Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California

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City of Chico, Parks Division

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Photographs were taken by PWA staff during the course of the assessment.

Photo 1. Road surface erosion on a relatively flat, undrained road segment in Upper Bidwell Park. Long lengths of uncontrolled runoff, and associated road surface erosion, were a common finding during PWA's sediment source assessment.

Photo 2. PWA Geologists document and map the current road conditions and sediment source problems, including stream crossings such as this one, on Upper Park Road in the Big Chico Creek watershed.

1 CERTIFICATION AND LIMITATIONS

This report, entitled *Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California,* was prepared by or under the direction of a licensed professional geologist at Pacific Watershed Associates Inc. (PWA), and all information herein is based on data and information collected by PWA staff. Sediment-source inventory and analysis for the project, as well as erosion control treatment prescriptions, were similarly conducted by or under the responsible charge of a California licensed professional geologist at PWA.

The interpretations and conclusions presented in this report are based on a study of inherently limited scope. Observations are qualitative, or semi-quantitative, and confined to surface expressions of limited extent and artificial exposures of subsurface materials. Interpretations of problematic geologic and geomorphic features (such as unstable hillslopes) and erosion processes are based on the information available at the time of the study and on the nature and distribution of existing features.

The conclusions and recommendations contained in this report are professional opinions derived in accordance with current standards of professional practice, and are valid as of the submittal date. No other warranty, expressed or implied, is made. PWA is not responsible for changes in the conditions of the property with the passage of time, whether due to natural processes or to the works of man, or changing conditions on adjacent areas. PWA is not responsible for any erosion control treatments that may have been improperly or inadequately implemented in the Upper Bidwell Park Road project area during the course of this assessment for which PWA was not informed and did not provide construction management services or complete post-implementation reviews. Furthermore, to be consistent with existing conditions, information contained in this report should be reevaluated after a period of no more than three years, and it is the responsibility of the landowner to ensure that all recommendations in the report are reviewed and implemented according to the conditions existing at the time of construction. Finally, PWA is not responsible for changes in applicable or appropriate standards beyond our control, such as those arising from changes in legislation or the broadening of knowledge, which may invalidate any of our findings.

Certified by:

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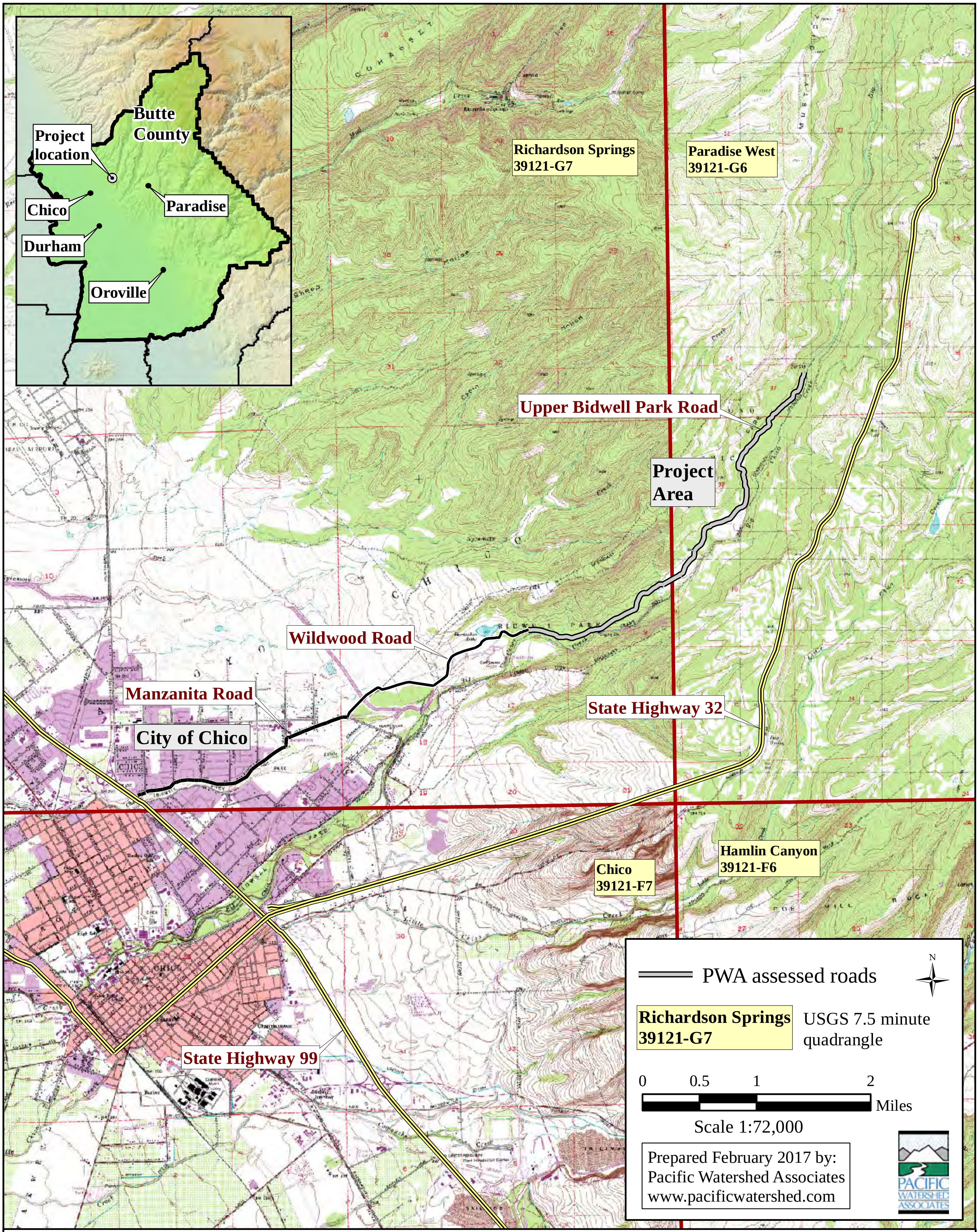
2 PROJECT OVERVIEW

In 2017, City of Chico, Parks Division, contracted Pacific Watershed Associates, Inc. (PWA) to complete a road inventory and assessment to identify road-related erosion and sediment delivery features, and to develop a treatment plan for 4.40 mi of Upper Park Road in Upper Bidwell Park within the Big Chico Creek watershed (Map 1). Bidwell Park was first established in 1905. The need for an erosion control and treatment action plan is recognized by the City of Chico and follows the BPMMP guidelines and vision. The Big Chico Creek watershed encompasses a watershed area of approximately 72.0 mi^2, entering the Sacramento River west of the City of Chico. The watershed is located within Butte and Tehama Counties and contains important habitat for anadromous salmonids, including spring, fall/late fall, and winter-run Chinook salmon and steelhead trout (CDFW, 2001). In December 2012, a severe storm damaged several sections of Upper Park Road. The impacts to the road, streams and sensitive shallow soils on the hillslopes had dramatic effects.

Two of the most important elements of long-term restoration and maintenance of both water quality and fish habitat from forested and wildland watersheds is the reduction of on-going and future impacts from upland anthropogenic (human caused) erosion and sediment delivery associated with roads, trails, and other land management activities and disturbed areas. Sediment delivery to stream channels from roads and road networks has been extensively documented in managed steepland watersheds and is recognized as a significant impediment to water quality and the health of salmonid and aquatic habitat (Furniss et al., 1991; Higgins et al., 1992; Harr and Nichols, 1993; Flosi et al., 2010; NMFS, 2000, 2001). Roads modify natural drainage networks and accelerate erosion processes. These changes can alter physical processes in streams, leading to impaired streamflow regimes, sediment transport and storage, channel bank and bed configurations, substrate composition, and stability on slopes adjacent to streams. These changes can have important biological consequences, and they can negatively affect the aquatic ecosystem (Furniss et al., 1991). Unlike many watershed improvement and restoration activities, erosion prevention through "storm-proofing" rural, ranch, and forest roads provides both immediate and long term benefits to the streams and aquatic habitat of a watershed (Weaver et al., 2015; Weaver and Hagans, 1999; Weaver et al., 2006). It measurably diminishes the impact of road-related erosion on the biological productivity of the watershed's streams, and allows future storm runoff to cleanse the streams of accumulated coarse and fine sediment, rather than permitting continued sediment delivery from managed areas.

The purpose of this road erosion inventory project was to assess current and future erosion problems along 4.40 mi of Upper Park Road, a wildland road in the Big Chico Creek watershed, and develop prioritized erosion control and erosion prevention treatment plans to diminish or prevent future sediment delivery from the road. Each recommended treatment is consistent with the natural resource conservation goals and objectives written into the implementation strategies and guidelines of the Final Bidwell Park Master Management Plan (BPMMP). The BPMMP is used as the primary document for guiding policy decisions, managing data, assigning priorities management tasks and new projects, and as a means of conflict resolution and protecting physical resources and natural processes. It’s a natural resource protection and resource management guide, and functions as the primary instrument in determining the appropriateness



Map 1. Location map for the Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan.

P:\GIS\10288 Big Chico Creek 2017\10288 map 1 - location.mxd of uses and needs for adaptive management (City of Chico 2008). At the request of the City of Chico, Parks Division, Park and Natural Resource Manager, PWA evaluated vehicular access to the end of the road for visitors with private vehicles and considered alternatives for seasonal access and improved parking areas.

A team of PWA professionals and technicians inventoried 4.40 miles of Upper Park Road, identifying and characterizing road surface drainage problems, stream crossings and other site features where the road system is, or will, erode and deliver sediment to Big Chico Creek or its tributaries. Using the field inventories and data analysis, PWA identified 43 individual features and 3.42 mi of hydrologically connected roads (plus ditches and cutbanks) that either are currently eroding and delivering sediment to tributaries to Big Chico Creek, or which show a potential to do so in the future (see maps in back of report). PWA recommends treating all 43 features and 3.42 mi of road for erosion control and erosion prevention. Individual treatment features include 40 stream crossings, 2 ditch relief culverts, and 1 spring, as well as road surface drainage and associated erosion (Table 1). Based on analysis of the inventory data, we estimate that implementing all of the recommended treatments detailed in this report could prevent delivery of approximately 3,572 yd^3 of sediment to the Upper Bidwell Park Road project area and Big Chico Creek. This includes approximately 2,082 yd^3 of sediment projected to be delivered from individual erosion features during the coming decades and 1,490 yd^3 of fine sediment projected to originate from the chronic erosion of road surfaces and cutbanks during the next 10 year period (Table 2). Sediment data and volume estimates are the types of data that are important to agencies that have funds for eligible water quality and aquatic habitat restoration projects.

Table 1. Inventory results for sediment delivery features and hydrologically connected road segments, Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California.

Sources of sediment delivery	Erosion and sediment delivery sites recommended for treatment (#)	Hydrologically connected road segments recommended for treatment (mi)	Total length of roads surveyed for project (mi)
Stream crossings	40	3.09	-
Ditch relief culverts	2	0.09	-
Spring	1	0.24	-
Total	**43**	**3.42**	**4.40**

Big Chico Creek serves as a migration corridor and provides spawning, holding, and rearing habitat for anadromous salmonids which have been listed for protection under the California and/or federal ESA (City of Chico, 2008). The BPMMP and the 2001 California Department of Fish and Wildlife (CDFW) Spring-run Chinook Salmon Report data for “Big Chico Creek” suggested rearing and spawning habitat as a limiting factor for overall stream health (City of Chico, 2008). Both reports recommend: (1) decreasing the intensity and duration of suspended sediment and turbidity; (2) decreasing stream temperature; (3) increasing woody cover in the

Table 2. Estimated future sediment delivery for features and road surfaces recommended for treatment, Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California.

Sources of sediment delivery	Estimated future sediment delivery (yd^3)	Percent of total
1. Episodic sediment delivery from road-related erosion features (indeterminate time period)		
Stream crossings	2,082	100%
Ditch relief culverts	0	0%
Spring	0	0%
Total episodic sediment delivery	**2,082**	**100%**
2. Chronic sediment delivery from road surfaces and erodible cutbanks (estimated for a 10 yr period)		
Total chronic sediment delivery	**1,490**	**-**
Total estimated future sediment delivery for the project area	**3,572**	**-**

pools and flatwater habitat; and (4) that increasing high quality riparian complexity is desirable. Section 6 of this report shows a list of potential funding sources and amounts that are available for aquatic habitat restoration projects for salmonid recovery.

The expected benefit of implementing the road-related erosion control and erosion prevention treatments recommended in this report lie in the reduction of both short- and long-term sediment delivery to streams in the Big Chico Creek watershed, which contain important habitat for Chinook salmon and steelhead production in Sacramento River basin. This assessment includes prioritized action plans for cost-effective road-related erosion prevention and erosion control treatments, which, when implemented and employed in combination with protective land use practices, can be expected to contribute to the long-term protection and improvement of water quality and salmonid habitat in the Upper Bidwell Park project area.

This assessment represents a critical first step in reducing road-related erosion and improving salmonid habitat in the project area. In developing this plan, PWA designated inventoried road segments and identified erosion-source features for upgrading. All upslope road treatment prescriptions follow guidelines described in the *Handbook for Forest, Ranch and Rural Roads* (Weaver et al., 2015), as well as *Part X* of the California Department of Fish and Game *Salmonid Stream Habitat Restoration Manual* (Weaver et al., 2010). Assessment data for episodic and chronic sediment sources are summarized in Tables 1-5 and Maps 2, 2A, 2B and 3, 3A, 3B. Projected requirements for heavy equipment, labor and estimated project costs for the proposed treatments are provided in Tables 6 and 7.

Construction and installation instructions, as well as site specific specifications for the recommended erosion control and erosion prevention treatments, are provided in Appendixes A, B, and C. Appendix A explains the general principals, terminology, and minimum road "storm-proofing" standards recommendations described in the *Handbook for Forest, Ranch and Rural*

Roads (Weaver et al., 2015). Appendix B displays a comprehensive list of inventoried features on Upper Park Road showing field data, erosion impacts and analyses, including treatment immediacy and volume estimates of potential sediment delivery for the feature-specific problem and hydrologically connected road segments. Appendix C displays design details in schematic drawings, showing construction and installation techniques for recommended erosion control and erosion prevention treatments for stream crossings and road alignments.

3 FIELD DESCRIPTION OF THE ASSESSMENT AREA

3.1 Location and Travel Directions to the Field Area

The Upper Bidwell Park Road project area is located in Bidwell Park, east of the town of Chico, CA (Map 1). The area is accessed from the southwest by taking CA State Highway 32 (Deer Creek Highway) east out of Chico approximately 15 minutes to Upper Bidwell Park. From town, travel CA State Highway 32 approximately 2.0 miles to Manzanita Road, then turn left. Travel on Manzanita Road to Wildwood Avenue for 4.40 miles, then turn right at the traffic circle and follow Wildwood Avenue to the parking lot nearby the Upper Park Road gate. Although Upper Bidwell Park is public land and has permissible vehicular access for visitors, official access within the Upper Park Road project area is recommended by contacting City of Chico staff.

Landowner address:
Park and Natural Resource Manager
City of Chico, Public Works, Parks Division
965 Fir Street, Chico, CA 95927
(530) 896-7801

4 FINAL TREATMENT ACTION PLAN

4.1 Upper Park Road Assessment (4.40 mi)

Upper Park Road (4.40 mi) was constructed and maintained to support land use, recreation, and river access and has been in existence since the early 1900s. The entire project road length is within the bounds of the City of Chico Upper Bidwell Park property, which encompasses nearly 4,000 acres in the Big Chico Creek watershed (Map 1). Seasonal travel along the mainline access road is possible by visitors with 4wd and 2wd vehicles, including recreationists, mountain bikers, and equestrians. Several parking areas are available for day use. Most of the road had been constructed before California Forest Practice Rules in the 1970's and minimum road standards were developed: therefore most of the road does not meet today's generally accepted standards for a "storm-proofed" road (see details in Appendix A and Weaver et al., 2015)).

In winter 2017, PWA assessed 4.40 mi of maintained, seasonal road in Upper Bidwell Park, as well as several maintained parking areas that provide recreationists with river and swimming hole access. Although a short segment of the road near the entrance gate is paved, the majority of the road has a rocked or partially rocked running surface.

The road has culverts installed at most stream crossings, and its surface is drained through the use of road surface insloping, inboard ditches, and a few ditch relief culverts. Most of the stream crossing culverts currently have old, concrete culverts with hand placed rock used to form culvert headwalls. PWA observed that along many of the road segments, excessively long lengths of road surface and inboard ditches are hydrologically connected to stream channels. Years of road maintenance grading has created a berm on the outside edge the road that collects and concentrates runoff during storms and prevents it from being dispersed onto the adjacent hillslope.

Although there is acknowledgement of best management practices (BMP) in the BPMMP, there are only a few road segments that have road drainage structures to help disperse concentrated road runoff and prevent the runoff from being directly connected to the Big Chico Creek stream network. We found that Upper Park Road affected the geomorphic and hydrologic processes by various primary mechanisms: rainfall interception directly by the road surface, accelerated erosion from increased surface erosion processes, diverted hillslope runoff patterns, concentrated runoff on the road surface and in the ditches affecting channel structure and geometry, altered surface flow paths, and negative interactions with woody debris at stream crossing culverts. These erosion mechanisms involve different physical processes, have various effects on erosion rates and are not uniformly distributed on the landscape. The hydrologically connected road surfaces often drain directly into culverted stream crossings or to ditch relief culverts that feed into the stream network. As a result, fine sediment derived from road surface runoff, ditch incision, and cutbank ravel are being delivered directly to the stream system. These types of sedimentation issues have been noted as a high priority for treatment and remediation.

Most of the parking areas are located on the outside (downslope) edge of the road and are built on thin soils or imported surfacing underlain by shallow bedrock. These resistant parking areas produce surface runoff quickly but typically exhibit minimal erosion. The types of road-related problems with low volumes of sediment erosion and delivery were evaluated and noted as having a low treatment immediacy.

4.2 Field Techniques and Data Collection

Methods - Field inventory work was completed by trained field personnel experienced and knowledgeable in forest and watershed geomorphology, hydrology, and road management and use. The inventory staff is also skilled and experienced in identifying ongoing or potential road erosion problems, evaluating the potential for erosion and sediment delivery, and developing and implementing road treatment prescriptions designed to be both effective and cost-effective. The field crew included 2-3 people so that problems and treatments could be jointly reviewed and discussed. Problematic features were identified for review by the project manager and/or the professional geologist in responsible charge of geologic components of the project.

All field and GIS data collected and compiled into the relational databases were checked by PWA staff for consistency and accuracy. This process of “database cleaning” ensures that all project roads and treatment features are properly recorded, and that all assigned treatments are adequate and consistent with the needs of the forest manager. The PWA project manager used database queries to identify locations needing final field checking at the close of the project, including features with high treatment immediacy (priority) ratings, features with unclear or missing data, large volume sites, and complex sites that required additional review of erosion potential and sediment delivery calculations.

PWA verified the accuracy of GIS data by cross-checking the mapped features in the GIS database and the features in the field database to ensure that all feature locations were correctly identified. This process reveals any feature that was mapped in the field that is missing a GPS data point. A data point for the feature can then be digitized using the field mapped location. In rare instances in which a feature is neither mapped in the field nor recorded with GPS coordinates, PWA uses sketches on the field data forms from the same vicinity to reconstruct the feature location and add it to the GIS and field databases.

Upper Park Road assessment - The Upper Park Road sediment source assessment consisted of two components: (1) a complete field inventory to document all current and potential road-related sediment delivery sources along approximately 4.40 mi of road; and (2) the development of a prioritized action plan for cost-effective erosion control and erosion prevention treatments, including site-specific recommendations for road upgrading and various storm-proofing treatments at stream crossings, road drainage features and other sediment delivery sites (see Appendix B for site-specific recommendations).

For the first phase of the project, PWA completed a field inventory of road-related sediment source features. *Road-related features* are defined as erosion locations along a road, or caused by the road, where eroded sediment is, or could be, delivered to a watercourse. Sediment source features inventoried as part of the *Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan* primarily consist of stream crossings, potential and existing fillslope instabilities, ditch relief culverts, areas of streambank erosion, and various road surface discharge points (e.g., roadside gullies, berm breaks, waterbars or low points) where road surface and/or inboard ditch flow is discharged to tributaries to Big Chico Creek. For each feature identified as a potential or existing source of sediment delivery to the stream system, PWA staff plotted its location on laminated 1:3,000 scale GIS-generated field maps with Mylar overlays. PWA staff recorded a series of field observations and measurements for each inventoried feature on data forms including: (1) detailed feature description; (2) nature and magnitude of existing and potential erosion problems; (3) likelihood of erosion or slope failure; (4) length of hydrologically connected road surface, cutbank, and inboard ditch associated with the feature; and (5) treatments needed to prevent or minimize future sediment delivery. Field crews used GPS units to acquire accurate location data for features, and downloaded treatment feature data points to be converted to GIS spatial data.

For each existing or potential erosion feature (with the exception of stream crossings), PWA technical staff evaluated the potential for erosion and sediment delivery, and collected field measurements (length, width, and depth of the potential erosion area) to derive a likely erosion volume. The field crew then estimated the proportion (percent) of the eroded sediment that would likely be delivered to a watercourse if no erosion prevention or erosion control treatments were applied. Field notes, treatment prioritization, site specific erosion volumes, and field measurements are displayed in Appendix B.

At each site proposed for treatment, field crews defined the limits of expected disturbance area or excavation. Treatments areas for stream crossing upgrade work were flagged at both the upstream and downstream extent of the proposed stream crossing treatment site. A flag with a written site number was also hung along the road at each proposed treatment site. Most stream crossings in the Upper Park Road project area were Type 1 or Type 2, with a few more complex Type 3 stream crossings[1]. PWA field crews used tape and clinometer surveying techniques at all stream crossings to develop longitudinal profiles and cross sections, and compiled the data necessary to calculate potential sediment delivery volumes derived from the PWA Stream[2] computer program. This proprietary software, developed by PWA, provides accurate and reproducible estimates of the potential volume of erosion at a stream crossing, whether over time or during any possible catastrophic, storm-generated washouts. The program is also used to calculate excavation, removal, and end-haul volumes, including stream crossing reconstruction geometries and volumes for road upgrading projects.

An evaluation of treatment immediacy (priority) was also completed for each proposed treatment feature, based on the potential or likelihood of sediment delivery from the feature to stream channels in the project area, the expected volume and rate of sediment to be delivered to the streams, the ease and cost of accessing the feature for treatments, recommended treatments, logistics, costs, and the level of urgency for addressing erosion problems at that location. In addition, field crews measured the lengths of hydrologically connected road surfaces and ditches to derive estimates for chronic fine sediment delivery, on a decadal basis. Field crews noted increased site prioritization for road segments with evidence of past erosion and the greatest length of hydrologically connected road. Some of the assessed road segments are feeding over 1,200 ft of road and ditch to the stream network. Stream crossing features were additionally evaluated for potential fish barriers and passage.

4.3 Results of the Road-Related Sediment Source Assessment

The purpose of the field assessment was to identify and quantify all road-related features that are currently eroding and delivering sediment to streams in the Upper Park Road project area, or show a potential to do so in the future. Features with evidence of active or potentially active erosion, such as a diverted stream or long length of connected road and ditch runoff, were individually judged as having an increased treatment priority. Any on-going or potential erosion features identified in the field that did not show evidence for sediment delivery to a stream were not included in the inventory, or prescribed and prioritized for treatment. They were considered maintenance issues and not threats to water quality or aquatic habitat. However, since most of the road system is hydrologically connected to the stream network, the majority of the road (78%) has been prescribed for road drainage improvements and sediment control treatments. Maintenance problems on the remaining sections (22%) are fairly minor in comparison.

4.3.1 Summary of field data and analyses

PWA field crews identified a total of 43 erosion sites and 3.42 mi of the 4.40 mile road length to be hydrologically connected to streams; these road segments have the potential to deliver sediment directly to Big Chico Creek and its tributaries (Map 1; Table 1). We recommend that all 43 of the inventoried erosion features and all of the 3.42 mi of hydrologically connected road

[1] Definitions for Types 1-3 stream crossings are from Weaver et al., 2006.
[2] PWA Stream for Windows v. 2.0, June 2001 / Enhancement copyright 2001; Pacific Watershed Associates Inc. / Portion copyright U.S. Department of the Interior National Park Service.

segments be treated for sediment control and erosion prevention. Features with a high likelihood of future erosion, such as a plugged culvert or long lengths of uncontrolled road runoff, were judged as having a high priority for treatment. Understanding the relation between the magnitude and frequency of sediment erosion and delivery, and comparing that erosion to other features assessed in the watershed, is the best way to determine the relative treatment immediacy at a sediment source site.

Stream crossings represent the majority (93%) of recommended treatment features, by number, for the assessment area (Table 1). We project that approximately 2,082 yd^3 of future road-related sediment delivery will originate from stream crossings if they are left untreated, which is 58% of total episodic and chronic future sediment delivery for the project area, combined (Table 2). PWA also recommends treatment for 2 ditch relief culverts related to the road system and 1 spring feature (Table 1). Total estimated potential episodic and chronic sediment delivery for all recommended treatment features is approximately 3,572 yd^3 (Table 2).

Of the 40 inventoried stream crossings, 35 have the potential to divert in the future and 7 of the streams are currently diverted out of their natural stream channels (Table 3). Of the existing 37 culverts at stream crossings, 27 (77%) are undersized and not sufficiently designed for the 100-yr peak storm discharge, and 15 are judged to have a high potential to become plugged by sediment and debris and (Table 3, Figure 1).

Figure 1. This stream crossing site is plugged by a boulder that dwarfs the concrete culvert inlet. The culvert is undersized for the upslope drainage area and was assigned a high priority for treatment.

PWA field crews measured 3.42 mi of road surfaces and/or ditches currently draining to stream channels, either directly to stream crossings or via gullies formed by road runoff, and recommends all 3.42 mi for treatment (Table 1). From these hydrologically connected road segments, we estimate that approximately 1,490 yd^3 of sediment could be delivered to stream channels in the Upper Bidwell Park project area during the next decade if no efforts are made to change road drainage patterns and disperse road surface runoff (Table 2). We emphasize that this estimate is for a 10 yr period, and over longer time periods, for example the average 30-50 yr lifespan of a stream crossing culvert, this number could be considerably greater. In addition, sediment production associated with hydrologically connected roads is predominately fine grained sediment generally less than 10mm in size. This grain size is well documented to adversely impact most instream spawning and rearing habitats utilized by salmonids.

Of the 43 inventoried erosion features that PWA has recommended for treatment, we designated three (3) with priority rating of high or high-moderate (Tables 4a, 4b and Maps 2, 2A, 2B). For example, a high priority stream crossing (site #38) has an actively diverted stream and over 935

Table 3. Erosion problems at stream crossings, Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California.

Stream crossing problem	# Inventoried	Percent of total[a]
Stream crossings with diversion potential	35	88%
Stream crossings currently diverted	7	18%
Crossings with culverts that are likely to plug[b]	15	38%
Crossings with culverts that are currently undersized for the design peak flow[c]	27	68%

[a] From Table 1, total stream crossings = 40.
[b] Culvert plug potential is moderate to high.
[c] Culverts in stream channels that are too small to convey the calculated 100-year peak storm flow.

Table 4a. Treatment immediacy ratings for sediment delivery features and associated lengths of hydrologically connected road, Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California.

Treatment Immediacy	UPGRADE		Estimated future sediment delivery from inventoried erosion features (yd^3)[a]		Estimated future sediment delivery from road, ditch and cutbank surfaces (yd^3)[b]	
	Upgrade features[c] (#)	Road length[d] (mi)				
High	1 Stream crossing	0.18	47	2%	69	5%
High-moderate	2 Stream crossings	0.13	59	3%	91	6%
Subtotal	***3 features***	***0.31***	***106***	***5%***	***160***	***11%***
Moderate	16 Stream crossings	0.95	1,070	51%	346	23%
Moderate-Low	11 Stream crossings	1.00	517	25%	487	33%
Subtotal	***27 features***	***1.95***	***1,587***	***76%***	***833***	***56%***
Low	10 Stream crossings, 2 Ditch relief culverts, 1 Spring	1.16	389	19%	497	33%
Subtotal	***13 features***	***1.16***	***389***	***19%***	***497***	***33%***
Total	**43 upgrade features[c]**	**3.42**	**2,082**	**100%**	**1,490**	**100%**

[a] Episodic sediment delivery for road-related features (indeterminate time period).
[b] Chronic sediment delivery from adjacent hydrologically connected roads, ditches and cutbanks (estimated for a 10 yr period).
[c] Upgrade features: 40 stream crossings, 2 ditch relief culverts, and 1 spring.
[d] *Road length* refers to hydrologically connected road reaches adjacent to recommended treatment features.

Table 4b. Individual upgrade features listed by treatment immediacy, Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California.

