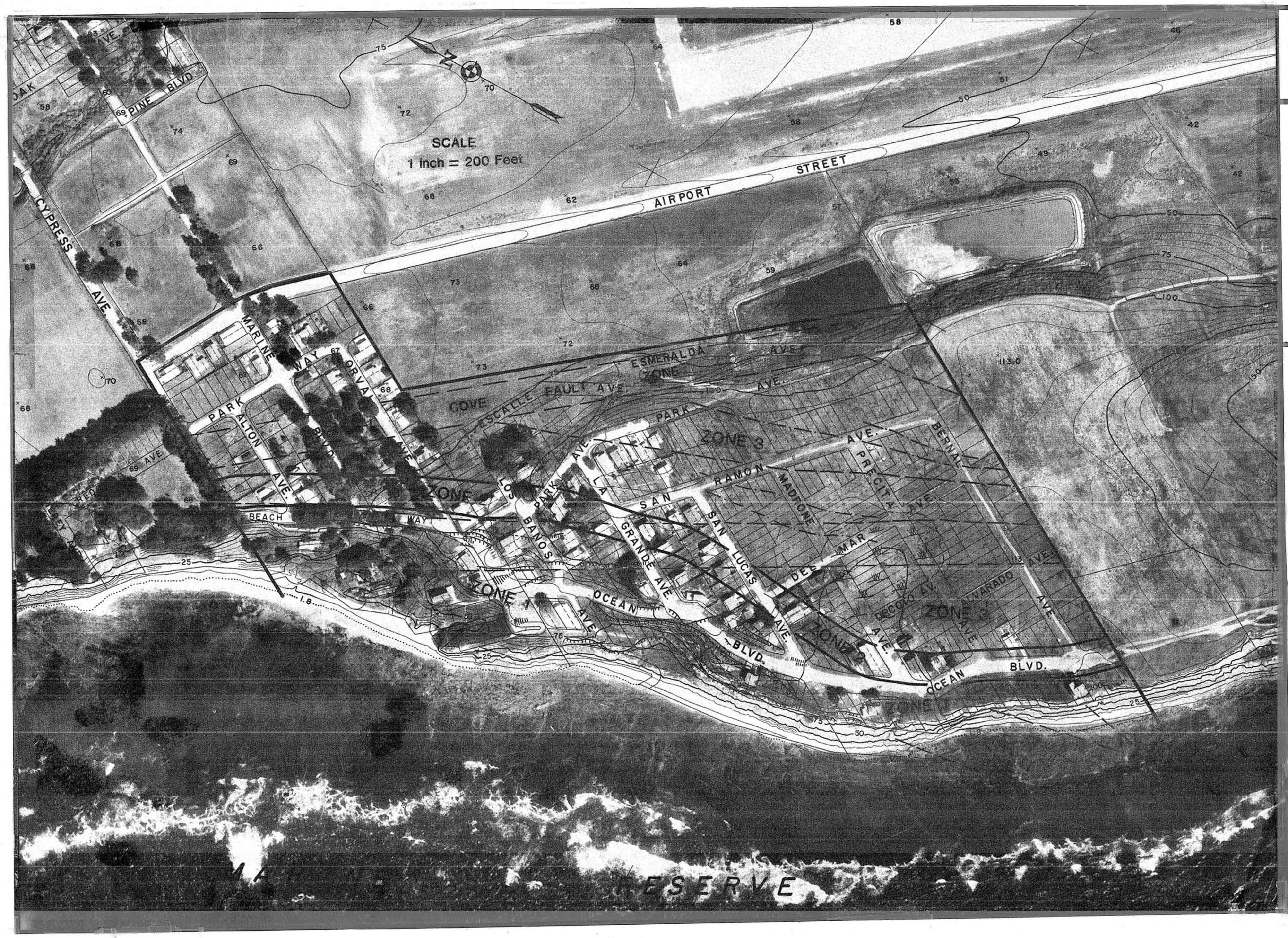
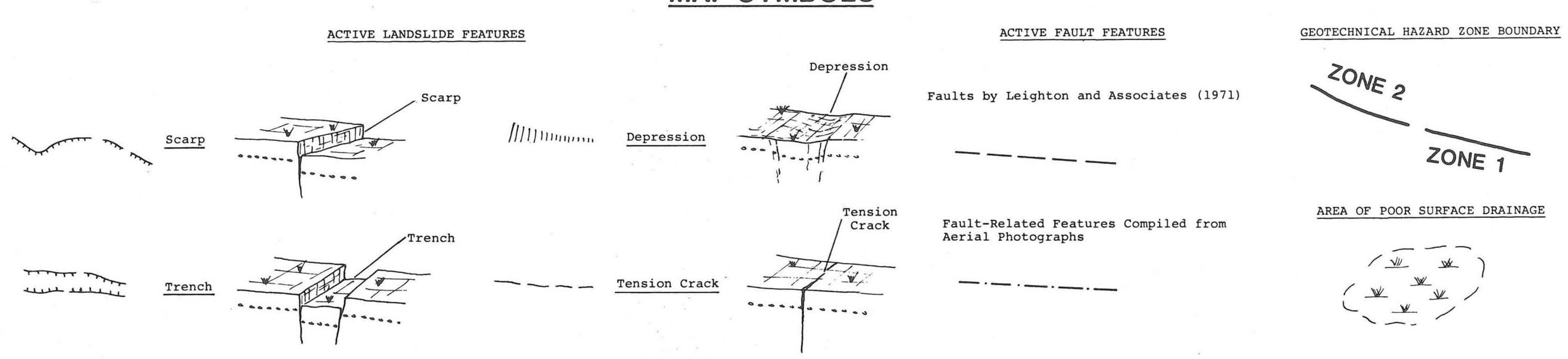
William Cotton and Associates	GEOTECHNICAL CONSULTANTS 314 TAIT AVE, LOS GATOS, CA 95030	
GEOTECHNICAL HAZARDS MAP SEAL COVE STUDY AREA		
PLATE NO. 1	SCALE: 1"=200'	DATE: 8/5/80
PROJECT NO. G 112-80	GEO./ENG. BY:	APPROVED BY:

Geologic Analysis of the Seal Cove Area

GEOTECHNICAL HAZARDS MAP



MAP SYMBOLS



EXPLANATION

GEOTECHNICAL HAZARD ZONE	RISK ASSESSMENT	REQUIRED GEOTECHNICAL INVESTIGATION
ZONE 1 ■ Includes all lands located along the western seacliff that are adversely affected by active landslide processes and accelerated seacliff erosion. The position of the eastern boundary of this zone is established by the easternmost extent of active landsliding plus a setback of 50 feet. The setback zone includes lands which lie outside or east of the active landslides but are expected to experience problems in the future (i.e. 50± years).	***UNSTABLE*** ■ Risk to development in this zone is considered to be extremely high. It is reasonable to conclude that slow progressive landsliding and seacliff retreat will continue, resulting in structural and property damage. This is especially true for structures or utilities located astride active surface breaks. Rapid catastrophic slope failure of the high, steep portion of the seacliff located west of Ocean Boulevard is a clear probability. Such an event could involve the loss of life as well as significant property damage. The feasibility of reducing the risk to acceptable levels is extremely low. * No additional development should be allowed in this zone.	■ No investigation deemed feasible due to the severity of the instability.
ZONE 2 ■ Includes all lands within a 100-foot wide zone located immediately adjacent to the zone of active landsliding and accelerated seacliff erosion (i.e. Zone 1). The position of the eastern boundary of this zone is established in part by an approximate 2:1 (i.e. 26± degrees) projection measured from the base of the high seacliff located west of Ocean Boulevard.	***QUESTIONABLE STABILITY*** ■ Risk to development in this zone is considered to be moderate to high. Eastward progression of active landsliding is difficult to predict with reliable accuracy. The likelihood of eliminating the risk is very low, however it may be possible to significantly reduce the impact of the hazard by properly designed foundations. * No development should be allowed in this zone until stability is clearly demonstrated by the required geotechnical investigations.	■ Engineering geologic investigation by a certified engineering geologist and a soil and foundation engineering investigation by a registered civil engineer, or a combined equivalent of the above. • Scope of both investigations should be directed toward a detailed evaluation of the potential landslide hazards in this zone. In most cases, landslide studies will require extensive subsurface work in order to provide the necessary technical data to conduct a detailed slope stability analysis. The geotechnical analysis should provide acceptable factors of safety to clearly demonstrate stability before construction is allowed in this zone.
ZONE 3 ■ Includes all lands located outside of the areas affected by active or potential landslides.	***MOST STABLE*** ■ Risk to development in this zone is considered to be low to moderate. The major geologic hazard in this zone is the threat of surface faulting along the master fault trace and several branching fault traces of the Seal Cove fault. These faults are active and capable of producing damaging surface faulting, strong ground shaking and ground failure. The relative risk associated with poor surface drainage and potentially expansive soils is generally regarded as moderate to locally high. The feasibility of reducing the risks to acceptable levels in this zone is considered high. This can be accomplished by careful siting of homes away from active faults, using careful structural and foundation design and adequate surface drainage plans. However, it is possible that some residential parcels will be judged unbuildable due to high seismic hazards. * Development should be allowed in this zone on parcels found to be free of hazardous conditions by the required geotechnical investigations.	■ Engineering geologic investigation by a certified engineering geologist and a soil and foundation engineering investigation by a registered civil engineer, or a combined equivalent of the above, unless evidence is available to show that such investigations are not required. • Scope of engineering geologic investigation should address the seismic hazards related to the master and branching traces of the Seal Cove fault. Particular emphasis of the engineering geologic investigations should be placed on the evaluation of possible surface faulting. Investigative techniques within this area will require the use of subsurface trenching and possibly geophysical traverses unless clear evidence is established to show that no active fault crosses the parcel in question. • The soil and foundation engineering investigation should address, but not necessarily be confined to, the following items: site preparation and grading, surface drainage, and design parameters for residential foundations.

