SPECIAL REPORT 188

LANDSLIDES IN THE INTERSTATE 5 CORRIDOR BETWEEN VALENCIA AND GORMAN, LOS ANGELES COUNTY, CALIFORNIA

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CALIFORNIA GEOLOGICAL SURVEY

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INTRODUCTION

Figure 1. Oblique aerial view of the Interstate 5 corridor, looking north, over the 5-mile grade section.

Interstate 5 is the primary north-south freeway in the state of California. It runs from the Mexican border to the Oregon border, and passes through the major metropolitan areas of San Diego, Los Angeles and Sacramento. It is the main freeway connecting the northern and southern portions of the state. The section of I-5 north of Los Angeles connects the Los Angeles basin with the San Joaquin Valley across the Transverse Ranges. This section of the highway traverses the steep east-west trending mountains in a northwest trending structural trough known as the Ridge Basin Syncline. The current alignment is a four-lane freeway that was completed in 1969. Previous alignments have followed similar routes and include old Highway 99 and the old Ridge Route.

A number of factors combine to make this segment of highway vulnerable to damaging landslides. These include the rugged topography, weak rocks, and moderate seasonal and occasionally heavy rainfall, which leads to elevated groundwater in landslides and slide-prone slopes. Slope movements in the region range from nuisance mudflows to large deep-seated bedrock slides with potential for major highway disruption.

To place the landslides of this highway segment in regional perspective, and to provide background data for potential stabilization projects, the California Department of Transportation, Office of Infrastructure Research contracted with the California Department of Conservation's California Geological Survey (CGS) to prepare maps of the Interstate 5 corridor between Valencia and Gorman specifically, post mile 55 to post mile 80 (Figure 2). These maps include a geologic map, a map of landslides in the highway corridor, and maps of those landslides most likely to affect the highway. The mapping area includes the highway alignment and the surrounding area generally up to 1/2 mile to either side of the roadway. The maps do not indicate the probability of

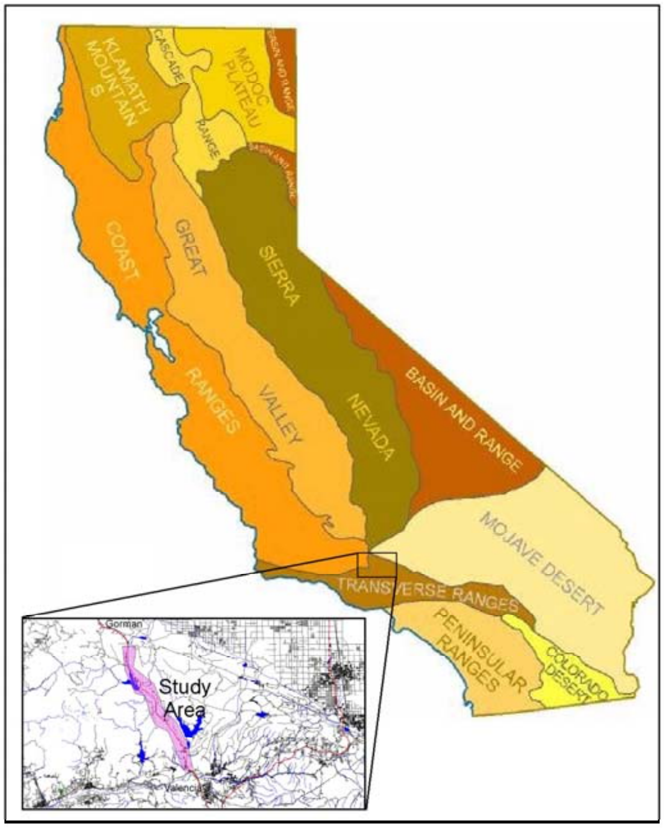


Figure 2, Index map showing the I-5 corridor across the Transverse Ranges

movement of any individual landslide or the stability of areas outside of mapped landslides. However, the characteristics of each mapped landslide and physical properties of the geologic units can be used by engineers and geologists at Caltrans in the planning of more detailed evaluations for roadway improvement projects.

The maps presented here were prepared at a scale of 1:12,000 (1 inch = 1000 feet) by compilation of previous mapping, interpretation of aerial photographs and original field mapping. These maps were prepared using a computer geographic information system (ArcView v. 3.2) on scanned images of USGS 7.5-minute topographic quadrangles. Portions of the Frazier Mountain, Lebec, Black Mountain, Liebre Mountain, Whitacker Peak, Warms Springs Mountain, Val Verde and Newhall quadrangles form the base map of Plates 1 and 2. The geologic and landslide maps were drawn in the computer GIS, which includes database tables describing each feature mapped.

REGIONAL OVERVIEW

The segment of Interstate 5 discussed in this reportis located in the Transverse Ranges geomorphic province. The Transverse Ranges is a geologically complex region characterized by east-west trending mountain ranges and compressional tectonics associated with a bend in the right-lateral San Andreas Fault. Late Cenozoic uplift has resulted in exposure of basement rocks as old as Precambrian, a Mesozoic and Cenozoic supra-crustal series, and broad down warped basins that have received voluminous late Tertiary fill. These basins serve as natural highway corridors through the Transverse Ranges.

On the southern slopes of the Transverse Ranges, Interstate 5 roughly follows Ridge basin, a thick sequence of late Tertiary sedimentary rocks that have been folded and uplifted. Ridge basin is the northward projecting arm of a late Tertiary basin that included Ventura and Soledad basins to the south. At the southern end of the corridor Ridge basin joins with Soledad Basin. This area is covered with more recent Pleistocene fluvial deposits of the Saugus Formation and alluvium. Deposition in the

Ridge basin was concurrent with deformation in the Transverse Ranges. Stratigraphic relationships between the sedimentary units and various faults within and bounding Ridge Basin provide temporal control for the tectonic development of this part of the Transverse Ranges. For this reason, and because of the oil and gas potential of sedimentary basins of this type, the geology of Ridge Basin has been extensively studied (Woodburne, 1975; Crowell and Link, 1982; Dibblee, 1982).

Sedimentary rocks in the southern part of the I-5 corridor are predominantly Miocene shale and sandstones of the Castaic Formation. Pleistocene sandstone and conglomerate of the Saugus Formation is exposed at the southern end of the corridor. The northern part of the corridor is mostly underlain by the Ridge Basin group, which consists of the Violin Breccia, Ridge Route Formation, Peace Valley Formation, and Hungry Valley Formations. The Violin Breccia is exposed along the San Gabriel Fault and is thought to represent talus and alluvial fan deposits at the base of the active San Gabriel fault scarp. The other units of the Ridge Basin group are non-marine basin fill consisting of interlayered sandstone, siltstone, shale and conglomerate, which interfinger with the Violin Breccia.

