TODD T. CARDIFF, ESQ.
ATTORNEY AT LAW

121 BROADWAY
SUITE 358
SAN DIEGO CA
92101

T 619 546 5123
F 619 546 5133

cardifflaw@cox.net

February 18, 2010

Delivered via first class mail and email

Planning Department
City of Carlsbad
ATTN: Van Lynch
1635 Faraday Avenue
Carlsbad, CA 92008
Van.lynch@carlsbadca.gov

RE: Geotz Seawall (CDP 09-13)
Comments on Negative Declaration

Dear Van Lynch,

Thank you very much for your time and accepting these comments. I am a member of the Advisory Board of the San Diego Chapter of the Surfrider Foundation. The Surfrider Foundation is a non-profit, grassroots organization dedicated to the preservation of the world's ocean's waves and beaches. We have over 50,000 members in 90 chapters world-wide, including in Japan, Brazil, Australia and Europe. The San Diego Chapter is the largest and oldest chapter in the United States.

First, we request the City of Carlsbad hold the comment period open for another twenty days. I was informed today that Dustin Rosa, one of the activists that opposed the project did not receive notice of the negative declaration/initial study. He was one of the original opponents of the emergency seawall permit and spoke at the City Council. His comments should be considered.

In addition, I am informed and believe that the Coastal Commission has not had a chance to submit comments within the 20 day time frame, and has not been consulted regarding the impacts of this seawall. (Pub. Res. Code § 21080.3.) Clearly, the Coastal Commission, which has appeal jurisdiction over the seawall, and has original jurisdiction to the south and below mean high-tide line, should have been consulted regarding the impacts the seawall would have on State's lands.

Secondly, it appears that the initial study is deficient in its review of the significant impacts of seawalls. Seawalls eventually destroy beaches through a process called passive erosion. Passive erosion is defined as the loss of beach caused by fixing in place the back end of the beach on an eroding shoreline. The high tide continues to migrate landward, but the natural erosion of the bluff is stopped by the seawall. The dry sand area of the beach is squeezed and lost when the migrating high-tide intersects with

the seawall. Eventually, as the beach continues to erode, there is no dry sand even at medium to low tides.

This is especially disconcerting at the location of this project. The project is located just north of a public access stairway. The public will eventually lose access traveling north along the beach. While the seawall may not immediately block access, the eventual loss of the beach is a given, and will block off anything to the north of stairway. There is a significant impact on recreation.

In addition to passive erosion, seawalls have "end effects" meaning that seawalls actually increase the erosion to the natural bluff at the end of the seawall. There is nothing in the initial study which describes these end effects and how it proposes to mitigate such effects.

I also note that there is nothing in the initial study which describes the mitigation for the loss of sand that would normally be contributed to the beach through erosion. However, it should be noted that all the current sand mitigation programs are not effective in mitigating the loss of beach. First, the SANDAG mitigation program is not guaranteed to put sand at the project site. In addition, such massive sand replenishment project cost 17 million dollars and was only effective at widening the beach for five years. This seawall must consider the impacts over the life of the structure.

Finally, as indicated in my earlier correspondence, a cumulative analysis of the impacts caused by seawalls should be conducted. The loss of sand, beach access and wildlife habitat is significant. It is very important for the City to prepare an EIR to determine whether the risks to the beachgoers is so great that they wish to approve a seawall (as opposed to one of the many alternatives) that will destroy the beach.

To aid in your analysis of potential impacts, I have attached a law review article published in 2007 by Meg Caldwell and Crag Segall in Ecology Law Quarterly. Meg Caldwell was chair of the California Coastal Commission and director of the Natural Resources Law and Policy Program at Stanford Law School. Please consider her analysis of seawalls.

Sincerely,

Todd T. Cardiff, Esq.

Dear Todd,
Thank you for everything you have done to protect our coast. Meg

No Day at the Beach: Sea Level Rise, Ecosystem Loss, and Public Access Along the California Coast

Meg Caldwell[*] *and Craig Holt Segall*[‡]

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[*] Meg Caldwell is Senior Lecturer in Law and Director of the Environmental and Natural Resources Law and Policy Program at Stanford Law School and a Senior Lecturer at Stanford's Woods Institute for the Environment. From 2004 to 2006 she served as chair of the California Coastal Commission, as a member of the board of the California Coastal Conservancy, and as a member of California's Marine Life Protection Act Blue Ribbon Task Force. This paper grew out of remarks delivered at a conference on "Litigating Takings" sponsored by the Georgetown Environmental Law & Policy Institute, the Georgetown University Law Center, the California Center for Environmental Law & Policy, and the Boalt Hall School of Law at the University of California Berkeley; the authors thank all the organizers. The authors are grateful for the comments, research suggestions, and case updates generously provided by Joseph Barbieri, Peter Douglas, John Echeverria, Jonathon Gurish, Gary Griggs, Lesley Ewing, Ralph Faust, Jason Malinsky, Alice Reynolds, Casey Roberts, Matt Rodriguez, Hope Schmeltzer, Stephen Schneider, Sam Schuchat, Jennifer Seidenberg, James G. Titus, and Sara Wan which greatly improved this paper. Any errors that remain are decidedly the authors' own. The views expressed in this Article are those of the authors and should not be attributed to any agency or department of the state of California. Please direct all correspondence to megc@stanford.edu.

[‡] Craig Holt Segall graduated from Stanford Law School in May 2007. He earned his degree in biology specializing in ecology and evolution from the University of Chicago and has worked for NRDC, Environmental Defense, and Earthjustice. He hopes that his children will be able to enjoy a diverse and vital California coast.

INTRODUCTION: CLIMATE CHANGE AND THE COAST

The sea is rising. All along the hundreds of miles of the California coast, global warming will cause higher water, more powerful storms, and increased coastal erosion.[1] The California Coastal Commission and its predecessor regional commissions have worked to protect the state's coastal resources since the Commission's creation by voter initiative in 1972 and formalization in the California Coastal Act of 1976. Climate change–induced sea level rise presents the Commission—and all those who use and value the state's coastal resources—with a stark new set of challenges.[2]

As sea level rises, pressure to armor the coast will grow. The bluffs and cliffs of the California coast may appear stable, but they are, in many places, riven with faults, joints, and fractures, and are often composed of unstable rock. Battering winter storms and high tides have and will continue to cause bluff collapse and the loss of structures built upon bluffs. Property owners, if allowed to do so, will attempt to forestall the inevitable with seawalls, rock revetments, and other barriers to the sea. But these walls, though temporarily freezing the coast in place, will have significant social and ecological costs. Beaches below the walls may be eroded away, or the thin ribbon of sand remaining will be blocked from the public by massive shoreline protection structures. Where estuarine marshes, which provide significant nursery habitat for many marine species, are threatened by sea level rise, coastal armoring will prevent marsh migration, leading to the eventual loss of ecosystem function. All along the coast, the dire effects of climate change may be amplified by the effects of shoreline armoring.

1. *See generally* DAN CAYAN ET AL., CAL. CLIMATE CHANGE CTR., PROJECTING FUTURE SEA LEVEL (2006) [hereinafter PROJECTING FUTURE SEA LEVEL RISE].

2. While both "global warming" and "climate change" are used interchangeably in the popular press, we use the term "global warming" to refer to the direct increase in temperature associated with increasing greenhouse gas concentrations. By "climate change," we mean the larger complex of changes in weather patterns associated with this warming.

Yet, the California Coastal Commission and the state of California can begin now to plan for sea level rise. Although future warming may be reduced if major global efforts are initiated soon, it cannot be wholly prevented, thereby imposing significant responsibilities upon the stewards of the coast. Sea level rise is an enormously complex public policy problem; this Article is intended only as a starting point for what should be an extended statewide conversation. We first place the problem in context by discussing the basic threats posed to the coast. We then suggest a set of policy responses that the Commission and other land use bodies should consider adopting, ranging from carefully planning new development, to restricting armoring privileges of existing development, to designing unavoidable armoring structures for minimal ecological harm. Development should be channeled away from vulnerable coastal areas through amendments to Local Coastal Programs.[3] Existing structures in the urban cores of the state present a more difficult problem; some form of protection will often simply have to go forward. Even then, engineering expertise must be brought to bear to ensure that coastal protection devices minimize environmental damage.

