CALIFORNIA'S COASTLINE: EL NIÑO, EROSION AND PROTECTION

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INTRODUCTION
While the El Niño concept is a relatively new one to many residents of California, historical records from Peru documenting El Niño events in the equatorial Pacific go back at least 4 centuries (Quinn, et al., 1987). The last major El Niño event affecting California took place in 1982-83 and produced $8 billion in damage worldwide, with $2 billion of this damage in the United States. This event affected the entire coast of California from Del Norte county on the north to San Diego county on the south and produced in excess of $100 million in storm damage during January alone: 27 oceanfront homes and 12 businesses were completely destroyed, 3000 homes and 900 businesses were damaged, and 11 of the 15 coastal counties were declared state and federal disaster areas (Swisher, 1983). Public damage reached nearly $34 million and much of this was concentrated in parks and recreational areas in Los Angeles and San Diego counties. The majority of the private losses (which totaled $46 million) occurred in Santa Cruz, Los Angeles and Orange counties as structural damage to homes. Businesses suffered an additional $16 million in damage (Swisher, 1983).

Why was there so much damage during the 1982-1983 winter? Two factors were important in producing these losses.

• The sea levels along the entire California coast were elevated well above predicted tidal heights, primarily due to thermal expansion of sea water due to the influx of warm water from the equatorial Pacific. On January 27, during the highest spring tides of the year, the largest recorded waves arrived. Sea levels recorded at tide gages in San Diego, Los Angeles and San Francisco ranged from 0.95 to 1.77 feet above predicted and were the highest recorded throughout the entire historic tide gage record at all three sites.

• Nearly all historic coastal storm damage in California has occurred at high tide. A number of storms, accompanied by large waves, struck the coast in the first three months of 1983 and at least seven of these arrived coincident with high tides, further elevated by El Niño conditions. As a result, beaches were eroded, did not recover prior to the arrival of the next storm and high tide, and therefore continued to erode. As a result, storm waves broke closer to structures or on structures and inundated areas normally protected by wide beaches. Waves caused 20-40 feet of dune/bluff recession at Pajaro Dunes, a private oceanfront development in central Monterey Bay. At Del Mar, waves reduced the beach profile by 10-15 vertical feet as sand was transported offshore.

All oceanographic signs throughout the latter part of 1997 indicate that a very significant El Niño event was underway, perhaps the largest of this century. Most would agree, however, that it is impossible in December to predict the impacts of this developing El Niño on coastal California during the subsequent winter months simply because of uncertainties and unknowns: future storm tracks and storm frequency, sea levels, and tide/wave interactions.
California has 1100 miles of shoreline, 950 miles or 86% of which is eroding. The length of the coast has not changed significantly in historic times but the population which utilizes and has developed on the coast continues to increase (Figure 1). At the
time of the last major damaging El Niño in 1982-83, the state’s population stood at 24.8 million people. At the time of the arrival of the 1997 event, the state’s population had increased 29% to 32 million. Eighty percent of these people live within 30 miles of the shoreline and 4 million live within 3 miles of the water’s edge.

As a result of topography, climate, availability of water to some degree, and therefore historical development patterns, the coastal population is not evenly distributed throughout California’s coastal counties (Griggs, Pepper and Jordan, 1992). Residents in rural Humboldt County have about eight feet of shoreline each, whereas residents of suburban Los Angeles County have less than half an inch. Overall, each resident of the state would have about two inches of coastline if it was accessible, but this is not the case for much of the rugged and inaccessible central and northern coast. In addition, the coastline must be shared with the millions of visitors. To make matters worse, the population of the state is projected to reach 50,000,000 by the year 2020 (California Department of Finance, 1989).

CALIFORNIA’S COASTAL HAZARDS
Coastal geologic hazards in California occur most frequently in the form of shoreline erosion (both bluff and beach) and coastal flooding (both wave impact and inundation). Human interference with coastal processes (such as sand supply and littoral drift) and coastal bluff stability (increased surface runoff, loading, or elevated ground water tables) have exacerbated hazardous conditions in many locations.

The California shoreline has three distinct hazardous geomorphic environments where widespread development has taken place: eroding cliffs or bluffs, the back beach, and
coastal dunes. A survey of existing oceanfront public and private structures and infrastructure indicates that the risks of building in these environments were either not recognized or not respected when permits were granted or construction took place. Politics and economics have also played an important role in particular locations (Griggs, Pepper and Jordan, 1992).

