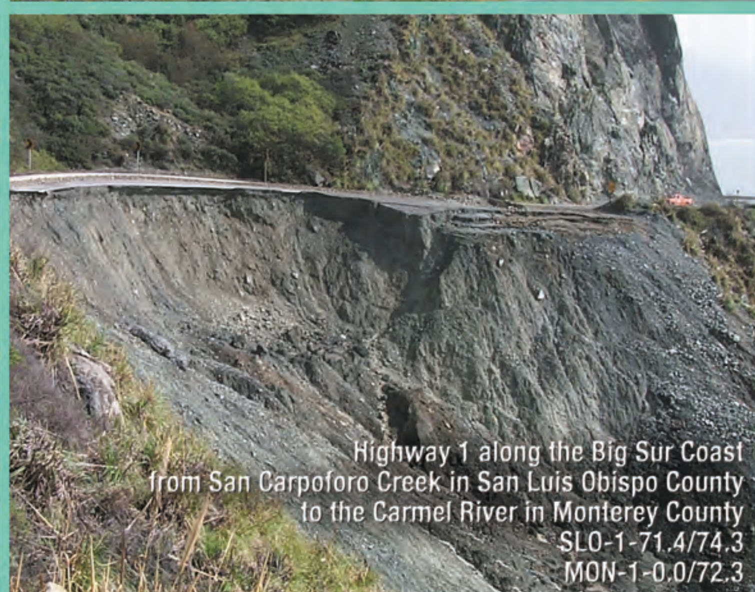
BIG SUR

COAST HIGHWAY MANAGEMENT PLAN

Guidelines For Landslide Management and Storm Damage Response

An Element of the Corridor Management Plan July 2003 Draft



Highway 1 along the Big Sur Coast
from San Carpoforo Creek in San Luis Obispo County
to the Carmel River in Monterey County
SLO-1-71.4/74.3
MON-1-0.0/72.3

U.S. Department of Transportation
Federal Highway Administration

Caltrans

Caltrans District 05

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ACKNOWLEDGEMENTS

These guidelines represent a considerable work effort by a variety of dedicated people. In addition to the consistent high quality work of professional staff of the Department of Transportation and its consultants, numerous individuals volunteered their valuable time to make meaningful contributions to these guidelines.

Community members volunteered their time to help shape these guidelines by participating in various working group sessions and providing input to draft written products. Among the most enduring and passionate of these volunteers have been Mary Trotter, Ken Wright, John Harlan, Jeff Norman. Likewise, invaluable participation by public agency staff included Holly Price (Monterey Bay National Marine Sanctuary); Lois Harter (CA Department of Parks & Recreation); Lee Otter and Mark Johnsson (CA Coastal Commission) and Jeff Main (Monterey County Planning & Building). Participation by many others at various stages of the effort added tremendous value and insight.

Consultant support provided a critical role in several ways. A team assembled by Parsons Brinckerhoff for the CHMP made this undertaking possible and also brought the talents and dedication of Ben Strumwasser (Public Affairs Management) and Pat Gelb (Parsons Transportation Group) who consistently brought good energy and professional quality to the project.

Interagency partnerships with the US Geological Survey, UC Santa Cruz through the hard work of Dr. Cheryl Hapke provided for innovative research and analysis about coastal landslides; Chris Wills and Mike Manson with the California Geological Survey (CGS) developed the excellent reference of baseline landslide mapping and characterization.

Individual staff from the Department of Transportation who have made special contributions to these guidelines include John Duffy, who has made tangible to many the complex phenomena of landslides and the principles of living with the ever-present evolution of the landscape. Under the direction of Ron Richman, David Serafini developed the first comprehensive GIS database of locations exhibiting instabilities along the route; Ron also provided instrumental guidance to the work performed by CGS. The combined experiences of Zeke Dellamas, Steve Hendrickson, Grant Krueger, Steve Balaban and Teresa Salak brought invaluable perspectives into the development of these guidelines; furthermore, the leadership of Steve Price continues to provide the essential direction to determine a clear course of action that allows for practical solutions. Gina Francis invested terrific energy and skill into the organization of information and concepts as presented in this document. The dedication of Andy Richardson and Morgan Gaudioso provided the expert GIS work and production of maps for these guidelines.

The overall undertaking of the Big Sur Coast Highway Management Plan has been a team effort of extraordinary magnitudes and owes everything to the commitment and dedication of these people and so many others who have not been named here.

Cover Graphics and Design by David Meyers and Whitney Fisher

1.0 Introduction

These guidelines support the Coast Highway Management Plan (CHMP), which addresses the Highway 1 corridor along California's Big Sur Coast. This corridor extends 75 miles from San Carpoforo Creek in San Luis Obispo County (SLO-1-71.4) to the Carmel River in Monterey County (MON-1-72.3) (Figure 1). The goal of the CHMP is to preserve, protect and restore the unique qualities of the corridor while ensuring the continued safe and efficient operation of the highway.

Figure 1: Location map for the Big Sur Coast Highway Management Plan.

The CHMP consists of a corridor management plan and three sets of management guidelines. The primary document provides comprehensive background information and an action plan to address issues associated with managing the highway corridor; the guidelines documents build on actions outlined in the management plan.

The Guidelines for Landslide Management and Storm Damage Response address a range of strategies and actions available to the Department of Transportation (Department) and its partners as the Department strives to maintain highway operations through the narrow, geologically complex, geographically remote, resource rich Big Sur corridor. The guidelines are intended to be tools for agency partners and other stakeholders to become more effective in working together, and thereby, better to serve the public and protect the resources held in the public trust.

1.1 Background for the Guidelines

The ongoing natural processes that shape the spectacular Big Sur coastal corridor create huge challenges for the Department of Transportation, which is charged with maintaining Highway 1 through the corridor. The steep mountains are strained by a weak structure of various rock types. The erosive forces of heavy seasonal storms, wave action of ocean and simple gravity all exploit weaknesses in these rock-clad coastal slopes with predictable results: landslides.

As an engineering organization, the Department is skilled at responding to the challenges of maintaining a highway in a difficult environment. The Department has decades of experience avoiding and minimizing impacts to the Big Sur highway with well-engineered projects: engineered slopes, culverts, and bridges. The Department has always employed the latest research and state-of-the-art design, materials and equipment in undertaking such projects. The Department also has proven capabilities responding to slides and washouts with effective notification and traffic control and timely repairs to reestablish full use of the route. This capability is critical because Highway 1 is the lifeline to several well-established communities along the corridor and a major travel destination for tourists as well. Highway closures and extended delays reverberate throughout the coastal communities whose economies are heavily dependent on recreational travel.[1]

Although the Department has an outstanding record for maintaining the roadway and restoring access for safe travel, the accumulated consequences of repairs and related highway improvements have been perceived as threatening the qualities and resources most highly treasured in the coastal corridor. Virtually all of the Department's processes with respect to undertaking corridor projects have been modified or restructured through the years in response to environmental considerations: visual impacts from large cut and fill slopes, spread of invasive plants, impacts to marine and upland coastal habitats, and proliferation of standard highway treatments. The Department recognizes that efforts to manage the highway corridor must be undertaken in a manner that is environmentally sensitive. The need to balance decisions among many stakeholder interests is evident in the numerous regulatory approvals required to develop a project.

Communications and consultations among corridor stakeholders were tested during the extended road closures that followed outsized storm events in several late-20th century seasons, of which 1997-98 is the most recent. These events brought a new level of highway dependence into sharp focus for both the Department and the community of local residents and businesses. The shared experience of undertaking complex and costly and time-consuming earthwork, repairs, and site restoration during emergency conditions also caused the Department and its partner agencies to consider new ways of working together in the corridor. All stakeholders were motivated to consider ways not only to improve communications in the throes of an emergency, but also to avoid or lessen the effects of future damage through prevention projects, proactive planning and pre-need agreements.

The myriad issues related to the 1997-98 slides prompted the undertaking of the Big Sur Coast Highway Management Plan. The need for detailed information about storm damage phenomena and effects on corridor stakeholders, who included the Department, property owners, resource agencies, the traveling public and others, was understood early on. There

[1] JRP Historical Consulting Services, Inc. *A History of Road Closures Along Highway 1 in San Luis Obispo and Monterey Counties,* November 2001.

was a collective willingness to collaborate in efforts to prevent, anticipate and minimize future impacts to the coast highway corridor. The CHMP process has been based in an understanding that success in finding the solutions that best respond to environmental conditions and social values cannot be accomplished independently by the Department of Transportation.

This compendium provides a common base of information to guide future decisions and to ensure an appropriate balance among the concerns and values of all parties. This document is a reference guide for stakeholders and includes the following elements:

1. Geology of the Big Sur Coast: the factors influencing slope stability and variations along the corridor
2. Interventions to manage landslides: opportunities and consequences, known and unknown
3. Current strategic options for maintaining a highway through a landslide-prone environment
4. Programs for landslide management: how the Department organizes and funds its work
5. The Department's current disciplined approach to corridor projects
6. Available techniques and their applicability
7. Future actions for continuous improvement

1.2 Need & Purpose for the Guidelines

The Department of Transportation currently undertakes projects along the Big Sur Coast according to a rational and disciplined process. The process is bounded by factors including the current level of information about geology; past experience working in the corridor environment; and the match of the project characteristics with current programs, available resources, and the interests and requirements of other stakeholders. Although the Department's processes are disciplined, they are improved constantly. The CHMP itself has been an opportunity to improve the Department's processes with more effective partnerships, improved methods, and better information.

The need for these guidelines is directly related to those events that triggered the development of the CHMP: episodic storm damage events that require rapid decisions and effective response. Although management practices continually evolve with information and knowledge available, the Department's processes and actions have not always been well understood by stakeholder groups. Critics of some of the Department's actions or approach bring attention to the reactive nature of management activities, and particularly emergency repairs that require response in crisis mode. In fact, expenditures on this stretch of Highway 1 between 1996 and 2002 have amounted to over $110,000,000 with nearly half this total for actions that qualified as emergencies. The 1998 El Nino storms clearly weigh heavily in this time period, which may not make it a typical average cycle. Nevertheless, El Nino conditions are cyclical patterns that can be expected to return to the Big Sur Coast.

With limited tolerance to highway closures and increasing expenditures and delays related to the disposition of excess material, it is evident that the Department together with its stakeholders must outline a common course of action for dealing with these recurring events.

The Landslide Management and Storm Damage Response Guidelines will be an important tool for improving the process of managing the highway. The guidelines will enhance the effectiveness of partnerships and collaborative decision-making by providing a common base of information about the corridor and identifying important issues that must be considered in undertaking any action. When time is critical for restoring essential service, it is important to have a common understanding of the safeguards available to ensure that environmental protection measures are part of the response. When time is less critical, it is important to be moving forward with research, preventive actions and programmatic-type agreements that will lessen the impacts of future emergencies. The guidelines can serve as a foundation for such agreements between the Department and regulatory agencies, satisfying regulatory requirements related to certain types of highway-related actions in advance of need, thus reducing the time required to take such actions.

The guidelines also identify the need for additional funding and research by demonstrating how the research findings would be applied to achieve results that are critical to multiple stakeholders. As a work in progress, the guidelines will serve as the record for new information about managing the corridor as such information becomes available.

In summary, these guidelines are intended to improve collaborative decision-making based on the best available information.

1.3 Stakeholder Participation

The planning process that led to the development of these guidelines was based in stakeholder participation. Technical sessions of the Storm Damage Response and Repair Working Group served as a major forum for this participation. These sessions provided opportunities for stakeholders to articulate and prioritize problem issues, share information, identify information needs and work toward long-term solutions. The Working Group's deliberations established the following principles:

Guiding Principles for Storm Damage Response & Repair
1. Respect travelers' needs for timely information on highway conditions
2. Act immediately and responsibly to protect or restore highway access.
3. Promote interagency solutions to prevent, anticipate and respond to disruptions caused by storm events.
4. Pursue solutions that avoid or minimize overall adverse environmental impacts and respect natural processes.

The Working Group also outlined the following objectives for these guidelines:

- Improve efficiency of emergency communication and notification for overall better response to restore transportation function
- Limit the impact of landslides on highway operations
- Reduce the volume of excess material in the course of highway repairs
- Identify options for re-use of excess material to reduce the amounts for disposal

- Achieve response strategies that avoid or minimize adverse impacts to the environment
- Select mechanical responses (to storm damage) that mimic natural processes as much as possible, striving to achieve outcomes that might resemble conditions without the highway
- Respect the environment, both land-based and marine, in the course of undertaking repairs and removing landslide debris
- Consider repair strategies and alternatives that avoid or minimize impacts to sensitive environmental resources, including the marine environment: seek a balanced approach among the variety of sensitive habitats that could be affected
- View the coastal environment as a system in dynamic equilibrium: honor the natural processes of erosion; avoid import of exotic material into terrestrial or marine environments; and avoid export of indigenous material from its natural system
- Keep the highway safe and open to travel in a fiscally and environmentally responsible manner

1.4 Regulatory Context

Activities for managing the highway are subject to a complex regulatory environment. Each of the following agencies may have jurisdiction over activities undertaken by the Department of Transportation:

- California Coastal Commission
- California Department of Fish & Game
- California Department of Parks & Recreation
- County of Monterey
- County of San Luis Obispo
- Monterey Bay National Marine Sanctuary
- National Marine Fisheries Service
- Regional Water Quality Control Board
- US Army Corps of Engineers
- USDA Forest Service
- US Fish & Wildlife Service

The Department anticipates that the CHMP will provide the foundation for programmatic-type agreements that will satisfy regulatory requirements applicable to certain types of highway-related actions.

The California Coastal Act regulates development in the coastal zone. These guidelines apply primarily to the activities that would be considered development projects under the Coastal Act. In many cases, capital highway improvements constitute such development. Capital improvements are conducted under the authority of the Department, usually under the State Highway Operation and Protection Program (SHOPP), which covers traffic safety, roadway rehabilitation, roadside rehabilitation, and operations.

Both Monterey and San Luis Obispo Counties have been delegated authority to administer the Coastal Act through certification of their respective Local Coastal Programs. Their authority is for actions above the mean high tide; actions below that limit remain under the jurisdiction of the California Coastal Commission.

As an alternative to project-by-project review and permitting under the Coastal Act, the Department will pursue the opportunity to implement a Public Works Plan. This provision may provide a means to greater efficiency in the reviews of certain of the Department's capital projects. A Public Works Plan could address projects at multiple sites along the corridor. Certification of a Public Works Plan by the Coastal Commission entails reviews, public hearings and a finding of consistency with the Coast Act and conformity with any certified local coastal program. If a Public Works Plan was certified, the Department would not be required to obtain separate coastal development permits, emergencies permits, or permit waivers for individual projects that are found to be within the scope of the plan. The Department would still be responsible for environmental review and compliance with conditions of approval the Commission might impose. The Department would still be responsible for regulatory compliance with all other applicable environmental regulations.

Much of the work the Department undertakes along the Big Sur coast is for maintenance and repair purposes. Maintenance activities are exempt from the California Coastal Act. The Act defines such activities as those "necessary to preserve the highway facility as it was constructed and that do not result in an addition to, or enlargement or expansion of, the object of those repair or maintenance activities…" [California Coastal Act Section 30610]. Although most maintenance activities do not require formal environmental review, actions must comply with provisions of environmental laws and regulations. For example, certain maintenance activities related to channel maintenance are subject to Section 1601 of the California Fish & Game Code.

Jurisdiction by State Parks or the US Forest Service may apply to both capital projects and maintenance activities that involve land controlled by these agencies.

1.5 Applicability and Authority

These guidelines apply to the CHMP study area, which extends 75 miles along Highway 1 from San Carpoforo Creek in San Luis Obispo County (SLO-1-71.4) to Carmel River in Monterey County (MON-1-72.3).

The guidelines are intended to facilitate decision-making by the Department of Transportation and regulatory agencies toward coordinated responses to highway actions. Community and non-governmental stakeholders who participate in decisions may also refer to this document.

The guidelines are not considered regulatory in nature. The guidelines are consistent with the Department's existing authority and responsibility to maintain and operate the highway. The guidelines do not alter the Department's obligations to comply with state and federal environmental laws and regulations, nor do they imply any change in the authority or any agency with jurisdiction over specific actions of the Department.

1.6 Organization of this Document

The Guidelines for Landslide Management and Storm Damage Response document is intended to provide corridor stakeholders with a common base of information about the corridor and actions that can or might be taken to improve landslide management. The document is comprised of seven major sections, the first of which has conveyed the background and purpose for the guidelines and a brief account of the regulatory context for the capital and maintenance projects that are carried out under the authority of the Department of Transportation. The remainder of the guidelines document provides descriptions of the coastal geology, types of earth movement that occur along the corridor, and the way the Department organizes its work to operate and maintain Highway 1 through the corridor. The document also identifies in some detail the best available techniques deployed in the corridor, considerations in using each technique and unsettled issues pertaining to their use.

Section 2 provides an overview of the geology of the Big Sur Coast and defines the types of landslides that occur along the coast. For considering strategies for handling excess materials, this section introduces concepts related to managing instabilities and presents findings of recent research into historical volume losses along the coast.

Relevant program terminology of the Department of Transportation is introduced in Section 3. Corridor stakeholders became familiar with the three-pronged management approach of prevention, response and anticipation during the CHMP process. Section 3 describes how these three approaches would be addressed within the Department's two main program areas for projects on Highway 1, the maintenance and capital improvements programs.

The Department undertakes actions along the coast highway according to a rational, disciplined process that is described in Section 4. This process is followed for every project, whether maintenance or capital improvements and whether aimed at prevention, anticipation or response.

Section 5 introduces and describes major strategies for undertaking three large categories of work in the corridor: (1) managing for landslides, (2) culvert and drainage management, and (3) earthwork, which is an inherent aspect of the two preceding categories.

At any point in time, the Department uses many specific techniques to manage the corridor. These techniques, known collectively as Best Available Techniques, are presented in Section 6. Each of the Best Available Techniques is attended by considerations that may determine its applicability in given circumstances or location. Some of the techniques are controversial. Many will be supplanted as new research findings become available or new technological breakthroughs occur.

In the course of evaluating existing information and current programs and practices, the Storm Damage Response and Repair Working Group identified additional information and resources, unavailable at the present that could improve capabilities to manage the highway in the geologically unstable coastal environment. The guidelines document concludes with Section 7, identifying future research, funding changes, and actions that would contribute to continuous improvement of landslide management practices.

2.0 Overview of Geology & Landslides on the Big Sur Coast

The Big Sur coast is located within a geologically complex part of the Coast Ranges geomorphic province, which extends for about seven hundred miles within California from Santa Barbara County to the Oregon border. The Big Sur coast is noted for its abruptly steep slopes, which rise from sea level to over 3000 feet within less than three miles. Uplift of the Santa Lucia Mountains and continuing wave erosion at their base has formed precipitous slopes in many types of bedrock and overlying surficial deposits. The steep slopes, constant wave action, winter storms, and types of bedrock and cover have proven to be key ingredients for numerous landslides that characterize the area.

Much of the information for this section is from *Landslides in the Highway 1 Corridor: Geology and Slope Stability along the Big Sur Coast* prepared by the California Division of Mines & Geology's (now California Geological Survey), November 2001.

2.1 Coast Geology

Rock types of the Coast Ranges belong to all three major rock classes: igneous, metamorphic and sedimentary. The most widespread geologic unit is the Franciscan Complex, composed of variably metamorphosed fine to medium grained graywacke sandstone and highly sheared shale. Other minor components of the Franciscan Complex include serpentinite, greenstone and chert.

In areas underlain by the Franciscan complex, all of the rock types tend to be weak, intensely sheared and slightly metamorphosed sedimentary rocks or overlying unconsolidated deposits. The tectonics of the region, driven by right-lateral motion on the San Andreas fault system, has led to compression and uplift of these sedimentary rocks in recent geologic time. Uplift of such weak rocks has led to high rates of erosion and abundant landslides.

The other major rock mass in the study area is the Salinian block, which extends southeast from Monterey and Salinas. This block of distinctive rocks is bounded by the San Andreas fault on the east and the Sur-Nacimiento faults on the west. In contrast to the areas underlain by the Franciscan complex, where no crystalline basement rocks are exposed, granitic and metamorphic rocks underlie large areas of the Salinian block. One of the more extensive areas of granitic rocks is the northern Big Sur coast, from Rocky Creek north to Monterey. Metamorphic rocks of the Sur complex and overlying Cretaceous through Miocene sedimentary rocks underlie the remainder of the Salinian block from Rocky Creek south along the coast or just inland to south of Lopez Point.

The Salinian block bedrock is harder and in most places more resistant to landsliding than typical Franciscan bedrock, but the steep natural slopes lead to numerous landslides in most rock units. Deep weathering of many Salinian block rocks has broken down mineral grains within once-hard and landslide resistant rocks, leading to surficial layers in many areas of "decomposed" or weakened rocks that are relatively prone to landsliding. Landslides in Salinian block bedrock are both large intact blocks of bedrock that move as rock slides and areas of deeply weathered coarse soils that mobilize as debris flows. Sedimentary rocks overlying the Salinian block basement are commonly weaker than the granitic and metamorphic rocks and more prone to sliding as intact masses on weak bedding planes.

2.2 Factors Influencing Slope Stability Along Highway 1

The uplift of the Coast Ranges, the inclination of slopes, the underlying rock types and geologic structures, landforms, fire history, rainfall and waves related to winter storms all influence slope stability along the Highway 1 corridor in the study area. In addition to the natural processes that have led to numerous landslides along the coast, construction practices used in building the original highway and in maintaining it have affected the stability of slopes locally.