The dominant structure in the area is a northwest plunging syncline along the axis of Ridge basin. This results in beds that generally dip to the northwest on the east side, to the northeast on the west side, and to the north in the axial region of the basin. Differential erosion has resulted in a series of resistant ridges and dip slopes. The northwest to northeast facing dip slopes are particularly vulnerable to landslides.

STUDY AREA

The Interstate 5 corridor described in this report extends from P.M. 55 near the junction with State Highway 126 to P.M 80 near the junction with State Highway 138. The route now followed by Interstate 5 was established in 1969. Some parts of the old Highway 99 were used for the new alignment. New freeway was constructed for other portions where the old highway was either left in place and maintained, or abandoned. The five-mile grade section just north of Castaic was constructed in the 1930s as part of Highway 99, and then converted to Interstate 5 northbound during the 1969 construction. The southbound lanes were constructed on a new alignment 0.5 miles eastward. The alignment crosses two arms of Pyramid Reservoir. Filling of the reservoir in 1973 inundated Highway 99 and two major fills for Interstate 5.

A number of factors affect the stability of slopes in this region and may increase the likelihood of landslides. The Interstate 5 corridor traverses areas of rugged terrain with substantial cuts and fills. In Cherry Canyon a 2:1 fill is over 250 feet deep and approximately 3000 feet along the highway. At Black Mt. M-10 a 2:1 cut is over 350 feet high. Vegetation ranges from grassland to dense chaparral. Wildfires commonly strip large areas of vegetation. The corridor is very close to several major active faults. The San Gabriel fault is in the western most part of the mapped area for this project. The San Andreas fault is approximately 1.5 miles from the northern end of the corridor. The Garlock and Big Pine faults intersect with the San Andreas fault a short distance north of the corridor.

GEOLOGIC MAPPING

The Interstate 5 corridor is almost entirely within a geological feature known as the Ridge basin. Ridge basin was initially a marine embayment connected to the Soledad and Ventura basins to the south. This is recorded by the Castaic Formation, a succession of marine shales with arkosic sandstone interbeds (Dibblee, 1982). In the Pliocene, rapid uplift of source areas accompanied by tectonic subsidence of Ridge basin resulted in deposition of an enormous thickness of mostly non-marine sediment with a stratigraphic thickness in excess of 30,000 feet. These rocks are assigned to the Ridge Basin group. Over the years different names have been applied to the various sedimentary units, although there is general agreement at the formation level.

The geologic map (Plate 1) was prepared by compiling previously published geologic maps, and performing additional interpretation of aerial photographs, and field mapping. Dibblee Foundation geologic maps of the pertinent quadrangles were scanned and digitized to create the geologic map of the corridor. Then our additional interpretation of landslide deposits was added, as well as minor revisions to some geologic units.

GEOLOGIC UNITS

The San Gabriel fault slices through the southeast portion of the Interstate 5 corridor, separating rocks of diverse origin. Most of the corridor is northeast of the fault and includes rocks of the Ridge basin Group and Castaic Formation.

Castaic Formation

The Castaic Formation (Tc, Tcs) is the oldest sedimentary unit exposed in the corridor. It is a marine sequence of late Miocene age composed primarily of shale with interbedded siltstone, sandstone, and conglomerate (Yeats, et. al., 1985). The shale facies (Tc) is the dominant unit and consists of dark gray micaceous shale, with minor sandstone interbeds. This unit underlies much of the southern third of the corridor and is particularly susceptible to landsliding. The sandstone facies (Tcs) consists of light brown fine- to medium-grained arkosic sandstone, with minor shale interbeds. The sandstone facies typically occurs as sporadic layers and lenses within the eastern exposures of the Castaic Formation, and is less susceptible to landsliding.

Ridge Basin Group

Most workers agree that the Ridge Basin group should be divided into four formations. Rather than forming a simple layer cake, the stratigraphy is more complex with many of the units interfingering. The Violin Breccia is exposed along the San Gabriel Fault and is thought to represent talus and alluvial fan deposits at the base of the active San Gabriel fault scarp. The Peace Valley Formation occurs mainly along the west side of the basin and the Ridge Route Formation occurs mainly along the east side. Both are composed predominantly of interbedded sandstone and shale with subordinate conglomerate. However the Ridge Route Formation is generally coarser and consists of shallow water basin-margin deposits, whereas the more fine-grained Peace Valley Formation represents axial deposits (Link and Osborne, 1982). All three units are contemporaneous and interfinger with one another. All three units are conformably overlain by the Plio-Pleistocene Hungry Valley Formation, which consists of alluvial deposits.

Violin Breccia

The Violin Breccia (Tvb) is a remarkable unit. It is exposed along the east side of the San Gabriel fault for a distance of 35 km. Its exposures are generally within 1-2 km of the fault, and it has a stratigraphic thickness of over 11,000 m (Crowell, 1982). Deposition of the Violin Breccia is thought to have occurred over the lifespan of the San Gabriel fault, or roughly 7-9 million years. The Violin Breccia interfingers laterally, and is contemporaneous with the Castaic Formation and all units of the Ridge Basin Group. The oldest beds are 10-12 million years old, deposited in the upper Miocene, and the youngest beds are of Pliocene age, about 3 million years old. The beds overlap to the north as a result of strike slip displacement along the San Gabriel fault. Consequently, no more than about one third of the total stratigraphic thickness is present at any one place.

Lithologically the Violin Breccia is a sedimentary breccia composed of blocks and boulders of varions size embedded in an earthy and sandy matrix. All of the clasts appear to originate from a limited source in the Frazier Mountain area. The coarse gneissic rubble along the fault grades laterally in as little as one kilometer into the sandstones and shale of the Castaic Formation and Ridge Basin Group.

Ridge Route Formation

The Ridge Route Formation (Trr, Trri) is essentially a coarse-grained marginal facies of the Ridge Basin Group deposited along the eastern margin of Ridge Basin (Link, 1982). It consists predominantly of sandstone, conglomeratic sandstone, and mudstone. Toward the central part of the basin the Ridge Route interfingers with the finer-grained deposits of the Peace Valley Formation. Five major clastic tongues of the Ridge Route Formation cross the basin and interfinger with the Violin Breccia. Many smaller tongues and individual beds pinch out in the Peace Valley Formation. The sandstones are mostly well cemented and fairly resistant to landsliding. However the sporadic shale interbeds are potential slide planes.

Peace Valley Formation

The Peace Valley Formation (Tpv) is the fine-grained axial facies, deposited in the central region of the basin (Link, 1982). It is a thick sequence of shale with minor siltstone and sandstone. Minor amounts of dolomicrite, pyritic shale, and gypsiferous siltstone are also present (Irvine, 1977), suggesting an isolated non-marine basin environment. It interfingers with both the Ridge Route Formation and the Violin Breccia. The shale and siltstone of the Peace Valley Formation is typically dark gray, gray or green-gray, well bedded and poorly indurated. However, in some places it is exceptionally well indurated. Dip slopes underlain by the Peace Valley Formation are particularly unstable due to its poorly indurated character in most exposures.