Structures located on urban peripheries and in rural areas may often threaten important ecological or social values. Here, the Commission can defend and continue to deploy an existing network of "no future armoring" permit conditions and litigate to defend the state's public trust interest in the shoreline. The Commission may also encourage the State Coastal Conservancy to purchase erosion control easements, which allow the state to decide whether or not a property will be allowed to armor. We classify all of these strategies as variations on the theme of the "rolling easement," a device, rooted in statutory or common law or in permit conditions, that allows the publicly owned tidelands to migrate inland as the sea rises, thereby preserving ecosystem structure and function. We consider the possibilities for such easements in California and past experience with them across the country.

In cases where easements cannot be obtained and there is no other basis for permit denial, the Commission could at least require that armoring structures do not eliminate or impede the public's access along the shore and that they incorporate shoreline design principles that allow ecosystem continuity between the ocean and the shore.[4] These solutions would likely not trigger major regulatory takings concerns and would

3. Although larger questions of state infrastructure are outside the scope of this paper, rechanneling transportation and other infrastructure spending away from fragile coastal areas would also be an important step. Local Coastal Plans (LCPs) will be involved in many of these decisions. They are the plans, developed by local land managers and overseen by the Coastal Commission, by which much of the California coast is managed. *See infra* notes 77–82 and accompanying text.

4. *See infra* notes 225–227 and accompanying text.

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help prepare the state for the challenges of the decades to come. Adaptation to climate change is necessary, but we need not adapt in ways that amplify ecological and social damage along our shores.

I. SEA LEVEL RISE IN CALIFORNIA

Because the severity of global warming over the next century is not fully known, predicting sea level rise is necessarily an imprecise effort. However, the California Climate Change Center's 2006 reports and other assessments do provide a range of future sea levels; *all* possibilities within this range require a policy response.[5] Atmospheric warming in California will range between 3 and 10.5° F over the next century, depending upon many variables within our climate system, as well as the speed with which we are able to reduce greenhouse gas emissions.[6] In the center of the range—based upon steadily rising emissions over the next century—temperature increases between 5.5 and 8° F are predicted.[7] These temperature increases would trigger a wide array of changes throughout the state. Snowpack in the Sierra Nevada, which provides most of the state's freshwater, is very likely to decrease progressively across the century; even in projections based upon moderate warming, as much as 40 percent of the snowpack may be lost.[8] Water supply could fall by as much as 50 percent.[9] In the Central Valley, water loss will combine with temperature increases to decrease the productivity of the fruit and dairy

5. *See* PROJECTING FUTURE SEA LEVEL, *supra* note 1; INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE (IPCC), CLIMATE CHANGE 2001: THE SCIENTIFIC BASIS (2001); *see also* U.S. ENVTL. PROT. AGENCY (EPA), THE PROBABILITY OF SEA LEVEL RISE (1996). In this document, the EPA provides probability estimates on sea level rise culled from pooled expert opinion. Although dated, they still provide ballpark estimates. For instance, they predict a 50 percent chance that sea level at San Diego will rise 45 cm by 2100 and a 5 percent chance that the sea will rise 86 cm. *Id.* at 145. There is also a small chance that the sea could rise a few meters in the next two centuries. *Id.* At the time of this writing, the fourth IPCC report had not yet been fully released. This report, however, does confirm that sea level rise rates have nearly doubled in the last decade—although it is not yet clear if this rate increase will continue. IPCC, CLIMATE CHANGE 2007: THE PHYSICAL SCIENCE BASIS, SUMMARY FOR POLICYMAKERS 7 (2007). The IPCC further found that, at current temperatures, the entire Greenland ice sheet would melt over the next thousand years, raising global sea level by about 7 meters. *Id.* at 17. The behavior of the ice sheet is poorly understood, however, and the IPCC notes that "dynamical processes related to ice flow not included in current models but suggested by recent observations could increase the vulnerability of the ice sheet to warming, increasing sea level rise." *Id.* This means that existing sea level rise estimates may well be *under*estimates: the problem could very likely be worse than we know.

6. AMY LYND LUERS ET AL., CAL. CLIMATE CHANGE CTR., OUR CHANGING CLIMATE: ASSESSING THE RISKS TO CALIFORNIA 3 (2006).

7. *Id.*

8. DAN CAYAN ET AL., CAL. CLIMATE CHANGE CTR., SCENARIOS OF CLIMATE CHANGE IN CALIFORNIA: AN OVERVIEW 14–16 (2006), *available at* http://www.climatechange.ca.gov/research/impacts/pdfs/CEC-500-2005-186-SF.pdf [hereinafter SCENARIOS OF CLIMATE CHANGE IN CALIFORNIA].

9. *Id.* at 16.

industries.[10] The risk of wildfire in the surrounding mountains could increase by as much as 55 percent.[11] The particulates and smoke from these projected fires will add to growing air pollution and heat waves that will make urban life difficult and public health risks more pressing.[12] In short, California's residents will be in dire need of "a day at the beach." Unfortunately, the beach itself may not be there for them.

The extent of sea level rise is difficult to predict at any particular location, dependent as it is upon complex interactions including: the climate system, thermal expansion of ocean water,[13] the breakup of both the Greenland ice cap, continental glaciers, and the ice shelves of Antarctica, and regional uplift due to tectonic plate movement and postglaciation rebound. The effects of a rising sea level will be amplified by the short-term but substantial impacts of high tides and atmospheric forcing, including storm surge due to climate change-enhanced winter storms.[14] Globally, sea level has risen by 120 meters over the last 18,000 years. The average rate during the last 3,000 years has only been about 1–2 centimeters (cm) per century, but the past century saw an average of 10–20 cm of sea level rise around the globe.[15] This long-term rise has been driven by ice melt from the retreating Greenland and Antarctic ice sheets, the melting of continental glaciers that covered much of North America and northern Europe and Asia during the last Ice Age, as well as by thermal expansion of the oceans.[16] Long-term sea level measurements in California show a regional rise of 15–20 cm over the last century, or about 2 millimeters (mm) per year.[17] As climate change accelerates, global sea level rise is expected to increase—rising as much as 72 cm by the end of the century at the highest emissions trajectories (but in the vicinity of 20 cm under more moderate emissions trajectories).[18] In California, the range runs between 89 cm and 10 cm (at the lowest emissions trajectories) over the next century—well above the historic rate.[19] The lower end is considered to be "somewhat unlikely," as the ocean is already rising at that rate *without* increased polar melting

10. *Id.* at 19.
11. *Id.* at 22.
12. *Id.* at 26–29.
13. As the temperature warms, water expands—a small effect that is globally significant.
14. PROJECTING FUTURE SEA LEVEL, *supra* note 1, at ix.
15. *Id.* at 1; *see also* IPCC, CLIMATE CHANGE 2001, *supra* note 5, at 659 (reviewing the literature of past sea level rise).
16. PROJECTING FUTURE SEA LEVEL, *supra* note 1, at 1.
17. *Id.* at ix.
18. *Id.* at 5–6.
19. *Id.* at ix, 21; *see also* SCENARIOS OF CLIMATE CHANGE IN CALIFORNIA: AN OVERVIEW, *supra* note 8, at 10.

and thermal expansion and even some low-end trajectories predict as much as 54 cm of sea level rise.[20]

While sea level increases in the middle to upper portion of the projections will present serious concerns in their own right, the combined influence of stronger storms and sea level rise will substantially amplify the potential for serious erosion and inundation along California's coast. Global warming is associated with an increase in El Niño/Southern Oscillation (ENSO) conditions.[21] The trade winds normally lead to the buildup of the Pacific Ocean's warmest waters in the western equatorial portion of that ocean. During ENSO years, however, the trade winds weaken and the warm pool of water flows east towards South America where it then flows both north and south, bringing warmer water up along the California coast.[22] This warm water pool alters the weather pattern in the eastern Pacific, allowing strong storms to attack the coast from the west and southwest.[23] The majority of storm damage on the California coast has occurred during ENSO years.[24] During the ENSO winter of 1997–98, for example, severe storms caused damage in the hundreds of millions of dollars, often moving into California during high tides and adding storm surge to already high water.[25] The ENSO storms of the winter of 1982–83 were even more damaging than those of 1997–98 due to the greater coincidence of storm wave arrival at time of high tides and because many of the most threatened properties had been armored before the arrival of the 1997–98 ENSO.[26] Such events will increase in frequency, pounding beaches with strong waves and undercutting bluffs.