Slope steepness. Slopes along the Highway 1 corridor range from moderate to extremely steep. The steepest slopes are along the sea cliffs. Some sea cliffs are as steep as 56° and as high as 400 feet. More typically, sea cliffs are about 200 feet high and have slopes of approximately 45°. Slopes this steep are characterized by bare rock outcrops and landslide scars. Most landslides on such steep slopes involve shallow soil and loose rocks, moving as debris slides and rock falls. Slopes to the crest of the ridge above the highway are not so precipitous, but many slopes as steep as 27° to 31° extend to the ridge crests at over 2000 feet.

These steep slopes are formed by a combination of uplift of the mountains that has been ongoing for millions of years and coastal wave erosion. The historic rate of uplift of the area between the San Simeon fault at San Carpoforo Creek and the Sur-San Gregorio fault zone at Hurricane Point, that is, the majority of the study area, is not known.

Wave erosion. The ocean helps to maintain the steepest slopes in the sea cliffs by removing loose rock deposited at the base and undermining the base of slopes, triggering landslides. The effect of wave erosion is greatest where steep high slopes extend upwards from the beach without intervening marine terraces and where weak rocks are found at sea level. Erosion of weaker rocks at sea level contributes to the instability of the harder rocks higher up the slopes. Landslide debris is eventually removed by the waves, decreasing the overall stability of the slide mass.

Rock type. Bedrock geology also has a very strong influence on the types and activity of landslides. The rock units in this highway corridor range from weak rock with pervasive shear surfaces and fractures (the Franciscan melange) to massive, hard rocks with few fractures (notably the charnockitic tonalite and granitic rocks). The melange is much more prone to landsliding. Tonalite is less prone to large rotational landslides and forms very steep slopes along the coast (historically, those slides that have occurred have been large and very damaging, notably the 1983 McWay (or J.P. Burns) slide). The granitic rocks on the northern part of the Big Sur coast, the quartz-diorite, granodiorite and granite, are similarly resistant to large landslides, though some slides are found in all units.

Weathering. The weathering characteristics of the bedrock units are also important factors in controlling the size and density of landslides. Weathering is not as important in rocks that are weak and soil-like in their unweathered state, but in hard rocks the speed and depth of weathering influences the potential for landslides.

Precipitation. Rainfall is a major factor in landslides. The Big Sur segment of Highway 1 receives up to 60 inches of rainfall annually, up to four times as much as the Salinas Valley on the landward side of the Santa Lucia Mountains. The greater rainfall increases the saturation of the landslide masses on the coastal slopes, decreasing their stability. Long-term steady rain leads to deep saturation of landslide masses and tends to destabilize the larger, deeper types of landslides. Short-term, very intense rain tends to trigger the shallower types of landslides, such as debris slides and debris flows.

Fire. Wildfires also contribute to the triggering of debris flows. The effect of fire on debris flow potential was demonstrated clearly in the Big Sur River watershed, where a fire in 1972 was followed by debris flows.

Geologic structure. The northwest trend of geologic structure, which is the similar orientation of bedding, shear zones and faults, controls the general trend of ridges and stream valleys. Bedding and shear zones dip to both northeast and southwest, leading to planes of weakness that favor landslides that move in those directions. The overall structural grain and orientation of common planes of weakness leads to relatively large landslides on slopes that face northeast and southwest.

Landforms. In some cases, the landforms created by landslides also perpetuate the slides. Closed depressions, troughs and benches that commonly form near the headscarps of landslides. This allows increased percolation of water into the slide mass and along the slide plane, where accumulated rainwater can destabilize the slide. Shallow debris slides may destabilize the adjacent upslope area when they move. This leads to a progressive upslope sequence of debris slides or debris flows.

Highway 1. The construction and maintenance of Highway 1 across many marginally stable and unstable slopes has also contributed to the triggering of new or renewed movement on landslides. Original construction of the highway left many steep cut slopes above the road, and blasting used during the original construction left loose and fractured rocks on these slopes, which has contributed to rock falls and small debris slides.

2.3 Types of Landslides

Landslide mapping performed by the California Geological Survey (CGS)[2] throughout the corridor has identified over 1500 landslides within about a three-mile-wide section along the 75-mile-long study area. A recent evaluation by the Department of Transportation indicates that 88 locations along the highway currently exhibit stress or influence related to underlying movements (depicted on Attachment 1).[3] The implications for Highway 1 are obvious: maintaining a reliable linear feature, such as a highway, in this unsteady landscape will always be challenging.

Of all the landslides along the Big Sur Coast section of the Highway 1 corridor, many are extensive, deep-seated slides that affect large areas. The predominant types of landslides described in the corridor are:

- ***Rock Slide*:** A slide involving bedrock in which much of the original structure is preserved.
- ***Rock Fall:*** A landslide in which a fragment or fragments breaks off of an outcrop of rock and falls, tumbles or rolls downslope.
- ***Earth Flow:*** A landslide composed of mixture of fine-grained soil, consisting of surficial deposits and deeply weathered, disrupted bedrock.

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[2] November 2001 (formerly the California Division of Mines & Geology, as referenced above)
[3] California Department of Transportation, *Potential Slope Instabilities in the Highway 1 Corridor: Road Condition and Hazard Potential at Sites Between San Carpoforo Creek and Carmel Highlands*. September 2001.

- ***Debris Slide:*** A slide of coarse-grained soil, commonly consisting of a loose combination of surficial deposits, rock fragments, and vegetation.
- ***Debris Flow:*** A landslide in which a mass of coarse-grained soil flows down slope as slurry.

> ***Note:*** Debris slides and debris flows are commonly found on a landform called a *debris slide slope*, which represents the coalesced scars of numerous landslides.

Another condition relevant on the coast is *bluff erosion* caused predominantly by wave action. While this natural process is not considered a landslide per se, the options for managing the highway in proximity to eroding bluffs are similar.

2.4 Applied Science along the Corridor

Strategies for the Big Sur Coast must build on the current body of knowledge. Site-specific information about the geology, patterns of change, and environmental sensitivity will all factor into decisions.

Recent inventories and databases include information that is relevant to developing integrated landslide and storm damage management strategies. Some of the studies described below are currently underway; others are planned to address critical gaps in current knowledge. Keeping databases current will ensure that the best information is availed to decision makers.

Landslide Activity

The California Geological Survey has divided the Big Sur coastal corridor into 12 distinct areas according to geological and landslide characteristics. The CGS has also indicated the relative landslide potential for each of the areas based on observed activity levels. Summary data for each of the 12 areas are presented in Table 1 and depicted on the corridor maps in Attachment 1.

Table 1: Characterization of Landslide Activity in the Highway 1 Corridor[4]

Highway Segment[5]	Geologic Characteristics	Landslide Characteristics
A San Carpoforo Creek to Ragged Point Resort (SLO-71.4 / 73.0)	Steep marine terrace and canyon.	Moderate potential for landslides. Canyon area prone to rockfall and small events. Some (wave) erosion may cause events below roadway.
B Ragged Point Resort to Salmon Cone (SLO-73.1 to MON-2.8)	Very steep slopes underlain by competent rocks of the Franciscan mélange.	Prehistoric slides. Small landslides common above and below highway. Some moderate events result in road closure. Moderate to high potential for landslides.
C Salmon Cone to Willow Creek (P.M. 2.8 /12.1)	Gentler slopes with scarps and benches. Weaker mélange bedrock. Prominent bands of serpentine which weakens rock structure.	Large recent landslides have damaged the road. Mixture of new and prehistoric slides with smaller slides later creating large events. High landslide potential. Very active.
D Pacific Valley Area (P.M. 12.1/16.6)	Gently sloping marine terrace and debris fan deposits. Uplifted terrace prevents wave erosion.	Low landslide potential. Moderate slides possible above highway.
E Pacific Valley to Limekiln State Park (P.M. 16.6 / 21.0)	Steep slopes rising almost directly from the beach. Cut slopes have caused landslides.	Relatively few large or active landslides. Moderate landslide hazard – mostly small to medium sized events.
F Rain Rocks to Cow Cliffs (P.M. 21.0 / 28.5)	Steep slopes. Rain Rocks slopes nearly vertical and composed of hard rock. Less steep slopes at Cow Cliffs with more fractured rock. Area in between consists of unstable Franciscan mélange.	Rain Rocks prone to rockfall due to hard rocks. Cow Cliffs prone to rock falls and debris slides. Highest level of landslide activity in the highway corridor located between these two points. Both historic and young activity.
G Cow Cliffs to McWay Canyon (P.M. 28.5 / 35.7)	Steep slopes of competent rock (Franciscan mélange, Cretaceous sandstone and conglomerate). Remnants of marine terraces and debris fans.	Moderate potential for small to moderate landslides. Human activities (ranching and road repair efforts) have created small, shallow events. Wave erosion can cause small slides.
H McWay Canyon to Castro Canyon (P.M. 35.7 / 43.0)	Uniformly steep slopes of 50% to 65%. Slopes are very stable and composed of Charnockitic Tonalite – a hard, massive, coarse-grained igneous rock with few fractures.	Moderate potential for landslides, mostly small rock falls and debris slides. Exceptional circumstances, like extreme rainfall, can cause major events.

[4] From California Division of Mines & Geology (now, California Geological Survey) in *Landslides in the Highway 1 Corridor: Geology and Slope Stability Along the Big Sur Coast*, November 2001.
[5] Locations are identified by postmile (P.M.) and are located in Monterey County unless specified as SLO for San Luis Obispo County.

Table 1: Characterization of Landslide Activity in the Highway 1 Corridor[4]

Highway Segment[5]	Geologic Characteristics	Landslide Characteristics
I Castro Canyon to Old Coast Road (P.M. 43.0 / 51.2)	Sur fault composed of a Franciscan bedrock block and a Sur complex block. Steep canyons. Debris flows through channels in the watershed and into the Big Sur River creating debris fans crossed by the highway.	Moderate potential for landslides, primarily debris flows and slides. Debris inundation common during heavy rain or winters following watershed wildfires.
J Old Coast Road to Little Sur River (P.M. 51.2 / 56.1)	Highway built on debris fans created by the deep slides and slow moving earthflows on hills east of the highway. Some steep sea cliffs and erosion.	Low to moderate potential for landslides. Deep movements and small debris flow scars. Erosion and small landslides can occur below the highway caused by waves.
K Little Sur River to Rocky Creek (P.M. 56.1 / 60.0)	Steep slopes underlain by weak rocks of the Tertiary Pismo Formation at the base faulted with Cretaceous rocks and Sur complex metamorphic rocks. Wave erosion is associated with the base of the rock and shearing in the fault zones weakens the rock structure. North of Hurricane Point, the area is underlain by marine terrace and debris fan deposits.	Large landslides occur that disrupt the highway. Debris flow scars are evident. Slopes at Division Knoll are prone to rock falls and debris slides. Segment of the greatest landslide potential in the northern portion of Big Sur.
L Rocky Creek to Point Lobos (P.M. 60.0 / 70.4)	This segment is underlain by granitic rock. Steep slopes east of the highway, but relatively far from the roadway.	High potential for debris flows/slides, but low potential to impact the highway as the flows usually pass under bridges and into the ocean.

Estimated Volume Loss

Recent research has examined changes in the coastal landform over time. This work has added to the body of knowledge concerning the characteristics and causes of sediment supply to the ocean below slide areas. Using aerial photography to develop digital terrain models, researchers have estimated volume loss over the 52-year period between 1942 and 1994.[6] Unfortunately, suitable photography is not available for quantifying “pre-highway” volume changes.

Study results were expressed as an estimated annual average rate of overall volume losses, by orders of magnitude, from the steep slopes fronting the ocean. The results of the study were reported for nine discrete segments along the corridor (Figure 2), also depicted on the corridor maps in Attachment 1. Sediment yield data varied significantly by segment, with a strong correlation between the local geology and sediment delivery rates. Areas along the southern Big Sur Coast, which is characterized by the highly sheared and weak rocks of the Franciscan mélange, showed the greatest annualized volume changes of over 90,000 cubic

[6] Hapke, Cheryl. *Estimated Sediment Yield from Coastal Landslides and Active Slope Distribution Along the Big Sur Coast.* February 2003.

yards per mile. Average annual volumes were estimated to be over 40,000 cubic yards per mile over the entire 75-mile long corridor (Figure 3).

The results provide valuable information about the magnitude and area distribution of volume losses in the post-highway era. The methodology is expected to be a valuable tool for accumulating a longitudinal record of sediment movement along the coast.

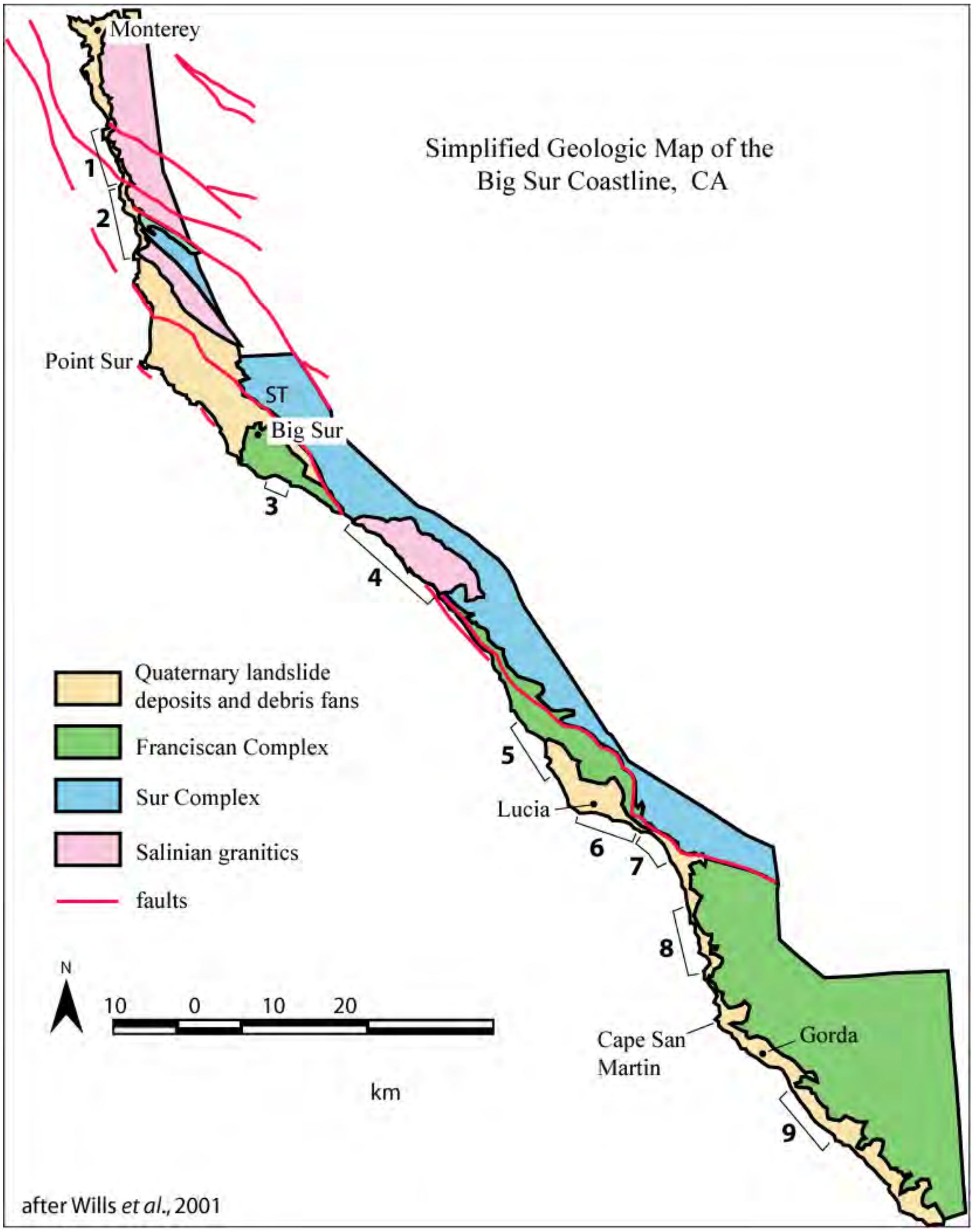


Figure 2: Geologic Map of the Big Sur coast area showing the general lithologies exposed along the coast. Major faults are shown as red lines. The numbers 1 – 9 are the locations of the specific study areas by Hapke (see also Attachment 1).

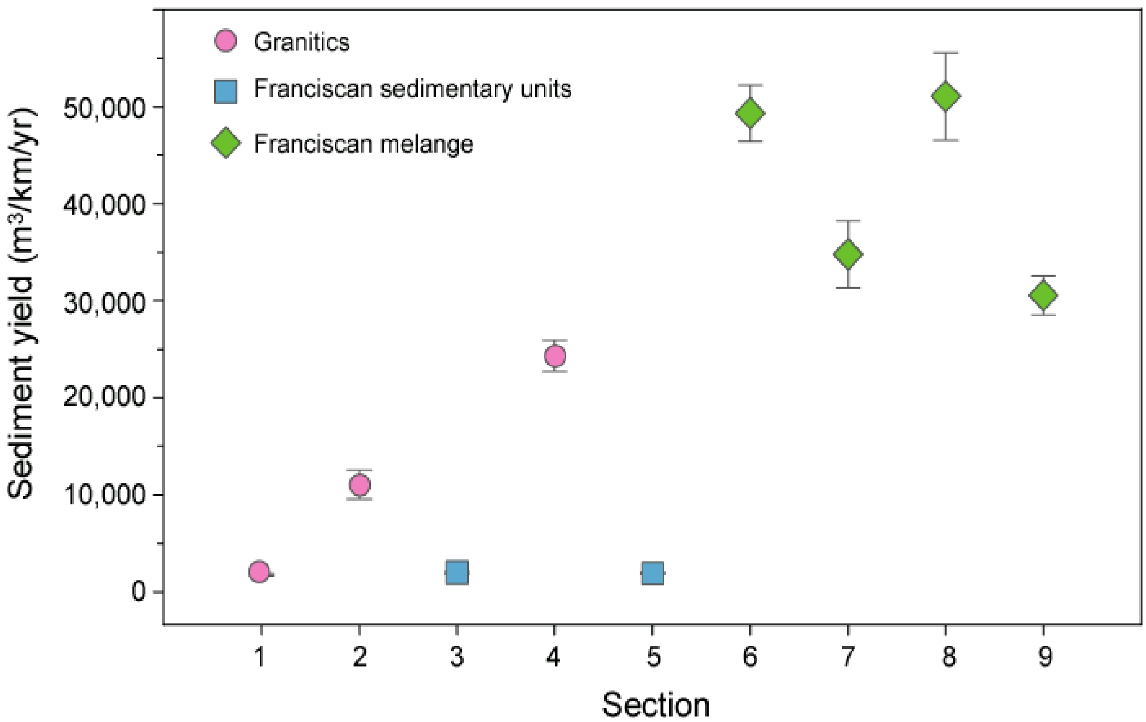


Figure 3: Relationship between lithology and sediment yield for the nine study sections of coastline. The sediment yield within the weak Franciscan mélange is consistently greater than the yield in the stronger granitics and sedimentary units of the Franciscan complex. (Hapke, 2003)

2.5 Evolving Practices for Managing Instabilities

Although landslides have been documented for thousands of years, it was not until the 18th and 19th centuries that landslide science developed in response to an expanding population that required improved infrastructure and related advances in civil engineering. These developments led to an improved understanding of how natural landslide processes interact with the human environment. As stated in the Transportation Research Board's *Special Report 247, Landslides: Investigation and Mitigation*, 1996, "The factors of geology, topography, and climate that interact to cause landslides are the same regardless of the use to which man puts a given piece of land. Over time, slope stability investigations have been influenced and integrated with broader land use planning and development." (TRB Special Report 247, 1996)

Landslide remediation efforts have evolved as new perspectives and new technologies have emerged over time. Advancements in understanding and improved technologies have influenced landslide investigations and mitigation methods: for example, the availability of geotextile products has led to new treatment options for slopes. (TRB, 1996).

Advancements have been shaped not only by science, but also by perceptions and constraints. Hazard and risk assessments combine geology and history (related to both geology and human development activity) to determine which technologies will best respond to a landslide event or reduce future hazards. Concerns regarding terrestrial and aquatic environmental protection and socioeconomic considerations have grown concurrent with the development of new technologies. Recognition and understanding of the potential for landslides to affect valuable marine resources has developed more recently. The designation of the Monterey Bay National Marine Sanctuary has focused attention on this aspect of managing the highway in relation to landslides.

Environmental protection and socioeconomic factors are now major considerations and often impose constraints on selecting and applying highway repair strategies and techniques. The interaction of concerns suggests the need to balance technological solutions with the necessary protections for a healthy environment and sustainable social economy. Because landslides can damage and destroy infrastructure and other development, historically the focus has been on the costs and inconveniences associated with the disruptions that landslides cause for people. This focus is expanding to address environmental concerns. While engineering solutions tend to be based upon measurable phenomena (such as soil types, slope ratios and drainage), environmental and social solutions draw upon an integrated system of ecological science and social values (such as how changes can affect a terrestrial or marine habitat, a scenic view or a business). State and federal environmental laws and regulations now prescribe the processes that seek a balance.

Perceptions of coastal landslides have also evolved as people become more aware of the nature of landslides and how they contribute to Big Sur as a unique place. Now that a large inventory of information has been assembled, landslides are being understood as the primary natural process that shapes the landform and creates the essential character of the coast.