Hungry Valley Formation

Hungry Valley Formation (Thvs) conformably overlies all other formations of the Ridge Basin Group. It consists of white conglomeratic sandstone, brown sand stone and interbedded gray and brown sandstone (Link, 1982). These are alluvial deposits that are thought to be derived from sources to the north, although no source area has been clearly identified (Crowell, 1982b).. The lower part of the Hungry Valley Formation interfingers with the Violin Breccia. However in the northwest corner of the basin the younger Hungry Valley deposits overlap the Violin Breccia and the San Gabriel fault, indicating the time at which this strand of the fault became inactive. Exposures of the Hungry Valley Formation are in the northern end of the Interstate 5 corridor. In this area, compressive stress associated with the San Andreas fault has warped these rocks into east-west trending folds of relatively low amplitude superimposed on the Ridge basin syncline. The low amplitude of the folds is not conducive to the formation of large dip slopes. Also the coarse-grained Hungry Valley deposits are generally stronger and form more stable slopes than the finer-grained deposits of the Ridge Basin Group. Consequently Relatively few landslides occur in exposures of the Hungry Valley Formation.

Units southwest of the San Gabriel fault

Only a small part of the Interstate 5 corridor lies southwest of the San Gabriel fault. Rocks southwest of the San Gabriel fault are represented by the Towsley Formation and the Pico Formation.

Towsley Formation

The Towsley Formation (Ttoc, Ttog) is a marine unit with three members (Yeats, et. al., 1985), two of which have been mapped in the corridor. The Hasley Conglomerate Member (Ttog) is a red-brown basal conglomerate that contains distinctive rounded anorthosite clasts. The claystone/siltstone member (Ttoc) represents deep marine deposition. It is somewhat susceptible to landsliding, although none of the mapped slides within the corridor occur in the Towsley Formation.

Pico Formation

The Pico Formation (Tps) is generally of shallow marine origin overlies the Towsley Formation unconformably (Yeats, et. al., 1985). Two units are recognized within the Pico Formation, one of which has been mapped in the corridor. The sandstone member (Tps) is the coarser member and consists of light gray to tan fine-grained to pebbly sandstone. One landslide in the corridor is partially within the Pico Formation.

Saugus Formation

The Saugus Formation disconformably overlies the Pico Formation southwest of the San Gabriel fault. Northwest of the fault, the Saugus rests with angular unconformity atop the Castaic formation. The deposits of the Saugus Formation represent alluvial deposits of the ancestral Santa Clara River (Dibblee, 1982). Dibblee (1997) designates the Saugus Formation as Plio-Pleistocene based on work by Kew (1924). However more recent geochronologic and paleontologic studies have failed to support a Pliocene designation (Yeats et. al., 1985). The formation consists of weakly cemented gray pebbly conglomerate, sandstone and siltstone. The weakly cemented sandstones are relatively unstable on steep slopes, and a number of small slides occur in the Saugus Formation near the southern end of the corridor.

Surficial deposits

Five units of relatively undeformed surficial deposits are recognized within the Interstate 5 corridor. Although the Saugus Formation is composed of Pleistocene alluvial deposits, its degree of deformation warrants separate consideration from other relatively undeformed Quaternary alluvial deposits.

Stream Terrace deposits

Stream Terrace deposits (Qt) are associated with modern drainages and consist of poorly consolidated gravel, sand, and silt. They form gently tilting surfaces well above the level of active drainages. They rest with angular unconformity on all older formations. Some terraces form cliffs when they are cut by a meander of the active drainage. Although the faces of these cliffs are generally only a few tens of feet high, the faces are unstable.

Older alluvium

Older alluvium (Qoa) are the older dissected deposits of modern drainages that are outside and above the active floodplain. These deposits are poorly consolidated to unconsolidated sand, gravel and silt. They may display some soil development.

Younger alluvium

Younger alluvium (Qa) represents the deposits of modern drainages that are within active floodplains but outside the active channel. These deposits are unconsolidated sand, gravel and silt, generally with little or no soil development.

Stream gravel

Stream gravel (Qg) is the sand and gravel within the active channel of major streams.

Landslide deposits

The landslide deposits (Qls, Qls?) shown on the geologic map are the larger and deeper slides from the landslide map. Landslide areas are divided into landslides (Qls) and questionable landslides (Qls?) reflecting the designation from the landslide map described below. Definite and probable landslides are designated Qls, while questionable landslides are designated Qls?. The materials in the landslide deposit are highly variable, depending on the source material and range from nearly intact sandstone to completely disrupted clay soils.

Artificial fill

The artificial fill (af) unit on the geologic map depicts the more significant areas where fill has been placed by human activity. Most of the fill areas are associated with the Interstate 5 freeway. Some are associated with urbanization in the cities of Valencia and Castaic. The highway fills generally fill in canyons and derive their material from nearby cuts. The material in the fills depends on the nearby bedrock lithology. Some fills cover significant areas at the scale of our maps. The stability of existing fill slopes depends on a number of factors and must be evaluated on a case specific basis.

LANDSLIDES

More than 200 landslides were mapped in the Interstate 5 corridor area between P.M. 55 and P.M. 80 (Plate 2).). Although we have attempted to show all landslides, there may be some small shallow slides that have occurred within the past four years (the most recent aerial photographs used in this study were taken in 1999).

The landslide map (Plate 2) was prepared primarily by interpretation of aerial photographs, with review of previous reports and field checking. Landslides shown on previous maps, unpublished CGS mapping, and in reports prepared for Caltrans, were checked on aerial photos and in the field, if possible. The boundaries of landslides from previous work were revised and additional landslides were added based on geomorphic interpretation for this investigation.

In this study we have recognized, classified and mapped landslides based on their geomorphology. Landslides displace parts of the earth's surface in distinctive ways, and the resulting landforms can show the extent and characteristics of the landslide. Recognition of these landforms (scarps, troughs, benches and other subtle topographic features) allows the geologist to recognize, map and classify most landslides. For this study, landslides were recognized by their topographic expression, as interpreted from topographic maps and aerial photographs, and seen in the field. For each landslide we have attempted to record the characteristics of the slide, generally following the recommendations of Wieczorek (1984). Portrayal of landslides on the map includes a pattern, which designates the type of slide (materials and type of movement). The color of the slide area signifies its level of activity, and the thickness of the outline signifies the confidence of our interpretation as described below.

