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Sediment movement from a manipulated landslide along the central California coast

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SEDIMENT MOVEMENT FROM A MANIPULATED LANDSLIDE ALONG THE CENTRAL CALIFORNIA COAST

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ABSTRACT

SEDIMENT MOVEMENT FROM A MANIPULATED LANDSLIDE ALONG THE CENTRAL CALIFORNIA COAST

By Kenneth P. Israel

The Lone Tree landslide area has been an actively eroding debris flow since the late 1970's, and suffered localized failure as a result of the Loma Prieta earthquake on October 17, 1989. The slide closed a section of California State Highway One.

This study is a review of California coastal policies applied to this road repair, and a geotechnical investigation of the subsequent fill.

In 1991 the California Coastal Commission approved repair of this portion of State Highway One in Marin County. The Commission required mitigation of 5.61 acres in Bolinas Lagoon, and monitoring of the fill's potential impacts.

The geotechnical monitoring investigation found the average volume of sediment eroding from the fill per month during 1991-1994 was 4,145 cubic yards, with estimates of the fill's life to be between 15 and 31 years, and erosion rates an order of magnitude greater than natural conditions.

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CHAPTER 1

Introduction

Seacliff erosion by mass-wasting, which modifies shorelines posing danger to human structures, is a widespread process along the seismically active coastline of California. One example of this process is the Lone Tree landslide located in the Central terrane (Figures 1&2 and Photos 1&2) of the Franciscan assemblage and is underlain almost entirely by rocks of Jurassic and Cretaceous age (Blake, 1974; Bailey, 1971). Blocks of radiolarian chert, graywacke, and shale are contained in a melange matrix (Bailey, 1971). The Franciscan complex is generally believed to represent oceanic trench deposits deformed and uplifted in conjunction with subduction at the boundary between the Farallon and North American lithospheric plates (Bailey, 1971). The end product of the dynamic tectonic history of the Franciscan Central complex is a terrane highly susceptible to all forms of erosion, particularly landsliding (Griggs, 1985; Nolan and Janda, 1984; Ecker and Whelan, 1984; Ellen and others, 1983; Kelsey, 1978; Bailey, 1971).

Landslides are not solely an earthquake effect; many landslides and other mass movement events occur every year without any help from earthquakes (Fukuzono, 1990; Wolfe and Williams, 1986; Sidle, 1985; Swanston and others, 1983; Zaruba, 1982). Nevertheless, when an earthquake is centered in a hilly or mountainous area, any material which is in a state of precarious equilibrium may be started on its way downhill (Vidale and Bonamassa, 1990; McNutt and Toppozada, 1990; Sidle, 1985). The 1906 San Francisco earthquake, which had its epicenter north of the Bear Valley Ranch, initiated a number of landslides. Slope failure occurred along cliffs of earth or weak rock bordering the ocean (The California

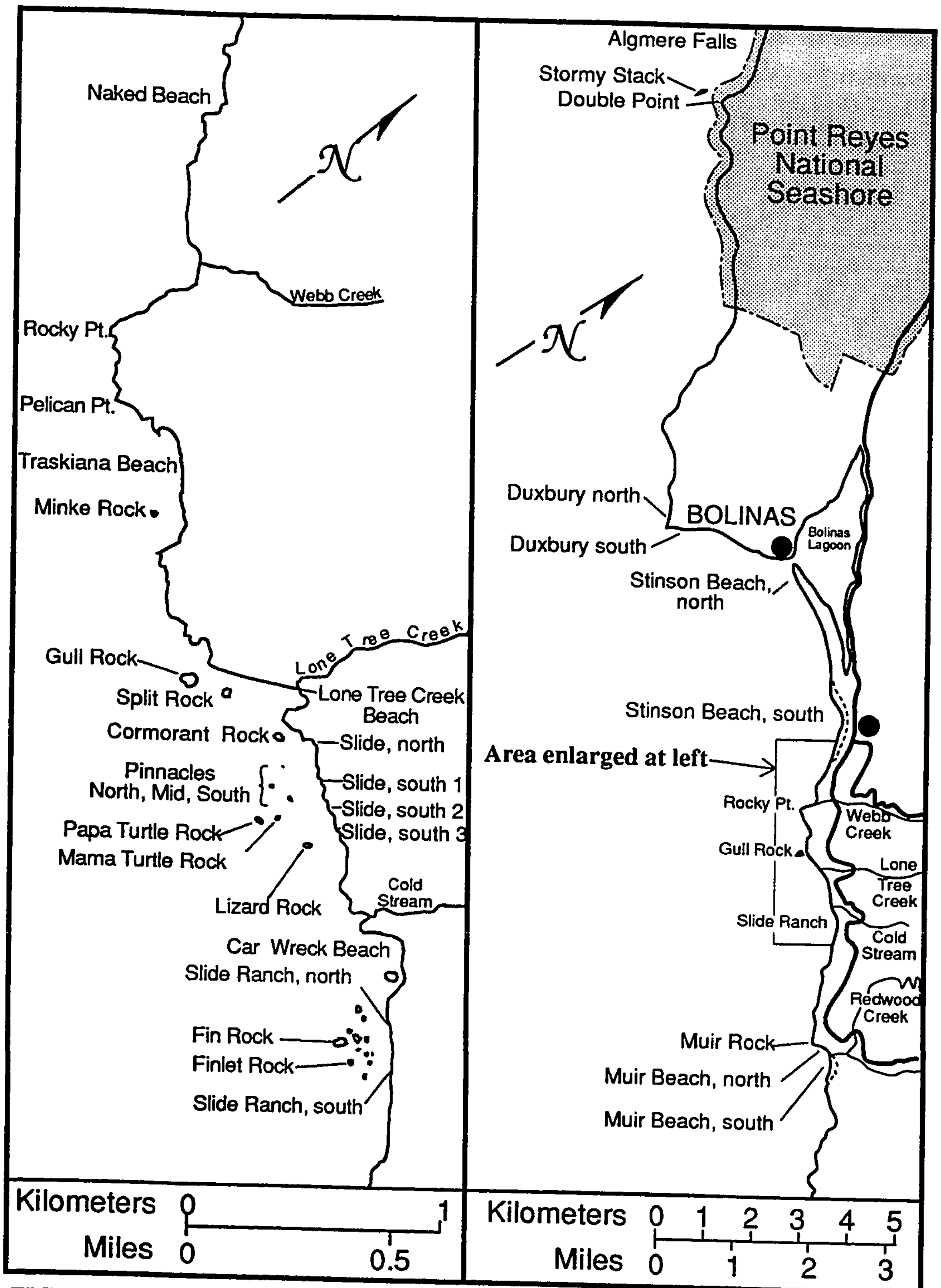

FIGURE 1: Place names near Lone Tree Landslide (right) and blow-up of coast from Slide Ranch to south end of Stinson Beach (left).

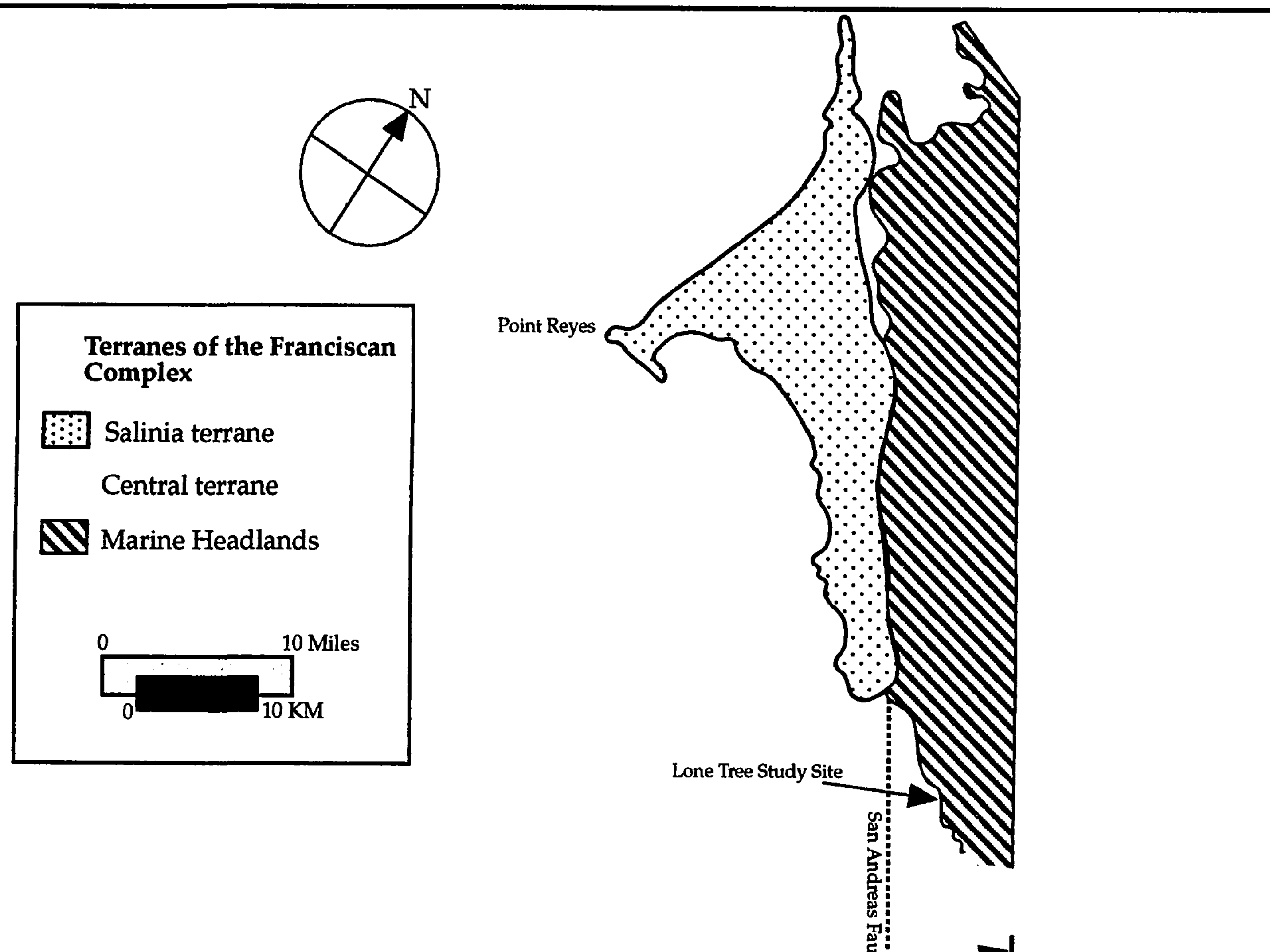

Figure 2. Terranes of the Franciscan Complex inthe San Francisco Bay area (modified from Blake, 1972.).

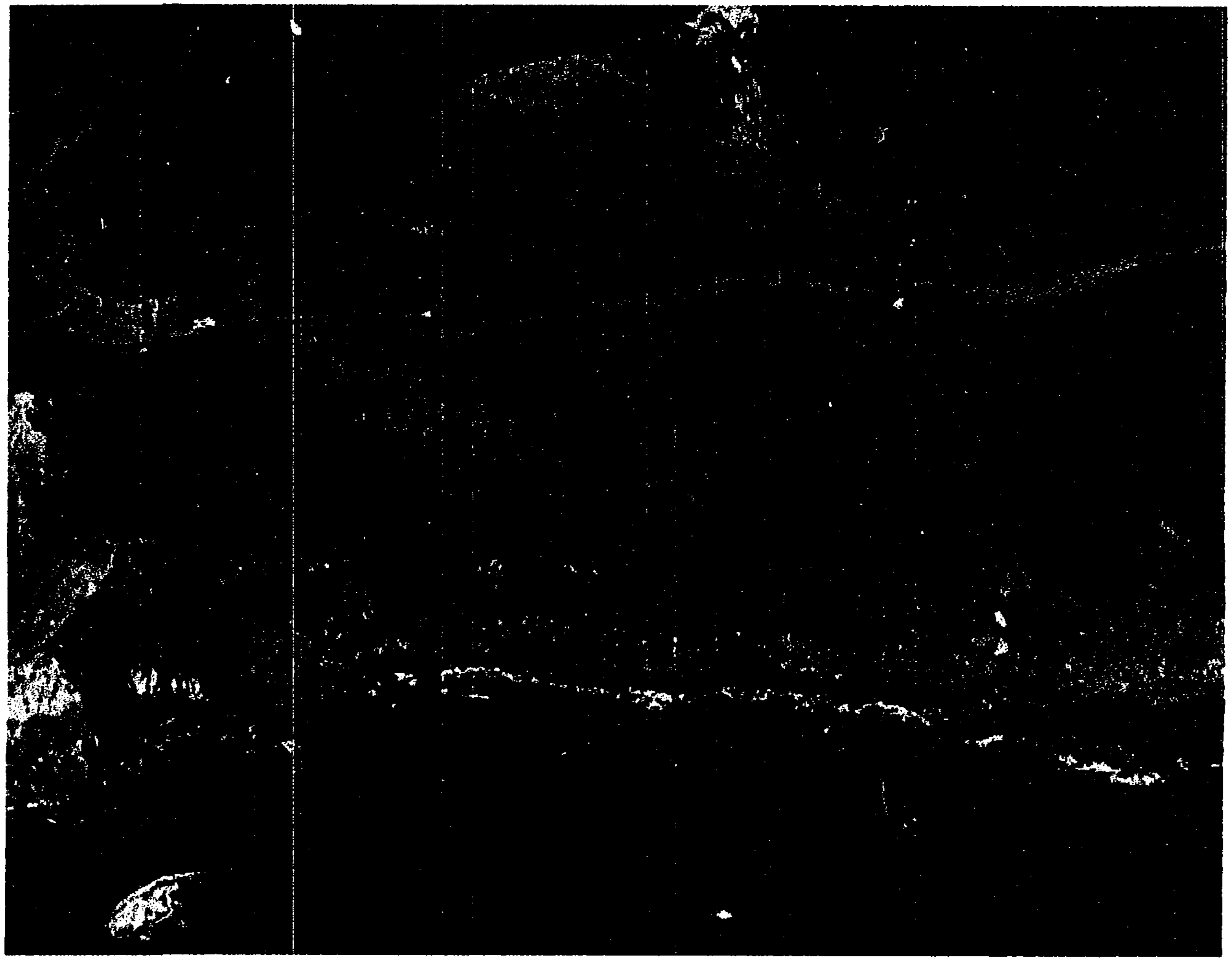

Photo 1. Landslide site in 1985 prior to 1989 event (June, 1985).

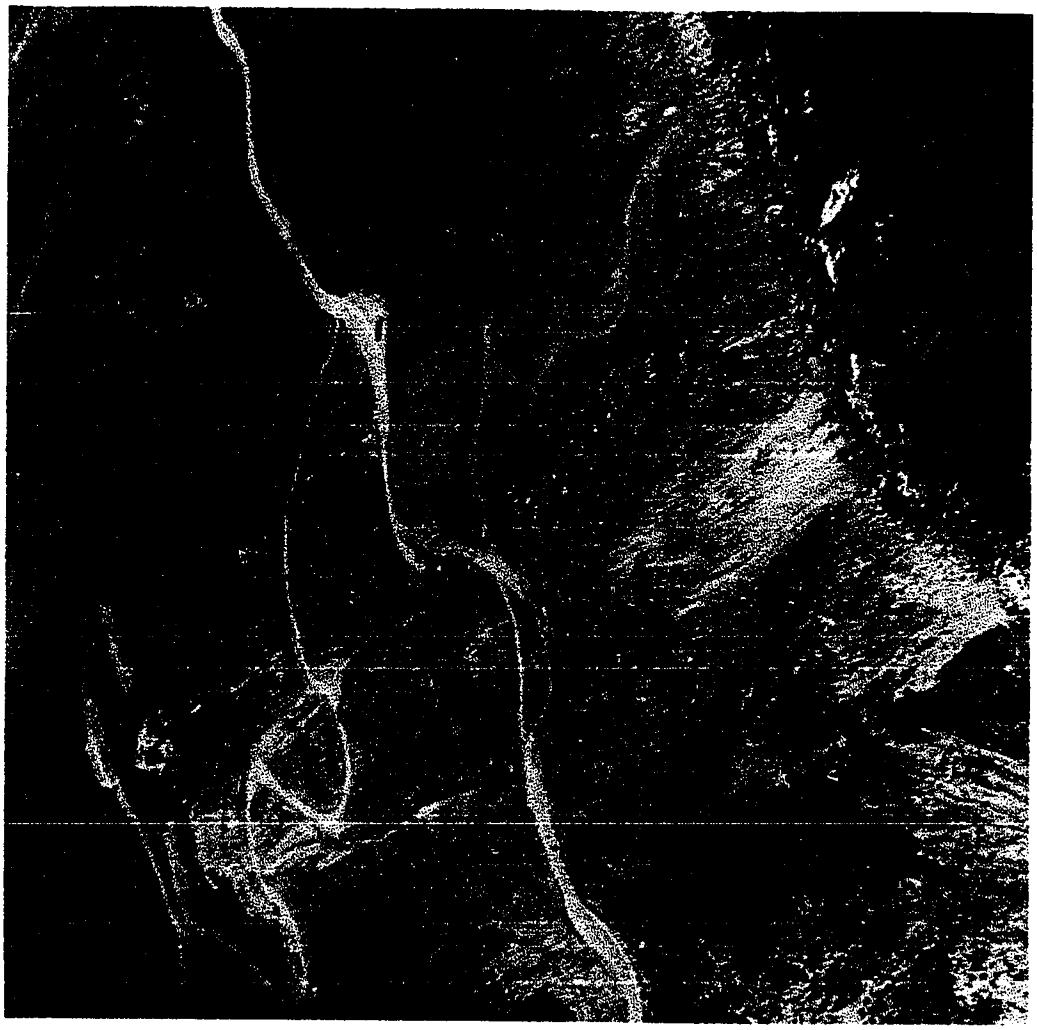

Photo 2. Original slide event at Lone Tree prior to manipulation (September, 1990).

Earthquake of April 18, 1906, Report of the State Earthquake Investigation Commission, 1908, p. 76). Widespread landslides are thus likely to occur within the Franciscan assemblage.

Slope development often involves the progressive accumulation of weathering products until failure is triggered by an event such as heavy rain (Cruden, 1991; Kelsey, 1980). Weathering also alters slope angle resulting in sites of instability that are susceptible to mass slumping or other movements. Spatial patterns of soil structure and dependent soil moisture, both storage and transmission, are important in understanding and predicting massive or catastrophic slope failure (Iverson, 1984; Hungr, 1981). These processes control slope stability and sediment movement, and therefore determine the rate of sediment input to the marine environment from coastal bluffs (Sidle, 1985; Iverson, 1984; Iverson, 1984).

The Lone Tree landslide area has been an actively eroding debris flow since at least the late 1970's when aerial photographs taken by CalTrans show the area in various stages of creep and flow (Photo 1). The Lone Tree landslide suffered widespread failure as a result of the Loma Prieta earthquake on October 17, 1989 (Photo 2), when the slide closed a section of California State Highway One between Muir Beach and Stinson Beach. Landslide repair was implemented during the spring of 1991 consisting of a natural landslide overlain by an erodible sediment fill, which was intended to stabilize or at least slow the movement of the natural slide (Photo 3). The site occupies both sides of Highway One from an elevation of 400 feet to the water's edge.