NOTES TO USERS

■ This map provides geotechnical data based on detailed surface mapping, interpretation of aerial photographs and the geologic data presented in the report entitled Geologic Report of Seal Cove - Moss Beach Area, October 15, 1971 by F. Beach Leighton and Associates. The map is primarily designed for use by geologists, engineers and planners and is not intended to be a substitute for detailed site specific geotechnical investigations.

Additional description and explanation of the geologic conditions of the Seal Cove study area may be found in the accompanying report entitled Geologic Analysis of the Seal Cove Area, County of San Mateo, August 5, 1980 by William Cotton and Associates.

GEOLOGIC ANALYSIS
OF THE
SEAL COVE AREA
COUNTY OF SAN MATEO

William Cotton and Associates

William Cotton
and Associates

GEOTECHNICAL CONSULTANTS
314 Tait Avenue, Los Gatos, California 95030
(408) 354-5542

David C. Hale, Director
Planning Department
County of San Mateo
590 Hamilton Street
Redwood City, California 94063

August 5, 1980
G112-80

Dear Mr. Hale:

In accordance with our agreement with the County of San Mateo (#5500-80-426) dated July 14, 1980, the final geologic report is hereby submitted.

As a result of our work, the original Geologic Map of the Seal Cove area has been updated and a number of recommendations are presented herein in order to help strengthen the present land use policies that control development.

Our report is presented in two basic parts consisting of a Conclusions and Recommendations section followed by a Technical Report section. The technical report describes the geologic data and analysis that we used to support the final conclusions and recommendations.

It has been our pleasure to be of service to the County on this interesting project. If we can be of help in clarifying any aspect of this report, please do not hesitate to contact our office.

Sincerely yours,

WILLIAM COTTON AND ASSOCIATES

William R. Cotton
Engineering Geologist, CEG 882

bp

Attached report

CONCLUSIONS

AND

RECOMMENDATIONS

GEOLOGIC
ANALYSIS
OF THE
SEAL COVE AREA

COUNTY OF SAN MATEO
CALIFORNIA

August 1980

William Cotton and Associates

CONCLUSIONS

The Seal Cove study area is exposed to a variety of geologic hazards that severely affect future land use decisions. These conditions and the level of associated risk were well documented nearly a decade ago by a County-authorized geologic study conducted by Leighton and Associates (October 1971). The present study was designed to update the geologic information presented in the Leighton report and to reevaluate the residential development regulations.

The following geologic hazards are the principal geologic concerns of the Seal Cove area:

Landsliding - Deep-seated landslides presently are destroying extensive sections of the seacliff region which define the western edge of the study area. Approximately 17 homes have suffered some form of structural damage due to landslide activity. The inland extent of the active landsliding from the coastline ranges between 100 to 400 feet; however, the average distance is nearly 250 feet. The average rate of landslide movement is very slow, probably ranging between 1 and 3 inches per year. However, the probability of accelerated movements is considered high in many local areas within the presently failing landslide complex. This is especially true of the high seacliff area located west of Ocean Boulevard where rapid catastrophic failure is a clear possibility.

Faulting - The active Seal Cove fault and a number of branching fault traces pass through the study area. The main trace is confined to a 100-foot-wide zone located along the eastern margin of the study area. Although most of this zone lies outside of the study area, the branching fault traces pass through the main portion of the residential area. All of these faults are considered to be active, and thus, capable of generating earthquakes with associated ground shaking, surface faulting and ground failure.

Seacliff Erosion - The entire coastline area presently is experiencing severe erosion by wave activity. This erosion process causes the seacliff to become undercut at its base and locally unstable. The oversteepened face of the seacliff responds by shallow, piecemeal sloughing; however, natural stability is never achieved due to the constant erosional activity within the surf zone. The result is a systematic retreat of the seacliff by local episodic sloughing. The average rate of cliff retreat is approximately 3 to 4 feet per year in the Seal Cove area.

A number of additional geologic problems have been identified in the Seal Cove area; however, these are relatively minor hazards when compared to those outlined above and can be significantly mitigated by design. These problems include potentially expansive soils, poor surface drainage and problems associated with shallow ground water.

RISK ANALYSIS

The development of sound public policy to deal with the geologic hazards of the Seal Cove area requires an answer to the question, "How safe is safe enough?" The information and anlysis presented in this report is an attempt to provide the necessary framework on which the appropriate County decisionmakers can judge acceptable levels of risk.

To properly assess the appropriate level of risk to the community, a number of important steps are essential. First, and probably most importantly, the presence of geologic hazards must be recognized. In the Seal Cove area, although the original subdivision was initiated in the early 1900's, the hazardous landslide and fault conditions were not recognized until nearly ten years ago. Consequently, many homes and streets were built on active landslides or astride active traces of the Seal Cove fault,and thus,have sustained considerable damage.

The second step in this process takes place after the geologic hazards have been recognized. This step requires detailed studies to determine the physical characteristics of the hazards. For the Seal Cove area,this was accomplished through the initial geologic study conducted by Leighton and Associates in 1971. They identified a large area of active landslides, and a number of fault traces associated with the Seal Cove fault. As an important part of their investigation, they provided a detailed description of the dimensions and level of activity of the landslides and faults.

Once the geologic hazards are recognized and carefully characterized, then the degree or level of risk associated with each hazard can be evaluated. In the Seal Cove area the present land use tends to limit the exposure of risk mainly to utilities, streets and houses; however, the potential for personal injury or loss of life is possible in local areas. The decision as to whether the various levels of risk are tolerable or intolerable to the public requires the input of the County decisionmakers. An important part of any risk analysis is the consideration of possible mitigating measures that could reduce the risk associated with each type of hazard. This kind of action is usually the product of the democratic process and depends as much on social, economic and environmental values as on geologic knowledge. There are a number of mitigating measures that may reduce risk to tolerable levels. For example, land use may be regulated to the degree that residential development is simply restricted from hazardous areas, thus the hazard is avoided and the risk is essentially eliminated. This has been done in the Seal Cove area by prohibiting construction in active landslide areas, astride active fault traces and close to the edge of the seacliff.

Another method of reducing the risk is by attempting to reduce the impact of the hazard. This might include requirements for special foundations for residential structures, improved drainage facilities, flexible utilities and stronger construction techniques. No significant attempts have been made in the Seal Cove area to reduce the impact of landslide or fault hazards by design, and indeed, to attempt to do so does not seem reasonable. Likewise, attempts to reduce the risk associated with the landslides and faults by controlling these hazardous processes is impractical, if not impossible.

In summary, it is our opinion that the only practical means of reducing the risk associated with landslide and fault hazards is by prudent land use regulations. Any land use policy should balance the risk against the social, economic and environmental cost in order to determine the level of risk acceptable to the community.

RECOMMENDATIONS

The following recommendations are presented for consideration by the County in order to establish prudent land use policies within the Seal Cove area. We believe that the recommendations are consistent with the goals and objectives of the Seismic Safety Element of the General Plan, the original recommendations presented in the Leighton report, and the minimum standards for geotechnical reports which were adopted by the County in 1977. However, after careful review by the County these recommendations may be altered to reflect the final expression of the County perception of acceptable risk.

1) Critical Hazards Area - Due to the complexity of the hazardous geologic conditions in the Seal Cove area we recommend that the entire study area be designated as a "Critical Geotechnical Hazards Area." Such a designation would "red flag" the region as an area of high geologic hazards for which special or more detailed geologic and soil investigations (i.e. geotechnical) will be required prior to development. Additionally, such a designation would alert present and future landowners to the hazardous conditions and the potential higher than normal cost of development.

To protect the interest of the County, individual landowners, and local developers geologic and/or soil investigations of appropriate level should be required fo all lands within the study area. These investigations will normally exceed the minimum standards adopted by the County and will specifically address the primary geology and hazard of the site in question.

2) Geotechnical Hazards Map - To facilitate the required geologic and/or soil investigations we have prepared a new hazard zonation map for the Seal Cove area. This map is a modification of the original map prepared by Leighton and Associates in 1971 and is based upon new landslide and fault information generated during the present study. The changes from the original zonation map include (1) combining hazard zone 3 and 4, and (2) moving the boundary of hazard zone 1 and 2 to the east. The geotechnical hazard zones have been compiled on the new 200-scale County base map which we believe is a more useful map because it superimposes property boundaries on an orthophotographic base.

The Geotechnical Hazards Map divides the Seal Cove area into three zones on the basis of similar geotechnical hazards or problems. Consequently, the terrain within each zone is considered to have similar potentials and constraints for development. In essence each zone reflects different levels of risk to man and structures.