Types of landslides

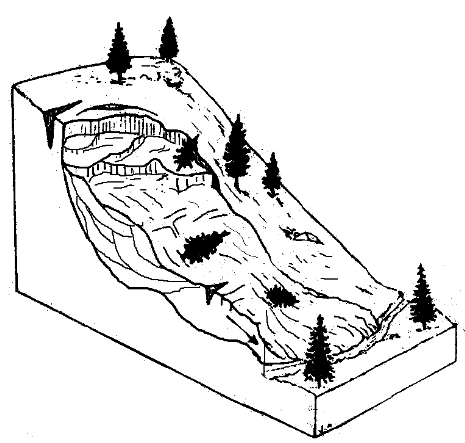
Each landslide is classified according to the materials involved and the movement type, as deduced from the associated landforms. A two-part designation is given to each slide, based on the system of Cruden and Varnes (1996). Materials are called either rock or soil, and soil is subdivided into fine-grained (earth) and coarse-grained (debris). This system was designed to allow a series of names that completely describes the materials and processes involved in a landslide. We have simplified the system slightly to use it in preparing an inventory map of an area. We use the terms and definitions of Cruden and Varnes, but have attempted to simplify the designations by listing only the primary classification of a given landslide. For example, our example diagram of a rock slide, (see below), is a rotational rock slide-flow in which the upper part of the slide has moved by sliding, but the lower part has disaggregated and is flowing. On this map this type of slide is shown simply as a rock slide. Using the Cruden and Varnes system to classify rock versus soil is also complicated by the various vague and overlapping meanings of those terms in common usage. In California, many geologic formations are not hard or indurated rock and it is possible to find all gradations between weak, soil-like, and hard rocks. Our general system is to call material “rock” if it has a geologic formation name and the original geologic structure can be discerned. By these criteria, a weak, poorly consolidated formation such as the Saugus Formation is classified as “rock” although parts of the formation could be classified as soil in engineering terms.

Applying the system of Cruden and Varnes (1996), with the criteria described above, there are four predominant types of landslides in this study area.

ROCK SLIDE: A slide involving bedrock in which much of the original structure is preserved. Strength of the rock is usually controlled by zones of weakness such as bedding planes or joints. Movement occurs primarily by sliding on a narrow zone of weakness as an intact block. Typically these landslides move downslope on one or several shear surfaces, called slide planes. The failure surface(s) may be curved or planar. In some older classification systems, slides with curved failure surfaces are commonly referred to as slumps, while those with planar failure surfaces are called block glides. In the Cruden and Varnes (1996) system, these are referred to as “rotational” or “translational” rock slides if the geometry of the failure surface is known.

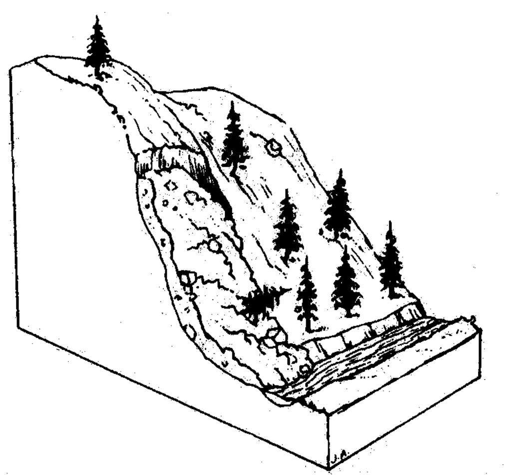
Rock slides commonly occur on relatively steep slopes in competent rocks. Slopes are commonly from 35% to as steep as 70%. Movement of an intact rock mass along a curved slide plane leads to a steep headscarp at the upper boundary of the slide. Immediately below the headscarp is a block that is commonly rotated so that it is less steep than the surrounding hillslopes. Below the bench, the slide mass may be intact and similar gradient to the surrounding slopes or may have additional scarps and benches. The lower parts of the slopes may bulge outward and be steeper that the surrounding slopes.

The rotation of the block that typically occurs in the upper part of a “slump” rock slide leads to a less steep area or in some cases a closed depression. These areas may accumulate and hold water more than the surrounding slopes. Recognition of landslides is aided if the accumulated water leads to significantly different vegetation, especially phreatophytic (water loving) vegetation in such areas. The improved water holding capacity of these areas also decreases the overall stability of the slide mass by allowing water more time to infiltrate the slide.



The larger and deeper rock slides are sensitive to conditions that affect the entire slope. A rise in the water table that may occur in high rainfall years may decrease the overall stability. Undercutting of the base of slope or addition of fill to the upper slope also tends to destabilize an existing slide. Movement is usually slow, on the order of millimeters per year, and incremental, sometimes only occurring in years of higher than normal rainfall. Movement can, however, accelerate in some cases to the point that the mass fails more rapidly, moving several meters in the course of a few days, or by breaking up into smaller rock falls and debris slides which can move several meters in a few minutes.

DEBRIS SLIDE: A slide of coarse grained soil, commonly consisting of a loose combination of surficial deposits, rock fragments, and vegetation. Strength of the material is low, but there may be a very low strength zone at the base of the soil or within the weathered bedrock. Debris slides typically move initially as shallow intact slabs of soil and vegetation, but break up after a short distance into rock and soil falls and flows.

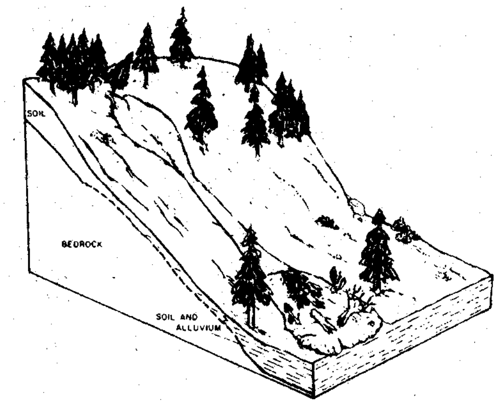


Debris slides commonly occur on very steep slopes, commonly as steep as 60% to 70%, usually in an area where the base of a slope is undercut by erosion. They are most common in unconsolidated sandy or gravelly units, but also are common in residual soils that form from the in-place weathering of relatively hard rock. Movement of the slide mass as a shallow slab leads to a smooth steep, commonly curved scar. The debris is deposited at the base, commonly as a loose hummocky mass, although the deposit may be rapidly removed by erosion. Debris slides form steep, unvegetated scars. Debris slide scars are likely to remain unvegetated for years. Revegetated scars can be recognized by the even steep slopes, and the shallow amphitheater shape of many scars.

Because debris slides are relatively shallow they are sensitive to changes that are smaller and may occur over shorter times than those that affect deeper slides. A single heavy rainstorm or series of storms may deliver enough rain to trigger debris slides. Individual debris slides may move at rates ranging from meters per day to meters per minute. Debris slide scars are extremely steep and therefore are very sensitive to renewed disturbance. Natural erosion at the base of debris slide scars may trigger additional slides. Cutting into the base of a debris slide scar by man may also trigger renewed slides. Even without additional disturbance, debris slide scars tend to ravel and erode, leading to small rock falls and debris slides from the same slope.