With this expanded perspective, efforts to prevent slides have evolved into efforts to manage instabilities to maintain traveler safety, local communities, and livelihoods while respecting landslides as part of the natural landscape. The philosophy can be said to have evolved from "moving the mountains" to "living with landslides." From grand civil engineering projects attempting to stabilize large landslides, the shift now is toward less ambitious approaches to achieve adequate stability with some allowance for local instabilities. This means highway repairs with fewer direct environmental impacts and a quicker reopening of the road after a landslide-related closure. Such approaches may require more intensive maintenance and associated traffic delays.[7]

The evolution in engineering approach described above is illustrated by comparing Caltrans responses to two recent El Nino storm periods. After the storms of 1983, highway repair from one large landslide (McWay Canyon, also known as JP Burns) resulted in the removal of 3.1 million cubic meters of earth and a one-year road closure. Highway repairs from three large landslides (Duck Ponds, Big Slide and Grandpa's Elbow) in 1998 resulted in the removal of only 700,000 cubic meters of earth and a three-month road closure (Figure 4). The minimal earthwork also resulted in fewer adverse aesthetic, habitat, traffic, and emissions impacts.

[7]"Living with Landslides on the Big Sur Coast: The challenges of maintaining Highway 1," John D. Duffy and Aileen Loe, California and the World Ocean Conference, October 2002.

Despite this major advance in repair techniques, excess material remains the one common denominator. Soil, rock and debris generated by landslides and their subsequent repairs need to be moved in order to restore the highway to service. Among the outstanding challenges is finding the best solutions for the proper handling and transfer of this material on this coast.

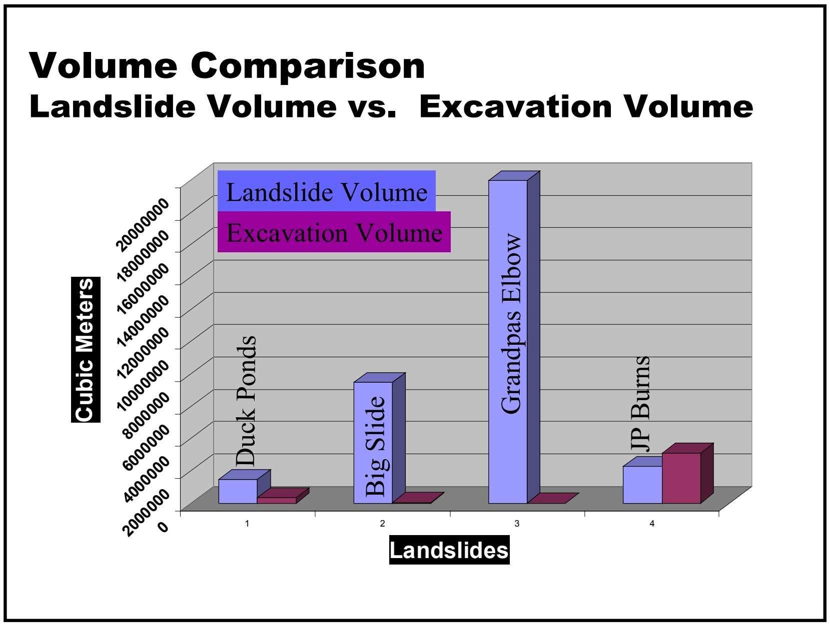


Figure 4: This graph represents the estimated volumes of excavation compared to the total volume of the land movements associated for the event in 1983 (JP Burns) and those from 1998.

2.6 Information Resources for the Corridor Environment

As a steward of the resources within the highway right-of-way, the Department of Transportation is responsible for carrying out actions in a manner that is sensitive to the potential environmental effects that may extend beyond the right of way.[8] Multi-disciplinary teams of technical specialists evaluate the presence of sensitive habitats and the potential adverse impacts from a proposed action. The environmental review process is well established by Department policy and procedure and further detailed with internal guidance.[9] Due to the land-based nature of the facility, the traditional focus for evaluating effects is on terrestrial resources. In steep coastal areas, however, where the land-sea interface is unmistakable, attention must also be directed toward the evaluation of potential effects to marine habitats.

Environmental reconnaissance in this corridor is enhanced with an extensive GIS-based inventory of corridor resources that has been compiled in support of the CHMP. The *Corridor*

[8] Caltrans is the lead agency as defined under CEQA. The Federal Highway Administration is lead agency under NEPA for highway projects that receive federal funding.
[9] Caltrans Environmental Handbook, Volumes I-IV. http://www.dot.ca.gov/ser/

Inventory of Natural Qualities[10] identifies and characterizes terrestrial resources along both sides of the highway, a corridor approximately 400 feet in width for the 75-mile corridor. The inventory includes vegetation communities, sensitive habitats, streams, and other special features, including wildlife corridors. Similar inventory information is available for cultural and historic resources, recreational features and scenic qualities along the corridor.

Shoreline and marine resources are characterized at a broad scale. However, limited information is available to characterize the potential for effects to marine habitats on a more site-specific basis from highway management activities. Protocols have not yet been established for shoreline habitat classification, estimation of impacts, and appropriate mitigation and monitoring. Information being developed under the leadership of the Monterey Bay National Marine Sanctuary will be a key component toward achieving such a protocol. In the interim, a preliminary set of guidelines for evaluating shoreline habitats has been drafted for purposes of discussion (see Appendix A).

The study of historical volume loss referenced in Section 2.4, above, contributed to knowledge of materials that have moved from terrestrial slopes into the ocean at various locations along the corridor. It was beyond the scope of that study to consider the deposition or movement of the material within the marine environment or its impacts on marine habitat. However, research into the effects of landslide-related highway repairs on marine habitats has been conducted at three locations in central and northern California: Lone Tree landslide (Sonoma County), Waddell Bluffs (Santa Cruz County), and McWay landslide (Monterey County-Big Sur Coast). Research at a number of other sites along the Big Sur Coast has been initiated to help characterize the conditions on and offshore of known landslide sites (Grey Slip, Willow Creek, Pitkins Curve and Big Creek). The potential for impacts is largely focused on conditions caused by burial, scour and turbidity from the input of large volumes of sediment in relatively short time periods.[11]

More information about shoreline dynamics and site-specific habitat sensitivity is important to better understand the potential effects to the nearshore and offshore marine environments from highway-related manipulation of landslides. Sediment balance relationships are also important in the equation. Neither of these components is well understood at this time. Recommendations within the larger context of the CHMP include pursuing actions that lead to an improved understanding of these habitats and the relationship to natural coastal processes. The objective for this is to advance the range of management solutions that may be available in the future.

[10] Parsons Transportation Group. *Corridor Intrinsic Qualities Inventory: Natural Qualities.* December 2001.

[11] See, for example, Tenera Environmental. "Shoreline Biological Assessment of Highway 1 Slide Area at Pitkins Curve, Monterey County," February 21, 2002, or Moss Landing Marine Laboratories, "Marine Disposal of Landslide Debris Along Highway One: Environmental Risk Assessment and Monitoring Protocols," February 1998.

3.0 Programs for Landslide Management Activities

Minimizing highway damage, service interruptions, and impacts to the environment requires a three-pronged management approach. ***Prevention*** is action taken in advance to avert slope failure from affecting the highway or to minimize the potential for damage. ***Response*** activities are conducted when a break in service has occurred or there is imminent threat to traveler safety or integrity of the facility. ***Anticipation*** refers to actions taken in preparation for breaks or disruptions in service that cannot be avoided and putting mechanisms in place to facilitate future responses.

These landslide management actions are funded under the Department's maintenance and capital improvement programs. Highway funds are limited and allocated on a competitive basis. The magnitude of the project and its source of funds are major factors in determining the time it takes to deliver a project.

3.1 Maintenance

Prevention

Work performed by Maintenance crews is the first level of prevention. A year-round planning strategy focuses primarily on ways to prevent the road from being closed and how quickly the crews can safely restore service if the highway becomes closed. A full range of maintenance duties is employed throughout the year to prevent or minimize damage from winter storms; the activities encompass maintenance of the roadbed, shoulders, and drainage and vegetation management.

The quality of the roadbed surface is important to ensure its ability to properly drain water. A poor quality surface can result in highway flooding, ineffective water flow, draining to the wrong side of the highway or not draining to the proper ditches and culverts. Repairing potholes in the surface helps maintain the quality of a smooth ride, but is also important to protect the integrity of the roadbed that can be threatened by aggravated deterioration.

Effective roadside management provides assurance for the quality of highway shoulders and the functioning of drainage facilities, which also includes vegetation management. Similar to concerns about the roadbed, the condition of the highway shoulder is important for ensuring effective drainage and stormwater runoff. Ensuring the proper functioning of drainages requires keeping ditches and culvert inlets clear of debris and major vegetation. Furthermore, ease of access to ditches and culverts by maintenance crews is important should they require remediation under storm conditions. Vegetation management also includes the removal of dead trees to avoid the potential for these trees to fall onto the road or knock down power lines.

Response

Maintenance crews perform storm response with continuous patrolling during daylight hours to ensure a roadway free of rocks and debris, clear downed vegetation and monitor drainage. The crews shovel out culverts and ditches that are starting to plug or drain improperly. Storm response also includes using equipment to clean up small slides. This work can be labor intensive, involving an entire maintenance crew for traffic control, equipment operation, spotting (for safety) and truck hauling the material away to temporary locations (such as turnouts). Further cleanup includes repairing potholes, hauling material from turnouts to locations for recycling or permanent disposal, equipment maintenance, removing other downed vegetation and repairs to drainage systems.

Maintenance crews are limited by their size (human power) and sometimes by the availability of equipment. When the needs posed by an event exceed the ability of the crews to respond, rented equipment may be used or capital program efforts may be initiated.

3.2 Capital Improvements

Capital improvements refer to the expenditure of funds for activities that go beyond routine maintenance and operations. The primary source of funds for capital improvements on Highway 1 is the State Highway Operations and Protection Program (SHOPP), which provides for improvements that are necessary to preserve and protect the state highway system. Projects are limited to improvements relative to maintenance, safety, and rehabilitation of state highways and bridges that do not add a new traffic lane to the system. A complete list of the categories of projects that are funded by this program is shown in Appendix B.

Planned Projects under SHOPP

SHOPP program funds are organized by funding limits into minor and major categories. Minor projects are broken down into two sub-categories: Minor B projects are limited to $110,000 and Minor A projects are limited to $750,000.[12] Minor program funds are provided on an annual cycle. Major SHOPP projects are those estimated to cost over $750,000 and are allocated on a two-year programming cycle.

Authority to manage SHOPP funds and set priorities varies by size of project. Discretionary authority to manage the Minor program funds is held by each of the 12 District offices of the Department of Transportation. A project over $750,000 that qualifies as a Major project under the SHOPP is subject to a statewide competitive process and requires approval from the California Transportation Commission (CTC) prior to beginning work, including the initiation of preliminary studies. The statewide competition is among all SHOPP project categories. Often, the most competitive projects are those to improve safety and those needed on routes with the highest traffic volumes. The majority of projects for this part of Highway 1 fall under the SHOPP category of Protective Betterments; these types of projects generally have difficulty competing at the statewide level unless there is a high degree of urgency. This is a limitation of existing funding programs.

The time to deliver a SHOPP project also corresponds somewhat to the project cost. Candidates for the Minor program (under $750,000) have the potential to proceed relatively quickly, since more local discretion is involved for setting priorities, initiating studies and awarding contracts. The Department has authority to begin studies for Minor projects prior to CTC approval of funds.

The competition for Major SHOPP projects (over $750,000) requires more formal scoping, process review and centralized contract authority. Initiating these projects requires approval by the CTC before any studies can proceed. As a result, these projects can take several years before they are programmed (funded); it may require an additional five to eight years after programming for a Major SHOPP project to come to fruition with completed environmental review, permits, project design and detailed plans.

[12] This amount represents the current limit, which is subject to periodic change as established by the California Transportation Commission (CTC).

Emergency Projects under SHOPP
Emergency project funding also comes from the SHOPP, but is accessed in different ways and according to certain limits. If the Governor of California or the President of the United States has declared an emergency, additional funds may be available. A presidential declaration authorizes use of Emergency Relief (ER) funds that are administered by the Federal Highway Administration.

The local District Director can authorize spending up to $120,000 for emergency work; the Department Director must authorize spending over that amount. The focus is on restoring the highway after damage but the work may include activities normally considered "prevention." This work is usually accomplished without the benefit of formal plans, unless an emergency condition arose during the development of a related project, such as a preventive action. Response is generally distinguished from prevention by an adverse situation that requires quick action to protect the public safety or integrity of the facility or to restore essential service.

SHOPP funding covers all three types of highway management activities, as described below.

Prevention
Projects initiated to prevent progressive failures affecting the highway are accomplished through the SHOPP. The Department regularly initiates projects to address specific deficiencies throughout the corridor; at any given time, more than a dozen projects are in development along the Big Sur Coast. The scope of projects under the category of prevention includes those to protect facilities from future catastrophic damage from natural events (storms, floods, landslides) or human-caused events. Examples of Roadway Protective Betterments that would be considered preventative include the following:

- Retaining or stabilizing features (e.g., retaining, crib or sheet pile walls; mechanically stabilized or reinforced embankments, rock slope protection, slope corrections, soil nailing)
- Culvert rehabilitation or replacement
- Minor realignments
- Rockfall protection measures (e.g., rocknet drapery, fence, sheds)
- Separation structures (e.g., viaducts and bridges)

Depending on the scope of the problem and the range of viable alternatives, these could be either minor or major projects.

Response
Where the highway is threatened with imminent failure or has been badly damaged by an event, Caltrans may determine that an emergency condition exists. Projects undertaken in response to a defined, immediate threat are classified as Major Damage restoration.

Such projects are undertaken in response to natural disasters, catastrophes or events such as storms, floods, fires, earthquakes, tsunamis (tidal waves), or volcanic action. Responses to man-made disasters such as large-scale civil unrest, hazardous material and chemical spills, explosions, and acts of war or terrorism are also included. Typical activities include emergency road openings (which may re-establish full service or provide temporary detour); large-scale debris removal and demolition; repairs and construction needed to restore the facility to its pre-disaster condition. Some realignment or upgrading of the original facility may be included, but the overall scope of the work must be associated with a catastrophic event.

Anticipation

This category of actions might be considered "preparedness planning". Not all events can be avoided; destructive events will occur despite the best preventative actions to minimize risk and the potential for damage. A primary example of anticipation is making arrangements in advance for transfer and disposal of excess material. Despite the pressing need for such efforts, however, most preparedness type actions would be considered "protective betterments" as defined by the SHOPP, and their ability to compete for statewide funding would be limited when urgency is not apparent and the project does not qualify as emergency work.

4.0 Using an Integrated Process

Developing projects to deal with the pressure of deteriorating conditions or responding to complete failure that disrupts service requires a high level of efficiency and coordination. Activities must be coordinated within the Department as well as among the regulatory agencies, community stakeholders and landowners adjacent to the project, particularly when project-related activities may extend outside the highway right-of-way.

4.1 Interdisciplinary Approach

Expertise from a variety of disciplines is critical to Caltrans' approach to evaluating conditions, exploring alternatives, and making recommendations regarding complex problems. Among the primary disciplines are:

- Geotechnical Engineering
- Environmental Planning
- Landscape Architecture
- Project Development
- Design
- Maintenance
- Hydraulics
- Construction
- Right of Way

4.2 Following a Logical Process for Decision Making

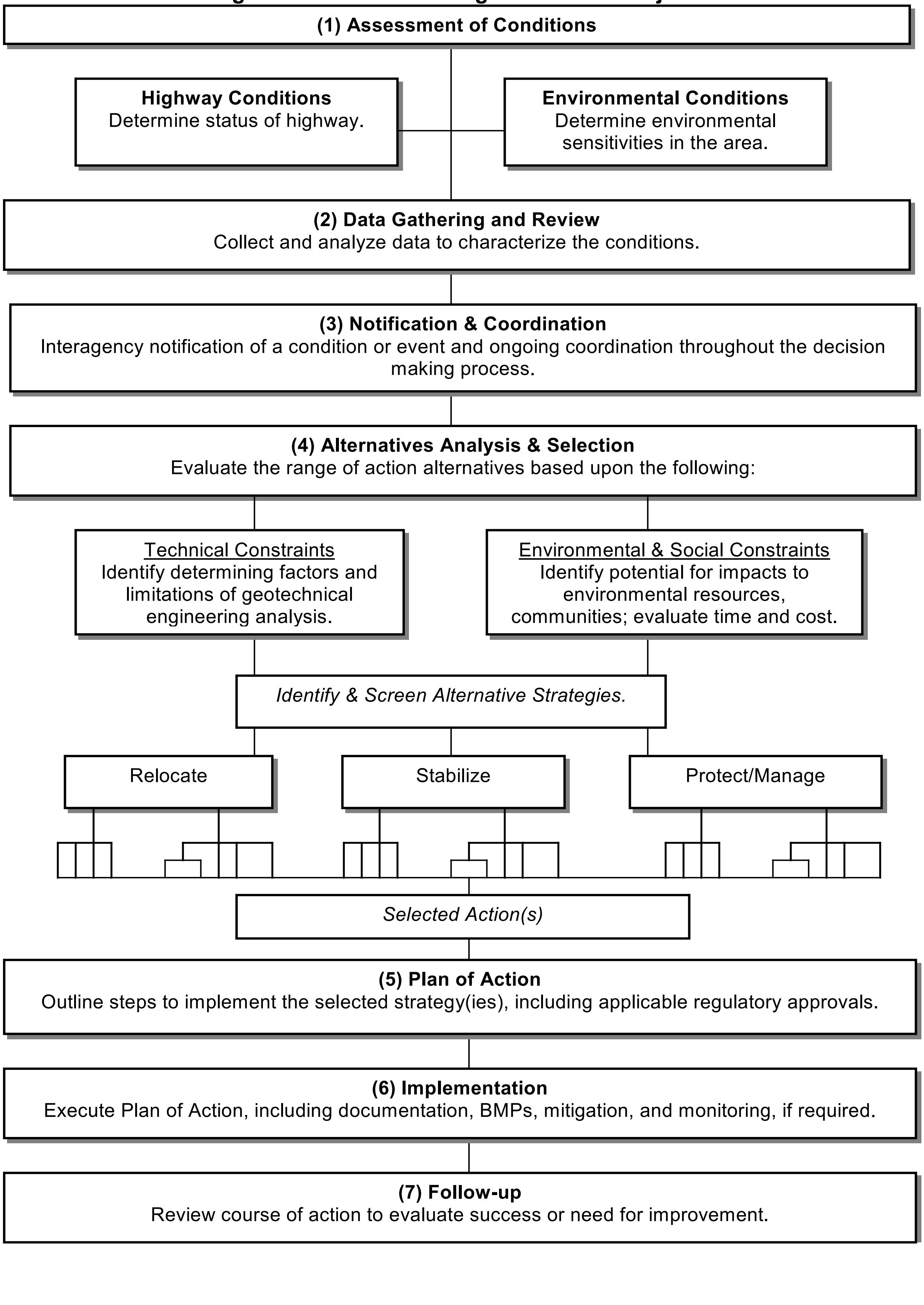
The Department follows a rational decision-making process for any project, whether a planned capital improvement or a project developed quickly in response to a site condition where traveler safety is compromised or the integrity of the highway is imperiled (Figure 5). While the process is applicable in any situation, the timeframe for proceeding through the steps will vary depending on the condition of the highway and the urgency to restore service. An urgent condition will progress on a very compressed timeframe (Figure 8). In any event, the progression must be reasonable and prudent for a timely response to address any situation where the integrity of the highway is compromised.

(1) Assessment of Conditions

Highway Conditions. When a deficiency is noted, an engineering site reconnaissance would be undertaken and the need for a project determined. The current assessment of corridor-wide conditions is catalogued as part of the Potential Slope Instabilities Database. In cases where projects have not been constructed and a situation escalates to where a break in service has occurred, the criteria to be used to evaluate the situation are outlined in Table 2 and described below (in no particular order):

- **Estimated Quantity of Material:** The estimated volume of material that appears to be involved in a landslide or debris flow event provides an order of magnitude that will help direct the response. Generally the first order of the threshold ranges offered (up to 1,000 cubic yards) is within the quantities that Maintenance crews may handle. The higher ranges reflect correspondingly more significant events and the options available to handle the material will be critical to determining the time required to restore service.

Figure 5. Decision Making Process for Projects



- **Estimated Duration of Closure:** Estimating the probable duration of closure is highly dependent on the overall quantity of material to be moved, but also on the selected repair strategy. Nevertheless, a provisional estimate about the potential closure (one lane or both lanes) is important for making provisions for emergency services, local and through traffic. Phasing that could enable access for emergency vehicles and essential services followed by considerations for an intermediate detour is included. The time periods shown in the table are indicators to guide development of provisions for accommodating local traffic (including commuters and school buses) and inter-regional traffic (visitors and long-distance travelers).

- **Proximity to Available Receiver Site (Haul Distance):** When excess material cannot be used for replenishment onsite or reused nearby, landslide material must be hauled to off-site locations. The distance of the haul determines the number of trucks required for efficient haul operations and, therefore, the production rate for moving material from the site to reopen the road. Generally speaking, hauling distances over 10 miles in one direction significantly impact production rates and the time to complete construction.

