 (4), and 9N11.3 (1). 8N19, 9N11.2, and 9N11.3 are all connected to each other and in the same watershed. The blocked stream crossings on 9N11.2 and 8N19 occur in clusters within two miles of each other, while the blocked stream crossing on 9N11.3 is located approximately four miles away from the clusters (Map 13). Photo 15 shows an example of a blocked and crushed culvert on 8N19, and Photo 16 shows an example on 9N11.2. The combination of these blocked stream crossings in one area likely contributes significant sediment to the surrounding stream network.

Recommendations

- Replace crushed culverts.
- Dig out and remove sediment from buried/blocked stream crossings to allow water to flow through the culvert.
- Place a vertical post at culvert stream crossings to mark their location and improve visibility during future grading activities.
- Avoid sediment deposition into stream channels during grading.

Map 13 – Crushed or Blocked Stream Crossings on 8N19, 9N11.2, and 9N11.3

Crushed and blocked stream crossings located on 8N19, 9N11.2, and 9N11.3. Nine (9) culvert stream crossings are completely buried by debris in this area.

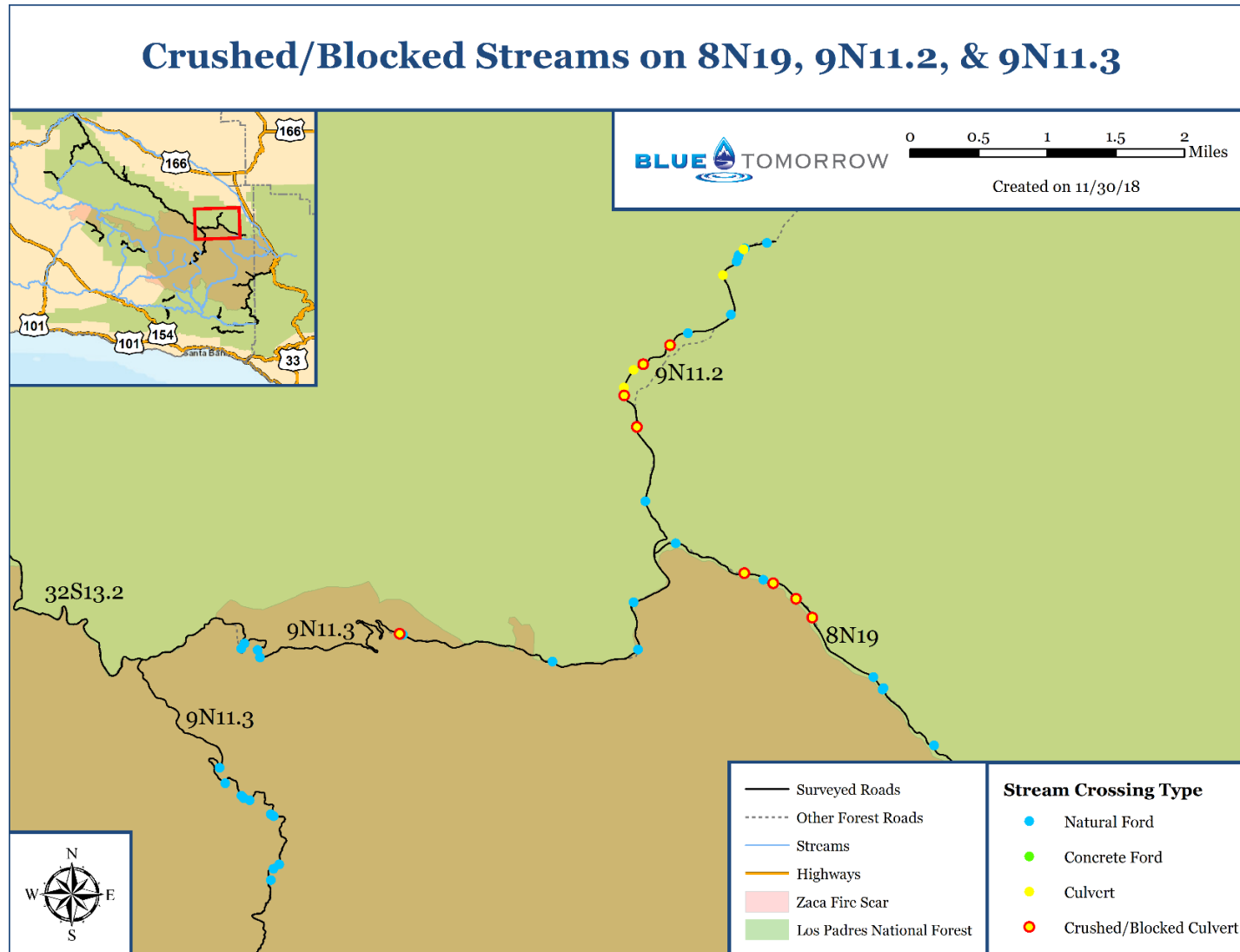


Photo 15 – Diverted Flow Path around Blocked Culvert on 8N19

Blocked culvert stream crossing on 8N19 caused by excess sediment (Point ID: 679). The stream flow path has been diverted by the road and creates a non-engineered drain point adjacent to the culvert.



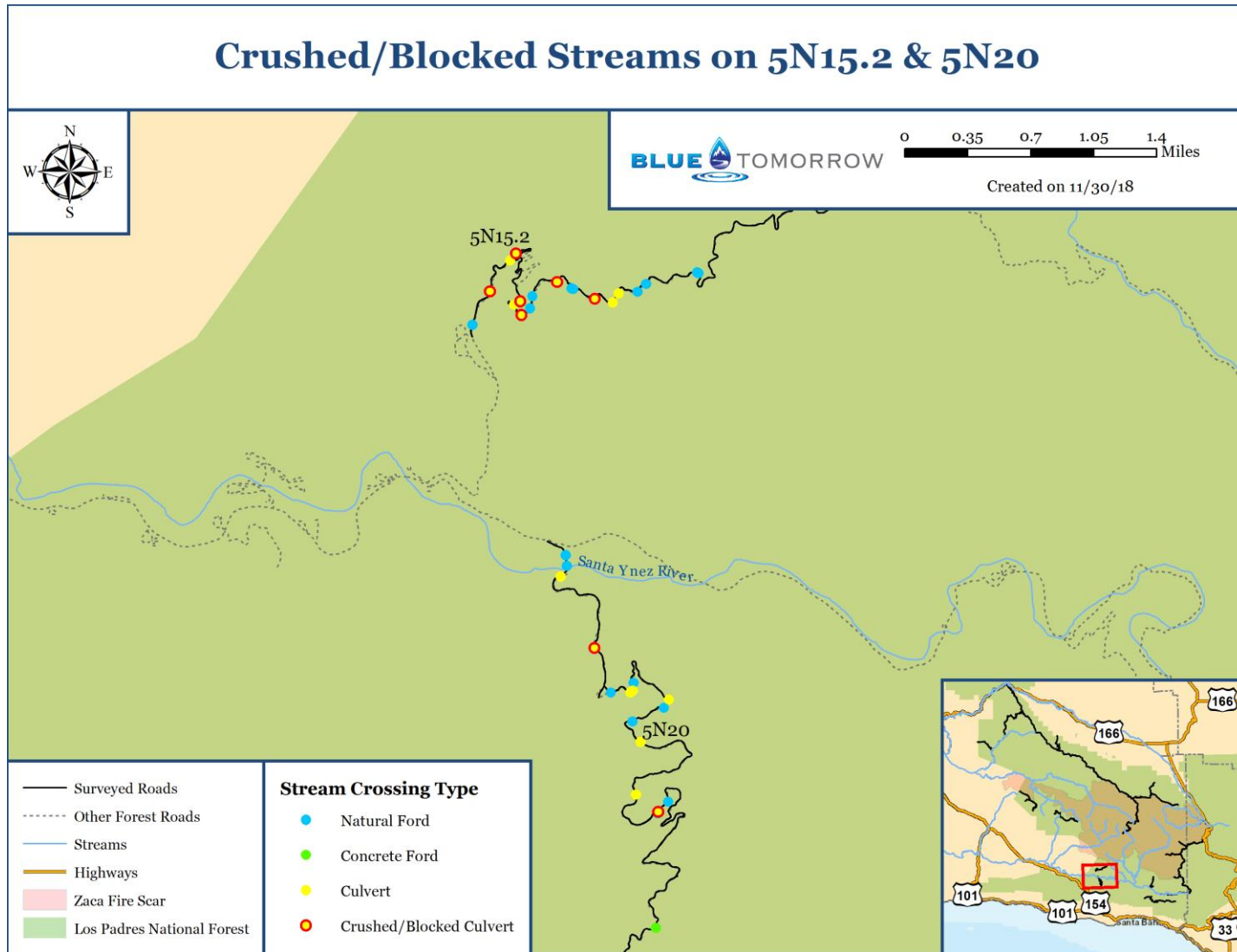
Photo 16 – Culvert stream crossing blocked by debris flow on 9N11.2

Blocked culvert stream crossing on 9N11.2 caused by debris flow (Point ID: 576).