ERODING BLUFFS OR CLIFFS
Eroding bluffs and cliffs represent California's most extensive coastal hazard and no area of the state has a monopoly on short-sighted planning in this environment (Figure 2). Because of California's location along an active plate boundary, tectonic uplift of the coastline has produced many square miles of easily developed flat marine terraces. From

![Figure 2a Construction on eroding coastal bluffs: Marin County](image)

![Figure 2b Construction on eroding coastal bluffs: Santa Barbara County](image)
Humboldt county in the north to San Diego county in the south, these flat benches have been developed with homes, condominiums, apartments, restaurants and hotels. In most locations, this development has encroached right to the cliff or bluff edge, where views of the ocean are unobstructed and property values are the highest, but where the risks to structures of continuing bluff retreat are the greatest.

Rates of coastal cliff retreat are primarily a function of the interaction of two factors: 1) the resistance of the cliff materials to erosion or failure, and 2) the degree to which the physical processes producing cliff breakdown or failure impact the cliffs. While most
coastal bluff erosion is often wave induced, both seismic shaking (Figure 3; Griggs and Scholar, 1997) and terrestrial processes (surface run-off and slumping or sliding) can play important roles, particularly where the cliffs are protected from wave attack. Average

Figure 3. Coastal bluff failure in Daly City from seismic shaking during the 1989 Loma Prieta earthquake.
long term erosion rates along the coast of California range from negligible where crystalline granitic rocks form the coastline (e.g., the Monterey peninsula), to as much as eight feet/year where unconsolidated dune sands form the bluffs (Figure 4). A few inches to a foot/year are typical average rates of cliff retreat in the sedimentary rocks which make up much of California's coast.

![Figure 4: Ft. Ord, northern Monterey Bay: where unprotected unconsolidated dunes on either side of the two breakwaters are eroding at average rates of approximately 3 ft/year. Note the lack at each end of the road at the beach in front of the rubble.]()

While qualitative information on coastal bluff retreat is readily available (e.g., old photographs, eroded roads, exposed storm drains and similar structures), accurate rates of shoreline erosion are more difficult to come by. Yet it is these long term rates that are what we should have determined and used in the past, and should be using now, to establish setback lines for any proposed oceanfront construction.

There are a number of methods which have been used to measure rates of coastal cliff erosion, each with their own limitations, costs and benefits, and which need to be understood before indiscriminately using "average" erosion rates. The basis for nearly all of these methods is 1) a set of historical aerial photographs and/or maps which span as long a time period as possible, and 2) a tool or technique for measuring the change in shoreline or cliff edge position over the time span of the photos and/or maps.

The climatic representativeness and length of time covered by the air photos or maps, the experience and skill of the interpreter, scale and resolution or clarity of the photos, the degree of photographic distortion and any efforts to rectify or correct for the distortion, the ability to locate and measure from reference points in the photographs to
the cliff edge, and the technique used to perform the measurements and rectification, all affect the data derived and the erosion rates which are ultimately determined.

Unfortunately, long term average annual cliff erosion rates have not been accurately determined for most of the shoreline of California. There are a number of reasons for this lack of data: 1) relatively few investigators have taken the time to determine accurate long term measurements. 2) failure to obtain the long term photographic or map base needed for such measurements. 3) most studies have been relatively short term or have covered very small areas. 4) a lack of trained investigators, and 5) a lack of the equipment or tools for either checking the photos for distortion, correcting the photographs or for making accurate erosion rate measurements.

In addition to the lack of erosion rate measurements at the time when most coastal construction took place, there are several additional factors which appear to have been responsible for the nearly continuous development of the eroding oceanfront cliff and bluff tops of most of southern California’s coastline and portions of the central state’s coast: 1) the very high value of coastal real estate and therefore the political and economic consequences of denying building permits. 2) allowing infilling of existing developments, or using the stringline approach. 3) the lack of local or statewide policies or adherence to existing policies on setbacks, and 4) the assumption in some municipalities that armor would be allowed or even required as a means for halting shoreline erosion at the time when oceanfront structures became threatened.