Highway One was reopened in June 1991 after moving more than 1,000,000 cubic yards of sediment, placing the road on a relatively stable surface in back of the slide plane. Material was disposed of on the west side of the road in a

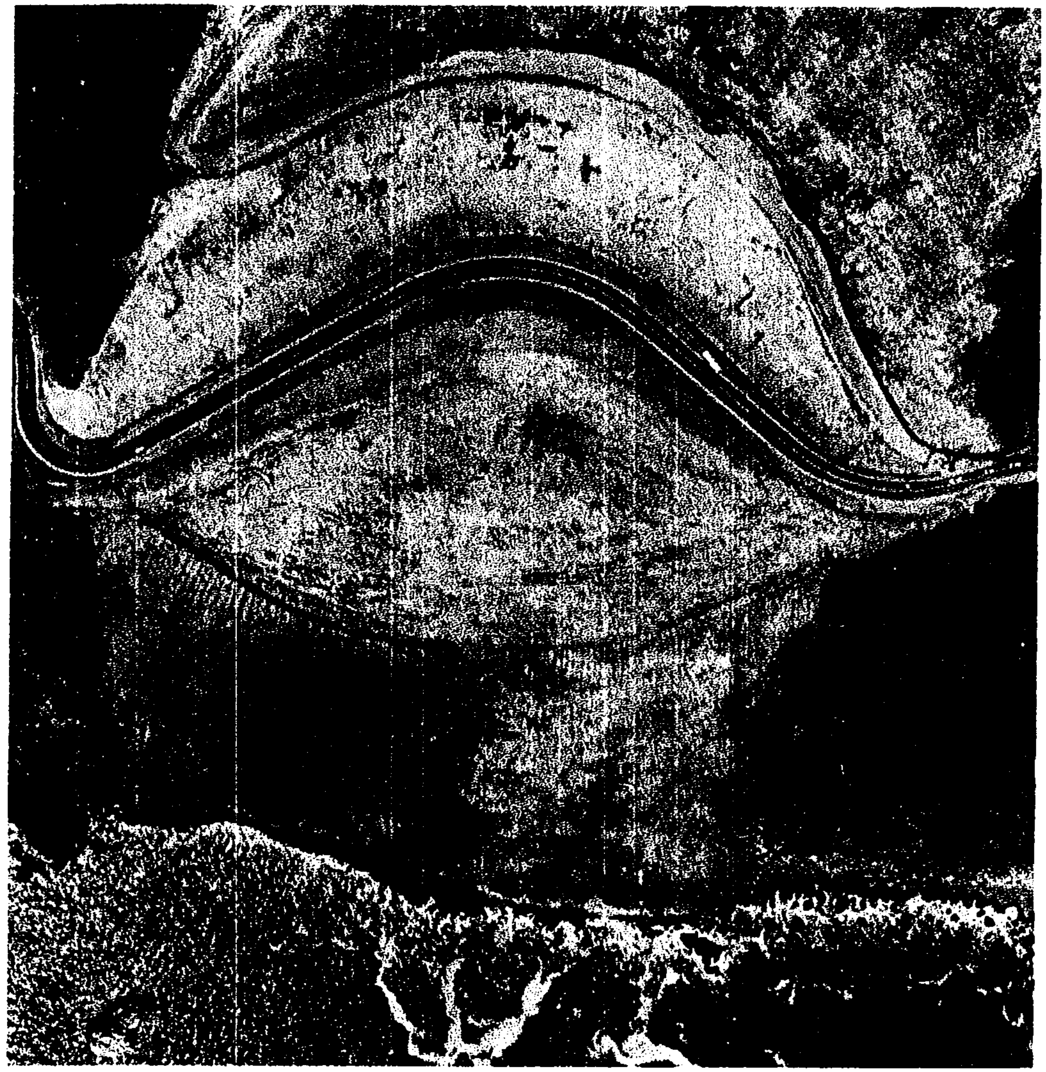

Photo 3. The Lone Tree slide/fill after manipulation by CalTrans (July, 1991).

large sediment fill (Photo 3). The seaward edge of the toe of the 1991 fill initially extended over 100 feet laterally into the subtidal environment, directly burying marine intertidal and subtidal rock and sand environments.

The fill represents an artificially induced 100 to 1000 year extreme sediment movement event that was sampled before the fill manipulation was completed on the natural landslide (i.e., time zero). Monitoring of the slide and fill began in the spring of 1991, and its movement patterns have been tracked from this 'time zero' date (June 1991) to estimate the sediment movement process from the new source (e.g., the fill). This rare event not only allowed for prefill sampling, but the ability to track a massive sediment movement signal from its inception over time.

Objectives

The goals of this thesis are to:

1) Monitor the repaired slope for geomorphologic changes over time;
2) Evaluate the input of sediment into the marine environment, and provide estimations of the short-term and long-term sedimentation rates from the fill;
3) Evaluate the potential impact on the local and regional marine environment;
4) Examine and review the manipulation design implemented (e.g., the fill) with regard to California coastal policy and management goals.

The specific questions to be answered in this thesis are:

1) What are the primary sediment source areas of the fill, and how has the rate of movement changed since its completion in 1991?
2) What factors contribute to movement of the fill?
3) What State policies and management guidelines were used for this coastal highway manipulation/development project?
4) What were the specific coastal policy and management decisions made with regard to the fill design?
5) Was the manipulation plan for this project the best alternative at the time?
6) What relevancy does this project have to other coastal manipulation/development projects along the coastal areas of California?
7) What recommendations could be made with regards to long-term coastal resource protection and coastal land use management?

California Coastal Environmental Policy

California has the second longest shoreline of any state in the nation and has the most comprehensive effort by a state to regulate development on its coastline (Harris, 1978).

The people of California enacted coastal legislation in 1972 by direct vote on an initiative, the California Coastal Zone Conservation Act, commonly called Proposition 20. The coastal program was established without federal urging, with coastal planning based on the San Francisco Bay Conservation and Development Commission (BCDC) model. Responsibility was shared between six Regional Commissions and the state Coastal Commission. Regulation and planning took place simultaneously.

The regional and state commissions were charged with preparation of a Coastal Plan for areas within the designated coastal planning area. After four years of work and public hearings a plan was completed, containing 162 policy recommendations (Healy, 1978). Proposition 20 objectives required a comprehensive, coordinated enforceable plan for orderly conservation and management of the coastal zone (Healy, 1978). See Figure 3 for the California Coastal Zone boundaries.

This California Coastal Conservation Plan was submitted to the Governor and Legislature at the end of 1975 as a basis for coastal legislation. The Legislature did not adopt the Coastal Plan; rather, it extracted certain principles of the Plan (Healy, 1978).

Under great political pressure, the Legislature enacted the 1976 California Coastal Act, which retained the commission structure and directed appeals of local actions to

THE COASTAL ZONES

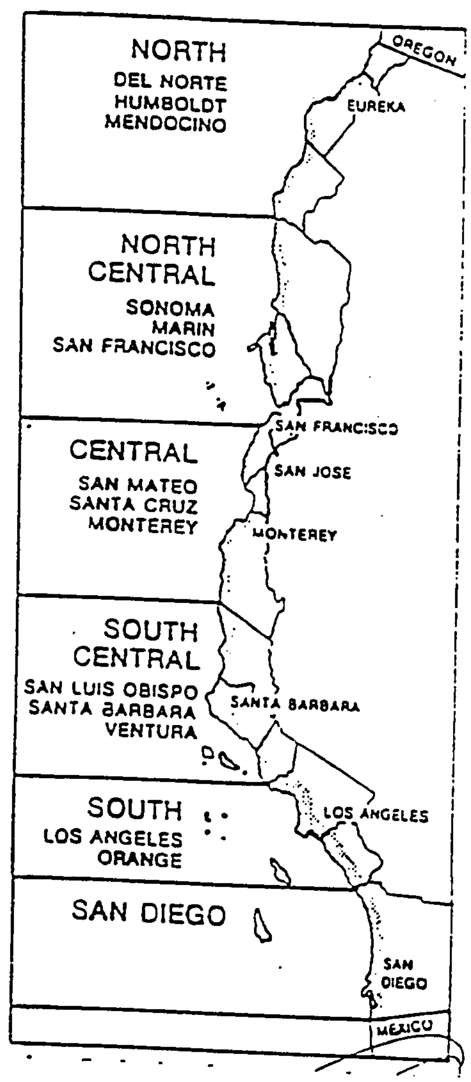

Figure 3. Coastline in Crisis (Tom Harris, 1978).

the California Coastal Commission. The heart of the Coastal Act was the Local Coastal Program (LCP) which returned responsibility for coastal management to local governments (California Coastal Commission, 1975).

Local Coastal Programs are implemented through City or County General Plans and Ordinances, through Land Use Plans and Maps, through the administrative policies of the city or county (California Coastal Commission, 1975). Local agencies have a great deal of discretion in dealing with and interpreting the LCP's.

The chief advantage of the LCP process is that plans for the coast must fit local conditions and must also conform to state coastal policies and comply with the California Coastal Act (1976). When all LCP's for the 15 counties and 53 cities are complete they form the coastal plan for the 1000+ mile California coastal zone. The disadvantage of the LCP is that economic interests may gain control at the local level and the long-term view of coastal management may be lost (Healy, 1978). The LCP is therefore vulnerable to the political process.

Much has been accomplished in California in the 1972-1994 period as a result of coastal legislation. Communities now have control over local development through the Local Coastal Program (LCP's) (California Coastal Act, 1976). The California Coastal Commission now has its power limited to specifics which affect an entire region or the entire state such as power plant siting, offshore oil exploration, or coastal highways and their maintenance (California Coastal Commission, 1975).

The Coastal Act is credited with preservation of coastal open space and of stifling fears of a wall-to-wall and border-to-border condominium coastal fortress (California Coastal Act, 1976). Public views have been protected, public access to the beaches allowed and in some instances mandated (Healy, 1978).

California, because of the Coastal Act, has preserved coastal dependent agriculture and coastal farm land (Healy, 1978). In some cases, such as artichokes, this represents 85% to 95% of the nation's source of these specialized food crops (Healy, 1978).

Even though the California Coastal Commission has blocked oil projects in environmentally fragile environments (Harris, 1978) budget and staffing cuts by the governor have weakened the agency's ability to monitor and direct development along California's coast (Healy, 1978).

The Regional Commissions have insisted on development conditions for architectural and landscape design standards (Harris, 1978). They have protected wetlands, marshes, sloughs, and estuaries (Healy, 1978). In rural areas, State Highway One remains a scenic rural two lane road with limited viewing pull-out spaces. Development has been limited to that which is "coastal dependent" (Healy, 1978).

Urban development has taken place, but within urban areas, it has not been extended to non-urbanized areas. Harbors have been improved and modernized (Healy, 1978).

In summary, legislation protecting the California coastline is struggling to both protect California's coastal environment, and be flexible enough to deal with the demands of the state's growing population. One of the decisions that has been made by Californians is to maintain coastal State Highway One, and to keep it open to all vehicular traffic. That decision has created conflict between CalTrans (i.e., California Department of Transportation) and the permitting agencies who give permission to CalTrans each time there is a case in which the road is threatened by roadside hazards (i.e., rockfalls, landslides, etc.). These agencies are both resource (i.e., parks department, marine sanctuaries, etc.)

and planning (i.e., local city and county planning departments, etc.). A case study for the application of these coastal management policy guidelines and the maintenance of State Highway One is the repair in 1991 of the Lone Tree landslide. The following study is a review of the coastal policies that were applied to this project by the Coastal Commission, and the mandated geotechnical monitoring program. The monitoring program was implemented to determine whether this repair project would have significantly greater sediment erosion and deposition rates than the estimated average coastal erosion rates elsewhere along the Marin Headlands.

CHAPTER 2

Analysis

Policy Review of the Lone Tree Fill

The information from which this research will draw is based on the following: 1) interviews with representatives from the relevant State permitting agencies, 2) an examination of their permitting files for this project, and 3) a review of the specific coastal zone management acts applied.

All data to be gathered that have contributed to coastal policy and management related to this project have already been generated by the agencies involved. I have compiled all written data that specifies coastal policy and management regulations to be followed, how those objective regulatory goals were either followed or compromised, and which agencies were involved, or should have been involved.

Results

Policy Review of the Lone Tree Fill

Coastal Commissions Recommendations

In January, 1990, California State Highway One between Muir Beach and Stinson Beach in Marin County was closed due to a landslide (Figure 1 and Photo 2). The landslide, which had damaged the highway on previous occasions (Photo 1), was accelerated by ground shaking during the Loma Prieta earthquake on October 17, 1989. The slope on which the highway was located moved downward (i.e., seaward) at a rate of more than one foot per month (Figure 7). The highway was ultimately closed to all traffic, due to the rapid earth movement.

The closure of State Highway One caused a severe problem for both residents and visitors. The alternate route for traffic between Bay Area communities and Stinson Beach and Bolinas was the Panoramic Highway. Traffic congestion and accidents resulted on the Panoramic Highway, which itself is subject to some instability.

The Department of Transportation submitted a coastal development permit application on April 30, 1990 to remove unstable material on top of the slide plane and to relocate the roadway to a more stable location, inland of the active slide plane. At the time of the permit repair application, the Department had not selected a preferred alternative from among the various methods of disposal of the slide material. Therefore, the application was not filed as complete.

The project site lies within Mt. Tamalpais State Park, near the Golden Gate National Recreation Area and the Gulf of the Farallones National Marine Sanctuary, and is subject to the regulatory requirements of the County of Marin, Coastal Commission, U.S. Army Corps of Engineers, and other agencies. In April, July, and August of 1990, numerous meetings of agencies with jurisdiction over the project were held to discuss the highway repair project. During these discussions, it became evident that the ordinary process of review by all of the agencies would take a substantial period of time before repair of the highway could commence. Consequently, representatives of the involved agencies agreed to compress the time required for review as much as possible (California Coastal Commission Report, Permit 1-90-109, December 18, 1990).

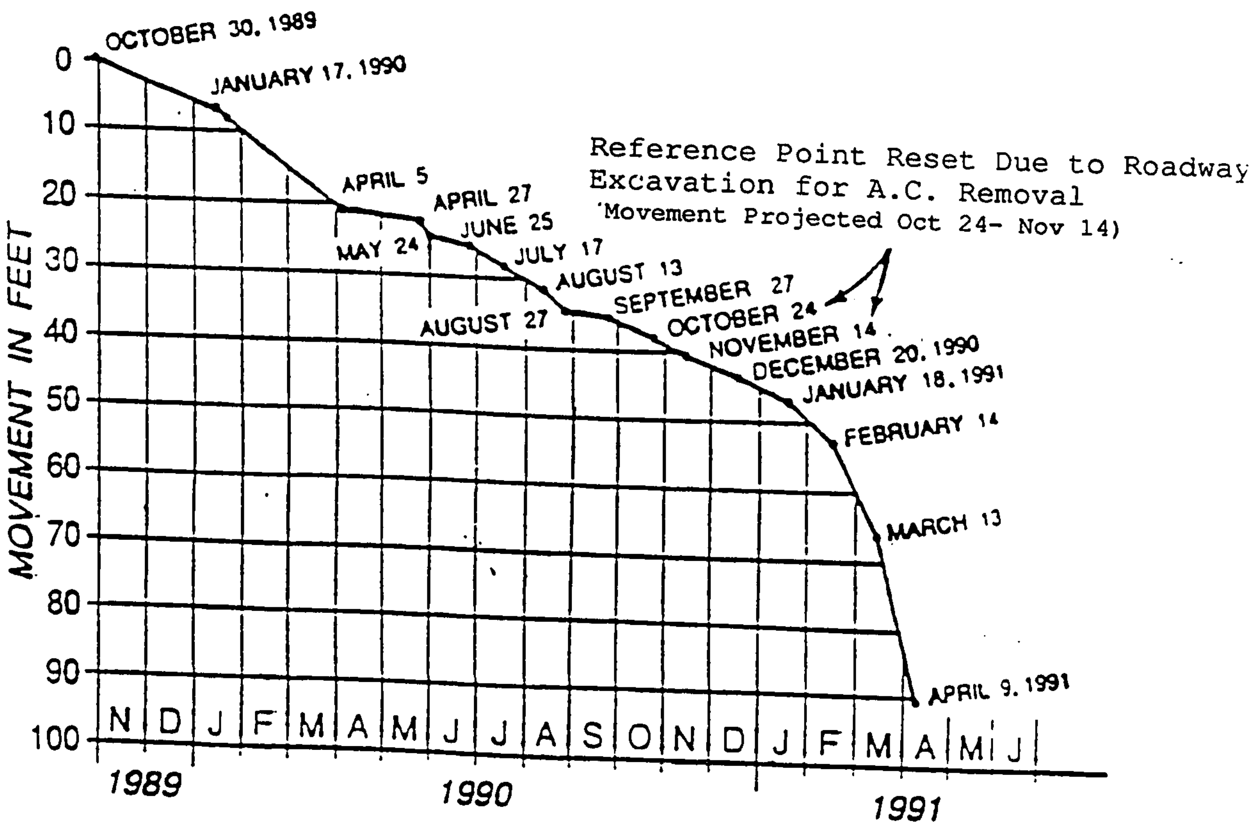

FIGURE 7 Resultant slide movement, October 30, 1989–April 9, 1991, Lone Tree landslide (resultant movement is vectorial summation of horizontal and vertical displacements).

For the Coastal Commission, the compressed review schedule meant that the Commission would review the coastal development application for the project as soon as the draft (rather than the final) environmental document was available from the Department of Transportation. Completion of requirements of the California Environmental Quality Act and National Environmental Policy Act followed the Commission's action on the project (California Coastal Commission Report, Permit 1-90-109, December 18, 1990).

Ordinarily, completion of environmental review prior to the Commission's review of a coastal development permit application allows the Commission the opportunity to consider the comments of other responsible agencies regarding the project, as well as the responses to those comments by the project sponsor. At the time, the comments of other agencies and responses to them had not yet been transmitted formally to the Coastal Commission staff, but CalTrans had informally provided the staff with the general substance of those comments (California Coastal Commission Report, Permit 1-90-109, December 18, 1990). The proposed recommendations and findings which follow reflect those comments.

Findings and Declarations

The Commission found the following:

On January 11, 1991 the Commission approved Coastal Development Permit No. 1-90-109 authorizing repair of the slide-damaged portion of State Highway One in Marin County (Figure 1). The project involved excavating the uphill portion of the slide and moving the material seaward to allow placement of the roadway on a more stable alignment. Some 201,000 cubic yards of fill were placed within the Coastal Commission's jurisdiction area on state tidelands, and due to subsequent sloughing and slumping, the coverage of ocean floor reached 5.61 acres by September, 1991.

The construction work to repair the highway took place relatively rapidly, and it was reopened to traffic in June of 1991. Mitigation work required by Special Condition No. 1 of the Coastal permit proceeded slowly since 1991 (See Appendix D; Special Conditions Number 1).

The pace of mitigation had been slow for a number of reasons. Among them is that no approved mitigation plan was in existence at the time the State Highway One repair project commenced (California Coastal Commission Report, Permit 1-90-109, December 30, 1992). In the interest of time, the repair work started first, and mitigation planning followed. The Commission recognized the urgency of re-opening State Highway One and allowed what amounted to a reversal of the ordinary course of events (California Coastal Commission Report, Permit 1-90-109, December 18, 1990).

Another reason for delay was that mitigation necessarily had to occur off-site, because there was no way to create open ocean at or near the site where fill was placed in the tidelands. Instead, the Commission required that mitigation occur elsewhere in the Marin County coastal zone, and the Commission gave CalTrans flexibility to select a program involving either in-kind mitigation or out-of-kind wetland mitigation (California Coastal Commission Report, Permit 1-90-109, December 30, 1992). CalTrans also had the flexibility to implement a mitigation project directly or to do so in cooperation with another public entity.

In designing a mitigation program, the Department of Transportation formed a technical advisory committee (i.e., TAC) to help review mitigation proposals (California Coastal Commission Report, Permit 1-90-109, December 18, 1990). Definition of alternative mitigation sites required monitoring of existing conditions at various sites over one or more seasons, thus resulting in additional time.

The commission's role in the mitigation process was two-fold: (1) participation in the technical advisory committee, and (2) the participation in a series of actions on permit amendment requests and condition compliance reviews (California Coastal Commission Report, Permit 1-90-109, December 30, 1992). The effect of these actions and reviews has been to reflect both changing conditions and new information and to approve partial fulfillment of the marine mitigation requirement of Conditions No. 1 (see Appendix D) through implementation of a project to remove old fill (including a toxic waste dump) from Bolinas Lagoon. The fill removal project was authorized by a separate permit, No. 1-93-07. That project was completed according to the Commission-required deadline of January 1994 (California Coastal Commission Report, Permit 1-90-109, March 31, 1994).

Fill in Coastal Water

As described in the introduction, the rerouted highway and most of the area affected by grading and disposal of spoils lie onshore within the coastal development permit jurisdiction of the County of Marin. The land seaward of California State Highway One falls within the appeal area where coastal permit actions by the County may be appealed to the Coastal Commission (California Coastal Commission Report, Permit 1-90-109, December 18, 1990). Some 2.5 acres of subtidal and intertidal area at the base of the bluff is the site of the earthen platform, which temporarily supports the fill slope embankment (California Coastal Commission Report, Permit 1-90-109, December 18, 1990). This subtidal and intertidal area lies within the permit jurisdiction of the Coastal Commission, and impacts on that area are the primary focus of this project. The following section discusses several issues to be analyzed, including the extent of geotechnical information collected in the field work portion of this study, and the appropriateness of mitigation measures for impacts on the marine environment.

Placement Of Fill In Coastal Waters

Section 30233 of the Coastal Act sets forth a three part test for all projects involving the filling of coastal waters and wetlands (See Appendix B for a review of Section 30000 of the Coastal Act). These are:

1. The project is limited to one of eight stated uses (See Section 30233, Appendix B).
2. The project has no feasible less environmentally damaging alternative; and
3. Feasible mitigation measures have been provided to minimize adverse environmental effects.

The Lone Tree project needed to satisfy each of the three parts of the test to be consistent with Section 30233(a). Failure to meet any one of the parts of the test would be grounds for denial of a permit application.

Allowable uses

In its action approving CDP No. 1-90-109 for the placement of fill in coastal waters, the Commission found that the fill was proposed in conjunction with a highway repair project and thus constituted an incidental public service. Therefore, the fill was an allowable use under Section 30233(a)(5), and the Commission determined the project was consistent with the first part of the three-part test under Section 30233(a).