During storms that raised water level height furthest beyond historic norms, wave strength and energy also increased markedly, amplifying erosive force.[27] Because the nearshore wave height varies directly with water depth and wave energy varies with the square of wave height, accelerating sea level rise will strongly increase the force of breaking waves in newly deepened near-shore waters, further exacerbating erosive losses.[28] As sea level rise exceeds the rate observed over the last century

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20. PROJECTING FUTURE SEA LEVEL, *supra* note 1, at ix, 21.

21. *Id.* at 12.

22. Gary Griggs et al., *Weather, Climate Change, Sea Level, and the Coastline*, *in* LIVING WITH THE CHANGING CALIFORNIA COAST 18, 24–25 (Gary Griggs et al. eds., 2005).

23. *Id.* at 22.

24. *Id.*

25. PROJECTING FUTURE SEA LEVEL, *supra* note 1, at 13; *see also* U.S. Geological Survey, *El Niño Sea-Level Rise Wrecks Havoc in San Francisco Bay Region*, USGS Fact Sheet 175-99 (1999), *available at* http://pubs.usgs.gov/fs/1999/fs175-99/ (values are in 1998 dollars).

26. *See generally* Gary Griggs & Kristine Brown, *Erosion And Shoreline Damage Along the Central California Coast: A Comparison Between The 1997–98 and 1982–83 Winters*, 66 SHORE & BEACH 18 (1998) (discussing relative damage).

27. SCENARIOS OF CLIMATE CHANGE IN CALIFORNIA: AN OVERVIEW, *supra* note 8, at 11.

28. CAL. COASTAL COMM'N, OVERVIEW OF SEA LEVEL RISE AND SOME IMPLICATIONS FOR COASTAL CALIFORNIA 14 (2001).

and winter storms potentially grow stronger and more frequent, existing coastal protection structures will fail more often and damage to coastal development will increase.[29]

Increased coastal erosion will exacerbate pressure to armor the new stretches of the coast and to strengthen existing armoring. Approximately 72 percent of California's coastline consists of steep cliffs or bluffs. This apparent bulwark is, however, far from stable and has eroded almost 45 kilometers (km) over the past 18,000 years in some regions, including San Francisco. Sedimentary bluffs already erode at a rate of between 10 and 30 cm per year, yet it is on these bluffs, which often front large flat marine terraces, that most of California's coastal development has occurred.[30] Californians have responded by armoring their coast with defense structures; at present, at least 10.2 percent of the state's Pacific coast is armored and a third of the Southern California coast sits behind some armoring structure.[31] The impulse to armor stems from a serious erosive threat. The U.S. Geological Survey has identified significant coastal vulnerability to future sea level rise along the coast from San Luis Obispo to San Diego and from San Francisco to the shores of Monterey Bay.[32] In the San Francisco/Monterey region, for instance, sea level is already rising at approximately 2 mm per year, combining with significant erosion rates and wave energy rankings to give the region "a background of high vulnerability."[33] It is in this area and in other high vulnerability zones in Southern California that population growth near the beaches is also at its highest. The same factors that make the coast vulnerable also make it most desirable for development. It is here, where beaches are present and bluffs rise in flat terraces, allowing for easy development, that people want to live near the ocean. The result, without a sea level rise policy, is a fortified coast.

A fortified coast comes with major financial, social, and ecological costs. These range from aesthetic losses to new barriers to public access to, critically, the physical losses of the beaches themselves—both to large

29. PROJECTING FUTURE SEA LEVEL, *supra* note 1, at 30.

30. Gary Griggs & Kiki Runyan, *Cliff Erosion and Bluff Retreat Along the California Coast*, 2003 PROC. OCEANS 1219 (2005). As the California coast rose, waves cut large flat terraces in the rock at various levels as the coast and the ocean moved in relation to each other.

31. *Id.* at 1226. Note that seawalls and revetments are distinct from the breakwaters that protect harbors, which are designed to create still water to shelter vessels, rather than to prevent erosion.

32. *See* E. ROBERT THEILER & ERIKA S. HAMMAR-KLOSE, NATIONAL ASSESSMENT OF COASTAL VULNERABILITY TO SEA-LEVEL RISE: PRELIMINARY RESULTS FOR THE U.S. PACIFIC COAST, U.S. GEOLOGICAL SURVEY OPEN-FILE REPORT 00-178 (2000), *available at* http://pubs.usgs.gov/ of/2000/of00-178/. The National Oceanic and Atmospheric Administration (NOAA) gathers sea level trends and other useful data in searchable format at http://tidesandcurrents.noaa.gov/.

33. *Id.*

erosion control structures and, most importantly, to the ocean as armoring leaves beaches unable to retreat before the rising sea.

The direct visual impacts of coastal armoring are significant—a fortress wall behind the public beach is quite different than a natural sea cliff.[34] In the past ten years, many seawalls have been given a colored and textured coating to blend with natural bluffs.[35] Nevertheless these structures can also directly occupy the beach; a rock revetment may cover thirty to forty feet of beach width, as it must slope outward from the cliff top, typically at a 2:1 or 1.75:1 (horizontal to vertical) slope, replacing public beach with a boulder field.[36] Seawalls, however, will normally occupy much less beach area. Armoring covers sandy beach that otherwise could be used for access and recreation.

Armored walls also diminish, or destroy altogether, coastal access.[37] Rather than being able to scramble down bluffs and dunes, beach-goers encounter vertical concrete walls or riprap fields, cutting them off from the sand below.[38] These structures are not cheap. In 1999 dollars, heavy revetments cost as much as $2,000 per linear foot and full seawalls ran to as much as $4,500 per square foot.[39] Economic costs to wall the beach are significant.

There is also less beach to access. Even without directly influencing erosion, armoring threatens beaches as sea level rises. Armoring fixes the back of the beach, stopping natural shoreline erosion that would otherwise cause beaches to migrate inland as the water rises. As a result, the rising water covers the existing beach and no new beach is created. Coastal managers refer to this phenomenon as "passive erosion." This lost beach is at the core of the armoring threat: seawalls act in concert with rising water to make beaches disappear. As the beaches vanish, so does habitat for wildlife,[40] vital public space, and a landscape that is central to California's quality of life.

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34. Garry Griggs, *California's Retreating Coastline: Where Do We Go From Here?*, PROC. AM. METEOROLOGICAL SOC. ANN. MEETING (San Diego) 83,241, 83,243 (2005).

35. *See* Gary Griggs et al., *Responding to Coastal Hazards*, *in* LIVING WITH THE CHANGING CALIFORNIA COAST, *supra* note 22, at 126–27 (providing examples of camouflaged armoring).

36. Griggs, *supra* note 34, at 83, 244.

37. *Id.* at 83,245.

38. In cases where armoring structures cover a cliff face, where access would be difficult even without a structure, seawalls can be designed to improve access conditions by, for instance, adding stairways and other access routes.