The physical conditions and the associated risk of the three zones are described on the Geotechnical Hazards Map along with the various levels of geotechnical investigations required to evaluate the particular hazards in each zone. The following section describes the criteria for each hazard zone, defines the associated risk for development in each zone and defines the scope of required geotechnical investigations. It is recommended that the Geotechnical Hazards Map be officially adopted by the County as part of the final land use policy to guide future development in the Seal Cove study area.

ZONE 1 - Includes all lands located along the western seacliff that are affected by active landslide processes and accelerated seacliff erosion. The position of the erosion boundary of this zone is established by the easternmost extent of active landsliding plus a setback of 50 feet. The setback zone includes lands which lie outside or east of the active landslides but are expected to experience problems in the future (i.e. 50± years).

Risk Assessment - Risk to development in this zone is considered to be extremely high. It is reasonable to conclude that slow progressive landsliding and seacliff retreat will continue, resulting in structural and property damage. This is especially true for structures or utilities located astride active surface breaks. Rapid catastrophic slope failure of the high, steep portion of the seacliff located west of Ocean Boulevard is a clear probability. Such as event could involve the loss of life as well as significant property damage.

The feasibility of reducing the risk to acceptable levels is extremely low.

No additional development should be allowed in this zone.

ZONE 2 - Includes all lands within a 100-foot wide zone located immediately adjacent to the zone of active landsliding and accelerated seacliff erosion (i.e. Zone 1). The position of the eastern boundary of this zone is established by a 2:1 (i.e. 26± degrees) projection measured from the base of the high seacliff located west of Ocean Boulevard.

Risk Assessment - Risk to development in this zone is considered to be moderate to high. Eastward progression of active landsliding is difficult to predict with reliable accuracy.

The likelihood of eliminating the risk is very low, however it may be possible to significantly reduce the impact of the hazard by properly designed foundations.

No development should be allowed in this zone until stability is clearly demonstrated by the required geotechnical investigations.

Required Geotechnical Investigation - Engineering geologic investigation by a certified engineering geologist and a soil and foundation engineering investigation by a registered civil engineer, or a combined equivalent of the above.

- Scope of both investigations should be directed toward a detailed evaluation of the potential landslide hazards in this zone. In most cases, landslide studies will require extensive subsurface work in order to provide the necessary technical data to conduct a detailed slope stability analysis. The geotechnical analysis should provide acceptable factors of safety to clearly demonstrate stability before construction is allowed in this zone.

ZONE 3 - Includes all lands located outside of the areas affected by active or potential landslides.

Risk Assessment - Risk to development in this zone is considered to be low to moderate. The major geologic hazard in this zone is the threat of surface faulting along the master fault trace and several branching fault traces of the Seal Cove fault. These faults are active and capable of producing damaging surface faulting, strong ground shaking and ground failure.

The relative risk associated with poor surface drainage and potentially expansive soils is generally regarded as moderate to locally high.

The feasibility of reducing the risks to acceptable levels in this zone is considered high. This can be accomplished by careful siting of homes away from active faults, using careful structural and foundation design and adequate surface drainage plans. However, it is possible that some residential parcels will be judged unbuildable due to high seismic hazards.

Development should be allowed in this zone on parcels found to be free of hazardous conditions by the required geotechnical investigations.

Required Geotechnical Investigation - Engineering geologic investigation by a certified engineering geologist and a soil and foundation engineering investigation by a registered civil engineer, or a combined equivalent of the above.

- Scope of engineering geologic investigation should address the seismic hazards related to the master and branching traces of the Seal Cove fault. Particular emphasis of the engineering geologic investigations should be placed on the evaluation of possible surface faulting. Investigative techniques within this area will require the use of subsurface trenching and possibly geophysical traverses unless clear evidence is established to show that no active fault crosses the parcel in questions.

- The soil and foundation engineering investigation should address, but not necessarily be confined to, the following item: site preparation and grading, surface drainage, and design parameters for residential foundations.

All of the geotechnical investigations should reference this report and the geologic data presented in the Leighton and Associates report of 1971 and the Seismic and Safety Elements of the General Plan of 1976. The geotechnical reports describing the results of these investigations should be reviewed by the County Geologist following the procedure that is currently in practice. The recommendations expressed in the soil and foundation engineering reports and/or the engineering geologic reports should become conditions of any development application.

TECHNICAL REPORT

GEOLOGIC ANALYSIS
OF THE
SEAL COVE AREA

County of San Mateo

California

August 1980

William Cotton and Associates

William Cotton
and Associates

GEOTECHNICAL CONSULTANTS
314 Tait Avenue, Los Gatos, California 95030
(408) 354-5542

To: David C. Hale
Planning Director
County of San Mateo

August 5, 1980
Project G112-80

From: William Cotton and Associates
Geotechnical Consultants

Subject: Geologic Analysis
Seal Cove Area
County of San Mateo, California

INTRODUCTION

At the request of the County of San Mateo we have completed an investigation of the geologic conditions of the Seal Cove area. The primary purpose of our work was to evaluate and update the existing Geologic Map of the area, to identify and characterize the geologic hazards that constrain development, and to evaluate the level of risk associated with the hazardous conditions.

The geologic investigation included the following tasks: (1) detailed geologic surface mapping of the study area at a scale of 1 inch = 200 feet, (2) compilation and analysis of geologic and soil engineering data taken from reports and maps held in the County files, (3) stereoscopic evaluation of sequential aerial photographs, and (4) discussions with area landowners. The equivalent of eight man-days were spent collecting and compiling field data.

In preparing this report we have relied heavily on the following documents:

- Geologic Report of Seal Cove and Moss Beach Area,
  F. Beach Leighton and Associates,
  October 15, 1971.

- Geotechnical Hazards Synthesis Map for San Mateo County, Leighton and Associates, and San Mateo County Planning Department, June 1975.

- Seismic and Safety Elements of the General Plan, Vol. 1 and 2; San Mateo County Planning Department, December 1976.

The geologic data and discussions presented in this report should be regarded as updated and reevaluated information taken from the Leighton report and should not be considered to supersede or diminish the importance of their work. Future development in the Seal Cove area should not proceed without reference to both of these reports and the data compiled for the seismic safety element of the County of San Mateo.

ACCOMPANYING ILLUSTRATIONS

Geotechnical Hazards Map, 1 inch = 200 feet, Plate 1 Pocket

Index Map, Figure 1

Topographic and Geologic Index Map, Figure 2

Schematic Geologic Cross Section, Figure 3

Mode of Rock Slump Failure, Figure 4

Progressive North to South Failure of Seacliff Region, Figure 5

Progressive Seacliff Erosion, Figure 6

Seal Cove Fault System, Figure 7

DEVELOPMENT HISTORY

The portion of coastal San Mateo County that is included in this study is a residential section known as Seal Cove which is located in the southern part of the community of Moss Beach (Figure 1). The northern and southern boundaries of the study area are defined by Cypress and Bernal Avenues, respectively, and include all of the residential property located between the Half Moon Bay Airport and the ocean.

The Seal Cove area was subdivided into residential parcels about 1908. The area was subdivided into 2500 square foot lots with roads and improvements (i.e., streets, sidewalks and utilities) without regard for the geologic constraints. In fact, the primary attraction of the Seal Cove area was the presumed relatively low level of risk associated with the setting as compared to the San Francisco region that was devastated during the earthquake of 1906. The existing street alignments and the lot configurations are essentially the same as the original 1908 development plan. Since that time, residential construction has proceeded at a rather slow, piecemeal rate with home construction being limited to parcels of 5000 square feet.

In the late 1960's development in portions of the Seal Cove community was identified by the U.S. Geological Survey as being constrained by high geologic hazards due to active landsliding and accelerated coastal erosion. On the basis of this information, the County of San Mateo placed a building freeze on the Seal Cove area and authorized Leighton and Associates, the County Geologists, to complete a detailed geologic study of the area and to provide the County with guidelines for future development. The geologic study was completed and the final report was accepted by the County in October of 1971. The Leighton report clearly identified the primary geologic constraints of the Seal Cove as landsliding, faulting, and seacliff erosion. In addition, the report identified less severe potential problems associated with poor surface drainage, high ground water, and expansive soils. On the basis of these concerns, the Seal Cove area was divided into four Geologic Hazard Zones that define different levels of relative geologic stability. The description of each zone identifies the primary geologic hazard that constrains development and defined the type of geologic and soil report that would be required prior to residential development. Table 1 outlines the four hazard zones as presented in the Leighton report of October 15, 1971.