Coastal communities from one end of the state to the other have lost entire oceanfront streets, utility lines, lots of record and homes through the ongoing process of cliff erosion over the last century (Figure 5). New developments are still being proposed on eroding or unstable bluffs and small, older weekend beach cottages are still being torn down.
and replaced by larger new homes. When the California Coastal Act was passed in 1972, coastal hazard issues were not as obvious as they have become since 1978. During the last two decades winter storm wave attack has been more severe along the coast than it had been in the previous three decades. Although statewide guidelines were established in the Act for determining the stability of coastal bluffs and potential development, there is no statewide policy establishing safe setback distances from cliff or bluff edges. As a result, some jurisdictions use a predetermined, fixed setback, although these vary from as little as 10 to as much as 320 feet. Others employ a cliff retreat rate (supposedly site specific) applicable over a specific time period or structural lifespan, most commonly a 50-year period (Griggs, Pepper and Jordan, 1992).

BACK-BEACH CONSTRUCTION
Virtually all California beaches undergo striking seasonal changes in width in response to changing wave climate. Due to long term fluctuations in wave climate, the year to year seasonal changes may be more or less extreme. For many of the same reasons that Californians have so intensively developed the coastal bluffs, they have also built directly on the beach in many locations. Throughout much of coastal California, homes have been built either directly on concrete slabs or above the sand on wooden pilings or concrete piers. Much of the over $150 million in storm damage along the California coast since 1978 occurred when storm waves combined with high tides washed through such beachfront developments as Stinson Beach, Rio del Mar, Malibu, Del Mar, Oceanside, and Imperial Beach.

Damage during the 1983 El Niño winter included undermining of shallow pilings or piers so that homes collapsed onto the beach (Figure 6). Homes on low pilings were also uplifted by waves at high tide and smashed through pilings as they fell. In addition,
waves overtopped low protective seawalls and either damaged or destroyed the homefronts facing the sea (Figure 7). Nonstructural damage such as losses of decks, beach stairways, patios, yards and landscaping was widespread in these oceanfront locations. Events of this sort will not occur with any regularity or predictability, but the fact that these homes are built directly on or over beach sand is clear evidence of the wave inundation which can be expected at these locations.

The storm damage to these beachfront areas during recent years is clear testimony that either 1) these risks were not adequately evaluated, 2) that the hazards of living on the beach were disregarded in the planning process, or 3) that the coastal armor was going to provide complete protection from wave attack. A partial explanation for these shortcomings lies in: 1) the relatively infrequent simultaneous occurrence of very high tides and large waves such as occurred in 1983; 2) the tendency for people to have short "disaster memories" and buy or rebuild after damaging storms; 3) the large number of immigrants to California in recent years who have not experienced coastal hazards; and 4) the moderate climate and storm history of the 30 year period from 1946 to 1976, an era of rapid population growth and intense coastal development in California.

Many homes and protective structures were approved and built by planners, engineers, and contractors without firsthand experience with a winter such as 1983, and therefore, suffered from inadequate setbacks, elevation, or design considerations (i.e. wave runup elevation, scour depth, etc.). Additionally, there is commonly a significant time lag between the collection of coastal process or hazard data by scientists and utilization of
the data by engineers, such that many structures have been underdesigned through utilizing outdated, generic, or cookbook design criteria or physical process information.

Despite California's intense beach level development, neither the California Coastal Act nor the subsequent Interpretive Guidelines specifically recognized the hazards of direct wave impact or wave/tidal inundation (coastal flooding) on beach level structures (Griggs, Pepper and Jordan, 1991: 1992). As a result, policies at the state's local government level on beach front construction vary widely. Most of the state's coastal jurisdictions have adopted FEMA Flood Insurance Rate Maps which delineate zones that are subject to different degrees or elevations of coastal flooding. Although these maps were originally developed for insurance purposes, they now have regulatory status. The lack of state guidelines for safe development at beach-level has led to continued development and reconstruction in hazardous locations.

COASTAL SAND DUNES

In contrast to the east and Gulf coasts of the United States, where coastal barrier islands and dunes are the typical land forms, the California coasts is characterized by coastal mountains, terraces, cliffs and bluffs, with only occasional lowlands where dunes have developed. Dune fields have formed in the central and southern Monterey Bay area, Pismo Beach, Oxnard, and along portions of the Los Angeles and Orange county coasts.

Sand dunes form an important buffer to wave action and also provide an extra reservoir of sand for beaches during periods of extreme wave attack. During calmer weather periods the beaches will widen, and where dunes have formed, they will build outward and upward. During winters of extreme waves, these same dunes may be severely eroded simply because they consist of unconsolidated sand and offer little resistance to wave attack. In some areas of California, the dune vegetation, which stabilizes the sand, has been removed as construction has taken place, in some cases, directly on the frontal dune. The frontal dune is an active land form which migrates over time, and centuries of experience on the east coast indicates this is not a wise place for any permanent construction.