Alternatives

CalTrans addressed a number of alternatives to the ocean disposal of the fill during the hearing for the original permit, however, the placement of fill in the ocean was selected as the only feasible alternative. CalTrans originally designed the ocean fill project with a compacted earthen platform at the base of the fill, armored with large rocks and boulders. This method of construction would have slowed the rate of sloughing from the fill slope, as fill compaction and armoring would have increased the resistance to wave undercutting and erosion. By containing the fill slope, the armored fill would also have limited the footprint of the fill and reduced the area of ocean floor impacted by direct burial. However, this method of construction was judged as infeasible by CalTrans to implement in the field. Consequently, CalTrans decided to push the spoils into the ocean without armoring, and the Commission determined the project was consistent with the second part of the three-part test under Section 30233 (a) when it approved Amendment No. 1-90-109-A2 (California Coastal Commission Report, Permit 1-90-109, October 27, 1993).

Mitigation for significant impacts

The original permit imposed two special conditions requiring mitigation for the proposed fill. Special Condition No.1 required a mitigation plan for the filling of 2.5 acres of ocean bottom, either through the creation of 2.5 acres of new intertidal and subtidal marine habitat similar to the habitat being filled, or the restoration of 2.5 acres of degraded or filled marine or wetland habitat. Special Condition No.2 required a marine monitoring program to assess the impacts caused by the fill project. The

Commission found that these two measures constituted feasible mitigation measures that would minimize the adverse impacts of the fill and found the project consistent with the third part of the three-part test under Section 30233(a).

In its approval of Amendment No.1-90-109-A2, submitted by CalTrans to address the extra amount of fill required for the slide project, the Commission found that, the implementation of the Bolinas Lagoon project provides 2.01 acres of mitigation towards that needed to offset the 5.61-acre area impacted by the placement of the fill. Additional mitigation of 3.6 acres was needed to fully mitigate for the fill. The Commission amended Special Condition No.1 to require mitigation of 5.61 acres by the implementation of the Bolinas Lagoon project, and implementation of 3.6 acres at a second site. Special Condition No.1 specified January 11, 1994 as the deadline for completing all mitigation work for the project. Should the Bolinas Lagoon project not be implemented by the deadline, the condition imposed a 0.5-acre penalty beginning on that date and increasing 0.5 acre for every subsequent 6 months until the project is implemented. The condition also retained October 31, 1993 as the deadline for submitting a marine mitigation plan that would detail the specific mitigation that would be performed to satisfy the remaining 3.60 acre of required mitigation.

CalTrans completed the Bolinas Lagoon restoration project November 30, more than a month before the deadline imposed by Special Condition No.1.

As discussed, CalTrans consultants also prepared a restoration plan for Big Lagoon to satisfy the remainder of its mitigation obligation. However, CalTrans was not able to meet the October 31, 1993 deadline for submitting a marine mitigation plan for the remaining mitigation work. The deadline for submittal of the marine mitigation plan was extended to March 1, 1994. CalTrans indicated the planning work fell behind schedule because the consultants determined that it would be critical to collect data from the site during the summer of 1993 before the restoration plan could be prepared because of the change in conditions resulting from the end of a long drought and the need to fill in gaps in fisheries data.

The Commission found that the need to examine changing conditions at the proposed restoration site due to the break in the six year drought was important as the new information dictated how the restoration plan could best be implemented to ensure greater success. Ensuring the ultimate success of the restoration project in compensating for the impacts of the marine fill from the California State Highway One slide repair project was more important than merely implementing a restoration project of questionable feasibility by a particular deadline. Furthermore, the Commission found that the break in the drought was not an event that could have been anticipated at the time the Commission imposed the October 31, 1993 deadline for submittal of the restoration plan.

The State Route One Technical Advisory Committee had endorsed restoration at Big Lagoon as the site for providing the balance of the mitigation required by the Commission as well as the other agencies that needed to issue permits for the project. The Committee was established pursuant to a condition of the permit granted by the U.S. Army Corps of Engineers for the Highway One Lone Tree Slide Repair project to advise CalTrans in the development of mitigation measures required by the Corps, the Commission, the Regional Water Quality Control Board, and the State Lands Commission. The Committee is composed of representatives of various government agencies, non-profit organizations, and advocacy groups with knowledge and interest in the project and the area.

The Commission achknowledged that to abandon Big Lagoon as a restoration site would considerably delay completion of the full mitigation of the slide repair project. CalTrans had invested a considerable amount of time in planning for Big Lagoon. Few other possible restoration sites were available within the Marin coastal zone, and none had been investigated to the degree of the Bolinas Lagoon and Big Lagoon sites. Therefore, the Commission found that extending the deadline requested by CalTrans was appropriate.

Even with this extension of the deadline for submittal of a plan, CalTrans also missed the deadline of January 1994 for completion of all of the required mitigation. In its approval of Amendment No.1-90-109-A2, the Commission noted that it was likely that implementation of all of the required mitigation would not occur by January of 1994, as required by the original permit. The Commission declined to consider an extension of the deadline at that time, noting that the restoration plan was required to contain a feasible implementation schedule and amending the implementation deadline prior to receiving such a feasible implementation schedule from CalTrans was inappropriate.

Discussions between CalTrans and the Commission focused on an amendment request to extend the mitigation completion deadline at the same time it submitted the completed marine restoration plan. CalTrans anticipated the request would be submitted in time to be considered at the Commission's March 1994 Commission meeting in San Rafael. The Commission found that consideration of any deadline extension would take place after the restoration plan and its implementation schedule had been developed. Any modification of the deadline made prior to receiving the restoration plan and the implementation schedule would only have been speculative, and necessitated reconsideration of the deadline because the implementation schedule developed by CalTrans demonstrated that such an arbitrarily assigned deadline was infeasible to meet.

In making this determination that the deadline for implementation was to be considered after submittal of the Big Lagoon restoration plan and its accompanying implementation schedule, the Commission made clear its desire to complete full mitigation as soon as possible. When it approved Amendment No.1-90-109-A2, the Commission included a finding in the amendment stating the following:

"It is expected that an amendment request from the applicant to extend the mitigation implementation deadline will be forthcoming. However, as it found in acting on the original permit for the fill project, the Commission will be inclined to consider a mitigation ratio greater than 1:1, if additional time beyond the existing 3-year deadline is required for implementation of full mitigation..." (California Coastal Commission Report, Permit 1-90-109, December 30, 1992).

The Commission continued to reserve the right to consider requiring a higher mitigation ratio at the time of the request to extend the deadline for completion of the mitigation.

See Appendix D for details of the Approval with Conditions and Special Conditions for this permitted project.

Other State and Local Issues Considered

California Environmental Quality Act

As specified in Amendment No.1-90-109-A3, 5.61 acres of mitigation is necessary for the loss of marine habitat. The amended project will not have a significant, adverse impact on the environment, within the meaning of CEQA (California

Coastal Commission Report, Permit 1-90-109, October 27, 1993).

Public Access

The project site is located at the base of a steep and eroding bluff where public access from State Highway One to the shoreline is not feasible. Although the shoreline in the area is a part of Mt. Tamalpais State Park, and therefore public entry is theoretically possible, the nature of the terrain essentially rules out public use of the area. Placement of fill material in the ocean adjacent to the shoreline therefore did not have a significant effect on public access to the area (California Coastal Commission Report, Permit 1-90-109, December 30, 1992).

Marin County Local Coastal Program

The county of Marin reviewed the coastal development permit application for the portion of the State Highway One repair project which lies onshore. Although the Commission ordinarily waits for local government approval of coastal development permits and any other local permits before reviewing a project, the Commission found that the urgency of the road repair project in this case justified review by the Commission before LCP approval. Since a major public works project was at issue, Marin County's action on the coastal development permit for the on-shore portion of the project is subject to appeal to the Coastal Commission, pursuant to Section 30603(a)(5) of the Coastal Act.

With the fill design approved, CalTrans began the cut and fill operation in March of 1991, and completed the project in July 1991. The geotechnical portion of this project now becomes important as an evaluation technique for the impact of the erodible fill design, and its application to the coastal permitting process. The following is the analysis of the geotechnical investigation of the Lone Tree fill.

CHAPTER 3

Methods

Geotechnical Investigation of the Fill

This coastal disturbance 'case study' will be evaluated in relation to coastal policy and management decisions made in approving the project, and whether the project was a success in meeting the specified goals of coastal management. This evaluation is then used to suggest how this project and other future coastal disturbance projects may be handled more effectively, efficiently, or economically in the future.

The geotechnical investigation was designed to determine whether this coastal manipulation would add significant amounts of sediment to the nearshore marine environment. Estimates of coastal erosion from the fill included the determination of the geometry, velocity, and hydrologic conditions of the fill. To determine the geometry and velocity of the landslide, and the site-specific geologic and hydrologic conditions, a detailed geotechnical investigation was initiated by CalTrans in 1990 and a research team from Moss Landing Marine Laboratories in January of 1993.

Active Slide Plane

The limits of the fill along the west-trending ridge line and the northeast lateral margin were defined (Figure 4). The southwest lateral margin and the toe of the rupture were clearly located due to its location along the land/ocean interface (e.g., the shoreline).

Fourteen inclinometers were installed by CalTrans around and on the slide/fill (Figure 5). Inclinometer data from SI1-6 (locations not graphically represented) were used to determine the depth of the basal shear surface (e.g., slide plane) (Figure 6), and the velocity of the upper portion of the slide by SI7-14, which might be the catalyst for the continued movement of the fill area. Inclinometers were monitored approximately once a month by CalTrans with the data being logged in a field notebook and later transferred to computer. Three of the inclinometers were located along an upper bench (i.e., SI7-9), three were located along a midslope bench (i.e., SI10-12), and two were located along the roadway in back of the fill (i.e., SI13-14) (Figure 5).

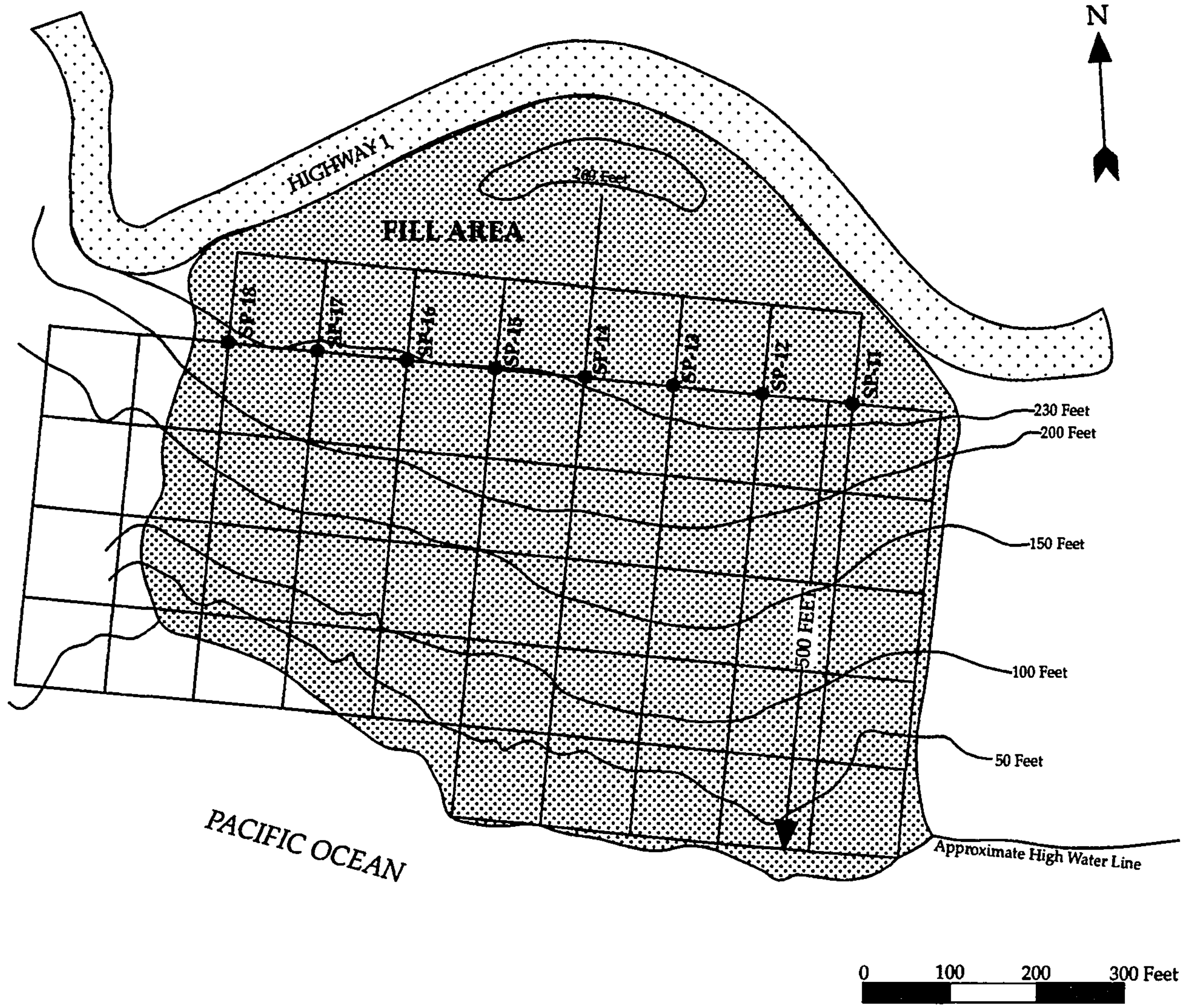

Figure 4. Map of Lone Tree fill area with permanant survey point location and grid overlay. The limits of the fill are shaded (Israel, 1994).

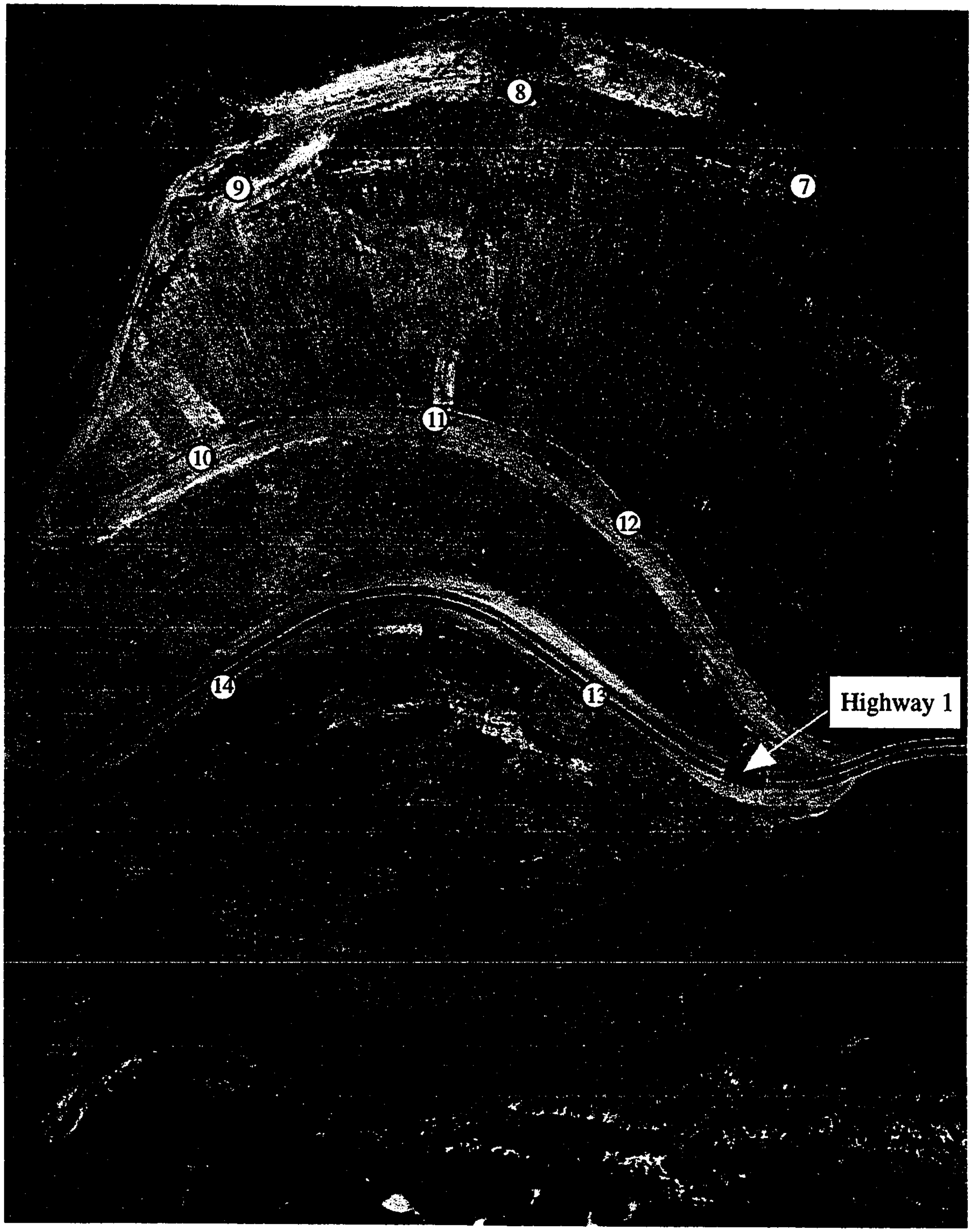

Figure 5. Aerial photograph (1994) of the Lone Tree Fill showing the approximate locations of inclinometer stations (Israel, 1995).

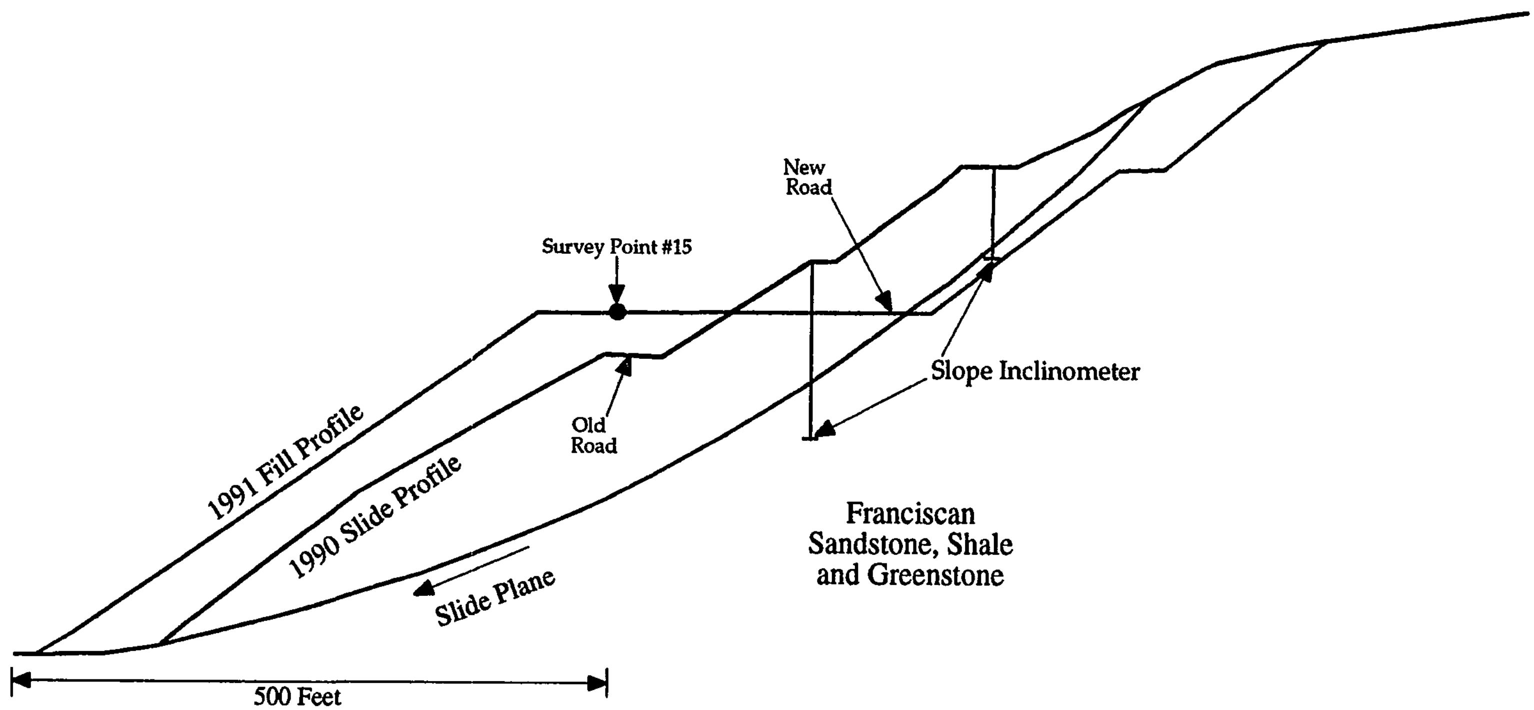

Figure 6. Engineering geologic cross section showing original slide and post-construction fill profiles. Note the base of the landslide, the geologic materials at depth, and the appoximate locations of the permanant survey points (Israel, 1994).