39. LESLEY EWING ET AL., PROCEDURAL GUIDANCE DOCUMENT: BEACH EROSION AND RESPONSE 39 (1999). Beach replenishment—a less invasive option when confronted with rising seas—is also expensive and difficult, as it requires continuous intervention. *Id.*

40. One recent study found rising sea level would destroy vital seabird habitat and that the effects would be particularly acute if seawalls prevented inland migration of what habitat might be able to advance in front of the rising waves. *See* H. Galbraith et al., *Global Climate Change and Sea Level Rise: Potential Losses of Intertidal Habitat for Shorebirds*, 25 WATERBIRDS 173

Armoring structures also cut off the sand supply from eroding bluffs. While 70 to 90 percent of beach sand comes from rivers and streams, the majority of the remainder comes from eroding bluffs and cliffs; this contribution is highly variable, reaching as much as 10 percent of sand supply in some places.[41] With upstream dams capturing river sediment and coastal armoring reducing coastal erosion, sediment supply to beaches has been appreciably reduced. As much as 50 percent of the sand originally delivered to the coast in Southern California, 31 percent in Central California, and 5 percent in Northern California has been lost, the great majority of this impounded behind dams in reservoirs.[42] Recently, arguments to expand California's reservoir capacity have found new vigor as the state's water managers raise concern about how climate change will affect the reliability of the state's water supply.[43] Because global warming will influence demand for both dam construction and beach armoring, it poses a double threat to the sand supply. Further sand source losses should be avoided. The combined effects of a reduced sand supply, armoring structures that cover beach areas, and increased storm erosion may shrink or eliminate the beach itself—depending on wave and current conditions—transforming a beach with a wall at its back into a thin sliver of sand at the base of the seawall, or worse, no beach at all.[44]

California's rapidly growing resident and tourist populations will find themselves competing for a diminishing resource. At present, if we divide up California's 1,100 miles of coast evenly between its thirty-seven million residents, we would each have about two inches of shoreline. However, much of the coastline north of San Francisco as well as the Big Sur area is steep, mountainous, and inaccessible, so the amount of sandy coast per person is reduced further—to only about one inch per person.[45] The state's population is growing and the resource growing ever more scarce. In the next twenty years alone, demographers expect between

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(2002); *see also* J.E. Dugan & D.M. Hubbard, *Ecological Responses to Coastal Armoring on Exposed Sandy Beaches*, 74 SHORE & BEACH 10 (2006).

41. Griggs, *supra* note 34, at 83,246; *see also* Kristin Patsch & Gary Griggs, *Littoral Cells, Sand Budgets, and Beaches: Understanding California's Shoreline*, Univ. of Cal. Santa Cruz & Cal. Coastal Sediment Management Workgroup 17–22 (2006) (discussing sand budgets for California littoral cells).

42. *See* MICHAEL SLAGEL & GARY GRIGGS, CUMULATIVE LOSS OF SAND TO THE CALIFORNIA COAST BY DAM IMPOUNDMENT (2006), *available at* http://www.dbw.ca.gov/csmw/PDF/ Slagel&Griggs_CA_Dams_Manuscript.pdf.

43. *See, e.g.*, Glen Martin, *The Great Thirst: Looking ahead to post-global warming life in California, 60 years hence*, S.F. CHRON., Jan. 7, 2007, at C-M 9; Bettina Boxall, *Governor puts global spin on state's need for dams*, L.A. TIMES, Jan. 12, 2007, at B-1.

44. Griggs, *supra* note 34, at 83,246–47. These manmade structures are not cheap: typical construction costs for seawalls and revetments today range from about $3,000 to $10,000 per front foot, or $15 to $50 million per mile.

45. This is a linear measure—coasts are classically fractal, with each headland and rock creating more surface area. But, for our purposes, it illustrates the ever-growing demand for a limited resource that characterizes California's coastal politics.

seven and eleven million new residents in California.[46] To complicate matters, Californians share our personal inch with millions of visitors who help support the state's thriving ocean economy. As urban and built environments expand, California's wild coastal areas will come under increasing development pressure and attendant pressure to armor. Unable to migrate past the walls, our intertidal zones, beaches, and dune systems will yield to the rising sea.

Growing demand for armoring is only one of many threats that climate change will bring to the California coast. Coastal ecosystems already stressed by anthropogenic impacts such as overfishing, habitat loss and destruction, invasive species, and pollution face major perturbations from climate change.[47] Warmer summer temperatures may weaken the California Current, the upwelling off California's coast that sustains our highly productive fisheries.[48] Warmer winters will lead to more precipitation falling as rain and less as snow, producing greater coastal flooding from swollen rivers. Repeated flooding events may reduce coastal water quality due to increased urban runoff and spikes in sediment and nutrient loading from flood-stage rivers, potentially triggering toxic algal blooms.[49] And, in addition to the rising sea, which will gradually force shifts in intertidal species distribution, warmer waters will force many species north, into new geographic ranges.[50] The seas are also a major carbon sink; as they absorb our carbon dioxide, they are gradually acidifying and becoming hostile to marine life.[51] The prospect is one of near total ecological disruption and there is evidence that the process is beginning. In 2005 and 2006, warmer oceans visibly disrupted the food chains off our coast. The usual cold-water upwelling failed, decimating populations of rockfish, Cassin's auklets, and common

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46. Pub. Pol'y Inst. of Cal., California's Future Population (2006), http://www.ppic.org/content/ pubs/jtf/JTF_FuturePopulationJTF.pdf.

47. *See generally* LEON E. PANETTA, PEW OCEANS COMM'N, AMERICA'S LIVING OCEANS: CHARTING A COURSE FOR SEA CHANGE (2003) (detailing threats to the ocean and recommending an integrated national policy to address them); U.S. COMM'N ON OCEAN POLICY, AN OCEAN BLUEPRINT FOR THE 21ST CENTURY (2004) (analyzing U.S. ocean management and proposing new legal coordinating structures).

48. Franklin Schwing, Presentation, *The Impact of Climate Change on California's Coasts and Oceans: Beyond Sea Level Rise* (Oct. 5, 2006). The fate of the California Current is unclear; there is some evidence that warmer temperatures will increase the cold water upwellings that drive it, in the short term. In the long term, however, major disruption is a serious possibility. Chris D. Harley et al., *The Impacts of Climate Change in Coastal Marine Systems*, 9 ECOLOGY LETTERS 228, 230 (2006).

49. Schwing, *supra* note 48.

50. *Id.*; *see also* George N. Somero, *Linking Biogeography to Physiography: Evolutionary and Acclimatory Adjustments of Thermal Limits*, FRONTIERS IN ZOOLOGY, Jan. 2005, *available at* http://www.frontiersinzoology.com/content/pdf/1742-9994-2-1.pdf (discussing physiology basis for shifts in species ranges due to temperature changes).

51. *See, e.g.*, Carles Pelejero et al., *Preindustrial to Modern Variability in Coral Reef pH*, 309 SCIENCE 2204 (2005) (discussing growing acidity and threat to coral reef ecosystems).

murres.[52] While the causes of decline are complex—these species were already in decline due to overfishing of either the species themselves or their forage species—their failing populations may well be just the beginning of a period of generalized collapse across many species and ecological communities.[53]

Coastal managers are asking for guidance to address these threats. A recent comprehensive survey of California's coastal managers found that only two counties had plans that consider climate change and *none* considered its impact upon coastal systems.[54] While over 90 percent of coastal managers are concerned about global warming, most have simply not yet taken action.[55] Thankfully, almost 70 percent are inclined to take action as soon as possible.[56] They have not had any state level guidance or received the additional funding and staffing they need to begin to deal with the impending crisis in addition to their regular duties.[57] State level managers, including the Commission, can provide both advice and resources to ensure that local coastal managers anticipate and address climate-based threats. Admittedly, many of these threats are out of the hands of local managers: they simply cannot change global emissions profiles. They can, however, contribute to the state reaching its goals to reduce greenhouse gas emissions by squarely evaluating coastal projects for their contribution to damaging emissions and by shaping local land use patterns to mitigate the interactions between global warming and local decisions.[58] Climate change threatens the coast in myriad ways; coastal managers should work to ensure that it does not also generate an armored coast or put more structures and lives at risk due to rising seas.