Feature type	Upgrade feature ID # (see Map 3)
High treatment immediacy	
Stream crossing	#38
High-moderate treatment immediacy	
Stream crossing	#27, 39
Moderate treatment immediacy	
Stream crossing	#1, 2, 6, 9, 16, 25, 26, 28, 31, 34, 35, 36, 37, 40, 41, 43
Moderate-low treatment immediacy	
Stream crossing	#4, 11, 12, 14, 18, 19, 22, 24, 30, 32, 42
Low treatment immediacy	
Stream crossing	#3, 7, 8, 10, 15, 17, 21, 23, 29, 33
Ditch relief culvert	#5, 13
Spring	#20

ft of hydrologically connected road surface contributing eroded road sediment directly to the stream. We estimate that treating these erosion features could prevent the episodic delivery of 106 yd^3 of sediment to streams in the project area, which is approximately 5% of the total site-specific, episodic sediment delivery projected for the project area. In addition to episodic sediment delivery, PWA estimates that 160 yd^3 of fine sediment chronically eroded from the adjacent road surfaces and ditches will be delivered to these 3 stream crossing sites during the next 10 years (Table 4a). The longest section of road that is hydrologically connected to the stream network is over 1,200 linear feet in length.

Most of the erosion features on the Upper Park Road were classified as having a moderate or moderate-low treatment immediacy or priority. These included 27 stream crossings (Tables 4a and 4b; Maps 2, 2A, 2B) with an estimated 1,587 yds^3 of future sediment delivery if and when they fail. Fine sediment delivery from surface erosion on the adjacent hydrologically connected road surfaces and ditches to these 27 stream crossings represents another 833 yds^3 of sediment delivery over the next decade. This represents about 76% of the total estimated site-specific sediment delivery, and 56% of the total estimated chronic sediment delivery, from the entire project area.

Finally, we assigned a low priority to 13 road upgrading features, including 10 stream crossings, 2 ditch relief culverts and one spring site (Table 4a). We estimate that implementing erosion control and erosion prevention treatments for these features could prevent 389 yd^3 of sediment delivery to streams in the project area during the coming decades, as well as 497 yd^3 of sediment delivery during the next 10 yr from adjacent segments of eroding, hydrologically connected road, ditch, and cutbank surfaces (Table 4a).

4.4 Potential stream crossing barriers to fish and aquatic organism passage

Culverts pose the most common migration barriers associated with road networks (Furniss, 1991). None of the 40 stream crossings were identified as being on fish-bearing streams, based on existing biologic data and PWA field observations. Stream crossings of intermittent and perennial streams can be barriers to passage of aquatic organisms.

4.5 Unusually Problematic or Complex Features

4.5.1 Features requiring immediate treatment

Based on field data and analyses, PWA recommends treating one high priority feature (#38) and two moderately-high features (#27 and #39) in the project area as soon as feasible to avoid imminent erosion and sediment delivery (Tables 4a, 4b, Maps 2, 2A, 2B and 3, 3A, 3B):

1. Feature #27 is a culverted stream crossing with a moderately-high treatment immediacy. This ephemeral stream has a properly sized plastic 24 inch diameter culvert, however, the culvert is set high in the fill and is exposed in the middle of the road surface. There is no road fill or driving surface over the exposed plastic culvert (Figure 2). In addition, a long length of uncontrolled road surface and ditch (620 linear ft) delivers concentrated surface runoff and eroded fine sediment to the inlet of the culvert at the stream crossing. The inboard ditch leading to the crossing from the left road approach is eroded and actively downcutting, which also delivers coarse sediment to the culvert inlet and stream. This crossing should be upgraded with an armored fill or properly placed culvert designed to pass the peak 100-year flow estimates. The road surface on the right hinge line should be dipped to prevent stream diversion. The left road approach should be treated with road outsloping (including berm removal) and rolling dips, or ditch relief culverts to prevent an estimated 118 yd^3 of fine sediment from being delivered to the stream system at this location.

Figure 2. At feature #27 the stream crossing culvert is exposed by erosion cause by an active road surface gully.

2. Feature #38 is an unculverted, filled stream crossing where the road crosses a steep ephemeral stream. The site is classified as having a high treatment immediacy. Although estimated future sediment delivery at this location is relatively low (approximately 116 yd^3), the stream is currently diverted to an adjacent stream crossing (feature #39) immediately to the left where it enters that culvert. In the future, the diverted stream may jump its course out of the diversion ditch and erode the roadbed in one or more locations. In addition, a long length of contributing road surface and ditch (935 ft) delivers surface runoff and eroded fine sediment to the inlet of the culvert at stream crossing #39. The inboard ditch is eroded and actively downcutting, which also delivers coarse sediment to the culvert inlet and stream channel. Installing a 24 inch diameter culvert in the stream

crossing and treating the road approaches with 4 rolling dips and 750 ft of berm removal will prevent an estimated 116 yd^3 of eroded sediment from entering the stream system.

3. Feature #39, as previously mentioned above, receives stream flow from a diverted stream (feature #38) located immediately to the right of the crossing. This stream crossing has an undersized 12 inch diameter concrete culvert which is currently plugged by sediment. This site has been evaluated as having a moderately-high treatment immediacy. The culvert outlet is set high in the fill with a 6 ft drop at the outlet. The fillslope and adjacent hillslope have been deeply eroded (gullied) by stream flow. Upgrading this priority stream crossing with an armored fill or properly sized and installed culvert, and treating the adjacent road approaches with a rolling dip, 90 ft of road surface outsloping, and berm removal will prevent approximately 32 yd^3 of sediment from entering the stream system.

4.5.2 Features restricting access

A long section of road between stream crossings #27 and #28 contains uncontrolled road surface runoff that collects and concentrates on the road bed and has created a deep and continuous gully down the center of the road (Figure 3). The road surface gully is relatively large and has downcut deeply into the road surface, exposing the top of the stream crossing culvert at feature #27 (Figure 2). The gully currently requires careful navigation to pass in a 4wd vehicle and is impassable by 2wd vehicles. The road surface leading to, and including, the gullied section will need to be upgraded by reshaping and construction of road drainage structures to disperse road surface runoff sufficient to prevent renewed gullying and to improve (disperse) long term road drainage.

Figure 3. Vehicular passage with a 2wd car is inhibited by this large gully down the center of Upper Park Road.

4.5.3 Features with a large fill volume

One feature in the Upper Bidwell Park Road project area has a future sediment delivery volume greater than 450 yd^3. Feature #1 is a relatively large crossing of an intermittent stream with a large fill (see maps in back of report). The current 24 inch diameter culvert is set high and short in the fill and was set on top of an old debris fan and sediment wedge near the inlet of the stream crossing. The road surface is paved and built on a steep road approach. The road's outer fillslope is benched with a foot path that crosses the fillslope near the culvert outlet. Strong flow emerges from the culvert outlet and has created a scour hole and eroded the stream channel below its natural grade. Upgrading this stream crossing will prevent approximately 465 yd^3 of sediment from entering the stream system if it were to fail.

Another site, Feature #11, is an ephemeral stream with a poorly installed, plugged, 18” diameter concrete culvert (see maps in back of report). The stream crossing has diversion potential and the culvert is set high in the fill with a shot-gunned outlet. As a first step the undersized culvert should be cleaned. When funding is available upgrading this feature with a properly sized and installed 24 inch diameter culvert will prevent 80 yd^3 of sediment from entering the stream system.

4.5.4 Parking areas for visitors with private vehicles

PWA evaluated the existing conditions of the visitor parking areas on the 4.40 mile segment of Upper Park Road. We identified, mapped and assessed 16 parking areas (Parking Areas “F” through “U”) to determine if sediment control and erosion prevention treatments could be applied to protect or improve water quality. Our observations did not identify a single notable erosion feature that delivered sediment to the stream network. We found that the majority of parking areas were constructed directly upon bedrock, with minor surfacing, which is largely resistant to erosion and mechanical wear from vehicle traffic (Figure 4).

In general, PWA determined that preventing run-on from Upper Park Road is a key factor in erosion prevention of the parking areas. Maintaining Upper Park Road as an insloped road while near the parking areas on the outer edge of the road prevents run-on and consequent erosion. Continued maintenance of the overall area at these generally small-sized parking areas also reduces the area of disturbance which can help reduce the magnitude of parking area erosion. Utilizing large rocks around the perimeter of each parking area is a good method that is currently being used to control off-area vehicle use and it serves to minimize the area of disturbance.

Figure 4. Each individual parking areas showed minimal signs of erosion or sediment delivery. It will important to reduce any potential run-on that may negatively affect these parking areas.

At the end of the 4.40 mile road is Parking Area “U.” Here PWA identified an active spring and standing water around the perimeter of the inside edge of the parking area which should not be disturbed by vehicular traffic. In addition, as previously mentioned in this assessment report and BPMMP Trails Plan, this parking area is relatively small and probably not appropriately sized for an emergency vehicle turn-around. CAL FIRE’s Fire Safe Regulations Public Resource Code 4290 defines roads standards for fire equipment access, including turn-around standards, which must allow for a safe opposite change of direction for emergency equipment. Designs are required to either be a hammerhead/T or terminus bulb (CAL FIRE, 2016). Turn-arounds with a minimum turning radius of 40 feet from the center line of the road are required at dead-end roads, such as Parking Area “U.”

The Parks Division may wish to temporarily or permanently limit or discontinue private vehicle access while maintaining access for park maintenance and emergency vehicles needed for trail maintenance, fire prevention, and public safety, as well as a trail connection for recreationists. We have suggested several different strategies for either upgrading the road, converting the road to a trail or decommissioning (closing) the road to vehicle access and environmentally restoring the alignment. As mentioned in the BPMMP Trail Plan, access for vehicles should be limited to the dry season and prevented during the rainy season when roads are moist and wear more readily. In addition, parking access should be limited and restricted to a defined number of visitor vehicles, if not, parking lot expansion should be considered wherever suitable vehicular traffic access by visitors is allotted in the future.

4.5.5 Road access for visitors

Currently, visitors with private vehicles access the entire length of Upper Park Road (4.40 miles), as well as mountain bikers, pedestrians and equestrians. Increased use and intensity of use, both on designated roads, trails and by off-trail activities, are creating additional pressures on the Upper Park Road and natural resources (BPMMP, 2008). Conflicts between competing user groups may be settled with creative management strategies and forming separate trails or requiring trails of differing design criteria. These issues are expected to continue to intensify as the City of Chico and surrounding areas grow. During the road assessment, PWA briefly evaluated road access options for multiple user groups and the current management policy for Upper Bidwell Park.

In December 2012, a severe storm damaged several sections of Upper Park Road. While the Parks Division was later able to re-grade and add road surfacing (base rock) along a section of the road to the Diversion Dam parking Area “L” located at milepost 1.77 to allow access for seasonal vehicular traffic, staff kept the section beyond the Diversion Dam closed because of the narrowed width and steep grade of the road, potential road wear, past roadway erosion and gullying, and lack of road base.

Parks Division staff has been concerned that any partial repairs would disturb the existing road substrate, causing increased erosion and further damage. PWA evaluated the visitor access issue and existing conditions of Upper Park Road regarding the Parks Division concerns. Since the closure of the road for vehicular access by visitors, road wear has reduced. We found that beyond the Diversion Dam Parking Area “L” access for visitors with private vehicles should be closed primarily due to the terminus of the road located at mile post 4.40 (Parking Area “U”), which is too small to accommodate visitor parking and emergency vehicles (i.e. fire truck, ambulance, etc.) turn-around point. This issue is mentioned in the BPMMP Appendix E Trails Plan. We agree with the listed Alternative B in the BPMMP

Figure 5. The bare surface area on the road is reduced beyond the gate located at the Diversion Dam Parking Area. Reduced levels of vehicular use can allow vegetation to cover the road and reduce the intensity and magnitude of road-related runoff, erosion and sediment delivery.

Trails Plan, and suggest closure to unrestricted vehicular users at the Diversion Dam Gate policy be implemented year round, while access for patrol vehicles, emergency fire and medial use remain year-round.

The access route to the end of Upper Park Road also has road drainage problems, and several long lengths of undrained road and ditch have caused erosion of the roadway making it difficult to navigate in a 4wd vehicle; it is largely impassable with a 2wd vehicle, and needs to be treated. Although this erosion and basic drivability problem can be treated with reshaping and road drainage treatments (including outsloping the road, berm removal, and installing rolling dips) additional problems with unrestricted vehicular access may still need to be considered when reopening or closing this part of the road.

Long term road management and treatment considerations are worth mentioning beyond the Diversion Dam Parking Area. The road could be permanently, temporarily or seasonally closed, or it could be treated, opened, or converted into one of several different configurations. These could include one or a combination of the following road treatments:

1. Upgrading to the same standard as the rest of the road;
2. Upgrading to a lower traffic standard, lower level of use, and/or as seasonal use only;
3. Conversion from road to trail (trail use types and standards can vary);
4. Partial decommissioning – partial recontouring, with hydrologic outsloping and vegetation restoration of road bench;
5. Full decommissioning – full recontouring (topographic obliteration) of road prism with subsequent site restoration and revegetation.

4.6 Recommended Treatments

PWA recommends 17 different types of erosion control and erosion prevention treatments for the Upper Bidwell Park Road project area. The overall design plan treatments are for road upgrading. The higher initial costs of designing a road that weathers well can be amortized by lower future maintenance costs (Furniss, 1991). Treatments for Upper Park Road are organized into 2 categories (feature-specific treatments (e.g., stream crossings) and road surface drainage treatments; see Table 5). In addition to the treatment summaries in Table 5, detailed treatment information is included in the assessment database. Feature-specific treatment recommendations, data, and overviews of construction and installation techniques for Upper Park Road are provided in Appendixes A, B, and C.

4.6.1 Feature-Specific Treatments

Stream crossing upgrade treatments are primarily implemented to reduce the risk of catastrophic failure and sediment delivery resulting from gullying, headcut migration, stream diversion and stream crossing failure (washout). Stream crossings should be designed (or redesigned) to minimize impacts to water quality and to handle peak runoff and flood waters. There are three basic subcategories of permanent stream crossings; 1) bridges and arches, 2) fords and armored fills, and 3) culverts. PWA recommends that all 43 inventoried erosion features (sites) be upgraded (Map 2, 2A, 2B; Tables 4a, 4b). Each recommendation is dependent on a number of factors and elements that were considered before selecting the final design. New stream crossing upgrades are designed to follow current standards and make future failures less likely to occur and reduce the vulnerability of a stream crossing to failure and to possible stream diversion.

Recommended treatments to upgrade the features include replacing undersized culverts at 18 stream crossings and installing 1 culvert at an unculverted (filled) stream crossing. In these locations our treatment recommendations are suitable and have the appropriate design geometry for installing a new culvert or replacing the current culvert with a new culvert. All new stream crossing culvert installations should be properly sized for the 100-year recurrence interval design streamflow discharge (Table 5). As previously mentioned, stream crossings that are designed to meet the minimum standards and basic design considerations will significantly reduce the risk of catastrophic failure and sediment delivery.

Table 5. Recommended treatments for all inventoried sites and road surfaces, Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California.

Treatment type			No.	Comments
Site specific treatments	Stream crossing treatments	Culvert (replace)	18	Replace 19 undersized, poorly installed, or worn out culverts (feature #1, 2, 3, 7, 9, 11, 12, 16, 19, 22, 24, 25, 26, 34, 36, 40, 41, 42).
		Culvert (install)	1	Install a properly sized culvert to pass storm flow (feature #38).
		Wet crossing (armored fill crossings)	18	Install 18 armored fill crossings using 190 yd^3 of riprap and rock armor (feature #4, 6, 10, 14, 17, 18, 23, 27, 28, 29, 30, 31, 32, 33, 35, 37, 39, 43).
		Critical dip or dipped crossing	19	Install to prevent stream diversions (feature #1, 2, 3, 7, 8, 11, 12, 15, 16, 21, 22, 24, 25, 26, 34, 36, 38, 40, 42).
	Other	Soil excavation	28	At 28 features, excavate and remove 948 yd^3 of sediment, primarily at stream crossings (feature #1, 2, 3, 4, 6, 7, 9, 10, 11, 12, 14, 17, 18, 23, 27, 28, 29, 30, 31, 32, 33, 34, 35, 37, 38, 39, 40, 43).
		Rock (armor)	13	At 13 stream crossings, armor outboard and/or inboard fillslopes using 490 yd^3 of riprap and rock armor (feature #1, 2, 3, 7, 9, 11, 12, 22, 25, 34, 36, 38, 42).
Road surface treatments	Road drainage structures	Ditch relief culvert (install)	1	Install 1 ditch relief culvert with a downspout to improve road surface drainage (feature #1).
		Clean ditch relief culvert	1	Clean inlet of ditch relief culvert to prevent plugging (feature #5)
		Rolling dip	77	Install to improve road drainage.
	Road shaping treatments	Outslope road and remove ditch	22	At 22 locations, outslope road and remove ditch for a total of 8,870 ft of road to improve road surface drainage.
		Outslope road and retain ditch	3	At 3 locations, outslope road and retain ditch for a total of 550 ft to improve road surface drainage.
		Inslope road	3	At 3 locations, inslope road for a total of 950 ft to improve road surface drainage.
		Remove berm	28	At 28 locations, remove berm on outer edge of road for a total of 12,160 ft to improve road surface drainage.
		Clean or cut ditch	2	At 2 locations, clean or cut ditch for a total of 100 ft.
	Other	Pave road	1	At 1 location, repave road for a total of 500 ft^2.
		Rock road surface	3	At 3 locations, rock road surface for a total of 1,350 ft^2.
		Reroute road	4	At 4 features, realign road for a total of 1,925 ft to improve road surface drainage (feature #9, 13, 16, 19) and decompact current road alignment to prepare the road surface for placement of excavated fill and/or facilitate water infiltration and restoration.

Upgrading treatments also include constructing 18 armored fills in locations that are suitable for "wet crossing" construction. An armored fill crossing is built to convey stream flow directly across the roadbed and down an armored fillslope to the natural channel below. Generally an armored fill crossing is intended for low-volume traffic areas, such as open space districts and parklands. Armored fills are a good design for small ephemeral and intermittent streams when the majority of the traffic will be crossing during low flow or dry conditions (Weaver et al., 2015). When designed and properly built, armored fill crossings are a good option for low volume, low maintenance, low use routes, such as Upper Park Road.

Stream crossings with a diversion potential occur wherever the road climbs through the crossing site and where the road approach slopes away from the stream crossing. If the culvert plugs, the backed up flood waters will be diverted out of the channel, down the road alignment and eventually onto adjacent, unprotected hillslopes. The dip in the roadbed is critical, in the case of a plugged culvert, to direct flow over the low point (dip) in the fill and back into the natural channel. A total of 19 critical dips or dipped fills will be constructed at stream crossings to prevent future stream diversions.

A total of 13 stream crossing fills that were designed with fillslope angles greater than 50% (2:1) will be armored using 300 yd^3 of riprap and rock armor for providing fillslope stability and erosion prevention. Compaction of the fillslope face and slope gradient is one of the key factors that influence the stability of fillslopes. On fillslope angles steeper than 50% grade, riprap is used as a stabilization measure as well as a non-erodible erosion control "mulch" on fillslopes that may lack vegetation. Used as mulch, riprap prevents soil surface raindrop erosion, rilling and gullying caused by concentrated road surface runoff. Fillslope riprap armor has been sized according to expected stream velocities and slope gradients, it should consist of well-graded mixture of hard, large to smaller rock sizes to minimize void space and create a dense layer of interlocking angular rock fragments.

4.6.2 Road Surface Treatments

Figure 6. Road surfaces, berms and ditches capture and transport hillslope runoff and direct rainfall during storms. Road surface and ditch runoff often flow down the road grade and directly into stream crossing culvert inlets.

Significant goals of the project are to achieve more normalized hillslope drainage and to hydrologically disconnect Upper Park Road from tributaries to Big Chico Creek to the extent feasible. A "hydrologically connected" road or road segment has been defined as: "Any road segment that has a continuous surface flow path to a natural stream channel during a runoff event" (Furniss et al., 2000).

Wherever a hydrologic connection exists, road surface runoff and fine sediment is delivered to streams every time there is a rainfall event sufficient to produce surface runoff and cause erosion of bare soil areas. Concentrated runoff on compacted surfaces and ditches results in erosion and road-related sediment transport to nearby streams. The most common road-related bare surface areas include unpaved road surfaces, as well as bare (unvegetated) fillslopes, cutbanks, ditches, and landslide surfaces. PWA identified and mapped 78% of Upper Park Road (3.42 miles) as being hydrologically connected to stream channels (Figure 6).

The road surface treatments PWA has recommended are designed to control, direct and disperse road surface runoff and ditch flow onto adjacent hillslopes by reshaping the roadbed and constructing road drainage structures. These techniques act to disperse road surface runoff and reduce or prevent delivery of concentrated road runoff and fine sediment to streams (Weaver et al., 2015). At total of 3.42 miles of road surface upgrading treatments are designed to redirect surface runoff, recommendations include outsloping, insloping, berm removal, and installing rolling dips and ditch relief culverts to more frequently discharge runoff along Upper Park Road. Upgrading treatments also include locally realigning or rerouting 4 short sections of the road that are poorly located and infeasible to effectively drain and stabilize (Table 5). For each recommended road surface drainage treatment where ground disturbance will occur we estimated the volume and trucking cost to apply road rock surfacing, which curtails road surface erosion by fortifying the road surface and reducing the rate of downwearing, surface erosion, and fine sediment production and delivery; a total of nearly 3,100 yd^3 of base rock will be used to treat the road surface where road upgrading (reshaping and/or drainage structure construction) is recommended.

Reducing the length of road (3.42 miles) and number of road segments that are hydrologically connected to streams will directly and immediately improve water quality in Big Chico Creek. The principals of road surface design is really road drainage design, protecting the integrity of the road and minimizing erosion and sediment pollution. As shown in Table 5 and Appendix C, the <u>primary</u> recommended road surface treatments for upgrading Upper Park Road include:

1) Outsloping 8,870 ft of road by removing the inboard ditch and outsloping 550 ft of road while retaining the inboard ditch;
2) Installing 77 rolling dips along Upper Park Road;
3) Removing the outside road berm for a total of 12,160 feet.

For Upper Park Road, outsloped roads with rolling dips and no ditch or berms along the outside edge of the road are considered the best, most preferred road shape and drainage configuration for most circumstances. Over 9,000 ft of Upper Park Road is suitable and has been recommended for road outsloping (Figure 7). Each segment of outsloped road will have the outside berm removed and will be resurfaced with road rock. An outsloped road cross section is likely to capture and disperse road surface runoff. It has less environmental impact and lower maintenance costs than other designs. Outsloping high priority road segments of Upper Park Road will minimize flow volumes and the magnitude of runoff in the inside ditch, as well as reduce the potential for erosion, hydrologic connectivity and sediment delivery from the road surface. An outsloped road ensures that turbid road runoff and fine sediment eroded from the roadbed will be quickly drained to the outside edge of the road where it can be safely discharged onto vegetation and into undisturbed slopes (see Appendix C for typical design drawings).

Figure 7. Roads that are flat in cross section, with an outside berm and inside ditch, intercept do not allow the runoff to leave the road. Concentrated road surface and ditch runoff flows down the road with increasing velocity and discharge, creating surface erosion, rills and gullying.

However, outsloping is not always enough to get surface runoff out of wheel ruts and off the road rapidly. In this case, in addition to outsloping and berm removal, rolling dips will be necessary to disperse surface runoff from outsloped roads. Rolling dips and a smooth, outsloped road surface are critical to maintaining a well-drained, outsloped road. A total of 77 rolling dips are recommended to treat high priority, hydrologically connected road segments on Upper Park Road. Rolling dips are smooth, angled depressions constructed in the road bed that drain the surface runoff to the outside of the road and disperse it onto the native hillside. Dips should be constructed deep enough into the road subgrade with an outsloped dip axis and long, shallow approach on their up-road side and a more abrupt rise, or reverse grade, on their down-road side (Weaver et al., 2015). PWA designed rolling dip spacing dependent on the grade of the road, length of uncontrolled runoff, as well as the erodibility of the road surface (e.g., rocked or native).

In addition <u>secondary</u> recommended road surface treatments for upgrading Upper Park Road are shown in Table 5 and Appendix C, and include:
1) Installing 1 ditch relief culvert and cleaning 1 ditch relief culvert.
2) Insloping 950 ft of road.
3) Cutting and cleaning 100 ft of existing inboard ditch.

4) Applying a total of 1,350 yd^3 of road rock at 3 sites on existing rocked roads.
5) Realigning road for a total of 1,925 linear ft to improve road surface drainage at 4 sites and decompacting the current road alignment to prepare the road surface for placement of excavated fill and/or facilitate water infiltration and site restoration.

4.7 Heavy Equipment and Labor Requirements

Equipment needs for erosion control treatments in the assessment area are detailed in the project database and summarized, based on treatment prioritization, in Table 6. Most treatments require the use of heavy equipment, including an excavator, bulldozer, dump trucks, grader, roller, water truck and others. Some hand labor is required for installing culverts and applying seed and mulch to ground disturbed during heavy equipment operations. Equipment needs are reported as equipment times, in hours, to treat all features and road segments. These estimates only include the time needed for the actual treatment work, and do not include additional construction activities such as constructing temporary access at washed out stream crossings, staging equipment and materials at work features, installing temporary erosion control features, sediment barriers and traps, or traveling between features.

PWA estimates that erosion control and erosion prevention remediation in the Upper Park Road project area will require 267 hr. of excavator time and 328 hr. of bulldozer time (Table 6). Dump truck operators will require almost 4 hr. to transport excavated fill to appropriate disposal locations, as well as time for importing 13 yd^3 of road rock and 490 yd^3 of riprap to specific locations. Water truck operators will require approximately 71 hr. for stream crossing backfill compaction and 15 hr. for dust abatement during final road grading. Finally, approximately 71 hr. of labor time will be required for feature-specific tasks and an additional 66 hr. for various tasks, including transporting materials, spreading straw mulch and erosion control seed, and final stabilization (not included).

Table 6. Estimated heavy equipment and labor requirements based on treatment immediacy, Upper Bidwell Park Road Sediment Source Assessment and Treatment Action Plan, Butte County, California.[a]

Treatment immediacy	# of features	Excavated volume[b] (yd^3)	Excavator (hrs)	Bulldozer (hrs)	Dump truck (hrs)	Water truck (hr)	Labor
High or high-moderate	3	192	17	27	0	6	3
Moderate or moderate-low	27	2,381	195	226	4	48	61
Low	13	451	55	75	0	17	7
Total	**43**	**3,024**	**267**	**328**	**4**	**71**	**71**

[a] Equipment and labor times do not include hours necessary for day-to-day logistics, opening roads, traveling between features, transporting culverts, spreading road rock, and spreading straw and mulch.
[b] Excavated volume includes material permanently removed and stored as well as material excavated and reused for backfilling upgraded stream crossings.

To prevent post construction erosion, all bare soil areas not on the road bed or ditch should be seeded with native grasses appropriate for the area. In addition, bare soil areas with any risk of sediment delivery should be mulched with weed-free straw to prevent post-construction surface erosion and sediment delivery until vegetation is established. As a final step in the completion of this project, approximately 370 oak trees and native woody plants will be planted within the disturbed work area. These trees will be planted to replace trees lost during the upgrading process, stabilize the freshly excavated fillslopes and stream banks, and provide future riparian cover over tributary streams to Big Chico Creek.

4.8 Final Upslope Implementation Budget

4.8.1 Estimated Road Treatment Implementation Costs

The estimated total cost to implement the recommended erosion control and erosion prevention treatments for the Upper Park Road assessment area is approximately $457,000 (Table 7). Approximately $76,000, or 20% of the total project cost, is projected for contracting, coordination, treatment layout, construction management, data analysis and cost tracking, implementation monitoring and final reporting. Costs detailed in Table 7 also include expenses for the use of lowboy trucks to haul construction equipment to and from the work area (footnote "f"); truck/trailer time for delivering straw mulch and culverts to work features (footnote “g”); Water truck time required for road upgrading treatments, including final road grading (footnote “h”); and labor time for seeding and spreading straw mulch for erosion control (footnote “i”).

Most of the treatments listed in this plan are not complex or difficult for equipment operators with experience in road upgrading and decommissioning operations on forestlands and rangelands. The costs in Table 7 are assumed reasonable if work is performed by experienced outside contractors, and there is no added overhead for contract administration and pre- and post-project surveying. It is assumed contractors will be used on a time (hourly rental rates) and materials basis, as this will reduce pre-construction survey staking and contract development while at the same time increasing flexibility in adapting treatments, as needed, based on specific site conditions. The use of inexperienced operators or the wrong combination of heavy equipment would require additional technical oversight and supervision in the field, as well as an escalation of the costs to implement the work. To help insure success of the project, it is imperative that only the most experienced and reliable heavy equipment operators be employed under the supervision of a professional geologist experienced in road upgrading treatments and construction management, and that the project coordinator is on-site full time at the beginning of the project and intermittently after equipment operations have begun.

5 ROAD MAINTENANCE

Once the recommended erosion control and erosion prevention treatments are implemented, maintenance inspections will need to occur annually, at a minimum. Regular maintenance is required to keep roads in good condition and to identify and correct problems promptly (Furniss, 1991). Upper Park Road maintenance inspections can identify and treat erosion problems before erosion and sediment delivery become significant, or before complete failure occurs. It is beneficial to conduct stream crossing culvert inspections during the summertime, so that there is ample time to request heavy equipment to remove sediment deposits, large rocks or floatable debris at the culvert inlet which block flow or threaten to plug the culvert before winter rains. In addition to the annual, pre-winter road and drainage structure inspections, park personnel need to perform emergency inspections and maintenance during and following large storms and floods.