Movement Rates

To determine the geometry of the landslide the following steps were taken:

An array of permanent survey points were located and surveyed by CalTrans perpendicular and parallel to the assumed direction of movement. Survey points were monitored by CalTrans usually once a month using a total station theodolite and reflector prism. Measurements were logged in notebooks and later stored on computers that allowed for data manipulation and velocity movement calculations to be accomplished at Moss Landing Marine Laboratories. Estimates of sediment input into the marine environment (e.g., a sediment budget) were calculated from sediment yield data, volumetric changes in annual topographic profiles along the survey point monitoring lines, and approximate depth to slide shear surface (data provided by CalTrans). The estimate of sediment yield from the Lone Tree landslide below the highway is developed from the rate of slide movement, the length of the cliff face that is attacked by waves, and the height of the cliff. Multiplication of these figures provides an estimate of the total flux of material moved into the offshore environment. Figure 4 shows the location of the permanent survey points and monitoring lines.

Hydrologic Conditions

In order to measure hydrologic conditions, the inclinometer casings were slotted to allow ground water to enter. Piezometers inside the inclinometer measured changes in water levels within the fill material. Water levels were monitored at the same time inclinometers were surveyed, which was approximately once a month.

Stream Discharge

Three streams, Webb Creek, Lone Tree Creek, and Cold Stream (Figure 1) were periodically monitored after significant rainfall in the area to determine their relative input of sediment to the nearshore environment. The streams were sampled for their velocity, size, and amount of suspended sediment load to determine their maximum sediment transport into the nearshore environment. The sampling periods occurred during or within a day of rain storms, and the measurements were taken three times at each station for the purpose of averaging the data. A standard hand-held flow meter was used to determine each stream's water velocity, and a measuring tape was used to determine the geometry of the stream (i.e., height, width, depth) at permanent sampling locations. Three water samples were taken at each stream sampling location following each velocity measurement. These water samples were .250 qts each, and were later filtered through a .5 micron glass fiber filter to determine the weight of suspended material per sampled volume of water. To determine the amount of sediment deposited from the streams into the nearshore environment over various periods of time, calculations were made using the above data, and correlated with levels of rainfall. An estimated transport of stream suspended sediment in tons/year was calculated for all monitored streams.

Meteorological Conditions

To determine local meteorological conditions a weather station was installed approximately two miles north of the study site at the southern tip of Stinson Beach State Park. Continuous meteorological data were collected and downloaded via modem into a computer at Moss Landing Marine Laboratories approximately once a month. These data include hourly wind speed, wind direction, and rainfall in inches.

Results

Geotechnical Investigation of the Fill

The geotechnical investigation of the fill provides estimates of sediment loading at the fill since completion in 1991, and from stream and cliff erosion in the region. The investigation includes the determination of the geometry, velocity, and hydrologic conditions of the fill. The geotechnical analysis of the completed fill occurred from 1991 to 1994, allowing for the determination of the effectiveness of the coastal policy and management decisions made by the Coastal Commission in approving the erodible fill design. An evaluation of this coastal manipulation design relative to State coastal policy applied is then possible.

Active Slide Planes

The surface limits of the fill were determined by carefully mapping the cracks around the fill perimeter using aerial photographs, and by frequently monitoring the permanent survey points and the monitoring lines. Figure 4 shows the limits of the fill based upon the results of the mapping and surveying data.

Additionally, by monitoring the inclinometers it was possible to determine the depth of the landslide. Figure 6 shows the original post-slide profile, as well as the slope profile after the overburden had been removed and the fill created in 1991. The results indicated that after construction, the fill extended to an elevation of 260 ft mean sea level (MSL), and was approximately 800 ft wide. The highway is located at an elevation of 210 to 230 ft MSL as it crosses the fill. The sediment volume of the fill was estimated to be 1,000,000 cubic yards.

Figure 6 shows an engineering geologic cross section derived from survey point elevations and data from inclinometers SI1, 2, and 4 on 12/22/89 (locations not graphically represented). A relatively sharp basal shear surface (e.g., slide plane) was located in boreholes approximately 100 feet below the surface of the original slide. The slide plane is still active at this depth and a new, second, slide plane may be located along the surface of the original slide, which is up to 170 feet below the fill surface. The fill material continues to move along the original slide plane, and possibly other slide plane surfaces. These latter surfaces have not been determined at this point in time, but there are indicators of their presence, such as the persistence and growth of localized slumping features, ground water percolation along the face of the fill at elevations not associated with the original slide plane surface elevation, and large extensional fractures and vertical displacement along the upper bench of the fill.

Movement Rates

By monitoring the permanent survey points and the monitoring lines from 1991-1994 it was possible to determine: (1) the cumulative and incremental distance that the fill had moved, (2) the sediment volume change along the survey point lines, and (3) the velocity field within the fill. Post construction fill movement rates (1991-1992) and volume of eroded fill material was high because of transport by wind and waves of loose fill material into the nearshore environment (CalTrans aerial photos from June 1991 to June 1992). Also, the fill material underwent initial settling and compaction during the post construction period, as reflected by the rapid movement at the permanent survey points (Figure 8). Within a short period of time these levels of erosion and movement dropped to comparable summer/fall levels. Figure 8 indicates that the fill was moving at an average velocity of .13 feet/month (summer) and .04 feet/month during the fall of 1991, and remained relatively constant during the winter and spring 1991/92 to .10 and .05 feet/month respectively. The 1992 summer/fall movement conditions were .07 feet/month and .06 feet/month. By the winter and spring of 1992/93 the movement rates had increased again to .14 and .09 feet/month respectively. The rate of fill movement correlates with variations of rainfall, with increasing slippage during peak rainfall periods (Figure 9). However, the fill appears to be in constant motion toward the ocean during both the rainy and dry seasons of the year, in contrast to other documented landslide cases (Crozier, 1986) which tend to show a correlation between ground water levels and landslide movement. In these cases there was little landslide activity until the water table was elevated to a critical point, after which slide movement began.

Figure 9 shows the average rate of movement per month in feet for the fill during the entire period of 1991, 1992, and 1993, as well as averaged over this same period. There was a substantial velocity increase in 1993, corresponding to the first year of above average rainfall following six years of drought.

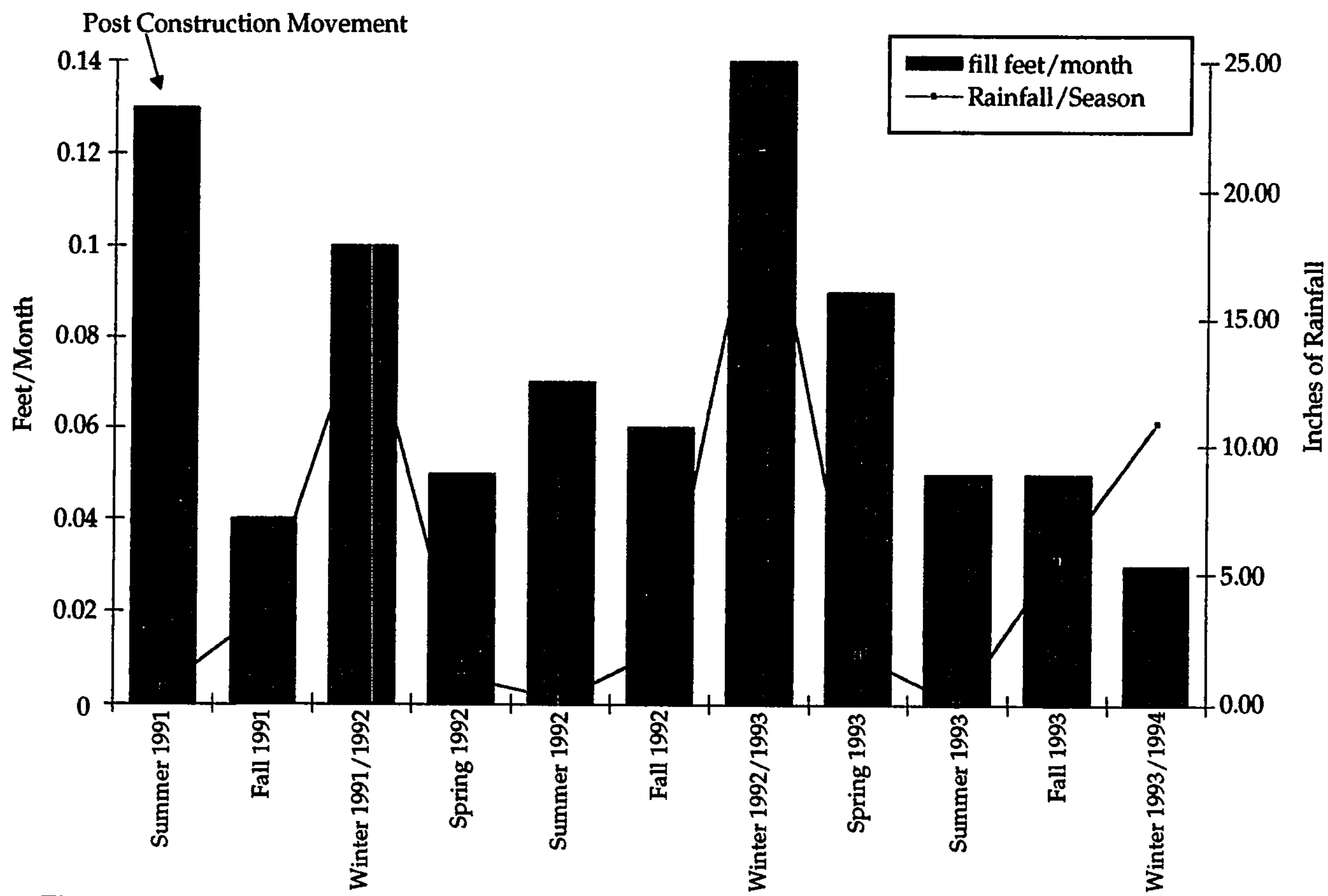

Figure 8. Average seasonal velocity of the fill from 1991-1994. Rain data from the Stinson Beach weather station.

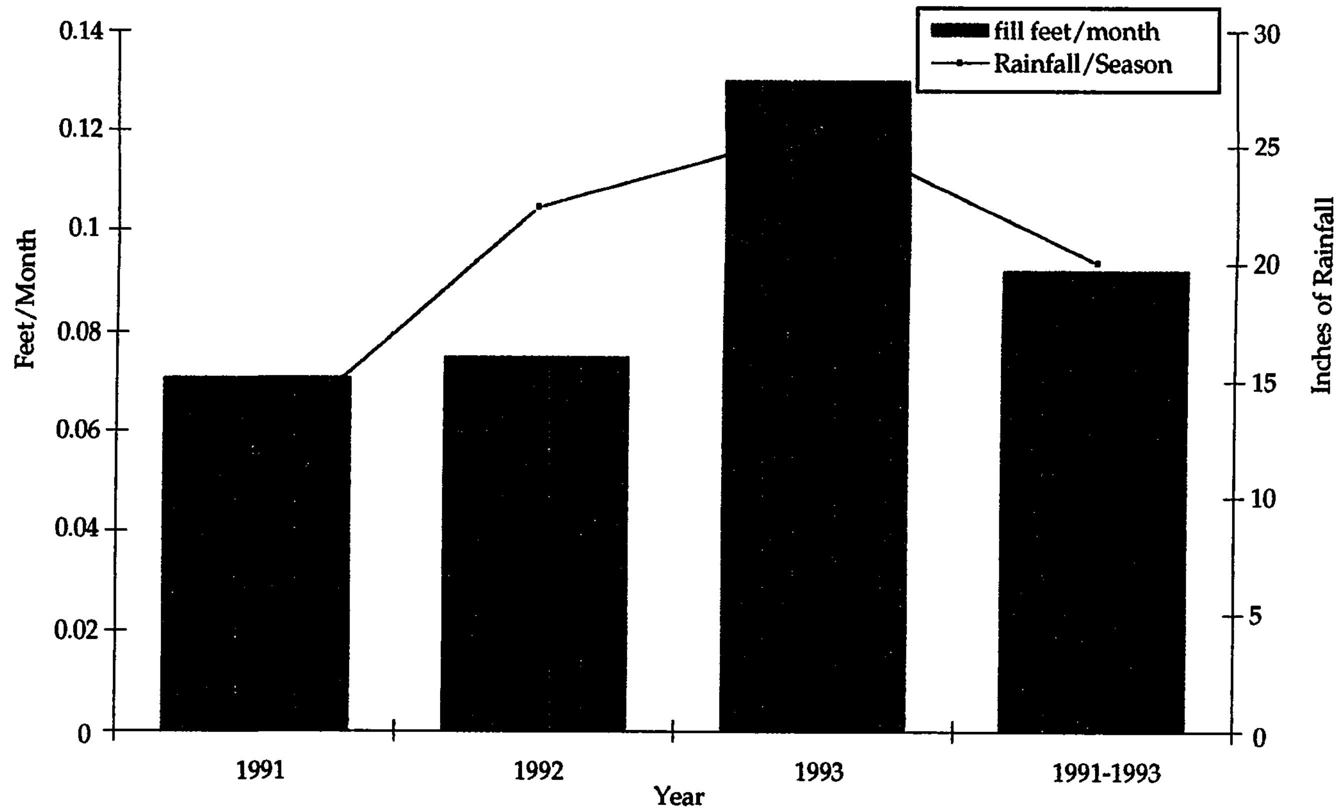

Figure 9. Average annual velocity of the fill 1991-1994, including annual variation in rainfall from the Stinson Beach weather station.

Figure 10 shows the cumulative movement for all of the 8 survey points located along the top bench of the fill. These data demonstrate that movement occurred at all stations, and was not confined only to discrete areas of the slide. However, survey points 16-18 showed movement rates, which at times far exceed the average rates for all points combined (Figure 11).

Erosional Mechanisms

These changes in movement rate are the result of slumps. Smaller slumps occurred on the south end of the fill toe, as well as on the larger northern half of the fill. The latter slump feature, and the numerous smaller gullies covering the remaining part of the north face of the fill, have grown in size as large extensional fractures along the top of the fill have formed. These cracks extend across the entire top bench of the fill and down along the southern half of the fill to south Lone Tree beach. The cracks are also associated with a large rotation of fill material along either a new slide plane or the original slide plane. Evidence from annual topographic maps (CalTrans topographic maps of Lone Tree 1991-1994) and aerial photographs of the fill detail the morphologic changes of other slumping events along the face of the fill (Figure 12-13 and Photos 1-4 summarize this process). These data suggest that extensional cracks can be surficial representations of a new head scarp based on Crozier's (1986) definition of mass movement formation. This slumping event is exhibiting indications of a much larger deep seated slump that will incorporate the length of the fill over-time.

Erosion Rates and Distribution of Slumping

The annual volumetric changes of sediment eroding from the face of the fill along each monitoring line were calculated to understand erosional mechanisms of the fill (Figure 12). The volume of the original fill, or new overburden, is greater along profiles 14-17, which would act to increase driving forces in this region of the original

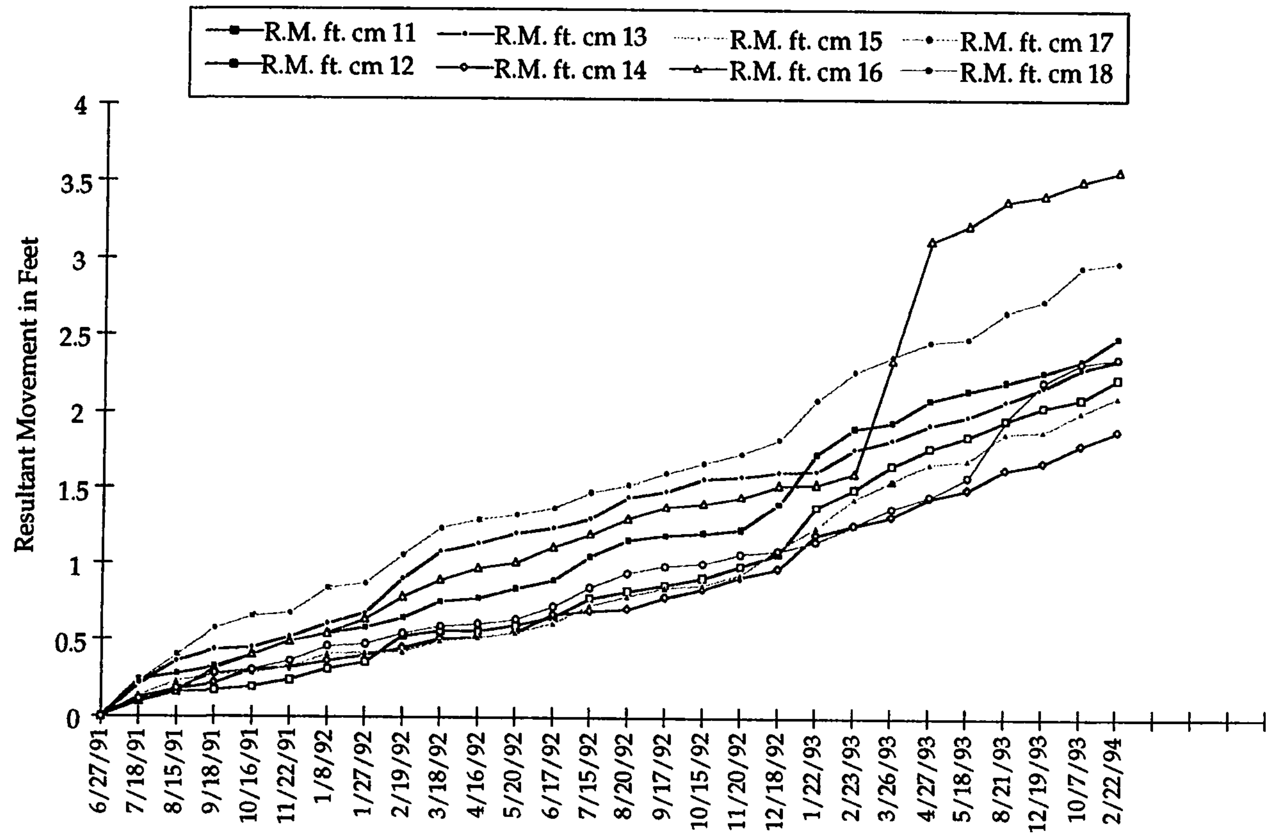

Figure 10. Cumulative movements at survey points along the top of the fill from 1991-1994.

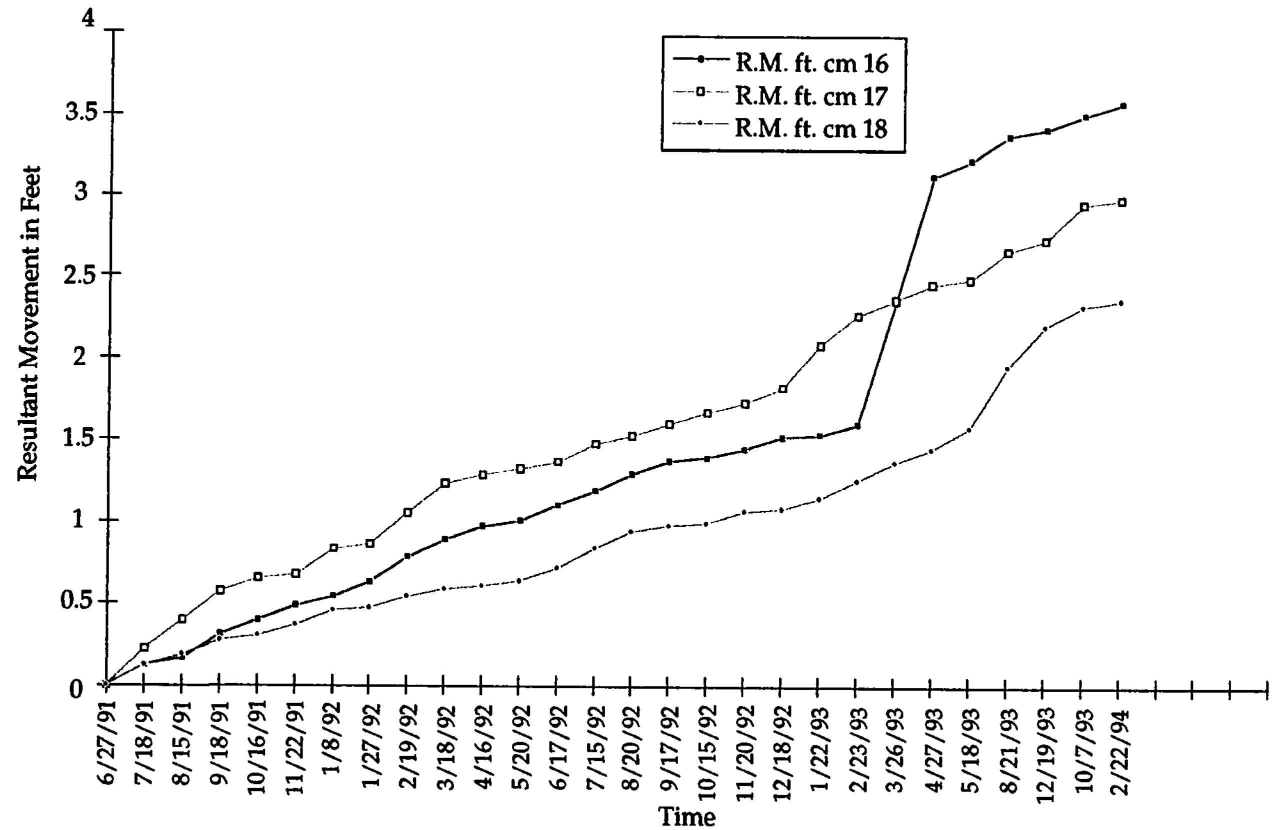

Figure 11. Cumulative movements at survey points with unusually high movement rates from 1991-1994.