Nonetheless, the frontal dune in central Monterey Bay was intensively developed with homes and condominiums in the late 1960's and 1970's; the waves during the 1983
El Niño cut back the beach and dune and threatened dozens of ocean front homes (Figure 8). Only the emergency emplacement of rip rap saved the homes from collapse as the foredune was eroded. A permanent revetment was subsequently built at cost of approximately $5 million along a mile of dune frontage.

RESPONDING TO SHORELINE EROSION

The storm damage over the past 20 years along the California coast has brought the issue of ocean front construction, coastal hazards and El Niño to the forefront, here and elsewhere. When the tide is high, waves are large, cliff or dune retreat and beach erosion can occur rapidly, threatening, damaging or destroying property, homes, and public infrastructure which have been safe for years. The 1983 losses were a reminder and wake up call for many.

As the 1997 El Niño develops, many are wondering what to expect. As has been stated earlier, predictions for the winter are impossible due to the number of uncertainties, but the historic record does provide some insight. A careful analysis of the history of coastal storm damage along the Monterey Bay coastline of central California since 1910, indicates that 46 of the 61 damaging storms (or 75%) during this time period occurred during El Niño events (Curt Storlazzi, University of California, Santa Cruz, unpublished research). This strong correlation indicates that coastal storm damage is much more likely during El Niño years.

Coastal erosion or retreat is a natural ongoing process, intensified during El Niño years, which has only become a problem because we have built permanent structures in areas that are prone to erosion or wave impact. Beaches, dunes, low bluffs, or high cliffs are all temporary features that will continually be shaped or altered by wave forces. Although cliff retreat or beach erosion does not necessarily occur with regularity, all of

Figure 8: Erosion of the unconsolidated dunes at the Pajaro Dunes central Monterey Bay development during the 1983 winter.

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our knowledge and experience from the past indicate that much of the coastline is constantly changing, some areas slowly, others more rapidly. The more rapid or frequent the changes, the greater the potential impact on any structures we build in this environment. Unfortunately, many homes and other improvements were built literally within a stone’s throw of the waves, and herein lies the problem. The Pacific Ocean is 10,000 miles wide and not too concerned about 100 yards of shoreline at the edges. In California and elsewhere around the country, however, we have built right at the edge. Where we have made that decision, there are going to be some inevitable and expensive consequences.

OPTIONS IN AREAS UNDERGOING RETREAT
There are several options for property owners, whether public or private, for areas or structures threatened by coastal erosion. These include retreat or structural relocation (Griggs, 1995), nourishment, and armoring. While some buildings have been relocated or demolished, and beach nourishment has taken place as a byproduct of harbor dredging, over the past 50 years the typical response to shoreline erosion in California has been armoring, or the construction of seawalls and revetments. As of 1990, an astonishing 130 miles or 12% of the entire shoreline of the state had been armored, with the more populated central and southern California counties more extensively armored than the north coast (Figures 9 and 10). In the 14 year period from 1971 to 1985, primarily as a
response to coastal storm damage during the El Niño events of 1978 and 1983, the length of the state's shoreline armored increased 220% or by an additional 58.5 miles (Figure 11). At present day costs of $1000 to over $3000/foot, a mile of armor or seawall today has a price tag of $5 million to over $15 million, a cost often covered in the past either by state or federal funds or by insurance settlements. In either case, it is more often than not the general public who has ultimately paid for many coastal protection structures. Coastal protection structures in California have a mixed record of success (Fulton-Bennett and Griggs, 1986). There are structures which were built almost 70 years ago...
which are still intact and functioning (Figure 12), others which have not survived a single winter, and still others which have been repeatedly destroyed and rebuilt (Figure 13). Because many of these seawalls and revetments were built following the damaging
storms of 1983, they have not yet experienced severe wave conditions. The 1983 waves and high tides destroyed many of the weaker existing seawalls such that those that did survive and the newer ones built since, presumably will have a higher survival and success rate during future storms.