Poorly maintained road surfaces will channel water, reduce road life and increase erosion and sedimentation to streams. Over years of continued road use and repeated maintenance grading, road surface materials have broken down and have been graded to the side of the road, thereby creating berms and preventing proper road surface drainage. Inadequate or improper maintenance activities can lead to substantial increases in road surface runoff, road erosion, stream sedimentation and off-site stream channel erosion (Furniss, 1991). Dispersing and maintaining dispersed road surface runoff is critically important to reducing and minimizing these impacts.

Upper Park Road is slightly "through-cut" (trench-like with berms or cuts on both sides) and flat in cross section. As a result, the road exhibits poor road drainage and actively eroding ditches. Steep road segments beyond the Diversion Dam experience the highest rates of wear. Road outsloping and road surface drainage structures are needed to lessen the flow volumes in the ditch and further disperse surface runoff. As is common on many unpaved roads here and elsewhere, routine road surface maintenance (smoothing) activities are contributing to the slightly through-cut road and berm development; it is a common result of annual maintenance grading and consequent gradual lowering of the road surface (Figure 8). Poor road surface drainage will not improve until the road berm is removed or the road is outsloped, raised and crowned, or paved.

Figure 8. On Upper Park Road a berm has formed after years of grading and road surface erosion. The berm captures and concentrates road runoff, preventing it from being dispersed onto the hillside, and accelerates road surface and ditch erosion rates.

Serious damage to the road structure and road surfaces have been identified with the loss of road drainage, erosion of road surfacing materials and excess standing water on the surface. Ruts and mud indicate that road strength is deteriorating (Weaver et al., 2015). This bermed and through-cut road has locally led to the development of rills and gullies where the road is steep, and to potholes and mud puddles where it is gentle. Outside berms created by maintenance grading have unintentionally concentrated road runoff during winter storms and need to be removed from the outside edge of the road wherever they are preventing proper road drainage.

The first rule of maintaining a stable road surface is to minimize unrestricted visitor traffic and grading during the wet weather season or when the road is vulnerable to damage. We understand Upper Park Road benefits greatly by closing vehicle access for several days during the wet weather season. In locations on Upper Park Road where there are potholes, washboarding, or exposed base materials maintenance grading can regrade the road by cutting deeply into the road surface and ripping the road bed so loose material on the regraded surface will mix, compact, and bind with underlying material. Otherwise, individual potholes and tire ruts from vehicles that are patched will quickly reform in the same sections of road.

Road surface grading and maintenance grading of ditches should not happen along the entire road on an annual basis. Road surfaces and ditches should be graded where prioritized as necessary and only when needed to maintain a stable, smooth running surface to retain the most effective, dispersed surface drainage (Weaver et al., 2015). PWA recommends that prioritized road segments be ripped or deeply scarified and new loads of graded rock aggregate spread, mixed, and compacted in the existing road surface materials. Berms with good surfacing materials along the outside edge of the road can be retrieved and worked back into the roadbed. Over grading often results in unnecessary erosion and increases road surface rock wear. Steep road segments will quickly lose their running surfaces with frequent grading so operators should raise the blade wherever grading is not needed. The implementation of proper and protective road management and maintenance is key to minimizing road damage, minimizing a road's impact to water quality and reducing maintenance needs and costs.

In general, ditches should not be carrying large volumes of water. Additional rolling dips connected to the inside ditch and a few more ditch relief culverts can be installed to drain ditches more frequently. Rock armor can be installed to protect ditches from downcutting on steep sections of road or in through cut road sections where the road cannot be drained. Ditch erosion can be kept to a minimum by retaining vegetation and adding seed to promote fast growing erosion control vegetative cover. Hydrologically connected ditches should be viewed as sediment filtering and trapping structures used to encourage sediment deposition. Once ditches are regraded and maintained they can be seeded to reestablish a vegetation cover and control sediment.

Once the road has been treated (reshaped and drained more effectively), annual inspections and regular road maintenance is essential to protect the road, prevent sedimentation of streams and protect downstream water quality and aquatic habitat. Maintenance inspections are conducted to determine which road surfaces and drainage structures are in need of repair or maintenance so they function as originally designed and constructed. All roads should be regularly inspected and maintained prior to the beginning of the rainy season, whether they are mainline arterial routes or local, dead end spur roads receiving minimal traffic. Inspections should be performed on the most-at-risk features and structures first, and then low priority road segments and sites second.

During annual inspections, staff members can take down information in the field by noting the current conditions and maintenance requirements that should be addressed before the next wet weather season. Overtime, each existing drainage structure or problematic maintenance site should be inventoried and placed on a master list for quick reference. Road maintenance should address the road surface, stream crossings, cutbanks and fillslopes, as well as drainage structures and erosion control measures. Maintained culverts should be cleaned from floating debris or rocks that impede flow capacity. Armored fills can be cleaned-up and evaluated to determine if rock sizes are appropriate for high flows or if additional or larger rock needs to be added after flood flows. Rocked surfaced roads that are permanent can be inspected to evaluate if the traffic types and intensities are damaging the road and additional surfacing needs to be added.

6 FUNDING SOURCES

The City of Chico, Public Works, Parks Division is responsible for maintaining and protecting water quality in Bidwell Park in the Big Chico Creek watershed. The Parks Division oversees and manages several programs that help assist in the reduction of erosion and sedimentation, and the improvement of salmonid habitat in the Big Chico Creek watershed. Specific responsibilities, duties, expectations, and guidelines are thoroughly outlined in the City of Chico's management plan for the park. Several funding and environmental programs are available to help fund solutions regarding erosion prevention and sediment control, water quality, fish habitat and watershed improvement. The following are some of the grant programs that are available through state and federal agencies:

State Water Resources Control Board, Proposition 1 Storm Water Grant Program (SWGP). The SWGP authorized $7.545 billion in general obligation bonds for water projects including surface and groundwater storage, ecosystem and watershed protection and restoration, and drinking water protection. The State Water Board will administer Prop 1 funds for five programs. Of the $7.545 billion, Prop 1 (Section 79747) provides $200 million in grant funds for multi-benefit storm water management projects. It identifies funds available for multi-benefit storm water management projects which may include green infrastructure, rainwater and storm water capture projects and storm water treatment facilities. There is also the 319(h) program that funds sediment remediation work.

CDFW Fisheries Restoration Grant Program. The California Department of Fish and Wildlife (CDFW), through the Fisheries Restoration Grant Program (FRGP), solicits proposals for projects that restore, enhance, or protect anadromous salmonid habitat in anadromous watersheds of California, or projects that lead to restoration, enhancement, or protection of anadromous salmonid habitat. There are four focuses under which funds can be awarded: Fisheries Restoration Grant Program (FRGP), Steelhead Report and Restoration Card Program (SHRRC), Forest Land Anadromous Restoration (FLAR), and Commercial Salmon Stamp Program (CSS).

NOAA DARRP Restoration Implementation Grants. The National Oceanic and Atmospheric Administration (NOAA) restores marine and coastal natural resources damaged by hazardous waste, oil spills, and other physical impacts. Through this funding opportunity, NOAA seeks to collaborate with non-federal partners to accomplish common restoration goals related to these damages. Applicants selected through this federal funding opportunity will be capable of implementing restoration activities across a wide geographic scale. Recipients, in collaboration with NOAA and trustee councils, will select, implement, and oversee activities identified in natural resource damage assessments and restoration plans, or develop or solicit projects to meet restoration goals. Project implementation may include direct implementation by the recipient, or through contracts or sub-awards. Applicants with technical capabilities related to particular geographic areas, long-term ecological monitoring or site maintenance, or specific natural resources (i.e. fish, marine mammals, birds, corals) are encouraged to highlight those skills.

Partners for Fish and Wildlife. The Partners for Fish and Wildlife (PFW) Program, under the U.S. Fish and Wildlife Service, is a voluntary, incentive-based program that provides direct technical and financial assistance in the form of cooperative agreements to private landowners to restore and conserve fish and wildlife habitat for the benefit of federal trust resources. The PFW

Program is delivered through more than 250 full-time staff, active in all 50 States and territories. Partners for Fish and Wildlife Program staff coordinate with project partners, stakeholders and other Service programs to identify geographic focus areas and develop habitat conservation priorities within these focus areas. Geographic focus areas are where the PFW Program directs resources to conserve habitat for federal trust species. Project work plans are developed strategically, in coordination with partners, and with substantial involvement from Service field staff. Projects must advance their mission, promote biological diversity, and be based upon sound scientific biological principles. Program strategic plans inform the types of projects funded under this opportunity.

The Sierra Nevada Conservancy (SNC) is a California state agency that initiates, encourages, and supports efforts that improve the environmental, economic, and social well-being of the Sierra Nevada Region, its communities, and the citizens of California.

The Sierra Nevada Watershed Improvement Program (WIP) is a coordinated, integrated, collaborative program to restore the health of California's primary watersheds through increased investment, needed policy changes, and increased infrastructure. This comprehensive effort is being organized and coordinated by the SNC and U.S. Forest Service (USFS) in close partnership with other federal, state, and local agencies, as well as diverse stakeholders, and aims to increase the pace and scale of restoration in the Region.

The focus of this grant program is on forest health projects that result in multiple watershed benefits, consistent with the following purposes identified in Proposition 1:

- Implement fuel treatment projects to reduce wildfire risks, protect watersheds tributary to water storage facilities, and promote watershed health.
- Protect and restore rural and urban watershed health to improve watershed storage capacity, forest health, protection of life and property, and greenhouse gas reduction.
- Implement watershed adaptation projects in order to reduce the impacts of climate changes on California's communities and ecosystems.

7 CONCLUSIONS

At the request of City of Chico Parks Division, PWA has completed the Upper Park Road comprehensive sediment source assessment and treatment action plan for road-related erosion and sediment delivery to Big Chico Creek and its tributaries, in Upper Bidwell Park, Butte County, California. The purpose of this road erosion inventory project was to assess current and future erosion problems along 4.40 mi of Upper Park Road, a wildland road in the Big Chico Creek watershed, and develop a prioritized erosion control and erosion prevention treatment plan to diminish or prevent future sediment delivery to Big Chico Creek and its tributaries.

Each recommended treatment is consistent with the natural resource conservation goals and objectives written into the implementation strategies and guidelines of the Final Bidwell Park Master Management Plan (BPMMP). All upslope road treatment recommendations follow guidelines described in the *Handbook for Forest, Ranch and Rural Roads* (Weaver et al., 2015), as well as *Part X* of the CDFG *Salmonid Stream Habitat Restoration Manual* (Weaver et al., 2010). The recommendations and costs contained in this final summary report reference current road “storm-proofing” standards of erosion prevention and sediment control and local private sector heavy equipment and labor rates.

Ultimately, we found that the current conditions of Upper Park Road has modified the natural runoff regime and stream network, and accelerated road-related erosion rates and hillslope processes. Past construction practices, ineffective or poor road drainage, and deferred or locally ineffective maintenance activities has led to altered hillslope drainage patterns, increased runoff, and accelerated hillslope and road erosion. It has also likely resulted in correlative off-site impacts including downstream channel instability, bank erosion, water quality impacts, and degraded aquatic habitat.

To assist in future road and resource management, this road-related sediment source assessment and prioritized action plan provides field-based data needed to cost-effectively treat existing and potential sources of erosion and sediment delivery from 43 individual erosion sites along 4.40 mi of parkland roads. In addition to specific erosion sites, we have included treatment prescriptions for 3.42 mi of hydrologically connected roads that are currently eroding and delivering fine sediment and road runoff to tributaries to Big Chico Creek. This will prevent approximately 2,082 yd^3 of projected sediment delivery from individual erosion features during the coming several decades, and almost 1,500 yd^3 of fine sediment delivery from the chronic erosion of road surfaces, cutbanks and ditches during the next decade. These pending and potential impacts can be prevented as soon as the proposed road upgrading work is undertaken.

An evaluation of treatment immediacy (priority) has been completed for all 43 erosion sites recommended for treatment. This priority ranking is based on the likelihood of erosion and sediment delivery, the expected magnitude (volume) and rate of sediment to be delivered, and the sensitivity of resources at risk. Most of the erosion features on the road (56%) were classified as having a moderate treatment immediacy, and these typically included undersized and plugged culverts, and gullies on the road surface and in the ditch. None of the 40 stream crossing that were identified were fish bearing streams. The erosion assessment identified a few generalized problem sites that require immediate treatment, including site features judged as having a high priority for treatment, features restricting Upper Park Road access, stream crossings with large fill volumes, as well as specific locations where there is unrestricted vehicular access and parking areas for visitors.

An integral part of this assessment is the prioritized plan of action for cost-effective erosion prevention and control, employing mostly road upgrading treatments on Upper Park Road. The expected benefit from employing these treatments lies in the reduction of both chronic and episodic sediment erosion and delivery to streams. The increased initial costs of redesigning and reshaping specific road sections to weather storms and visitor traffic should be balanced by lower long term maintenance costs and reduced downstream impacts. The estimated total cost to implement the entire upgrade plan for Upper Park Road, as detailed here, is approximately $457,000. When implemented and employed in combination with protective land management and visitor use practices, the treatment prescriptions outlined in this action plan may be expected to significantly improve road conditions (drivability and access) for visitors, reduce long term road maintenance costs, and provide for long-term protection and improvement of water quality and salmonid habitat in the Big Chico Creek watershed.

Overall, PWA estimates that erosion control and erosion prevention remediation in the Upper Park Road project area will require approximately 10-12 weeks for a heavy equipment team to implement, including labor hours needed to complete the treatment prescriptions. To help insure success of the project, we recommend that only the most experienced and reliable heavy equipment operators be employed under the supervision of a professional geologist experienced in road upgrading treatments and construction management, and that the project coordinator is on-site full time at the beginning of the project and intermittently once equipment operations have begun.

Table 7. Estimated equipment times and costs to implement road upgrading, erosion control and erosion prevention treatments, Upper Bidwell Park Road, Butte County, California.

Cost category[a]		Cost rate[b] ($/hr)	Estimated Project Times			Total estimated costs[e] ($)
			Treatment[c] (hr)	Logistics[d] (hr)	Total (hr)	
Move in, move out[f]	Excavator	135	3	--	3	405
	Bulldozer	135	3	--	3	405
	Dump truck	155	6	--	6	930
	Roller	135	3	--	3	405
	Water truck	145	3	--	3	435
	Grader	176	3	--	3	528
	Truck/trailer	85	6	--	6	255
	Pilot car	55	9	--	9	495
Road opening	Excavator	215	6	--	6	1,290
	Bulldozer	181	6	--	6	1,086
Heavy equipment for feature-specific treatments[g]	Excavator	215	215	65	280	60,200
	Bulldozer	181	179	54	233	42,173
	Dump truck	155	4	1	5	775
	Roller	163	16	5	21	3,423
	Water truck	145	41	12	53	7,685
	Truck/trailer	85	47	14	61	5,185
Heavy equipment for road drainage treatments[h]	Excavator	215	59	18	77	16,555
	Bulldozer	181	149	45	194	35,114
	Dump truck	155	0	0	0	0
	Roller	163	75	23	98	15,974
	Water truck	145	45	14	59	8,555
	Grader	176	15	5	20	3,520
Laborers[i]		70	137	41	178	12,460
Rock costs (includes trucking for 3,105 yd^3 of road rock and 490 yd^3 of riprap)						107,842
Culvert materials costs (60' of 18"; 590' of 24"; 40' of 30"; 310' of 36" and 200' of 6" diameter flex pipe, including costs for downspouts and couplers)						41,264
Permitting						5,000
Mulch and seed for 0.9 acres of disturbed ground[j]						960
Trees for replanting[k]						2,155
Miscellaneous erosion control supplies and rental equipment (trash pump, fabric etc.)						5,820
PWA supervision, coordination, layout, and reporting[l]						76,179
Total Estimated Costs: $457,073						

(Continued on next page.)

Table 7—continued.

[a] Costs excluded from the list are for (1) tools and miscellaneous materials, (2) variable administration and contracting expenses, and (3) repaving upgraded roads.

[b] Heavy equipment costs include operator and fuel. Costs listed are estimates for favorable local private sector equipment rental and labor rates.

[c] Treatment times refer to equipment hours expended explicitly for road upgrading treatments, erosion control and erosion prevention work at all project features and roads.

[d] Logistics times for heavy equipment (30%) include all equipment hours expended for opening access to features on maintained and abandoned roads, travel time for equipment to move from feature to feature, and conference times with equipment operators to convey treatment prescriptions and strategies. Logistic times for laborers (30%) include estimated daily travel time to project area.

[e] Total estimated project costs for equipment rental and labor are based on private sector rates. Materials costs are subject to change.

[f] Lowboy hauling costs are based on one haul each (1 to move in and 1 to move out) at 3 hr/trip for excavator and bulldozer.

[g] An additional 40 hr of truck time are added for delivering straw to features and for delivering culverts. An additional 7 hr of excavator time is added to assist with culvert loading and transport.

[h] An additional 15 hr of water truck time is added for final grading.

[I] An additional 54 hr of labor time are added for spreading straw mulch and seeding and for culvert installation. This includes 40 hr of labor for initial delivery of straw to work sites and 14 hr to spread straw.

[j] Seed costs are based on 35 lb of native seed per acre at $15/lb. Straw needs are 50 bales per acre at $10/bale. Labor time for straw mulching and seeding is 16 hr per acre.

[k] Total cost to purchase and replant approximately 370 native trees and woody plants. Costs assume $55/hour labor to replant and $1.50/tree. Subsequent watering costs, if needed, is not included.

[l] Supervision time includes detailed layout (flagging, etc.) prior to equipment arrival, training of equipment operators, construction management during equipment operations, oversight of labor work, and post-project documentation and reporting.

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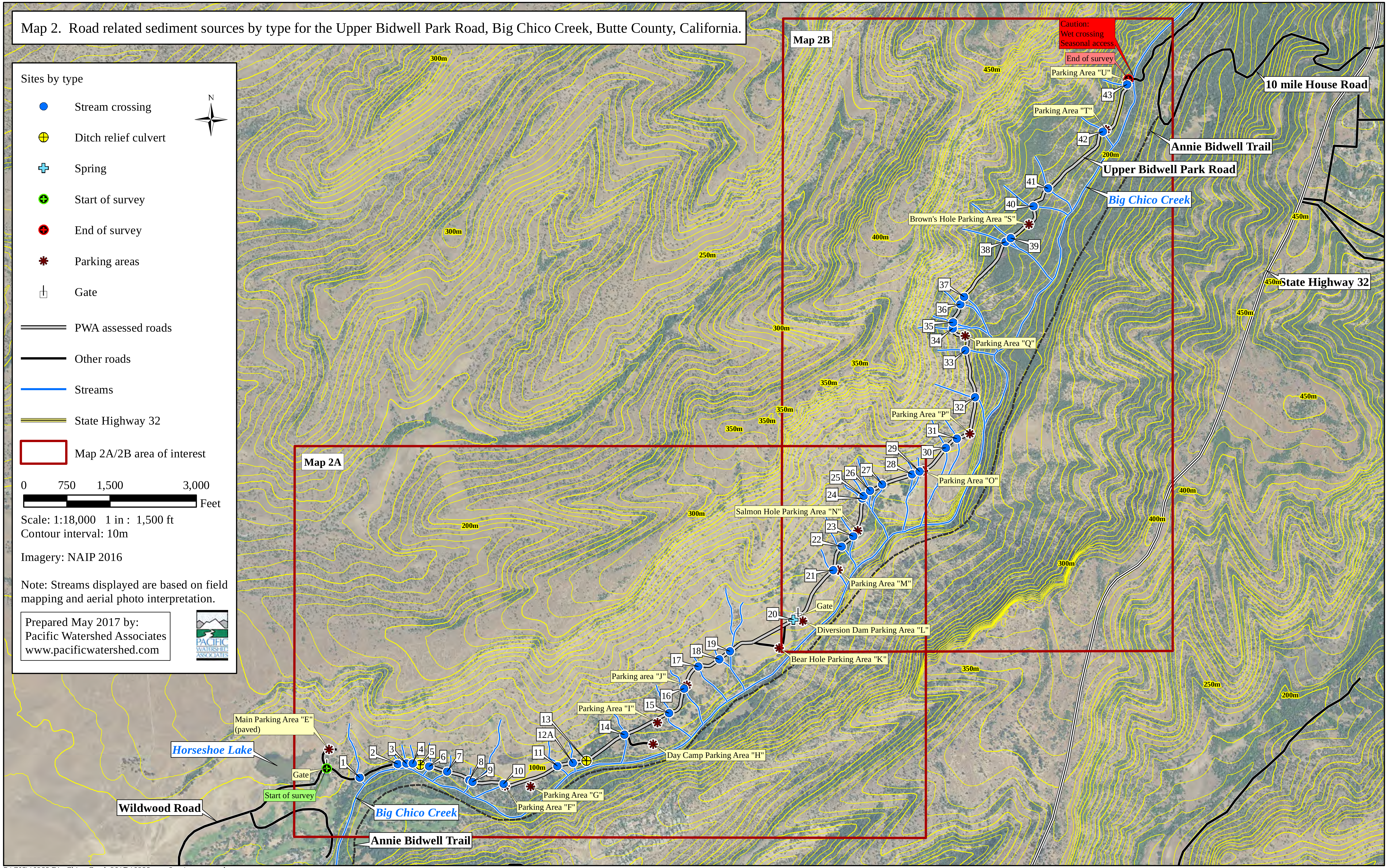

Map 2. Road related sediment sources by type for the Upper Bidwell Park Road, Big Chico Creek, Butte County, California.

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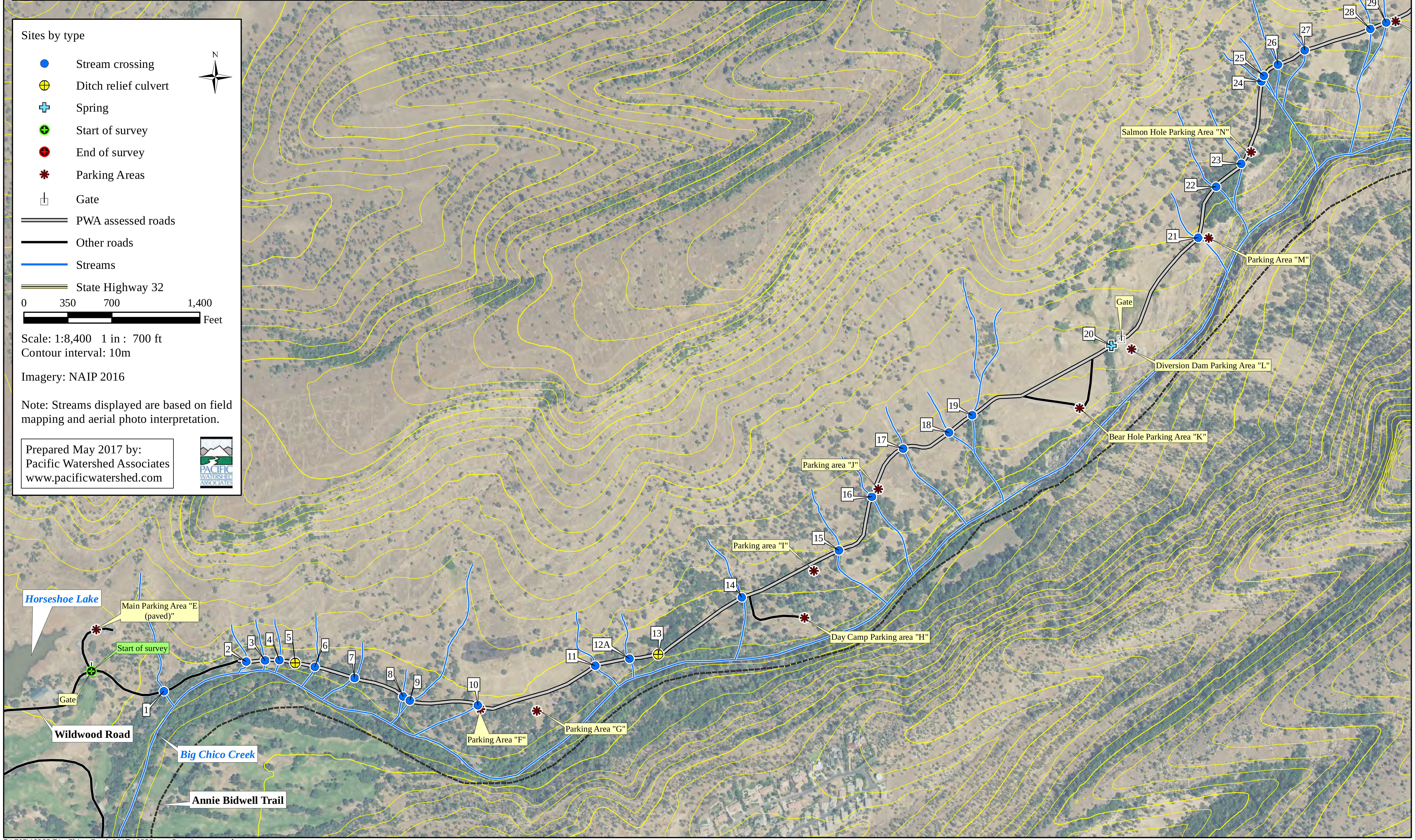
Map 2A. Road related sediment sources by type for the Upper Bidwell Park Road (South), Big Chico Creek, Butte County, California.



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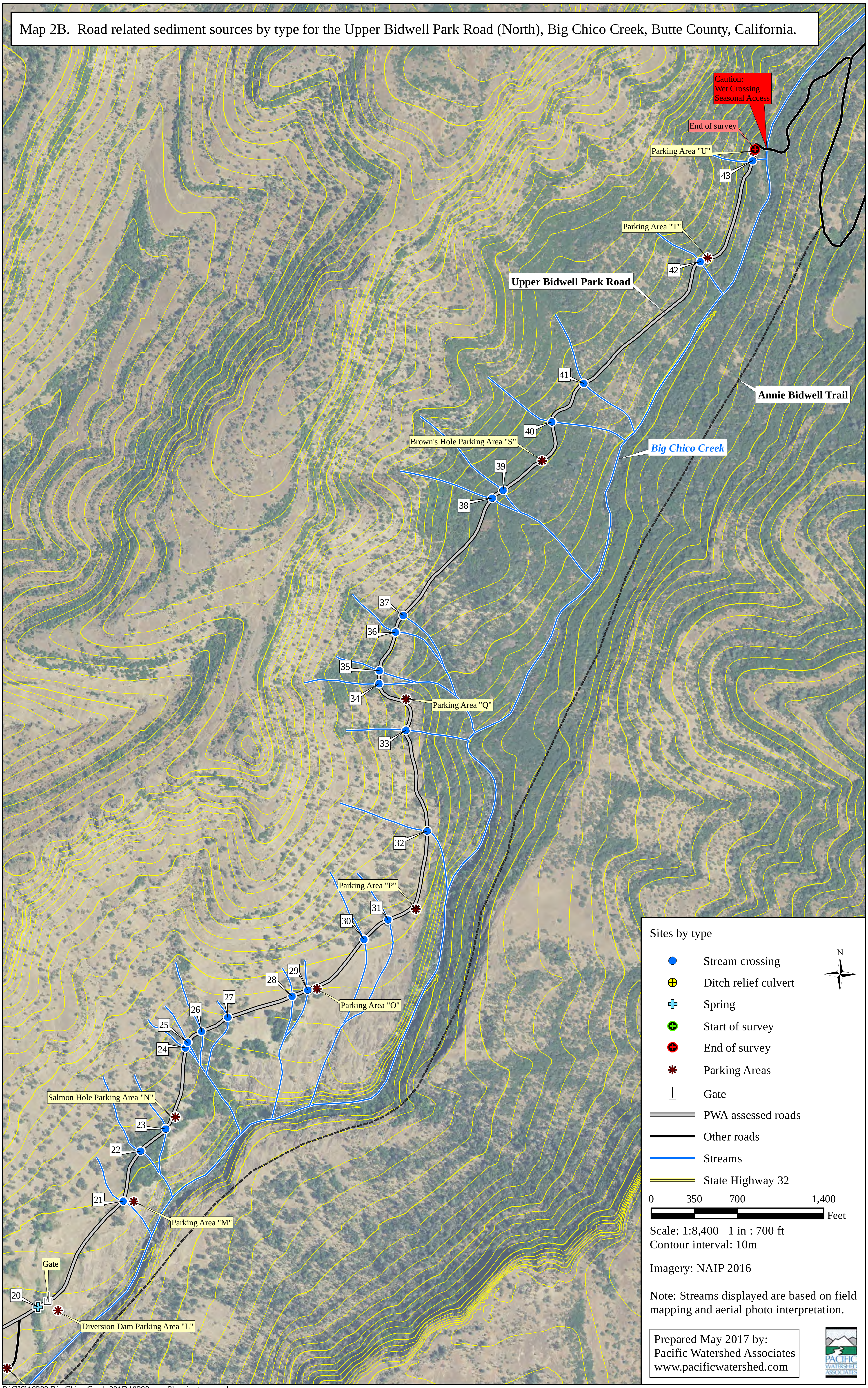

Map 2B. Road related sediment sources by type for the Upper Bidwell Park Road (North), Big Chico Creek, Butte County, California.