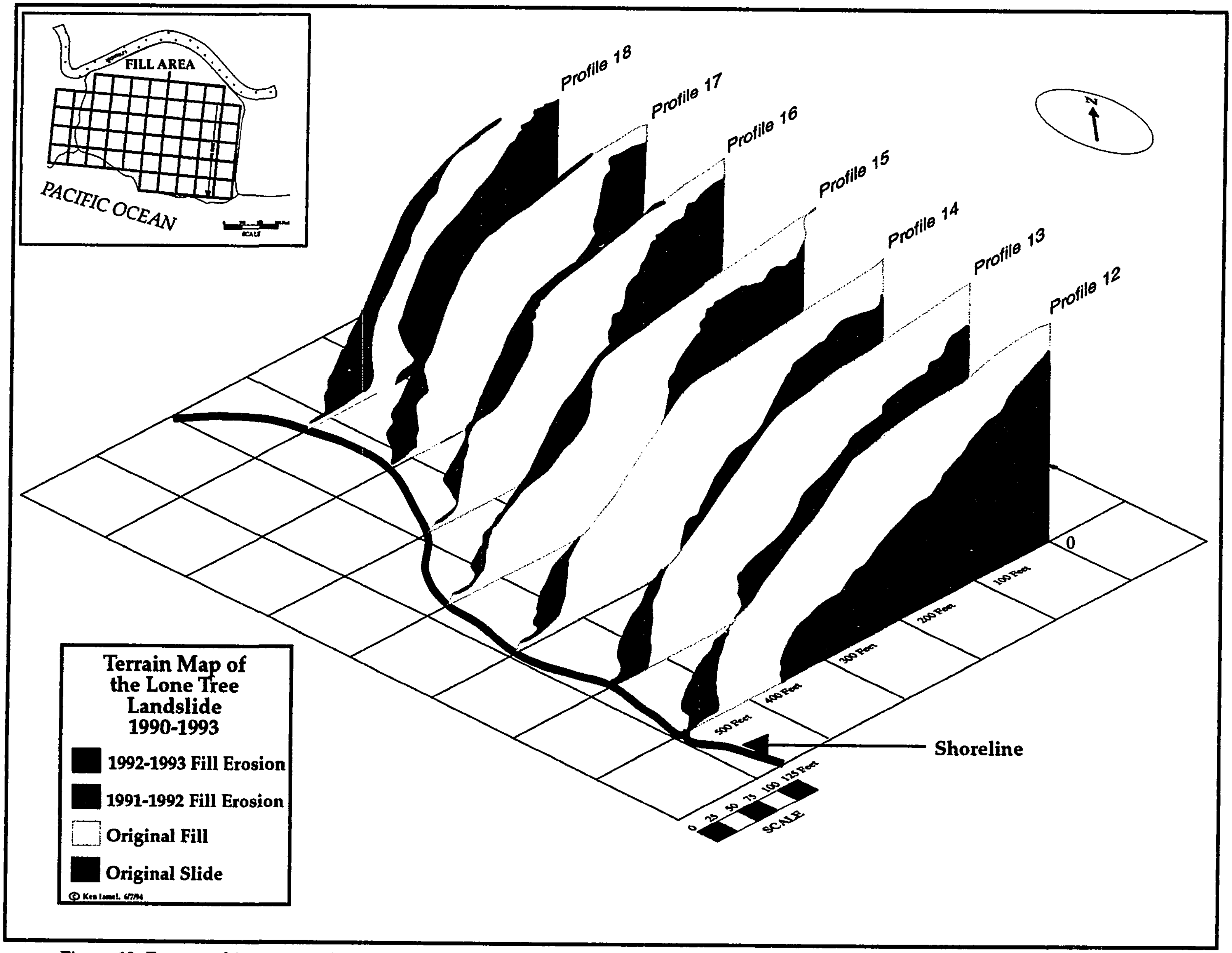

Figure 12. Topographic cross sections 1990-1993 along all survey point lines (see Figure 4).
Data obtained from annual topographic maps provided by CalTrans (Israel, 1994).

buried landslide and slide plane, resulting in continued movement of the fill. Along profiles 15-18 there is more slumping occurring on the face of the fill, which is also located above the most active area of the original slide. This is in marked contrast to a low degree of slumping and erosion occurring along profiles 12-14, which are in historically less active areas of the original slide, based on historical photos (1980-1989) of the fill area provided by CalTrans.

More erosion occurred along the entire fill area during the first year of post construction (1991-1992) than during the subsequent year (1992-1993). Erosion mechanisms since the initial post construction period (summer 1991) have changed from mainly surficial movements of sloughed sediment to discrete slumping events that have progressed from profile 18 to 15, in conjunction with the growth of rotational cracks along the upper bench area (Figures 12 and 13). Profile 18 has the highest 1992-1993 erosion rates. The west end of the slide, shown by Profile 18, contains the largest cracks and slumps on the fill. Currently, this cracking, which is associated with the slumping event at profile 18, extends all the way across and down the face of the fill to profile 12 (Figure 13 and Photo 4).

The most stable area of the fill is the southeast end, shown on profiles 12 through 14, and has the most abundant armoring. This area, which overlies a less historically active part of the slide, has a lower angle of repose and has shown a decrease in erosion rates from 1991-1992 to 1992-1993.

Sediment Budget and Life of the Fill

The balance or net sediment change, either progressing toward the ocean or eroding back toward the original coastline location prior to the fill, is indicated in Table 1. The average volume of sediment eroding from the entire fill per month during 1991-1994 was 4,145 cubic yards. This indicates that net sediment transport from the fill was

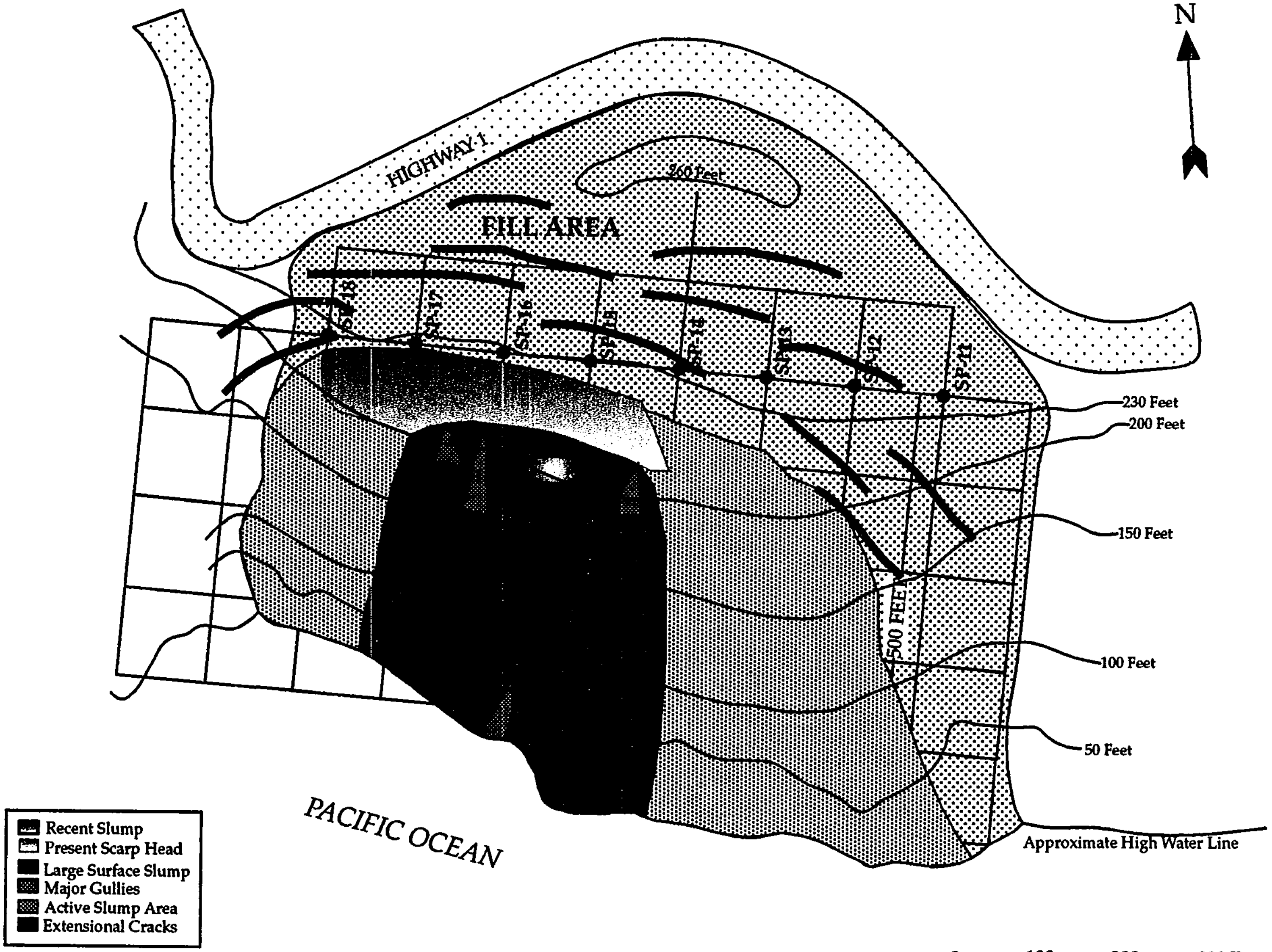

Figure 13. Map of Lone Tree hazard fill area with permanant survey point location and grid overlay. The limits of the fill are shaded (Israel, 1994).

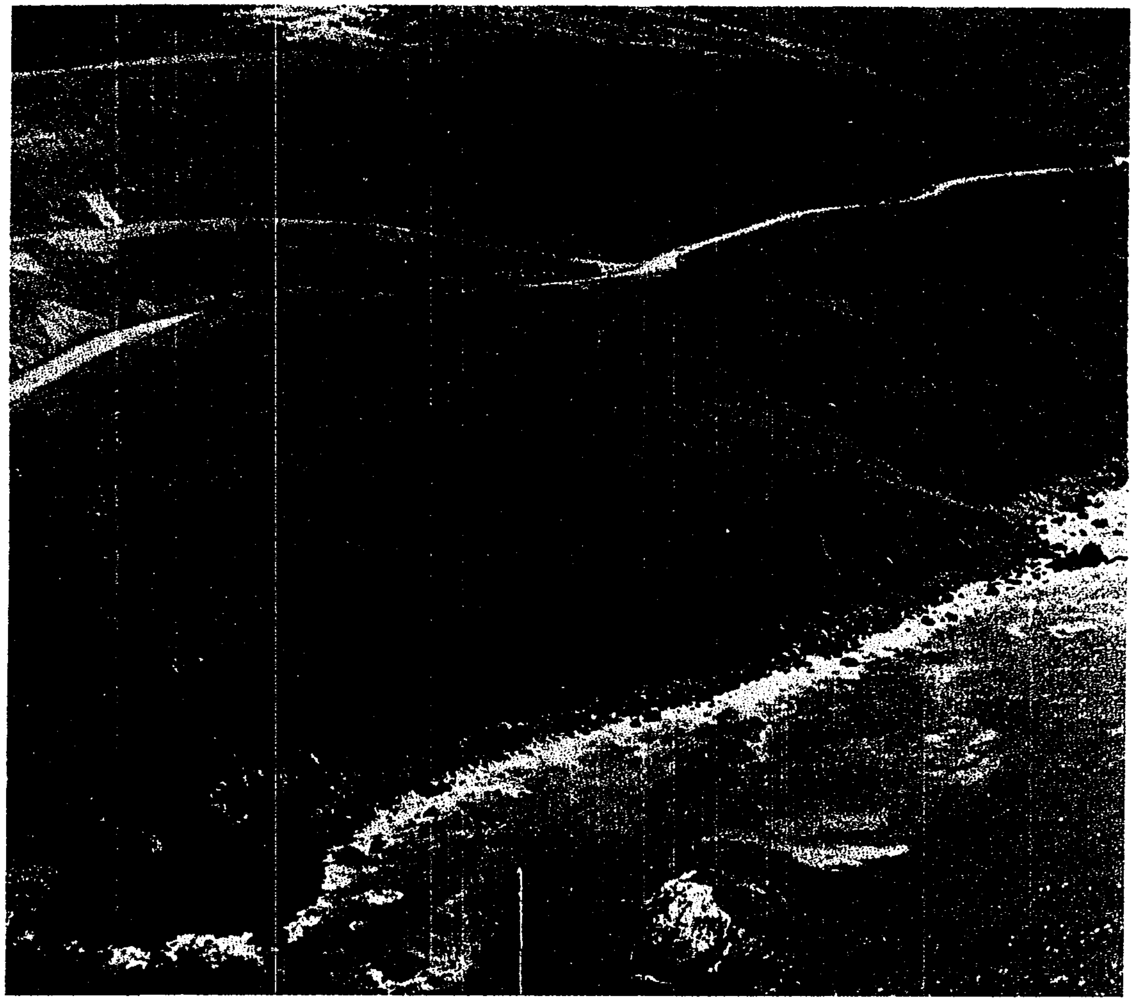

Photo 4. The Lone Tree slide/fill three years after manipulation showing signs of erosion (e.g. gullies) and mass movement (e.g. slumping) (June, 1994).

taking place. Calculations of this movement along the fill shows the average rate of sediment discharge per linear foot per year from the fill was 70.1, and 33.6 cubic yards for 1991-1992 and 1992-1993 respectively. The average erosion rate for that time was 51.8 cubic yards per linear foot per year.

Survey Point	Sediment Lost (cubic yards) 1991-1992	Sediment Lost (cubic yards) 1992-1993
12	6,857	3,247
13	7,789	4,698
14	6,608	1,443
15	13,126	5,669
16	13,618	5,670
17	8,765	5,923
18	3,650	2,318

Table 1. Sediment lost along survey point transect lines and integrated over a horizontal distance of 100 feet along the fill from 1991-1993.

The calculations of movement rates, in conjunction with the erosion rate data, allowed us to estimate the life of the fill. It is estimated to be between 15 and 31 years at the currents rates of erosion.

Hydrologic Conditions

Ground water levels were measured above the basal shear surface during the period June 1992 to June 1993 (Figure 14). Although water levels sometimes correlate with rainfall (Figure 15), the data are difficult to interpret. This may be a result of the inclinometers being located above the active slide plane area (Figure 5), or area of activity which could be correlated with variations in the level of ground water (e.g., increase or decrease in pore water pressure). Transport of water along the original slide plane, or other yet unknown slide plane(s), may also be a contributing factor in the continued movement of the fill, but were not correlated with fluctuations in ground water level.

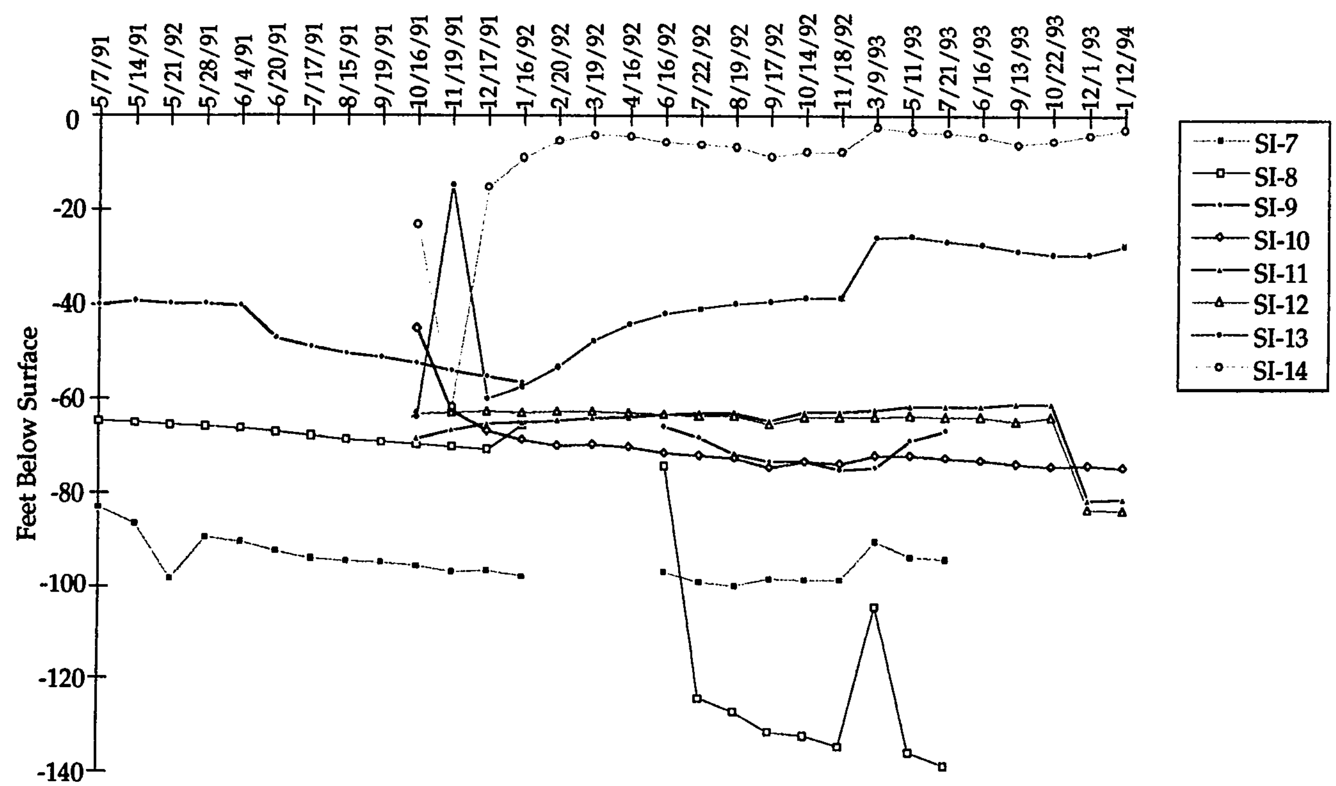

Figure 14. Ground water levels at slope indicator sites from 1991-1994.

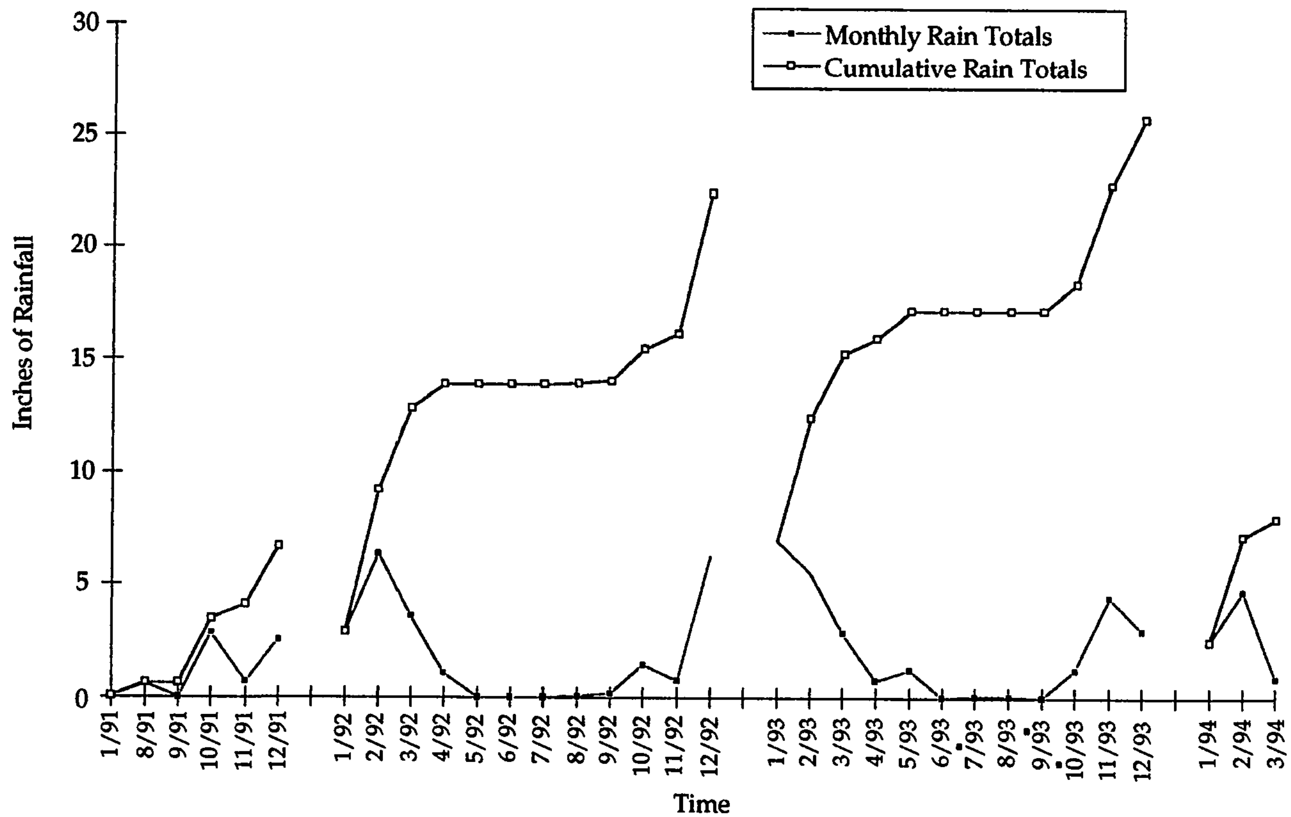

Figure 15. Rainfall totals at the Stinson Beach weather station from 1991-1994.