- **Roadway Status:** The integrity of the highway is assessed based on the degree of damage or imminent threat. The type and presence of cracking may pose a variable threat depending on other conditions at the site. Determining the degree of stress and threat to highway stability is a critical judgment by professional staff. The distinctions provided indicate whether hillside stability can be carefully monitored (i.e., without immediately requiring a closure), or whether a section of the roadway is so damaged that it must be partially or completely closed to protect traveler safety.

- **Detour Length:** The availability and length of detours to bypass a damaged section of highway is an important factor. Generally, few alternatives exist on this coast; in some cases, existing private or public connections can be upgraded or new connections can be provided. On most sections of the coast, however, opportunities for detours are extremely limited. The length of the detour option is an indicator of the potential severity of the service disruption.

Environmental Site Conditions. An environmental site reconnaissance would also be undertaken to locate and identify resources near the event or proposed project. Many Highway 1 corridor environmental resources have been catalogued as part of the Potential Slope Instabilities Database and the CHMP inventories of intrinsic qualities: Natural, Historic, Cultural, Scenic, and Recreational Qualities Inventories.[13]

- **Topographic Conditions:** Topographic considerations include geology, slope stability, seismicity, hydrology, water quality, storm water runoff, wave action, and

[13] Farwestern Anthropological Research Group. *Cultural Resources Inventory of Caltrans District 5 Rural Highways*. June 2001; JRP Historical Consulting Services. *Corridor Intrinsic Qualities Inventory: Historic Qualities*. November 2001; Parsons Brinckerhoff. *Corridor Intrinsic Qualities Inventory: Cultural Qualities*. March 2002; California Department of Transportation. *Historic Resources Inventory Report*. November 1996; Parsons Transportation Group. *Corridor Intrinsic Qualities Inventory: Natural Qualities*. November 2001; Pattillo & Garrett Associates. *Corridor Intrinsic Qualities Inventory: Recreational Qualities*. November 2001.

climate (precipitation and wind erosion). Each of these factors affects the stability of the area and can limit the range of appropriate responses based on engineering and volume demands. Slope, soil type, water availability, and erosion can be structurally challenging, singly or in combination. These factors also indicate the potential for loose debris that may affect downstream locations. Responses must consider these factors or system failure may occur. Assessment of these conditions also indicates the location of potential landslide movement to inform advance planning.

- **Biological Resources:** Biological resources include terrestrial and marine habitats, special-status plants and animals, the coastal zone, and wetlands and other waters of the United States. Construction, earth moving, or disposal activities can damage these resources both directly and indirectly. Areas with sensitive resources may constrain activities that utilize heavy equipment or involve excavation, sidecasting, hauling, or land coverage. If such activities are critical to the response, mitigation measures such as worker education, avoidance, temporary species relocation, covering of loose earth products, removal and stockpiling of top soil, and replacement and enhancement of disturbed areas, can be identified early in the planning process.

- **Community Resources:** Community resources include cultural and historic resources, visual and aesthetic resources, public recreation lands and private property. Such resources may be negatively affected by construction activity through displacement or direct loss. Therefore, the range of acceptable landslide responses may be limited if the surrounding environment contains these assets.

(2) Data Gathering and Review

Once on-site conditions are assessed, more comprehensive and detailed information about the site would be collected and evaluated. Physical conditions affecting the site would be noted, such as geologic characteristics, soil type, topography, settlement patterns, groundwater, anticipated subsurface conditions and history of activity. Environmental resource information would expand the assessment of habitat types, biological, cultural and visual resources. A preliminary geotechnical investigation would be conducted to develop comprehensive information about site conditions and constraints. Information needs and level of analysis for the affected disciplines, such as environmental review and geotechnical investigations, are performed in accordance with Department policy and procedures as well as established internal guidance documents.[14]

(3) Notification and Coordination

This step is relevant to agency and community stakeholders. For non-emergency conditions, interagency coordination proceeds through traditional methods. However, in order to improve the efficiency of interagency coordination to accelerate response and restoration of highway service, a new notification form should be developed for non-emergency projects. The process for ensuring priority given to the review of protective betterment type projects is an important aspect of agencies' shared responsibility for preventing or reducing the magnitude of a potential failure. Timing and frequency of coordination (corresponding to project milestones) will vary with individual projects. Under emergency conditions, the Interagency

[14] Caltrans Standard Environmental Reference, including the Caltrans Environmental Handbook (Volumes I-IV) which outlines guidance for evaluating impacts under CEQA/NEPA and resource-specific laws and regulations. http://www.dot.ca.gov/ser/

Emergency Notification Form (ENF) is used as the primary tool to coordinate among agencies that may have jurisdiction over certain activities (Appendix C). Appropriate information is also provided to travelers, both local and inter-regional traffic, residents, and businesses (Appendix D).

Table 2. ASSESSMENT OF HIGHWAY CONDITIONS

INCREASING SEVERITY

Estimated Volume (cy) To be removed	Expected Duration of Closure (total elapsed time to full 2-way service)	Proximity to Available Receiver Site (Haul Distance)	Roadway Status	Detour Length
Up to 1,000	Temporary lane closure or Complete highway closure up to 12 hr	On site 0-miles	Roadway intact (burial or encroaching threat-erosion)	Up to 1-mile
		0-10 miles		
Up to 100,000	Long-term lane closure up to 10 weeks Complete highway closure up to 5 days	10-50 miles	Distressed pavement (cracking)	1-10 miles
		50+ miles		
			Loss of Roadway	
Up to 1,000,000	Long-term lane closure over 10 weeks		Shoulder	10-100 miles
	Complete highway closure up to 1 month		1 lane	No detour available (landlocked)
	Complete closure up to 6 months		2 lanes	
	Complete closure up to 1 year			

(4) Alternatives Analysis and Selection

A range of alternative response or repair strategies would be developed based on site conditions and characteristics of the surrounding environment. Cost estimates would also be prepared as part of this step. An initial range of alternatives would be derived with information from the geotechnical site investigation (for understanding physical parameters and technical constraints) together with information about environmental sensitivities and community needs. Field exploration would usually be supplemented with additional subsurface testing and analyses to better describe anticipated subsurface conditions. A review of the potential for environmental effects, including biological, cultural (contemporary, historic, prehistoric) and visual impacts would be conducted.

The analysis at this stage would identify both the repair technique (construction) and secondary actions, such as the recommended disposition of excess material and site restoration strategy. In combination, the technical information together with the consideration for environmental and socioeconomic impacts screens the range of alternatives for developing an action plan.

Under non-emergency conditions, the geotechnical analysis would be described as part of a written report. Environmental considerations would be reviewed in compliance with CEQA and NEPA and other resource-specific laws and regulations, as applicable to the project.[15] Under emergency conditions, all of the same information would be collected, but it would be documented in an abbreviated format. The scope and level of detail of the information, however, may be less; in particular, subsurface exploration of conditions may be limited. Generally, an alternatives analysis conducted under shorter timeframes may favor a more conservative approach.

Coordination activities initiated in step 3 would extend to the evaluation and selection of a preferred alternative. As with the documentation, the degree of coordination activity would vary with the time available (i.e., during emergency procedures, certain coordination activities may be waived or conducted within a compressed timeframe).

To thoroughly understand the various options, each alternative should include a preliminary plan of action and describe proposed mitigation and monitoring requirements and other follow-up that may be required. Written documentation of the alternatives analysis is an important component of the decision-making process.

(5) Plan of Action

Steps would be outlined to implement the selected repair strategy, including applicable regulatory approvals prior to commencing work. The steps may include any additional notification, coordination of environmental review and regulatory permits, right-of-way, site preparation, restoration planning, engineering design (roadway and structures, as applicable) and construction. Interdisciplinary review of the proposed plan is essential since implementation will require interdisciplinary action. Since action by several agencies may also be required, coordination and feedback processes are critical to ensure that all steps and coordination requirements are clear to all parties.

[15] Professional staff, in accordance with well-established guidelines for review and analysis, performs both the geotechnical and environmental evaluations.

(6) Implementation

Carry out the actions as outlined above, ensuring that all requirements are identified and honored in the field. Any required changes must be carefully evaluated and documented as they occur. Appropriate coordination consistent with agreed-upon parameters and as applicable to the nature and extent of any changes will be conducted.

(7) Follow Up

The follow-up portion of the process encompasses monitoring, evaluation, reporting, and recommendations for any future action. Follow-up documentation would take the form of a Project Completion Report (Appendix E). The Project Completion Report would document:

- Information about the project as built.
- Review of environmental impacts (associated with project construction).
- Successes or failures encountered with mitigation measures.
- Any additional monitoring or follow-up requirements.

An evaluation of the implementation program (looking at both processes and actions) would be conducted on an annual basis. Needs for improvement would be outlined as specific actions.

Figure 6. Project Processing

Decision Process Step	Information: Method	Information: Detail	Funding: Regular SHOPP: Minor	Funding: Regular SHOPP: Major	Funding: E*: Emergency
(1) Highway Assessment	Annual monitoring report	Updated database of potential slope instabilities with identification of potential projects	x	x	
	Interagency ENF	See ENF			x
(2) Data Gathering & Review	GIS Database Review Site Investigations Field Review	Technical Reports as outlined for each discipline	x	x	
		Technical memoranda for each discipline			x
(3) Notification & Coordination	Priority project processing**	Corresponding to the potential for specific impacts, regulatory jurisdiction and potential traffic disruption	x	x	
	Expedited procedures or waivers				x
(4) Alternatives Analysis & Selection	Supporting documentation for project specific environmental review	Corresponding to the potential for impacts to sensitive resources	x	x	x
(5) Plan of Action	Project Approval Document and Contract Plans	As necessary to guide construction activities and interagency coordination; supplemental documentation may be required for interagency coordination	x	x	
	Memoranda	As outlined to include agency responses to the ENF			x
(6) Implementation	Construction & Mitigation	N/A	x	x	x
(7) Follow Up	Project Completion Form and Annual Review	Description of impacts/mitigation; successes and failures	x	x	x

* Pursuant to a determination by the Department of Transportation that an emergency condition exists.

** Identification of priority processing details consistent with each agency's responsibilities and obligations is recommended as a future action towards the CHMP objective of environmental streamlining.

5.0 Fundamental Highway Repair Strategies

This section provides an introduction to the basic strategies available to the Department for highway repair and landslide management, culvert and drainage maintenance and repair, and earthwork. This information lays the foundation for the best practices presented in Section 6.

5.1 Managing for Landslides

The Department employs three approaches or strategies for maintaining a functioning highway in a landslide-prone environment:

- Relocation or Separation
- Stabilization
- Management and Protection

These strategies are not mutually exclusive, nor listed in any particular order. A repair project for an individual location may include elements or techniques from more than one strategy, depending on the specific site conditions. In the descriptions and examples that follow for each of the three strategies, an indication is given as to whether minor or major SHOPP funding would be most likely. Given an escalation of circumstances, usually precipitated by a natural event such as a storm or earthquake, any of these projects could be undertaken as part of the Emergency Relief program with SHOPP funding under certain circumstances.

Relocation or Separation
This strategy involves moving the roadway alignment away from the problem area, thereby separating the highway from further influence of the natural land movements. Relocation protects the public investment in the facility while allowing the natural processes associated with landslides to continue without interference. This approach includes minor realignments as well as construction of bridges, viaducts, and tunnels. In many cases, a separation project requires substantial planning and involves high costs and considerable time for project delivery. Except for a minor realignment-type project, most of these projects would compete for funding among major SHOPP projects.

Stabilization
Stabilization refers to techniques applied to a slope to prevent or minimize movements from either above or below the highway. Examples of stabilization techniques include buttresses, retaining walls, crib walls, shoreline armor, anchor bolts and reinforced earth embankments. Completely removing an unstable mass (potential landslide) is also a legitimate stabilization technique. Aspects of stabilization approaches may also include modifications to control surface or subsurface water to avoid retention or concentration of water that could lead to severe erosion or saturation and ultimately slope failure. Depending on the magnitude of the instability, stabilization-type projects could be funded under the minor or major SHOPP program.

Management and Protection
The primary objective of management and protection is to reduce the potential for damage from future movement or failure. Management and protection techniques apply a variety of measures to protect the traveler from harm and the highway from damage. The newest techniques are consistent with a strategy of “living with” a certain amount of

on-site movement by balancing the forces of the instabilities. Techniques include reducing the driving forces of a landslide (for example, removing a mass of material from the head of a landslide) or increasing the resisting forces (such as buttressing a slope). While balancing forces may prevent or reduce the likelihood of a larger scale event (or movement), slopes may continue to move more gradually. While localized (or smaller) instabilities may continue to be apparent, stability may be achieved more globally.

Other management and protection techniques include installation of rockfall protection devices such as rocknet fences or drapery, construction of catchment areas allowing material to accumulate safely away from the traveled way, and simple embankment reconstruction. These techniques, which are both economical and practical, are now employed regularly throughout the corridor. As with stabilization type projects, either minor or major SHOPP programs may fund management and protection activities.

5.2 Managing Drainages and Culverts

Managing the flow of water under and around Highway 1 along the Big Sur Coast is also essential to continued highway operations. Over 700 culverts carry water under this 75-mile stretch of highway, while approximately 40 bridges span larger waterways or steeper canyons.[16] The primary function of good drainage is to prevent ponding of water on the roadway and to maintain the free flow of water around and across the highway. An active program is necessary to ensure the proper functioning and overall integrity of the drainage facilities.

Drainages are important components in the overall landscape and can serve multiple functions. Cross-highway drainages may have a function as a natural wildlife corridor. In some cases, these same areas may provide conduits under the highway for pedestrian or other non-motorized access as well. The extent to which wildlife crossings may be present along individual drainages is included in the Natural Qualities Inventory.[17] Further information that may be used to determine wildlife corridors that may coincide with cross-highway drainages is available from a volunteer “roadkill survey”[18]. Data collected over several years time may be used to identify trends in wildlife crossing patterns. The multiple functionality of drainages is an important consideration in the overall scheme of managing these features that are most well-known for conveying water.

Although overside drains and bridges also have important functions in conveying water across or under the highway, the focus of this discussion is culverts. Culverts consist of three main components: the pipe or box, the inlet and the outlet. Each component is periodically evaluated against multiple criteria for healthy function, but these criteria generally take into consideration *flow, energy dissipation,* and *structural integrity*.

Proper *flow* is maintained by ensuring that facilities remain free from obstructions, such as woody growth and sediment build-up. Obstructions can result in water and debris backing up behind the roadway embankment, and in severe cases, loss of the roadway. *Energy dissipation* focuses on the outlet of a culvert or overside drain and at the piers of

[16] *Draft Culvert Inventory for the Big Sur Coast Highway Management Plan.* May 2002
[17] Parsons Transportation Group. *Corridor Intrinsic Qualities Inventory: Natural Qualities*. December 2001.
[18] Smiley, John. Big Sur Coast Highway Volunteer Roadkill Survey. 2003. http://www.redshift.com/~bigcreek/roads/roadkill_survey/index.html

bridges (scour) to ensure that erosive action from the water is not causing an aggravated condition that is threatening either to the environment or to the structural integrity of the facility itself. The *structural integrity* of the facility, including the fundamental condition of the pipe and its component ends, is important to ensure that the system operates as a fully functioning unit to handle water and the associated debris that gets carried downstream.

As noted in Section 2.3, above, debris flows are common in some places along the corridor. Debris flows occurring upstream from the highway can have a severe impact on the facilities, which emphasizes the need to manage the debris as well as the water that flows downstream, especially during a storm event. Three techniques for effectively managing culverts are:

- Debris Management
- Rehabilitation
- Replacement

Debris Management

Debris-flow protection strategies can be looked at as measures to protect the highway before or after debris enters the right-of-way. Strategies attempting to mitigate debris flow before it gets to the highway are complex and this rugged section of coast is not conducive to them. An example would be construction of basins to impound debris before it reaches the highway. Inter-agency cooperation – for example, to ensure that trimming vegetation to improve fire safety does not pose culvert debris management problems downstream – could be undertaken on a regional or watershed basis. This is an option for future exploration.

There are prudent methods to handle debris flows once they reach the highway, and the best method would be simply to allow debris to continue beneath the highway unimpeded. Generally, only the largest of culverts or a bridge would accommodate major debris flows. Larger culverts also enable easier passage by wildlife. Sizing a culvert to pass debris flow is difficult. A bulking factor can be added to account for an estimated quantity of suspended sediment and bed load but there is still uncertainty about what the debris will contain. A general idea of the future debris can be gained from past debris flows.

Candidate locations for debris-flow protection projects may be identified with information from the landslide maps produced by the California Geologic Survey. Typical methods to protect an inlet from debris flow include installation of risers, bear traps, debris racks, and overflow inlets. The first three measures trap debris while allowing water to continue to flow into the inlet; the overflow inlet is a second large culvert installed at a higher elevation than the first, allowing water to flow through if the original culvert becomes blocked. These actions serve to prevent highway inundation and potential loss of the roadway.

Debris management techniques can be installed as part of regular maintenance or may be funded as part of a Minor project.

Rehabilitation

Rehabilitation is an intermediate measure to extend the service life of an existing culvert and can be carried out with relatively little disruption to traffic and the surrounding environment. These strategies involve protecting and reinforcing the existing culvert, generally by lining them, before excessive corrosion causes the culvert to lose its shape or escaping water has eroded its essential support. The lining options include liners of plastic, resin and cement mortar. All rehabilitation strategies require complete cleaning of the existing culvert and access to both the inlet and outlet. These techniques are often funded as part of the Minor program.

Replacement

Culvert replacement is necessary when the service life has been reached and the facility can no longer be maintained effectively and is beyond simple repair or even rehabilitation. Replacement may also be necessary if other activities occur in combination, such as landslides, where an event may cause collapse or serious deformity. Two methods for replacement are available: cut and cover or jacking. Cut and cover is the simplest method, involving excavation of a trench to remove and then replace the culvert in place. The second method, jacking, is generally used when culverts are located under deep fills; this technique employs a type of tunneling and usually requires construction of temporary pits at the inlet and outlet ends. With few exceptions, culvert replacement projects are funded as part of the Minor program.

5.3 Earthwork and Handling of Excess Material

Properly handling earthwork activities is a combination of reducing overall disturbance to the extent practicable to minimize generation of excess material and finding suitable destinations for any such excess.

Even using the most prudent construction techniques to minimize the area of disturbance, some excess material must generally be transferred from a work site in order to reopen the highway for service. The earthwork activities described below can result from activities undertaken as described in Sections 5.1 and 5.2 above. The amount of excess material generated and how it is handled are the controlling factors in determining how quickly highway service can be restored after significant storm damage.

Figure 7 below illustrates the relative time to opening based on hauling distances for excess material; the example is based on a hypothetical situation where 20,000 cubic yards of material must be removed to restore service. In addition to delay, the cost of handling material is high in relation to total construction costs. For a single repair project during in the year 2000, the cost of truck hauling was approximately $1,200/day per truck. Twenty trucks, each having a capacity of 10-cubic yards, were involved in the operation, resulting in an estimated expenditure of $24,000/day for hauling costs alone. Additional direct costs are incurred for loading, traffic control, and spreading the material at its destination. Indirect but very real costs are not charged to the project: roadway wear and tear, impacts to travelers and loss of business revenue for the duration of a closure.

All of the earthwork activities described here result from activities undertaken as described in Sections 5.1 and 5.2. Determining the disposition of that material, however, has been the subject of much discussion and is not easily resolved.

Earthwork Strategies

The Department's historic approach to earthwork related to highway projects along the Big Sur corridor is captured by the familiar mantra: "reduce, reuse, recycle." These three options are not mutually exclusive. They can be used singly or in combination for any given situation. However, even where reduction, reuse and recycling are achieved, residual material may remain that requires further handling. The full array of options for handling material on the Coast Highway corridor is the following: reduce, reuse, recycle, replenish and dispose.

(1) Reduce overall quantities by selecting maintenance and repair techniques and practices that reduce the overall footprint of disturbance and in the case of repairs are the least disruptive beyond the event that destabilized the highway.

(2) Reuse material that is viable for other highway maintenance or reconstruction projects. Rock and soil suitable for other highway repairs would be re-used locally or in other parts of the corridor, as needed. For structural use, the material cannot be high in organic matter; for revegetation efforts, organic material such as duff or topsoil is an important component. Care must also be taken to avoid the export of exotic plant material within the corridor. Material slated for reuse may require double handling as it may be stockpiled and processed for later use.

