GRIGGS 131

California's Retreating Coastline: What Next?

Gary B. Griggs [1]

Abstract: The coast of California is retreating in response to a continuous sea level rise over the past 18,000 years. Of more immediate concern to California, however, are the impacts of severe El Nino events, specifically, large storm waves and elevated sea levels as we experienced in 1982-83 and 1997-98. The state's coastal property values are at all time highs, with houses literally on the sand for sale in the $5-$10,000,000 range. While the entire state's shoreline has migrated eastward 5-15 miles over the past 15,000 years, because of the investment and high property values, significant public and private funds have been expended in efforts to slow or halt any additional retreat. Our future options are limited, however, and they need to be both sustainable and cost-effective over the long term.

Over the past 50-75 years, the typical response to coastal retreat has been the construction of seawalls or revetments. Seawalls, however, which have a number of impacts, are designed to protect bluffs and cliffs, not to preserve beaches. Thus a conflict has developed between cliff-top homeowners and the public who use the fronting beaches. While some states have banned all new hard protective structures, proposals for new seawalls in California are still frequent but face increasing public opposition. Simultaneously, local governments have organized with the help of lobbyists to push for funding for beach replenishment and nourishment. While there have been millions of cubic yards added to the beaches of southern California from large coastal construction projects, there have been very few sites to date where sand was imported solely for nourishment. Due to the high littoral drift rates that characterize California's coast, it can be expected that the life span of nourished beaches in most locations will be relatively short. While artificial beach nourishment is very expensive and short lived, trapping the sand so that more of it stays on the beach could provide greater long-term benefits. Many of California's beaches exist because of littoral barriers such as headlands that serve as groins. Trapping this sand on the beaches would provide significant and sustained benefits as would the release or removal of the large volumes of sand trapped behind the many stream impoundments.

---

1. Director - Institute of Marine Sciences, University of California, Santa Cruz

Introduction to the Problem

California's coastline, like its fisheries, is approaching a crisis point. This has resulted from a combination of natural processes and cycles, combined with human intervention and population growth. The coast of California is the meeting place of human migration and development on the one hand, and wave attack, cliff retreat, rising sea level, El Nino events, and sand supply reduction and disruption on the other.

The shoreline of California, as well as most of the rest of the world, is retreating in response to a continuous rise in sea level over the past 18,000 years. While sea level rise rates have slowed over the last 3000-5000 years, there is no indication that this will subside in the near future; in fact, most scientists predict an increase in this rate due in large part to the continuing production of greenhouse gases by an expanding industrial civilization.

Sea level is as high today as it has been for the past 125,000 years. Tide gauges around the world indicate a global rise of about a foot over the past century due to a combination of the melting of ice caps and glaciers, and also to thermal expansion as the waters of the ocean warm. The best estimates of sea level rise in this century are about three feet above the present. While there are ~100 million people globally living within three feet of sea level who would be driven inland by such an increase, 125,000 years ago sea level was about 15 to 20 feet higher. The impacts of a rise of this magnitude are difficult to contemplate. Yet coastal populations worldwide, as well as in California, need to realize that continued sea level rise and shoreline retreat is a reality and that we need to make decisions on both present shoreline structures and future land use with this in mind.

Of more immediate concern to California have been the impacts of severe El Nino events, specifically large storm waves and elevated sea levels such as those we experienced in 1982-83 and 1997-98. The beginning of a 25-year long period of more frequent El Nino Southern Oscillation (ENSO) events in 1978 altered our perception of coastal hazards in California. The preceding three decades (~1945 to 1978) was an era generally characterized by a cool or La Nina phase and less frequent large coastal storm events, lower average precipitation and overall less severe climate and hazards along California's coast. Over the past 25 years, however, the El Nino phase that has dominated the Pacific Basin has taken a large toll on California's coastal development. The 1983 event was a wakeup call and led to $180,000,000 (2002 dollars) in damage along the state's coastline (Griggs and Savoy, 1985; Storlazzi, Willis and Griggs, 2000; Storlazzi and Griggs, 2002).

While severe beach erosion occurred along the central California coast during the more recent 1997-98 El Nino event, within a year, all of the beaches surveyed had essentially returned to their previous widths (Figure 1a,b,c; Brown, 1998).

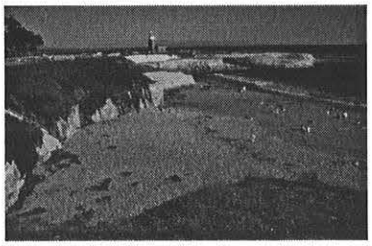

Figure 1a. Beach West of Pt. Santa Cruz (Its Beach) before the 1997-98 El Nino.