Stream and Meteorological Conditions

Stream and rain data have been collected and summarized in Table 2 and Figure 15. The volume of stream water runoff was closely correlated with rainfall (Figures 15 and 16). A correlation diagram of 48 hour rain totals and volume of water measured at the monitored streams stations typically shows this correlation (Figure 17). Some volume measurements do not show this correlation, such as on February 10, 1992 and February 19, 1995. This maybe due to localized weather patterns being different on occasion between the location of the weather station at Stinson beach and the stream stations which are located 2 miles to the south. The monitoring documented the significant increase in stream runoff associated with major storm events during the winter of 1993. Although streams do transport sediment into the nearshore marine environment, our measurements indicate that this source is not significant when compared to other sources of sediment deposition such as Lone Tree fill or other sources within the region of the fill (Tables 2 and 3).

Summary of Results

The geotechnical investigation was designed to determine whether this coastal manipulation would add significant amounts of sediment to the nearshore marine environment. It was found that:

1) the active slide plane is located approximately 170 feet below the fill surface;

2) movement rates varied between .04 feet/month and .14 feet/month, that the movement occurred along the entire fill area, and that the northern areas of the fill had

at times far higher rates of movement than the southern portion of the fill;

3) erosional mechanisms have predominantly been mass movement slumping events and gully formation along the face of the fill, and will continue to be such for the life of the fill;

4) erosion rates and distribution of slumping have been highest along the areas of greatest overburden and historical landsliding (i.e., north end), and lowest along areas that were historically less active with smaller amounts of overburden (i.e., south end);

5) the average volume of sediment eroding from the entire fill per month during 1991-1994 was 4,145 cubic yards, which estimates the life of the fill to be between 15 and 31 years;

6) hydrologic conditions were not clearly interpretable; and

7) that volume of stream runoff and sediment transport to the nearshore environment correlated with rainfall, that major storm events contributed the most to sediment transport in these monitored streams, but that this source of sediment is not significant when compared to other sources of sediment such as the Lone Tree fill or other sources within the geographic region.

Date	Stream Location	Avgerage Velocity (m/sec)	Stream Area (m2)	Volume (m3)	Suspended Sediment (g/l)
3/13/91	L.T. Creek	1.37	0.640	0.877	0.120
	Cold Stream	0.91	0.500	0.455	0.120
	Webb Creek	0.72	0.160	0.115	0.150
3/24/91	L.T. Creek	2.32	0.620	1.438	0.140
	Cold Stream	1.79	0.480	0.859	0.120
	Webb Creek	1.59	0.140	0.223	0.140
3/25/91	L.T. Creek	2.22	0.110	0.244	0.150
	Cold Stream	2.01	0.190	0.382	0.100
	Webb Creek	0.93	0.280	0.260	0.150
3/27/91	L.T. Creek	1.89	0.260	0.491	0.130
	Cold Stream	1.34	0.260	0.348	0.150
	Webb Creek	1.36	0.093	0.126	0.120
4/18/91	L.T. Creek	0.32	0.065	0.021	0.010
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
4/30/91	L.T. Creek	0.37	0.020	0.007	0.030
	Cold Stream	0.15	n/f	n/f	0.000
	Webb Creek	0.14	n/f	n/f	0.000
5/31/91	L.T. Creek	n/f	n/f	n/f	0.000
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
12/20/91	L.T. Creek	1.91	0.130	0.248	0.270
	Cold Stream	1.41	0.110	0.155	0.340
	Webb Creek	1.44	0.110	0.158	0.210
1/7/92	L.T. Creek	2.27	0.150	0.341	1.010
	Cold Stream	1.5	0.120	0.180	0.910
	Webb Creek	1.61	0.140	0.225	0.950
1/17/92	L.T. Creek	0.41	0.046	0.019	0.050
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
2/10/92	L.T. Creek	0.7	0.057	0.040	0.042
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
3/14/92	L.T. Creek	0.96	0.049	0.047	0.400
	Cold Stream	0.36	0.130	0.047	0.320
	Webb Creek	0.32	0.100	0.032	0.370
4/6/92	L.T. Creek	0.21	0.160	0.034	0.025
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
4/9/92	L.T. Creek	n/f	n/f	n/f	0.000
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
6/12/92	L.T. Creek	n/f	n/f	n/f	0.000
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
9/26/92	L.T. Creek	n/f	n/f	n/f	0.000
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000

Table 2: Water flow and suspended sediment in local streams around Lone Tree slide. n/f=no flow

Date	Stream Location	Avgerage Velocity (m/sec)	Stream Area (m2)	Volume (m3)	Suspended Sediment (g/l)
10/29/92	L.T. Creek	0.97	0.120	0.116	0.250
	Cold Stream	0.65	1.510	0.982	0.600
	Webb Creek	n/f	n/f	n/f	0.000
12/3/92	L.T. Creek	0.16	0.044	0.007	0.015
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
12/30/92	L.T. Creek	0.69	0.086	0.059	0.050
	Cold Stream	0.52	0.043	0.022	0.050
	Webb Creek	0.05	0.034	0.002	0.050
1/15/93	L.T. Creek	1.41	0.235	0.332	0.320
	Cold Stream	1.16	0.397	0.459	0.270
	Webb Creek	0.71	0.089	0.063	0.410
2/4/93	L.T. Creek	0.54	0.246	0.786	0.050
	Cold Stream	0.51	0.506	1.012	0.050
	Webb Creek	n/f	0.135	0.135	0.050
2/12/93	L.T. Creek	0.69	3.038	3.725	0.050
	Cold Stream	0.85	2.383	3.229	0.050
	Webb Creek	0.46	0.236	0.695	0.075
2/19/93	L.T. Creek	1.24	10.463	11.700	0.450
	Cold Stream	0.65	1.923	2.569	0.300
	Webb Creek	0.89	0.516	1.407	0.500
4/8/93	L.T. Creek	0.31	0.305	0.615	0.050
	Cold Stream	n/f	n/f	n/f	0.000
	Webb Creek	n/f	n/f	n/f	0.000
10/14/93	L.T. Creek	0.51	0.222	0.732	0.020
	Cold Stream	0.43	0.49	0.92	0.040
	Webb Creek	n/f	0.11	0.11	0.040
11/10/93	L.T. Creek	0.10	0.062	0.162	0.020
	Cold Stream	n/f	n/f	0.00	0.000
	Webb Creek	n/f	n/f	0.00	0.000
12/10/93	L.T. Creek	1.31	0.225	1.535	0.350
	Cold Stream	1.10	0.39	1.49	0.400
	Webb Creek	0.61	0.10	0.71	0.300
1/25/94	L.T. Creek	0.45	0.216	0.666	0.050
	Cold Stream	0.47	0.52	0.99	0.050
	Webb Creek	n/f	0.13	0.13	0.025
2/8/94	L.T. Creek	0.27	0.200	0.470	0.020
	Cold Stream	n/f	n/f	0.00	0.000
	Webb Creek	n/f	n/f	0.00	0.000
2/18/94	L.T. Creek	0.96	0.059	1.019	0.270
	Cold Stream	0.42	0.18	0.60	0.100
	Webb Creek	0.52	0.13	0.65	0.200
3/25/94	L.T. Creek	2.20	0.100	2.300	0.670
	Cold Stream	1.67	0.08	1.75	0.450
	Webb Creek	1.72	0.11	1.83	0.430

Table 2 (Continued): Water flow and suspended sediment in local streams around Lone Tree slide. n/f=no flow

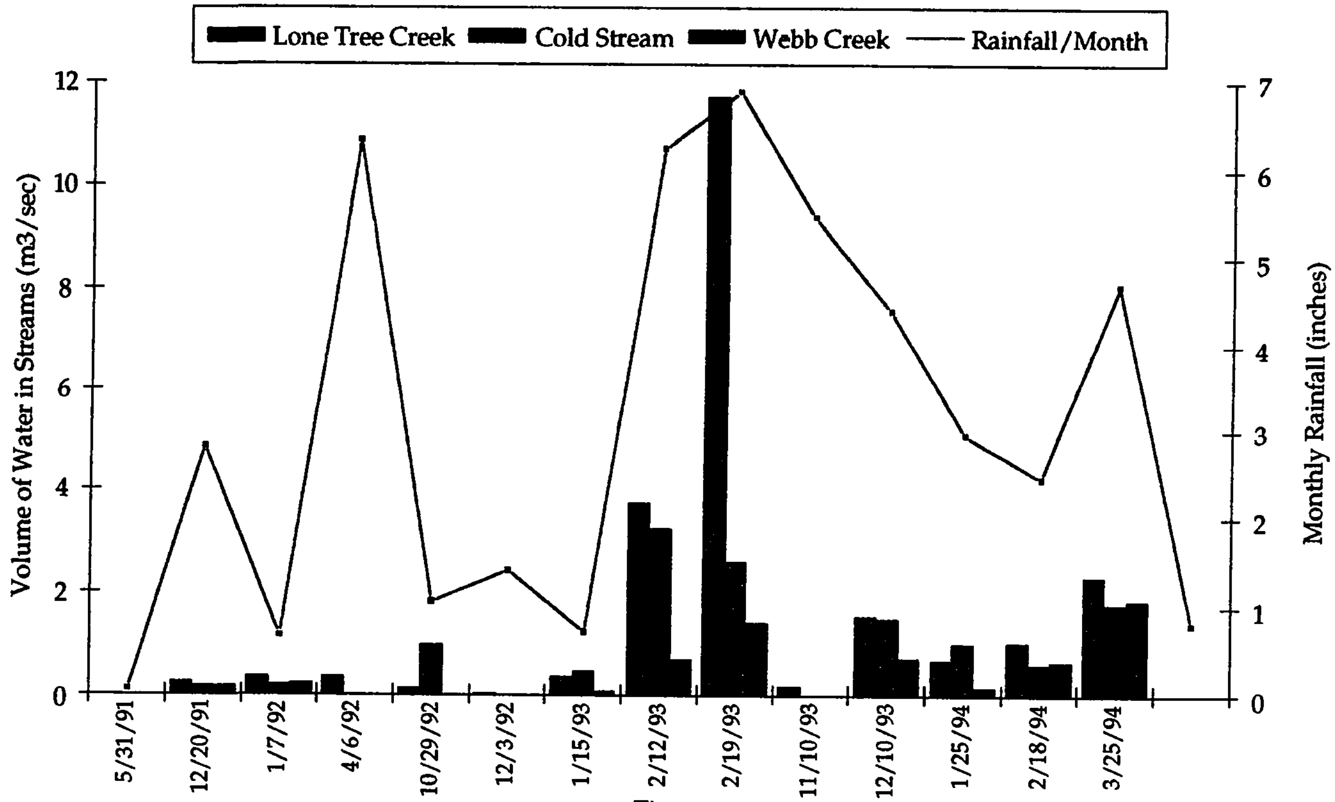

Figure 16. Volume of water in streams near Lone Tree fill 1991-1994, including monthly rainfall at the Stinson Beach weather station.

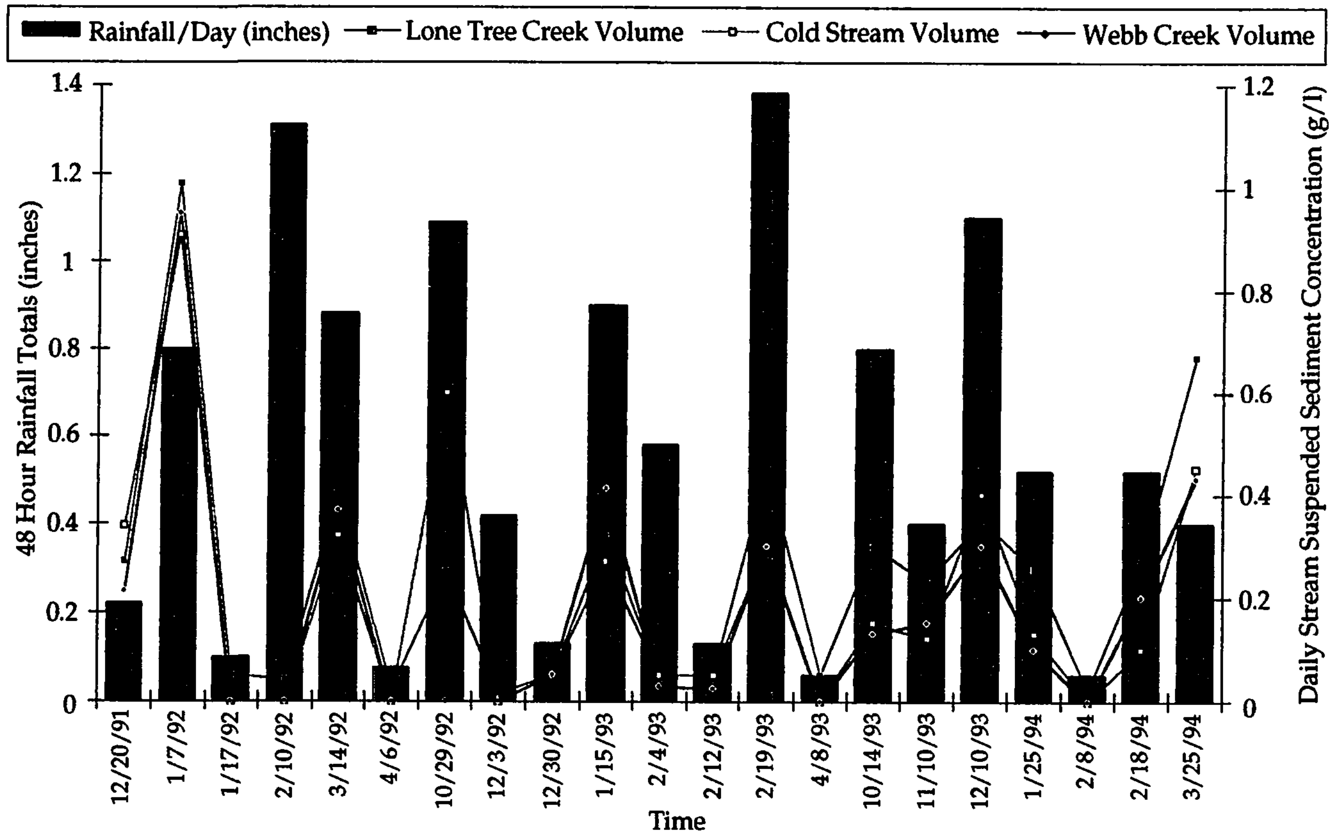

Figure 17. Correlation of rainfall amount within a 48 hour period of time with suspended sediment concentration measurements in streams 1991-1994.

Suspended Sediment		
Station	Year	Tons/Year
MOSS LANDING STREAM STATIONS		
Lone Tree Creek	1991	928
Lone Tree Creek	1992	1936
Lone Tree Creek	1993	2346
Cold Stream	1991	1004
Cold Stream	1992	1977
Cold Stream	1993	2260
Webb Creek	1991	740
Webb Creek	1992	1512
Webb Creek	1993	1784
REFERENCE STREAMS		
Pine Creek	1968	380
(at Bolinas)	1969	7,580
	1970	33,400
Morses Creek	1968	49
(at Bolinas)	1969	49
Walker Creek (near Tomales)	1971	41,500
Salmon Creek (near Bodega)	1971	8,600
Big Sulfer	1965	856,000
Creek	1966	260,000
(near Cloverdale)	1967	295,000
	1968	103,000
Dry Creek	1965	2,283,000
(near Geyserville)	1966	717,000
	1967	554,700
	1968	186,700
	1969	694,500
	1970	1,216,000
	1971	302,200

Table 3. Suspended sediment loads from Moss Landing stream stations and other selected reference stations (From Jackson and Brown, Jr., 1974).

CHAPTER 4

Discussion

Preconstruction Geotechnical Concerns

The Geotechnical Report accompanying the Initial Study by CalTrans in 1990 provides estimates of the annual sediment loading along Route 1 from streams and cliff erosion, in the vicinity of the slide. It finds that, "Sediment production from coastal erosion is insignificant compared to the sediment production of the rivers and streams" (Geotechnical Report accompanying the Initial Study by CalTrans, 1990). The estimated sediment yield from the coast near the Lone Tree landslide is compared with maximum yields over a three year period from Dry Creek near Geyserville. Dry Creek is not in the Bolinas Littoral Subcell and the sediment yields from Dry Creek would have little if any effect on, or relationship to, shoreline processes in the Bolinas Subcell. Pine, Morses and Audubon Creeks are in the Bolinas Subcell and the sediment loading from Lone Tree slide erosion should be compared to these stream sediment load estimates. When this comparison is made, the yields from coastal erosion are a significant part of the sediment production, in sharp disagreement to estimates made by CalTrans.

Erosional Mechanisms

Sediment data are given in the report for the years from 1965 to 1971, or a smaller interval within this time span, and are approximately 20 years old (Geotechnical Report accompanying the Initial Study by CalTrans, 1990). Since there have been few major land use changes in west Marin over the past 20 years, these data may be representative of current yields.

The estimate of sediment yield from the Lone Tree landslide below the highway is developed from the rate of slide movement, the length of the cliff face that is attacked by waves, and the height of the cliff face. Multiplication of these figures provides an estimate of the total flux of material moved into the offshore environment. The estimate of sediment yield with the preferred alternative is somewhat confusing and should be reexamined. Specifically the 1990 report should have examined the movement of the slide seaward of the highway and should have considered the volume of material in the fill.

Movement Rates

In the estimate for sediment loading from the existing slide the report stated that "The slide is displacing downward and seaward at a rate of 3 to 4 feet per month" (Geotechnical Report accompanying the Initial Study by CalTrans, 1990). However, in the estimate for sediment loading, after the erodible fill is in place, the slide mass below the road was anticipated by CalTrans to remain stable after the fill is completely removed (Geotechnical Report accompanying the Initial Study by CalTrans, 1990). This stability assumption seems to be based on a factor of safety calculation (e.g., calculated margin of safety before a slope is considered unstable) for the lower slope. The input for this analysis includes the profile of the ground surface and the slide plane, the unit weight of the slide material, water levels and strength parameters. As the fill erodes, the ground surface profile will change and the factor of safety should change in concert. The factor of safety should be calculated for various stages of erosion of the fill to guarantee that the surface profile will maintain a stable slope throughout the life of the buttress. CalTrans stated that the future stability of the lower slide is not essential for the projects stability (Geotechnical Report accompanying the Initial Study by CalTrans, 1990). This statement was not supported with additional data showing the failure surface in relation to the road location.

Additionally, the Geotechnical Report accompanying the Initial Study by CalTrans (1990) indicated a second landslide to the southeast of the landslide proposed for repair. As diagrammed in Figure 6, the fill would be placed on the entire original slide. Additional weight by construction and fill material can frequently initiate landslide movement, and, if the surcharge weight of the fill at the head of this section increases the driving forces, it could destabilize the entire fill. Additional information should have been provided on the effect of the fill on the southeast section of the slide complex.

Hydrologic Conditions

Another concern is with the lower slide water management. CalTrans has located ground water above the failure surface, but no water management techniques, such as horizontal drains, were proposed for the slide mass underlying the buttress. An analysis of the ground water influence on the slide and the need for mitigation of potential hazards should have been conducted.

Erosional Rates and Distribution of Slumping

Estimates for future annual sediment loading from coastal erosion were based on the estimates for current annual loading, given as cubic yards per linear foot of shoreline. This estimate assumes that there are no changes in the shoreline other than the increase in length due to the point source of sediment. The addition of 1,000,000 cubic yards of sediment constitute a major change in the backshore and cliff slope. The yield per linear foot of shoreline should increase somewhat due to this addition of material. Future shoreline erosion might be a combination of the existing erosion from the slide material and coastal cliffs and new erosion from the fill. It seems that the analysis in the Geotechnical Report assumed that only the new platform and embankment material would erode and that the original landslide material along the coast, which is now eroding, will stop moving seaward and become stable.