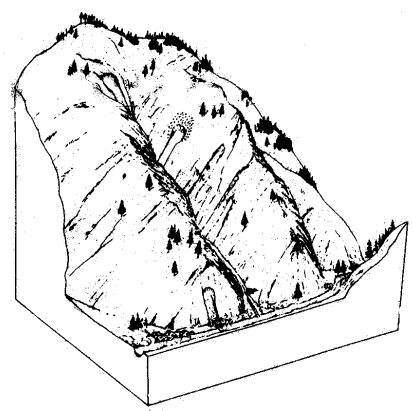
DEBRIS FLOW: A landslide in which a mass of coarse-grained soil flows downslope as a slurry. Material involved is commonly a loose combination of surficial deposits, rock fragments, and vegetation. High pore water pressures, typically following intense rain, cause the soil and weathered rock to rapidly lose strength and flow downslope.

Debris flows commonly begin as a slide of a shallow mass of soil and weathered rock. Their most distinctive landform is the scar left by the original shallow slide. The path of the debris flow may be marked by a small drainage that has been stripped of



vegetation. The debris flow may not leave any deposit if it flows directly into a larger creek and is immediately eroded away. Many debris flow deposits are ephemeral, but in some cases successive debris flows may deposit material in the same area leading to a debris fan, which resembles a small, steep alluvial fan.

Because debris flows are relatively shallow they are sensitive to changes that are smaller and may occur over shorter times than those that affect deeper slides. Debris flows are especially sensitive to changes in water conditions in slopes. They are triggered in natural conditions by factors that increase the pore pressures in the shallow subsurface, commonly at the base of the soil. A single heavy rainstorm or series of storms may deliver enough rain to trigger debris flows. Individual debris flows may move at rates ranging from meters per hour to meters per second. Works of man that tend to concentrate water on steep slopes have to be carefully designed to avoid increasing the potential for debris flows.

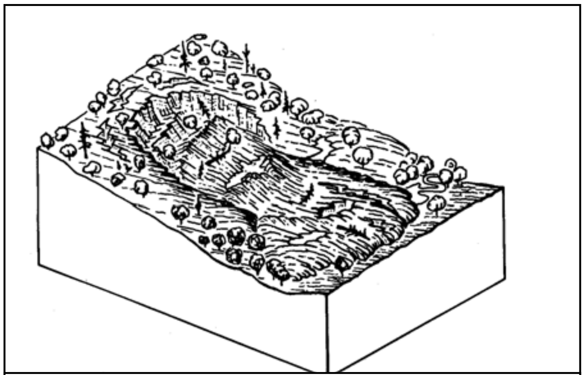


DEBRIS SLIDES and DEBRIS FLOWS are commonly found on a landform called a DEBRIS SLIDE SLOPE, which represents the coalesced scars of numerous landslides that are too small to depict on a map of this scale. These landforms are generally very steep, and have developed in areas of weak bedrock mantled with loose, thin soils and covered with sparse vegetation.

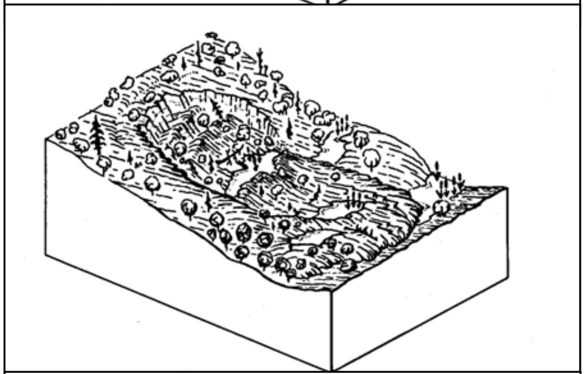
Debris slide slopes are typically very steep, 60% and steeper is common. Areas in which the dominant form of erosion is by debris slides and debris flows are characterized by uniform very steep slopes, commonly with each small canyon having rounded amphitheater-shaped heads.

Activity of landslides

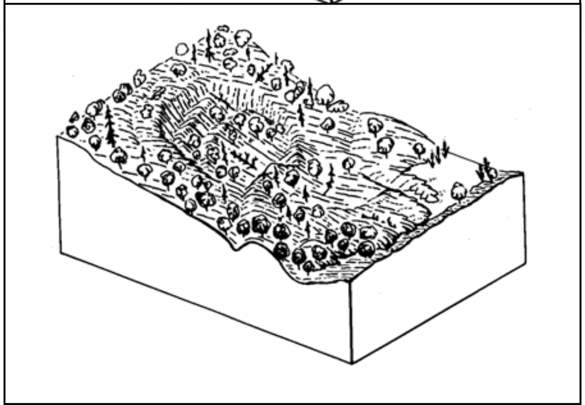
Each landslide is classified based on the recency of activity into one of four categories based on the system of Keaton and DeGraff, (1996). The diagrams below illustrate levels of activity (diagrams from Wieczorek, 1984).



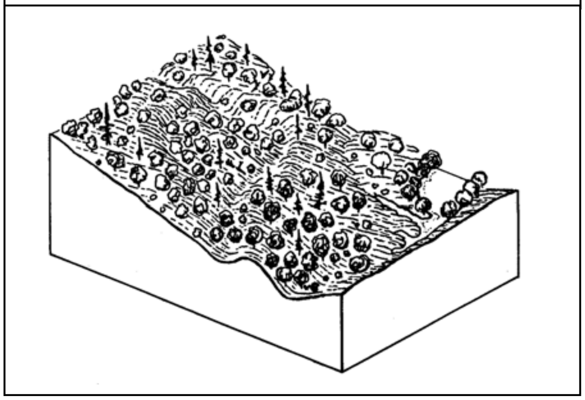
active or historic: The landslide appears to be currently moving or movements have been recorded in the past. Fresh cracks, disrupted vegetation or displaced or damaged man-made features indicate recent activity. Water may be ponded in depressions created by rotation of the slide mass or blockage of stream drainage.



dormant-young: The landforms related to the landslide are relatively fresh, but there is no record of historic movement. Cracks in the slide mass are generally absent or greatly eroded; scarps may be prominent but are slightly rounded. Depressions or ponds may be partly filled in with sediment, but still show phreatophytic vegetation.



dormant-mature: The landforms related to the landslide have been smoothed by erosion and re-vegetated. The main scarp is rounded, the toe area has been eroded and some new drainages established within the slide area. Benches and hummocky topography on the slopes are subdued and commonly obscured by dense, relatively uniform vegetation.



dormant-old: The landforms related to the landslide have been greatly eroded, including significant gullies or canyons cut into the landslide mass by small streams. Original headscarp, benches and hummocky topography are now mostly rounded and subtle. Closed depressions or ponds now filled in. Vegetation has recovered and mostly matches the vegetation outside the slide boundaries.