Map 14 – Crushed or blocked stream crossings on 5N15.2 & 5N20

Crushed and blocked stream crossings located on 5N15.2 and 5N20.



6.3 Gullies

Gully erosion is a significant problem that often occurs where concentrated flows begin on relatively steep long slopes with erodible soils. The formation of gullies may be exacerbated after fires due to a decrease in vegetation and their root systems. Gullies extend concentrated flow paths, contribute to increased delivery of sediment to the stream network, and threaten road integrity if occurring within the road fill.

Roads to Consider for Repair

Gullies were found to be most numerous on 32S13.1 (Sierra Madre), 11N03 (Miranda Pine), 9N11.3, and 9N11.4 (Buckhorn). Each of these roads have a steep hillside gradient. Because of the increased sediment erosion associated with gullies, particular attention should be paid to roads with stream connectivity. 11N03, 9N11.3, and 9N11.4 are each connected to streams. 11N03 is 33% stream connected, 9N11.3 is 33% stream connected, and 9N11.4 is 28% stream connected.

Recommendations

- Perform remedial maintenance by treating existing gullies with plugs, vegetation, biotechnical, or mechanical methods.
- Add flow diffusers below culvert outlets to slow and disperse water flows.
- Construct additional drain points to reduce length of road drained by individual constructed drain points.
- Perform regularly scheduled drain maintenance to ensure that all engineered drain points are not orphaned.

6.4 Non-Engineered Drain Points

Non-engineered drain points form when concentrated flows on the road surface leave the road in an unplanned manner. Because water typically must be channelized to have enough energy to create a non-engineered drain point, this may lead to increased fill erosion and eventually to gully formation.

Roads to Consider for Repair

Roads with a high percentage of non-engineered drain points include 11N01.3 (57%), 9N11.4 (49%), and 6N03 (45%).

11N01.3 (Bates) has a similar topography and use to 11N03 (Miranda Pine). However, 11N01.3 has a much higher percentage of non-engineered drain points, as discussed in Section 3.5. The low percentage of non-engineered drain points on 11N03 can be explained by the high frequency of constructed drain points. In contrast, 11N01.3 has a low frequency of constructed drain points. On part of this road, non-engineered drain points are extremely numerous, where constructed drain points are limited and very spread out.

9N11.4 (Buckhorn) and 6N03 (Potrero Seco) each have an appropriate number of constructed drain points; however, lack of a strong berm enables flow paths to leave the road prism.

Recommendations

- Perform remedial maintenance by treating non-engineered drain point erosion with plugs, vegetation, biotechnical, or mechanical methods.
- Construct additional drain points to reduce the length of road drained by individual constructed drain points.
- Repair damaged constructed drain points so flow can drain as intended.
- Reinforce or construct berms so that water is kept within the road prism until it leaves at a constructed drain point.

6.5 Orphaned Drain Points

About 2.9% of all drain points were orphaned. The majority of orphaned drain points were caused by the creation of a berm in front of the drain. A berm blocks runoff from exiting the road at the intended drain point, causing it to continue further down the road. About 62% of all orphaned drain points were the result of the creation of a berm which blocked the drain point or deposited excess sediment in the flow path leading to the drain. Clusters of orphaned drains have a cumulative effect and can cause more collective erosion than single orphaned drain points. When multiple drain points in a row are orphaned, water is diverted even further down the road. This increases the amount of runoff, which can overload road segments and increase road surface erosion. Due to the increased volume and velocity of water, runoff may drain from the road prism at non-engineered drain points.

Roads to Consider for Repair

Both 9N11.4 (Buckhorn) and 5N20 (Arroyo Burro) had clusters of orphaned drains. Each of these roads was recently graded prior to surveying, which likely created or reinforced the berms that blocked the drain points.

Recommendations

- Install or maintain markers at essential drain points to increase visibility during road work, including grading or berm building.
- Maintain intended road surface shape.
- After grading, clear any berm or excess sediment from drain points in order to create a flow path for runoff.