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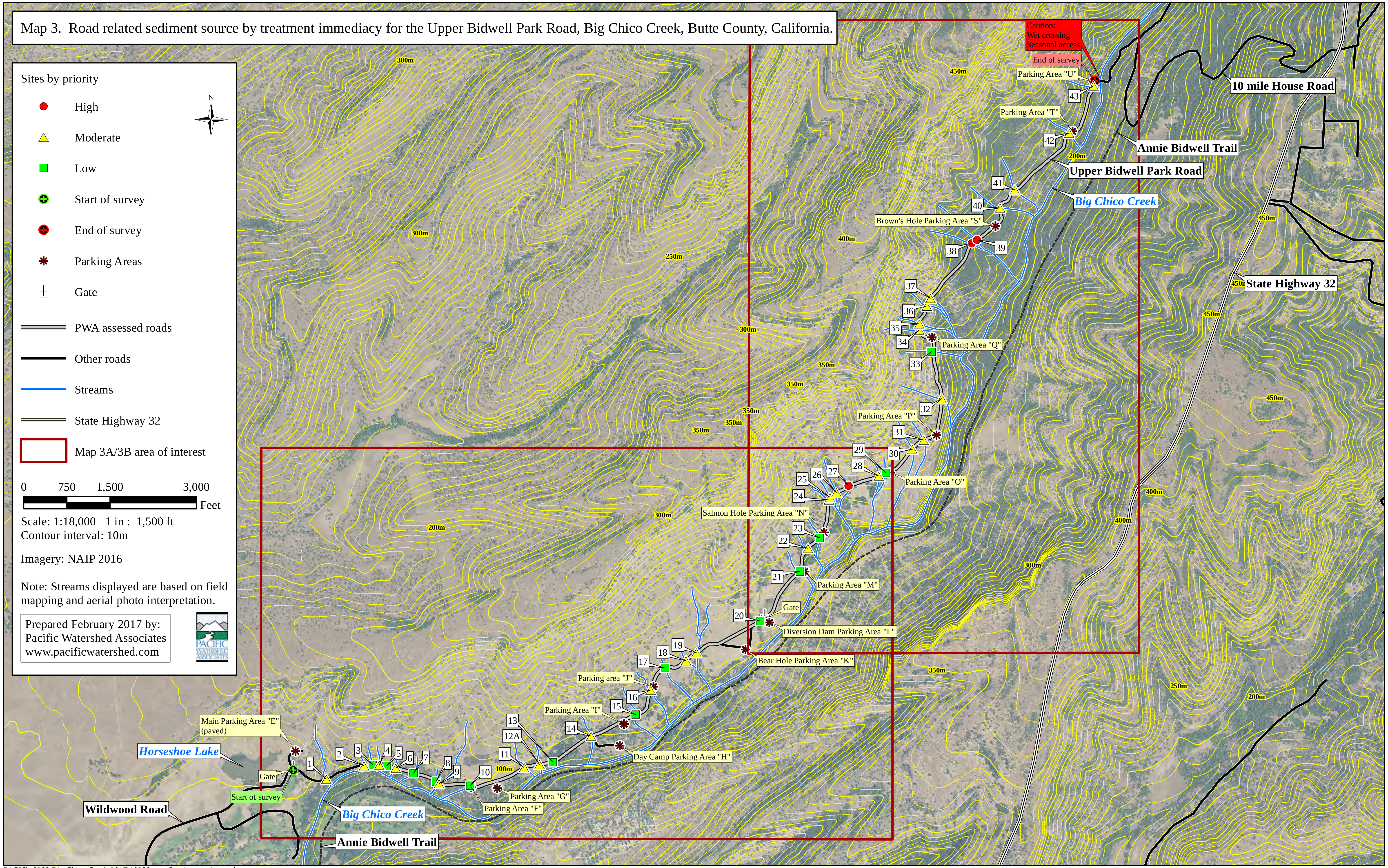

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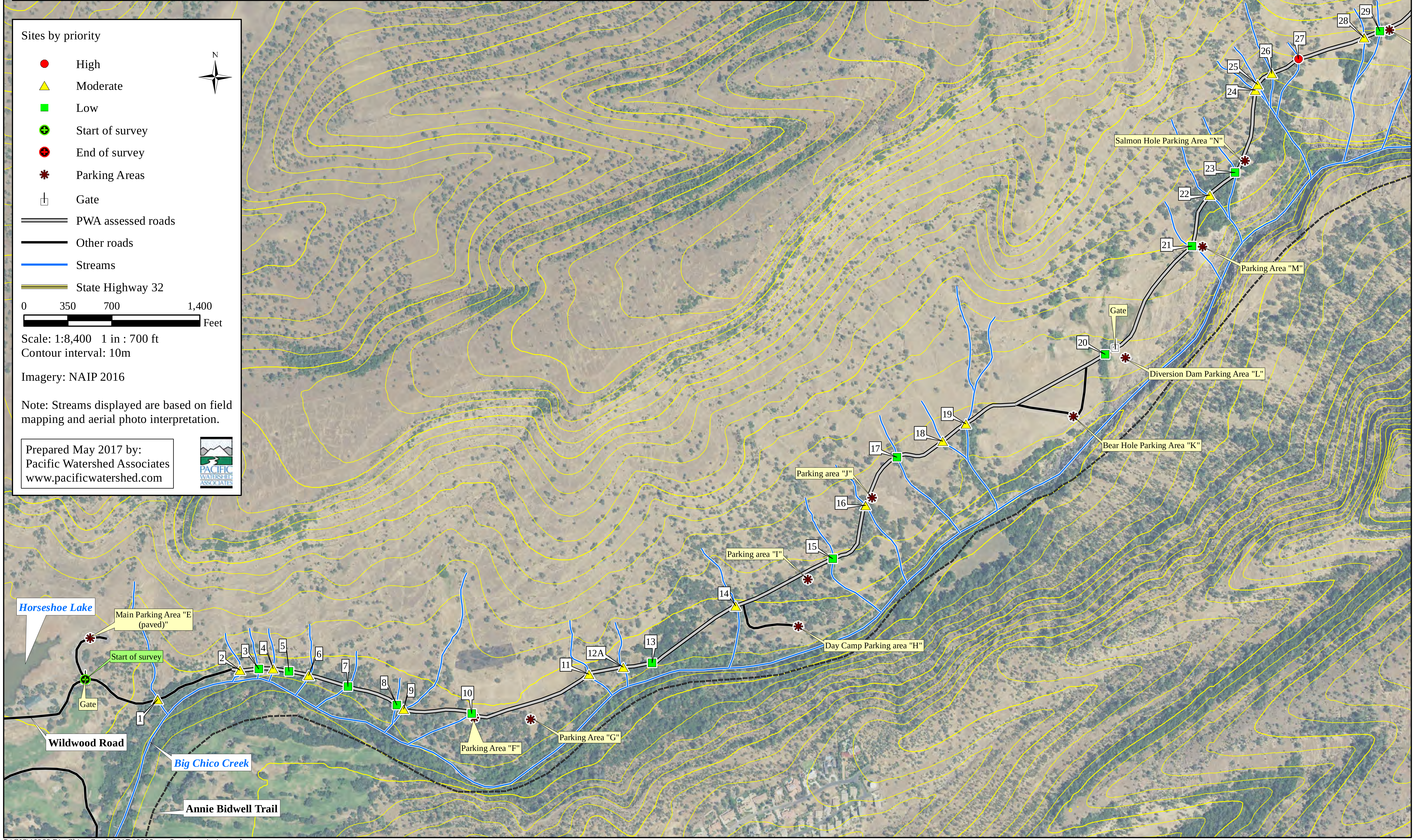
Map 3A. Road related sediment sources by treatment immediacy for the Upper Bidwell Park Road (South), Big Chico Creek, Butte County, California.



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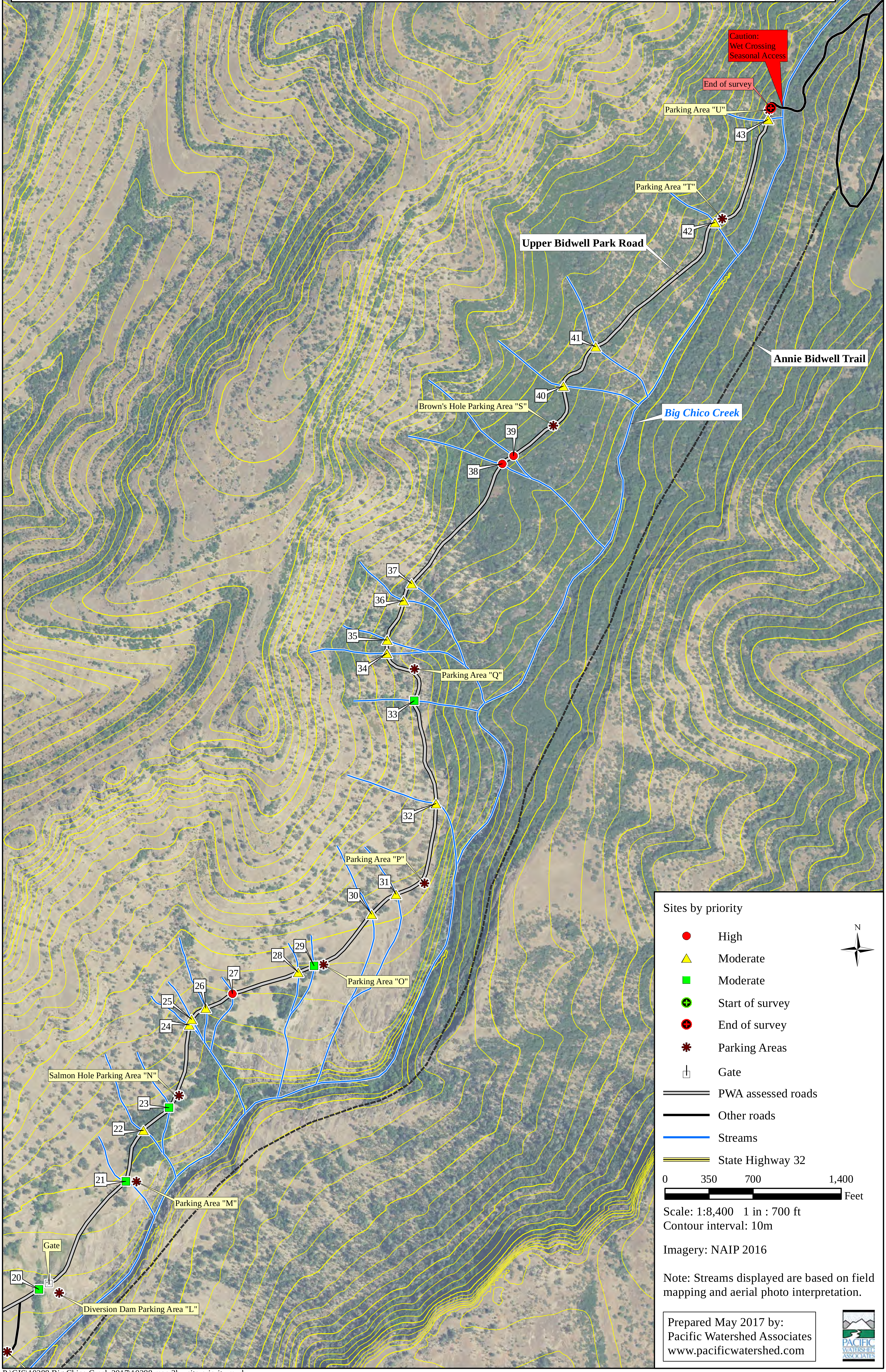
Map 3B. Road related sediment sources by treatment immediacy for the Upper Bidwell Park Road, Big Chico Creek, Butte County, California.



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APPENDIX A

Terminology and techniques used in road related erosion control and erosion prevention projects

1. Sources of road related erosion
2. Overview of storm-proofing roads

1 SOURCES OF ROAD RELATED EROSION

Sources for erosion and sediment delivery are divided into two categories: (1) sediment from specific treatment sites, and (2) sediment from the surfaces of road segments of varying lengths—and their associated cutbanks and inboard ditches—that are hydrologically connected[1] to streams.

Site-specific erosion is termed *episodic* because it is projected to occur during storm events that may occur over an indeterminate time. Some sites, such as unstable fillslope landslides on steep hillslopes, may show evidence for imminent failure, erosion, and sediment delivery. But typically, individual sites can only be evaluated in terms of their likelihood to fail during the next severe storm or runoff event, with plans designed to prevent erosion and sediment delivery as a result of that eventuality.

In contrast to site-specific episodic erosion, erosion from road surfaces is termed *chronic* because it occurs on an on-going basis, during every rainfall event that results in surface runoff. Chronic road surface erosion is primarily dependent on the level of road usage, the erodibility of the road surface, the steepness of the road, and the amount of surface runoff that is collected, concentrated, and discharged from the road. PWA provides estimates of chronic erosion and sediment delivery for a 10-year period, based on empirical calculations for fine sediment generation from hydrologically connected road surfaces and associated bare cutbanks and ditches (Weaver et al., 2006). The amount of fine sediment delivered to stream channels from these eroding road surfaces can be substantial over time, and in many watersheds may represent the greater detriment to fish habitat and the aquatic ecosystem.

1.1 Site-Specific Erosion Sources

1.1.1 Stream crossings

A stream crossing is the location where a road crosses a stream channel (Weaver and Hagans, 1994). Drainage structures used in stream crossings include bridges, fords, armored fills, culverts, and a variety of temporary crossing structures. When they erode, sediment delivery from stream crossings is always assumed to be 100%, because any sediment eroded from the crossing site is delivered directly to the stream (Furniss et al., 1997; Weaver et al., 2006). The size of the stream affects the rate of sediment mobilization and movement, but any sediment delivered to small ephemeral streams will eventually be transported to downstream fish-bearing stream channels. Because of this, it is important to identify all stream crossings and evaluate the potential for erosion and sediment delivery from the site.

Common features of stream crossings that lead to erosion problems include (1) fill crossings without culverts, (2) crossings with undersized culverts, (3) crossings with culverts susceptible to being plugged, (4) crossings with culvert outlet erosion, (5) crossings with logs or debris buried in the fill intended to convey streamflow (i.e., *Humboldt crossings*), (5) crossings with a potential for stream diversion, and (6) crossings that have currently diverted streams.

[1] *Hydrologically connected* describes sites or road segments from which eroding sediment is delivered to stream channels (Furniss et al., 2000).

A *fill crossing* is a stream crossing without a culvert or other drainage structure to carry the flow through the road prism. At such sites, stream flow either crosses the road and flows over the fillslope, or is diverted down the road via the inboard ditch. Most fill crossings are located at small Class II or III streams[2] that only have flow during larger runoff events. *Armored fill crossings* and *ford crossings* are designed to be functional, unculverted stream crossings. A properly constructed armored fill crossing is based on a site-specific design, using a mix of riprap-sized rock to minimize erosion while allowing the stream to flow across the road prism (Weaver et al., 2006). A ford crossing may use rock armor to stabilize the roadway, but the road is built essentially on the natural streambed and fill is not used.

Humboldt crossings are constructed from logs or woody debris, usually laid parallel to flow, which are then covered with fill. Humboldt crossings are susceptible to plugging, gullying, and washout during storm flows (Weaver et al., 2006). Older Humboldt log crossing structures beneath more recently installed culverts are often found in rural northern California road networks.

Large volumes of erosion may occur at stream crossings when culverts are too small for the drainage area and storm flows exceed culvert capacity, or when culverts become plugged by sediment and debris. In these instances, flood runoff will spill across the road, allowing erosion of the stream crossing fill and development of a *washout crossing*. Washout crossings will remain highly problematic as the streambed and banks continue to erode and adjust to a stable grade.

Serious erosion problems may also occur where a stream crossing has a *diversion potential*. Stream diversions occur at stream crossings that are unculverted, or have culverts that plug during a flood event, allowing water to spill out onto the road surface or into the ditch, and flow down the road and onto adjacent hillslopes or into nearby stream channels. When this occurs, the roadbed, hillslope, and/or stream channel that receives the diverted flow may become deeply gullied or destabilized. Road and hillslope gullies can develop and enlarge quickly and deliver large quantities of sediment to stream channels (Hagans et al., 1986; Furniss et al., 1997). Streamflow that is diverted onto steep or unstable slopes may also trigger hillslope landslides and large debris flows.

To be considered adequately sized, culverts at stream crossings must have the capacity to convey a 100-year peak storm flow[3] with sediment and organic debris in transport (USDA Forest Service, 2000; Weaver et al., 2006). In areas where large woody debris may lodge against the culvert, trash racks should be installed slightly upstream from culvert inlets as an additional precaution against plugging. Substandard stream crossing culverts include those that are not large enough to convey a 100-year flow, or are installed at too low of a gradient through the stream crossing fill. Installing a culvert at a shallower grade than the natural upstream channel will cause sediment and debris to be deposited at and immediately upstream of the culvert inlet,

[2] In general, Class I streams are waterways containing viable or restorable fish habitat, or are the source of domestic water supplies. Class II streams are those that support non-fish aquatic species. Class III streams are defined as channels with a defined bed and banks and showing evidence for sediment transport. Class IV streams are man-made watercourses.
[3] The *100-year peak storm flow* for a location is the discharge that has a 1% probability of occurring at that location during any given year.

which promotes plugging and decreases the culvert's capacity to carry streamflow. The outdated practice of installing culverts at insufficiently low gradients was once employed as a cost-cutting measure, because it requires a shorter length of pipe to convey flow through the road. In the long run, however, this practice often proves detrimental to erosion control and maintenance efforts because it allows the culvert to discharge water onto unconsolidated road fill rather than into the preexisting stream channel, resulting in pronounced erosion of the outboard, downstream fill face.

1.1.2 Landslides

Landslides with the potential to fail during periods of intense and prolonged rainfall events are identified in the field by tension cracks, scarps showing vertical displacement, corrective regrowth on trees (i.e., pistol butt trees) and perched, hummocky fill indicating surface instability. As a standard practice, PWA maps all existing and potential landslides observed in the field, but only inventories those that are associated with roads and show a potential to deliver sediment to a watercourse. Types of landslides in a road related erosion assessment typically include (1) road fill failures, (2) landing fill failures, (3) hillslope debris slides, and (4) deep-seated, slow landslides. The majority of treatable landslides in an assessment area are often the result of failure of unstable fill and sidecast material from earlier road construction. Preemptive excavation of small, current or potential landslides is an effective technique for erosion control, achieved by removing the unstable material and redepositing it in a stable, designated location either at or near the treatment site. Conversely, large, deep-seated landslides are usually found to be technically infeasible to treat.

1.1.3 Ditch relief culverts

A *ditch relief culvert* (DRC) is a plastic, metal, or concrete pipe installed beneath the road surface to convey flow from an inside road ditch to an area beyond the outer edge of the road fill. When properly spaced, DRCs limit the quantity of water available to cause erosion at any single location, allowing flow to disperse and reducing the likelihood of gullies forming at their outlets. It is sometimes necessary to install downspouts or rock armor at DRC outlets to further dissipate energy and prevent erosion.

1.1.4 Discharge points for road surface, cutbank, and ditch erosion.

Unpaved road surfaces, and their associated cutbanks and inboard ditches, are major sources for erosion and delivery of fine sediment to stream channels. For paved roads, ditches, cutbanks, and unpaved turnouts may still represent active sediment sources. Road surface, cutbank, and ditch erosion is termed "chronic" because it occurs throughout the year, and may include one or more of the following processes: (1) mechanical pulverizing and wearing down of road surfaces by vehicular traffic; (2) erosion of unpaved road surfaces by rainsplash and runoff during periods of wet weather; (3) erosion of inboard ditches by runoff during wet weather; and (4) erosion of cutbanks by dry ravel, rainfall, slope failures, and brushing/grading practices. *Discharge points for road surface, cutbank, and ditch erosion* are locations where sediment-laden flow from poorly drained road/cutbank/ditch segments exits the roadway to be delivered into the stream system. Discharge points are often in the form of roadside gullies or waterbars, but on some low gradient or streamside roads may simply be low spots where concentrated flow exits the road and is delivered directly to a stream without gully formation.

1.1.5 Additional site-specific sediment sources

Additional, less frequent sources of sediment delivery that may be found in an assessment area include:

Point source springs. Point source springs refer to sites where spring flow is entering the roadbed and causing erosion. Flow from multiple springs may become concentrated along a road with inadequate drainage structures, creating roadside gullies or fillslope failures.

Sites of bank erosion. Bank erosion sites refer to locations of streambank erosion caused or exacerbated by emplacement of a nearby road.

Swales. Swales are channel-like depressions that only carry minor flow during periods of extreme rainfall.

Channel scour. Channel scour refers to the widening or deepening of stream channels as a result of increased flow levels.

Non-road related upslope gullies. These are sites of focused runoff that form upslope from a roadway, and may exacerbate erosion at the roadway or contribute sediment to the system during high discharge.

1.2 Evaluation of Hydrologically Connected Road Segments

PWA measures the lengths of hydrologically connected road segments adjacent to sediment delivery sites, such as on either side of a stream crossing, ditch relief culvert, or discharge point, to derive an estimate for total potential sediment delivery from connected road surfaces in the project area. In addition, because the adjacent hydrologically connected road segments contribute to the overall erosion and sediment delivery problem at a site, PWA considers the treatment site and adjacent road segments as a unit when estimating future sediment delivery and developing treatment prescriptions for that location.

2 OVERVIEW OF STORM-PROOFING ROADS (ROAD UPGRADING AND DECOMMISSIONING)

Forest and rural roads may be storm-proofed by one of two methods: upgrading or decommissioning (Weaver and Hagans, 1994, 1999; Weaver et al., 2006). Upgraded roads are kept open, and are inspected and maintained. Their drainage facilities and fills are designed or treated to accommodate the 100-year peak storm flow. Conversely, properly decommissioned roads are closed and no longer require maintenance. Whether through upgrading or decommissioning, the goal of storm-proofing is to make the road as “hydrologically invisible” as possible, that is, to minimize the hydrologic effects of the road and to reduce or prevent future sediment delivery to the local stream system. A well-designed storm-proofed road includes specific characteristics (Table A1), all proven to contribute to long-term improvement and protection of watershed hydrology and aquatic habitat.

2.1 Road upgrading

Road upgrading involves a variety of treatments used to make a road more resilient to large storms and flood flows. The most important of these include upgrading stream crossings (especially culvert upsizing to accommodate the 100-year peak storm flow and debris in transport, and treatments to correct or prevent stream diversion); removing unstable sidecast and fill materials from steep slopes; and applying road drainage techniques (e.g., installing ditch relief culverts, removing berms, constructing rolling dips, insloping or outsloping the road) to improve dispersion of surface runoff. Road upgrading often also includes adding road rock or riprap as needed to fortify roads and crossings. The treatments are fully described by Weaver et al. (2006).

2.1.1 Installing rolling dips

Rolling dips are installed on low- to moderate-gradient, hydrologically connected roads to disperse surface runoff and discharge it onto the native hillslope below the road. Rolling dips may extend from the inboard edge to the outboard edge of a road prism, or just on the roadbed, and are constructed at intervals as needed to control erosion (typically 100, 150, or 200 ft). They are effective in reducing year-round (“chronic”) sediment delivery from road surfaces, and are designed to be easily drivable and not impede vehicular traffic.

2.1.2 Road shaping

Road shaping changes the existing geometry or orientation of the road surface, and is accomplished through insloping (sloping the road toward the cutbank), outsloping (sloping the road toward the outside edge), or crowning (creating a high point near the center axis of the road so that it slopes both inward and outward). Like rolling dips, road shaping is used to prevent uncontrolled delivery of road surface runoff by dispersing it into the inside ditch or onto the hillslope below the road. This is also effective in preventing the formation of gullies at the edge of the road, and localized slope instability below the road. Road shaping is almost always used in concert with rolling dips to disperse surface runoff.

Table A1. Characteristics of storm-proofed roads (*from* Weaver et al., 2006).

Storm-proofed stream crossings • All stream crossings have a drainage structure designed for the 100-year peak storm flow (with debris). • Stream crossings have no diversion potential (functional critical dips are in place). • Stream crossing inlets have low plug potential (trash barriers installed). • Stream crossing outlets are protected from erosion (extended beyond the base of fill; dissipated with rock armor). • Culvert inlet, outlet, and bottom are open and in sound condition. • Undersized culverts in deep fills (greater than backhoe reach) have emergency overflow culvert. • Bridges have stable, non-eroding abutments and do not significantly restrict 100-year flood flow. • Fills are stable (unstable fills are removed or stabilized). • Road surfaces and ditches are "hydrologically disconnected" from streams and stream crossing culverts. • Class I stream crossings meet CDFG and NMFS fish passage criteria (Taylor and Love, 2003).
Storm-proofed fills • Unstable and potentially unstable road and landing fills are excavated or structurally stabilized. • Excavated spoil is placed in locations where it will not enter a stream. • Excavated spoil is placed where it will not cause a slope failure or landslide.
Road surface drainage • Road surfaces and ditches are "hydrologically disconnected" from streams and stream crossing culverts. • Ditches are drained frequently by functional rolling dips or ditch relief culverts. • Outflow from ditch relief culverts does not discharge to streams. • Gullies (including those below ditch relief culverts) are dewatered to the extent possible. • Ditches do not discharge (through culverts or rolling dips) onto active or potential landslides. • Decommissioned roads have permanent drainage and do not rely on ditches. • Fine sediment contributions from roads, cutbanks, and ditches are minimized by utilizing seasonal closures and implementing a variety of surface drainage techniques including berm removal, road surface shaping (outsloping, insloping, or crowning), road surface decompaction, and installing rolling dips, ditch relief culverts, waterbars, and/or cross-road drains to disperse road surface runoff and reduce or eliminate sediment delivery to the stream.

2.1.3 Installing ditch relief culverts

A ditch relief culvert is a drainage structure (usually an 18 in. pipe) installed across a road prism to move water and sediment from the inboard ditch so that it can be dispersed on native hillslope downslope from the road. Ditch relief culverts are used to drain ditch flow on roads that are too steep for rolling dips or outsloping, as well as at sites with excessive flow from springs or seepage from cutbanks.

2.1.4 Excavating unstable fillslope

The fillslope, the sloping part of the road between its outboard edge and the natural ground surface below, may fail or show signs of potential failure. As a preventative measure, unstable fillslope sediment is excavated and relocated (endhauled or pushed) to a permanent, stable spoil disposal site.

2.1.5 Upgrading stream crossings

Techniques used to remediate road related erosion at a stream crossing are dependent on the size of the stream channel, and specific physical characteristics at the crossing site. Class I and large stream crossings may require a bridge, or, if their banks are small or low gradient, a ford crossing may be suitable, particularly if seasonal use is anticipated. A common approach to upgrading moderate-sized crossings of Class II and III streams is to construct a culverted fill crossing capable of withstanding the 100-year flood flow. Techniques for upgrading small and moderate-size stream crossings include:

Installing or replacing culverts. A culvert capable of withstanding the 100-year peak storm flow is installed or replaced in the fill crossing. Culverts on non fish-bearing streams are placed at the base of fill, in line and on grade with the natural stream channel upstream and downstream of the crossing site. Backfill material, free of woody debris, is compacted in 0.5-1.0 ft thick lifts until 1/3 of the diameter of the culvert has been covered. At sites where fillslopes are steeper than 2:1, or where eddying currents might erode fill on either side of the inlet, rock armor is applied as needed.

Installing an armored fill. Armored fills are installed on smaller stream crossings with relatively small fill volume, but where debris torrents are common, channel gradients are steep, or inspection and maintenance of a culverted crossing is impossible or unlikely to occur. The roadbed is heavily rocked and a keyway at the base of the outboard fillslope is excavated and backfilled with interlocking rock armor of sufficient size to resist transport by stream flow. Armored fill crossings are constructed with a dip in the axis of the crossing to prevent diversion of the stream flow, and focus the flow over the part of the fill that is most densely armored.

Installing secondary structures. A variety of secondary structures may be used to increase the function of small stream crossings by allowing uninterrupted stream flow, decreasing plugging, and controlling erosion. Where a culvert has been improperly installed too high in the fill, a *downspout* may be added to its outlet to release the flow close to the ground surface, rather than letting it cascade from the height of the culvert. *Rock armor* may be used to buttress steep fillslopes, as well as to prevent erosion of inboard or outboard fillslopes by eddying currents. A *trash rack* placed in the channel above a culvert inlet will trap debris and reduce plugging. To prevent stream diversion should the culvert become plugged or its capacity exceeded, a *critical dip* (essentially a rolling dip constructed on the down-road hingeline of the fill) may be installed to ensure that stream flow will be directed across the road and back into the natural channel. Finally, an *overflow culvert* may be a necessary addition at a culverted crossing where, because of site conditions, plugging or capacity exceedence of the primary culvert is anticipated.

2.2 Road decommissioning

In essence, decommissioning is “reverse road construction,” although complete topographic obliteration of the roadbed is not usually required to achieve cost-effective erosion prevention. In most cases, serious erosion problems are confined to a few, isolated locations along a road (perhaps 10% to 20% of the full road network to be decommissioned) where stream crossings need to be excavated, unstable sidecast on the downslope side of a road or landing needs to be removed before failure, or the road crosses unstable terrain and the entire road prism must be removed. But typically, lengths of road beyond the extent of individual treatment sites usually require simpler, permanent improvements to surface drainage, such as surface decompaction, additional cross-road drains, and/or partial outsloping. As with road upgrading, the heavy equipment techniques used in road decommissioning have been extensively field tested and are widely accepted (Weaver and Sonnevil, 1984; Weaver et al., 1987, 2006; Harr and Nichols, 1993; Pacific Watershed Associates, 1994).