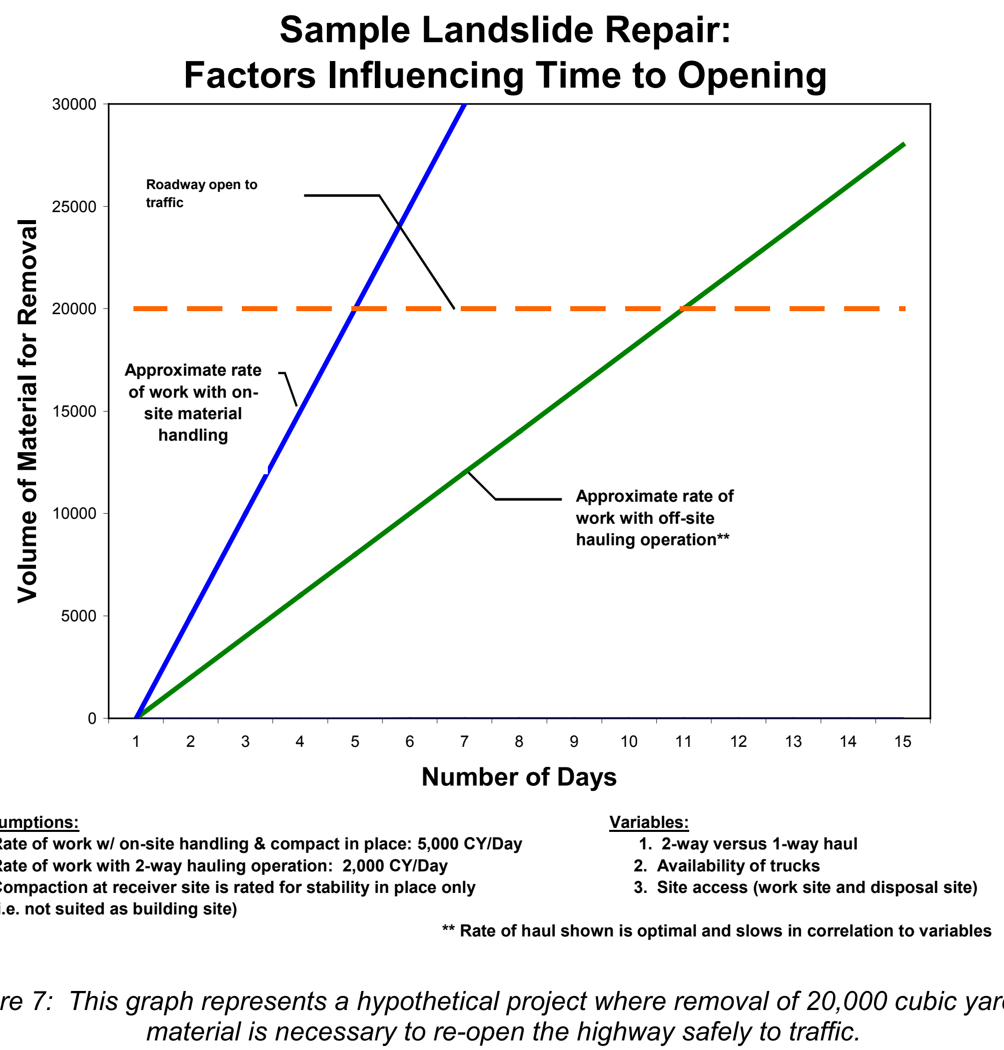


Figure 7: This graph represents a hypothetical project where removal of 20,000 cubic yards of material is necessary to re-open the highway safely to traffic.

(3) Recycle material for non-highway uses, either along the corridor or elsewhere. This involves transferring material that has commercial value for use in other approved public or private development projects or activities. Recycling may require double handling or long transport.

(4) Replenish sediment supplies to natural systems by removing or bypassing man-made barriers. Replenishment would take place in circumstances under which the highway (or highway management practices) may inhibit natural flow of sediment.

(5) Dispose of any remaining excess material that cannot be put to any other beneficial use. Disposal may require double handling depending on its final destination.

Assuming the most vigilant actions to minimize the quantity of material that would require any transfer (i.e. opportunities to first reduce, reuse and recycle are maximized), residual material is a given under many circumstances. The primary decision is to locate an appropriate receiver site. Trucks are the conventional means of transport.

Receiver Sites

Determining the final destination for residual material is a discretionary action. As with repairs, alternatives must be considered; unlike repairs, the range of potential locations is fundamentally broader.

Suitable receiver locations within the corridor are extremely limited. Under current practice, the default response is to take material to landfills, either commercial facilities or private or public properties, where a landowner/manager will accept the material. In preparing material for its ultimate destination (also the case for reuse and recycling) temporary stockpile areas are often needed. Stockpiling is a useful option for expediting aspects of a highway repair before material can be processed or hauled to its destination. Stockpiling involves double handling.

Due to the magnitude of the potential events and the effort required to prepare a site, permanent receiver sites less than 5,000 cubic yards are generally not cost effective for the Department. Receiver sites of 50,000-100,000 cubic yards offer economies of scale and so may warrant investigation, environmental evaluation, design and permitting.

In the summer following the 1998 El Nino, the Department began the process of developing potential disposal sites that could be used in response to future storm events. Initially, 45 terrestrial sites were identified and sent through a screening process. The Department approved nine of those sites with a Negative Declaration under CEQA. Four of those sites are proceeding through the regulatory permit process.

Natural sinks for sediment must also be considered as an important option for handling material. Along this corridor, the ocean is considered a natural sediment sink. Landslides and streams deliver sediment to the ocean as part of natural coastal erosion processes. The degree to which human influence aggravates the volume of material generated remains an unanswered question[19]. Future research findings may determine the degree to which regulators will allow the ocean to be relied upon as part of the solution to handling excess material. Decisions on this subject will rely on a formal

[19] Hapke, 2003.

environmental review process to carefully evaluate the various alternatives and the potential environmental effects.

Where repair techniques have involved mechanical excavation of slopes, relatively recent regulatory decisions have generally precluded options involving the ocean as a sediment sink[20]. However, where the source and quantity generated is accepted as entirely natural (defined loosely as involving no mechanized or human-assisted excavation of a slope), the ocean has been accepted as a legitimate sediment sink.[21]

The potential for adverse environmental impacts is the driving factor in the decision-making process. Adaptation and tolerance of the receiver site or habitat must be evaluated to determine the severity and duration of potential effects. Changes to terrestrial sites with appropriate surface treatment to restore vegetation have traditionally met with greater acceptance in the coastal development permit process than changes to the shoreline. This is due in part to a lack of scientific information on which to assess recovery rates of shoreline intertidal habitats from the potential effects of burial, turbidity and scour. Regulatory agency managers have requested additional study of the sensitivity of these habitats and a better (quantitative) understanding of the ambient sediment budget to advance decision-making on this subject.[22]

Transport Mechanisms

Trucking is the conventional method for transport, trips over 10-miles one-way from the source are considered long-haul trips, where costs increase exponentially. Barge transport to other destinations may be an option in the future. Such an option would likely driven by the commercial value for suitable material.

Several transport mechanisms may also be considered under scenarios involving the ocean a natural sediment sink. These include mechanically depositing material over the side of the highway; loading natural landslides for gradual deposit by wave action; barging material to approved offshore ocean disposal sites; and pumping material into the surf zone or beyond in order to avoid burial of intertidal habitats. These mechanisms are still under discussion as to whether they are appropriate along the Big Sur Coast.

5.4 Weighing the Options and Managing Risk

Given the responsibility to preserve the integrity of the highway, the Department maintains full-time crews in the field. These maintenance crews are the first-line of observation and action on a daily basis. Staff from the geotechnical branch also makes regular reviews of active landslide areas, which may include monitoring with scientific instrumentation to detect and record information about subtle movements.

Managers employ databases to organize and track information centrally about two critical aspects of highway management and function: landslides and drainages served

[20] By application of current regulations of the Monterey Bay National Marine Sanctuary.
[21] Resulting from over 20 years of investigation, research and negotiation. Waddel Bluffs, Santa Cruz County.
[22] Initial components for developing a sediment budget along the Big Sur Coast may be initiated by the US Army Corps of Engineers through a Coast of California Study.

by culverts.[23] While the traditional approach is to look at isolated sites at a point in time, an interdisciplinary team with access to a well-maintained comprehensive database can consider conditions at multiple locations concurrently or observe trends at specific sites over time.

Multi-disciplinary teams with specialized expertise evaluate problem areas or notable changes in conditions. Locations that exhibit high rates of change, or are chronic and highly labor intensive to maintain, may be identified as potential project locations. Once initiated, a formal investigation would determine whether a preventive type project could effectively correct or improve an existing situation. The investigation would also identify a range of possible technical solutions. With good information about the potential solutions, managers can seek funding to complete project development and construction (see Section 3.2).

Available funds are insufficient to address all the locations along the Big Sur Coast that exhibit stress from underlying movements or instabilities. Even if funds were available, the degree to which the sum of the repairs would measurably improve reliability along the corridor might not outweigh the cumulative impacts to the surrounding area and the long-term, nearly continuous disruptions to traffic during construction of the repairs. It is not desirable to initiate projects at every location of instability along the Big Sur Coast. However, advancing knowledge of potential trends and hazards is recommended to develop a more systematic long-term management approach.

As the owner and operator of the highway, the Department continuously evaluates risk and sets priorities for repair at individual sites throughout the corridor. Under the current approach, those locations where instabilities are known to have the greatest potential to adversely affect traveler safety or threaten the integrity of the highway are given the highest priority. Careful engineering judgment is required to make this determination.

When initial assessments indicate repair can be accomplished for $750,000 or less, projects can be initiated under the Minor program. Projects are initiated for programming as a Major project when enough information is available to demonstrate that the repair strategy is likely to exceed the Minor limit and the urgency of the situation will make it competitive on a statewide basis.

Traditional maintenance activities are generally carried out within parameters that do not require individual regulatory approvals.[24] Implementing more involved preventive or corrective action usually requires greater levels of coordination and a longer timeframe. Ultimately, delivering such projects in a timely fashion becomes a responsibility shared among a number of stakeholders.

Effective coordination must involve community and other non-governmental stakeholders in the decision-making process in conjunction with traditional review by regulatory agencies. Because there are times when the Department must act quickly, it is important that stakeholder issues have been well defined ahead of time

[23] See Locations of Potential Slope Instabilities and Culvert Inventory Databases.

[24] Note that certain maintenance actions, such as work in streambeds or sensitive habitats, are subject to compliance with resource-specific laws and regulations, such as the California Fish & Game Code and the Federal Endangered Species Act.

When a capital improvement is funded to undergo the formal project development process, detailed site investigations are conducted. If a project is not approved to undergo project development and an urgent situation develops, accelerated action will take place. The risk in expediting the analysis and design in such a situation is that the conservative engineering approach will prevail. The more information available, the more thorough the analysis can be that informs the design.

Fundamentally, as an essential service, any break in highway continuity needs to be restored as soon as possible. As a first priority, safe emergency vehicle access is critical. Accommodating local and through traffic is the next priority, and must also ensure traveler safety. Since existing detours via local roads are not readily available on the Big Sur Coast, establishing a practical detour may also be part of the repair strategy. Such detours can require new construction or upgrades to existing private or public roads. Unless a structural solution is contemplated, the single greatest factor driving the time required to reopen the highway is the efficiency of moving material (quantities, rates, and distance), see Figure 6.

The emphasis on effective interagency coordination relies on both a shared understanding of programs and funding and a shared commitment to a set of process-related practices. These are outlined as follows:

- Minor SHOPP projects can be delivered most rapidly, as these programs are managed locally (District 5).

- Delivery of Major SHOPP projects requires greater time, in part due to the statewide competition for funds. These projects may be more likely to involve structures, requiring detailed investigations, foundation studies and design.

- Emergency Relief (ER) funding is made available only under a declared state of emergency. This funding is also from the SHOPP.

- Any project could be elevated to an emergency project should conditions deteriorate before design and all approvals are obtained. The Forest Boundary viaduct illustrated this, where geotechnical investigation had been underway when a failure impacted the southbound lane.

- The Department is granted statutory authority to determine when an emergency exists for the condition of the highway.

Given the conditions above, the following actions are suggested for the Department to take:

- Maximize opportunities to evaluate and monitor site conditions on a corridor-wide basis, that would promote more trend analysis and enable evaluation of potential solutions at a larger scale.

- From the trend analysis, identify priority locations for geotechnical and environmental site investigations.

- Initiate projects where a specific need is identified and a concept for a feasible solution validated.

- Analyze proposed improvements in respect to resource impacts (e.g., impacts to terrestrial or marine habitats and/or sensitive species) and considerations for cost, community disruptions, and delays in restoring highway service.

A suggestion for key stakeholders is to cooperate in designing and sponsoring research and demonstration projects that will clarify the impacts and tradeoffs of projects and practices on the corridor.

6.0 Best Available Techniques

Remaining up to date with developments in new technology and materials is a high priority for the Department. Innovation in methods and materials is often the means to improve outcomes while reducing or avoiding impacts to the environment. This section of the guidelines describes best available techniques for handling the following categories of activities:

1. Landslide Management
2. Drainageway and Culvert Management
3. Earthwork and Materials Handling

The techniques described below are theoretically feasible for the Department to consider. Several techniques, however, have not been tested or are not readily available for use for a variety of reasons including costs and completion of environmental analysis. As innovation continues, many of today's best available techniques will be modified or supplanted over time, requiring updates to these guidelines. Modifications considered for implementation in the corridor will be evaluated through an inter-disciplinary approach.

6.1 Landslide Management

The best available techniques for landslide management are organized into three types of strategies:

Relocate or Separate - The basic strategy is to relocate or separate the roadway from the area of instability. This type of approach includes such construction techniques as viaduct/bridges, tunnels, or realignment of the roadway.

Stabilize - This strategy employs a variety of techniques to improve stability in place. This approach includes techniques such as buttresses, reinforced earth embankments, retaining walls, anchor bolts, soil nails, slope excavation and shoreline armor.

Manage and Protect – This strategy seeks to "live with" the landslide by hindering its movement and providing protection for travelers with physical barriers. Approaches include manipulating areas within a landslide in attempt to balance the driving and resisting forces or installing rockfall protection devices.

RELOCATION / SEPARATION

VIADUCT OR BRIDGE

Description

Bridge and viaduct structures are constructed to span major waterways or areas of instability; with the structure's foundations anchored into stable rock, flowing water or landslide debris continues while not interfering with the roadway and vice versa. The roadway exists on the deck surface (or superstructure) supported by a substructure of abutments, columns or piers and their foundations. A viaduct usually consists of a series of short structural spans, and may be partially constructed by a continuous roadway section. A sidehill viaduct might be envisioned as a half-bridge in the lengthwise direction, where, for example, the northbound lane is built as a typical roadway section and the southbound lane is built on a structure. Structure types and materials are selected based on geotechnical and environmental considerations, aesthetics, constructability, costs and traffic handling.

Application Criteria

Bridges and viaducts are considered in areas with high volumes of water or storm-related debris or where surface land movements can be bypassed. A bridge might also be considered where a more direct alignment across a canyon would be more cost effective and less damaging than following the terrain to the head of a gorge in order to make a crossing. A critical factor for determining the feasibility of any structure is locating suitable material to ensure a secure and stable foundation for the supporting piers and abutments.

Considerations

- *Separates roadway and terrain, minimizing disruption to existing terrain*
- *Minimal excavation and limited footprint*
- *Reduces roadway maintenance requirements*
- *Increase structure maintenance effort (inspection, monitoring and maintenance)*
- *Opportunity for aesthetic/architectural enhancement or "signature" design High construction cost*
- *Long lead time required for implementation*
- *Permanence of structure may constrain options for future improvements*

Sample Locations

- Forest Boundary Landslide (MON-1-1.5)
- Rain Rocks (MON-1-21.3)
- Willow Springs (MON-1-11.5)

Figure 8: The Forest Boundary side-hill viaduct completed in 2001.

RELOCATION / SEPARATION

TUNNEL

Description

A tunnel allows passage directly through a land barrier, such as a steep hill or mountain. Tunnels may allow a more direct route between two points without significant alteration of the landform.

Application Criteria

Important criteria for constructing a tunnel include the integrity and strength of the landmass: can the mass withstand the tunneling operation without collapse and can stable entry and exit portals be secured? Long-term lifecycle and maintenance costs must also be considered when evaluating alternatives for circumnavigating versus boring through the mountain. Power is also required for lighting and ventilation systems.

Considerations

- *Ability to penetrate rather than alter terrain*
- *Minimal footprint compared to slope excavation alternatives*
- *Opportunity to improve roadway geometry*
- *Direct route may bypass areas requiring intensive maintenance*
- *Natural flow of material and roadway coexist with fewer conflicts*
- *Very high design and construction cost*
- *Long lead time for implementation*
- *Increased structure maintenance effort (inspection, monitoring and maintenance)*
- *Provisions for lighting, ventilation and drainage*
- *Permanent structure may constrain options for future improvements*
- *Obstructs views from the road*

Sample Locations

- Waldo Tunnel, Route 101 Marin Co.
- Gaviota Tunnel, Route 101 Santa Barbara Co.
- Cascade Highway, Route 20, Washington

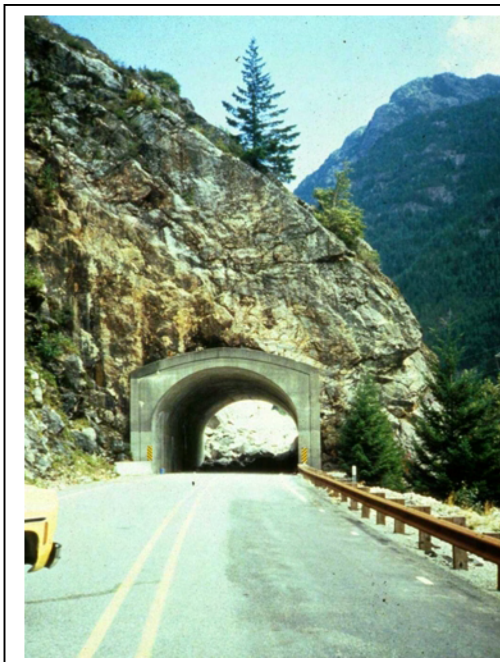


Figure 9: A two-lane tunnel on the Cascade Highway, State Route 20 in Washington.

RELOCATION / SEPARATION

REALIGNMENT

Description

Realignment moves the roadway away from an encroaching threat or instability and may vary greater in length and horizontal offset. On the Big Sur Coast, the degree of offset is constrained by the topography. Constructing a tunnel or bridge (above) is a form of realignment. Depending on the location, a typical roadway realignment on the coast involves some degree of excavation. Realignments accomplished with steep cut slopes may also require a catchment area in anticipating of localized sloughing that would be expected.

Application Criteria

Realignments can be considered where the highway can be moved to a more stable location or to facilitate traffic handling from a repair.

Considerations

- *Ability to move the roadway away from the problem area*
- *Opportunity to improve roadway geometry*
- *Facilitate traffic handling*
- *Typically more cost effective than other relocation/separation strategies*
- *Aesthetics and ability to revegetate new cut and fill slopes*
- *Presence of sensitive corridor resources*
- *Changes in access to adjoining areas.*

Sample Locations

- Pitkins Curve (MON-1-21.5)
- Mill Creek (MON-1-18.6)
- Hurricane Point (MON-1-59.0)

Figure 10: The roadway was realigned into the slope and a catchment area was provided at Hurricane Point.

STABILIZATION

BUTTRESS

Description

A buttress is a gravity system that depends on the friction and shear between the facing units and their combined weight to retain backfill or to enable slopes to stand more steeply than they could without reinforcement. Buttresses may be constructed with rock or wire enclosed gabions (containing smaller rock); in some cases, retaining walls also act as a buttress.

Application Criteria

Buttressing is a potential solution for small scale, local instabilities where there is a sound foundation for the buttress materials and sufficient area for access and constructability. Availability of suitably sized material is also a consideration.

Considerations:

- *Minimal footprint*
- *Reduces need for slope reconstruction or regrading*
- *Low cost*
- *Difficult to revegetate*
- *Access and constructability*

Sample Location

- Gorda, MON-1-10.1

Figure 11: The Gorda Retaining Wall (MON-1-10.1) is a large scale buttress, which supports the highway across a large landslide.

STABILIZATION

RETAINING WALLS

Description
Retaining walls are a means of preserving slopes and allowing them to stand steeper than without reinforcement. A retaining wall can be used for either cut or fill slopes. There is a wide variety of wall types and materials available including cast-in-place concrete; concrete or rock masonry; concrete, steel or timber crib walls; and an array of earth retaining systems that may combine tie-backs, soil reinforcement and facing panels. Factors that influence the selection of type and materials include the geology, design loading, height, foundation, constructability, costs and aesthetics.

Application Criteria
Areas with tight constraints where the footprint and earthwork must be minimized to reduce overall impacts; areas where steep slopes can be stabilized and minimize the effects of erosion. Examples of constraints include environmentally sensitive areas, right-of-way, native habitats and visual resources. Site geology is important to determine the maximum wall height, which is governed by the bearing capacity of the foundation material and the global stability of the site.

Considerations

- *Reduces earthwork and allows steeper slopes that minimize overall footprint*
- *Opportunities for aesthetic/architectural treatments*
- *Visibility*
- *Moderate cost*
- *Longer lead time for implementation*
- *Constructability requirements*

Sample Locations

- Grey Slip (MON-1-6.7)
- El Sur Ranch sheet pile wall (MON-1-55.1)

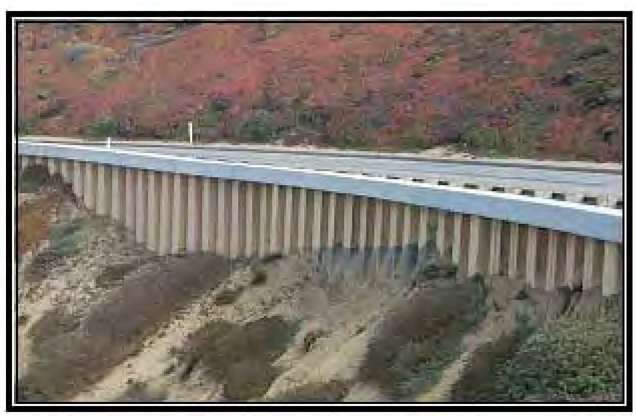


Figure 12: A sheet pile retaining wall was constructed near the El Sur Ranch (MON-1-55.1) to stabilize the roadbed from movement undercutting

STABILIZATION

ENGINEERED SLOPES

Description

Engineered slopes describe the application of specialized techniques to reinforce a cut or fill slope or to control settlement and erosion. Examples include lightweight fill; geotextile mats; grids or membranes to improve bearing capacity; slope benching and drainage systems to control surface and subsurface water, pore pressure and erosion. Techniques may also employ surface materials such as jute or mesh netting to control erosion and facilitate plant establishment.