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52. *See* Jane Kay, *Sea Life Counts Dive for 2nd Year*, S.F. CHRON., June 23, 2006, at A-11; Marcus Wohlsen, *Warmer Oceans Disrupt Pacific Food Chain for Second Year*, ASSOCIATED PRESS, July 22, 2006.

53. One ominous sign of this is reported in Anthony J. Richardson & David S. Schoeman, *Climate Impact on Plankton Ecosystems in the North Atlantic*, 305 SCIENCE 1609 (2004), who find that warming is associated with declining plankton populations, which are the base of the oceanic food chain. Shifts in planktonic abundance and productivity have the potential to destabilize both marine and terrestrial ecosytems. *Id.*

54. Susanne C. Moser, Presentation, *Getting Ready for Climate Change: Helping California Adapt to the Impacts in Coastal Areas*, at 14 (Oct. 5, 2006) (on file with authors).

55. *Id.* at 9.

56. *Id.* at 11.

57. *Id.* at 15.

58. California is addressing global warming at a statewide level, most recently by imposing carbon caps that will reduce state emissions of greenhouse gases. *See generally* California Global Warming Solutions Act of 2006, CAL. HEALTH & SAFETY CODE §§ 38500–38599 (West 2006). The Coastal Commission has also begun work to improve coastal awareness of climate change issues. *See generally* CAL. COASTAL COMM'N, *supra* note 28 (setting forth basic science of sea level rise and analyzing policy responses). Preventing excessive coastal armoring is only one of many important policy decisions to make. This Article does not attempt to treat how the Coastal Commission or local decision makers can and should evaluate projects for their individual or collective contributions to greenhouse gas emissions, directly or indirectly.

Tools are available that, if used now, can prevent at least some of the damage that inappropriate development and armoring would otherwise produce. In the next section, we review lessons from other states and the options available in California to begin to adapt to climate change on the coast.

II. TOOLS TO PROTECT THE NEW COAST

The California Coastal Act sets out five basic policy objectives for coastal use, these range from protecting ecosystems to ensuring public access to furthering local planning.[59] They are united by a concern with sustainability and stewardship and all of them are jeopardized by climate change and sea level rise. State agencies (and the Coastal Commission in particular) are charged with protecting and enhancing coastal resources, ensuring balanced resource use, maximizing public access, ensuring priority of coastal-dependent uses, and encouraging coordinated planning.[60] The walls that will accompany rising waters will likely destabilize coastal planning, limit public access, threaten coastal uses, and damage coastal resources. It is incumbent upon the state to begin to plan and prepare for sea level rise impacts now, while early action can still be effective. Although owners of existing structures are permitted to armor under certain conditions,[61] the Commission and other state agencies still have a range of management options available to them that respect property owners' rights. These methods, discussed below, should be implemented within a larger sea level rise strategy to maximize effectiveness.

California's Pacific coast—as distinct from San Francisco Bay, which is separately administered[62]—is of central importance to the work of five

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59. These purposes are to:

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

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

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

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

(e) Encourage state and local initiatives and cooperation in preparing procedures to implement coordinated planning and development for mutually beneficial uses, including educational uses, in the coastal zone.

CAL. PUB. RES. CODE § 30001.5 (West 2006).

60. *Id.*

61. *Id.* § 30235.

62. This is not to say that San Francisco Bay is immune from these problems. Rather, the San Francisco Bay Conservation and Development Commission is well aware of the distinct challenges posed by sea level rise in a confined space (the Bay, for instance, may lose many of its salt marshes) and is beginning to take action. *See, e.g.*, Mike Taugher, *Under Water by 2100?*

state agencies: the California Coastal Commission, the State Lands Commission, the State Coastal Conservancy, the State Parks Commission, and the California Ocean Protection Council.[63] The Coastal Commission is the lead regulatory and permitting agency, charged with implementing coastal development plans and approving plans developed by local authorities under delegated authority.[64] This Article focuses primarily on opportunities before the Coastal Commission, but all five agencies have roles to play. The Coastal Conservancy, also established in the Coastal Act of 1976, serves as a "repository for lands whose reservation is required to meet the policies and objectives" of the Coastal Act.[65] The Conservancy acquires property and subsidiary property interests to serve these purposes.[66] The State Lands Commission owns and manages publicly owned land below the mean high tide line.[67] The Department of Parks and Recreation and the State Parks Commission also manage important coastal resources, including near-shore marine reserves and dozens of state beaches and coastal state parks.[68] Finally, the Ocean Protection Council, formed by the California Ocean Protection Act of 2004, is charged with coordinating all state coastal and ocean management agencies.[69] These agencies will need to work together to develop a coordinated plan of policy development, regulatory change, and property rights acquisition to help the California coast adapt to climate change.

Climate change and sea level rise will pose a significant threat to the ecological health and public use values of the California coast. Coastal policy should be addressed towards maintaining those values to the maximum extent possible. Although other solutions are, no doubt, possible and important, we suggest three avenues for adaptation.

First, the Coastal Commission should consider encouraging the revision of Local Coastal Programs (LCPs), which govern coastal development patterns, to steer new development *away* from areas vulnerable to the effects of sea level rise. As the Commission cannot mandate changes to LCPs, this important phase of the work will rely on

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Risk of the Rising Sea: Scientists Seek Ways to Avert a Creeping Catastrophe in Bay Area, SAN JOSE MERCURY NEWS, Jan. 26, 2007.

63. This is, of course, an oversimplification. The Public Utilities Commission, which manages railroads, and Caltrans, which manages roads, will also play important roles in any effort to readjust state infrastructure to ameliorate the coastal armoring crisis.

64. The Coastal Commission interacts with a network of local jurisdictions, which are encouraged to develop their own Local Coastal Plans (LCPs). If the LCP complies with the goals of the Coastal Act, the Commission certifies the plan and transfers development permitting authority to the local jurisdiction.

65. CAL. PUB. RES. CODE § 31104.1.

66. *Id.* § 31105.

67. *Id.* § 6301.

68. *Id.* §§ 501, 530.

69. *Id.* §§ 35500–35650.

making a clear case to local leaders that they should act now to protect their coastal resources.

Second, the Coastal Commission should work to avoid future armoring by developing a suite of policy tools that we class under the general name of "rolling easements." The concept, popularized by U.S. Environmental Protection Agency (EPA) Sea Level Rise Project Manager James G. Titus, is a catch-all term for "a broad collection of arrangements under which human activities are required to yield the right of way to migrating shores."[70] Such an easement—whether guaranteed by permit conditions, purchased or donated by a landowner, or mandated by regulation underlain by the public trust doctrine—helps to maintain the ecosystem services[71] provided by the living coast. In California, these easements would fall into three main classes, largely defined by the time at which coastal structures were built, the ecological and recreational importance of the shoreline below them, and whether there could be suitable upland for the shoreline to migrate into. First, structures built before the Coastal Act's 1976 adoption are often permitted to armor if various conditions are met.[72] Post-1976 structures without "no future armoring" conditions in their original coastal development permits have also been permitted to armor in the past.[73] For these structures, rolling easements will have to be secured through purchase, donation, or litigation. Second, by the mid-1980s, the Commission had begun to incorporate "no armoring" provisions into coastal development permits. Structures built under this system, which extends to the present, cannot legally armor.[74] Finally, structures yet to be built may be addressed

70. James G. Titus, *Rising Seas, Coastal Erosion, and the Takings Clause: How to Save Wetlands and Beaches Without Hurting Property Owners*, 57 MD. L. REV. 1279, 1313 (1998).

71. Ecosystem services are the vital functions provided to human society by functioning ecosystems. Examples include the water filtration services and fishery nursery provided by wetlands, the pollination services provided by native insects, the air quality maintenance and soil retention services provided by forests, and so on. For a fuller introduction to the subject, see Ecological Society of America, Ecosystem Services, http://www.esa.org/education/edupdfs/ecosystemservices.pdf#search=%22Ecosystem%20Services%22 (last visited May 15, 2007).

72. *See infra* notes 136–160 and accompanying text.