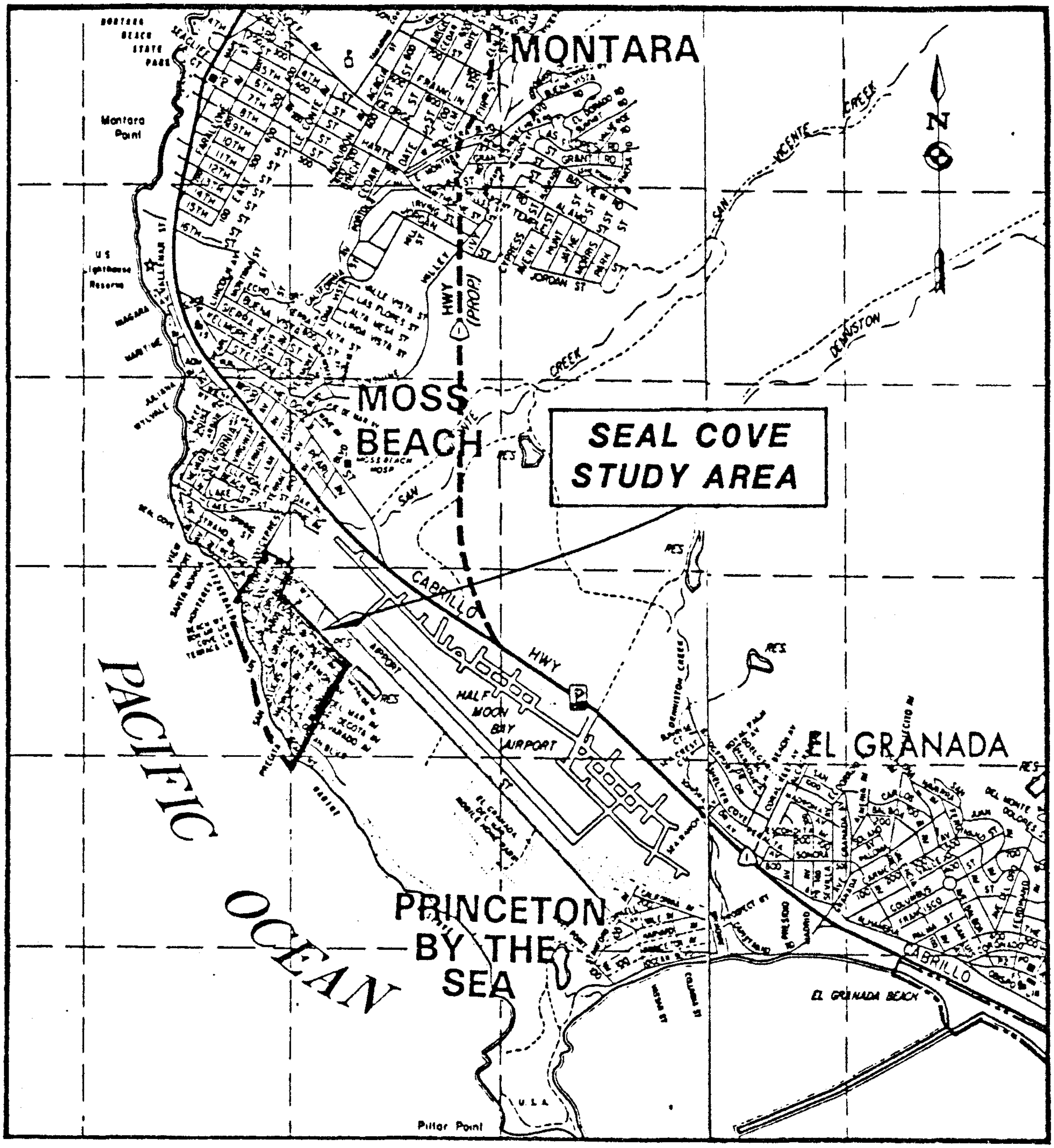


FIGURE 1 - INDEX MAP

SEAL COVE STUDY AREA
COUNTY OF SAN MATEO, CALIFORNIA

ZONAL RATINGS	GEOLOGIC STABILITY RATINGS	MAJOR GEOLOGIC PROBLEM TYPES	NATURE OF FUTURE GEOLOGY AND SOILS REPORTS REQUIRED
1	MOST SEVERE INSTABILITY	LANDSLIDING (RAPID MOVEMENTS LIKELY)	FEASIBILITY OF CORRECTION HIGHLY IMPROBABLE
2	UNSTABLE	PROGRESSIVE LANDSLIDING, EROSIONAL RETREAT OF BLUFFS, HIGH GROUND WATER AND ACTIVE FAULTING	DETAILED SUBSURFACE INVESTIGATIONS WILL BE NECESSARY TO ANALYZE INSTABILITY
3	DEGREE OF INSTABILITY QUESTIONABLE	COMBINATIONS OF THE ABOVE	DETAILED SUBSURFACE INVESTIGATIONS WILL BE NECESSARY TO DETERMINE DEGREE OF STABILITY
4	MOST STABLE	TYPICAL SOILS PROBLEMS (EXPANSIVE SOILS, ETC.); LOCALIZED GEOLOGIC PROBLEMS (SOIL CREEP, ETC.); SEISMIC RESPONSE, ETC.	CONVENTIONAL INVESTIGATIONS WILL PROBABLY BE ADEQUATE

TABLE 1 - GEOLOGIC HAZARD ZONES AS DEFINED BY LEIGHTON AND ASSOCIATES, OCTOBER 15, 1971

In November of 1971 the County accepted the conclusions and recommendations of the Leighton report and imposed a number of building restrictions on the parcels within the four hazard zones. In addition, Leighton and Associates prepared and sent to the County a specified set of guidelines for geologic and soil investigations conducted in the Seal Cove area. On the basis of the new information, the building freeze was lifted but residential development was allowed to proceed only after the necessary geologic and/or soil investigations were satisfactorily completed. The required reports were reviewed by Leighton and Associates on a part-time basis until 1975 when the County retained A. C. Neufeld as the permanent County Geologist.

The present policy regarding geologic and soil reports has been altered slightly from the recommendations of the Leighton report. At present, detailed geologic and soil investigations are required in Geologic Hazard Zones 1 and 2; however, in zones 3 and 4 such investigations are only required when a parcel is located within fifty feet of a mapped fault. Normally, areas located outside of the fifty foot zone do not require any geologic or soil report prior to construction. The adequacy of the geologic and soil report are evaluated by the County Geologist according to the Minimum Standards for Geotechnical Reports adopted by the County and the review procedures developed by the County Geologist. In some cases the County Geologist has imposed stricter and, at times, more reduced standards where local geology or soil data warrant such changes.

Since the suspension of the 1971 building freeze, 16 new homes have been constructed in the study area. These homes are situated within the following Geologic Hazard Zones as defined by Leighton and Associates:

ZONE 1 - Most severe instability	- no development
ZONE 2 - Unstable	- 9 new homes
ZONE 3 - Degree of instability questionable	- 5 new homes
ZONE 4 - Most stable	- 2 new homes

Our evaluation of the locations and conditions of the new homes indicates that the present stability of most homes is good; however, the safety of two of these homes is in question. These homes are situated in Geologic Hazard Zone 2. The specific locations and geologic concerns of these structures are outlined below:

LOCATION	GEOLOGIC PROBLEM
131 La Grande Avenue	Home, deck and patio constructed within several feet of an active landslide scarp
821 Ocean Boulevard	Front portion of home and driveways are situated over an active landslide tension crack

The home on La Grande was constructed east of a major, active landslide scarp that was well documented in the Leighton report, and recognized by the owner's consultants prior to construction. But at the time that the home on Ocean Boulevard was constructed, no surface evidence of landsliding was noted. Apparently the landslide-related surface cracking has extended to this location since the Leighton investigation of 1971. Small incipient surface cracks can be traced from the parcel on Ocean Boulevard to the east under the neighboring parcel where residential damage is more pronounced, and then north across La Grande Avenue to the prominent scarp area located west of 131 La Grande Avenue.

Our analysis of the geologic hazards of the Seal Cove area indicate that the landslide activity is progressing as predicted nearly a decade ago; however, the previously mapped fault pattern appears to be more complex. As a result of our work we have reevaluated the original hazard zones and have altered the positions of some boundaries. Additionally, we have recommended specific changes in the type and scope of future geotechnical investigation in the Seal Cove area.

PHYSICAL PARAMETERS: Topographic, Geologic and Seismic

The Seal Cove area is characterized by a unique set of physical parameters that strongly influence safe development. The physical conditions that have the most influence are those that relate to the topographic, geologic and seismic setting of the study area. The general characteristics of each of the conditions and their associated constraints and potentials for development are described in the following sections.

TOPOGRAPHIC SETTING - The portion of the community of Moss Beach that is included in this investigation is situated at the north end of a prominent northwest-trending ridge (Figures 2 and 3). The ridge extends from Pillar Point on the south to beyond Seal Cove for a distance of approximately two miles. An east-west profile across the ridge is assymetrical, characterized by a high, near-vertical seacliff along the western side, a nearly flat terrace surface along the top of the ridge, and a gentle, east-facing slope along the eastern border. The average elevation is nearly 100 feet throughout most of the ridge area, but the ridge top rises to approximately 175 feet above sea level south of the study area. Within the immediate residential portion of the study area the topography is relatively flat with a topographic relief of no more than 25 feet.

The present topography of the Seal Cove area and the surrounding ridge is the product of a long history of rather dynamic geologic processes, of which most are still actively modifying the area. These processes include active landsliding, accelerated seacliff erosion and young fault activity. The terrain that is not affected by these hazardous processes have a relatively high potential for safe development. Such areas are within the essentially flat terrace region situated east of Beach Way and Ocean Boulevard.