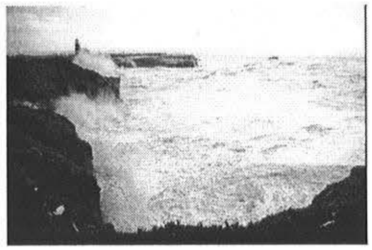

Figure 1b. Its Beach in February 1998

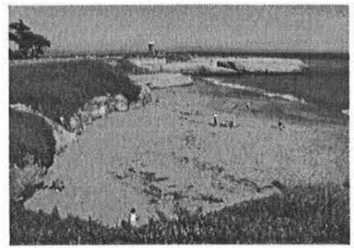

Figure 1c. Its Beach following the 1998 El Nino.

However, it was the cliff or bluff erosion, which is non-recoverable and where major losses occurred in both 1982-83 and 1997-98 that continues to concern us. A combination of new state residents with a desire to live on the coast, astronomical prices for coastal land and homes, and perhaps short disaster memories and political pressure have led to continuing development of oceanfront property (Figure 2).

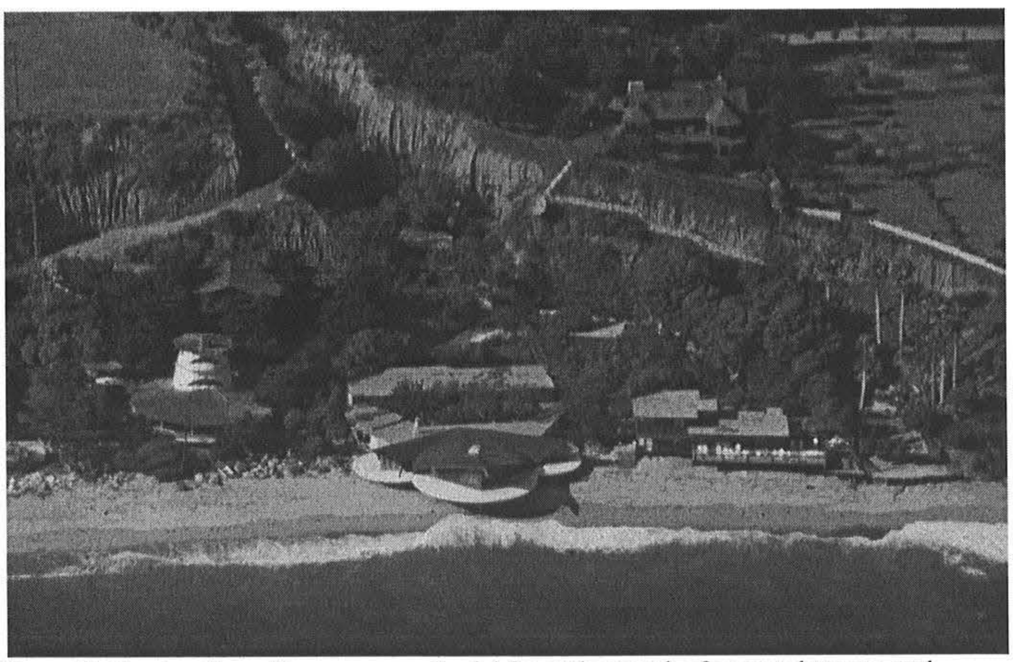

Figure 2. Construction of homes on an alluvial fan at the mouth of a coastal stream, and on the beach at Malibu.

California's population reached 35 million in 2002, a doubling s`ince 1965. The state's coastal property values are at all time highs, with houses literally on the sand for sale in the $5-$10,000,000 range (Figure 3). While the entire state's shoreline has migrated eastward 5-15 miles over the past 15,000 years, because of the investment and high property values, significant public and private funds have been expended in efforts to slow or halt any additional retreat. Our future options are limited, however, and they need to be both sustainable and cost-effective over the long term. The lack

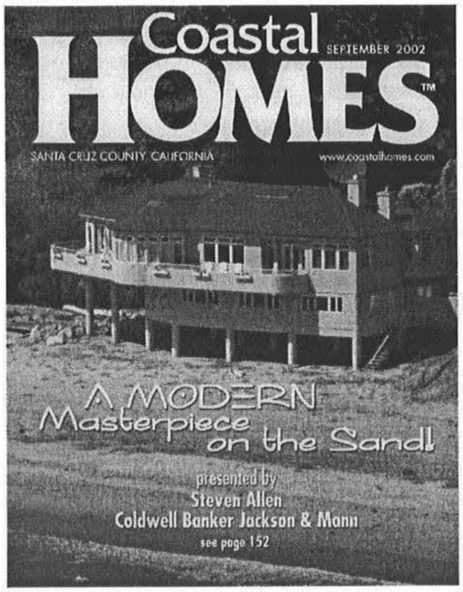

Figure 3. Advertisement for a house for sale on the beach of Northern Monterey Bay for $9,900,000.

of any certainty in the maximum elevation that sea level will ultimately rise to, or knowledge of when this will occur, make if very difficult to develop sensible and balanced long-term strategies for responding to coastal erosion. In addition, the slow rate of this inundation gives sea level rise a low priority in the perceptions of most coastal residents.

Options for the future

Relocation

Most oceanfront residents and government agencies that have some shoreline stake or responsibility have responded to the damage and losses of the recent past with proposals for reconstruction or repair of structures or infrastructure, and seawalls or revetments. In a few severe cases, homes or infrastructure have actually been relocated or abandoned (Figure 4a and 4b).