Table 16 – Major issues and recommendations by road

Summary of major issues observed at road segments and recommendations for mitigation.

Road	Issue	Recommendation
5N15.2	Buried Stream Crossings	Excavate and remove sediment inside culverts from six buried stream crossings.
5N20	Orphaned Drains	Install markers at essential drain points to increase visibility of drain points during road work, including grading. After grading, clear any berm or excess sediment from drain points in order to create a flow path for runoff.
6N03	Bypassed and Eroding Broad Based Dips	Replace eroded fill around culverts. Reinstall displaced culverts. Reinforce fill around culverts in areas with high erosion with erosion resistant materials such as concrete or crushed rock (gravel).
	Non-Engineered Drains	Construct new and reinforce existing berms on fillslope edge of road to prevent runoff from exiting the road at non-engineered drain points.
8N19	Buried Stream Crossings	Excavate and remove sediment inside culverts from six buried stream crossings.
9N11.2	Buried Stream Crossings	Excavate and remove sediment inside culverts from six buried stream crossings.
9N11.3	Buried Stream Crossings	Excavate and remove sediment inside culverts from six buried stream crossings. Replace eroded fill around culverts.
	Bypassed and Eroding Broad Based Dips	Reinstall displaced culverts. Reinforce fill around culverts in areas with high erosion with erosion resistant materials such as concrete or crushed rock (gravel).
	Gullies	Repair existing gullies and add rip rap to drain outlets. Add flow diffusers or culvert extensions.
9N11.4	Orphaned Drains	Install markers at essential drain points to increase visibility of drain points during road work, including grading. After grading, clear any berm or excess sediment from drain points in order to create a flow path for runoff.
	Bypassed and Eroding Broad Based Dips	Replace eroded fill around culverts and reinstall displaced culverts. Reinforce fill around culverts in areas with high erosion with erosion resistant materials such as concrete or crushed rock (gravel).
	Non-Engineered Drains	Construct new and reinforce existing berms on fillslope edge of road to prevent runoff from exiting the road at non-engineered drain points.
	Gullies	Repair existing gullies and add rip rap to drain outlets. Add flow diffusers or culvert extensions.
11N01.3	Non-Engineered Drains	Construct new and reinforce existing berms on fillslope edge of road to prevent runoff from exiting the road at non-engineered drain points.
11N03	Gullies	Repair existing gullies and add rip rap to drain outlets. Add flow diffusers or culvert extensions.
32S13.1	Gullies	Repair existing gullies and add rip rap to drain outlets. Add flow diffusers or culvert extensions.

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8.0 APPENDIX A1 – GLOSSARY OF TERMS

Broad Based Dip	Either a constructed dip (designed into the grade of the road) or natural large grade reversal (where two opposing hillslopes meet) in the road. These are large enough that an entire vehicle can fit inside the feature.
Bypassed and Eroded	When water drains to the side of or under the culvert instead of through the culvert, causing erosion of the road surface and fillslope.
Cutslope	The steep slope on the uphill side of a road, which is the result of the removal of hillslope material to make a flat surface for the road.
Diffuse Flow	Flow that runs perpendicular to the direction of travel and off the road surface without concentrating into a substantial rill, or a loose or extremely vegetated road surface that does not concentrate any surface water.
Ditch	A channel, typically cutslope side, where water flows along the road to the next drain point.
Ditch Relief Culvert	A culvert that drains water from the inboard ditch under the road onto the hillslope. These culverts drain water from the road and cutslope, not from a continuous channel.
Drain Point	Any place along a road where water from the road flows off of the road and away from the road prism.
Excess Deposition	When sediment clogs a drain point, significantly reducing functionality. Typically refers to lead off drain points.
Fill Erosion	Active undercutting of the road prism at the drain point outlet. A localized phenomenon, often due to excessive drop below a culvert pipe or poor design or function of the drain point.
Fillslope	The steep slope on the downhill side of a road, which is the result of the addition of material (fill), often from the cutslope, to make a flat surface for the road.
Flow Diffuser	A device used to reduce the velocity of water leaving the culvert before it reaches the fillslope or hillslope to prevent the culvert water from incising into the fillslope or hillslope.
Flow Diversion	When a stream channel has been captured by the road or ditch and delivered to a point down the road.
Flow Path	The course runoff takes or would take within the road prism.
Forest Floor	Where flow discharges onto the soil surface without downcutting.
Gullied Road	Extreme erosion from concentrated flows on the road surface. Gullied flow paths are deeper than 6 inches.