GEOLOGIC SETTING - The geologic setting of the Seal Cove area is defined by a variety of earth materials, active slope failure processes and a complex fault zone related to the Seal Cove fault system. The following discussion is designed to present a general description of the geologic setting. For a more detailed account, the Geologic Report of Seal Cove-Moss Beach Area, October 15, 1971 by F. Beach Leighton and Associates, should be consulted. Their report presents a large volume of detailed surface and subsurface geologic data in written and illustrative form. The description of the geologic setting included in this report is based on our field mapping and the information presented in the Leighton report.

The primary earth materials in this part of the Seal Cove community can be divided into two dramatically different types of bedrock units which are overlain by two types of

EXPLANATION

Earth Materials

SURFICIAL UNITS

Qls - Landslides

Rock slumps of surficial and bedrock material

Qt - Marine Terrace

Unconsolidated gravel, sand and silt

BEDROCK UNITS

Tp - Purisima formation

Highly fractured siltstone, shale and sandstone

Kg - Montara Quartz Diorite

Coarse-grained quartz diorite

Map Symbols


Geologic Contact

Faults


Landslides

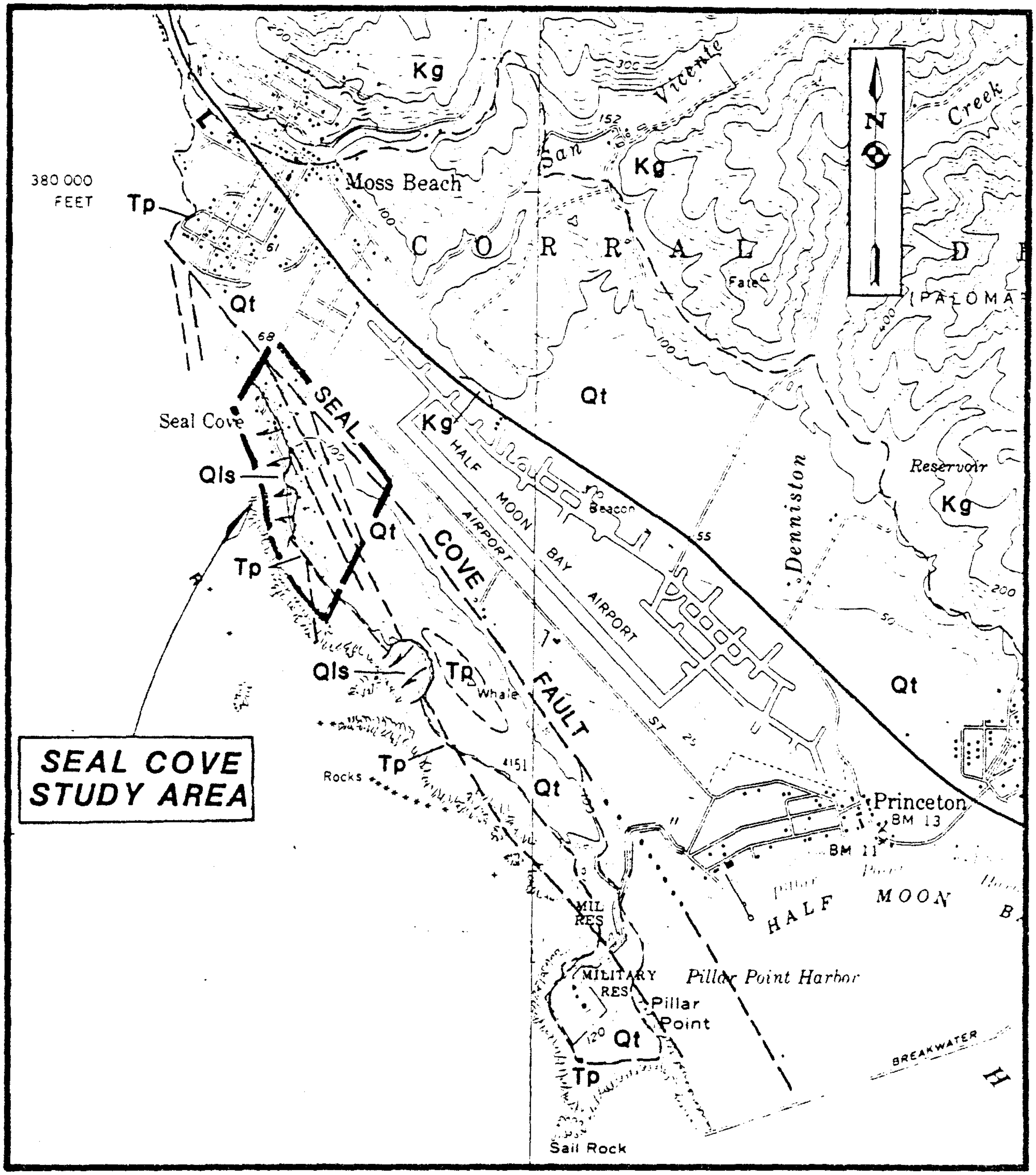


FIGURE 2. TOPOGRAPHIC AND GEOLOGIC INDEX MAP

SEAL COVE STUDY AREA
COUNTY OF SAN MATEO, CALIFORNIA
Scale 1 inch = 2,000 feet

Topographic base map, Montara Mountain and Half Moon Bay Quadrangles, 7.5 minute. U.S. Geological Survey

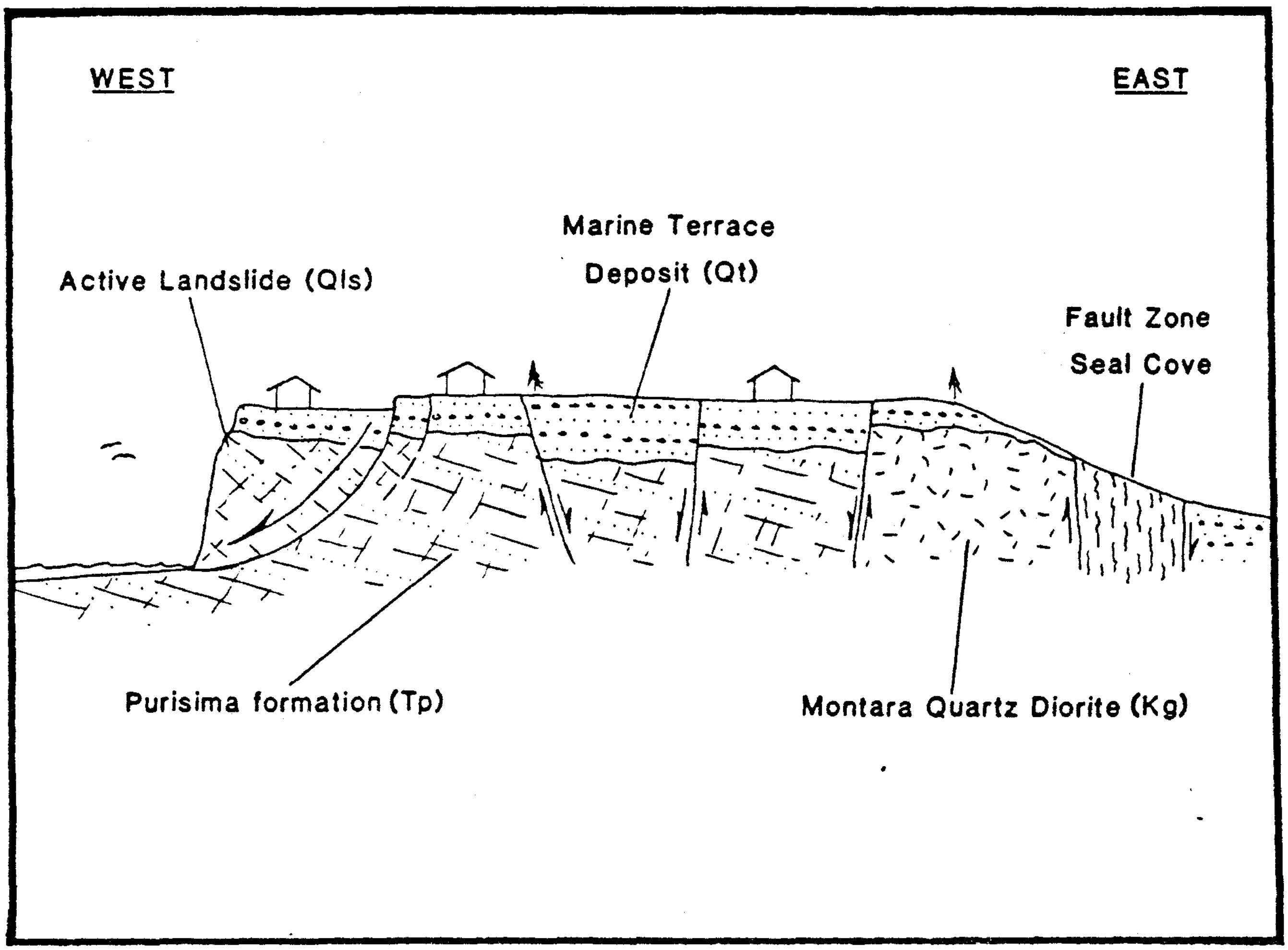


FIGURE 3 SCHEMATIC GEOLOGIC CROSS SECTION

SEAL COVE STUDY AREA
COUNTY OF SAN MATEO, CALIFORNIA

surficial deposits (Figures 2 and 3). The two bedrock units consist of a relatively fine-grained sequence of sedimentary rocks belonging to the Purisima formation (Tp) and a massive coarse-grained igneous rock of the Montara Quartz Diorite (Kg). These materials make up the bulk of the rock materials that form the prominent ridge topography, however, in most areas the bedrock is covered by the surficial deposits. The surficial materials consist of a sedimentary Marine Terrace deposit (Qt) that blankets all of the nearly flat topography of the study area, and a complex of active landslides deposits (Qls) which are presently destroying large sections of the western seacliff region. The following discussion describes the physical nature of each type of earth material in the Seal Cove area.