73. For a discussion of the controversy around armoring of post-Coastal Act structures, see Todd T. Cardiff, Comment, *Conflict in the California Coastal Act: Sand and Seawalls*, 38 CAL. W. L. REV. 255 (2001).

74. *See infra* notes 160–163 and accompanying text. No legal challenges to these provisions have been filed to date. Should the Commission's "no future armoring" conditions face legal challenge, however, the agency is well positioned to defend the imposition of the conditions along the following reasoning. To begin with, the conditions serve a fundamental purpose of preserving the state's ability to steward public trust lands as they physically shift from natural and climate change forces by preserving the trust lands themselves. Next, Coastal Act section 30253(2) provides that new development "shall assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs." The "no future armoring"

through a new rulemaking barring armoring in many areas of the coast or through continued use of strengthened permit conditions. It is important to emphasize, however, that not all structures in any class need be barred from all forms of protective devices. The Commission should act judiciously to enforce rolling easements in areas of the most pressing ecological need and upland availability. In areas without rolling easements, protective devices could be allowed if they result in truly minimal environmental damage. Structuring planning to predict future population growth and sea level rise, and to accurately identify threatened areas, will be a continuing policy challenge.

The third category of adaptation arises in cases where armoring must be allowed for either statutory or prudential reasons. Here the Commission should insist that: (a) where feasible, armoring structures follow living shorelines design principles, which are engineering plans created to maximize the ecological connectivity of the land/sea interface;[75] and (b) the public's right to access along the shore is maintained through access stipulations in armoring permits and, in some cases, by protecting the beach itself through beach nourishment and other preservation strategies.[76]

A. Reshaping Local Coastal Programs: Coastal Commission and Local Government Jurisdiction Within the Coastal Zone

As a starting point, the Coastal Commission would do well to undertake an immediate and detailed review of existing LCPs to determine whether coastal zone jurisdictions deal appropriately with sea level rise in general and armoring in particular.[77] The Coastal Act allows for significant local decision-making authority over permitting questions in the coastal zone, with LCPs and the Commission itself ensuring that statewide interests are protected when development proposals are reviewed. An LCP is the fundamental planning unit of the Coastal Act,

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conditions effectuate this statutory prohibition and make explicit the state's intention to protect public trust lands and resources.

75. Maryland and Virginia, among other eastern states, have led the way on the development of living shorelines principles. They encourage the use of wetlands, natural stones, and sturdy plants along shore margins, and have seen preliminary evidence demonstrating that strengthening natural shores provides superior wave protection by diffusing wave energy rather than just absorbing it, as hard barriers do. Lara Lutz, *Shoring Up Coasts Against Erosion*, CHESAPEAKE BAY J., Nov. 2005, *available at* http://www.bayjournal.com/article.cfm?article=2651.

76. "Beach nourishment" is a mechanical process by which tons of sand are trucked to diminishing beaches—or gathered from the sea floor by pumping—in an effort to replace sand lost to erosion. It is costly and not a permanent fix, as adding sand does not change the underlying forces that are eroding the beach.

77. *See* CAL. PUB. RES. CODE §§ 30500–26(West 2006) (setting forth the process for LCP development, certification, and amendment)

giving local governments the authority to shape development in their region with the supervision of the Commission.[78] Seventy-four coastal cities and counties have adopted LCPs, which consist of land use plans and legal tools to realize the plan on the ground.[79] These plans vary by the needs of each community but must conform with the basic policies and intentions of the Coastal Act; to ensure that this is the case, the Commission examines each LCP for certification under the Coastal Act. If it finds that an LCP does not conform with the policies of the Act, it will suggest revisions to the local government, which must address the suggested revisions within a year.[80] Upon certification, the Commission transfers permitting authority to the local government.[81] The Commission itself, however, retains jurisdiction for structures on tidelands and other submerged lands and is the appellate body for permitting decisions. It also reviews any LCP amendments, and retains the right to review existing LCPs to ensure that they are administered to "conform[] with the policies" of the Act.[82]

Exactly which legal standards apply to coastal development applications depends on the nature of the development, the exact location of the property at issue, and the certification status of the LCP for the jurisdiction in which the property is located. For development approvals that are properly appealed from local jurisdictions to the Commission, the Commission applies the standards established in the certified LCP and the public access policies of the Coastal Act.[83] For coastal zone developments in jurisdictions for which there is no LCP or the LCP is not certified, the Commission applies the standards and policies set forth in the Coastal Act.[84] The majority of public and private property within the coastal zone is managed under LCPs, rather than under the direct authority of the Commission.[85] Thus, changes to LCPs can have significant impacts on statewide land use.

Essentially all coastal development requires a permit.[86] Local governments with permitting responsibilities must take action to defend their own coasts. The Commission can use the LCP revision and review process to motivate, but not force, this effort. The consequences for local jurisdictions that refuse the recommendations of the Coastal Commission

78. *Id.* § 30500.

79. The Commission maintains a database of approved LCPs at http://www.coastal.ca.gov/la/lcpstatus.html. *See also* CAL. PUB. RES. CODE §§ 30511–30512.

80. CAL. PUB. RES. CODE § 30519.5(a).

81. *Id.* § 30519.

82. *Id.* §§ 30519.5(a), 30500–26; *see also* Cal. Coastal Comm'n, Local Coastal Programs, http://www.coastal.ca.gov/lcps.html (last visited Apr. 8, 2007).

83. CAL. PUB. RES. CODE § 30603 (West 2006).

84. *Id.* § 30517.5(b)(2).

85. *See supra* note 79.

86. CAL. PUB. RES. CODE § 30600.

depend on the certification status of the LCP at issue. For LCPs that have not yet been certified, the jurisdiction risks certification denial if it declines to adopt the recommendations of the Commission. For existing certified LCPs, the local jurisdictions risk no penalty for ignoring the Commission's recommendations through the review process. Thus, for the large portion of the coast under management through certified LCPs, the Commission must lead by example and persuasion, rather than through coercion.

The Commission should consider drafting exemplar sea level rise LCP amendments that could be adapted and implemented by local governments along the coast depending on their local circumstances. Local coastal managers looking for state guidance on climate change are likely to respond positively to a Commission-produced text for sea level rise LCP amendments and the Commission's encouragement of their use by local governments.

The Commission should urge revision of LCPs to channel development, including public infrastructure, well away from areas threatened by sea level rise and associated hazards.[87] Revisions should be designed to maximize ecosystem services—from aesthetic pleasure to public access to habitat for important species—that the coast provides. The revisions should head off development in areas of high erosion vulnerability, because such development will lead to armoring and the loss of ecosystem function and public access. The research needed to properly plan this effort will require jointly mapping two complex processes: likely growth and development patterns, and likely sea level rise. Charting these two, potentially mutually reinforcing threats, along with areas of particular ecological and social value, will be a significant effort, but is essential to avert major losses. Some vulnerability maps are already available, but more detailed maps covering larger areas will need to be produced.[88] The Commission should collaborate with the Coastal Conservancy and other interested parties on a detailed survey of the California coast to determine vulnerabilities and areas where allowing natural landscape migration will be critical to coastal resource protection

87. As discussed in note 63, *supra*, the state infrastructure agencies will also have to be involved in this effort.

88. For a set of maps covering the California coast, but at a relatively coarse resolution, see the regional chapters and coastal hazard projections in LIVING WITH THE CHANGING CALIFORNIA COAST, *supra* note 22. Much older versions of these maps are online at Western Carolina University's Coastal Hazards clearing house at http://coastalhazards.wcu.edu/CoastalHazardMaps/California/California.htm. The Coastal Commission has also begun to develop very coarse-scale maps. *See* CAL. COASTAL COMM'N, *supra* note 28, fig.10. These efforts are not yet sophisticated enough to enable policymaking at the resolution necessary to safeguard the coast. Under Coastal Act section 30341, the Commission can undertake studies and prepare maps and plans to carry out the policies of the Coastal Act. Commission maps and plans must be adopted through a public hearing process.

or coastal recreation. Such locations might include the remarkable wetlands of Elkhorn Slough on Monterey Bay, the salt marshes that fringe Humboldt Bay, or the elephant seal breeding grounds at Piedras Blancas near San Simeon on the Big Sur coast. Particularly at risk are coastal wetlands and estuarine environments, which are of extraordinary ecological importance, are already rare, and have often seen extensive restoration spending.