Gully	An erosional feature that results from excessive discharge at a given point. Gullies are deeper than 6 inches and extend at least 10 feet downslope of the edge of the fillslope.
Hillslope	The natural gradient of the hill that is not part of the road prism.
Inboard	The cutslope side of the road.
Inslope	When a road surface has been canted down towards the inboard side of the road so that any water on the road would flow towards the cutslope and into a ditch (if present).
Mass Wasting	The geomorphic process by which soil, sand, and rock move downslope, typically as a mass, largely under the force of gravity, but frequently affected by water and water content. Also known as slope movement.
Earth/Soil Slide	A mass wasting event in which soil is the predominant sediment debris.
Rockfall	A mass wasting event in which rock is the predominant sediment debris.
Soil Creep	The slow downward progression of rock and soil down a low grade slope.
Lead off	A ditch that moves flow from the roadside and leads it onto the hillslope.
Non-Engineered Drain Point	A naturally occurring drainage feature between constructed drain points where water leaves the road or ditch in an unplanned manner. This can occur where a ditch has become dammed by debris, where a rut diverts over the fillslope, or when water flowing against a berm erodes through and escapes over the fillslope.
Obstruction	Barriers or impediments to water flow below a drain's discharge point on the hill. This can include logs, boulders, trees, or brush that act to slow the flow and cause sediment deposition.
Occlusion	When sediment blocks a portion or all of a culvert inlet. Occlusion can prevent water from flowing through the culvert at maximum capacity and can increase sediment carried with runoff to the discharge point.
Orphan	A drain that was designed to drain water or has drained water in the past but does not drain anything at the time of data collection.
Outboard	The fillslope side of the road.
Outslope	When the fillslope side of the road has been canted down towards the outboard side of the road so that any water on the road would flow towards the fillslope and generally out of the road prism.
Rilled	Water channels from concentrated flow that exceed 0.25 inches in depth.
Road Line	The surface of the road, as seen on a map.

Road Prism	The area composed of the road surface, cutslope, and fillslope. The section of the hillslope, flat, ridge, etc. that has been directly affected by the construction of the road.
Road Surface Erosion	Erosion caused by concentrated flow on the road surface.
Rocky Road Surface	When boulders are commonly exposed and impede the quality of travel.
Rutted Road Surface	Wide, deep depressions, typically due to wet weather traffic or over-loading of the road surface.
Stream Crossing	When an established stream channel that has flow for at least part of most years crosses the road.
Natural Ford	Un-reinforced stream crossing where the road goes through the stream.
Concrete Ford	Stream crossing where the road goes through the stream, that has been reinforced with concrete.
Culvert Crossing	Constructed to drain water flowing down the hillside into stream channels under the road, via a culvert, minimizing capture of road generated sediment and runoff.
Sump	A closed depression where water is intentionally sent to infiltrate. This can occur where two roads join or where the ground is very flat and little water accumulates. Can be any place where water enters and does not escape, including a holding pond or a very flat section of road where water ponds and puddles on the surface.
Water Bar	A water diversion feature cut into the road surface with a grader blade or other equipment. Smaller than a broad based dip.
Wheel Rut	Parallel depressions or worn areas along the length of the road, due to the frequent travel of motor vehicles, which often route water down the road.

9.0 APPENDIX A2 – TABLES

Table 17 – LPNF inventory roads by accessibility and priority

Summary of identified roads for GRAIP inventory in the LPNF by road number, road name, length in miles, accessibility, and priority (1, 2, or 3).

Road Number	Road Name	Length (mi)	Accessibility	Priority
11N01.3	2 Bates Canyon	6	Passable	1
11N03	Miranda Pine	10	Passable	1
11N04.4	3 Colson Cyn.	2	Hiking only	1
32S13.1	Sierra Madre	29	Passable	1
32S13.2	1 Sierra Madre	25	Passable	1
5N12.1	East Camino	13	Passable	1
5N12.2	East Camino	1	Passable	1
5N13.3	Murieta	8	Passable	1
5N15.3	2 Romero Camuesa Fdr	1	Passable	1
5N16	Big Caliente	3	Passable	1
5N20	Arroyo Burro	6	Passable	1
7N04	Tinta Cyn. OHV	3	Unknown	1
8N02	Zaca Ridge Rd. OHV	7	Passable	1
9N11.2	Buckhorn	5	Passable	1
9N11.3	Buckhorn	14	Passable	1
9N11.4	Buckhorn	22	Unknown	1
5N01	Pendola Jeep	11	Motorcycle or ATV	2
6N03	Potrero Seco	22	Passable	2
6N11	Don Victor	7	Hiking only	2
6N14	Santa Cruz	4	Unknown	2
6N17	Hildreth Pk.	18	Hiking only	2
6N24.1	Pie Canyon	3	Motorcycle only	2
6N24.2	Pie Canyon	2	Motorcycle only	2
6N30	Oglivy Ranch	3	Motorcycle only	2