2.2.1 Road ripping or decompaction

Road ripping is a technique in which the surface of a road or landing is disaggregated or "decompacted" to a depth of at least 18 in. using mechanical rippers. This action reduces or eliminates surface runoff and usually enhances revegetation.

2.2.2 Installing cross-road drains

Cross-road drains (also called “deep waterbars”) are large ditches or trenches excavated across a road or landing surface to provide drainage and prevent runoff from traveling along, or pooling on, the former road bed. They are typically installed at 50, 75, 100 or 200 ft intervals, or as necessary at springs and seeps. In some locations (e.g., streamside zones), partial outsloping may be used instead of cross-road drain construction.

2.2.3 In-place stream crossing excavation (IPRX)

IPRX is a decommissioning treatment used for roads or landings that are built across stream channels. The fill (including the culvert or Humboldt log crossing) is completely excavated and the original streambed and side slopes are exhumed. Excavated spoil is stored at nearby, stable locations where it will not erode. In some cases, this may necessarily be as far as several hundred feet, or more, from the crossing. An IPRX typically involves more than simply removing a culvert, as the underlying and adjacent fill material must also be removed and stabilized. As a final measure, the sides of the channel may be cut back to slopes of 2:1, and mulched and seeded for erosion control.

2.2.4 Exported stream crossing excavation (ERX)

ERX is a decommissioning treatment in which stream crossing fill material is excavated and the spoil is hauled off-site for storage (the act of moving spoil material off-site is called “endhauling”). This procedure is necessary when large, stable storage areas are not available at or near the excavation site. It is most efficient to use dump trucks to endhaul the spoil material.

2.2.5 In-place outsloping (IPOS)

IPOS (also called "pulling the sidecast") calls for excavation of unstable or potentially unstable sidecast material along the outside edge of a road prism or landing, and placement of the spoil on the roadbed against the corresponding, adjacent cutbank or within several hundred feet of the site. As a further decommissioning measure, the spoil material is placed against the cutbank to block vehicular access to the road.

2.2.6 Export outsloping (EOS)

EOS is a technique comparable to IPOS, except that spoil material is moved off-site to a permanent, stable storage location. EOS is required when it is not possible to place spoil material against the cutbank, e.g., where the road prism is narrow or where there are springs along the cutbank. EOS usually requires dump trucks to endhaul the spoil material. This technique is used for both decommissioning and upgrading roads, but as the roadbed is partially or completely removed, EOS is more commonly used for decommissioning.

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Table B1. Field observations and treatment recommendations for road related features, Upper Bidwell Park Road, Butte County California.

Site #	Treatment immediacy	Problem	Estimated future sediment delivery (yd^3)	Hydrologically connected road length		Comment on Problem	Comment on treatment
				Left road length (ft)	Right road length (ft)		
1	M	Stream crossing	465	0	750	Paved road, Cement inlet. High in fill. Hiking trail crosses fill prism below road. Stream could divert left in future. First five hundred feet is through cut. Ditch shows no sign of wear. Road is paved with a deep through cut. Outer edge is 50' wide. No options for drainage within through cut. Most of the erosion at this site occurs last 10' where pipe outlet is set high in the fill. Hiking trail crosses stream below road prism.	1. Excavate crossing from top flag to bot flag. 2. Install 24" diameter cmp set at grade. 3. Armor inboard fillslope with 35 yd^3 of 1' - 2' diameter riprap. 4. Armor outboard fillslope with 55 yd^3 of 1' - 2' diameter riprap 5. Install critical dip on left hinge line. 6. Cut the ditch for 50' to right of DRC and armor ditch with 1 yd^3 of 0.5' diameter rock. 7. Install 18" diameter x 40' long DRC, 80' up right road at end of throughcut. 8. Install 18" diameter x 20' long downspout to DRC. 9. Endhaul spoils.
2	M	Stream crossing	129	300	0	Two 2' x 0.5' streams flow down to this 24" diameter concrete culvert. The pipe is very short/high in fill, creating a large gully down to Big Chico creek. Road to left is gravel, road to right is paved. An old gully exists to right of outlet gully.	1. Excavate crossing from top flag to bottom flag. 2. Install 24" diameter cmp set at grade. 3. Armor inboard fillslope with 15 yd3 of 1' - 2' diameter riprap. 4. Armor outboard fillslope with 20 yd3 of 1' - 2' diameter riprap 5. Install critical dip on right hinge line. 6. Stockpile spoils local.
3	L	Stream crossing	63	15	0	Culvert set high in fill, old concrete culvert buried/plugged adjacent. Problem here is culvert is short, high in fill. Small gully from culvert outlet to Class I, Big Chico Creek.	1. Excavate crossing from top flag to bottom flag. 2. Replace culvert with 24" diameter culvert set to grade. 3. Armor outboard fillslope with 10 yd^3 of 1' - 2' diameter rip rap. 4. Armor inboard fillslope with 5 yd^3 of 1' -2' diameter riprap. 5. Install critical dip on right hinge line. 6. Outslope road for 115' to left. 7. Stockpile spoils locally.
4	ML	Stream crossing	36	145	0	A very small near origin Class III stream originates upslope in a grassland prairie. Bedrock is exposed in the channel directly above the inlet.	1. Construct a broad dip through road prism. 2. Excavate a keyway 7'W x2'D x 20'L=10 yd^3. 3. Armor keyway with 10yd3 of 0.5' - 1.5' diameter riprap 4. Install 20 yd^3 road rock to driving surface. 5. Install 1 rolling dip up left road ~75' at spring near power pole. 6. Store spoils locally left and right.
5	L	Ditch relief culvert	20	180	0	Plugged DRC set ~50' to right of road low point, where water ponds in rain event. DRC no longer functioning. Small swale behind road leads to low point. Ponding can be fixed by outsloping road.	1. Outslope road for 180' and remove ditch. 2. Clean inlet if DRC.
6	M	Stream crossing	0	0	0	A rowdy Class III stream flows down to an undersized 18" diameter concrete culvert. The culvert is in a high spot with puddles in the road left and right. Diversion potential to left and right.	1. Excavate top to inlet to create a 6' wide channel bottom and 2:1 stream sideslopes. 2. Create a broad dip through road prism. 3. Excavate keyway 10"W x 2'D x 25'L=20 yd^3. 4. Armor keyway with 20 yd^3 of 1' - 2' diameter riprap. 5 Install 20 yd^3 road rock to driving surface through crossing. 6. Stockpile spoils locally.

Table B1. Field observations and treatment recommendations for road related features, Upper Bidwell Park Road, Butte County California.

Site #	Treatment immediacy	Problem	Estimated future sediment delivery (yd^3)	Hydrologically connected road length		Comment on Problem	Comment on treatment
				Left road length (ft)	Right road length (ft)		
7	L	Stream crossing	86	225	0	Small near origin stream. Undersized concrete culvert set high in fill at outlet. Channel deeply incised at culvert outlet. Headcut active at OBF. Road is flat and captured by berm. Fine sediment drains past crossing and to puddle on right road approach.	1. Excavate crossing from top flag to bottom flag. 2. Install 30" diameter x 40' long cmp set to grade. 3. Install critical dip on right hinge line. 4. Outslope road 225' left. 5. Remove berm for 200' left. 6. Armor 100% of outboard fillslope with 1' - 2' diameter riprap. 7. Armor 100% of inboard fillslope with 1' - 2' diameter riprap. 8. Stockpile spoils locally.
8	L	Stream crossing	59	0	120	A small Class III stream with a 30" diameter plastic culvert, set slightly askew to the right. This is a low power stream with low erosion potential.	1. Install a critical dip on the left hinge line.
9	M	Stream crossing	134	300	115	Road is aggressively insloped. Two concrete culverts are undersized and plugged. Inboard ditch leads to crossing (rilling and gully before inlet). Stream has a moderate power moving cobble sized rock and gravel, big scour hole at the outlet.	1. Excavate crossing from top flag to bottom flag. 2. Install a 36" diameter x 50' long cmp, and re-align left road from left hinge line of crossing to drainage break left (300 ft), move out 25' upon rebuild. 3. Armor outboard fillslope with 30 yd^3 of 1' - 2' diameter riprap. 4. Armor inboard fillslope with 15 yd^3 of 1' - 2' diameter riprap. 5. Outslope road and remove ditch for 300' to left. 6. Outslope and remove ditch for 115' to right. 7. Remove 250' of berm. 8. Install 1 rolling dip to left road.
10	L	Stream crossing	76	750	90	An 18" diameter plastic culvert drains a broad flat springy prairie area. There is no defined channel above the road, but overland flow is clearly evident and a 1' headcut has developed ~15' above the inlet. A small pool exists at the outlet and flow veers hard to right below bottom flag.	1. Create a broad dip through road prism. 2. Excavate keyway 7'W x 2'D x 20'L= 10 yd^3. 3. Install 10 yd^3 of 0.5' - 1.5' diameter riprap to keyway. 4. Stockpile spoils locally. 5. Outslope right road for ~100' by removing 7' x 2' berm and placing on inboard edge of road. 6. Rebuild road at 15' wide.
11	ML	Stream crossing	80	0	270	Small near origin stream with almost no erosion. Right road berm begins at road crest. A large rock plugs outlet of culvert.	1. Excavate crossing from top flag to bottom flag. 2. Replace culvert with a 24" diameter x 50' long cmp, set to grade. 3. Install a critical dip on left hinge line. 4. Armor lower 50% of outboard fillslope with 20 yd^3 of 1-2' rip rap. 5. Outslope and remove berm right for 270'. 6. Install 2 rolling dips to right road approach.
12	ML	Stream crossing	38	0	320	A small Class III stream flows down to an 18" diameter concrete pipe. Both inlet and outlet are well protected by hand made concrete walls. Flow exits the culvert and enters a second smooth steel culvert ~15' downslope. An old trail must have crossed here but is now abandoned and difficult to find.	1. Excavate crossing from top flag to bottom flag. 2. Replace culvert with a 24" diameter x 40' long cmp, set to grade. 3. Install a critical dip on left hinge line. 4. Armor lower 50% of outboard fillslope with 5cyds of 0.5-1.5' rip rap 5. Outslope 300' of right road by removing berm on OBF and place along inboard road. 6. Install 2 rolling dips to right road approach. 7. Remove lower metal cmp and create a 3' wide channel bottom and 2:1 streamside sideslopes, ~30 yd^3. 8. Stockpile spoils locally.

Table B1. Field observations and treatment recommendations for road related features, Upper Bidwell Park Road, Butte County California.

Site #	Treatment immediacy	Problem	Estimated future sediment delivery (yd^3)	Hydrologically connected road length		Comment on Problem	Comment on treatment
				Left road length (ft)	Right road length (ft)		
13	L	Ditch relief culvert	19	225	85	Road is through cut and insloped. Water can't drain off road. Long distance if uncontrolled run off leading to DRC. Delivers to Big Chico Creek. Big scour hole at outlet with ~2 yd3 past erosion.	1. Outslope road and remove berm for 80' to right. 2. Install 1 rolling dip to right road. 3. Outslope road and remove berm 400' to left of DRC. 4. Re-route road alignment towards creek for 500' near site #14. 5. Install 3 rolling dips to left road approach.
14	ML	Stream crossing	137	870	0	A small Class III stream flows down an 18" diameter concrete cmp. The pipe is set at grade with low erosion potential, but this site also receives 870' of left road contribution in the form of major rilling which is where the majority of sediment contribution comes from.	1. Create a broad dip through crossing prism. 2. Excavate a keyway 10'W x 2'D x 15'L= 11 yd^3. 3. Install 10 yd^3 of 0.5' - 1.5' diameter rock armor to keyway. 4. Stockpile spoils locally. 5. Outslope ~500' of left road by removing 4' x 3' berm on outboard fill and place it along IBR. 6. Remove remaining berm for 350'. 7. Install 3 rolling dips up left road approach.
15	L	Stream crossing	133	675	0	Proper sized culvert with low volume. Erosion is on road, not related to culvert. Outlet has large tree with in channel. Right road to site #14 is 890', with gully and rill development along the inboard side.	1. Install a critical dip, off set 30' to right of crossing. 2. Outslope left road 675' and remove berm for 600'. 3. Install 3 rolling dips to left road approach.
16	M	Stream crossing	104	330	0	Two small streams flow down to an 18" diameter concrete culvert. The site also receives ~330' of left road via major rilling directly down to culvert inlet. Best to treat left road approach by moving road out ~25' and reconstructing with a 5% - 6% outslope. The old road alignment should be decommissioned by ripping the road prism and pulling back the berm.	1. Excavate crossing from top flag to bottom flag. 2. Install 24" diameter cmp set at grade. 3. Install a critical dip on right hinge line. 4. Stockpile spoils locally. 5. Move road out ~25' and re-align for 225' up left road and build with a 5% - 7% outslope (begin at upper edge of Parking Area J). 6. Rip old road prism to decommission.
17	L	Stream crossing	44	80	125	Inboard ditch delivers sediment to stream crossing inlet from left to right. Stream approaches culvert from multiple locations. Inboard berm is supposed to direct flow toward culvert. Culvert is undersized, small fill volume makes good condition for armored fill.	1. Excavate a broad dip through the road prism 60'W x 1'D x 20'L= 53 yd^3. 2. Excavate a keyway 7'W x 2'D x 15'L= 8 yd^3. 3. Armor keyway 7'W x 2'D x 15'L= 10 yd^3 of 0.5' - 1.5' diameter riprap. 4. Outslope left road 80' and remove berm and fill ditch. 5. Outslope right road 125' and remove berm and fill ditch. 6. Transition right approach into new road alignment, detailed in site #16 notes.
18	ML	Stream crossing	72	50	460	A very small near origin Class II stream flows out of a broad headwall prairie area down to a 12" diameter concrete culvert. The inlet is close to plugging, but is open. The outlet is protected with hand placed rock armor.	1. Excavate a broad dip through the road prism. 2. Excavate a keyway 10'W x 2'D x 15'L= 11 yd^3. 3. Armor keyway 10'W x 2'D x 15''L= 10 yd^3 of 0.5' - 1.5' diameter riprap. 4. Remove berm up right road 4' x 2' x 450'. 5. Install 1 rolling dip ~75' up right road approach.

Table B1. Field observations and treatment recommendations for road related features, Upper Bidwell Park Road, Butte County California.

Site #	Treatment immediacy	Problem	Estimated future sediment delivery (yd^3)	Hydrologically connected road length		Comment on Problem	Comment on treatment
				Left road length (ft)	Right road length (ft)		
19	ML	Stream crossing	148	765	105	Road runoff causes gully on OBF ~35' to right of crossing. Plastic culvert inlet with cement outlet. Culvert non-functional, flow beneath current culvert exits fillslope below outlet. Inboard ditch directs flow diverted from stream to left at site #20 to this crossing. Springy ponds in road and cannot drain ~90' to right of crossing. Outboard headcut and inboard ditch/gully give us ~5 yd3 of past erosion.	1. Excavate crossing from top flag to bottom flag. 2. Replace culvert with a 36" diameter x 50' culvert set to grade. 3. Install a rolling dip 90' to right of crossing to drain spring. 4. Armor outboard edge of rolling dip with 10 yd^3 of 0.5-1.5' diameter riprap. 5. Outslope 90' and remove berm for 105' to right, and fill the ditch. 6. Install 5 rolling dips to left road. 7. Outslope 900' and remove berm for 800' to left, and fill ditch. 8. Road will be re-aligned to the left, see site # 20 for details.
20	L	Spring	106	1010	250	A large spring originates above the road over a wide stretch of open prairie. Some flow goes right to site #19 and some flow left to this site. Water ponds along the inboard road for ~50' up right road. Flow enters two culverts. One is a concrete culvert and the other is steel at the inlet, but concrete at the outlet.	1. Clean inboard ditch for ~50' up right road to help drain spring flow down to culvert inlets. 2. Remove berm for 4' x 2' x 250' up right road. 3. Inslope left road for 500' from gate, up road. 4. Install 3 rolling dips beyond inslope section.
21	L	Stream crossing	70	421	110	Culvert here is set lower than stream grade. Stream channel has eroded back from inlet ~25' with headcut at terminus. Ditch to right is covered in duff and inactive. Ditch to left.	1 Inslope left road for 400', retain ditch. 2. Install 2 rolling dips to left road, connected to ditch. 3. Remove berm to left for 495'. 4. Outslope right road and remove berm 110', retain ditch.
22	ML	Stream crossing	103	280	0	A rowdy Class II stream flows down to an undersized 18" diameter concrete culvert. Both inlet and outlets are well armored with hand placed rock retaining walls.	1. Excavate from top flag to bottom flag. 2. Install a 36" diameter cmp set to grade. 3. Install a critical dip on right hinge line. 4. Install 20 yd^3 of 0.5' - 1.5' diameter rip rap to outboard fillslope. 5. Stockpile spoils locally. 6. Install 1 rolling dip up left road.
23	L	Stream crossing	70	496	100	Most of the erosion here is from the road, not crossing related. Culvert is over sized, but too long. Bent and plugged with in road fill. Ditches seem fine, vegetated. Berm along most of road length. Left road grade changes abruptly 200' left of crossing.	1. Excavate a broad dip through crossing 60'W x 2'D x 10'L=44 yd3. 2. Excavate keyway 7'W x 2'D x 20'L= 10yd^3. 3. Armor keyway 7'W x 2"D x 20'L= 10yd^3. 4. Outslope 420' of left road and remove berm and ditch. 5. Install 1 rolling dip with in first 200' of crossing, install 2 rolling dips in last 420'. 6. Stockpile spoils locally.
24	ML	Stream crossing	59	75	0	A small Class III stream flows down to a 24" diameter cmp. The culvert is set at a sharp angle across the road but is in line with flow. The armor at the OBF is failing because of the culvert being set short and high in the fill.	1. Excavate crossing from top flag to bottom flag. 2. Install a 24" diameter cmp. 3. Lower road 2' after rebuild. 4. Install a critical dip on right hinge line. 5. Salvage rock armor and place on outboard fillslope, when pipe replacement is complete. 6. Stockpile spoils locally.
25	M	Stream crossing	31	0	120	No real crossing related erosion. Fines from road main contribution erosion and sediment delivery. Undersized culvert with slight diversion potential. Near origin tiny stream.	1. Excavate crossing from top flag to bottom flag. 2. Install a 24" diameter x 60' cmp. 3. Install a critical dip on right hinge line. 5. Armor lower 50% outboard fillslope with 5 yd3 of 1' - 2' diameter riprap. 6. Stockpile spoils locally.

Table B1. Field observations and treatment recommendations for road related features, Upper Bidwell Park Road, Butte County California.

Site #	Treatment immediacy	Problem	Estimated future sediment delivery (yd^3)	Hydrologically connected road length		Comment on Problem	Comment on treatment
				Left road length (ft)	Right road length (ft)		
26	M	Stream crossing	65	215	0	A rowdy Class III stream flows down to an undersized 18" concrete culvert. The pipe is short in fill, but set at grade. A large berm has been created between the inlet and IBR. There is ~200' of eroding inboard edge of the road. The left road approach is a deep through cut with no effective way to drain.	1. Excavate crossing from top flag to bottom flag. 2. Install a 36" diameter x 50' long cmp. 3. Install a critical dip on right hinge line. 4. Stockpile spoils locally.
27	HM	Stream crossing	118	620	0	Plastic culvert properly sized but set high in fill and exposed at road surface. Most of the erosion for this site comes from left road. Fix is with outsloping and rolling dips. Inboard ditch to left is being actively headcut. Left road has active rilling and gullying. Right road is badly gullied. Low volume of fill in crossing points to potential armored fill candidate if diversion potential removed.	1. Excavate a broad dip through road prism 60'W x 1'D x 15'L= 33 yd^3, remove old culvert and rebuild with no diversion potential. 2 Excavate a keyway 7'W x 2'D x 20'L= 10 yd^3. 3. Armor the keyway 7'W x 2'D x 20'L= 10 yd^3. 4. Outslope left road and remove ditch and berm for 620'. 5. Install 3 rolling dips to left road. 6. Stockpile spoils locally.
28	M	Stream crossing	36	160	0	A very small near origin Class III stream flows down to a 24" diameter cmp. The inlet is 10% plugged, but the outlet is 50% plugged with sandy fines. Flow veers hard right below the road.	1. Create a broad dip through road prism 2 Excavate a keyway 10'W x 2'D x 20'L=10 yd^3. 3. Armor the keyway 10'W x 2'D x 20'L= 10 yd^3, with 0.5' - 1.5' diameter riprap. 4. Install 20 yd3 road rock to driving surface. 5. Outslope left road 180' by removing 4' x 2' berm and placing along inboard road. 6. Install 1 rolling dip to left road. 7. Stockpile spoils locally.
29	L	Stream crossing	93	695	0	Road drainage uncontrolled with erosion and sediment delivery. Sediment delivery mostly road surface. Old rusty cmp. Left road contribution relatively easy to treat with outslope/remove berm/rolling dips.	1. Excavate a broad dip through road prism 60'x1'x15'= 33yd^3. Remove cmp and rebuild with no diversion potential. 2. Excavate keyway 7Wx2'Dx 15'L= 8yd^3. 3. Armor keyway 7Wx2'Dx15'L=1 03yd^3. 4. Outslope left road, fill ditch and remove berm for 695'. 5. Install 3 rolling dips to left road. 6. Stockpile spoils locally.
30	ML	Stream crossing	53	275	0	A very small near origin Class III stream flows down to an undersized 12" diameter cmp. The pipe inlet is steel but the outlet is concrete. This site also receives ~235' of left road, which contributes most, if not all fine sediment at this location. There is no evidence of stream flow below the road.	1. Excavate a broad dip through road prism. 2. Excavate keyway 10'W x 2'D x 15'L= 10 yd^3. 3. Armor keyway 10'W x 2'D x 15'L= 10 yd^3 of 0.5'-1.5' diameter riprap 4. Outslope ~275' of left road by removing 6' x 4' berm on outboard fill and placing material along inboard edge of road. 5. Install 2 rolling dips up left road. 6. Stockpile spoils locally.
31	M	Stream crossing	100	676	0	DRC with no delivery, 100' left of crossing. Spring 60' to left should be drained with rolling dip connected to ditch. Should maintain berms in parking lots and along parking zones.	1. Excavate a broad dip through road prism 60'W x 1'D x 15'L. 2. Excavate keyway 7'W x 2'D x 15'L= 10 yd^3. 3. Armor keyway 7'W x 2'D x 15'L= 10 yd^3 of 0.5' - 1.5' diameter riprap. 4. Outslope road and remove berm, and remove ditch for 60' to left. 5. Install 1 rolling dip 60' to left of crossing and connect to ditch. 6. Outslope left road past parking lot for 900', remove berm and fill the ditch. 7. Install 5 rolling dips up left road, past the parking lot. 8. Stockpile spoils locally.

Table B1. Field observations and treatment recommendations for road related features, Upper Bidwell Park Road, Butte County California.

Site #	Treatment immediacy	Problem	Estimated future sediment delivery (yd^3)	Hydrologically connected road length		Comment on Problem	Comment on treatment
				Left road length (ft)	Right road length (ft)		
32	ML	Stream crossing	55	375	0	Small near origin Class III stream. Low stream power. Iron canyon cliff is ~35' from outlet. Ditch shows signs of erosion, drains to DRC with no sediment delivery.	1. Construct armored fill with broad dip. 2. Install 10 yd3 of 0.5' - 1.5 ' diameter riprap. 3. Install 3 rolling dips, connected to the ditch. 4. Outslope 400' of left road.
33	L	Stream crossing	48	450	0	Undersized concrete culvert, small near origin stream. Very little erosion at this site. Most of erosion from gully/rill system developed in left road. Road is insloped with berm/inboard ditch along most of the length.	1. Excavate a broad dip through crossing, remove old culvert, rebuild crossing with no diversion potential. 2. Excavate a keyway 7'W x 1'D x 20'L= 10 yd^3. 3. Armor keyway 7'W x 2'D x 20'L= 10 yd^3. 4. Outslope left road and remove ditch and berm for 400'. 5. Install 3 rolling dips up left road. 6. Stockpile spoils locally 7. Retain insloped road through parking lot.
34	M	Stream crossing	82	100	0	Undersized concrete culvert is set short and high in the fill. Inlet well armored. Outlet well armored, but vertical.	1. Excavate crossing from top flag to bottom flag. 2. Install a 24" diameter cmp. 3. Install a critical dip on right hinge line. 4. Install 15 yd^3 of 0.5' - 1.5' diameter riprap on outboard fillslope. 5. Remove berm for 100' up left road. 6. Stockpile spoils locally.
35	M	Stream crossing	26	350	0	Stream diversion, fill crossing, small near origin stream. Left inboard ditch is vegetated and broad 5 'x 1'. No large gully, but rilling developed on left road approach. Site #34 is only 100' down right road (culvert). This sites flow diverts to site #34. 70' up left road is a swale with associated spring, needs rocked rolling dip.	1. Excavate a broad dip through the crossing 60"W x 1"D x 10"L=22 yd^3, rebuild road prism with no diversion potential 2. Excavate keyway 7'W x 2'D x 20'L= 10 yd^3. 3. Armor keyway 7'W x 2'D x 20'L= 10 yd^3 with 0.5' - 1.5' diameter riprap. 4. Outslope the road to left and remove the berm for 350', retain ditch. 5. Install 2 rolling dips to left road and connect to the ditch, first rolling dip 70' to left of crossing at swale, rock the dip 270 ft^2. 6. Stockpile spoils locally.
36	M	Stream crossing	49	130	0	Small stream flows down to a plugged 12" diameter concrete culvert. Pipe is short and high in the fill, but is well armored below outlet.	1. Excavate crossing from top flag to bottom flag. 2. Install 24" diameter cmp. 3. Install a critical dip on left hinge line. 4. Armor entire outboard fillslope with 10 yd3 of 0.5' - 1.5' diameter riprap. 5. Install 1 rolling dip to left.
37	M	Stream crossing	21	240	0	Small near origin stream, fill crossing. Diverted to right, delivers to site #36. Fines and small gravel from stream and fines from road are main sediment contribution. Water ponds at low spot ~90' up left road approach adjacent to functional DRC with no sediment delivery. 240' up left road is drainage divide.	1. Excavate a broad dip through the crossing 60"W x 1"D x 10'L=22 yd^3, rebuild road prism with no diversion potential 2. Excavate keyway 7'W x 2'D x 15'L= 8 yd^3. 3. Armor keyway 7'W x 2'D x 15'L= 10 yd^3 with 0.5' - 1.5' diameter riprap. 4. Outslope the road to left and remove the berm and fill ditch, for 240'. 5. Install 2 rolling dips to left road and connect to the ditch, with first adjacent to functional DRC, 90' left of crossing. 6. Stockpile spoils locally.

Table B1. Field observations and treatment recommendations for road related features, Upper Bidwell Park Road, Butte County California.

Site #	Treatment immediacy	Problem	Estimated future sediment delivery (yd^3)	Hydrologically connected road length		Comment on Problem	Comment on treatment
				Left road length (ft)	Right road length (ft)		
38	H	Stream crossing	116	0	935	A rowdy Class III stream is diverted to left ~80' to a small concrete culvert at stream crossing #39. A 7' tall x 25' wide rock retaining wall was constructed along outboard fill, no pipe evident at this site.	1. Excavate crossing from top flag to bottom flag. 2. Install 24" diameter cmp. 3. Install a critical dip on left hinge line. 4. Armor entire outboard fillslope with 10 yd^3 of 0.5' - 1.5' diameter riprap. 5. Install 4 rolling dip to right and remove berm for 750'. 6. Stockpile spoils locally.
39	HM	Stream crossing	32	0	90	Undersized concrete culvert is buried at the inlet by aggraded sediment wedge. Cobbles piled near buried inlet no berm to prevent diversion, water will overtop. Sediment from right road ditch delivered as fine sediment grading to cobble, vegetated. Concrete culvert high and short in fill, exposed in road surface. Site #38 flow is diverted and delivers to this crossing via inboard ditch right. Stream actively headcutting at outlet with in outboard fill, 6' drop to bottom flag.	1. Excavate a broad dip through the crossing 60"W x 1'D x 1'L= 33 yd^3, remove old culvert, rebuild road prism with no diversion potential 2. Excavate keyway 7'W x 2'D x 15'L= 10 yd^3. 3. Armor keyway 7’W x 2'D x 15'L= 10 yd^3 with 0.5' - 1.5' diameter riprap. 4. Outslope the road to left and remove the berm and fill ditch, for 90'. 5. Install 1 rolling dip to right road and connect to the ditch. 6. Stockpile spoils locally.
40	M	Stream crossing	36	310	0	A rowdy Class III stream has completely buried thin inlet at this location. The outlet is well rocked. Long length of undrained road delivers fine sediment to the stream crossing.	1. Excavate crossing from top flag to bottom flag. 2. Install 24" diameter cmp. 3. Install a critical dip on right hinge line. 4. Install 1 rolling dip left, connect to ditch. 5. Remove 310 feet of berm. 6. Stockpile spoils locally.
41	M	Stream crossing	89	100	120	Moderate powered stream approaches undersized concrete culvert. No crossing erosion. Ditches on left and right deliver fine sediment to this crossing. Cobble retaining wall with 8' drop to stream channel on OBF. Culvert set to proper grade and functional. Cobble retaining wall inboard fill as well. Stream channel rocky cobble through fine sediment.	1. Excavate crossing from top flag to bottom flag. 2. Install 36" diameter cmp. 3. Remove berm for 120' right. 4. Install 1 rolling dip left, connect to ditch. 5. Remove berm for 100' to left. 6. Stockpile spoils locally.
42	ML	Stream crossing	222	0	1265	A small flowing Class II stream flows down to a 36" diameter plastic culvert. There is a long road approach well suited for rolling dip installation. A small concrete culvert directly next to the newer 36" diameter pipe and appears to still function.	1. Excavate crossing from top flag to bottom flag. 2. Install 36" diameter cmp. 3. Install critical dip on left hinge line. 4. Armor outboard fill slope with 10 yd^3 of 1' - 2' diameter riprap. 5. Install 5 rolling dip left, connect to ditch. 6. Stockpile spoils locally.
43	M	Stream crossing	49	0	720	Undersized concrete culvert plugged and buried at inlet. Sediment debris lobe aggraded and developed at inlet. Erosion at this site is primarily from right road, ditches well vegetated. Right ditch is springy and delivers to culverted pedestrian crossing. No erosion at outlet of culvert or fillslope. Class I stream, Big Chico creek is ~100' below crossing. Yahi Trail crosses stream near culvert outlet/bottom flag.	1. Excavate a broad dip through the crossing 60'W x 1'D x 15'L=33 yd^3, remove old culvert, rebuild road prism with no diversion potential. 2. Excavate keyway 7'W x 2'D x 15'L= 10 yd^3. 3. Armor keyway 7'W x 2'D x 15'L= 10 yd^3 with 0.5' - 1.5' diameter riprap. 4. Install 5 rolling dips to right road and connect to the ditch. 5. Remove berm to right for 960'. 6. Stockpile spoils locally.