Application Criteria

Similar to retaining walls, engineered slopes are considered where there are limitations on overall width due to environmental or property constraints. Engineered slopes are considered where the construction of conventional slopes is not feasible due to presence of poor or unsuitable foundation soils, lack of suitable fill material, or unusual geotechnical or loading conditions.

Considerations

- *Slopes can be built steeper than the natural material would generally allow*
- *Minimizes earthwork; small footprint*
- *Alleviates surface erosion and facilitates plant establishment*
- *Moderate lead time for implementation*
- *Cost-effective*

Sample Locations

- North of San Carpoforo Creek (SLO-1-71.4)
- South of Garrapata Creek (MON-1-62.1)
- North of Rancho Barranca (MON-1-31.5)

Figure 13: This reinforced earth embankment is located north of Rancho Barranca (MON-1-31.5)

STABILIZATION

ROCK BOLTS AND SOIL NAILS

Description
Rock bolts and soil-nailing systems achieve stability by binding friable or fractured in-situ rock and soil slopes. The anchors may be driven directly into the rock or installed into pre-drilled holes and grouted. The treatments may be used in conjunction with facing materials such as welded wire mesh, concrete or stone panels or reinforced shotcrete.

Application Criteria
Rock bolting and soil nailing techniques are used to increase the strength and stability of existing rock and soil slopes. Soil nailing can also be used to facilitate methods of excavating a cut slope.

Considerations
- *Stabilizes in-situ materials with minimal or no excavation*
- *Minimizes overall footprint*
- *Cost effective*
- *Slope retains a relatively natural appearance*
- *Moderate lead time for implementation*
- *Challenging working conditions for personnel and equipment*

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Sample Location
- Highway 9 in Santa Cruz County (SCr-9-13.5)

Figure 14: Soil nailing and in-situ reinforcement used to stabilize a slope after a landslide above Highway 9 near Boulder Creek in Santa Cruz County.

STABILIZATION

ROCK SLOPE AND SHORELINE PROTECTION

Description

Large rock used to alleviate stream bank erosion or bluff retreat is known as rock slope protection (RSP). RSP armors slopes that support features of the highway against scour in a stream or the erosive action of tidal and wave action along the shoreline. Sizing the rock will depend on the magnitude of the erosive forces and it may be either grouted or ungrouted. Other methods of shoreline protection include seawalls and wire mesh gabions (wire baskets filled with rock and interwoven).

Application Criteria

Shoreline protection is considered where it is not practicable, either from an engineering standpoint or the allowable time, to implement a long-term solution such as relocating the highway away from the erosive forces or onto competent rock. Choice of type and design will depend on site-specific coastal processes and conditions including wave run-up, elevation of mean high water; shoreline morphology, erosion rates, coastal access, aesthetics and costs. The guiding principle for engineering design is to stabilize the shoreline; issues of sediment supply and potential effects to the nearshore habitats must be considered for suitability to an individual site.

Considerations

- *Prevents undermining or erosion of the roadway embankment from tidal and wave action*
- *Cost effective*
- *Flexible, allowing some shifting of rock without compromising overall stability*
- *Effects to nearshore environment*
- *Susceptible to ongoing damage and erosion*
- *Design choices must consider visual compatibility with the natural shoreline.*
- *Artificial structures can upset natural balances of sediment flux, including seasonal variations of beach sand*

Sample Locations

- Arroyo Del Oso, north of Piedra Blancas in San Luis Obispo County (SLO-1-65.3)
- Alder Creek (MON-1-7.9)
- Limekiln Creek (MON-1-20)
- Rocky Creek (MON-1-60.0)

Figure 15: Rock slope protection has been used as a temporary measure at Arroyo Del Oso until a long-term solution to realign the highway can be implemented.

STABILIZATION

EXCAVATION AND REMOVAL

Description

One traditional approach to landslide repair involves excavation and removal of an unstable mass (landslide) to re-establish a stable slope. Dewatering and creating benches on the slope are often integral aspects of the design and construction. Excavation techniques can vary depending on site conditions and available equipment. Flatter slopes provide greater local and global stability but produce larger quantities of excavation and have a larger overall footprint. Steeper slopes may result in localized instabilities, requiring a wider bench near the roadway for catchment of material.

Application Criteria

Used where other methods to achieve stability are not practical due to deep instability along discontinuous rock types, continued movement of a hillside, or unstable foundation materials.

Considerations

- *Provides long-term solution by removing source of instability*
- *Depending on mass of landslide, has the potential to generate large volumes of excess material*
- *Time in construction and secondary effects depend on methods of handling excess material*
- *Depending on techniques and equipment available, may result in relatively extensive footprint*
- *Very difficult to successfully revegetate excavated slopes*

Sample Locations

- Redwood Gulch landslide
- Highway 9 in Santa Cruz County (SCr-9-13.5)

Figure 16: The use of specialized equipment on Highway 9 in Santa Cruz County enabled excavation of a slide mass without the need for access roads, minimizing the overall impact area.

MANAGEMENT & PROTECTION

BALANCING FORCES

Description

These techniques involve balancing the forces of instabilities to achieve a condition of global stability and to prevent or reduce the likelihood and severity of a larger scale event, while accepting or "living with" continuing localized on-site settlement and creeping (slow) movements. The techniques include decreasing the driving forces (e.g. removing material from the head of a landslide) or increasing the resisting forces (such as buttressing the toe of a slope or dewatering).

Application Criteria

These techniques may be considered where their implementation will result in a reasonable degree of global stability of a landslide, and conventional landslide removal methods are not warranted or are undesirable for environmental or aesthetic reasons.

Considerations

- *Smaller footprint and reduction in earthwork/disposal quantities*
- *Less impacts, shorter timeframe and lower cost*
- *Tolerance for occasional localized instabilities*
- *Facilitates traffic handling*

Sample Locations

- Wild Cattle Creek (MON-1-17.7)
- Big Slide (MON-1-22)
- Grandpas Elbow (MON-1-23)
- Duck Ponds (MON-1-8.3)
- Grey Slip (MON-1-6.8)

Figure 17: Balancing forces is applied to management of the Grey Slip Landslide (MON-1-6.8)

MANAGEMENT & PROTECTION
ROCKFALL PROTECTION

Description
Rockfall protection techniques include surface scaling, rock catch fences, net drapery, catchment areas, rock bolting and rock sheds. Some slopes are managed with periodic scaling which is a method of prying loose rocks down from a natural rock slope surface. Other slopes require additional protection in the form of physical barriers to absorb energy and control continuously falling rock from a natural slope or to manage the sloughing material from excavation of a steep slope. These measures are all aimed to protect travelers and the roadway itself. Development of new technologies has advanced the availability of flexible barriers made of high strength materials and coatings that last longer and are less visually prominent than rigid or fixed barriers.

Application Criteria
Rockfall protection is considered where the amount, size or severity and past history of falling rocks presents a safety or maintenance concern.

Considerations
- *Minimal footprint, alleviates the need for aggressive solutions such as excavation or permanent slope treatments*
- *Methods can be used in combination*
- *Accessibility of catchment areas for maintenance*
- *Availability of space to accommodate a catchment area*
- *Ability to minimize visibility of rock net and mesh features with color coating*
- *Aesthetics*

Sample Locations
- Cow Cliffs (MON-1-28.3)
- Rain Rocks (MON-1- 2.8)
- San Marcos Pass,
  Highway 154 in Santa Barbara County

Figure 18: A flexible rocknet fence protects motorists at Cow Cliffs near the Big Creek Reserve on the Big Sur Coast.

MANAGEMENT & PROTECTION

ROCK SHEDS

Description
A rock shed provides protection to the highway traveler by creating a roof-type structure as a shield from chronic rock falls.

Application Criteria
Used where other protective methods cannot be applied due to terrain, space requirements, or severity of rockfalls.

Considerations

- *Provides high degree of protection*
- *Minimizes disruption of the natural flow of material across roadway*
- *Reduces daily maintenance requirements*
- *Massive structure may contrast with visual context*
- *High design and construction costs*
- *Interferes with views from road*
- *Long lead time to implementation*

Sample Locations

- Historic Columbia River Scenic Highway, Oregon
- New Zealand

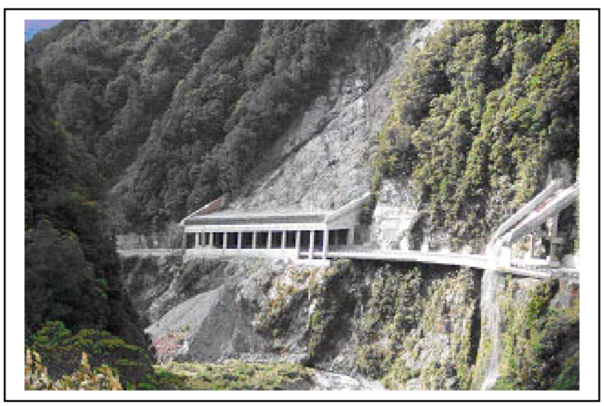


Figure 19: This rockshed protects a highway in New Zealand.

Figure 20: This rockshed protects a bicycle/pedestrian path on the Historic Columbia River Highway in Oregon.

6.2 Drainageway and Culvert Management

Drainage ways and culverts provide a means by which water, suspended sediment, and other organic material (leaves and woody debris) can pass around or beneath the roadway via bridge, pipe (of metal, plastic or concrete) or concrete box. These features are essential to maintaining the integrity of the roadway. Although the systems attempt to accommodate natural background flows as if the highway wasn't there, culvert design cannot completely avoid sediment deposition at the inlet and erosion at the outlet. Therefore, proper management of drainage ways and culverts require debris removal and basic structural maintenance.

Culvert maintenance requires periodic inspection to maintain flow capacity, prevent debris blockages and control erosion. Maintenance also involves repairing worn areas of the culvert or the inlet and outlet structures, and serves to extend the life of the system. It also helps prevent emergencies that require extensive cleaning or repair of the roadway following a drainage system failure.

The practices are organized into three types:

Debris Management - Debris management methods are meant to protect the roadway and upstream property from damage caused by debris blockages and overtopping. Protection strategies can deal with debris before or after it enters the highway right-of-way, although it is more feasible and economical to prevent the debris flows from reaching the highway. When debris blocks a culvert without any back up system, the incoming flow will continue to build up behind the roadway (i.e. the roadway embankment effectively becomes a dam), creating flooding upstream until it eventually overtops the road. Overtopping can result in severe damage to the roadway and the downstream embankment causing secondary problems with erosion and slope stability.

There are two methods of handling debris: adequately sizing the channel or culvert and intercepting debris upstream with control structures such as deflectors, racks, risers, additional culverts and inlets, debris basins and flexible barriers. Debris trap devices can lead to accumulation of debris at the inlet and therefore require ongoing maintenance for debris removal.

Culvert Rehabilitation - Rehabilitation extends the service life of a culvert. Generally less intrusive than a complete replacement, rehabilitation may include structural repairs, pipe lining and outlet protection.

Culvert Replacement - When conditions of a culvert deteriorate to a point where its support or integrity has been lost, rehabilitation is no longer an option and the culvert must be replaced. There are two basic replacement methods: cut-and-cover (trenching) and jacking (boring). Culverts in fill up to 20 feet deep are often replaced using the cut/cover method; jacking methods are considered where the culverts are under fills of 15 to 20-feet or more. Replacement projects can become complex since the waterways often provide sensitive habitat.

Design for a new culvert must consider hydraulic capacity, structural integrity and service life as well as the potential of the drainage as a wildlife corridor or as a route for recreational access to the coast.

From an engineering perspective, considerations include location, alignment, slope, type, strength, shape, jointing, and means of protection to meet the hydraulic, loading, and soil conditions. Use of the most appropriate culvert type for an area will ensure a long service life and reduce the level and frequency of maintenance.

DEBRIS MANAGEMENT

DEBRIS DEFLECTORS

Description

Debris deflectors create a "V" shape deflection system to guide medium and heavy debris or rocks away from the inlet to an accumulation point where the material can be easily collected and removed. Debris deflectors are suitable for large culverts constructed for high velocity flow and large debris (e.g. logs and boulders). Deflectors may be constructed from steel pipe, heavy rail, timber, and wire, depending on the size of debris that may impact the area.

Application Criteria

- Areas of high flow velocities or quantities
- Potential for large debris in the watershed
- Large capacity culverts

Considerations

- *Extends the life of the culvert*
- *Reduces the chance of culvert failure*
- *Facilitates maintenance, but requires periodic cleaning and removal of debris*

DEBRIS MANAGEMENT
FLEXIBLE DEBRIS BARRIERS

Description
Flexible debris barriers are located within stream channels and designed to collect debris (rocks, trees, mud, etc) before it reaches the inlet. Water can flow freely through the net. The system consists of steel posts that are supported by upslope anchors. Attached to the post is a net of steel cable or steel wire that can be fabricated in different configurations. The nets can remain in place until they are full at which time they can be cleaned out and reset.

Application Criteria
- Can be placed in areas in which small debris flows can be anticipated
- Can be adapted to many different channel configurations
- Effective on most type anticipated debris flows yet allows water to flow through it
- May be installed on a temporary or seasonal basis

Considerations
- *Effective in areas with anticipated heavy debris flows such as areas which have recently impacted by fires*
- *Very effective with proper siting and placement*
- *Impacts on riparian habitat*
- *Cost effective*

Figure 21: This flexible debris barrier installation in Aobandani Japan captured 750 cubic meters of material that came down the canyon as a debris flow. (photo from Brugg Cable Products, Inc.)

DEBRIS MANAGEMENT

DEBRIS RACKS

Description

Debris racks are located within the stream channel to collect debris before it reaches the inlet. Racks consist of rigid bars placed within the stream at a distance from the culvert to catch large debris that could clog the pipe. Debris storage areas near racks can minimize the frequency of removing and hauling material.

Application Criteria

- Areas of high flow quantities
- Must have adequate spacing to place the racks
- Large and small debris

Figure 22

Considerations

- *Extends the lifespan of the culvert*
- *Reduces the chance of culvert failure*
- *Facilitates maintenance*
- *Impacts on riparian habitat*
- *Proper siting and placement to effectively catch the debris*

DEBRIS MANAGEMENT

DEBRIS CRIBS

Description

Debris cribs or bear traps are taller structures (in comparison to debris racks) placed over the inlet with crib-type openings to allow water to flow through while keeping debris out, particularly coarse bed load or larger debris. Cribs provide a similar function as risers but are used where the culvert has little cover and the sediment is coarse. Debris cribs and risers are very efficient and require relatively low-maintenance. They can be made less visually prominent by selecting materials and finishes compatible with its surroundings.

Application Criteria

- Small culverts
- Areas of large debris or coarse bed load
- Areas with sharp grade changes
- Areas where deposits tend to collect at the inlet

Figure 23

Considerations

- *Extends the life of the culvert*
- *Reduces the chance of culvert failure*
- *Highly efficient*
- *Visibility*
- *Low maintenance*

DEBRIS MANAGEMENT

DEBRIS RISERS

Description

Debris risers are closed structures placed over the inlet to prevent debris from entering the culvert. They consist of a vertical culvert pipe covered by a grate that acts a riser. Slots are created within the vertical pipe to allow for continued water flow. If placed at the bottom of a steep area, the riser will cause ponding to reduce flow velocity and cause sediment to drop from the load. Risers can be created and installed at a lower expense than more labor-intensive structures like debris cribs, and be painted to blend into the natural background.

Application Criteria

- Low flow velocities
- Fine or small to medium size debris
- Boulder-free area

Considerations

- *Extends the life of the culvert*
- *Reduces the chance of culvert failure*
- *Highly efficient*
- *Visibility from the highway*
- *Low maintenance*

Figure 24: This riser allows for water to flow into the pipe inlet when debris builds up at the base.

DEBRIS MANAGEMENT

DEBRIS DAMS AND BASINS

Description

Debris dams and basins are used to impede stream flow, causing material to drop out of suspension and collect on the bottom. These structures are used if the height of the highway embankment and storage area is insufficient to accommodate a riser or a crib. Dams and basins can trap heavy boulders and coarse gravel. They are usually made of pre-cast concrete beams and rocks or with rock held by wire.

Application Criteria

- Areas with heavy boulders and coarse gravel
- Inadequate location for cribs or risers
- High velocity flows
- Suitable area for dam foundation

Considerations

- *Extends the lifespan of the culvert*
- *Reduces debris buildup or blockage*
- *Lower annual maintenance cost compared with removing debris from other structures*
- *Potential effects to habitat associated with alteration of natural flows*

DEBRIS MANAGEMENT

OVERFLOW CULVERTS

Description

Overflow culverts provide a secondary route for conducting water across the highway to prevent overflow damage. The overflow is located in the same general vicinity as the main culvert and act as an emergency back-up system.

Application Criteria

- Areas of high flow velocities or quantities
- Areas prone to debris blockage
- Areas where debris control systems are not feasible or effective

Considerations

- *Reduces potential for overtopping and potential for emergency repairs*
- *Higher annual maintenance costs*

DEBRIS MANAGEMENT

REDUNDANT INLETS

Description

Redundant inlets are additional collection systems, at a lower elevation than overflow culverts, that provide roadway protection should a culvert inlet become clogged with debris. The additional inlet structures intake water where it flows through the main culvert. The redundant inlet acts as an additional mouth for the culvert to prevent overtopping of the primary inlet.

Application Criteria

- Areas of high flow velocities or quantities
- Areas prone to debris blockage
- Areas where debris control systems are not feasible

Considerations

- *Reduces potential for overtopping and potential for emergency repairs*
- *Higher annual maintenance costs*

Figure 25: This system includes a redundant inlet, which is located at the base of the corrugated metal pipe riser, and a welded debris rack to protect the primary inlet of this culvert.

CULVERT REHABILITATION

STRUCTURAL REPAIR

Description

Damage to culverts is a result of erosion, distortion, joint separation, rust, abrasion, and other physical defects. Structural repair consists of a variety of methods to improve or maintain the integrity of the culvert and drainage channels. In addition to a thorough cleaning, many structural repairs can be considered rehabilitation of the culvert:

- Placing rip-rap to repair erosion around the culvert inlet and outlet structures
- Coating metal pipe with protective bituminous tar or asphalt mastic
- Applying concrete to metal culverts
- Paving and lining inverts to prevent abrasive wear on the bottom of the culvert
- Lining excessively corroded culverts with polyvinyl chloride (PVC) or polyethylene plastic (PEP) pipe
- Repairing and maintaining joints
- Correcting pipe distortion

Application Criteria

- Areas of wear-through abrasion and erosion of backfill materials.
- Areas of fill erosion.
- Areas where the culvert or drainage channel has been weakened, abraded, corroded, perforated, distorted, or otherwise compromised.

Considerations

- *Extends the life of the culvert and drainage channel*
- *Reduces the chance of culvert failure*
- *Cost effective*

CULVERT REHABILITATION

OUTLET PROTECTION

Description

Outlet protection measures reduce or prevent embankment erosion and scour where water discharges from the pipe at high velocities and where eddying may occur. Protection measures may include rock riprap, gabions, rock nets or grouted rock installed around the outlet. The energy from the flowing water is dissipated, thereby reducing its erosive potential.

Application Criteria

- Steep drainages with weak rock and soil structure
- Areas with high flow volume and velocity rates

Considerations

- *Prevents erosion of the culvert outlet and possible undercutting of the road*
- *Cost effective*
- *Minimal footprint*
- *Reduced damage to habitat*
- *Difficult to revegetate*
- *Access for construction*

Figure 26: A flexible rocknet barrier has been filled with rock to dissipate energy at the outlet known as "Straight Down" north of the Little Sur River in Monterey County. (MON-1- 57.2) This innovative technique minimizes disturbance of the slope.

CULVERT REHABILITATION
PIPE LINERS

Description
Various materials are used to line pipes that are abraded, corroded or perforated. PVC and HDPE plastic liners may be inserted into an existing pipe with use of heavy equipment. A resin cure liner is a sleeve-type cloth material placed inside a culvert where the cloth expands to coat and bond to the inner culvert wall. The resin is cured to form a rigid permanent bond to the culvert using steam or hot water. Cement mortar may also be used to line a culvert, either throughout the inner surface of the culvert, or on the bottom only, which receives the most wear from debris abrasion. While application to the bottom only is least costly and time consuming, it does not protect against failure on the less vulnerable sides and top of the pipe.

Pipe lining reduces the overall pipe diameter, but owing to the smooth lining surface, the pipe often retains its overall capacity and can be more hydraulically efficient than the existing pipe (in its original condition).

Application Criteria
- Pipes showing signs of corrosion
- Soil structure surrounding the pipe remains intact
- Culvert must be able to maintain its shape

Considerations
- *Extends the life of the culvert*
- *Cost effective*
- *Short timeframe to implement*
- *Improves efficiency for conveying water and debris*
- *Water diversion during construction*
- *Complete cleaning of culvert, inlet, and required before lining*
- *Construction requires use of heavy equipment*


Plastic Liner

Figure 27

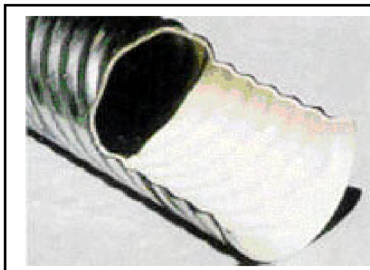

Resin Cure Liner

Figure 28


Cement Mortar Lining

Figure 29

CULVERT REPLACEMENT

REPLACEMENT PIPE MATERIALS – CONCRETE

Description

Concrete provides a thick, durable surface to line drainage channels and culverts. There are two principal types of concrete culverts: cast-in-place or pre-cast reinforced concrete boxes and cast-in-place or pre-cast circular concrete pipe – either reinforced or non-reinforced.