Surficial Units - the relatively unconsolidated deposits that overlie the bedrock material.

Landslide (Qls) - The landslide deposits are composed of both the overlying surficial Marine Terrace and the Purisima bedrock materials. The primary type of failure appears to be rock slump with movement concentrated along deep-seated failure planes. The landslides are concentrated in a coastal belt along the western margin of the study area that extends inland as far as 300 to 400 feet.

Marine Terrace (Qt) - These deposits form a blanket-like covering of gravel, sand, and silt that overlies the bedrock units throughout the relatively flat portion of the study area. The thickness ranges from 3 to 4 feet to as much as 40+ feet.

Bedrock Units - the relatively consolidated materials which form the major portion of the ridge and which the surficial units rest.

Purisima formation (Tp) - This unit consists of a thin-bedded, highly fractured, interlayered sequence of siltstone, shale, and sandstone. The bedrock is exposed along the entire length of the seacliff area and has been encountered in drill holes located approximately 800 feet east of the seacliff area.

Montara Quartz Diorite (Kg) - This bedrock type is not exposed at the surface but has been penetrated in drill holes along the eastern margin of the study area. It consists of deeply-weathered, medium- to coarse-grained quartz diorite.

The most active geologic process now operating in the study area are two distinctly different types of slope failure. They are confined to the seacliff region and include (1) deep-seated landsliding involving large segments of the seacliff, and (2) shallow sloughing and ravelling of the face of the seacliff.

LANDSLIDING - Active, deep-seated landsliding presently is affecting most of the seacliff located along the western margin of the study area. The average height of the seacliff is approximately 100 feet and, in most cases, the entire seacliff is involved in landsliding. The locations of the crowns (i.e. tops) of the landslides vary considerably, but in several places the crowns are located as much as 300 to 400 feet back (i.e. east) of the top of the seacliff, however, the average distance is nearly 250 feet. The depth to the basal slide planes of these landslides is not well known, but from the surface dimensions it is estimated that the depths equal or exceed the height of the seacliff. Thus, the toes (i.e. bottoms) of most of these landslides are near the base of the seacliff and sea level (Figure 4).

Detailed surface mapping and subsurface drill hole data strongly suggest that the mode or style of slope failure can be characterized as (1) progressing from the north to the south and (2) undergoing rotational failure along a concave-upward basal rupture surface. The north-to-south progressive failure is revealed by the pattern and dimension of the surface breaks noted along the crowns of the individual landslides (Figure 5). For example, the eastern limits of the landslides are commonly defined by one or more landslide-related geomorphic features including prominent crown scarps, trenches (i.e. grabens), linear depressions and tension cracks. The pattern of failure normally starts with a well-developed headwall scarp near the crown of a major landslide block. The scarps commonly are more prominent and better developed along their northern extensions. Most can be traced to the south along somewhat discontinuous curvilinear paths, but the scarps frequently diminishes in height to the south and eventually are replaced by shallow linear depressions or a series of tension cracks. Consequently, it appears that most of the landslide headwall scarps propagate slowly to the south from their points of initiation, following a scissor-like pattern with greater surface displacements being concentrated along the northern extension of the headwall scarps.

Although the basal rupture surfaces for most of the landslides is not well defined, they appear to be controlled structurally by the orientation and the spacing of the bedrock fractures. The stratification of the bedrock is inclined into the seacliff. Such an orientation usually accounts for increased slope stability, but the highly fractured nature of the bedrock and the presence of a prominent set of west-dipping continuous fractures reduce the strength of the bedrock and controls the mode of failure.