To date, however, relocation or retreat has not been a popular solution for oceanfront homeowners who understandably don't want to lose their house site or view. There are many sites along the coastline of California, however, where there are simply no other reasonable options and with continuing erosion, this choice will confront more and more homeowners (Figure 5).

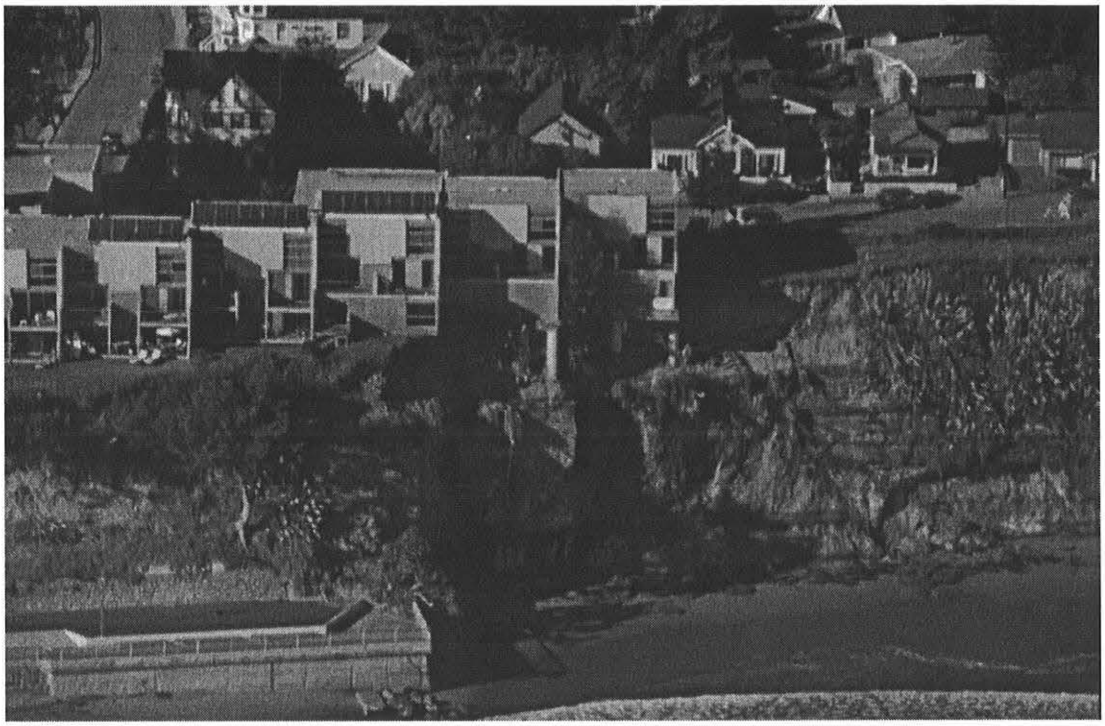

Figure 4a. An apartment complex overhanging the cliff edge in Capitola before the 1989 Loma Prieta earthquake.