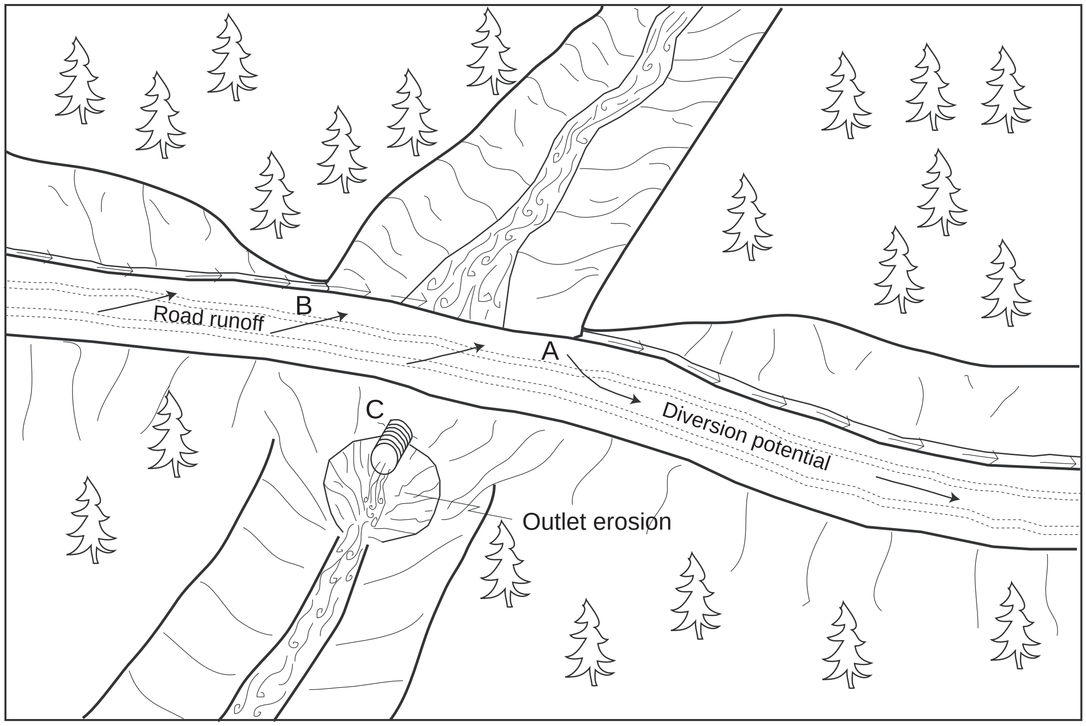
Typical Problems and Applied Treatments for a Non-fish Bearing Upgraded Stream Crossing

Problem condition (before)

A - Diversion potential

B - Road surface and ditch drain to stream

C - Undersized culvert high in fill with outlet erosion

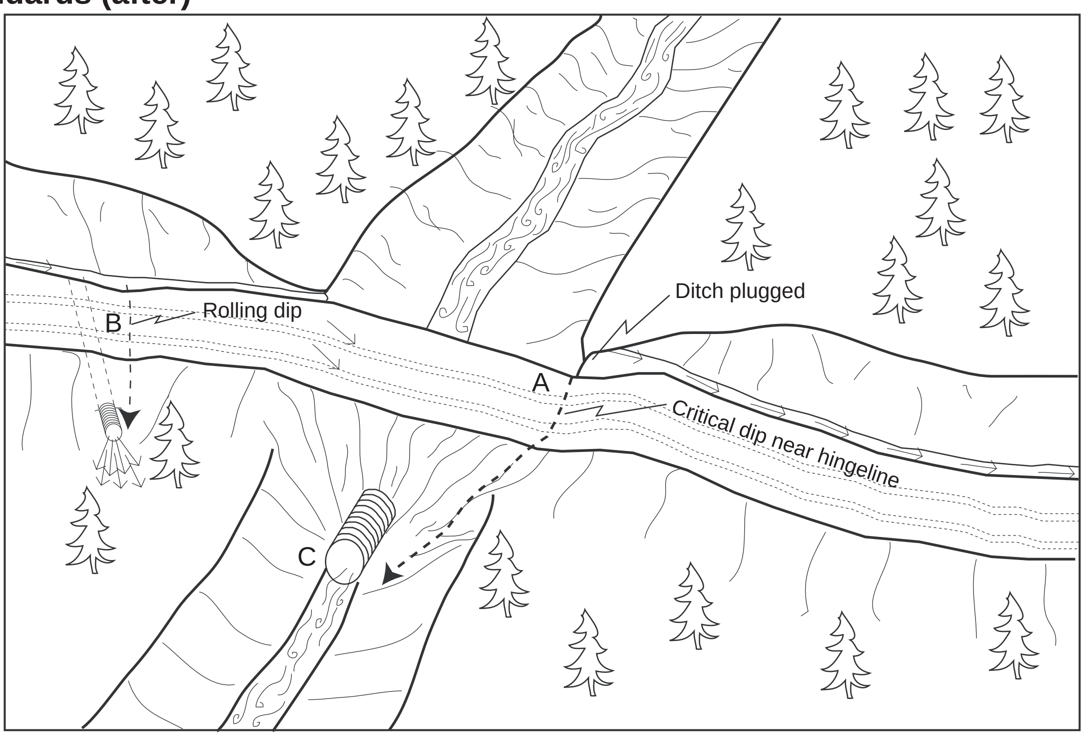


Treatment standards (after)

A - No diversion potential with critical dip installed near hingeline

B - Road surface and ditch disconnected from stream by rolling dip and ditch relief culvert

C - 100-year culvert set at base of fill



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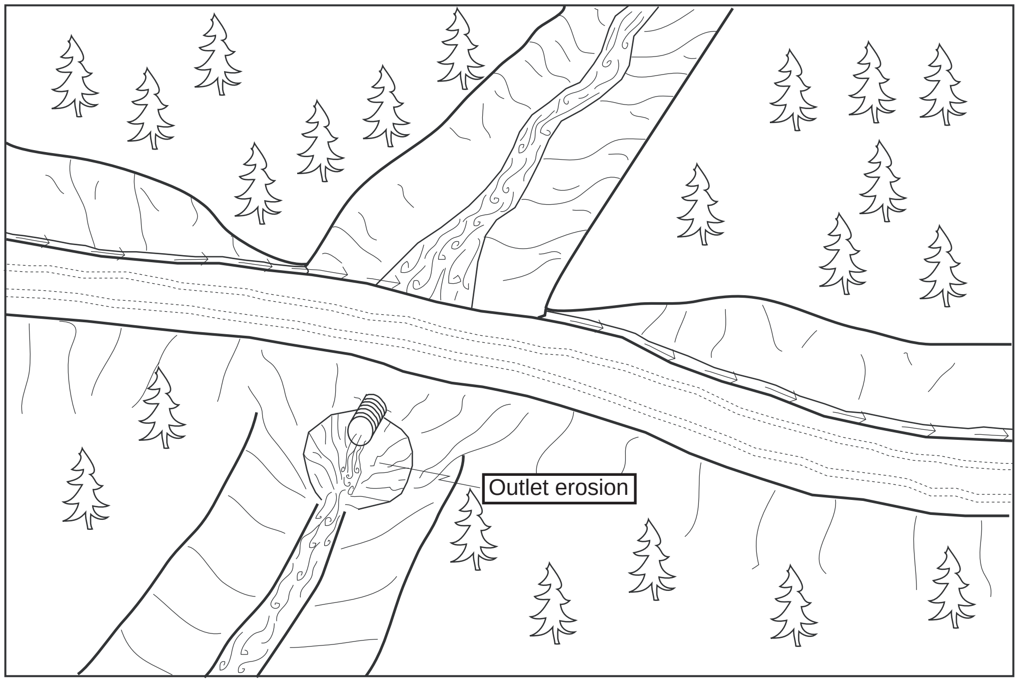
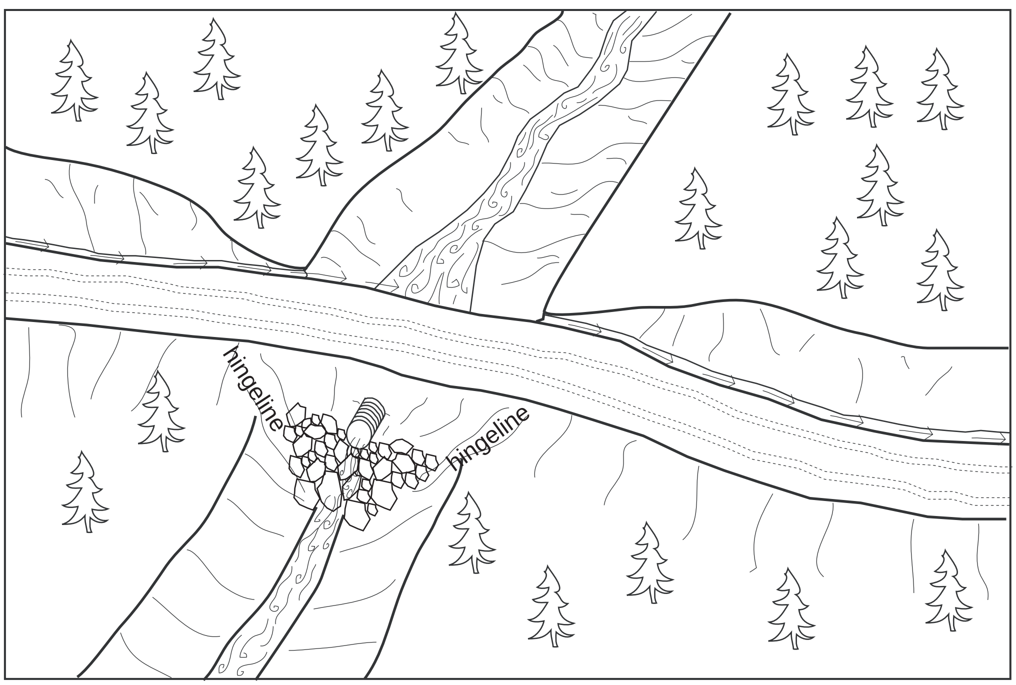
PWA Typical Drawing #1a

Armoring Fill Faces to Upgrade Stream Crossings



Problem: Culvert set high in outboard fill has resulted in scour of the outboard fill face and natural channel.
Conditions: The existing stream crossing has a culvert sufficient in diameter to manage design stream flows and has a functional life.



Action: The area of scour is backfilled with rip-rap to provide protection in the form of energy dissipation for the remaining fill face and channel.

Treatment Specifications:

1) Placement of rip-rap should be between the left and right hingelines and extend from a keyway excavated below the existing channel base level at the base of the fill slope up and under the existing culvert.
2) Rock size and volume is determined on a site by site basis based on estimated discharge and existing stream bed particle size range (See accompanying road log).

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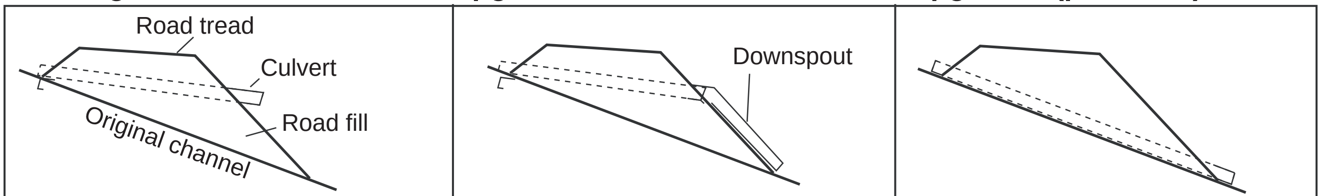
Typical Design of a Non-fish Bearing Culverted Stream Crossing

Existing | **Upgraded** | **Upgraded (preferred)**

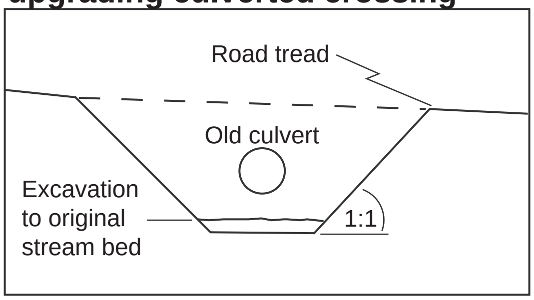


Existing
1. Culvert not placed at channel grade.
2. culvert does not extend past base of fill.

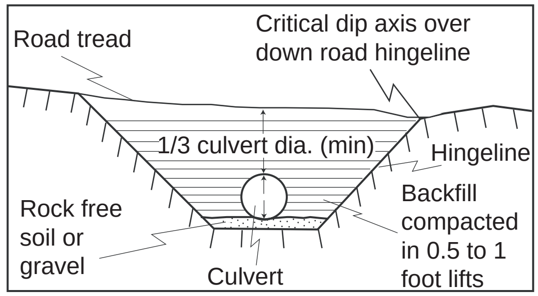
Upgraded
1. Culvert not placed at channel grade.
2. Downspout added to extend outlet past road fill.

Upgraded (preferred)
1. Culvert placed at channel grade.
2. Culvert inlet and outlet rest on, or partially in, the originial streambed.

Excavation in preparation for upgrading culverted crossing



Upgraded stream crossing culvert installation



Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calulations using a procedure such as the Rational Formula.

Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed, or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end then the other end of the culvert shall be covered and secured.;The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - Backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Erosion control measures for culvert replacement

Both mechanical and vegetative measures will be employed to minimize accelerated erosion from stream crossing and ditch relief culvert upgrading. Erosion control measures implemented will be evaluated on a site by site basis. Erosion control measures include but are not limited to:

1. Minimizing soil exposure by limiting excavation areas and heavy equipment distrubance.
2. Installing filter windrows of slash at the base of the road fill to minimize the movement of eroded soil to downslope areas and stream channels.
3. Retaining rooted trees and shrubs at the base of the fill as "anchor" for the fill and filter windrows.
4. Bare slopes created by construction operations will be protected until vegetation can stabilize the surface. Surface erosion on exposed cuts and fills will be minimized by mulching, seeding, planting, compacting, armoring, and/or benching prior to the first rains.
5. Excess or unusable soil will be stored in long term spoil disposal locations that are not limited by factors such as excessive moisture, steep slopes greater than 10%, archeology potential, or proximity to a watercourse.
6. On running streams, water will be pumped or diverted past the crossing and into the downstream channel during the construction process.
7. Straw bales and/or silt fencing will be employed where necessary to control runoff within the construction zone.

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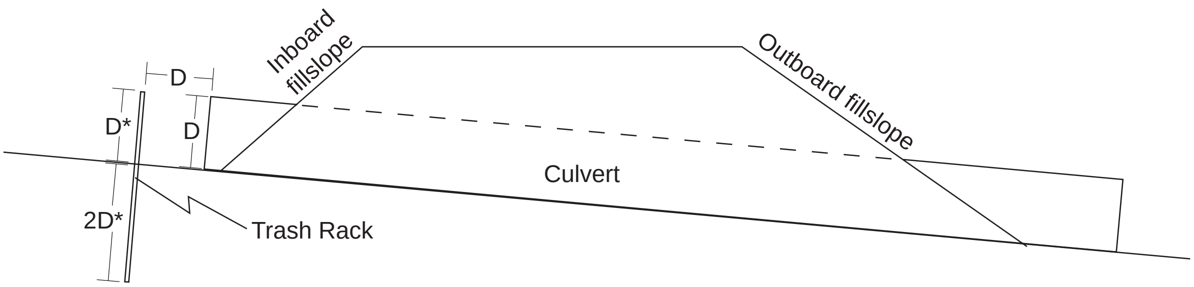
Typical Design of a Single-post Culvert Inlet Trash Rack

Cross section view



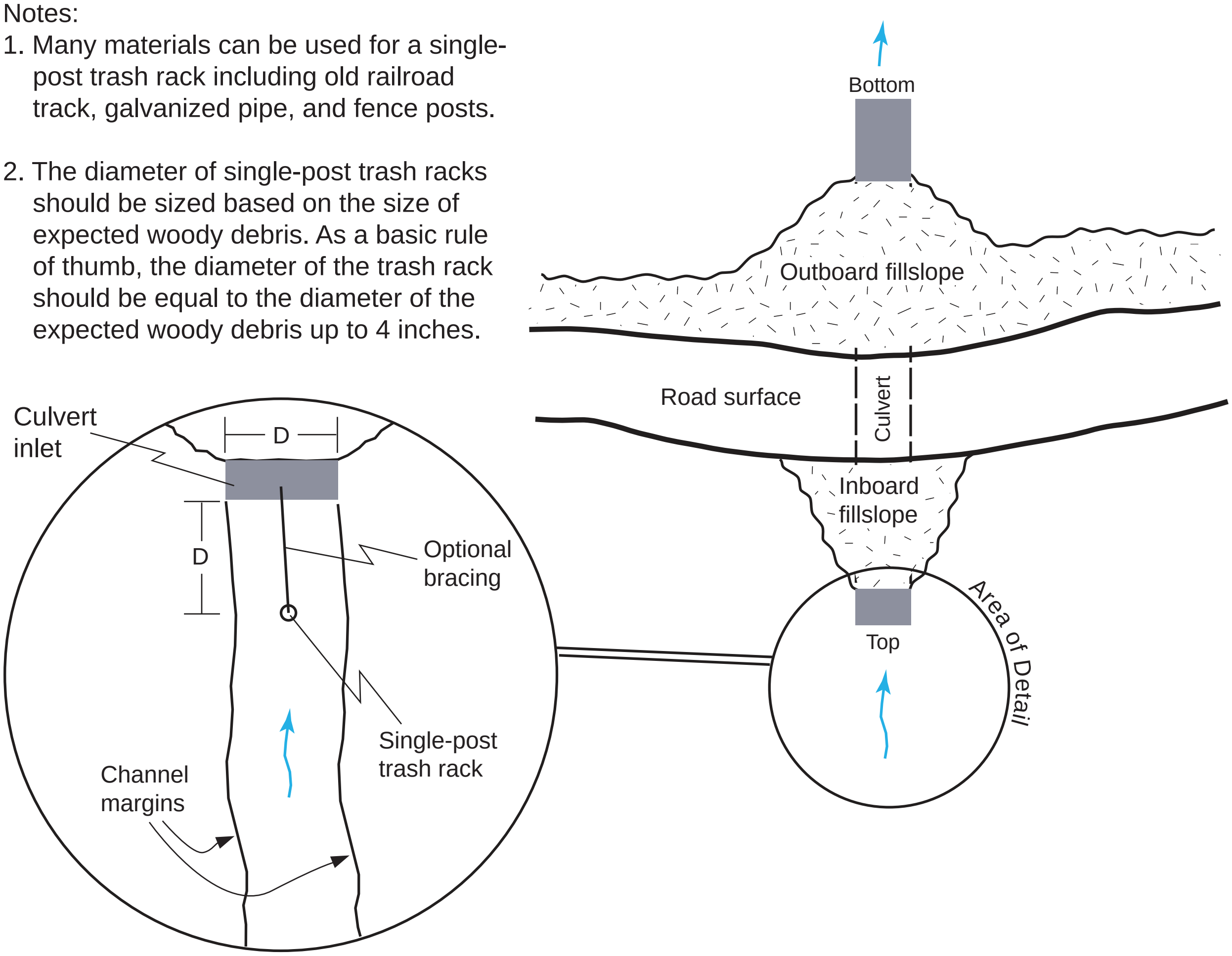
D - Culvert diameter
D* - If the culvert is designed for the 100-year peak storm flow, the trash rack height above the streambed should equal D.
If the culvert is undersized, then the trash rack needs to be extended vertically above the streambed to match or exceed the expected headwall height.

Plan view

Notes:

1. Many materials can be used for a single-post trash rack including old railroad track, galvanized pipe, and fence posts.

2. The diameter of single-post trash racks should be sized based on the size of expected woody debris. As a basic rule of thumb, the diameter of the trash rack should be equal to the diameter of the expected woody debris up to 4 inches.



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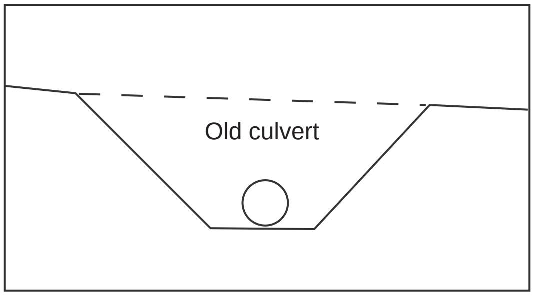
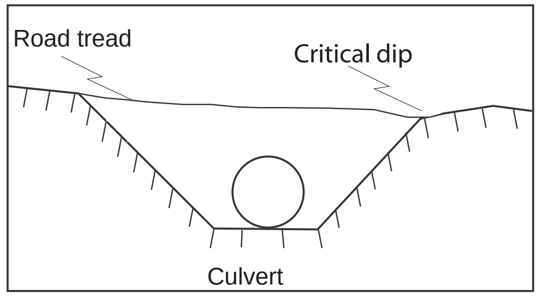
Typical Design of Upgraded Stream Crossings





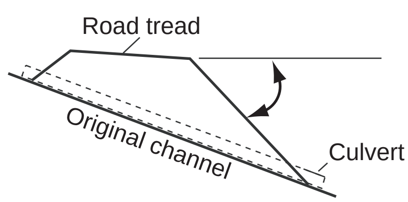
Stream crossing culvert Installation

1. Culverts shall be aligned with natural stream channels to ensure proper function, and prevent bank erosion and plugging by debris.
2. Culverts shall be placed at the base of the fill and the grade of the original streambed or downspouted past the base of the fill.
3. Culverts shall be set slightly below the original stream grade so that the water drops several inches as it enters the pipe.
5. To allow for sagging after burial, a camber shall be between 1.5 to 3 incher per 10 feet culvert pipe length.
6. Backfill material shall be free of rocks, limbs or other debris that could dent or puncture the pipe or allow water to seep around pipe.
7. First one end and then the other end of the culvert shall be covered and secured. The center is covered last.
8. Backfill material shall be tamped and compacted throughout the entire process:
   - Base and side wall material will be compacted before the pipe is placed in its bed.
   - backfill compacting will be done in 0.5 - 1 foot lifts until 1/3 of the diameter of the culvert has been covered. A gas powered tamper can be used for this work.
9. Inlets and outlets shall be armored with rock or mulched and seeded with grass as needed.
10. Trash protectors shall be installed just upstream from the culvert where there is a hazard of floating debris plugging the culvert.
11. Layers of fill will be pushed over the crossing until the final designed road grade is achieved, at a minimum of 1/3 to 1/2 the culvert diameter.

Note:
Road upgrading tasks typically include upgrading stream crossings by installing larger culverts and inlet protection (trash barriers) to prevent plugging. Culvert sizing for the 100-year peak storm flow should be determined by both field observation and calculations using a procedure such as the Rational Formula.

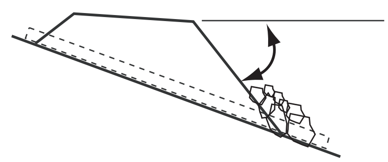
Armoring fill faces

Fill angles ≤ 2:1



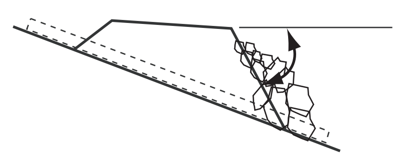
No rock armor needed

Fill angles (between 2:1 & 1.5:1)



Armor 1/4 up fill face

Fill angles (between 2:1 & 1.5:1)



Armor 3/4 way up fill face

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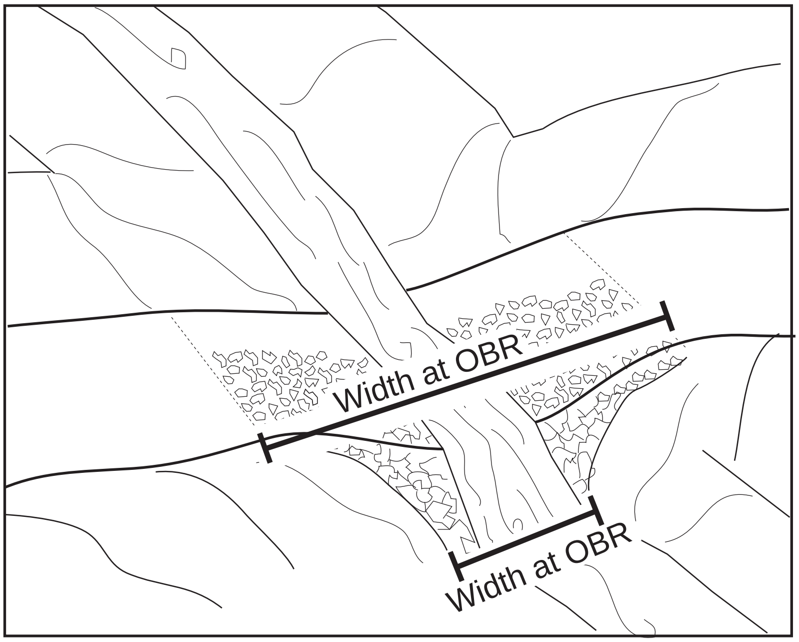
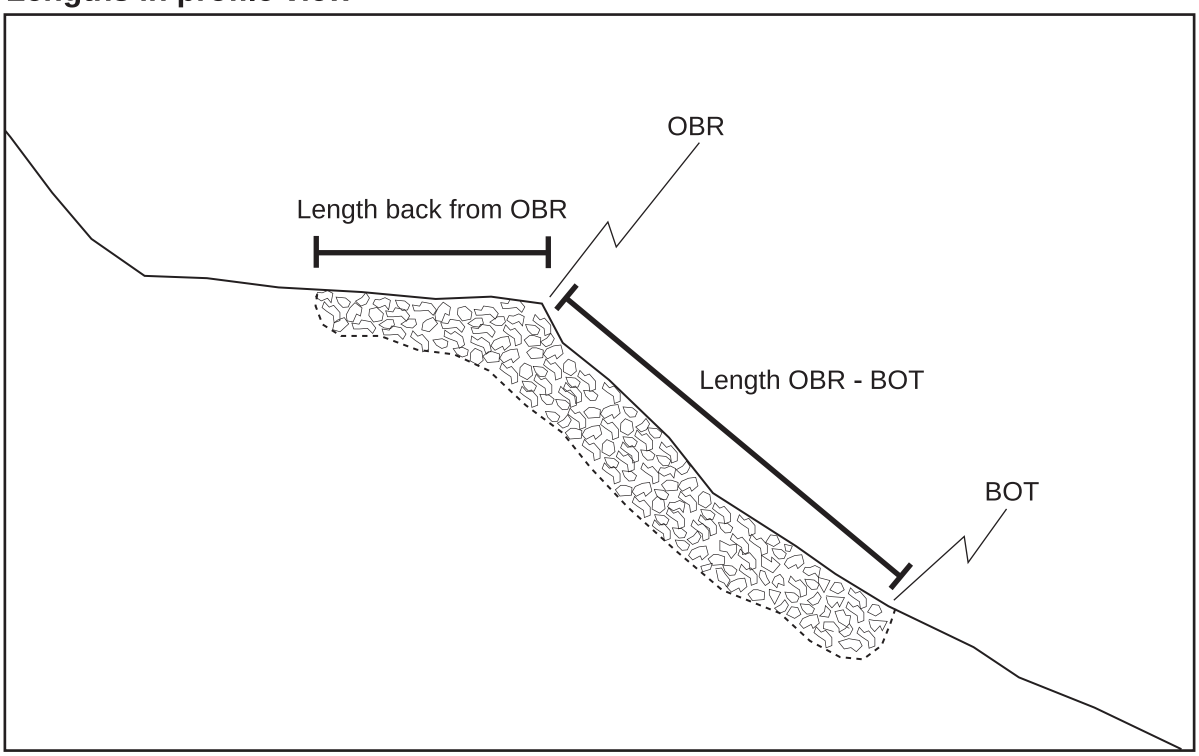
Typical Dimensions Refered to for Armored Fill Crossings