Confidence of Interpretation

Each area is classified as a definite, probable or questionable landslide. Because landslides are mapped based on their landforms, the confidence of identification is dependent on the distinctness of those landforms. Confidence of interpretation is classified according to the following criteria:

DEFINITE LANDSLIDE. Nearly all of the diagnostic landslide features are present, including but not limited to headwall scarps, cracks, rounded toes, well-defined benches, closed depressions, springs, and irregular or hummocky topography. These features are common to landslides and are indicative of mass movement of slope materials. The clarity of the landforms and their relative positions clearly indicate downslope movement.

PROBABLE LANDSLIDE. Several of the diagnostic landslide features are observable, including but not limited to headwall scarps, rounded toes, well-defined benches, closed depressions, springs, and irregular or hummocky topography. These features are common to landslides and are indicative of mass movement of slope materials. The shapes of the landforms and their relative positions strongly suggest downslope movement, but other explanations are possible.

QUESTIONABLE LANDSLIDE. One or a few, generally very subdued, features commonly associated with landslides can be discerned. The area typically lacks distinct landslide morphology but may exhibit disrupted terrain or other abnormal features that strongly to vaguely imply the occurrence of mass movement.

Each landslide is also classified by a number of other factors not portrayed on the map, but listed in the accompanying database table. The records in the database table include a unique number for each landslide in each quadrangle and a listing of the quadrangle. Other factors recorded for each landslide are:

Table 2: Additional GIS database fields.

FIELD	VALUES	NOTES
Depth	s,m,d	As interpreted from the geomorphology and classified into one of the following three categories: shallow <3 m, medium 3-15 m, deep >15 m.
Direction of movement	azimuth	
Primary geologic unit	Tpv, QTs	The geologic unit from the geologic map.
Primary lithology	ss, sh, ss-sh	Corresponding to the unit on the geologic map. In this area the lithologies are ss, sandstone, sh, shale and ss-sh, sandstone with lesser shale.
Secondary geologic unit	Trr, Tc	If a landslide involves two bedrock geologic units
Secondary lithology	ss, sh,	If a landslide involves two bedrock geologic units
Strike of bedrock	azimuth	
Dip of Bedrock	0-90 deg.	
Source of geologic data		Reference of previous geologic map containing strike and dip information or field locality number where strike and dip measured
area	Value	
perimeter	Value	

FACTORS INFLUENCING SLOPE STABILITY IN THIS HIGHWAY CORRIDOR

The inclination of slopes, their underlying rock types and geologic structures, landforms, and rainfall all influence the slope stability along the Interstate 5 corridor between Valencia and Gorman.

Bedrock geology has a very strong influence on the types and activity of landslides along the Interstate 5 corridor. Slopes along the corridor range from gentle to very steep. However, because of the influence of geologic structure, the majority of landslides are not necessarily on the steepest slopes. Significant sliding has indeed occurred on very gentle slopes. The synclinal structure of the basin has warped bedding into gentle to moderate northwestward to northeastward dips. A hogback topography has developed from the weathering of this structure. It is characterized by long strike ridges with relatively gentle dip slopes, and resistant ledges forming relatively steep anti-dip slopes. Most of the significant landslides in the Interstate 5 corridor occur on dip slopes. Bedrock lithology is also a factor in slope stability. Slopes of shale are generally much less stable than slopes of well-cemented sandstone or siltstone. This is due to a number of factors, which include lower shear strength, a planar fabric which leads to low weathering resistance and a preference for sliding along bedding planes, and impermeability which leads to concentration of water along bedding planes thereby lubricating potential slide surfaces. Although sandstones may also be well bedded and offer preferred directions for sliding, the planar fabric of shale is on a microscopic level, caused by the alignment of individual clay particles. For these reasons, landslides are more likely to occur in formations where shale is the dominant lithology, such as the Castaic Formation and the Peace Valley Formation.

Precipitation is a major factor influencing landslides. Based on Western Regional Climate Center data from the years 1948 to 1990, the area around the Interstate 5 corridor receives about 13 inches of rainfall annually. However, the rainfall in this area often comes as very intense storms of short duration. Although the average rainfall for any day of the year is less than 0.4 inches, extreme events commonly result in up to 3 inches of rainfall in 24 hours, and occasionally over 6 inches (Figure 2). These shorter term, but very intense rain storms tend to de-stabilize the shallower types of landslides, such as debris slides and debris flows. In wet years higher total rainfall can lead to elevated groundwater in landslides and slide-prone slopes, increasing the potential for larger, deeper slides.

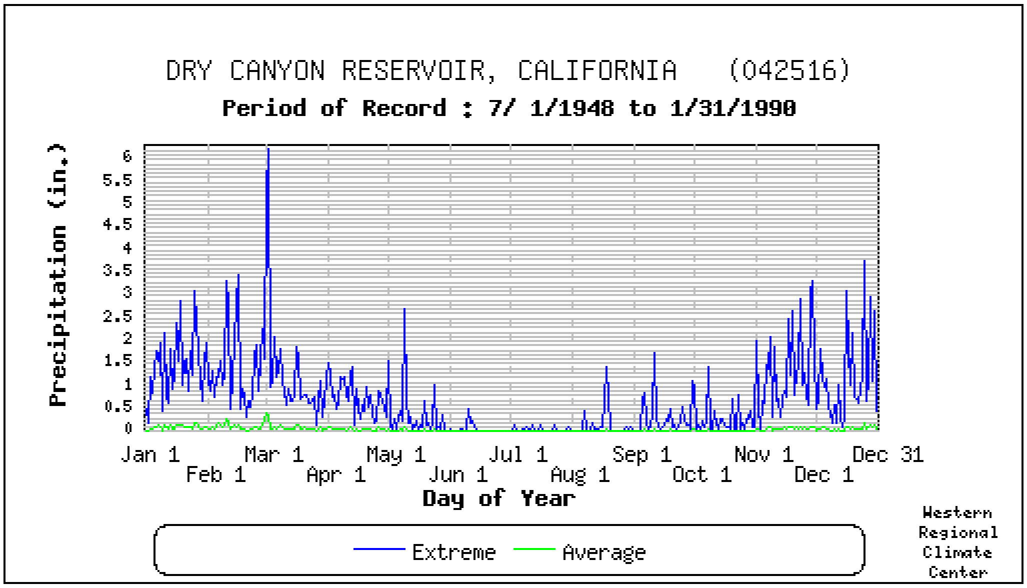


Figure 2. Average and extreme daily rainfall for Dry Canyon Reservoir, California, near Santa Clarita. Note that average daily rainfall is rarely over 0.4 inch, but extremes reach over 6 inches. From NOAA Western Regional Climate Center.

POTENTIAL FOR LANDSLIDES ALONG INTERSTATE 5

Landslides can and do damage and close roads, resulting in significant repair and maintenance costs. Economic losses can be significant to an entire region of the state if a major route is closed for a significant period. Besides the costs associated with landslide damage, some types of landslides pose a risk to the safety of the traveling public. None of these risks can be eliminated. If roads are to pass through regions like the Transverse Ranges where landslides are common, they will be exposed to some risk.