Road Number	Road Name	Length (mi)	Accessibility	Priority
7N05	Loma Victor	18	Hiking only	2
8N08.1	McKinley	5	Unknown	2
8N08.2	McKinley	5	Unknown	2
10N06.1	La Brea Cyn. OHV	4	Hiking only	3
10N06A	Barrel Spring C.G.	0	Hiking only	3
11N04.3	2 La Brea Ohv	12	Hiking only	3
11N04B	Lazy Camp Cg.	1	Hiking only	3
11N04C	Colson Cyn Sta	0	Hiking only	3
4N05.2	1 Superior Ri.	12	Unknown	3
4N05.3	2 Superior Ri.	3	Unknown	3
5N15.2	1 Romero Camuesa Fdr	11	Hiking only	3
8N19	West Dry	8	Unknown	3
TOTAL		304		

Table 18 – LPNF roads survey schedule

Survey schedule for LPNF Roads Erosion and Inventory Assessment Project by date and associated road.

Dates	Road
6/28/2017 - 6/29/2017	East Camino, 5N12.2
	East Camino, 5N12.1
7/5/2017 - 7/7/2017	East Camino, 5N12.2
	Big Caliente, 5N16
	Arroyo Burro, 5N20
7/10/2017 - 7/13/2017	<i>Whittier Fire</i>
7/17/2017 - 7/20/2017	East Camino, 5N12.1
	Big Caliente, 5N16
	Murieta, 5N13.3
	Portero Seco, 6N03
	Pendola Jeep, 5N01
7/24/2017 - 7/27/2017	Buckhorn, 9N11.3
	Buckhorn, 9N11.2
	West Dry, 8N19
	Sierra Madre, 32S13.2
7/31/2017 - 8/3/2017	Sierra Madre, 32S13.2
	Tinta Canyon OHV, 7N04
	Bates Canyon, 11N01.3
	Sierra Madre, 32S13.1
8/7/2017 - 8/10/2017	Sierra Madre, 32S13.1
	Miranda Pine, 11N03
	Miranda Pine Campground
	Johnson Sup OHV, 11N03A
8/14/2017 - 8/17/2017	Buckhorn Road, 9N11.4
	Romero Camuesa FDR, 5N15.2
	Buckhorn, 9N11.3

Dates	Road
8/14/2017 - 8/17/2017	Bluff Campground, 9N11A
8/22/2017 - 8/24/2017	La Brea Canyon OHV, 11N04.3
	Miranda Pine, 11N03
8/28/2017 - 8/29/2017	Lazy Camp Campground, 11N04B
	La Brea Canyon OHV, 10N06.1
	La Brea Canyon OHV, 11N04.3
9/4/2017 - 9/7/2017	<i>Unsafe working conditions – heat wave</i>
9/12/2017 - 9/15/2017	Potrero Seco, 6N03
	Hildreth Peak, 6N17
9/18/2017 - 9/19/2017	Zaca Ridge Rd. OHV, 8N02
	McKinley, 8N08.1
9/25/2017 - 9/28/2017	<i>Week off</i>
	La Brea OHV, 11N04.3
	Colson Canyon, 11N04.4
10/3/2017 - 10/6/2017	Colson Canyon Station, 11N04C
	Romero Camuesa FDR, 5N15.2
	Arroyo Burro, 5N20
	McKinley, 8N08.1
10/9/2017 - 10/12/2017	McKinley, 8N08.2
	McKinley Campground
	Pendola Jeep, 5N01
9/4/2018 – 9/6/2018	Don Victor, 6N11
	East Camino, 5N12.1
	Cachuma Mtn., 8N08.2

*Additional road surveys and QA/QC were conducted in September 2018.