The EPA has undertaken similar planning at the national level. The agency has begun producing sample maps highlighting areas likely to be armored under a business-as-usual scenario—the scenario in which state bodies do not undertake an aggressive effort to prevent unnecessary armoring, particularly in ecologically sensitive areas.[89] California will benefit from similar maps but should undertake efforts to produce its own expeditiously rather than wait for an uncertain federal rollout. Only with a strong sense of which coastal resources are at risk can the state, the Commission, and local jurisdictions plan sensibly.

B Implementing Rolling Easements in California

LCP amendments will be important tools in avoiding the "double pinch" on coastal resources caused by increasing development pressure and rising seas, but they are essentially forward-looking and many properties are already in harm's way. To address existing structures, the state ought to develop a flexible portfolio of rolling easement options. As discussed above, the legal support for a given rolling easement will vary based upon the context and age of the structure applying for armoring privileges. We begin by discussing the operation of a generic rolling easement and then turn to the various methods that California can use to create and defend such easements.

1. A Rolling Easement Example

How would rolling easements work in practice in California? Consider the scenario of a housing development slated to be built just above the beach. Below the low terrace where the housing is planned is a small strip of beach. As the sea rises and El Niño storms hammer the beach, the shoreline begins to erode towards the uplands. Without a rolling easement in place, the property owners would likely seek to erect some form of armoring, such as a seawall, revetment, or gunnite application to a bluff or cliff—perhaps covering the remaining beach with

89. *See* James G. Titus, Maps That Depict the Business-as-Usual Response to Sea Level Rise in the Decentralized United States of America (2004) (paper presented at the OECD Global Forum on Sustainable Development: Development and Climate Change), at 10–13 (discussing methodology), 19–21 (sample maps for areas of Maryland and North Carolina).

enjoyed by a private owner but merely clarifies that owner's existing rights.[91] Put simply, there can be no taking when the property owner never had a "right" to armor to begin with.

a. The Public Trust Doctrine

Because the public trust doctrine requires both that the state hold its coastal resources in perpetual trust for the people and that the state protect those resources, the doctrine provides the most fundamental basis for responding to the threats of coastal armoring. The doctrine is an ancient legal principle, dating back to Roman law, that the state hold its waterways in trust for the public's benefit. The trust inheres in the land, and property encumbered by the public trust doctrine can only be transferred out of the trust if such transfer will serve the trust purposes.[92] In recent years, the courts have understood trust purposes to include maintaining the ecological values of public lands and waters.[93] California courts have affirmed that navigable waters and the public beaches along them are held in trust for the public's benefit by the state.[94] The trust and its purposes are read expansively in California. As the California Supreme Court explained in the landmark Mono Lake case, "the objective of the public trust has evolved in tandem with the changing public perception of the values and uses of waterways."[95] Although originally imagined around navigation, commerce, and fishing, the trust purposes have been expanded to include public recreation and "there is a growing public recognition that one of the most important public uses of the tidelands . . . is the preservation of those lands in their natural state."[96] This implies not just prevention of development but the preservation of ecological process: California fulfills its public trust duties when it preserves trust lands "as ecological units for scientific study, as open space, and as environments which provide food and habitat for birds and marine life."[97] This is a public trust rationale for the maintenance of ecosystem function; it is these fundamental ecosystem processes that are most threatened by coastal armoring.

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91. *See* Lucas v. S.C. Coastal Council, 505 U.S. 1003, 1029 (1992).

92. Nat'l Audubon Soc'y v. Superior Court, 658 P.2d 709, 721–22 (Cal. 1983).

93. *See, e.g.*, Allan Kanner, *The Public Trust Doctrine, Parens Patriae, and the Attorney General as Guardian of the State's Natural Resources*, 16 DUKE ENVTL. L. & POL'Y F. 57, 61–88 (2005) (discussing origin and development of the doctrine).

94. Lechuza Villas West v. Cal. Coastal Comm'n, 70 Cal. Rptr. 2d 399, 417 n.19 (Ct. App. 1997) ("All navigable waterways are held in trust by the state for the benefit of the public.").

95. *Nat'l Audubon Soc'y*, 658 P.2d at 718–19.

96. *Id.* (quoting Marks v. Whitney, 491 P.2d 374, 378–80 (Cal. 1971)).

97. *Id.*

rock and concrete and certainly preventing the natural migration and survival of the beach. Similar scenarios apply to structures built slightly inland on marshlands and estuaries; there, storm waves will not often threaten but gradual sea level rise will cause the salt marsh to gradually migrate towards the buildings. If the buildings sit behind a bulkhead, the marsh will ultimately be unable to migrate and will drown beneath the rising waters.[90] In the alternate case, where the state holds a rolling easement, the property owners do not own the right to prevent the shore from moving. Instead, they may use their property as normal until the sea reaches it. At this critical point, they must either move their structures or cede them to the ocean or advancing marshlands. Erosion will likely occur relatively slowly, over several decades. Thus this eventual end date will likely not appreciably reduce property values. It will, however, ensure that the coast will remain public and healthy at the reasonable cost of discouraging unwise overdevelopment of areas vulnerable to near-term erosion.

This general easement model does not rely upon any particular legal device: rather, it describes the ecological effects of allowing the shore to move rather than impeding that movement with an armoring device. The appropriate legal device to reach this ecological and social goal will vary, as discussed above, based upon the age of the structure in question and the potential ecological and social costs associated with *allowing* versus *preventing* armoring. Below, we discuss the array of tools that the Commission and the state can rely upon to allow the shoreline to migrate when appropriate. These tools are underlain by the central concept of the public trust doctrine, which both motivates and requires the state to protect its coastal resources that are under attack from the combined effect of sea level rise and development that impedes the natural and expected shore migration process.

2. *Public Trust Doctrine, Custom, and Nuisance: Common Law Roots for Rolling Easements*

Although a rolling easement can be authorized through statutory action or judicial fiat, there is a strong argument that such easements are most fundamentally rooted in common law principles—primarily the public trust doctrine, although the laws of custom and public nuisance may also play a role. Expressly grounding rolling easements in the longstanding background principles of the common law and within the principles of property law helps to immunize the state from potential constitutional takings challenges because articulating such background principles does not change the existence of fundamental property rights

90. *See* Titus, *supra* note 70, at 1314–17.

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a. *The Public Trust Doctrine*

Because the public trust doctrine requires both that the state hold its coastal resources in perpetual trust for the people and that the state protect those resources, the doctrine provides the most fundamental basis for responding to the threats of coastal armoring. The doctrine is an ancient legal principle, dating back to Roman law, that the state hold its waterways in trust for the public's benefit. The trust inheres in the land, and property encumbered by the public trust doctrine can only be transferred out of the trust if such transfer will serve the trust purposes.[92] In recent years, the courts have understood trust purposes to include maintaining the ecological values of public lands and waters.[93] California courts have affirmed that navigable waters and the public beaches along them are held in trust for the public's benefit by the state.[94] The trust and its purposes are read expansively in California. As the California Supreme Court explained in the landmark Mono Lake case, "the objective of the public trust has evolved in tandem with the changing public perception of the values and uses of waterways."[95] Although originally imagined around navigation, commerce, and fishing, the trust purposes have been expanded to include public recreation and "there is a growing public recognition that one of the most important public uses of the tidelands . . . is the preservation of those lands in their natural state."[96] This implies not just prevention of development but the preservation of ecological process: California fulfills its public trust duties when it preserves trust lands "as ecological units for scientific study, as open space, and as environments which provide food and habitat for birds and marine life."[97] This is a public trust rationale for the maintenance of ecosystem function; it is these fundamental ecosystem processes that are most threatened by coastal armoring.

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96. *Id.* (quoting Marks v. Whitney, 491 P.2d 374, 378–80 (Cal. 1971)).