Application Criteria

- Low likelihood of movement or settlement of material surrounding the pipe
- High debris content areas

Considerations

- *Good resistance to abrasion and wear*
- *Long service life of 100+ years*
- *Can be used in less stable areas if suitable compaction can be achieved (with corresponding time and cost for construction)*
- *Susceptible to cracking and joint separation where underlying movement or settlement occurs*
- *Construction is labor-intensive*
- *Durability affected by acids, chlorides and sulfate in the soil and water*

Reinforced Concrete Pipe

Figure 30

CULVERT REPLACEMENT

REPLACEMENT PIPE MATERIALS – CORRUGATED METAL PIPE

Description

Galvanized corrugated metal pipe is a very common type of material used for culverts along the coast. The choice of corrugation type, shape, and protection is dependent on hydraulic, structural, and design service life considerations. Ten-foot sections of the pre-formed metal may be banded or riveted together to form longer culverts.

Application Criteria

- Suitable under many conditions, including areas where minor settlement or movement could occur
- Low debris content areas

Considerations

- *Lower initial expense than concrete*
- *More susceptible to wear and tear and corrosion (than concrete) requiring more frequent maintenance and potential repair*
- *May require special protection to meet design service life requirements.*
- *Ability to conform shape in light of settling and movement*

Corrugated Metal Pipe

Figure 31

CULVERT REHABILITATION

REPLACEMENT PIPE MATERIALS – PLASTIC

Description

Plastic culverts are composed of pre-formed corrugated polyethylene pipes. The plastic may be smooth or corrugated on the interior and can be reshaped with joints to correspond to the terrain and soil changes. Plastic culverts are usually 18 to 48 inches in diameter.

Application Criteria

- Suitable under many conditions, including areas where minor settlement or movement could occur
- Low debris content areas

Considerations

- *Lower initial expense than concrete*
- *Ability to conform shape due to settling and movement*
- *Service life 20-50 years*
- *More susceptible to debris wear than concrete*
- *Susceptible to fire damage and damage from exposure to sunlight*
- *Good abrasion resistance and virtually corrosion free.*

Polyethylene Pipe

Figure 32

CULVERT REHABILITATION

PIPE REPLACEMENT METHODS – CUT AND COVER

Description

The cut and cover method of replacement involves excavating a trench two feet wider than the new pipe. This method is often used when the depth to the inlet or outlet is relatively shallow (generally less than 15-feet below the roadway elevation, but not necessarily limited to such depth). When an excavation depth exceeds 5-feet, shoring, shields, trench wall sloping or other techniques may be required for worker safety. Once the pipe is in place, the trench is backfilled with the excavated material and the roadway reconstructed over the top.

Application Criteria

- Flow line is at a relatively shallow depth, generally less than 15-feet below the roadway elevation to the inlet or outlet
- Variable soil structure conditions

Considerations

- *Cost effective at shallower depths*
- *Cost and time in construction increase with depth of excavation*
- *Access to or from neighboring property*
- *Needs for site restoration*
- *Impacts to sensitive habitat*
- *Variable needs to accommodate traffic: one-way control, intermittent road closures, or construction of detour*
- *Construction footprint increases with depth of excavation, diameter of pipe and need for traffic detours*

Figure 33: Cut and cover installation with side slopes of the trench laid back, alleviating the need to shore up the walls of a vertical trench of this depth. The size of the trench corresponds to the depth to flow line and the diameter of the pipe. A smaller cut/cover operation may excavate a very narrow and shallow trench with vertical walls.

CULVERT REHABILITATION

PIPE REPLACEMENT METHODS – JACKING NEW CULVERTS

Description

Jacking is used to replace culverts under fills that are generally deeper than 15-20 feet. With this technique a tunnel is created, usually by an auger, to create a void ahead of the advancing hydraulically jacked pipe. Requirements for construction include excavating pits on both sides of the roadway to jack and receive the pipe; heavy equipment is used for boring and jacking 10- to 20-foot sections of the pipe at a time.

Application Criteria

- Flow line of the drainage exceeds 15-20 feet below the roadway elevation
- Reliable or near-uniform soil structure

Considerations

- *Costly operation that increases with pipe diameter and length*
- *Access to or easements from neighboring property*
- *Construction footprint increases with depth to flow line and diameter of pipe*
- *Needs for site restoration*
- *Impacts to sensitive habitat*
- *Traffic handling may be limited to intermittent delay with one-way traffic control as the roadway remains intact during the operation; construction of detours less likely than with larger cut-cover operations*
- *Potential to encounter rock, very hard or impenetrable material, increasing the cost and time in construction*

Figure 34: The crew operates heavy equipment in the jacking pit to install a new culvert under deep fill at Hubbell Gulch (MON-1-20).

6.3 Earthwork and Material Handling

In responding to a debris flow or other landslide activity, the issue that most influences the time required to re-open the highway is earthwork. The quantity of excess material, proximity of sensitive environmental resources, and availability and proximity of disposal sites are critical factors. This section describes the current understanding of the best available techniques and identifies strategies for future exploration and development.

As set forth in Section 5.3, the priorities for earthwork on the coast are "reduce, reuse, recycle, replenish, dispose". Reducing the quantity of excess materials is either the primary or a secondary objective of virtually all the roadway maintenance, landslide management, and drainage management efforts the Department undertakes in the corridor. However, in the case of some planned or unplanned projects, full use of reduction strategies cannot completely eliminate the generation of excess material that requires subsequent handling. Therefore, the discussion below focuses on methods for handling excess material.

The approaches to handling excess material may be used exclusively or in combination, depending upon site conditions, quantities of material and other factors as described for each.

Site Compatibility
Determining the ultimate destination should be based upon information about background natural conditions and natural system inputs:

(a) Seek compatibility with background conditions, including:
- Rock and soil types (physical characteristics)
- Location (habitats indicate adaptation to similar disturbances)
- Volumes (quantities of material are within range of historic patterns, chronic or episodic)
- Timing (seasonal or annual variations)
- Biological factors (including presence of rare and endangered species or exotics)

(b) Offset impacts of withholding natural sediment inputs
- Reduce the effect of highway as a sediment barrier (e.g., highway as a dam, where sediment carried by streams is trapped behind fill embankments (culverts), or detained on an artificial bench where rockfalls or landslide material is held.

(c) Monitor site conditions for change
- Verify or differ with anticipated changes
- Determine relative capacity for site recovery
- Duration appropriate and responsible to degree of potential impact (risk tolerance)

(d) Ensure disposal of man-made materials (i.e., steel, asphalt) at authorized sites, such as landfills or recycling centers.

Mode of Transport
At present, truck hauling is the method of transport for excess soil and rock to a designated receiver site, whether temporary or permanent, and whether for reuse, recycling, replenishment or disposal. Haul distance is an important factor in determining the time and costs for restoring service on the highway. Should barge transport be realized along the coast in the future, this mode could facilitate either transport to another land site (for re-use or disposal) or to an offshore site for replenishment or disposal options (see below). The replenishment and progressive disposal practices described below are assumed to require little or no truck hauling from the site of origin.

MATERIAL HANDLING

HIGHWAY REUSE

Description
This practice refers to incorporating excess material into the highway facility. Material may be used to re-profile (raise the grade of) a section of highway or buttress a slope or retaining wall. It may be placed as shoulder backing along the edge of pavement or as earthen berms that delimit the boundaries of pullouts or turnouts[25]. Topsoil may be collected for re-application during site restoration.[26] Rock may be screened for appropriate size and used as lining for roadside ditches to improve drainage. Unless special restrictions apply, material may be transported to other locations throughout the corridor where a need has been identified. Any transfer, however, must take into account the potential for and must avoid to the extent possible the transport of undesirable invasive plant seed or other exotic materials.

Application Criteria
- Material type and structure is suitable for roadway construction
- Material is low in organic matter and free of undesirable vegetation or seed
- Sensitive habitats can be avoided or impacts minimized by the reuse activity
- Rock can be screened

Considerations
- *Contribution to facilitating earthwork for restoring the highway.*
- *Proximity to sensitive environmental resources and habitats*
- *Potential for unintended spread of invasive plants*
- *Needs for follow-up weeding*
- *Visual compatibility and preservation of views from the highway*

Sample Locations
- Re-profiling Highway 1 south of Big Creek (2000)
- Re-profiling Highway 1 between Pitkins Curve and Big Slide

[25] Earthen berms also help prevent against illegal dumping of cars over steep cliffs, which has been documented at several locations throughout the corridor.
[26] See the *Vegetation Management Guidelines* prepared for the CHMP for more details on site restoration.

MATERIAL HANDLING

STOCKPILING

Description

Stockpiling refers to the practice of depositing excess material at sites along the highway corridor for temporary storage until the material can be processed for recycling or transported to its permanent destination (whether reuse, recycling or disposal). Stockpiled material may occupy any wide spot generally lacking substantial vegetation along the corridor, such as at pullouts.

Application Criteria

- Permanent receiver site not available in timeframe needed to restore highway service
- Material requires processing prior to reuse or recycling
- Stockpile location is previously disturbed, such as a pullout

Considerations

- *Expected timeframe for completing transfer to permanent location*
- *Potential to transfer undesirable plants or seed*
- *Entails double-handling of material which increases costs*
- *Needs for surface treatments on dry material to prevent wind and water erosion*
- *Thoughtful siting, to the extent practical, to avoid inadvertent blocking of coastal access or views even temporarily.*

Sample Locations

- Willow Springs
- Garrapata State Park

Figure 35: Temporary stockpiling near Garrapata State Park

MATERIAL HANDLING

REPLENISH: LOCALIZED SIDECASTING

Description

This approach assumes a condition where the highway acts as a barrier to the natural movement of a landslide, debris flow or other natural process delivering a significant amount of material to the highway. The principle behind this approach is to enable organic material generated by a landslide to continue relatively uncontrolled on its downward migration in its original location and in a manner consistent with background natural processes. The “destination” essentially remains unchanged, except for the period of being detained by the highway or a related feature (e.g. fill embankment damming a debris flow). In simple terms, this could be thought of strictly as “sweeping” the roadway clear of debris in the same location where it has fallen or carrying material over the highway fill slope barrier on a debris flow course.

Under this practice, debris from slopes above the roadway would be deposited immediately down slope of the highway. The objective is to enable material to continue the down slope or downstream transfer that would have occurred had the highway not been in place.

Given the intent to allow natural sediment transport mechanisms to continue unabated, artificial measures for controlling surface erosion would not be employed as a general rule, unless there was risk of aggravating a condition that would adversely affect a sensitive resource or the integrity of the highway.

Application Criteria

- Highway acts as barrier to continued movement of material down slope or down stream
- Volume of material side cast is limited to that displaced by natural event
- Material is organic in nature, i.e. free from built infrastructure elements such as concrete, asphalt, steel
- Areas with shoreline dynamics and habitat characteristics that indicate adaptation and tolerance of periodic inputs (relative quantities, rates).
- Area down slope or downstream characterized by conditions indicating that the side cast material would not disproportionately affect sensitive habitats, including the nearshore marine environment

Considerations:

- *Presence or absence of protected resources, sensitive habitat, or special status species*
- *Mimics natural processes of mass wasting*
- *Supports dynamic equilibrium of regional sediment inputs and outputs*
- *Needs for ongoing monitoring and reporting*

Sample Locations

- Waddell Bluffs, Highway 1 in Santa Cruz County
- Hubbell Gulch, MON-1-18.0

MATERIAL HANDLING

REPLENISH: SLOPE DETENTION

Description

This technique considers and would accept the ocean as a natural sediment sink and includes site-specific information about the tolerance for or adaptation to periodic burial, turbidity and scour. This technique also involves a higher degree of control or manipulation over the localized sidecasting described above and may involve import of material from other locations within the corridor where the material is geologically compatible. Under this scenario, material is placed in a manner that is considered relatively stable in the short term, but is understood to erode and enter the ocean over time through wave action or other major natural influence. In lay terms, this concept has been described as the "conveyor belt" approach.

Under this scenario, material would be placed above the shoreline, but the erosion of material may result in periodic or episodic pulses (high volumes at one time). This approach also aims for compatibility with the dynamic background conditions, but is conducted in a more controlled manner.

Application Criteria

- Material is organic in nature (free from built infrastructure elements such as concrete, asphalt, steel)
- Site characteristics suitable for controlled placement and wave action appropriate for gradual, if episodic, erosion
- Areas with shoreline dynamics and habitat characteristics that indicate adaptation and tolerance of periodic inputs
- Area down slope or downstream characterized by conditions indicating that the side cast material would not disproportionately affect sensitive habitats, including the nearshore marine environment.

Considerations:

- *Presence or absence of protected resources, sensitive habitat, or special status species*
- *Mimics natural processes of mass wasting*
- *Supports dynamic equilibrium of regional sediment inputs and outputs*
- *Needs for ongoing monitoring and reporting*

Figure 36: Slope detention is proposed as a pilot project at the Pitkins Curve Landslide, Highway 1 in Monterey County, PM 21.0.

MATERIAL HANDLING

DISPOSAL: LANDFILL

Description

Landfill refers to filling a terrestrial site with earthen debris (soil, rock, organic matter) on public or private property, including commercial sites.

Considerations

- Haul distance from source
- Volumes for transport
- Traffic impacts from haul operation
- Needs for site restoration and revegetation

MATERIAL HANDLING

DISPOSAL: NEARSHORE BYPASS

Description

This approach refers to a direct introduction of material to the ocean using methods that would avoid direct burial of nearshore and intertidal habitats. There are currently no applications of this approach along or near the Big Sur Coast. The closest related activity is harbor management dredging and disposal. The concept is to either pump or transport by barge material to a designated offshore disposal site. Implementation assumes availability of such an approved offshore disposal site and a feasible method of loading and transferring material from the source to the transport vehicle or mechanism.

Application Criteria

- Availability of an approved receiver site
- Suitability of material for receiver site
- Equipment and techniques available for loading and transferring material offshore
- Determination of cost effectiveness and feasibility

Figure 37: Barging material off the coast of Vancouver, British Columbia.

7.0 Future Actions

Throughout the planning process that led to the development of these guidelines, the Storm Damage Response and Repair Working Group noted informational gaps and institutional circumstances that should be addressed, but were considered as beyond the scope of these guidelines, but within the spirit of the CHMP for identifying specific actions for improving overall fulfillment of management responsibilities by multiple stakeholders. Several actions are recommended that may improve the overall approach to long-term management.

1. Pursue funded research to clarify policy options

a) Conduct preliminary geotechnical investigations on priority sites to identify trends about individual landslides and make recommendations for site management; evaluate priorities for protective betterments at a corridor scale.
b) Conduct shoreline and marine habitat analysis along stretches of coast in proximity to the highway where landslide-related management activities or repairs could affect the marine environment.
c) Correlate marine habitat sensitivities with sites that may be candidates for replenishment-type material handling strategies.
d) Conduct investigations toward estimating a sediment budget for the Big Sur Coast.

2. Pursue changes to improve delivery of needed "Protective Betterments"

a) Pursue Programmatic Agreements between the Department and individual regulatory agencies, such as the preparation of a Public Works Plan under provisions of the California Coastal Act for all landslide management and storm damage response activities.
b) Identify opportunities for alternatives or supplemental fund sources to initiate detailed studies and construction of protective betterments.
c) Identify watersheds with the greatest potential to generate debris flow based on vegetation, land use and geotechnical characteristics. Initiate a partnership with land management entities, property owners and regulatory agencies for cooperative watershed management

3. Use Best Available Information

a) Commit to continuous updating, collection, and sharing of best available information.
b) Test unproven techniques in controlled demonstration projects and pilot studies.

4. Establish a Technical Advisory Group

a) Monitor and evaluate implementation of guidelines
b) Update guidelines to reflect evolution of knowledge and best available techniques
c) Ensure completion of studies that are critical to fill important data gaps

8.0 References

California Department of Transportation. *Highway Design Manual*, 5th Edition.

California Department of Transportation. “Draft Preliminary Geotechnical Report Guidelines.” March 18, 1993.

California Department of Transportation. “Geotechnical Design Reports – Purpose, Development, and Application.” Draft. October 2, 1995.

California Department of Transportation. *Potential Slope Instabilities in the Highway 1 Corridor: Road Condition and Hazard Potential at Sites between San Carpoforo Creek and Carmel Highlands*. September 2001.

California Department of Transportation, District 5. *Culvert Inventory for the Big Sur Coast Highway Management Plan*. May 2002.

California Department of Transportation, District 5. *Mitigated Negative Declaration: Disposal Sites for Storm Damage Repair, Highway 1 Near Big Sur*, December 2000.

California Division of Mines & Geology (now, California Geological Survey). *Landslides in the Highway 1 Corridor: Geology and Slope Stability Along the Big Sur Coast*. November 2001.

California Geological Survey and California Department of Transportation. *Proceedings: 53rd Annual Highway Geology Symposium, San Luis Obispo, California.* August 13 – 16, 2002.

Duffy, John D. “Living with Landslides.” Powerpoint Presentation. Caltrans. January, 2001.

Duffy, John D. “New Technology & Innovation: Landslide Stabilization, Tecco System.” Powerpoint Presentation. Caltrans. January 2001.

Federal Highway Administration. “Debris Control Structures – March 1971.” Site accessed 10/1/02. http://www.fhwa.dot.gov/bridge/hec09.pdf

Hapke, Cheryl. *Estimated Sediment Yield from Coastal Landslides and Active Slope Distribution Along the Big Sur Coast.* February 2003.

JRP Historical Consulting Services, Inc. *A History of Road Closures Along Highway 1 in San Luis Obispo and Monterey Counties*. November 2001.

Monterey County Planning Department. *Big Sur Coast Land Use Plan, Local Coastal Program, Monterey County, California*. 1986.

Parsons Transportation Group. *Corridor Intrinsic Qualities Inventory: Natural Qualities*. November 2001.

Public Affairs Management. Summaries of Storm Damage and Maintenance Practices Working Group Meetings for the Coast Highway Management Plan. May 12, 2000 – March 29, 2002.

Smiley, John. “Big Creek Slide of March 2000: March 2000 – May 2002.” Site accessed August, 2002. http://www.redshift.com/bigcreek/roads/slide2000/index.html

Smiley, John. “Big Sur Coast Highway Volunteer Roadkill Survey.” February 2003. Site accessed Jun3 2003. http://www.redshift.com/~bigcreek/roads/roadkill_survey/index.html

Transportation Research Board. *Landslides: Investigation and Mitigation*. Special Report 247. 1996.

United States Department of Agriculture, Forest Service. *Slope Stability Reference Guide for National Forests in the United States*. Volume I. August 1994.

APPENDIX A – PRELIMINARY GUIDANCE FOR SHORELINE HABITAT ASSESSMENTS

Category	Components
Marine Biological Characterization	▪ What is the composition, abundance, and distribution of the major species? ▪ Are species of special interest present? What are they? ▪ Does the shoreline represent a unique habitat? In what manner? ▪ What is the spatial area of concern? ▪ Is there pre-existing evidence of sedimentation and sand scour?
Other Considerations	▪ Is the area of concern within other jurisdictions (e.g., National Marine Sanctuary, Areas of Special Biological Significance , preserves, reserves, refuges)? ▪ Are there other sensitive habitats between the highway and the shoreline (e.g., Smith's blue butterfly, rare plants, steelhead stream, riparian habitat)? ▪ Are the lands between the highway and the shoreline designated as part of any resource management program or system (i.e., National Forest, State Park, Natural Reserve)?
Risk Evaluation	▪ Will the effects of the landslide and side cast materials be irreversible (i.e., can species recover)? If recovery can be reasonably anticipated, what is the expected time frame for rebound to original conditions? ▪ What are the habitats and species at greatest risk? ▪ Will the landslide or side cast materials from road repairs cause permanent damage, temporary damage, or constant low-levels of disturbance? ▪ Is there potential for an environmentally sensitive habitat area to be significantly degraded? ▪ Can the credible risks be reduced or offset?
Social Acceptance and Considerations	▪ Does the shoreline represent an area of economic importance (e.g., fisheries value)? ▪ Is the area popular for recreational use (e.g., tidepooling, beach activities, diving, surfing)? ▪ Is the area clearly visible from the highway, designated vista point, public beach recreation area or other improved public viewing point?

The following table provides an example of how habitats can be "ranked" according to their risk potential to landslides and sedimentation effects from side cast materials, based on the biota present and physical setting. The habitat value gradient below does not account for other criteria, such as recreational use or economic importance.

Example Gradient of Biological Risk to Landslides and Side Cast Materials

High Habitat Value ⟶			**Low Habitat Value**
Highest Risk to Biota ⟶			**Lowest Risk to Biota**
Rocky bench or boulder field with high biodiversity, which is not largely influenced by natural sedimentation. Sandy beach with dense eelgrass beds. Sandy beach with abundant infauna (clams, sand crabs)	Boulder fields in high wave energy areas and sediments. Populations are adapted to persist in constantly disturbed environments.	Few rocks with limited biota influenced by natural sedimentation.	Sandy beach with lack of infauna (no clams, sandcrabs).