Sediment Budget and Life of the Fill

The analysis in the Geotechnical Report by CalTrans (1990) shows an annual increase in total sediment loads ranging from 8,000 to 9,600 cubic yards. If the entire 1,000,000 cubic yards of material can be expected to erode in 23 to 41 years (as stated in the Geotechnical Report by CalTrans, 1990), there would be an annual addition of 34,700 to 46,700 cubic yards of sediment to the offshore environment. This loading would almost double the existing loading to the Bolinas Subcell from coastal erosion, creeks and streams. The impacts to the offshore environment would be substantially different if coastal erosion increased annually by 34,700 to 46,700 cubic yards than if the increase were only 8,000 to 9,600 cubic yards. CalTrans should have reexamined the analysis for sediment loading from the proposed project and clearly described all assumptions and the nature of the analysis.

A final concern is with the quality of the landslide material. There was no analysis in the Geotechnical Report of the material which would be placed in the ocean or allowed to erode into the ocean. CalTrans should have taken some representative samples for a sieve analysis to determine the amount of material that would remain suspended in the water column and the amount that would settle out as bed load. The fill material should also meet EPA's criteria for ocean disposal.

Post Construction Fill Evaluation

Movement Rates

Estimates of sediment input to the ocean and predictions of future rates of input may influence the impact of the slide manipulation on the environment. The fill is moving downward and seaward at a rate of 0.092 feet per month. The toe of the fill extends into the sea with a talus slope covering most of the beach, including a wide range of rock sizes, especially cobbles and boulders. The average angle of repose of the talus slope is 35°, although the upper part of the slope is steeper (Photo 4). The entire slide beach and the adjacent fill cliffs are being eroded by wave runup. However, the talus beach area is partially protected or armored from wave erosion making this section of the fill stable over time.

Erosional Mechanisms

The amount of fill material entering the marine environment varies both seasonally and yearly, and severe winter storms cause most of the erosion and transport of material into the marine environment (Griggs and Savoy, 1985). These storms usually involve heavy rains and large waves, the two major erosional processes. Sediment transport from the fill is much lower in the summer when rain and wave action are also low.

Hydrologic Conditions

Rainfall has had a significant impact on the movement of fill material, through surface erosion, mass wasting events, and sediment slumping and sliding (Photo 4). Heavy rains increase the pore fluid pressure within the sediment, which is known to facilitate landslides (Harden, et al., 1978; Swanston, et al., 1983; Griggs and Savoy, 1985; Crozier, 1986). Rainfall also contributes to a rising ground water table that can move along the slide plane, where the potential for landslide movement is already high. Since the initial erosion of loose fill material following construction of the fill in July of 1991, slumping and sliding events have been correlated with increased rainfall.

Erosional Rates and Distribution of Slumping

Rainfall also erodes the surface fill material and transports it down erosional gullies cut into the face of the fill. By the summer of 1994, four gullies at Lone Tree had grown into larger crevasses. All four are located within 100 feet of each other along the most active section of the fill, the large northern slump shown in Figure 12 or 13 and Photo 4. The four large gullies were conspicuous in January 1992, and have grown in width and depth since then. Some portions of the gullies are armored by cobbles, and all will continue to transport sediment from the slide to the intertidal beach. Surface erosion of the fill including gully transport should become a more important mechanism of sediment transport as the fill toe becomes more stable, but mass wasting events are likely to continue as the major erosional process.

The average rate of sediment erosion from the Lone Tree fill is extremely high, 62.2 cubic yards per linear foot per year, with a yearly high of 84.1 cubic yards during 1991-1992 and a low of 40.2 during 1992-1993. In comparison, Griggs and Savoy (1985) estimated the rates of cliff erosion between Duxbury Point and Bolinas Point at 8.5 cubic yards per linear foot per year, ten times lower than the 1991-92 Lone Tree rate (Table 3). Their estimates from other less active sections of the north coast were 3.7 cubic yards per linear foot of cliff per year or less.

Sediment Budget and Life of the Fill

Almost 100,000 cubic yards of sediment was eroded from the fill during the first two years after placement (see Table 1). Assuming that average erosion rates at Lone Tree continue during 90% of the fill life span and that erosion rates will double during 10% of its life span because of extreme erosional events, it is estimated that the entire fill can be removed in 15 to 31 years. If the above estimates of fill decay are compared with estimates of average natural conditions by Griggs and Savoy (1985), Brown and Jackson (1974), and Van Velsor and Walkinshaw (1992) the natural erosion rate is calculated to be 24,000 to 31,200 cubic yards per year. The existing conditions since road repair have been estimated to be between 32,215 and 67,270 cubic yards per year. These erosion rate ranges are up to an order of magnitude greater than estimated natural conditions. This average rate is based on only two years of data, and extreme events are likely to modify the average rates.

Already the toe of the fill is quite well armored with large boulders to cobble-sized rocks and the major erosional gullies along the slide face are at least partially armored by small rocks. In contrast, the potential for highly significant mass wasting has never been greater. The evidence is indicated in the increase in the number and growth of large cracks along the top of the fill, especially during the wet winter of 1992/1993. The fill region potentially impacted by these cracks contains approximately 300,000 cubic yards of sediment, but this is only the fill material. Below this region, there is a 100 foot deep layer of old slide material between the bottom of the fill and the original slide plane. One of the major goals of future work should be to monitor closely the processes that might indicate a mass wasting event. If there are heavy rains this winter (1994-95) there is potential for increased vertical displacement and growth of the extensional cracks along the upper bench, and possibly a large slumping event from the fill.

Other Physical Studies at Lone Tree

Komar (1994) focused on erosion of the fill toe by developing a model on the frequency of waves attacking the fill toe and how this erosional process varied with tidal elevation and wave conditions. He also made qualitative observations of eroded rills on the fill surface, development of the rocky beach as partial protection from wave erosion, and general changes in fill morphology. In the short-term, Komar predicts that the armoring of the rills and development of a fronting beach has reduced the overall erosion of the debris and the transfer of sediments to the ocean. Over years and decades, he believes that the development of secondary slumps in the debris fill can renew the delivery of sediments to the ocean. In the long-term, he predicts that the morphology of the debris fill should approach the configuration of the natural landslide, an unmodified portion of which remains adjacent to the debris fill (Komar, 1994). This natural landslide has a substantial fronting beach which prohibits waves from almost never reaching the base of the slide. Where waves impact the slide, they primarily remove sediment transported to the beach through gullies cut into the landslide by runoff from rainfall and ground water.

The physical data collected in this thesis focuses on the fill's erosion and complement's Komar's work. As indicated earlier, recent expansions of large extensional cracks in the fill and general patterns of fill movement indicate the potential for significant slumping (1994/1995). Since at least half of the fill material, which eroded from the slide during the first two years, was from slumping events on the upper slide face (see Figure 12), the past development of rills and gullies was not complete. Therefore, while the slide toe has apparently become relatively stable (Komar, 1994), erosion of the surface of the face and especially mass wasting have become the most significant erosional processes sending perhaps several hundred thousand cubic yards of sediment into the ocean (Figure 13). These slumping events will continue to periodically occur into the future, thereby reducing the driving forces on the subsurface slide plane, which will increase the stability of the fill over time. Sediment input to the marine environment will decline from these surficial slumping and mass wasting events, and major gullies and rills will form on the fill slope and become the major sediment transport mechanism from the fill to the marine environment. However, as has been observed along this section of California's coast, major and minor mass wasting events will continue to plague this region given the highly erodible and unstable nature of this coastal sediment.

Suggestions for Future Work

The three streams monitored for sediment transport contribute relatively little sediment to the nearshore waters (Table 3). Although the fill is contributing fine sediment to the nearshore environment, it is not clear what the mechanism is by which the sediment leaves the fill. There are several possible mechanisms: sheet flow along the top of the fill, erosional channels cut into the top of the fill, sub-surface flow through the body of the fill (i.e., along slide planes), as well as direct erosion of the fill by wave action. Because the mechanism of sediment movement off the slide may be a major determinant in the timing and volumes of sediment input to nearshore waters, it is necessary to understand the relative importance of the four transport mechanisms.

The effort that has been put into stream monitoring could be re-directed towards monitoring the "streams", i.e., erosional channels or gullies, which have formed on the slide face. Semi-permanent stations could be established in erosional channels along the face of the slide. The subsurface flow and sheet flow could be monitored using appropriate techniques. These data would allow for more accurate estimations of the sediment budget for the slide, and better predict the circumstances under which erosional channels form. From a more complete understanding of sediment movement on slides and fills, better fill erosion designs, such as appropriate re-vegetation or sedimentation basins, could be instituted to decrease sediment movement off of slide and fill faces. While these techniques are not appropriate for the Lone Tree fill, which is designed to be erodible, they may be of extreme utility in future slides.

CHAPTER 5

Conclusions and Implications

Policy Plan and Permitting

On January 11, 1991 the California Coastal Commission, as required by the California Coastal Act, approved Permit No.1-90-109 authorizing repair of the slide-damaged portion of State Highway One in Marin County.

As a result of 201,000 cubic yards of sediment placed within the Coastal Commission's jurisdiction area on state tidelands, and covering approximately 5.61 acres of ocean floor, mitigation for lost marine habitat was required by CalTrans.

The original permit imposed two special conditions requiring mitigation for the proposed fill. Special Condition No.1 required a mitigation plan for the filling of 2.5 acres of ocean bottom, either through the creation of 2.5 acres of new intertidal and subtidal marine habitat similar to the habitat being filled, or the restoration of 2.5 acres of degraded or filled marine or wetland habitat.

Special Condition No.2 required a marine monitoring program to assess the impacts caused by the fill project. The Commission found that these two measures constituted feasible mitigation measures that would minimize the adverse impacts of the fill and found the project consistent with the Coastal Act requirements.

The Commission amended Special Condition No.1 to require mitigation of 5.61 acres by the implementation of the Bolinas Lagoon project, and implementation of 3.6 acres at a second site.

With the fill design approved, CalTrans began the cut and fill operation in March of 1991, and completed the project in July 1991. The geotechnical portion of this project now becomes important as an evaluation technique for the impact of the erodible fill design, and its application to the coastal permitting process. The following is a summary of the geotechnical investigation of the Lone Tree fill.

The geotechnical investigation was designed to determine whether this coastal manipulation would add significant amounts of sediment to the nearshore marine environment which is prohibited by the California Coastal Act. It was found that:

1) the active slide plane is located approximately 170 feet below the fill surface;

2) movement rates varied between .04 feet/month and .14 feet/month, that the movement occurred along the entire fill area, and that the northern areas of the fill had at times far higher rates of movement than the southern portion of the fill;

3) erosional mechanisms have predominantly been mass movement slumping events and gully formation along the face of the fill, and will continue to be such for the life of the fill;

4) erosion rates and distribution of slumping have been highest along the areas of greatest overburden and historical landsliding (i.e., north end), and lowest along areas that were historically less active with small amounts of overburden (i.e., south end);

5) the average volume of sediment eroding from the entire fill per month during 1991-1994 was 4,145 cubic yards, which estimates the life of the fill to be between 15 and 31 years;

6) hydrologic conditions were not clearly interpretable; and

7) that volume of stream runoff and sediment transport to the nearshore environment correlated with rainfall, that major storm events contributed the most to sediment transport in these monitored streams, but that this source of sediment is not significant when compared to other sources of sediment such as the Lone Tree fill or other sources within the geographic region;

8) the erosion rate ranges are up to an order of magnitude greater than estimated natural conditions in the region, and the potential for these high rates of mass wasting to continue are high.

During the time of geotechnical monitoring there were large amounts of sediment being eroded into the marine environment. However, the rates of natural erosion have been rough estimates, and the variability of coastal erosion could be great. It is therefor difficult to evaluate whether this project added significantly to the natural sediment budget of coastal erosion in this area. Possibly a more reasonable question would be one that addresses the relative significance of sediment erosion from a fill into a naturally turbid environment, like this one in Marin County, rather than put a requirement of no net coastal erosion increases from permitted projects. The next section addresses this question of necessary coastal management requirements.

Impact of Future Planning

One important insight from this thesis is that long term coastal management policy is needed to efficiently and economically keep State Highway One open. For example, when slides are repaired or bridges are replaced, both benefits (e.g., access, motor vehicle safety) and impacts may result (e.g., loss of marine habitats, degradation of scenic resources, impairment of recreational opportunities). Existing coastal plans and policies only deal with parts of these issues, and do not necessarily provide for procedural coordination between local, state and federal jurisdictions. Currently, CalTrans deals with coastal hazards, like the one at Lone Tree, on a case by case basis. There is little forethought as to how best to achieve agency coastal planning and management goals, while at the same time keeping the road open. The result has been a lack of a coordinated effort by CalTrans and coastal permitting agencies to work out acceptable agreements as to how to economically and ecologically deal with the ongoing coastal hazards that affect State Highway One.

A coordinated coastal management plan is needed with all resource and permitting agencies agreeing in advance on how different coastal hazard areas will be dealt with. The agreement would include maintenance design, monitoring, and mitigation. This 'Master Environmental Impact Statement' that I propose for coastal highway maintenance is an effort to fill this need by focusing on California's State Highway One as the central element in future land use, public access, and natural resource management decisions. See Appendix E for general outline for a Master Environmental Impact Statement.

An important consideration is the need for strict adherence to the certified Local Coastal Programs (LCP's) both in letter and spirit. Accordingly, this management plan is intended to supplement, not supplant, the applicable LCP policies. Implementation of various LCP's proposed standards and procedures may necessitate modifications of one or more of these LCD's through the amendment process. Also, some of the proposed Master Environmental Impact Statement standards and procedures can be implemented through interagency agreements or memoranda of understanding (MOU's).

The subject matter of the proposed Master Environmental Impact Statement initially focused on State Highway One maintenance activities. However, as the preparation of this thesis proceeded, I realized that it was necessary to also address related topics which were inextricably linked to the upkeep of State Highway One and coastal management. These topics include bridge replacement, providing pedestrian access along the coast, protecting tide pools and other marine habitats, and maintaining the visual quality of the California experience.

I also propose that a Regional Environmental Impact Statement in the form of a flexible document to include new scientific or management information be submitted by CalTrans for high risk landslide hazard areas that most likely will need quick permitting and repair. A regional environmental impact statement will help to more thoroughly evaluate coastal hazards along California State Highway One, including the potential natural and road maintenance impacts, and the required agreements among permitting agencies to repair the identified sites. This statement section requires integration of new information or ideas that help in making coastal policy and management more efficient and relevant. This could cut the cost of coastal road repair because permitting, monitoring, and mitigation agreements would be made in advance of the coastal disturbance problems. I believe that this approach would help protect California's natural coastal resources, both ecologically and economically.

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Appendix A

California Coastal Zone Management Review

Proposition 20

Proposition 20, the California Coastal Zone Conservation Act was approved by California voters in November 1972. The citizens passed Proposition 20, or the Save-the-Coast Initiative and bypassed the legislature by using the initiative process.

Similar to the earlier San Francisco Bay Conservation and Development Commission (BCDC) the coastal initiative was a last ditch effort by the citizens of California as a result of legislative inaction that extended over three years. It was the only remaining alternative for dealing with the growing problem of coastal development.

Earlier in 1972, when a Senate committee had killed yet another coastal bill, an alliance of conservation groups, known as the Coastal Alliance, launched a petition drive to qualify the coastal conservation proposal for the November 1972 ballot. With the accumulation of 418,000 signatures, the petition was eligible for ballot placement, to be voted on by California voters.

The fall campaign was well publicized by the media, expensive and emotionally charged. Supporters of the proposition sponsored grassroots bake sales and competitions to raise money. These volunteer organizations contributed $750,000 and thousands of hours of volunteer time. Opponents to the proposition raised $2.5 million.

In spite of the imbalance of campaign funds, 7.8 million Californians voted on Proposition 20, and 55% or 4.3 million people voted yes. It was a victory for coastal advocates in support of coastal protection.

This was a clear message from the people to the legislature, that the 1100 miles of California's coast must by protected from potentially environmentally destructive development.

(See Appendix B for the full legislative declaration of intent of Proposition 20.)

Proposition 20 states that, it is the policy of the state to preserve, protect and where possible to restore the resources of the coastal zone for the enjoyment of current and succeeding generations (Bodovitz, 1973).

Joseph Bodovitz, who was the first executive director of the California Coastal Commission and former Executive Director of BCDC, cited the rate of coastal change as important. His opinion, which was delivered to a Coastal Conference audience in 1973, indicated that he did not know what was in the minds of 4.3 million Californians, who voted for the State's coastal zone law, but suspected that one major factor was the rapidity of change (Harris, 1978).

The vote by 4.3 million people to preserve and protect the coast has served as a model for other coastal states. The goal is to permanently protect the natural and scenic resources, with an understanding of the delicately balanced ecosystem that needs to be protected from further deterioration and extinction. This has been California's response to the necessity for coastal conservation.

Proposition 20 designated a California Coastal Zone, which includes a 1,000 yard strip along the length of the coast. This protected strip has been widened and amended according to various regional and local regulations.

The coastal zone is geographically divided into 6 regions. These are (north to south):

North	Del Norte County Humboldt County Mendicino County
North Central	Sonoma County Marin County San Francisco County

Central	San Mateo County Santa Cruz County Monterey County
South Central	San Luis Obispo County Santa Barbara County Ventura County
South	Los Angeles County Orange County
San Diego	San Diego County (Healy, 1978)

The South region had only two counties with large populations, while San Diego with a large population and the possibility for much urban growth was in a region by itself. See Figure 3 for the California Coastal Zone boundaries.

Proposition 20 established 6 regional commissions and one state commission for the 15 coastal counties and 53 cities.

Each region was governed by a regional coastal commission. Half the members represented counties. The other half were appointed members and represented the public. The Governor, the Senate Rules Committee and the Speaker of the Assembly were each responsible for two appointments per commission. This appointment responsibility was a politically charged process. The initial appointments '72-'73, '73-'74 were the most uniformly conservation minded. As opposition forces organized, commission appointments tended to reflect more pro-development interests.

Regional commissions had joint responsibility for both the coastal permit process and the coastal planning process at the local level. This planning process included public hearings and recommendations on state coastal plans which were then forwarded to the state commission.

Each regional commission selected one member to represent the region at the state level. The second set of six commissioners were, like the regional commissioners, appointed by the Governor, the State Rules Committee and Speaker of the Assembly. Members of the public served two years and regional representatives served at the discretion of their appointive body. The state commission had three nonvoting members; the Secretary of the Resources Agency, the Secretary of Business and Transportation Agency and the State Land Commission Chair.

The California Coastal Commission was charged with responsibility of preparing a coastal plan for the Legislature and Governor by the end of 1975. This plan was to have been the basis for subsequent coastal law enacted by the Legislature.

The State Coastal Plan

The planning process for the California Coastal Plan of 1975 was a time consuming process involving significant public participation. The Coastal Plan was produced on an element by element planning process which involved extensive public hearings.

Initial research was done by staff at the state level. Recommendations were sent to regional commissions for consideration and public hearings.

Elements which were tentatively adopted by the state commission became part of the Preliminary Coastal Plan. This tentative plan was subject to public hearings at both the regional and the state levels. Thousands of citizens were active participants at the public hearing level.

Nine elements were added like building blocks, one after another. The commission purposely selected the less controversial ones first in order to start the planning process as quickly as possible and with as little resistance as possible. The nine elements of the 1975 Coastal Plan include (California Coastal Commission, 1975):

Marine Environment
Coastal Land Environment
Appearance and Design
Coastal Development
Energy
Transportation
Public Access
Recreation
Government Organization and Power

The Final Coastal Plan was agreed upon after a series of 20 final hearings. The Coastal Plan was submitted, December 1, 1975, to the legislature and governor as directed by Proposition 20. The plan submitted contained 162 policy recommendations for conservation and management of the coast.

The California Coastal Act Of 1976

The California Coastal Act was enacted by the legislature in 1976. It was created as the result of much political compromise and negotiation. The change in title, from Coastal Zone Conservation Act (1972) to Coastal Act, illustrates the strong change in philosophy away from conservation.

The Coastal Act received heavy opposition in the legislature, active lobbying efforts from Proposition 20 (1972) opponents, and mixed coverage by the media. A joint Senate/Assembly committee headed by Senator Jerry Smith managed to pull a final version through the legislative process.

The regional and state commission framework remained intact, however the coastal zone definition was modified. The original 1,000 yard boundary was amended, reduced in selected urban areas, and extended inland to cover watershed areas as far as five miles. Changes were primarily based on existing urbanization and development, and the area's resources and vulnerability to future development. The seaward limit was extended to three miles.