While coastal arming has some very real benefits, it is also accompanied by some very clear impacts (Griggs, et al., 1997). Unfortunately, with coasts retreating along all the nation's shorelines, and with considerable private property threatened, the plea for halting "coastal erosion" has been confused and been combined or interchanged with a plea to halt "beach erosion". There is a very important difference and distinction between protecting or preserving the beach, and arming the shoreline to halt cliff or bluff retreat, but this is rarely made clear.

Historically, seawalls have been built to protect buildings and not beaches (Pilkey, 1988). Because seawalls have been built at locations where shoreline recession or beach erosion is already evident, a connection has often been made between the two. As a result, the question has been asked: Do seawalls cause beach erosion? This question is now a concern to coastal engineers and geologists, as well as to planners who must make decisions as to whether a proposed protective structure should be constructed. While the issue of impacts in different coastal environments is still not completely resolved and therefore an area of active research, planners and decision makers are becoming more hesitant to grant permits or authorize money for structures.

Any large engineering structure placed on a beach is going to interact to some degree with the physical processes operating in this high energy environment. Without question, the construction of the numerous jetties and breakwaters along the Atlantic, Gulf and Pacific coastlines of the United States have produced significant shoreline change. The very reasons for building these structures is to alter the physical processes, such that protected and stabilized channel entrances or safe harbors were created. Rip-rap revetments, and seawalls are similarly built to alter or mitigate wave impact on the shoreline.
The impacts of seawalls or revetments on beaches are becoming clearer as a result of field studies in recent years and need to be understood and considered before additional armoring plans or projects are developed and approved. These impacts are threefold (Griggs, et al., 1997):

- **Impoundment or Placement Loss**: This effect is the most straightforward and predictable. When a structure is built seaward of the base of the bluff, cliff, or dune, well out on the beach profile, a given amount of beach is covered (Figure 14). Thus the effect is immediate beach loss; the extent of the loss being a function of how far seaward and alongshore the structure extends. Along the margin of northern Monterey Bay, California, for example, seawalls were built 100 to 250 feet seaward of the base of the bluff in order to allow homes to be built on the back beach. As a result, from Beach Drive in Rio Del

![Diagram](image)

(A) Beach without any coastal protection structures.

![Diagram](image)

(B) Beach impoundment due to construction of seawall and home.

![Diagram](image)

(C) Beach impoundment due to construction of revetment.

*Figure 14 Examples of beach loss through placement of protective structures*
Mar to Via Gaviota in Aptos Seacape, 100 to 250 feet of beach was permanently lost along one mile of coastline.

When a narrow vertical seawall is built against the base of a bluff or dune, however, there is essentially no placement loss. On the other hand, where a revetment is constructed to protect a bluff, it may reach a height of 20 feet or more, and extend seaward at a 1.5:1 or 2:1 slope, thus displacing or covering 30 to 40 ft of beach (Figure 4). Placement loss can easily be determined for any proposed revetment if the cross-sectional and alongshore dimensions are known.

- Passive Erosion: Whenever a hard structure is built along a shoreline undergoing long-term net erosion, the shoreline will eventually migrate landward beyond the structure (Figure 15). The effect of this migration will be the gradual loss of beach in front of the

![Diagram of initial shoreline profile showing beach width.](image)

![Diagram of shoreline profile after sea level rise and associated dune or bluff erosion. Although shoreline has migrated landward, beach width remains the same.](image)

![Diagram of shoreline profile following sea level rise where seawall has fixed shoreline position. Note reduced beach width.](image)

Fig. 15 Example of beach loss through passive erosion following placement of a seawall.

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seawall or revetment as the water deepens and the shoreface profile moves landward. This process is designated as passive erosion and appears to be the process which has been documented along many of the barrier islands of the Atlantic coast. As barrier island shorelines erode and migrate, threatening homes and property, seawalls are often constructed for protection. As landward migration of the unprotected portions of the islands continues, in part due to sea level rise, the beach profile also migrates landward, resulting in beach loss in those locations where the shoreline has been fixed by a hard structure (Tait and Griggs, 1990). Passive erosion has also been documented in the Monterey Bay area (Figure 4) where large amounts of rock have been placed to protect a bluffs top building on a military base. While a beach is present on either side of the rubble wall, the sand is now underwater in front of the rock and the beach has disappeared. This process of passive erosion appears to be a generally agreed upon result of fixing the position of the shoreline on an otherwise eroding stretch of coast, and is independent of the type of seawall constructed.

Thus, “protecting the shoreline” where it refers to armoring an eroding cliff or bluff, does not “preserve the beach” and in fact, with continuing coastal retreat and/or sea level rise, protecting the shoreline will lead to loss of the beach.