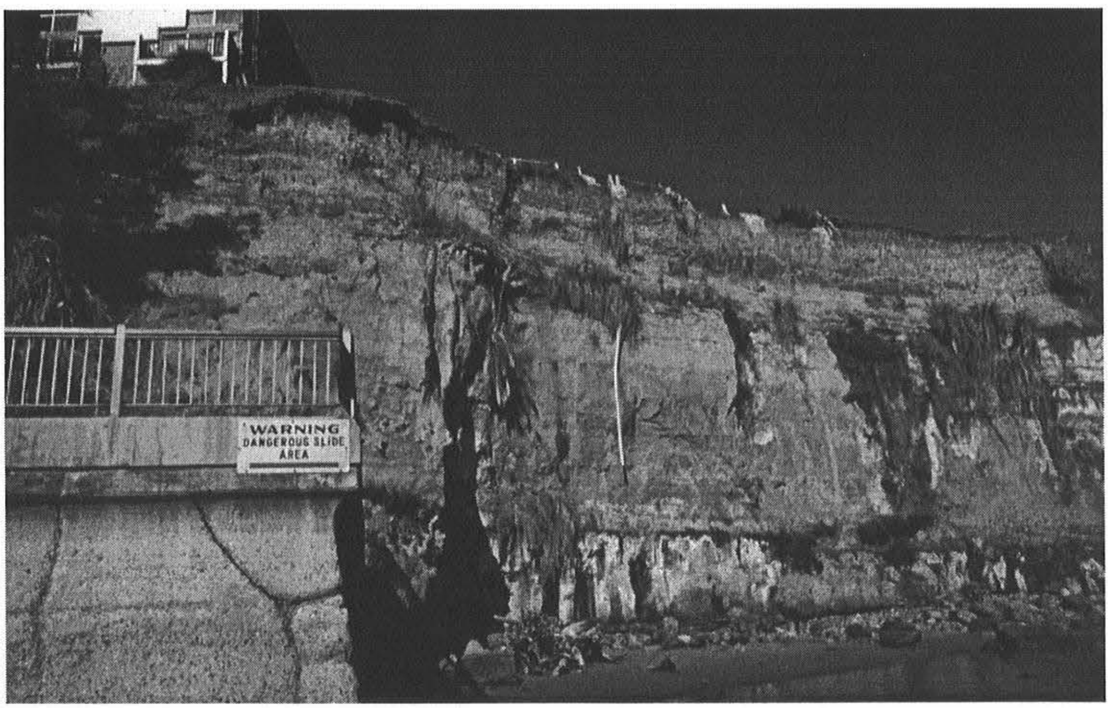

Figure 4b. The same site after the earthquake when six units had been demolished.

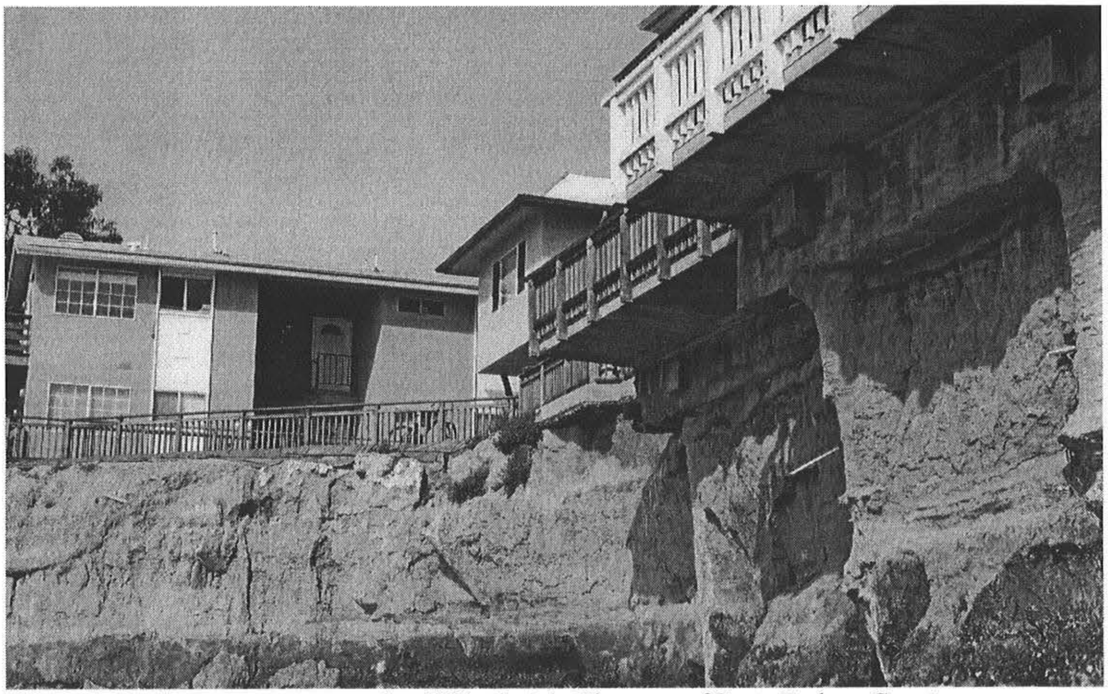

Figure 5. Undercut apartments on the cliff in the Isla Vista area of Santa Barbara County.

Armor

Over the past 50-75 years, the typical response to coastal retreat has been the construction of some armoring structure, usually seawalls or revetments. Twenty-seven miles of the California coast was armored in 1971, and by 1998 this had increased to 110 miles (10.3%), a four-fold or 400% increase in 27 years.

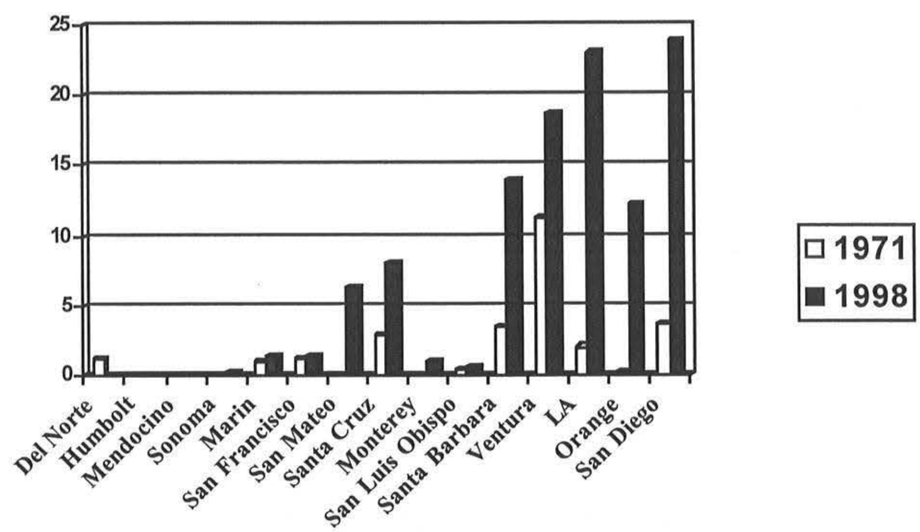

Figure 6. Runyan and Griggs, 2002
The number of miles of coastline armored by county in 1971 and 1998