Widths in oblique view



OBR - Outboard edge of road

Lengths in profile view



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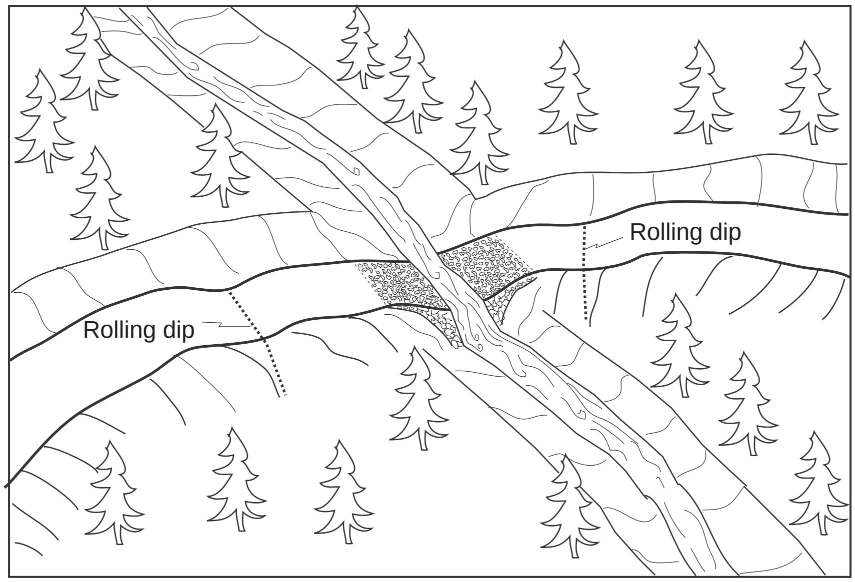
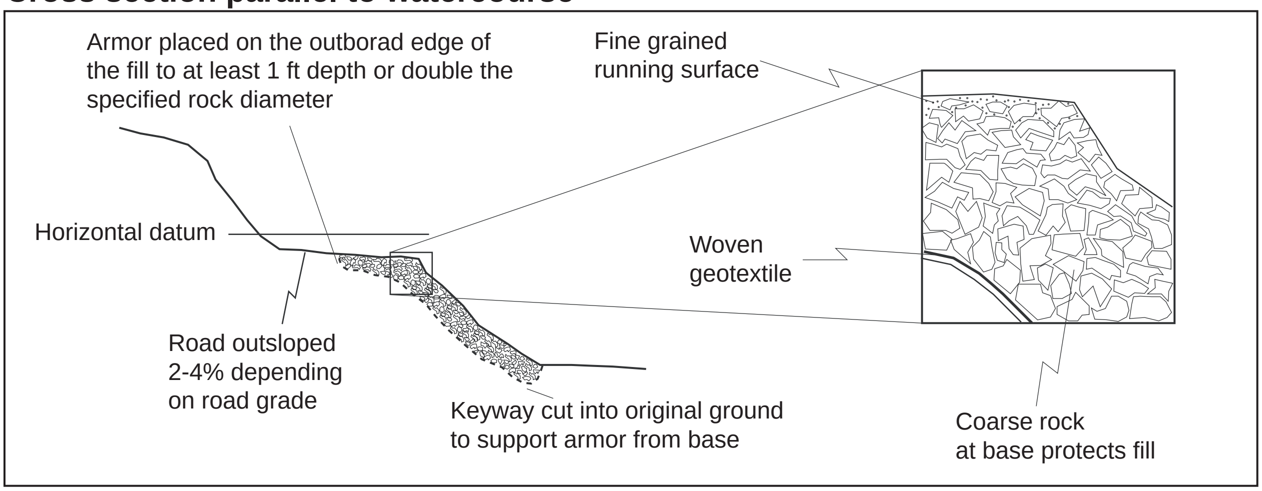
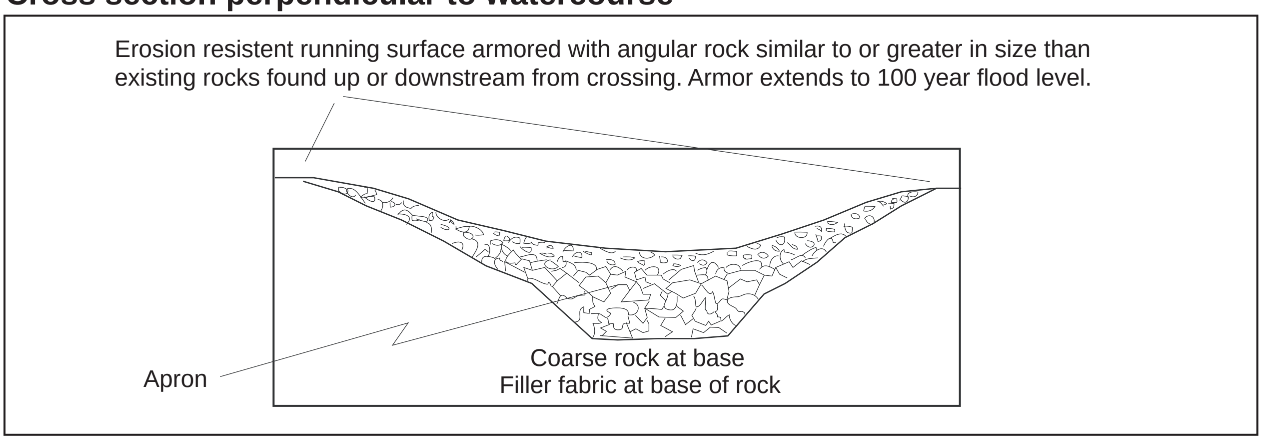
Typical Armored Fill Crossing Installation



Cross section parallel to watercourse



Cross section perpendicular to watercourse



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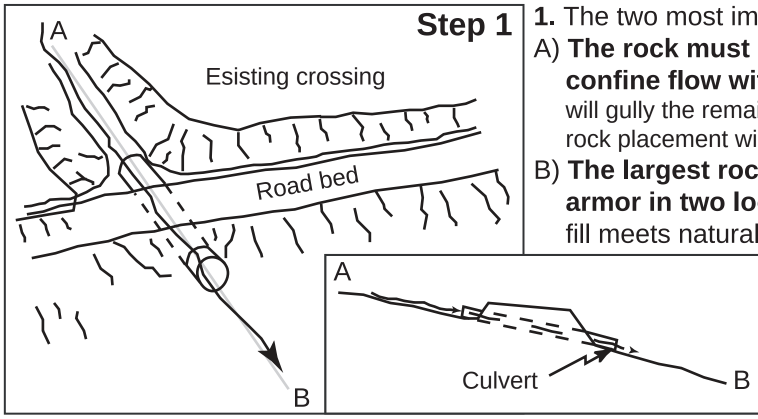
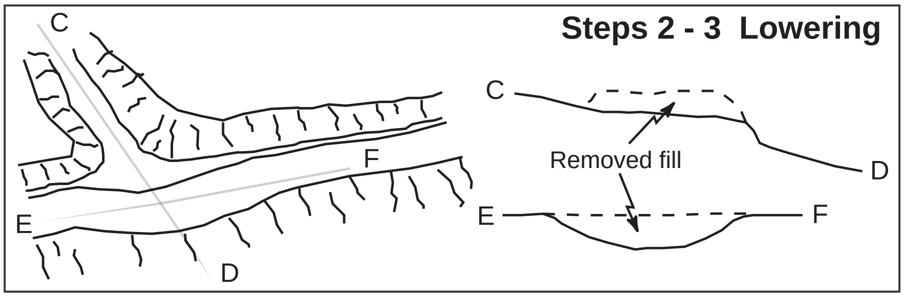
Ten Steps for Constructing a Typical Armored Fill Stream Crossing



1. The two most important points are:

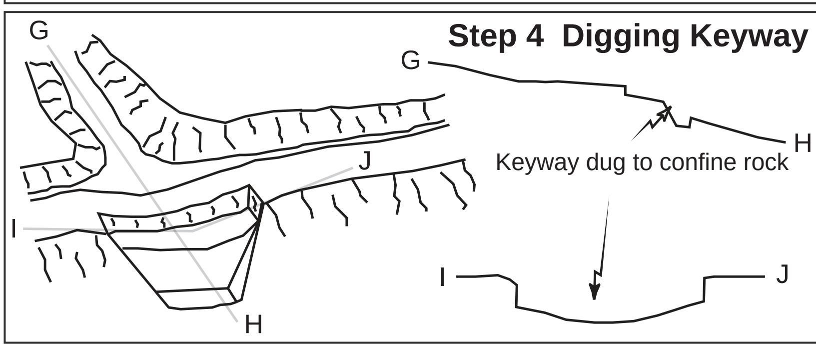
A) **The rock must be placed in a "U" shape across the channel to confine flow within the armored area.** (Flow around the rock armor will gully the remaining fill. Proper shape of surrounding road fill and good rock placement will reduce the likelihood of crossing failure).

B) **The largest rocks must be used to buttress the rest of the armor in two locations:** (i) The base of the armored fill where the fill meets natural channel. (This will butress the armor placed on the outboard fill face and reduce the likelihood of it washing downslope). (ii) The break in slope from the road tread to the outer fill face. (This will butress the fill placed on the outer road tread and will determine the "base level" of the creek as it crosses the road surface).



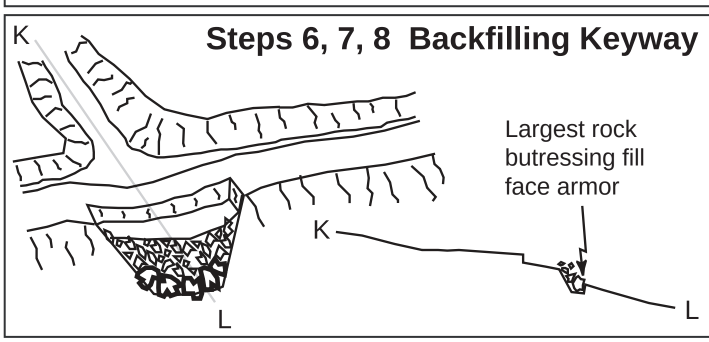
2. Remove any existing drainage structures including culverts and Humboldt logs.

3. Construct a dip centered at the crossing that is large enough to accomodate the 100-year peak storm flow and prevent diversion (C-D, E-F).



4. Dig a keyway (to place rock in) that extends from the outer 1/3 of the road tread down the outboard road fill to the point where outbaord fill meets natural channel (up to 3 feet into the channel bed depending on site specifics) (G-H, I-J).

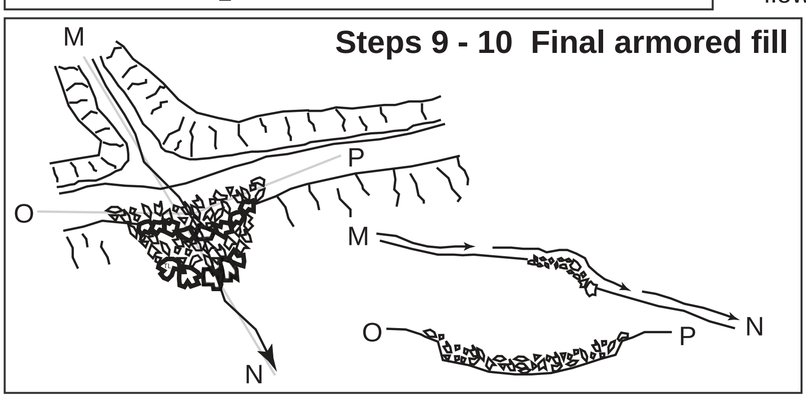
5. Install geofabric (optional) within keyway to support rock in wet areas and to prevent winnowing of the crossing at low flows.



6. Put aside the largest rock armoring to create 2 buttresses in the next step.

7. Create a buttress using the largest rock (as described in the site treatments specifications) at the base of fill. (This should have a "U" shape to it and will define the outlet of the armored fill.)

8. Backfill the fill face with remaining rock armor making sure the final armored area has "U" shape that will accomodate the largest expected flow (K-L).



9. Install a second buttress at the break in slope between the outboard road and the outboard fill face. (This should define the base level of the stream and determine how deep the stream will backfill after construction). (M-N)

10. Back fill the rest of the keyway with the unsorted rock armor making sure the final armored area has a "U" shape that will accommodate the largest expected flow (O-P).

Typical Drawing #7

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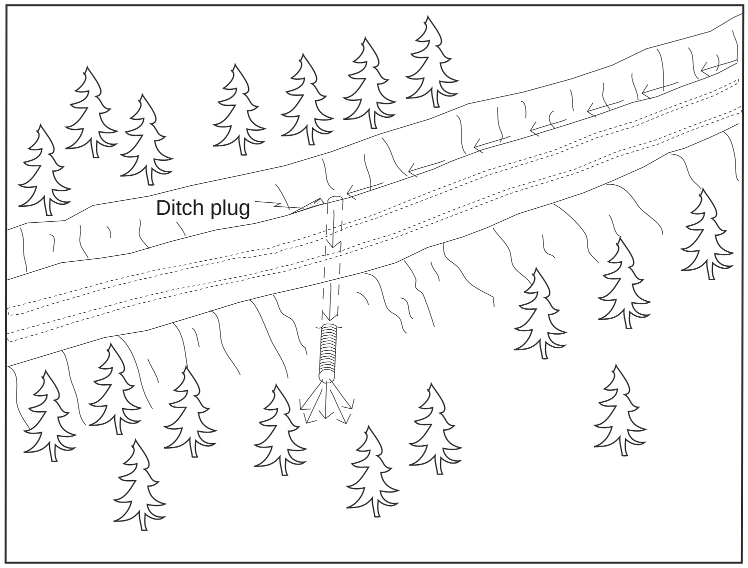
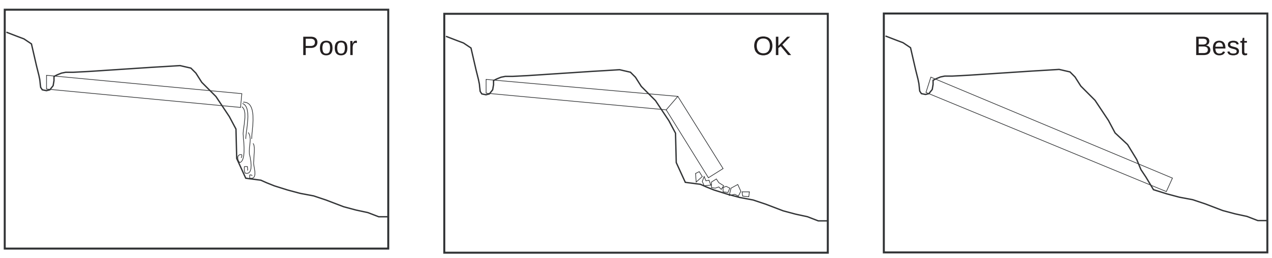
Typical Ditch Relief Culvert Installation





Ditch relief culvert installation

1) The same basic steps followed for stream crossing installation shall be employed.
2) Culverts shall be installed at a 30 degree angle to the ditch to lessen the chance of inlet erosion and plugging.
3) Culverts shall be seated on the natural slope or at a minimum depth of 5 feet at the outside edge of the road, whichever is less.
4) At a minimum, culverts shall be installed at a slope of 2 to 4 percent steeper than the approaching ditch grade, or at least 5 inches every 10 feet.
5) Backfill shall be compacted from the bed to a depth of 1 foot or 1/3 of the culvert diameter, which ever is greater, over the top of the culvert.
6) Culvert outlets shall extend beyond the base of the road fill (or a flume downspout will be used). Culverts will be seated on the natural slope or at a depth of 5 feet at the outside edge of the road, whichever is less.

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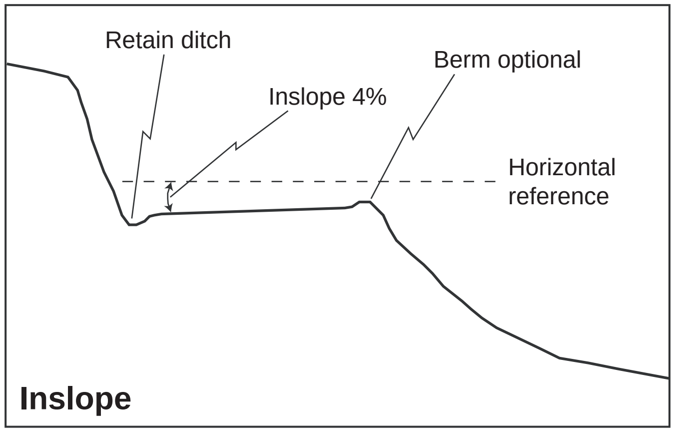
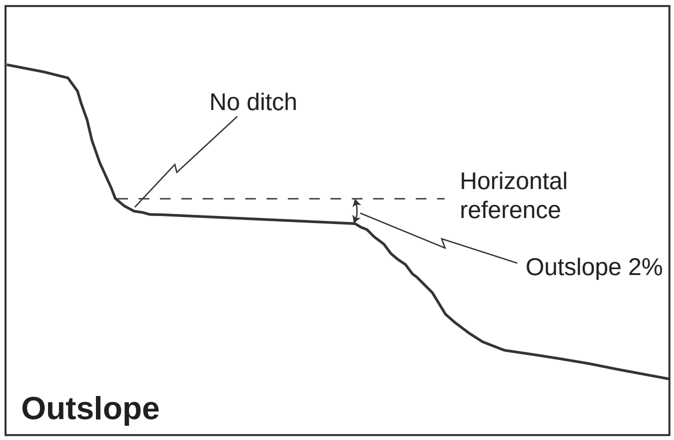
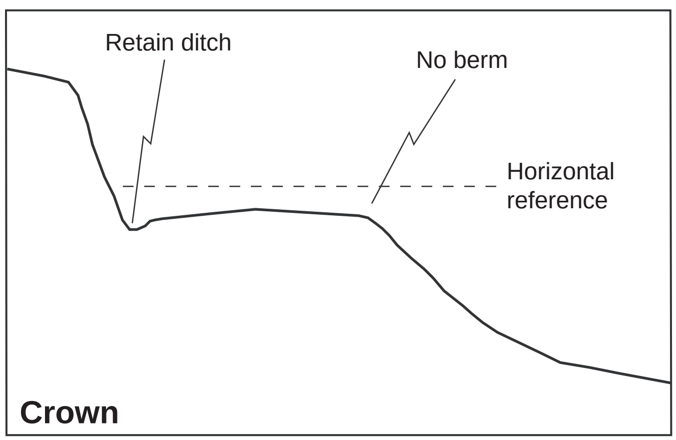
Typical Designs for Using Road Shape to Control Road Runoff







Outsloping Pitch for Roads Up to 8% Grade		
Road grade	**Unsurfaced roads**	**Surfaced roads**
4% or less	3/8" per foot	1/2" per foot
5%	1/2" per foot	5/8" per foot
6%	5/8" per foot	3/4" per foot
7%	3/4" per foot	7/8" per foot
8% or more	1" per foot	1 1/4" per foot

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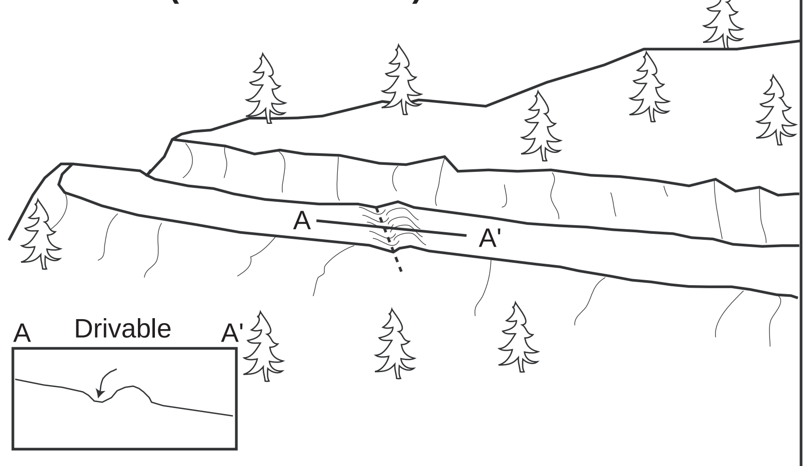
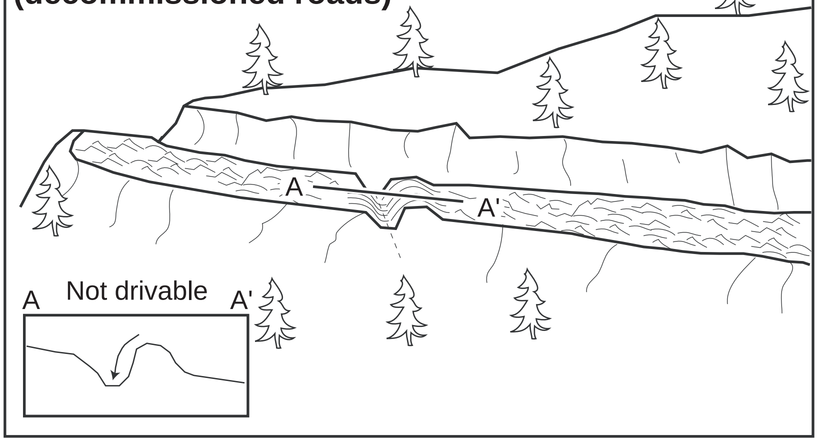
Typical Methods for Dispersing Road Surface Runoff with Waterbars, Cross-road Drains, and Rolling Dips

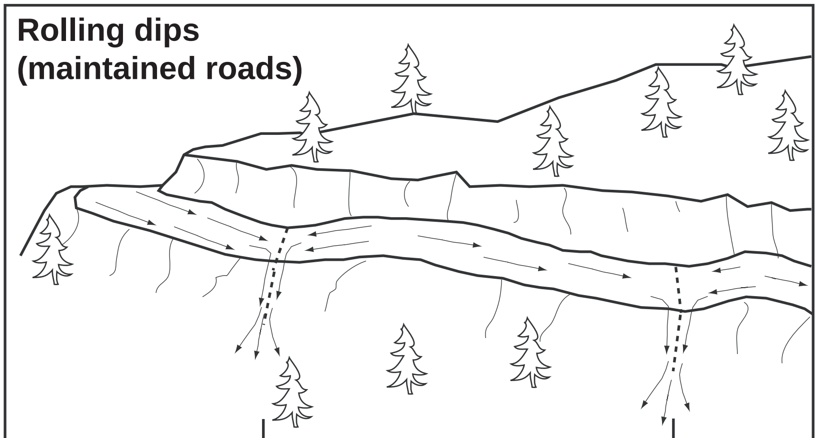
Waterbars (seasonal roads)



Cross-road drain and decompaction (decommissioned roads)



Rolling dips (maintained roads)



Rolling dip spacing dependent on road grade, soil erodibility, and proximity to stream

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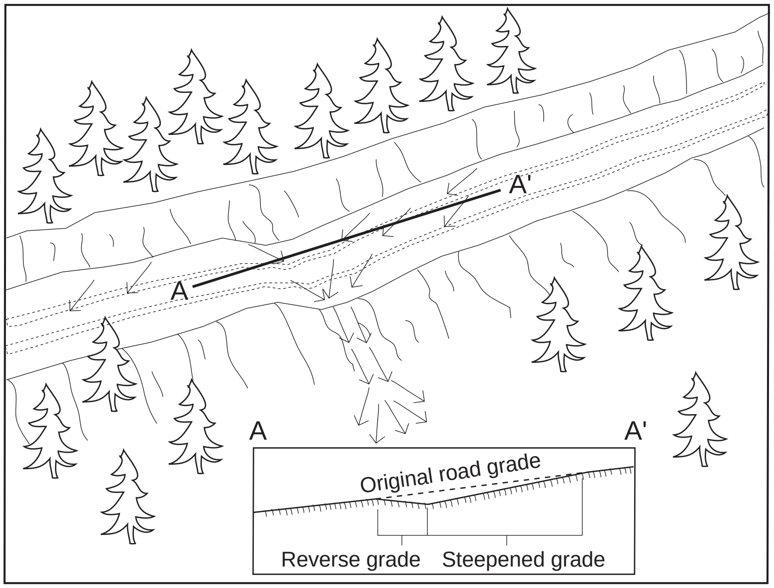
Typical Road Surface Drainage by Rolling Dips



Rolling dip installation:

1. Rolling dips will be installed in the roadbed as needed to drain the road surface.
2. Rolling dips will be sloped either into the ditch or to the outside of the road edge as required to properly drain the road.
3. Rolling dips are usually built at 30 to 45 degree angles to the road alignment with cross road grade of at least 1% greater than the grade of the road.
4. Excavation for the dips will be done with a medium-size bulldozer or similar equipment.
5. Excavation of the dips will begin 50 to 100 feet up road from where the axis of the dip is planned as per guidelines established in the rolling dip dimensions table.
6. Material will be progressively excavated from the roadbed, steepening the grade unitl the axis is reached.
7. The depth of the dip will be determined by the grade of the road (see table below).
8. On the down road side of the rolling dip axis, a grade change will be installed to prevent the runoff from continuing down the road (see figure above).
9. The rise in the reverse grade will be carried for about 10 to 20 feet and then return to the original slope.
10. The transition from axis to bottom, through rising grade to falling grade, will be in a road distance of at least 15 to 30 feet.

Table of rolling dip dimensions by road grade

Road grade %	**Upslope approach distance** (from up road start to trough) ft	**Reverse grade distance** (from trough to crest) ft	**Depth at trough outlet** (below average road grade) ft	**Depth at trough inlet** (below average road grade) ft
<6	55	15 - 20	0.9	0.3
8	65	15 - 20	1.0	0.2
10	75	15 - 20	1.1	0.01
12	85	20 - 25	1.2	0.01
>12	100	20 - 25	1.3	0.01

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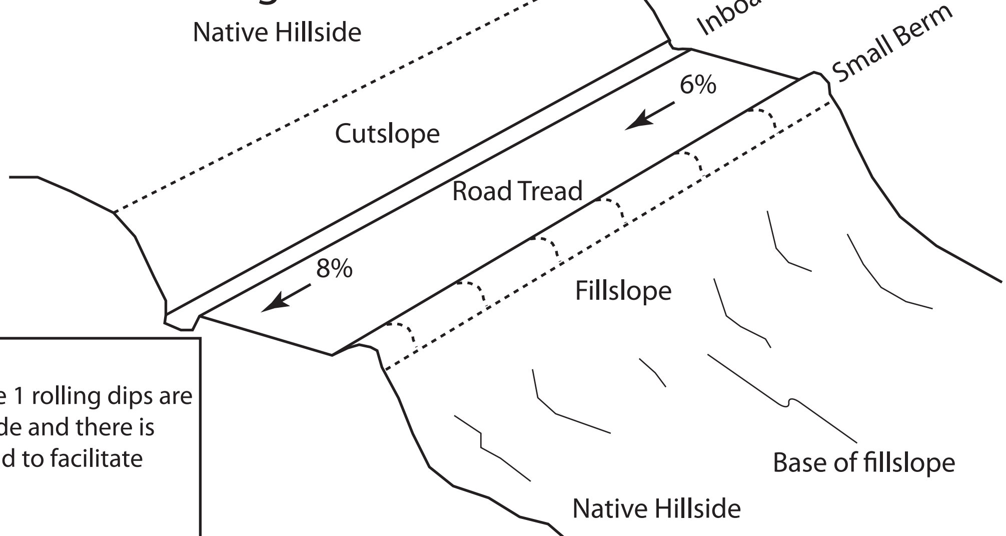
Standard (Type 1) Rolling Dip Construction

Existing Conditions



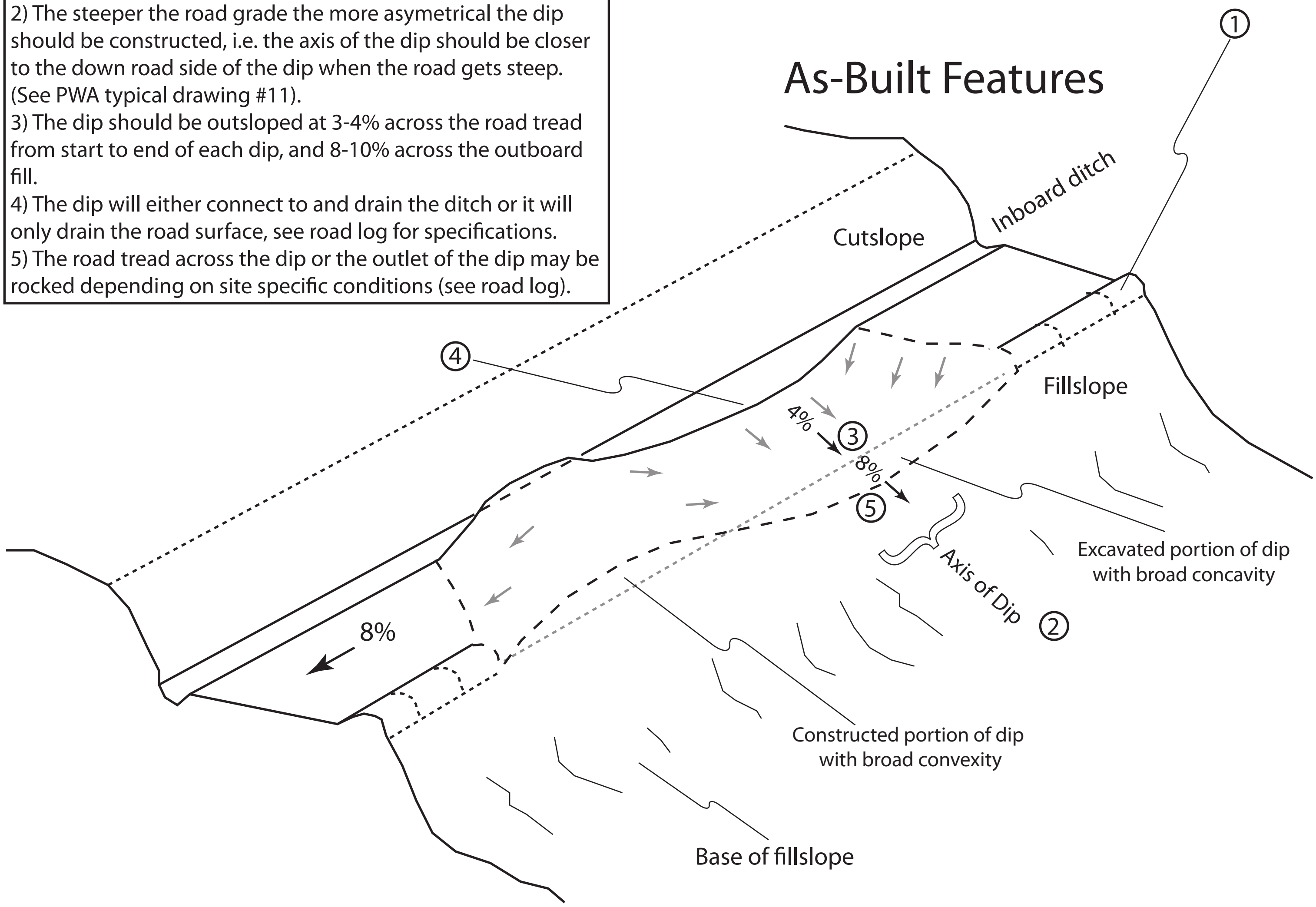
Notes

Rolling dip type 1 existing conditions: Type 1 rolling dips are utilized when roads are less than 12-14% grade and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

Design Notes:

1) The berm should be removed for the entire length of the dip.
2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).
3) The dip should be outsloped at 3-4% across the road tread from start to end of each dip, and 8-10% across the outboard fill.
4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.
5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).