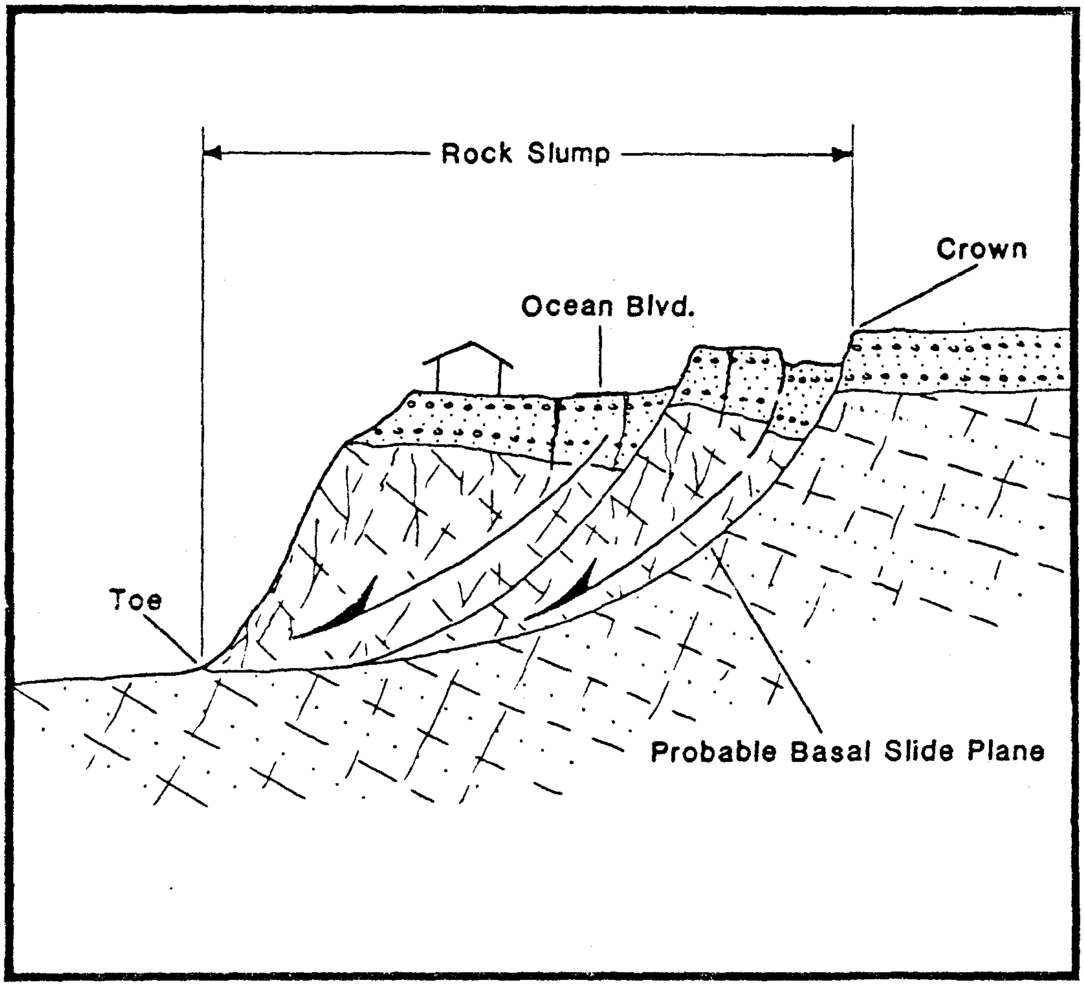


FIGURE 4 MODE OF ROCK SUMP FAILURE
SCHEMATIC CROSS SECTION

SEAL COVE STUDY AREA
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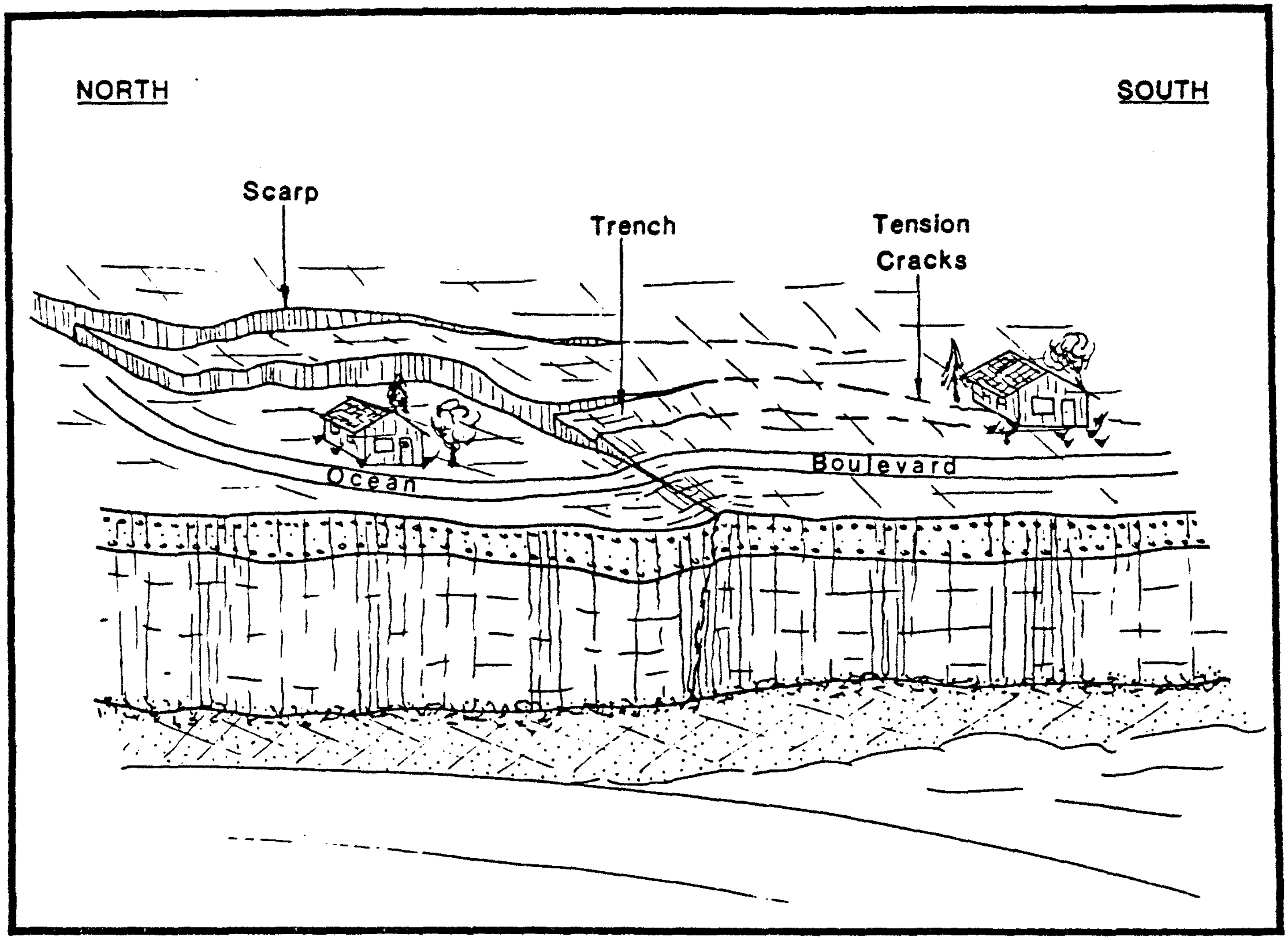

FIGURE 5 PROGRESSIVE NORTH TO SOUTH
FAILURE OF SEACLIFF REGION

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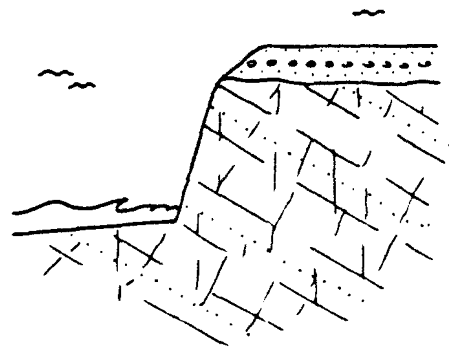
Thus when the relatively incompetent bedrock is exposed in a high, near-vertical seacliff that has been oversteepened by wave erosion, the rock becomes detached along the planar surfaces of the fractures. Consequently the seacliff fails in a type of landslide known as a rock slump (Varnes 1978) which normally involves bedrock materials that fail by rotation along a curved basal rupture surface.

The rate at which these large deep-seated landslide masses are failing can be estimated roughly by noting the increase in the scarp heights and in the length of extensions of the tension cracks since the completion of the original landslide mapping in 1971 (i.e. Leighton and Associates). Our measurements indicate that the rate of failure probably is approximately 1 to 3 inches per year; thus the rate of movement is regarded as very slow. However, the possibility of accelerated movements is considered high in many local areas within the presently failing landslide complex.

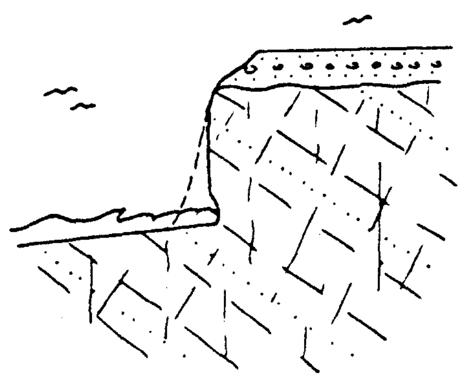
SLOUGHING - The most active form of slope failure along the seacliff is shallow, small-scale sloughing and ravelling of the face of the cliff. This process is initiated by wave erosion concentrated along the base of the seacliff (Figure 6). This erosional process causes the base of the seacliff to become undercut and locally unstable. The face of the seacliff responds to the oversteepened condition by localized piecemeal sloughing and ravelling. Most of the cliff retreat takes place during the winter season when storm waves vigorously erode and undercut the base of the seacliff. The weak, highly fractured siltstone and shale bedrock and the unconsolidated cover of marine terrace material are left in an oversteepened and unsupported condition, and consequently fail. The fallen debris temporarily protects the base of the cliff, but the waves eventually remove the debris and the oversteepening process starts anew.

An analysis of aerial and ground photographs taken over a period of fifty years, 1926 to 1976, and map extending back approximately 130 years reveals that the average rate of cliff retreat within the study area is now approximately 3 to 4 feet per year. However, this process is episodic and is controlled by a variety of local geologic conditions, thus the average rate cannot be projected into the future with any degree of certainty. For example, using this rate, it would be unreasonable to predict that the top of the seacliff will be located 30 to 40 feet east of its present location by 1990; there may be only 5 feet of cliff retreat in the next ten years, but 55 feet of retreat may occur the subsequent decade. Thus the average rate over a 20 year period would approximate 3 feet per year.

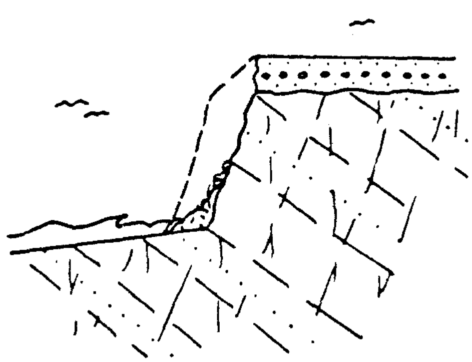
In conclusion, the seacliff portion of the Seal Cove area presently is failing by large deep-seated landsliding and small scale localized sloughing. Although both of these types of failures are partially induced by the oversteepening process



Stage 1-Relatively Stable Seacliff



Stage 2 – Local instability due to undercutting of base of seacliff



Stage 3 – Relative stability attained by piecemeal sloughing and ravelling

FIGURE 6 PROGRESSIVE SEACLIFF EROSION
SCHEMATIC DRAWINGS

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of wave erosion, they are dramatically different in scale and mode of failure. Likewise each presents a very different level of risk to future development.

In our judgment, attempts to control or reduce these hazards by engineering design would not be feasible. The scale of the large active landslides make any stabilization scheme essentially uneconomical, likewise an engineering solution needed to stop the erosional activity at the base of the seacliff would severely impact the James V. Fitzgerald Marine Reserve which includes the Seal Cove surface zone. Consequently it appears the most prudent way to reduce the risk is to avoid the areas that are vulnerable to these slope failure hazards.

SEISMIC SETTING - The principal structural feature within the study area is the Seal Cove fault zone and a number of subsidiary branch faults (Figure 7). The master trace of the fault appears to lie near the base of the east-facing slope which forms the eastern boundary of the study area. Here the master trace is considered to be within a zone of pulverized rock that is approximately 100 feet wide. West of this main zone, the location and character of faulting are less well understood. In this region at least three branch faults extend to the southeast from the main Seal Cove fault zone and pass through the study area (Leighton 1971). Subsequent site-specific geologic studies have confirmed with slight modifications the location of some of these branch fault traces. In addition, the analysis of aerial photographs conducted for this study and by A. C. Neufeld, San Mateo County Geologist, strongly indicate that several additional fault-related lineations cross the relatively undeveloped area located south of San Lucas Avenue.

These branch faults, like those in the main fault zone are considered to be normal faults characterized primarily by vertical displacements. The main fault trace is identified as the zone of greatest concentration of displacement. Indeed the east-facing slope that forms the eastern boundary of the study area is considered to be a fault scarp produced by displacement along the main trace of the Seal Cove fault. Although the branch faults also are considered to be active traces, both the surface expressions of these faults and the subsurface data presented by the Leighton report indicate that the amount of displacement and the state of activity along these faults probably is much less than the master trace.