Armoring is far more extensive in Southern California, however, with 34% of the combined coastlines of Ventura, Los Angeles, Orange and San Diego counties having now been protected by seawalls or rip-rap. Even armoring, however, is not a permanent solution, and even if done well, can be very expensive to install and maintain, and like any structure, will eventually fail (Fulton-Bennett and Griggs, 1986). Typical 2002 costs are in the range of $2000-$6000/front foot depending upon the type and size of the structure. Seawalls and rip-rap, however, are designed to protect bluffs and cliffs, not to preserve beaches. Thus a conflict has developed between bluff or cliff-top homeowners and the public who use the fronting beaches as well as the permitting agencies who must deal with these issues.

A number of significant concerns have been raised about seawalls over the past two decades, including visual impacts, restrictions on beach access, reduction of sand supply, and the loss of beach beneath or in front of seawalls due to placement losses and "passive erosion" (Griggs, 1999; Figures 7, 8).

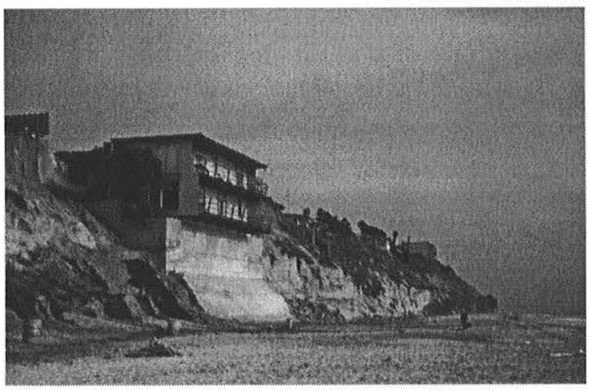

Figure 7. Bluff protection at Moonlight State Beach in Orange County.

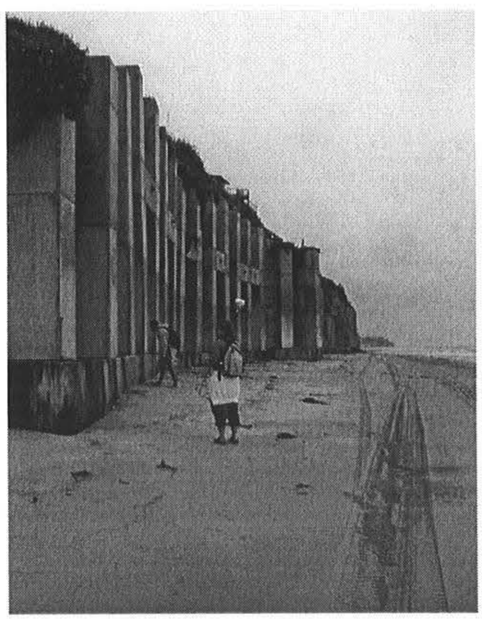

Figure 8. Large seawalls can significantly restrict direct beach access.

Among the most significant in terms of beach impacts are placement losses and passive erosion (Figure 9, 10). These raise the issue of to what degree private property owners should be allowed to impact public beaches in order to protect their own cliff or bluff top property. Or, in the case of government-funded projects, how much taxpayer's money should be spent on attempts to stabilize the position of an otherwise eroding coastline if it means beach loss or other impacts?

Figure 9. The placement of a large revetment will lead to the direct loss of much of the beach due to beach area taken up by the rock.