An evaluation of the potential consequences of landslides along Interstate 5 between Valencia and Gorman may help Caltrans plan for future landslide mitigation projects and prioritize more detailed studies of individual landslides. A thorough evaluation of the probabilities of landslide movement, or of the economic consequences of that movement is beyond the scope of this study. We do not have the detailed geotechnical data to evaluate the probability of movement of landslides, nor the economic data to measure their consequences. We can, however, assess the types of landslides and the general consequences of movement of those types of landslides. In the table below are the size, movement type, materials and activity level of a landslide, the velocity of movement that is typical of a type of landslide, and the proximity to the highway. One can assume that those landslides that have moved most recently are the most likely to move in the future, and that the types of movement that have occurred in the past will continue.

The consequences of landslide movement are related to the size of a landslide, and the amount and velocity of movement. Larger slides may displace more of a roadway, resulting in greater repair costs. Larger displacements also translate to greater repair costs. If large movements accumulate slowly, over years or decades, they may be a continuing maintenance problem where cracks are filled and pavement re-leveled frequently. Large, rapid, displacements of even small volumes of material may undermine the road or deposit material on the road sufficient to close or partially close the roadway. These smaller volume but rapidly moving slides are the most likely to pose a safety risk to the traveling public. Movement of large, deep landslides is less likely to occur rapidly, but could have particularly severe consequences. Large displacements of large, deep landslides may result in the roadway being closed for repair, or in the worst case closed for long periods for reconstruction or rerouting.

There are several areas along the Interstate 5 corridor where landslides could have a significant effect on the roadway. These are summarized in Table 2 and discussed briefly in the test below.

1) P.M. 55.5: A small definite, historic rockslide has occurred in the road cut adjacent the northbound onramp to Interstate 5 from State Highway 126. Some repair work had been done at the time of observation.

2) P.M. 61.2 to P.M.61.6: In this segment of highway, known as 5-mile grade, the alignment splits, with the northbound lanes approximately .5 miles west of the southbound lanes. For most of this segment the northbound lanes traverse Castaic Formation dipping northeastward in the direction of slope. Numerous landslides have been mapped on these northeast-facing slopes. The ones that may affect the roadway are described here. From P.M. 61.2 to P.M.61.6 three probable dormant, mature rockslides underlie the northbound lanes of the highway.

3) P.M. 62.1 to 62.3: A probable dormant, young rockslide underlies the northbound lanes of the highway. A small portion has been active historically in the highway cut above the road adjacent to the main slide. Some grading was done in 1983 to stabilize the slope above the roadway. A small questionable rockslide was mapped by previous work (Hernandez, 2003) just south of the main slide.

4) P.M. 62.2 to 63.9: A large complex of questionable deep rockslides underlies the southbound lanes, which form the eastern alignment. Previous workers have mapped this area as questionable landslide (Weber, 1984; Hernandez, 2003). Analysis of air Photos and topographic maps reveal features, such as benches and hummocky topography, suggestive of landsliding. However these features may be the result of differential erosion of resistant layers along an oblique dip slope. Field investigation suggests internal stratigraphic continuity across much of this area. Therefore it is unlikely that portions of this area have slid relative to one another. However it is possible that the entire area has moved as a relatively intact block.

5) P.M. 62.4 to 62.7: A definite historic earthslide has occurred in the fill below the northbound lanes. The fill at this location has a history of problems. The northbound lanes were constructed on the existing Highway 99 alignment. This segment is primarily cut with slivers of fill. According to a Caltrans report the fill was originally

placed by end dumping and was not keyed into firm material. This was thought to be a major factor contributing to the instability. The area was regraded and the slope was stabilized by the construction of two tie-back retaining walls, completed in 2002. This historic slide occurs within a larger questionable mature rockslide which extends from the bottom of Marple Canyon to the crest of the ridge.

6) P.M. 62.9: A questionable mature rockslide underlies the northbound lanes. This slide was mapped by Hernandez (2003), and the boundary revised here.

7) P.M. 64.0: A definite historic rockslide occurred in the slope descending westward from the northbound lanes at the northern end of 5-mile grade. A soldier-pile wall has been constructed since 1999 to stabilize the slope.

8) P.M. 65.4 to 65.7: The cut slope adjacent to the southbound lanes near Templin Highway has presented stability problems since construction of the freeway in 1969. A rockslide occurred in 1980 following heavy rains. The slope was repaired by regarding in 1983. Subsequent movement of the slide resulted in damage to the roadway. Numerous interim repairs to the pavement have been performed in the attempt to eliminate the humps and swales at this location. By 1993 slide movement had opened numerous tension cracks, and broken the concrete ditches on both benches. By 2002 it was apparent that a large deep, translational rock slide extends well beyond the boundaries of the cut. The slide is currently active and is delineated by cracks and scarps several feet high. The toe extends beneath the roadway and is causing it to heave. An ongoing investigation of this slide is being conducted by Caltrans.

Figure 3. Aerial view of the Templin Highway slide (P.M. 65.4 to 65.7). View is to the northwest. Photo by Caltrans, 1981.

9) P.M. 67.1: A definite historic rockslide has damaged the southbound lanes at this location. The movement occurred in 1998 on the slope descending westward from

the freeway. The slope has been regraded and stabilized by construction of a tie-back retaining wall.

10) P.M. 68.3: A definite historic debris slide was noted in the cut slope adjacent to the northbound lanes at this location. Some repair work has been done, however movement appears to have occurred since the repair. At the time of field work hummocky slide deposits were observed near the top of the slide, however the repair may not have extended this high. The slope steepens abruptly just below the second of three benches. Pressure ridges were observed in the middle of this bench.

11) P.M. 70.8-71.1: A probable young rockslide underlies the fill adjacent to the northbound lanes. Direction of movement is northwestward, obliquely toward the freeway. This slide is on a large dip slope that forms the southeastern slopes of Cherry Canyon.

12) P.M. 70.8-71.3: A large definite young rockslide is within 800 feet of the fill adjacent to the southbound lanes. This slide is also on the Cherry canyon dip slope. This slide is considered significant because of its size, proximity to a major highway fill, and because the same dip slope that underlies this slide and slide number 11 also underlies the highway.

13) P.M. 73.6-73.9: A pair of probable mature rockslides occur in the slope descending northwest toward Pyramid Reservoir, adjacent to the southbound lanes. This is a dip slope of relatively gentle gradient. The southernmost slide is shallow and the top appears to have been removed by the roadcut. The northernmost slide impinges on the Liebre Gulch fill.

14) P.M. 73.9-74.1: A large probable mature rockslide underlies the Liebre Gulch fill adjacent to the northbound lanes. This slide, like those across the freeway, is on a dip slope of gentle gradient. This slide probably did not move as an entire unit. Movement was most likely accommodated by the formation of many discrete slides moving at different times. Erosion has obscured the boundaries of separate slides, and their recognition is largely a matter of interpretation.