Considerations for Decision-making

<u>Minimization</u>	▪ Does the highway repair strategy minimize the potential for excess quantities of material? (i.e. reduce the need for disposal) ▪ Does the highway repair strategy reduce the risk of more massive failures (e.g., through reduction of driving forces or increased resisting forces as needed to promote stability, or replenishment of beaches or boulder fields that diffuse wave energy)?
<u>Evaluation of Alternatives</u>	▪ Are there alternative road repair and sediment disposal practices that can further avoid or minimize sedimentation effects to the shoreline? ▪ What are the trade-offs?

Post Construction and Disturbance Monitoring

<u>Impact Assessment</u>	▪ Did the landslide permanently change the habitat characteristics? ▪ Have native species been able to repopulate the disturbed areas? ▪ Has the landslide resulted in a species assemblage dissimilar to the pre-slide assemblage? ▪ If the habitat outcome is different than expected, is remediation recommended? If so, what would be appropriate?

APPENDIX B: STATE HIGHWAY OPERATIONS & PROTECTION PROGRAM ACTIVITIES

Goal Implementation of projects included in the State Highway Operation and Protection Program (SHOPP) and projects funded by the Minor Program.

Definition Government Code Section 14526.5 established the SHOPP to provide for improvements that are necessary to preserve and protect the State highway system. Projects are limited to improvements relative to maintenance, safety, and rehabilitation of State highways and bridges that do not add a new traffic lane to the system

Safety
Safety Improvements
Safety Enhancements
Upgrade Median Barriers

Bridge Preservation
Bridge Rehabilitation
Bridge Scour Mitigation
Bridge Rail Replacement and Upgrade
Bridge Seismic Restoration
Bridge Widening
Seismic Retrofit Phase 1

Roadway Preservation
Roadway Rehabilitation
Pavement Preservation
Long-Life Pavement Rehabilitation
Major Damage Restoration
Roadway Protective Betterments
Relinquishments
Signs and Lighting Rehabilitation

Roadside Preservation
Highway Planting Restoration
New Highway Planting
Urban Freeway Maintenance Access
Roadside Enhancement
Beautification and Modernization
Safety Roadside Rest Area Restoration
New Safety Roadside Rest Areas

Environmental Improvement
Noise Attenuation for Schools
Hazardous Waste Mitigation
Storm Water Mitigation

Mobility
Operational Improvements
Transportation Management
Weigh Stations & Weigh-In-Motion Facilities
Transportation Permit Requirements for Bridges

Facilities
Equipment Facilities
Maintenance Facilities
Office Buildings

Americans with Disabilities Act (ADA) Compliance Programs
New Curb Ramps
Administrative Office Buildings

Caltrans

District 5

GUIDELINES
INTERAGENCY NOTIFICATION
FOR
EMERGENCY HIGHWAY REPAIR

Purpose
Provide rapid communication to regulatory agencies about emergency highway repair work that may be within their jurisdiction and allow efficient response for authorizations that may be required prior to beginning certain operations.

Notification will not be made to report incidental natural events, such as routine storm patrol activity by maintenance crews. This notification process is intended to coincide with events affecting the status of the highway for the travelling public.

Step 1: Determine need for and type of notification

Threshold Criteria
When *any* of the following apply:

1) Situation satisfies CT definition of emergency, generally when highway travel is seriously impaired or threatened by natural events
    - Imminent threat to highway stability
    - Closure in one or both directions anticipated for a duration of 24+ hours

2) Material handling
    - Approval required for disposal of excess material

3) Extraordinary Maintenance
    - Considered above and beyond routine work

Types of Notification
1) Information Only
    - Material is handled on-site and no jurisdictional issues apply (e.g. material incorporated directly into roadbed repair on same alignment without expansion or realignment)
    - Material is hauled to a stockpile area or to an approved site (consistent with any conditions of approval, as applicable)

2) Potential Regulatory Action
    - Regulatory agencies need to concur regarding status of emergency under their own regulations
    - Work may require agency authorizations (verbal or written) in order to proceed with certain actions

Step 2: Providing the Information

A. Initial Notification

1) Information Only

Contents
- Face sheet (page 1 only)
- Photos, location map, brief narrative (if available)

Distribution
- Public/community
- Regulatory agencies

Internal Lead
- Co-leads: Public Affairs and Environmental Planning

2) Potential Regulatory Action

Contents
- Full multi-page form (info as complete as possible)
- Photos, location map, GIS info, brief narrative (when available)

Distribution
- Regulatory agencies

Internal Lead
- Environmental Planning

B. Updated Notification

Criteria
- Change in conditions has the potential to affect regulatory action
- Substantive change in the project/repair (extent of work, repair technique) relevant to regulatory jurisdiction
- Substantial new or additional information

Method
- Revision to original notification form
- Resubmit entire form (note "update" and boxes changed)

Distribution
- Same as initial notification

Timing
- During construction and as soon as information is known

C. Final Notification

Criteria
- Project completion (roadway construction)

Method
- Revisions to notification form
- Resubmit entire form (note "final" and boxes changed)
- Appendices added for completion of additional phases of work, such as revegetation and monitoring

Distribution
- Same as initial notification

Timing
- Submittal coincides with request for follow-up permits, as needed

EMERGENCY HIGHWAY REPAIR

INTERAGENCY NOTIFICATION

Information only ☐

Regulatory response needed ☐

Caltrans

INITIAL ☐
UPDATE ☐
FINAL ☐

Note box #'s:

DATE			
LOCATION **County** **Route** **Postmile**			
LOCATION NAME/DESCRIPTION			
TYPE OF FAILURE OR RISK			
PRIMARY CONTACT	**Phone Number**	**Fax Number**	**e-mail**

Emergency Declaration:
- ☐ CT Director's Order
- ☐ Governor Declaration
- ☐ Presidential Declaration

Urgency:
- ☐ No formal declaration, however, essential services, highway reliability and/or safety at imminent risk
- ☐ Declaration pending

State Lead Agency: CALTRANS
Federal Lead Agency: FHWA

Event:
- ☐ Storm
- ☐ Flood
- ☐ Landslide
- ☐ Earthquake
- ☐ Other

Status of Commencing Work:
- ☐ Has already begun
- ☐ Is expected to begin within 48 hours
- ☐ Is expected to begin beyond 48 hours from now

Work is required for:
- ☐ Immediate protection of life/property
- ☐ Maintain essential service
- ☐ Prevent an emergency/imminent risk of failure or further damage

Status of Highway Traffic
- ☐ Traffic remains open in two directions
- ☐ Limited with one-way traffic control
- ☐ Highway is closed in both directions
- ☐ Satisfactory detour ☐ is ☐ is not available at this time

Restoration of safe, reliable, two-way travel anticipated to be completed:
- ☐ Single phase- Full Opening
- ☐ Two phases- Emergency Opening/Full Opening
- ☐ Not yet determined
- ☐ Not Applicable

Comments:

*****Please acknowledge receipt—sign and return by fax this sheet *****

Name	**Title**	**Organization**	**Date**

Regulatory Jurisdiction & Application of Emergency Provisions

Coastal Act

- ☐ **CA Coastal Commission**
  - Jurisdiction by
    - ☐ Location-original jurisdiction
    - ☐ Property ownership – federal land
  - Type of Authorization
    - ☐ Exemption
    - ☐ Emergency Authorization only
    - ☐ Emergency Authorization w/follow-up CDP
    - ☐ Waiver of federal consistency determination
- ☐ **Local Agency** __
    - ☐ Exemption
    - ☐ Emergency Authorization only
    - ☐ Emergency Authorization w/follow-up CDP

Clean Water Act/Rivers & Harbors Act

- ☐ **US Army Corps of Engineers –** Sec 404, Sec 10
    - ☐ NWP 23 (Categorical Exclusion)
    - ☐ Other
- ☐ **Regional Water Quality Control Board –** Sec 401
    - ☐ Emergency Certification
    - ☐ Waiver of Certification

National Marine Sanctuaries Act

- ☐ **Monterey Bay Nat' Marine Sanctuary**
    - ☐ Waiver/exemption
    - ☐ Authorization of CDP

California Fish and Game Code

- ☐ **CA Dept of Fish & Game**
    - ☐ Waiver
    - ☐ Maintenance MOU
    - ☐ 1601 Agreement

Special Status Species

Consultation Req'd: ☐ Yes ☐ No

- ☐ US Fish and Wildlife Service
- ☐ National Marine Fisheries Service
- ☐ California Department of Fish and Game

Property Involvement

Work is confined to State Hwy R/W: ☐ Yes ☐ No

State Lands

- ☐ California State Lands Commission
- ☐ California Dept of Parks & Recreation
- ☐ Other

Federal Lands

- ☐ US Forest Service
- ☐ Other

Private

- ☐ Highway on private easement

PRELIMINARY RESPONSE

CA Coastal Commission – Date:
☐ Concur ☐ Do not Concur ☐ No additional authorization req'd to proceed ☐ Further authorization req'd to proceed

Local Agency-Date:
☐ Concur ☐ Do not Concur ☐ No additional authorization req'd to proceed ☐ Further authorization req'd to proceed

US Army Corps of Engineers-Date:
☐ Concur ☐ Do not Concur ☐ No additional authorization req'd to proceed ☐ Further authorization req'd to proceed

RWQCB-Date:
☐ Concur ☐ Do not Concur ☐ No additional authorization req'd to proceed ☐ Further authorization req'd to proceed

MBNMS-Date:
☐ Concur ☐ Do not Concur ☐ No additional authorization req'd to proceed ☐ Further authorization req'd to proceed

CA Dept of Fish & Game-Date:
☐ Concur ☐ Do not Concur ☐ No additional authorization req'd to proceed ☐ Further authorization req'd to proceed

Property Owner-Date:
☐ Concur ☐ No additional authorization req'd to proceed ☐ Do not Concur ☐ Further authorization req'd to proceed

BOX 1 DESCRIPTION OF DAMAGE OR IMMINENT THREAT

To Facility:

To Surrounding Area:

Available background information, including information on previous damage or repairs, if applicable.

Attach photographs

BOX 2 GENERAL DESCRIPTION OF SITE CONDITIONS

Describe the existing condition of the site, including wetlands, channels, streams, ponds, seeps and ditches, and other jurisdictional features. Include information on elevations, vegetation, property use, and structures.

BOX 3 PROJECT INFORMATION

Date of damage: **Proposed reconstruction starting date**:

Estimated duration of activity: ☐ Within the Season (approx 2 wks) ☐ Within the Year ☐ Multi-year

A capital improvement project previously identified (but not yet constructed) at this location: ☐ Yes ☐ No
If yes, indicate phase of review and **attach** additional information:

☐ Scoping ☐ Project Development ☐ Project Approved ☐ Design ☐ Advertising Contract

BOX 4 PRELIMINARY DESCRIPTION OF ANTICIPATED WORK

Include preliminary evaluation of whether initial response work will accomplish restoration of 2-lanes of traffic, or if additional work will be necessary to ensure reliability and safety.

Attach figures and maps, if available—

BOX 5 REMOVAL AND DEPOSIT OF MATERIAL

Material (rock, soil) has or will be deposited below the ordinary high water line for <u>fresh waters</u>?
☐ Yes or ☐ No
If yes, ☐ As a direct result of the event ☐ Related to necessary repair

Material (rock, soil) has or will be deposited below mean high water line for <u>tidal waters</u>?
☐ Yes or ☐ No*
If yes, ☐ As a direct result of the event ☐ Related to necessary repair

Mechanical material removal/excavation required ☐ Yes or ☐ No
If yes, ☐ loose material naturally deposited ☐ into more stable material

Preliminary volume estimate:
Volume of material to be <u>deposited</u>: **cubic yards (rock)**
Volume of material to be <u>excavated</u>: **cubic yards**

Amount of material below the ordinary high water mark or high tide line: **cy ,** **acres**
Type of material (rock/soil/debris): **Material source:**

Length of disturbance along roadway (from damage & repair combined): **linear feet (approx)**

BOX 6	IMPACTS ON TIDAL WATERS, WETLANDS OR MARINE SANCTUARY

Will the proposed work have temporary or permanent impacts, <u>beyond the damage caused by the event</u>, to wetlands, including seasonal wetlands, or within tidal or submerged lands: (i.e. additional impacts from repair)? ☐ Yes ☐ No

Will the proposed work have temporary or permanent impacts, <u>beyond the damage caused by the event</u>, to resources protected by the National Marine Sanctuary: (i.e. additional impacts from repair)? ☐ Yes ☐ No

If yes, please describe the resource; include one or more photographs of the existing conditions.

BOX 7	IMPACTS TO FRESH WATER DRAINAGES

Will the project or activity involve work in the bed, bank or channel of a river, stream (including seasonal streams), of extent or intensity <u>beyond the damage caused by the event</u>? ☐ Yes ☐ No

If yes, describe existing and proposed conditions.

Preliminary estimate of linear feet along the waterway that are involved -- ft.

BOX 8	POTENTIAL FOR IMPACTS TO SENSITIVE SPECIES OR HABITAT

List any state and/or federally listed species and/or associated habitat that occurs or may occur on the project site. If a federal or state listed species is being impacted, please provide a brief description of the habitat:

US Fish and Wildlife Service protocol surveys for the possible listed species have previously been conducted for this area?

☐ Yes, attached ☐ No

National Marine Fisheries Service—consultation on Essential Fish Habitat is required:

☐ Yes ☐ No

BOX 9	POTENTIAL FOR IMPACTS TO CULTURAL RESOURCES

Describe the potential for cultural, historic or prehistoric properties or resources within the project area:

A survey for cultural resources has been conducted: ☐ Yes ☐ No

Consultation is required: **SHPO** ☐ Yes ☐ No **ACHP** ☐ Yes ☐ No

BOX 10	NOTIFICATION PREPARED BY	
Name: **Position:** _____ **Signature:** ____________________ **Date:**		
Mailing Address		
Work Phone	**Fax #**	**E-mail Address**

Attachments:

APPENDIX D – EMERGENCY COMMUNICATIONS

The primary objective for effective communication during an emergency is to provide information that is:

- **Reliable**—Establish a best source for consistent and reliable information that enables people to make informed decisions about their travel.
- **Accurate**—Update relevant information as conditions warrant. The degree of disruption (ranging from "inconvenience" to "extreme" per CERP) and the dynamic nature of the work generally dictate the frequency, which may be needed on a daily basis under the most severe conditions.
- **Consistent**—The message sent and delivered by multiple sources, from official statements (press releases) to roadside flag-persons, is as consistent as possible. Given there is little control over "unofficial" sources of information, it is recognized that emphasis on the first two points to produce a reliable source of accurate information, can help control potential rumors.

Incident Command: Monterey County's Big Sur Coordinated Emergency Response Plan[27] is the guiding document for establishing the incident command system. Caltrans also uses the Big Sur Coast Emergency Operations and Notification Plan as a means of initiating and maintaining communications and operations during full closures of Highway 1 along the Big Sur Coast.

Public Information: Caltrans provides information about highway conditions or incidents are disseminated to Big Sur travelers and the local community. See attachment X for description of the information and distribution of the messages.

Agency Roles: Confirm agency roles and responsibilities for emergency communications:

Responsible Party	Area of Responsibility
Monterey Co. OES	Establish Incident Command and provide tactical incident and dispatch communications
Sheriff, CHP, Volunteer Fire Dept.	Emergency Services per Incident Command
Traffic Management Center (TMC)	Caltrans Operations
Caltrans Environmental Planning	Caltrans Interagency Coordination and Environmental Compliance
Caltrans Public Information	Traveler and Community Liaison
Big Sur Chamber of Commerce	Liaison to Community and Businesses

[27] Monterey County Office of Emergency Services. *Big Sur Coordinated Emergency Response Plan.* 1999

Caltrans

- Traffic Management Center (Operations)
- Environmental Planning (Interagency Coordination)
- Public Affairs Office (Traveler and Community Liaison) – writes and disseminates news releases; answers questions from the public, other agencies, and the media
- Caltrans Environmental Coordinator (monitor)—ensures storm damage construction is conducted in compliance with environmental regulations; primary liaison between Caltrans and regulatory agencies regarding changes in project scope, conditions, impacts or mitigation.*

Monterey County Office of Emergency Services

- Establishes Incident Command
- Provide tactical incident and dispatch communications

CHP and Monterey County Sheriff

- Emergency response providers

Big Sur Chamber of Commerce

- Liaison to community and businesses

APPENDIX E: PROJECT COMPLETION FORM

PROJECT COMPLETION FORM FOR
EA: ___________

PROJECT INFORMATION

(Attach Quad Map and Project Plan)

_______ ______ ____________
County Route Post Mile

Permits/Coordination

Agency

__ ACOE __ FWS __ NMFS __ MBNMS
__ USFS __ RWQCB __ CCC __ CDFG
__ DPR __ State Lands __ MonCo __ SLOCo

Proposed Project Description Impacts and Mitigation (Attach Categorical Exemption, Conditions Memo, and Technical Studies)

______________________ ____________________
Begin Construction Date End Construction Date

Description of Project as Constructed:

Environmental Impacts Associated with Project Construction:
Habitat (include type and acreage):

Species of Concern (include #'s disturbed by project):

Other Impacts (Water Quality, Visual Resources, Cultural Resources, Access):

Mitigation Implementation

Describe success in meeting project avoidance, minimization, and compensation measures:

If unsuccessful, explain failure to meet project avoidance, minimization, and compensation measures:

Additional Monitoring Requirements

Mitigation **Agency**

Date of Next Report

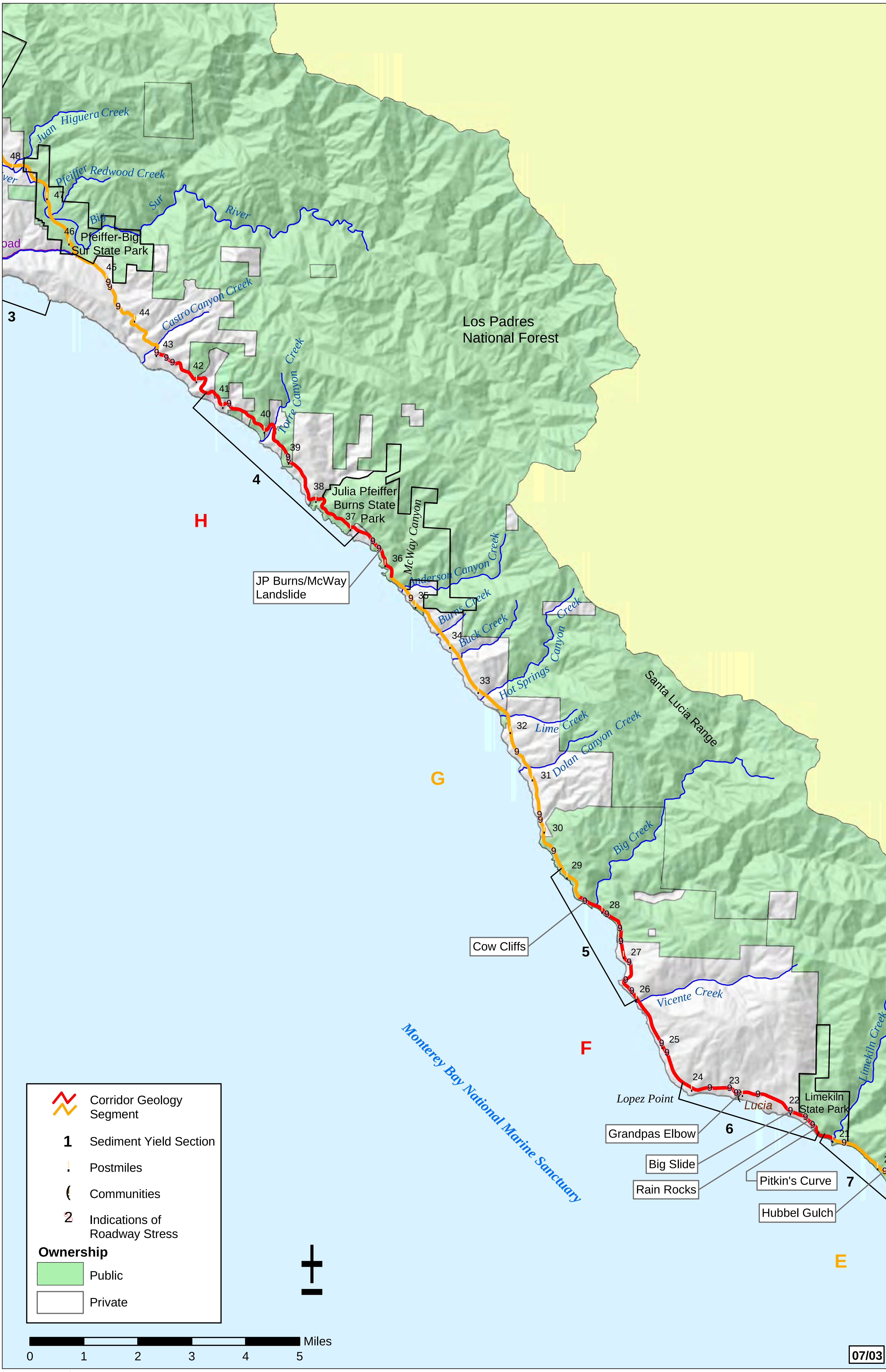
Signature Phone Date

Corridor Map

Guidelines for Landslide Management and Storm Damage Response

Attachment 1a (north)

Caltrans



Corridor Map

Guidelines for Landslide Management and Storm Damage Response

Attachment 1b
(central)

Corridor Map

Guidelines for Landslide Management and Storm Damage Response

Attachment 1c (south)