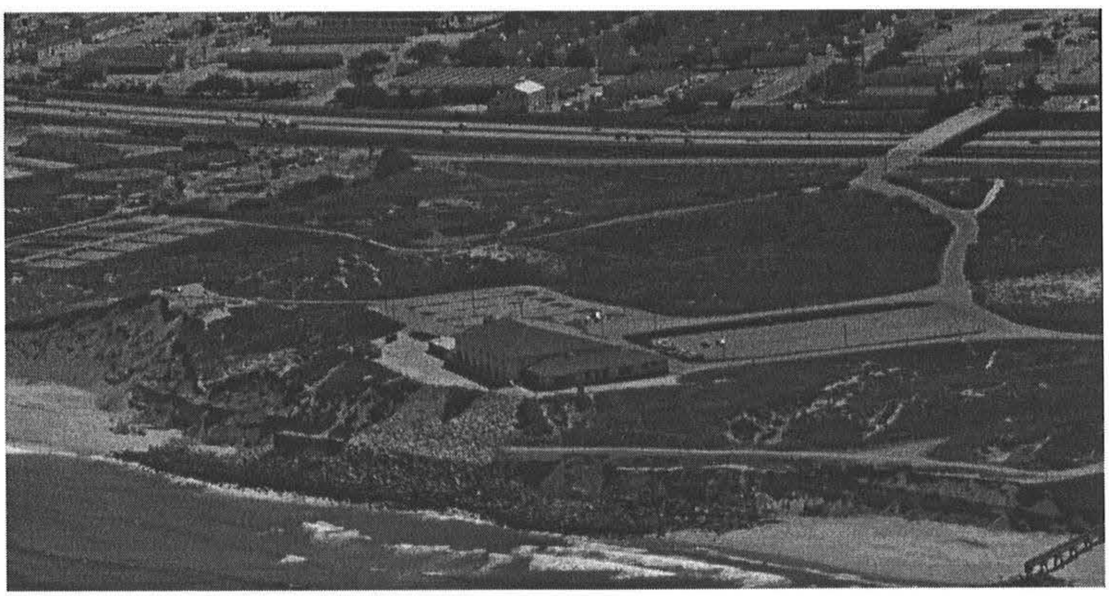

Figure 10. Passive erosion in the Ft. Ord area of central Monterey Bay. A beach still exists to either side of the rip-rap because the sandy bluffs have continued to erode. In front of the rip-rap, however, the beach has been lost due to passive erosion.

While several states have banned all new hard protective structures, proposals for new seawalls and revetments in California are still frequent but face increasing public opposition and agency scrutiny. The continued widespread reliance on protective structures and the scale of controversies they generate is in part a result of limited, ambiguous, and in some cases, conflicting policies set forth in the Coastal Act.

Beach replenishment, nourishment and retention

Wide beaches are the best natural buffers to coastline erosion although beaches will not halt a rise in sea level. As sea level continues to rise the shoreline will migrate, and in the absence of human intervention, the beach will migrate with the shoreline. California had beaches when the shoreline was 10 to 15 miles to the west 15,000 years ago, and in most places we still have beaches today.

However, beach sand delivery to the California coast has been seriously impacted (Coyne and Sterrett, 2002) and the shoreline has been hardened to prevent coastal erosion or shoreline migration. The greatest impacts have been in southern California where dams, reservoirs, debris basins and sand extraction have significantly reduced the natural flow of sand from the rivers and streams that historically provided 85 to nearly 100% of the beach sand. The most comprehensive study to date indicates, for example, that the fluvial sand supply to the Santa Barbara Cell has been reduced by 40.5%, to the Santa Monica Cell by 26%, to the San Pedro Cell by 66%, and to the Oceanside Cell by 53.8% (Willis, Lockwood and Sherman, 2002). In addition, 34% of the coastline of Ventura, Los Angeles, Orange and San Diego counties has been hardened or armored which, with a continuing rise in sea level, leads to passive erosion of the beach (Griggs, 1999).

Local governments have organized with the help of lobbyists to push for funding for beach replenishment and nourishment. Their objectives are to widen or rebuild beaches that could provide increased recreation area for both tourists and residents, and also help buffer the shoreline from wave attack. Arguments have been made that the beaches of California are eroding due to sand supply reduction. While significant impoundment of upstream sand supplies from the streams draining into the littoral cells of southern California has been well documented, it is not clear that this reduction has been directly reflected in sand supply at the coastline. To date, there have been no long-term documented or published records of systematic regional change in beach width or volume. The artificial widening of many beaches between the 1940's and the 1960's due to sand nourishment from the many large coastal construction projects, however, complicates any evaluation of long-term beach change in southern California. The beaches of the Santa Monica cell, for example, have been gradually returning to their natural widths at a time when sand reduction from dams and other diversions, and a return to more frequent and severe ENSO events, have significantly impacted the beaches of portions of southern California.

While there have been millions of cubic yards of sand added to the beaches of southern California over the past half century as a consequence or side effect of large coastal construction projects, there have been very few sites where sand was imported solely for nourishment. One of the first relatively large-scale beach nourishment projects was completed by SANDAG in 2001 after years of planning. This project dredged a total of 2 million yds^3 of sand from six offshore sites and placed it on 12 San Diego County beaches at a cost of $17.5 million, or $8.75/yd^3. Beach surveys, however, indicated by early 2002 that much of the sand had already been transported offshore or downcoast. Due to the high littoral drift rates that characterize California's coast (Table 1), it can be expected that the life span of nourished beaches in most locations will be relatively short.

A number of questions need to be answered before any large-scale artificial nourishment effort is undertaken. Are there available sources of large volumes of compatible sand? What are the impacts of removing, transporting and depositing the sand and are these acceptable? What are the costs of nourishment and now frequently will this have to be done? What is the life span of the nourished sand on the beach? And, is this a solution or response that is sustainable over the long term?