- Active Erosion: The ability or potential for a seawall or revetment to induce or accelerate erosion has been the source of most of the controversy over the past decade regarding the impacts of seawalls on beaches. Although different scientific opinions have been put forward regarding the impacts of these structures on adjacent beaches, there has, until recently, been a lack of field data with which to resolve the conflicting claims.

In an effort to resolve the issues of impacts due to active erosion, we initiated a program of field monitoring in northern Monterey Bay in 1986 with funding from the Engineering Performance of Coastal Structures Research Unit of the Coastal Engineering Research Center. Beach profiles were surveyed at several different seawalls as well as at adjacent control (unarmored) beaches over an eight year period. The objectives were to document the impacts of seawalls on the beach during the seasonal erosion/accretion cycle and to identify any long-term trends. The following conclusions from this work are based on the study of a beach which undergoes significant seasonal changes, but is not undergoing any net retreat over the 8 year study period, and also a shoreline characterized by ~300,000 cubic yards/year of littoral drift (Griggs, et al., 1997).

A number of consistent beach changes related to the seawalls studied were recognized during the long term monitoring. During the transition from summer to winter beach state, the berm is cut back preferentially in front of the seawalls relative to the adjacent unarmored beaches. Once the berm has retreated landward of the seawall, there are no significant differences between the beaches fronting the wall and those from the adjacent control beach. Repeated surveys and comparisons at both an impermeable vertical seawall and a sloping revetment indicate little consistent difference in profile response due to differences in permeability. Either the apparent differences in permeability of the two structures are not significant to wave reflection, or the importance of reflected wave energy to beach scour needs reconsideration.

Scour was often observed at the downcoast end of each structure as a result of wave reflection from the end section of the seawall. The extent of scour appears to be controlled by end section or return wall orientation, the angle of wave approach, and wave height and period. Surveys of the spring and summer accretionary phase indicate that the berm advances seaward on the control beach until it reaches the seawall. At that point, a berm
begins to form in front of the seawall and subsequent accretion occurs uniformly on both beaches. Thus, while the winter erosional phase is influenced to some degree by the presence of a seawall, this is not the case for the berm rebuilding phase.

Of perhaps greatest significance, at this location, is the comparison of time-averaged winter and summer beach profiles for the seawall-backed and control beaches (Griggs, et al., 1997). Comparison reveals no distinguishable differences between the winter profile for the seawall and control beaches and the summer profile for these same beaches.

A PLAN FOR ACTION AT THE STATE LEVEL
The storm damage, both during El Niño and non-El Niño winters of the past two decades, indicates that significant changes are needed in how we approach and deal with coastal hazards and the continuing pressure to develop in oceanfront areas of California. The past inconsistencies among local governments and state agencies who have responsibilities to regulate development indicate the lack of a guiding direction and the heavy influence of local economics and politics.

Through a process of hazard recognition and evaluation, followed by a standardized set of avoidance, mitigation or hazard reduction policies, the private and public losses from future shoreline erosion, El Niño and storm impact and sea level rise can be significantly reduced (Griggs, Pepper and Jordan, 1991). The objective is to reduce the number of people, as well as dwellings, structures, and utilities, both public and private, directly exposed to the hazards of both shoreline erosion and wave impact and inundation. The model of the Alquist-Priolo program, which established Special Studies Zones along California's active faults is an appropriate one to follow for the coastline.

The modest funding required to implement an Alquist-Priolo type program along the shoreline would have a high benefit-cost ratio. Initial investigations would establish the general hazard zones which would then be delineated on official state maps. Any development or significant changes in land use proposed within these areas at the local government (private or public) or state level would require complete geologic hazard investigations, report review by an independent qualified professionals, and appropriate setbacks and mitigation measures where appropriate.

The reduction of both risk exposure and public and private economic losses from geologic hazards in the coastal zone are objectives which need to be realized. The Coastal Act as well as the subsequent Interpretive Guidelines focused on what were deemed to be the critical issues of the time but were deficient in treating geologic hazards. Although some local governments have been effective in dealing with these issues, there are often inherent political and economic constraints at the local level which hinder effective land use regulation. A state level mandate, parallel to the Alquist-Priolo program, which provides a consistent, efficient, and streamlined approach for land use regulation in hazardous coastal areas can accomplish those objectives.

REFERENCES

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