Recent fault studies suggest that the Seal Cove fault zone is a segment of a major coastal boundary fault zone that merges with the San Andreas fault north of San Francisco (Greene and others, 1973; Weber and Cotton, 1980). This fault zone includes the Seal Cove, San Gregorio, Sur, San Simeon and Hosgri faults and extends to the south for more than 260 miles to the vicinity of Point Arguello. The largest historic seismic event recorded along the San Gregorio fault system

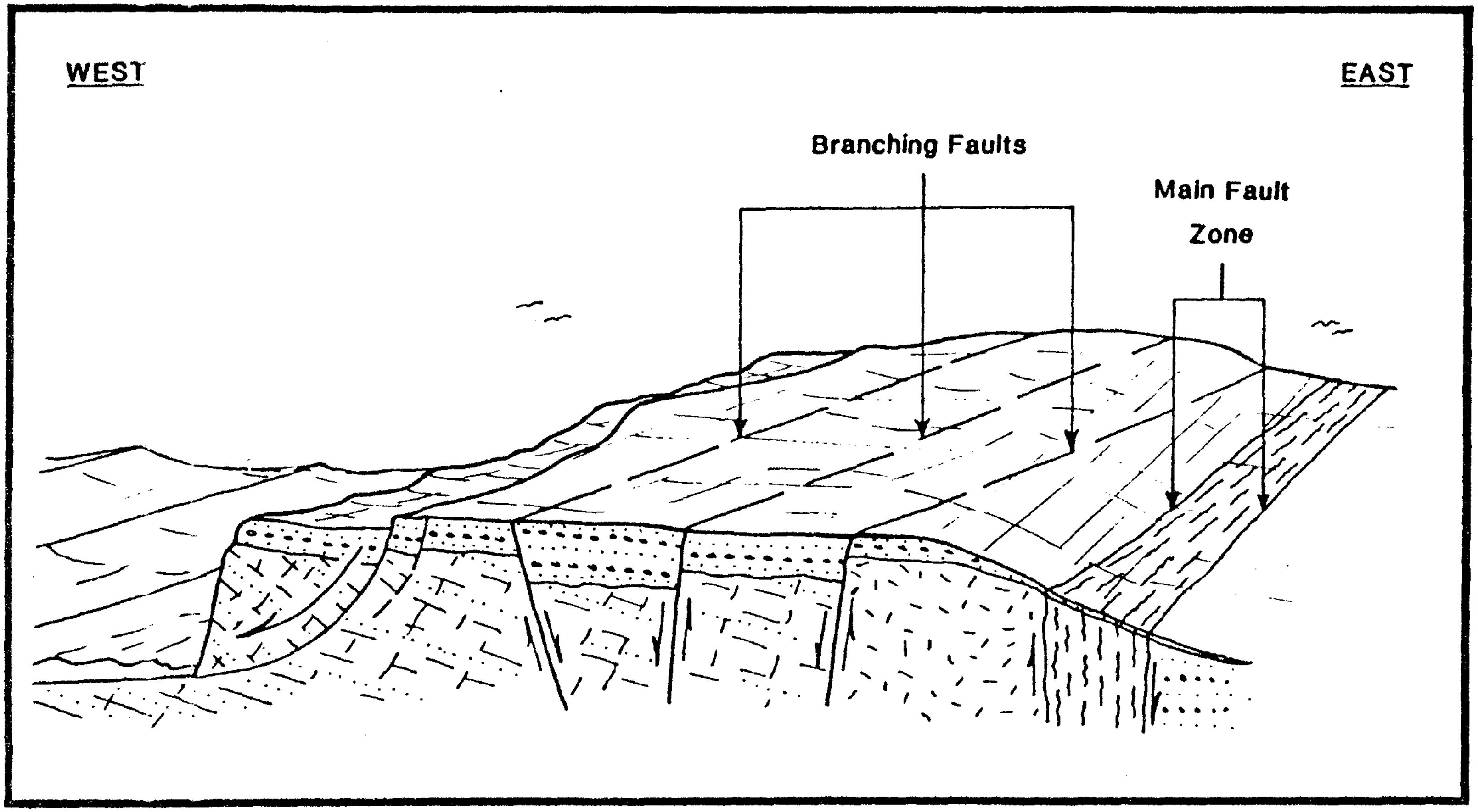

FIGURE 7 SEAL COVE FAULT SYSTEM

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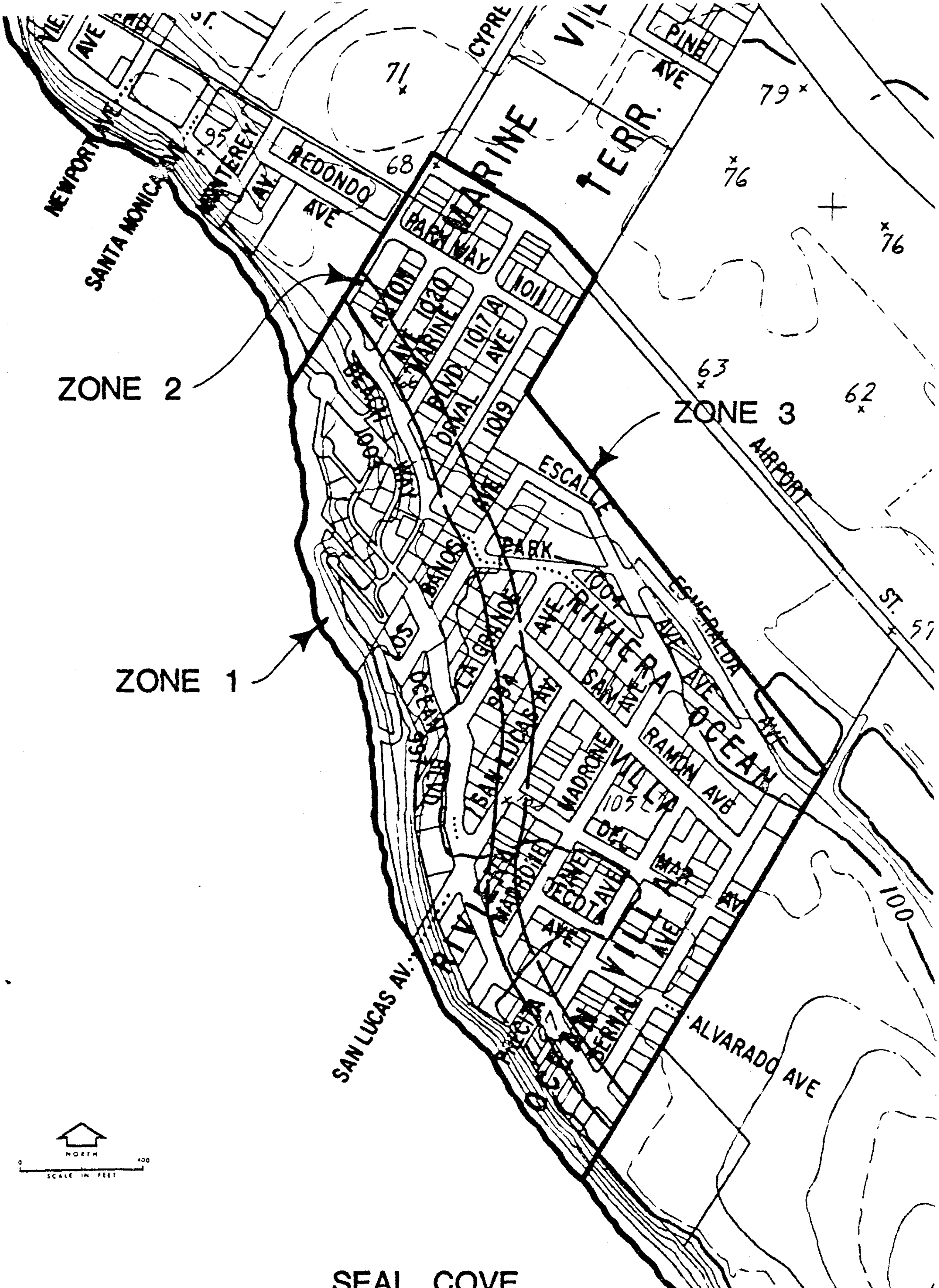
were two Richter magnitude 6.1 earthquakes which occurred within one hour of each other near the center of Monterey Bay in 1926. Studies of historic seismicity along the San Gregorio fault zone in the vicinity of Monterey Bay indicate that the fault zone probably is capable of producing an earthquake of Richter magnitude 7.2 - 7.9. Paleoseismologic research on the San Gregorio fault zone near Point Ano Nuevo, in San Mateo County, suggests that (1) earthquakes of Richter magnitude 7.6 - 7.7, and possibly greater than Richter magnitude 8.0, have occurred along the San Gregorio fault zone in the past and are anticipated to occur in the future, and (2) a reasonable estimate of the recurrence interval for major earthquakes (M 7.5) along the San Gregorio fault system is 225-400 years and probably is about 300-325 years (Weber and Cotton, 1980). Since the Seal Cove fault is considered to be an extension of the San Gregorio fault system, it is reasonable to attribute a similar level of seismic activity to the Seal Cove area.

In conclusion, the main trace and the branching traces of the Seal Cove fault are considered to be active. The branching faults located in the relatively undeveloped area south of San Lucas Avenue are only approximately located. Indeed, there may be additional fault strands that are as yet unrecognized in this region. Should a major earthquake take place along the Seal Cove fault the anticipated seismic hazards would be severe ground shaking, surface faulting along the master trace and branching fault traces and ground failure (landsliding, sloughing, settlement, etc.). The risk associated with these hazards can be dramatically reduced by carefully siting homes away from active fault traces or potential zones of ground failure and by careful structural and foundation design.



SEAL COVE
GEOLOGICAL HAZARDS ZONES