Table 1. Littoral Drift Rates along the California Coastline

Location	Littoral Drift Rate
Santa Cruz	~300,000 yds^3/yr
Santa Barbara	~300,000 yds^3/yr
Ventura	~600,000 – 1,000,000 yds^3/yr
Santa Monica	~275,000 yds^3/yr
Oceanside	~350,000 yds^3/yr

Replenishment through natural sources of sand is another approach being currently considered. The large volumes of sand now impounded behind dams and trapped in debris basins in southern California are a natural source of sand that is now being looked at carefully (Willis, Lockwood and Sherman, 2002). In particular, the Matilija Dam on the lower Ventura River and the Rindge Dam on Malibu Creek are essentially filled with sediment such that any water storage or flood control capacity has been reduced to insignificant levels. While studies are underway that are evaluating different approaches for dam removal and for transporting sand to the coast, environmental issues may take a number of years and millions of dollars to resolve. While dam removal is a logical, sensible and sustainable solution, the first major dam has yet to be removed.

Sand Retention

While artificial beach nourishment is very expensive and short-lived, trapping the existing littoral sand so that more of it stays on the beach could provide less expensive and more sustainable long-term benefits. Everts and Eldon (2000) recently reported that over 75% of the beaches in southern California exist because of littoral barriers. Two-thirds of those are natural structures such as rocky headlands, submerged reefs, rocky stream deltas or other types of irregular bathymetry that serve as natural groins. The remaining third are artificial barriers such as jetties, groins and breakwaters. The coast of central California is similar in that many of the beaches exist because of natural or artificial littoral drift barriers (Figure 11).

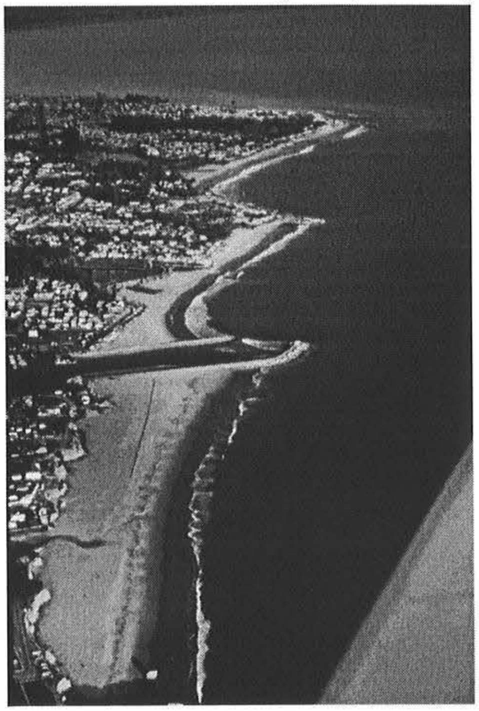

Figure 12. A rocky headland serves as a natural groin in San Mateo County.

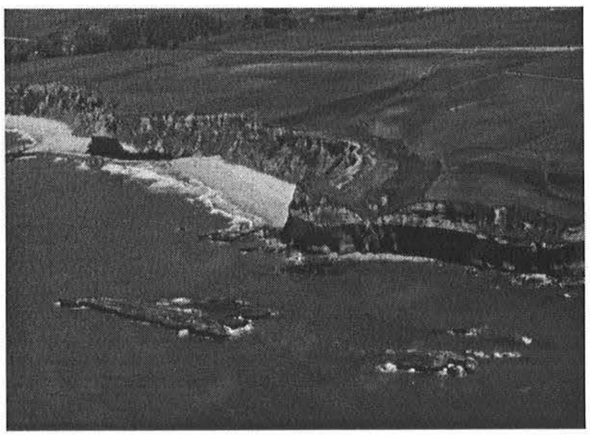

Figure 11. The beaches of Santa Cruz have been created as a result of sand impoundment upcoast of a jetty, and two natural headlands.

There are about 95 miles of shoreline between the Golden Gate and northern Monterey Bay and 30% of this consists of beaches, pocket beaches typically found at the mouths of coastal streams and in many places bounded by rocky headlands (Figure 12).

Groins have been successfully used at a number of locations in California, either individually (Figure 13) or as a group or a groins field (Figure 14). Groins, however, have often been thought of in association with much larger breakwaters and jetties as coastal engineering structures that have produced major downdrift impacts. Without question, the jetties and breakwaters that have created cost of California's harbors and marinas have had major impacts on littoral drift. As a result of this connection, groins have fallen into general disfavor in recent years and aren't often considered as viable solutions for either beach stabilization or as part of beach replenishment or nourishment projects. While there are a number of critically important site and design considerations and precautions involved with any groin project, they do basically mimic natural systems and become short artificial headlands. As such, they trap sand and either create beaches where they previously didn't exist or serve to widen existing beaches.

Groins are inherently flexible; they can be of different lengths, heights, and materials, made permeable or impermeable, and even constructed to look like the native bedrock (Figure 15). Siting, length and spacing of groins, and recharging of groins subsequent to construction are all necessary design issues to resolve at the onset. In either case, they do have the potential to reduce the problems or impacts of seasonal beach erosion or slow long-term cliff erosion.