As-Built Features



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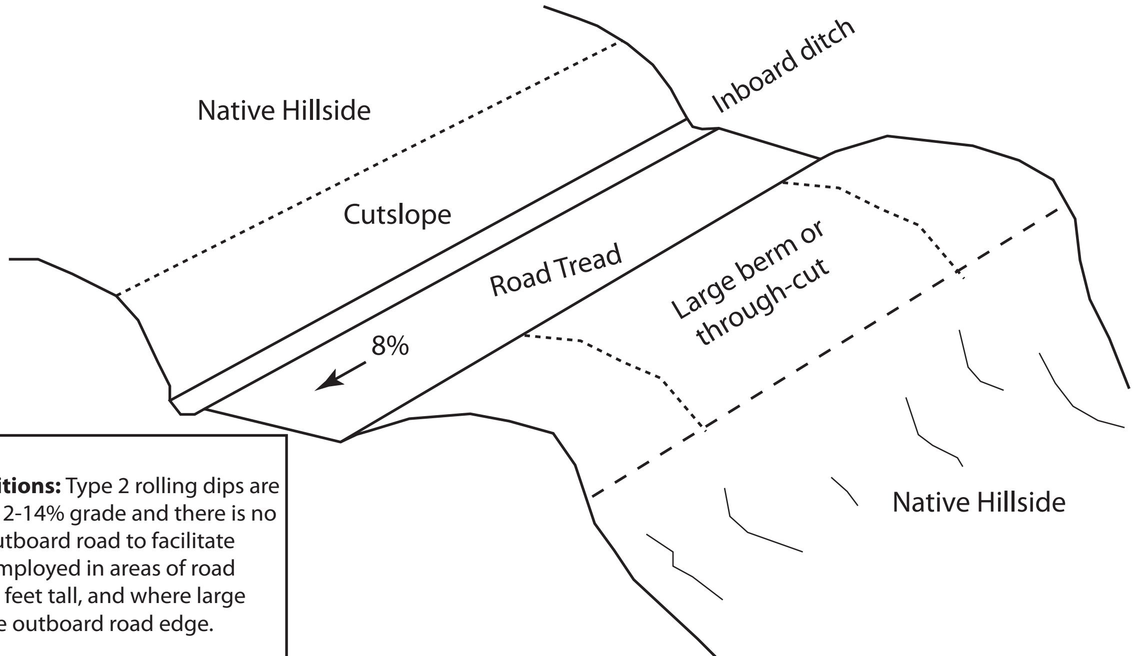
PWA Typical Drawing #19a

Type 2 Rolling Dip Construction

(Through-cut or thick berm road reaches)



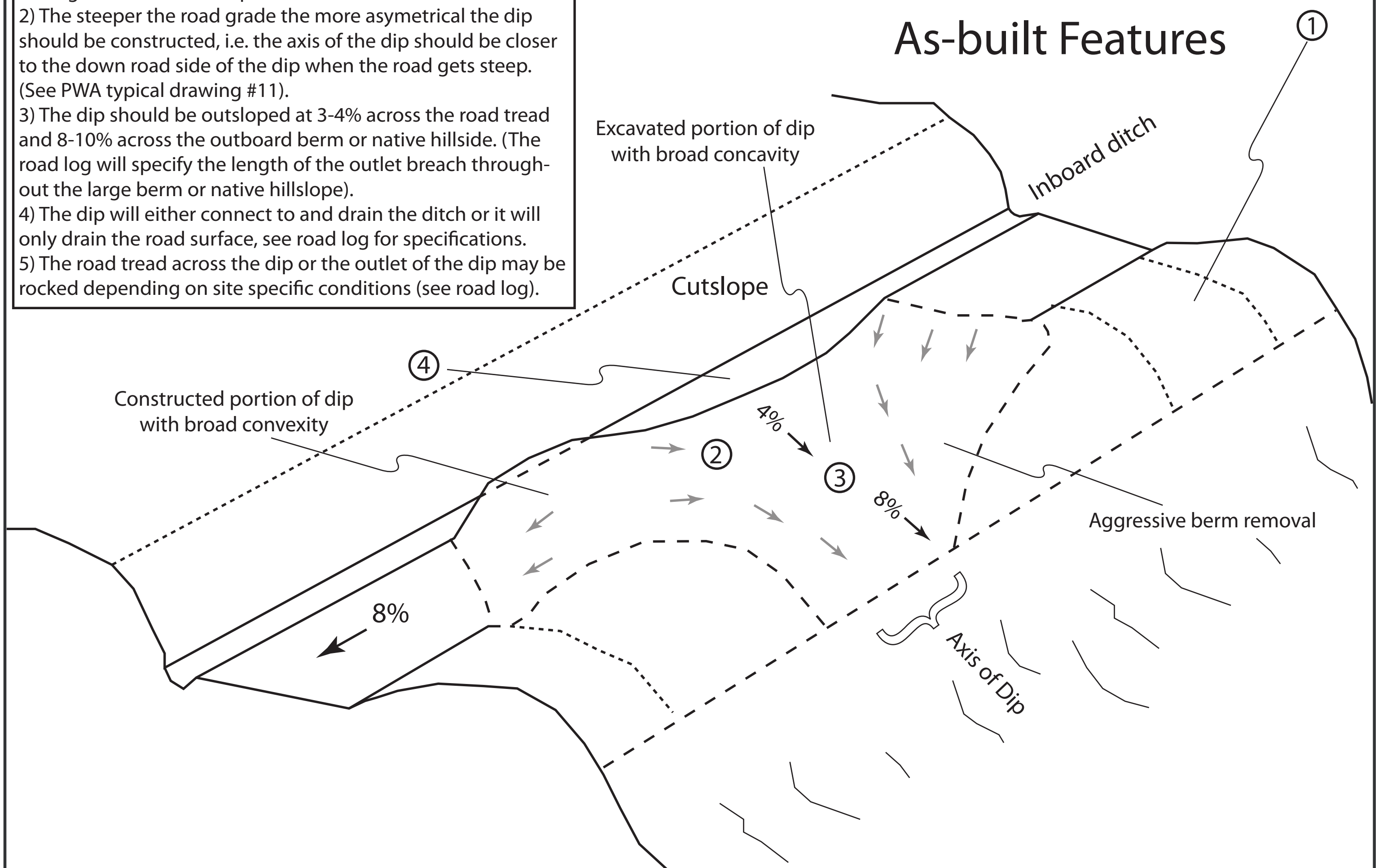
Notes

Rolling dip type 2 existing conditions: Type 2 rolling dips are utilized when roads are less than 12-14% grade and there is no proximal outfall adjacent to the outboard road to facilitate road drainage. These should be employed in areas of road through-cuts generally less than 3 feet tall, and where large wide and/or tall berms exist on the outboard road edge.

Design Notes:

1) The berm or native hillside should be removed for the entire length of the excavated portion of the dip, or, at a minimuim through the axis of the dip.
2) The steeper the road grade the more asymetrical the dip should be constructed, i.e. the axis of the dip should be closer to the down road side of the dip when the road gets steep. (See PWA typical drawing #11).
3) The dip should be outsloped at 3-4% across the road tread and 8-10% across the outboard berm or native hillside. (The road log will specify the length of the outlet breach throughout the large berm or native hillslope).
4) The dip will either connect to and drain the ditch or it will only drain the road surface, see road log for specifications.
5) The road tread across the dip or the outlet of the dip may be rocked depending on site specific conditions (see road log).

As-built Features



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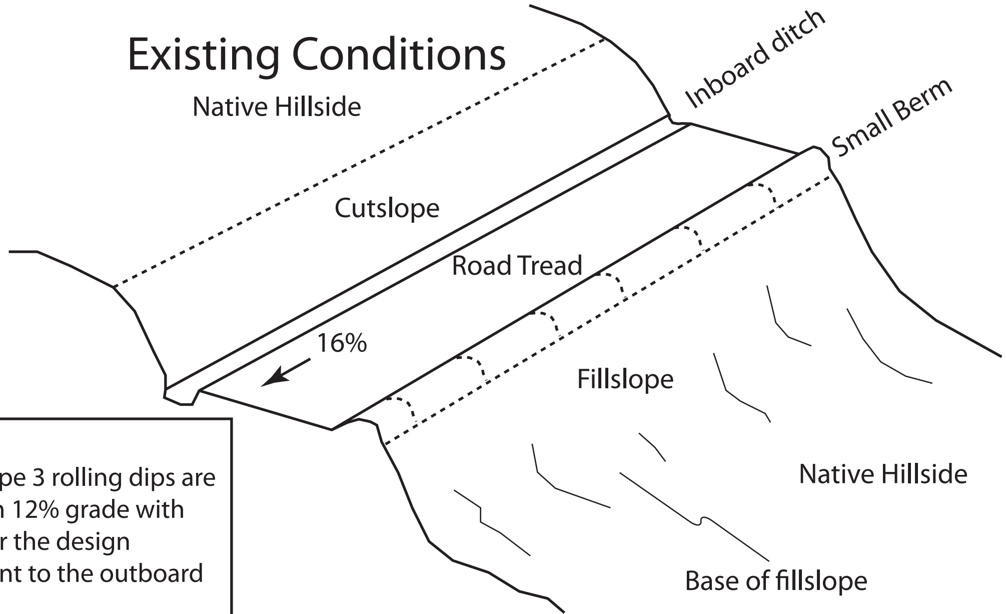
Type 3 Rolling Dip Construction
(steep slope outslope)

Existing Conditions

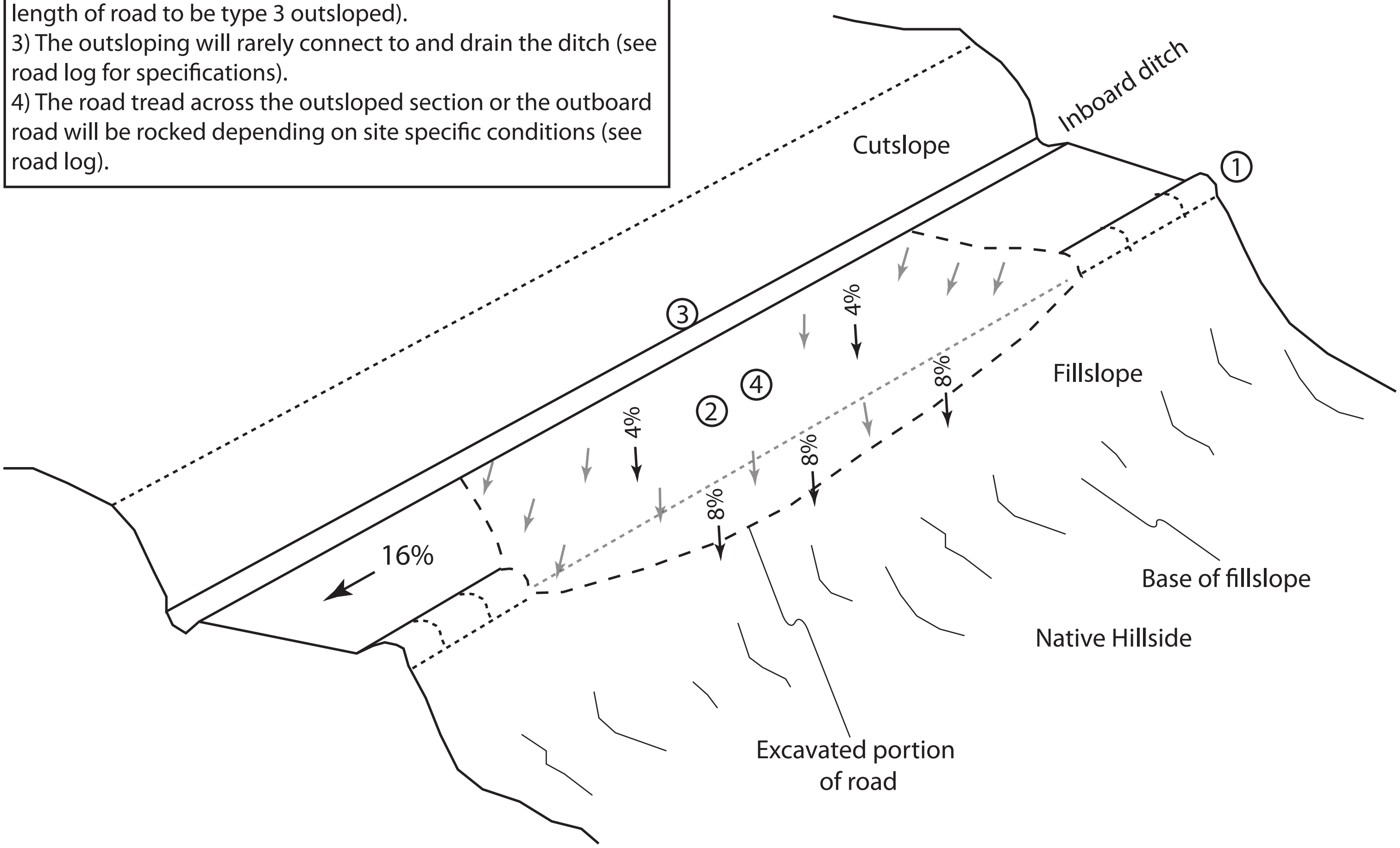


Notes

Rolling dip type 3 existing conditions: Type 3 rolling dips are utilized when roads grades are steeper than 12% grade with little opportunity to create reverse grade for the design vehicle, and there is proximal outfall adjacent to the outboard road to facilitate road drainage.

Design Notes:

1) The berm should be removed for the entire length of the outsloped section.
2) The dip should be outsloped at 2-4% across the road tread and 4-8% across the outboard fill. (The road log will specify the length of road to be type 3 outsloped).
3) The outsloping will rarely connect to and drain the ditch (see road log for specifications).
4) The road tread across the outsloped section or the outboard road will be rocked depending on site specific conditions (see road log).



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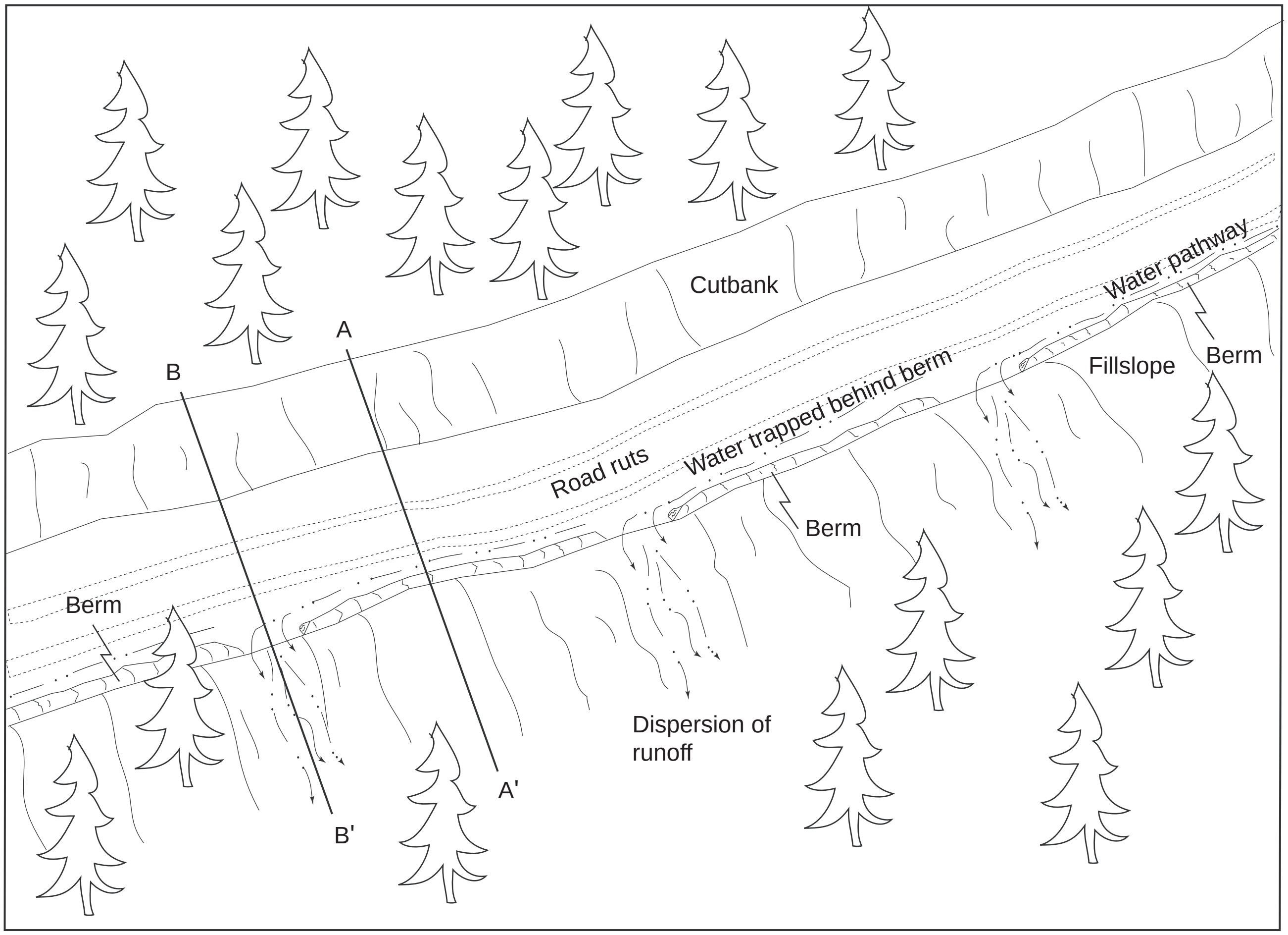
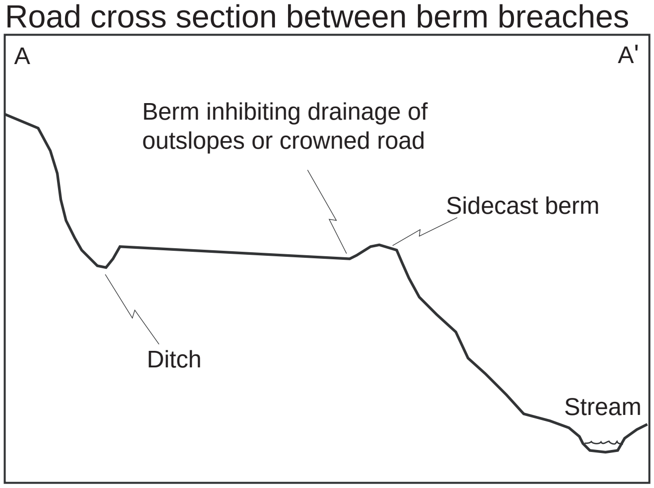
Typical Sidecast or Excavation Methods for Removing Outboard Berms on a Maintained Road

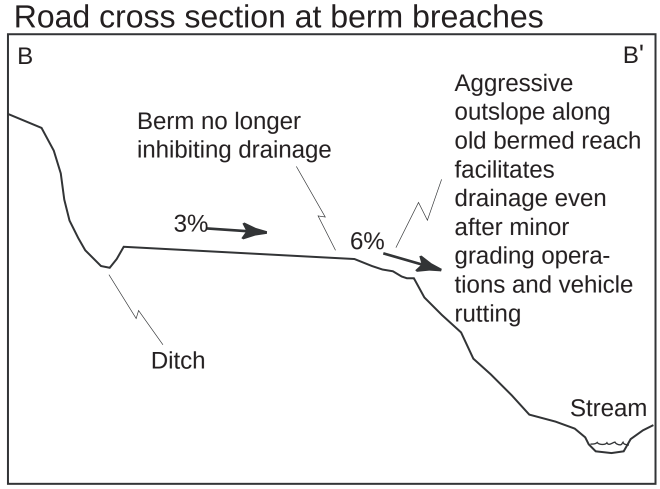
1. On gentle road segments berms can be removed continuously (see B-B').
2. On steep road segments, where safety is a concern, the berm can be frequently breached (see A-A' & B-B') Berm breaches should be spaced every 30 to 100 feet to provide adequate drainage of the road system while maintaining a semi-continuous berm for vehicle safety.



Road cross section between berm breaches



Road cross section at berm breaches



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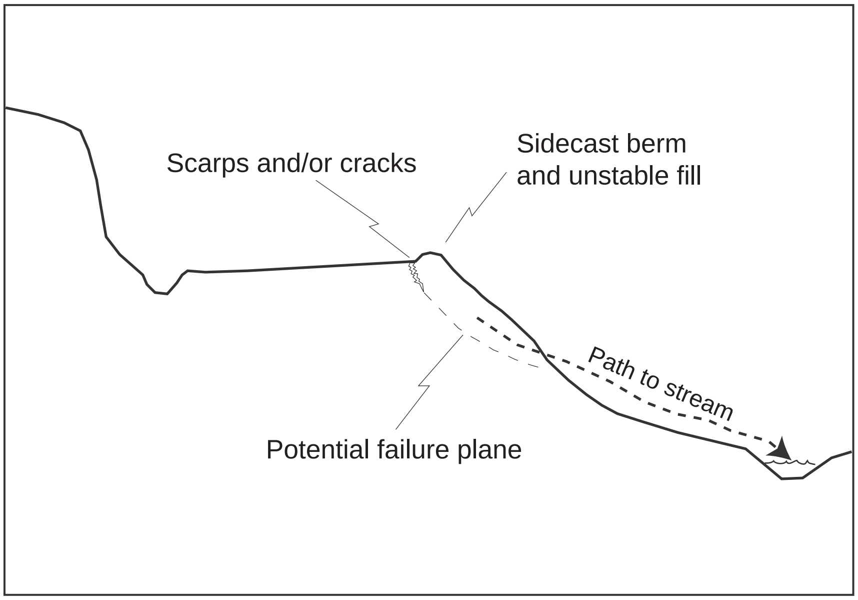
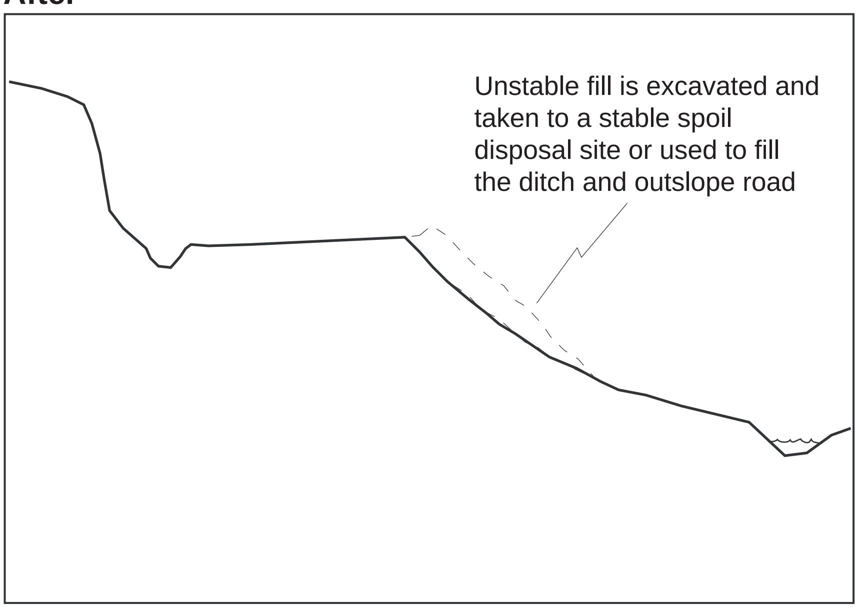
Typical Excavation of Unstable Fillslope on an Upgraded Road

Before



After



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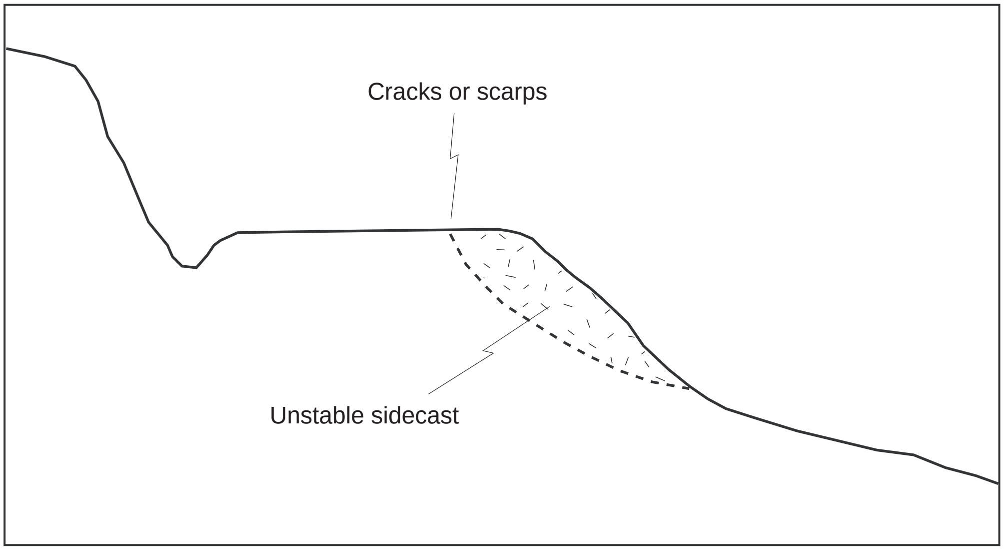
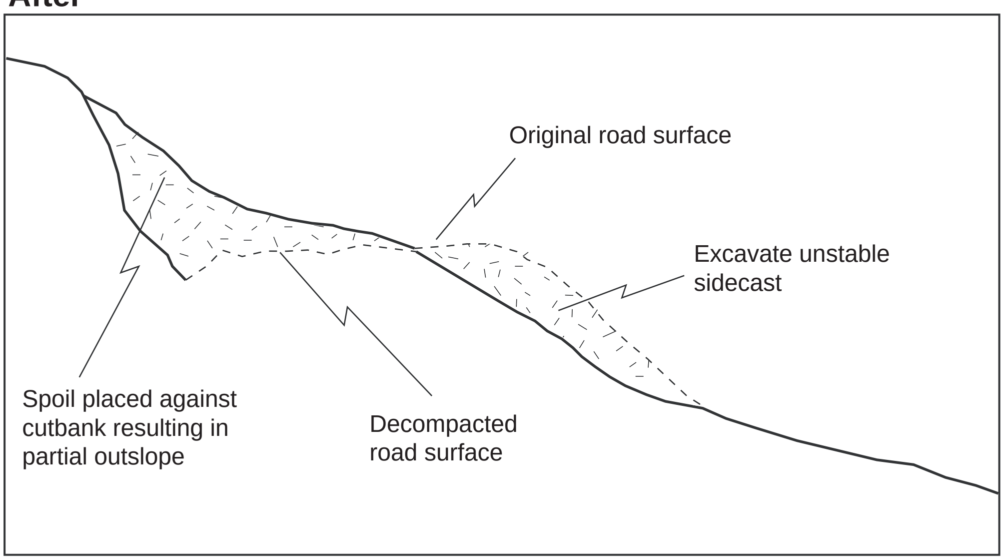
Typical Excavation of Unstable Fillslope on a Decommissioned Road

Before



After



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