The 1975 Coastal Plan was presented to the Legislature to be the basis for subsequent legislation. However, the 1975 Coastal Plan was never adopted, instead twelve principles were set forth as general guidelines.

Proposition 20 had taken the stance that the coast was a fragile, vulnerable resource of statewide concern and interest, which was not protected adequately by local government.

With the California Coastal Act of 1976, protection of the coast as a resource was restored to local government. The local governments' efforts in the form of Local Coastal Programs (LCP's) became the heart of the Coastal Act.

Local Coastal Programs (LCP's)

The state had set down twelve general policies concerning public access, coastal recreation, the special California marine environment, coastal land resources and coastal development.

Among the purposes of the Coastal Act was the protection of the environmentally sensitive habitat areas. Also it was the purpose of the Act to protect coastal area dependent agriculture, such as artichokes and Brussel sprouts, to protect wildlife habitats and archaeological resources against any significant disruption (California Coastal Commission, 1975).

The Coastal Act concentrated new developments in existing developed areas. This is consistent with the California Urban Strategy (1980); the first two priorities of the Urban Strategy are to maintain existing urban areas and develop within urban areas. Permitted development would be located and designed to protect views of the ocean. New developments were to maintain and enhance public access to the coast. Coastal dependent developments would have priority over other developments, which could be sited elsewhere (California Public Resource Code, Division 20, 1982).

Each local government was to be responsible for incorporating these policies into their own Local Coastal Program (LCP). Basically the LCP is a plan with accompanying laws and ordinances which set forth how the local government is going to comply with and implement the Coastal Act.

Land use decisions were returned to the local government once the LCP was approved by the regional and state coastal commissions. The commissions were responsible for analysis of each LCP and were responsible for compliance of each LCP with the California Coastal Act. Work on the LCP's was paid through a $4 million grant from the Federal Coastal Zone Management Act which provided 80% of the costs and a 20% matching fund from the state (Harris, 1978).

The California Coastal Commission

The California Coastal Commission took over a new but more demanding role when the regional commissions ceased functioning June 30, 1981.

The responsibility for protecting the coast remained with the California Coastal Commission until local governments completed Local Coastal Programs (LCP's). Also public access to the coast remained at the state level until local entities took responsibility for coastal regulation (Harris, 1978).

Of all states in the nation, California became the only state with a permanent statewide coastal agency. The California Coastal Commission, without regional commissions, became the sole coordinator of the state's coastal management program. All port plans and other coastal matters go directly to the state Commission for review. Any remaining LCP's must be reviewed and accepted by the state, and permits in areas lacking LCP's must be reviewed at the state level. Acting in a quasi-judicial position, the State Coastal Commission serves as an appeal body (California Coastal Commission, 1981).

The Commission is the lead agency for the state; it has the power to grant or issue certificates or statements required by federal law relating to the coastal zone (California Public Resource Code, Division 20, 1982).

Almost any activity which modifies existing conditions in the coastal zone is considered development, according to the 1976 Coastal Act, and requires a coastal permit. Permits are of three types: administrative, consent, or individual public hearings. The latter require individual analysis, public hearing and discussion and a separate vote by the Commission. (Appendix C describes the permit process in a flow chart)

The Commission may remove a coastal permit or remove an appeal for commission consideration, may delete a local coastal program (LCP); however, it must have the majority vote of all appointed members. The Commission is responsible for an annual report to the legislature and the governor (California Public Resource Code, Division 20, 1982).

Appendix B

Section 30000 of the Coastal Act

California Public Resources Code 27000

Division 18, proposed by Initiative Measure (1972) approved by the voter at the general election held November 7, 1972 was repealed by 27650, on January 1, 1977. The repealed sections created the coastal zone conservation commission and provided for its operation relating to conservation plan, permit procedures.

The sections of former division 18 (Section 27000, etc.) have been incorporated into Division 20 (Section 30000, etc.) or repealed.

Source: West's Annotated California Codes, Public Resources Code, Section 9501 to end.

30233. Section 30233 of the Coastal Act states as follows:

a) The diking, filling, or dredging of open coastal waters, wetlands, estuaries, and lakes shall be permitted in accordance with other applicable provisions of this division, where there is no feasible less environmentally damaging alternative, and where feasible mitigation measures have been provided to minimize adverse environmental effects, and shall be limited to the following:

1) New or expanded port, energy, and coastal-dependent industrial facilities, including commercial fishing facilities.

2) Maintaining existing, or restoring previously dredged, depths in existing navigational channels, turning basins, vessel berthing and mooring areas, and boat launching ramps.

3) In wetland areas only, entrance channels for new or expanded boating facilities; and in a degraded wetland, identified by the Department of Fish and Game pursuant to subdivision (b) of Section 30411, for boating facilities if, in conjunction with such boating facilities, a substantial portion of the degraded wetland is restored and maintained as a biologically productive wetland. The size of the wetland area used for boating facilities, including berthing space, turning basins, necessary navigation channels, and any necessary support service facilities, shall not exceed 25 percent of the degraded wetland.

4) In open coastal waters, other than wetlands, including streams, estuaries, and lakes, new or expanded boating facilities and the placement of structural pilings for public recreational piers that provide public access and recreational opportunities.

5) Incidental public service purposes, including but not limited to, burying cables and pipes or inspection of piers and maintenance of existing intake and outfall lines.

6) Mineral extraction, including sand for restoring beaches, except in environmentally sensitive areas.

7) Restoration purposes.

8) Nature study, aquaculture, or similar resource dependent activities.

b) Dredging and spoils disposal shall be planned and carried out to avoid significant disruption to marine and wildlife habitats and water circulation. Dredge spoils suitable for beach replenishment should be transported for such purposes to appropriate beaches or into suitable long shore current systems.

30001. Legislative findings and declarations; ecological balance.

The Legislature hereby finds and declared:

(a) That the California coastal zone is a distinct and valuable resource of vital and enduring interest to all the people and exists as a delicately balanced ecosystem.

(b) That the permanent protection of the state's natural and scenic resources is a paramount concern to present and future residents of the state and the nation.

(c) That to promote the public safety, health and welfare, and to protect public and private property, wildlife, marine fisheries, and other ocean resources, and the natural environment, it is necessary to protect the ecological balance of the coastal zone and prevent its deterioration and destruction. (Added by Stats. 1976, c.1330, §1.)

30001.2 Legislative findings and declarations: economic development.

The Legislature further finds and declares that, nothwithstanding the fact electrical generating facilities, refineries and coastal dependent developments, including ports and commercial fishing facilities offshore petroleum and gas development and liquefied natural gas (LNG) facilities may have significant adverse effects on coastal resources or coastal access, it may be necessary to locate such development in the coastal zone in order to locate such developments in the coastal zone in order to ensure that inland as well as coastal resources are preserved and that orderly economic development proceeds within the state. (Added by Stats. 1976, c.1330, §1.)

30001.5 The Legislature further finds and declares that the goals of the state for the coastal zone are to:

(a) Protect, maintain, and where feasible, enhance and restore the overall quality of the coastal zone environment and its natural and manmade resources.

(b) Assure orderly, balanced utilization and conservation of coastal zone resources taking into account the social and economic needs of the people of the state.

(c) Maximize public access to and along the coast and maximize public recreational opportunities in the coastal zone consistent with sound resources conservation principles and constitutionally protected rights of private property owners.

(d) Assure priority for coastal-dependent and coastal-related development over other development on the coast.

(e) Encourage state and local initiatives and cooperation in preparing procedures to implement coordinate planning and development for mutually beneficial uses, including educational uses, in the coastal zone. (Amended by Ch. 1090, Stats. 1979.)

30002. The Legislature further finds and declares that:

(a) The California Coastal Zone Conservation Commission pursuant to the California Coastal Zone Conservation Act of 1972 (commencing with Section 27000), has made a detailed study of the coastal zone; that there has been extensive participation by other governmental agencies, private interests, and the general public in the study; and that, based on the study, the commission has prepared a plan for the orderly, long-range conservation, use, and management of the natural, scenic, cultural, recreational, and manmade resources of the coastal zone.

(b) Such plan contains a series of recommendations which require implementation by the Legislature and that some of those recommendations are appropriate for immediate implementation as provided for in this division while others require additional review.

30003.

All public agencies and all federal agencies, to the extent possible under federal law or regulations or the United States Constitution, shall comply with the provisions of this division.

30004. The Legislature further finds and declares that:

(a) To achieve maximum responsiveness to local conditions, accountability, and public accessibility, it is necessary to rely heavily on local government and local land use planning procedures and enforcement.

(b) To ensure conformity with the provisions of this division, and to provide maximum state involvement in federal activities allowable under federal law or regulations or the United States Constitution which affect California's coastal resources, to protect regional, state, and national interests in assuring the maintenance of the long-term productivity and economic vitality of coastal resources necessary for the well-being of the people of the state, and to avoid long-term costs to the public and a diminished quality of life resulting from the misuse of coastal resources, to coordinate and integrate the activities of the many agencies whose activities impact the coastal zone, and to supplement their activities in matters not properly within the jurisdiction of any existing agency, it is necessary to provide for continued state coastal planning and management through a state coastal commission.

30011.

Nothing in this division shall authorize the commission to review a local government's application of the requirements of Section 65590 of the Government Code to any development. In addition, the commission shall not require any applicant for a coastal development permit other evidence of compliance with the requirements of Section 65590 of the Government Code. The commission may, however, solely in connection with coastal development permit applications described in subdivision (c) of Section 30600.1, require information about the status of a local government's action to apply the requirements of Section 65590 of the Government Code. This information shall be used for the purpose determining time limits for commission action on these applications as provided in the subdivision (c). (Added by Ch. 43, Stats, 1982.)

Appendix C

California Coastal Permits

California Coastal Permits

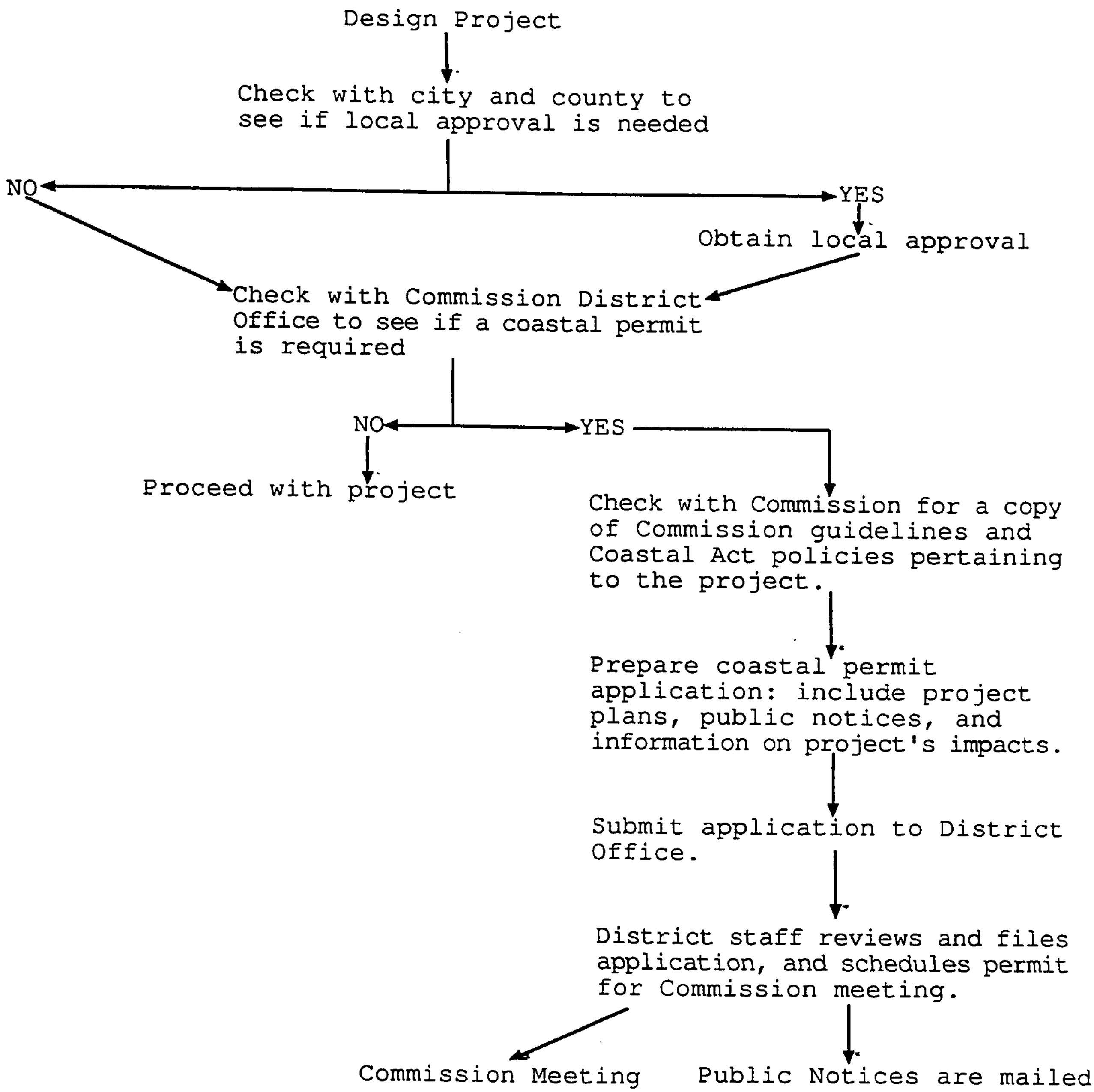
Administrative Permits- Administrative permits may be issued by the Executive Director for minor types of development. If no objections are raised by the Commission, the permit is automatically approved.

Consent Permits- Projects which do not raise significant issues or can be easily modified to conform with the coastal Act usually qualify for a consent permit. The commission generally approves a number of consent items together in one vote and does not discuss each project separately unless the public or several Commissioners raise a concern.

Individual Public Hearings- Applications that require individual analysis for conformance with Coastal Act policies are scheduled for public hearing, discussion, and a separate vote by the Commission. Commissioners may request that administrative or consent items also be scheduled for a public hearing if additional consideration is needed.

Source: Coastal News, California Coastal Commission, June/July 1981.

California Coastal Permit Process



Source: Coastal News, California Coastal Commission, June/July 1981.

Appendix D

Permit Conditions

Approval with Conditions

The Commission approved the coastal development permit, with the conditions below, on the grounds that the development is consistent with the requirements of Chapter 3 of the California Coastal Act of 1976. The project site is located between the sea and the first public road nearest the shoreline and conforms with the public access and public recreation policies of Chapter 3 of the Coastal Act. It will not have any significant adverse impacts on the environment within the meaning of the California Environmental Quality Act.

Standard Conditions

1. Notice of Receipt and Acknowledgment. The permit is not valid and development shall not commence until a copy of the permit, signed by the permittee or authorized agent, acknowledging receipt of the permit and acceptance of the terms and conditions, is returned to the Commission office.

2. Expiration. If development has not commenced, the permit will expire two years from the date on which the Commission voted on the application. Development shall be pursued in a diligent manner and completed in a reasonable period of time. Application for extension of the permit must be made prior to the expiration date.

3. Compliance. All development must occur in strict compliance with the proposal as set forth in the application for the permit, subject to any special conditions set forth below. Any deviation from the approved plans must be reviewed and approved by the staff and may require Commission approval.

4. Interpretation. Any questions of intent of interpretation of any condition will be resolved by the Executive Director or the Commission.

5. Inspections. The Commission staff shall be allowed to inspect the site and the development during construction, subject to 24-hour advance notice.

6. Assignment. The permit may be assigned to any qualified person, provided assignee files with the Commission an affidavit accepting all terms and conditions of the permit.

7. Terms and Conditions Run with the Land. These terms and conditions shall be perpetual, and it is the intention of the Commission and the permittee to bind all future owners and possessors of the subject property to the terms and conditions.

Special Conditions

1. The applicant shall mitigate for the placement of fill in ocean waters by providing a total of 5.61 acres of mitigation and completing the mitigation by January of 1999. The 5.61 acres of mitigation shall be composed of a combination of Proposal A and Proposal B of this condition. The mitigation proposals are as follows:

A. Implementation of the Bolinas Lagoon Restoration Project, as modified and approved by the Commission on January 13, 1993; and

B. Implementation of a wetlands mitigation plan for Redwood Creek near Muir Beach, prepared by a qualified biologist or hydrologist, reviewed and approved by the Commission, and including:

- plans of the mitigation site drawn to scale which fully depict both existing conditions and proposed improvements;

- an implementation schedule which indicates when necessary permits would be secured, when contracts for construction would be let, when construction would commence, and when various stages of the work would be completed;

- a five-year monitoring program designed to measure the success of the mitigation plan;

- a definition of "success" such that the density of flora and fauna is comparable with that in surrounding or nearby habitat areas of the same type, and;

- a provision that within the five-year monitoring period the applicant shall take additional steps as may be appropriate to ensure the success of the mitigation plan.

The mitigation plan shall be based on Modified Alternative B as defined in the Environmental Assessment prepared by Philip Williams and Associates (April, 1994) as endorsed by the Highway One Technical Advisory Committee in March 1994. The mitigation plan may be further modified through the environmental review process but shall in no event result in enhanced or restored wetlands with a total area of less than 3.6 acres.

The applicant shall ensure that the mitigation plan is implemented by or in cooperation with the National Park Service, Golden Gate National Recreation Area, as described in the Letter of Intent dated February 28, 1994 from the applicants, with the exception that implementation of the plan shall occur by January, 1999. The applicant shall notify the Executive Director in writing when each phase of implementation has been completed (i.e., upon completion of environmental review, right-of-way acquisition, completion of plans, awarding of construction contract, commencement of construction, and completion of construction).

Appendix E

Outline for Master EIR along Highway One

Outline for Master EIR along Highway One
Big Sur

Summary Section

Section 1: Description of the Project
Section 2: Description of the Environmental Setting

Section 1: Description of the Project

a. Precise Location and Boundaries
b. Statement of Objectives
    a. Coastal Erosion/Manipulation
    1. Case Studies with data
    2. Estimations of Coastal Erosion
    b. Coastal Hazards Ranking Map along Hwy 1
    1. Identified hazards
    2. Potential hazards and hazardous areas
    c. Ecological Impacts
    1. Terrestrial
    2. Marine
    d. Recommendations
c. Description of Project Characteristics

Section 2: Description of the Environmental Setting, Plans and Policies

a. Scenic Resources *
a. Natural Habitats *
a. Recreation and Public Access *
a. Traffic Management *

Section 3: Environmental Impact

a. General Types of Work On the Highway and Policies
    1. Slide Disposal
    2. Stream Crossings
    2a. Bridge replacement

2b. Culverts and fills

3. Fallen Rock Removal

4. Waddell Beach type of Ongoing Problem

5. Other Structures: Cribwalls, drainage structures, and tunnels (?)

b. Environmental Impact of the Proposed Action

1. Direct and Indirect

2. Define Episodic Events

2a. Largest

2b. Smallest

2a. Potential Episodic Event Impacts

3. The Relationship Between Short-Term Uses... and Lone-Term Productivity

4. Cumulative and long-term effects; reasons why the sponsor believes the project is justified.

5. Irreversible Environmental Changes

Irretrievable commitment of resources: primary and secondary impacts; environmental accidents.

6. The Growth Inducing Impact

Ways the project could foster growth; other projects that may encourage growth.

c. Recommendations

1. Mitigation Measures

1a. Avoidable adverse impacts; alternative mitigation measures.

2. Alternatives to the Proposed Project

2a. Reasonable alternatives; alternatives which reduce impacts

3. Landscape Restoration

3a. Exotic plant removal and revegetation with native plants

3b. Undergrounding of utility lines

4. Roadside Architecture

4a. Turnout and vista points: design and upkeep

4b. Shoulders: trees, bikelanes, etc.

d. Location-Specific Prescriptions (see map for location)

1. Slide Disposal (i.e., Mcway Fill)
2. Stream Crossings (i.e., Limekiln Creek)

2a. Bridge replacement

2b. Culverts and fills

3. Fallen Rock Removal
4. Waddell Beach type of Ongoing Problem
5. Other Structures: Cribwalls, drainage structures, and tunnels.

Section 4: Appendices

1. Excerpts from Big Sur Coast Land Use Plan
    - a. Critical Viewshed
    - b. Traffic Management
2. Summary of Design Standards for the Big Sur Coast Highway, Aug. 1980
3. Summary of California Coastal Act Provisions
4. Big Sur Local Coastal Plan
5. Local Coastal Programs
6. Monterey Bay National Marine Sanctuary: Summary of Regulations
7. Case Studies:
    - a. Lone Tree Fill
    - b. Waddell Bluffs
    - c. McWay Fill (i.e., J.P. Burns "Big" Slide)
    - d. Pescadero Creek Bridge replacement
8. Maps:
    - a. Slides and Stream Crossings
    - b. Sensitive Wildlife Areas
    - c. Important Botanical Areas
    - d. Big Sur Coast LUP Trails Plan
    - e. Monterey Bay National Marine Sanctuary Boundary