15) P.M. 74.3-74.4: A definite historic rockslide underlies the highway at this point. The direction of sliding is perpendicular to the highway. Bedding dips obliquely out of slope. The historic movement occurred at the eastern end of the cut adjacent to the northbound lanes in the initial phases of construction for the freeway. The gradient of the cut has been reduced to 4:1 in order to be shallower than the out of slope component of dip.

16) P.M. 74.7: A probable mature rockslide is adjacent to the southbound lanes. This slide is on the same west facing slope as slide 15, separated by a rib of bedrock. It does not extend as far upslope. The head is about even with the freeway.

17) P.M. 74.8-75.2: Liebre Gulch and West Liebre Gulch are tributaries to Piru Creek that became arms of Pyramid Reservoir when it was filled. Interstate 5 crosses them on major fills that are now partially inundated by the reservoir. A prominent ridge separates Liebre Gulch from West Liebre Gulch. The entire northwestern slope of this ridge is a dip slope and is extensively marked by landslides. The western end is now the bowl shaped scar of a large mature rockslide that extends from near the ridge crest to the bottom of West Liebre Gulch. Several smaller younger slides within the larger slide are separated by ribs of bedrock which may have moved with the larger slide.

The southeastern half of the West Liebre Gulch fill was placed on the deposits of this slide. Earthslides occurred in this fill in 1967 and 1968 during construction. The slides were in the southwestward descending embankment. The headscarp of the 1968 slide extended across the highway into the older landslide deposits. The slide debris was removed and a large buttress was constructed at the toe.

18) P.M. 75.3-75.5: Three small young rockslides occur in the slope that descends to the southbound lanes. The westernmost slide was reactivated in 1967 during freeway construction when a road cut encountered the slide. None of the slide material reaches the freeway.

19) P.M. 75.6 to 76.0: Northwest of West Liebre Gulch is another strike ridge with a dip slope on the northwestern side. This slope is also marked by numerous landslides. The ridgeline bends with the strike of bedding and as a result the landslides are funneled into a short canyon that was filled in for the freeway. The cut through this ridge is one of the largest on the Interstate 5 corridor. The fill to the northwest of the ridge covers landslide deposits on both sides of the freeway. They appear to be separate slides and are not connected beneath the freeway.

20) P.M. 76.1: Three probable mature rockslides occur in the slope descending westward from the southbound lanes. The top of the slope has been graded level to remove slide deposits and reduce loading.

21) P.M. 76.7: A definite historic rockslide occurs in the slope that descends westward from Interstate 5 to Highway 99. The slide occurred in 1952 and has been partially removed.

22) P.M. 76.9-77.0: A pair of definite historic rockslides mark the cut slope adjacent to the northbound lanes. The slides appear to be unstable wedges failures. Unstable wedges form by the intersection of bedding and joints.

23) P.M. 77.9: A probable old rockslide just south of the cut slope adjacent to the northbound Hungry Valley Rd. off ramp.

Table 2: significant landslides along the Interstate 5 alignment.

	Name	Type	Activity	Size (acres)	Depth	Probable rate of movement	Possible consequences	Comments
1	P.M. 55.5	RS	h	1.7	m	Slow to moderate	Lane closure	Some repair work already done
2	P.M. 61.2-61.6	RS	m	22.1	m	Slow to moderate	Lane closure	No evidence of current movement.
3	P.M. 62.1-62.3	RS	y, h	10.1	m	Slow to moderate	Lane closure	
4	P.M. 62.2-63.9	RS	m	380.4	m, d	Slow		
5	P.M. 62.4-62.7	RS,	y	22.2	m	Moderate	Road damage- cracks and grade offsets	Tie-back walls constructed. Completed in 2002
6	P.M. 62.9	RS	m	8.7	m	slow		No evidence of current movement.
7	P.M. 64.0	RS	h	7.9	m	slow	Road damage- cracks and grade offsets	Retaining wall constructed.
8	P.M. 65.4-65.7	RS	h	36.0	d	slow	Road damage- heaving	Investigation in progress
9	P.M. 67.1	RS	h	2.9	m	moderate	Road damage- cracks and grade offsets	Tie-back wall constructed.
10	P.M. 68.3	RS	h	1.5	s, m	moderate	Lane closure	Possible post-repair movement
11	P.M. 70.8-71.1	RS	y	8.8	m	slow to moderate	Damage to fill, sediment filling basins	
12	P.M. 70.8-71.3	RS	y	222.9	d	slow	Damage to fill	
13	P.M. 73.6-73.9	RS	m	16.0	s, m	slow	Damage to cut, Damage to fill	
14	P.M. 73.9-74.1	RS	m	82.7	m	Slow	Damage to fill	
15	P.M. 74.3-74.4	RS	h	36.2	m	slow to moderate	Highway closure	slope cut back to 4:1
16	P.M. 74.7	RS	m	11.9	m	slow	Road damage- cracks and grade offsets	
17	P.M. 74.8-75.2	RS	m, h	168.4	d, m	slow	Damage to fill, highway closure	Large complex of slides
18	P.M. 75.3-75.5	RS	y, h	5.3	m	slow to moderate	Lane closure	
19	P.M. 75.6-76.0	RS	m	33.5	m	slow	Damage to fill	
20	P.M. 76.1	RS	m	9.0	m	slow	Road damage- cracks and grade offsets	
21	P.M. 76.7	RS	h	4.6	m	Slow to moderate	Road damage- cracks and grade offsets	Partially removed
22	P.M. 76.9-77.0	RS	h	2.7	m	rapid	Lane closure	Slide debris removed
23	P.M. 77.9	RS	m	5.6	o	slow	sediment filling basins	No evidence of current movement

SUMMARY

Interstate 5 is the main north-south freeway in California, connecting several major metropolitan areas. Just north of Los Angeles it traverses a mountainous, landslide-prone area. These metropolitan areas would be significantly affected in the event of closure of this section of the freeway due to landslides. In order to evaluate the relative landslide hazards along this segment of the Interstate 5 corridor, Caltrans contracted with the California Geological Survey to map the geology and landslides of the corridor. This mapping will help Caltrans plan landslide mitigation along the existing roadway and evaluate potential means of avoiding the most severe hazards.

Over 200 landslides have been mapped within the corridor area. The type and activity of the slides, the level of confidence of our interpretation and several other factors are recorded for each slide. Bedrock geology was found to have a major influence on the probability of landsliding in the corridor. Most of the landslides occur on dip slopes underlain by shale rich formations such as the Castaic and Peace Valley Formations. Two concentrations of landslides are noted, one along 5-mile grade in dip slopes developed on the Castaic Formation, and another around Pyramid Reservoir in dip slopes underlain by the Peace Valley Formation.

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