There are many locations along the state's coastline where groins or other barriers could be built and initially charged with sand that could provide significant recreational area and shoreline protection. Hundreds of thousands of cubic yards of sand permanently leave California's beaches each year through submarine canyons. Best estimates are that, on average, ~1,800,000 yds^3 leaves the Santa Barbara Cell through Mugu and Hueneme submarine canyons, and ~350,000 yds^3 leaves the Oceanside Cell each year through Scripps and La Jolla submarine canyons (Runyan and Griggs, 2002). Trapping this sand on the beaches would provide significant and

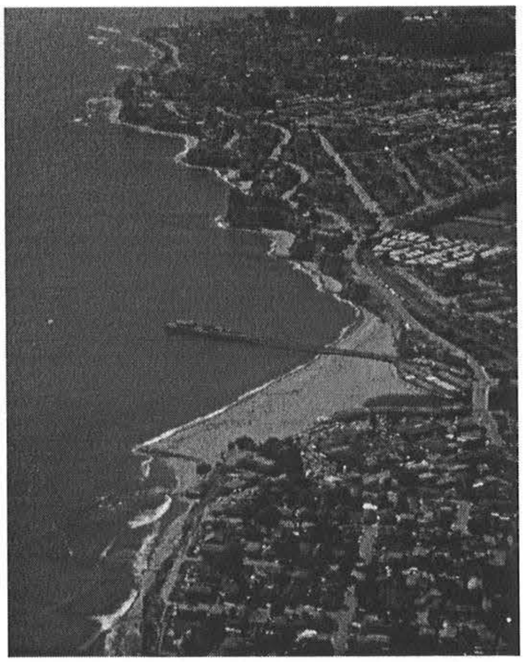

Figure 13. A groin was built at Capitola and artificially recharged to rebuild and stabilize the beach lost when an upcoast harbor was built.

Figure 14. A groin field constructed at Ventura has been successful in widening and stabilizing the beach.

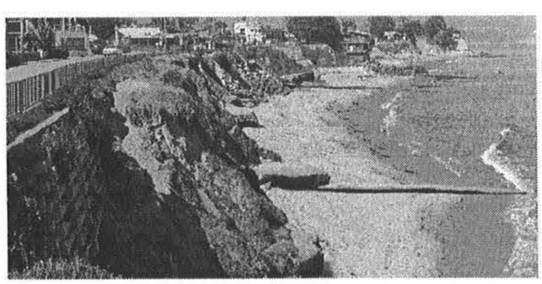

Figure 15. A visual simulation of the effect of groins proposed as extensions of natural rock points to help reduce erosion of a section of cliffs in Santa Cruz.

sustained benefits as would the release or removal of the large volumes of sand trapped behind the many stream impoundments that exist in southern California. To the degree that we can repair and replicate natural systems and also let natural processes do the necessary work of delivering sand, the shoreline of California will be better able so sustain its beaches.

REFERENCES

Brown, K.W., 1998. *The effect of the 1997-98 El Nino winter on beach morphology along the Santa Cruz County coastline*. Unpub. M.S. thesis, University of California, Santa Cruz, Earth Sciences Dept.

Coyne, M. and Sterrett,K. 2002. *California Beach Restoration Study*. Department of Boating and Waterways and State Coastal Conservancy, Sacramento, Ca.

Everts, C.H. and Eldon, C.D., 2000. Beach-retention structures and wide sandy beaches in southern California. *Shore and Beach* 68:3:11-22.

Fulton-Bennett, K.W. and Griggs, G.B., 1986. *Coastal Protection Structures and their Effectiveness*. Joint publication of California Department of Boating and Waterways and Institute of Marine Sciences, University of California, Santa Cruz, 48p.

Griggs, G.B., 1999. The protection of California's coast: past, present and future. *Shore and Beach* 67:1:18-28.

Griggs, G.B. and Savoy, L..E., 1985. *Living with the California Coast*. Duke University Press, Durham, N.C. 393p.

Runyan, K.B. and Griggs, G.B. 2002. *Contributions from coastal cliff erosion to the littoral budget*. In: California Beach Restoration Study, ed. By M. Coyne and K. Sterrett, Department of Boating and Waterways & State Coastal Conservancy, Sacramento, Ca. pp. 8.1 – 8.51.

Runyan, K.B. and Griggs, G.B., 2002. *Net/Gross Longshore Transport Rates, California*. Coastal and Hydraulics Engineering Technical Note, U.S. Army Corps of Engineers, 47p.

Storlazzi, C.D. and Griggs, G.B. 2000. The influence of El Nino-Southern Oscillation (ENSO) events on the evolution of central California's shoreline. *Geological Society of America Bull.* 112:2: 236-249.

Storlazzi, C.D., Willis, C.M. and Griggs, G.B., 2000. Comparative impacts of the 1982-83 and 1997-98 El Nino winters on the central California coast. *Journal of Coastal Research* 16:1022-1036.

Willis, C.M., Lockwood, B., and Sherman, D., 2002. *Impediments to the fluvial delivery of sediment to the shoreline.* In: California Beach Restoration Study, ed. by M. Coyne and K. Sterrett, Department of Boating and Waterways & State Coastal Conservancy, Sacramento, Ca. Pp. 7.1-7.48.