97. *Id.*

The trust attaches to the shores regardless of where they may move.[98] As shorelines erode, the public trust follows the eroding shoreline; similarly, as they accrete, the public trust moves seaward.[99] This is an important point, as it turns even coastline property held in fee simple into defeasible estates, thus private property may be converted into public trust land as the shore erodes.[100] California law on this question was recently clarified in *Lechuza Villas West v. California Coastal Commission*, a 1998 case pitting the Commission against a developer who wished to build houses (and extend the aptly named "Sea Level Drive") on a public beach below, in some areas, the mean high tide line.[101] The Commission denied the permit because the mean high tide line (and hence public trust property) extended into lands planned for development, and the court of appeal ultimately affirmed the Commission's decision.[102] In doing so, the court re-emphasized the ambulatory nature of the tidelands trust, whose boundaries move as the mean high tide line shifts. "The state owns all tidelands below the ordinary high water mark and holds such lands in trust for the public," the court explained.[103]

> The high water mark is the mark made by the fixed plane of high tide where it touches the land; as the land along a body of water gradually builds up or erodes, the ordinary high water mark necessarily moves, and thus the mark or line of mean high tide, i.e., the legal boundary, also moves.[104]

This principle "has long been a staple of the common law."[105] Thus Lechuza's property line (and the property line of *any* coastal landowner) "moves back and forth with the gradual, seasonal accretion and erosion of the shore."[106] Lechuza's development permit was rightly denied because it had "failed to meet its burden of showing that the project would not encroach on public tidelands."[107]

Although the *Lechuza* case dealt with tidelines shifting due to erosion processes, there is nothing in public trust jurisprudence that would deny the public its trust interest in cases where the sea begins to

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98. Titus, *supra* note 70, at 1368.
99. *Id.*
100. *Id.* at 1370; *see also* Joseph J. Kalo, *The Changing Face of the Shoreline: Public and Private Rights to the Natural and Nourished Dry Sand Beaches of North Carolina*, 78 N.C. L. REV. 1869, 1884–85 (2000) (explaining that title comes and goes with natural erosion).
101. Lechuza Villas West v. Cal. Coastal Comm'n, 70 Cal. Rptr. 2d 399, 399–404 (Ct. App. 1997).
102. *Id.* at 403.
103. *Id.* at 411 (quoting State Lands Comm'n v. Superior Court, 900 P.2d 648, 655 (1995)).
104. *Id.* (quoting City of Oakland v. Buteau, 179 P. 170 (Cal. 1919)).
105. *Id.*
106. *Id.*
107. *Id.* at 404.

rise due to global warming. As one California court has already recognized, "if the sea level does rise [due to global warming], so will the level of mean high tide" and with it, the public's trust rights in the shore.[108] Building a development or building a seawall for an existing structure will equally encroach on public tidelands as the sea rises and migrates toward and around the bases of buildings that once stood on dry land. Building a seawall does not eliminate the problem: a seawall that prevents the mean high tide line from migrating landward of the seawall artificially prevents the movement of the mean high tide line and denies the public its reversionary trust interest.[109] It also destroys the public's trust interests in the beach itself: with the beach damaged or entirely absent, the trust interests in access, navigation, fisheries, and ecosystem functions, among others, have been entirely lost. Seawalls violate the public trust in a time of rising seas.

In the absence of a seawall, the trust is preserved. Title would transfer under common law if erosion were allowed to occur; the rolling easement ensures that the shore will be able to move freely and that title to the migrating marsh or wet sand beach will ultimately shift to the public. As sea level rise expert James G. Titus puts it, "no one has an automatic right to build a bulkhead that causes the public's tidelands to disappear."[110] Thus, a rolling easement acts to prohibit the building of erosion control structures *now* to ensure that the public's rights vest in the future.

One important implication of this larger point is that statutes—including the Coastal Act—that grant some armoring privileges are only valid insofar as they maintain public trust rights. Statutes attempting to transfer lands or any property rights out of the trust would be "carefully scanned to ascertain whether or not such was the legislative intention."[111] Courts seldom allow transfers out of the trust: "if any interpretation of the statute is reasonably possible which would not involve a destruction of the public use or an intention to terminate it in violation of the trust, the courts will give the statute such interpretation."[112] Indeed, "a state, as administrator of the trust in tidelands on behalf of the public, does not have the power to abdicate its role as trustee in favor of private parties."[113] Trust property may only be transferred into private hands to

108. Littoral Dev. Co. v. S.F. Bay Conservation & Dev. Comm'n, 29 Cal. Rptr. 2d 518, 527 n.5 (Ct. App. 1994).

109. Titus, *supra* note 70, at 1370–72.

110. *Id.* at 1374.

111. Nat'l Audubon Soc'y v. Superior Court, 658 P.2d 709, 721–22 (Cal. 1983) (quoting People v. Cal. Fish Co., 138 P. 79 (Cal. 1913)).

112. *Id.*

113. City of Berkeley v. Superior Court, 606 P.2d 362, 365 (Cal. 1980).

support trust purposes.[114] Generally speaking, only very small transfers—made as parts of larger public projects—will be allowed. As the California Supreme Court concluded, while a transfer may occasionally be tolerated "we emphasize that the circumstances under which this may occur are of necessity unique, that the conditions sanctioning its approval must be scrupulously observed and satisfied, [and the parcel must be explicitly] determined by the Legislature to have no further value for the purposes of the public easement."[115]

This interpretive principle means that courts should support regulatory and statutory efforts that assert this basic trust principle by refusing to allow armoring that would impair the public's ancient trust rights. Indeed, even apparent statutory grants of armoring privileges, discussed below, may violate the public trust doctrine.[116] Overly broad armoring privileges, which violate trust principles, may never have been held by coastal property owners, and despite administrative permit grants to the contrary, must be viewed as illegal transfers out of the trust. Explicitly denying such "entitlements" would therefore merely be an articulation of a background principle of state property law firmly rooted in the public trust.

b. Custom

In addition to the public trust doctrine, rights of customary use may also limit the ability of shoreline owners to armor the coast, although in more limited cases. The principle of customary law has enjoyed a resurgence as a tool to open beaches to public access over the past four decades.[117] It may also be well suited, in some instances, to ensure that the public has a beach *to* access as the seas rise. Like the public trust doctrine, custom may constitute a background principle of law whose application could defeat a takings claim. In general, customary use can grant an easement over beach property and requires demonstrating that the use has been "ancient, continuous, peaceable, and free from dispute," as well as "reasonable, certain, obligatory, and consistent with other laws."[118] In short, a rolling easement can be based on customary beach use, although the degree to which custom applies will vary based on the history of a particular stretch of beach.

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114. *Id.*; *see also* CAL. PUB. RES. CODE § 6307 (West 2006) (limiting State Lands Commission's ability to transfer land out of the trust without explicit findings that such transfers will serve trust purposes).

115. City of Long Beach v. Mansell, 476 P.2d 423, 440 (Cal. 1970).

116. *See infra* notes 137–159 and accompanying text.

117. *See generally* David J. Bederman, *The Curious Resurrection of Custom: Beach Access and Judicial Takings*, 96 COLUM. L. REV. 1375 (1996).

118. Wendy Oram & Clay Valverde, Note, *Legal Protection of Surf Breaks: Putting the Brakes on Destruction of Surf*, 13 STAN. ENVTL. L.J. 401, 442 (1994) (synthesizing cases).

In California, the seminal custom case is the combined ruling in *Gion v. Santa Cruz* and *Dietz v. King*, a 1970 California Supreme Court decision that set forth the basic legal principles.[119] In that case, the court explained that while the public can acquire a prescriptive easement over the private dry sand areas of a beach (in essence placing private land under an easement for public use without the owner's permission), "the question is whether the public has engaged in long-continued adverse use of the land sufficient to raise the conclusive and undisputable presumption of knowledge and acquiescence, while at the same time it negatives the idea of a mere license."[120] Put another way, those "seeking to show that land has been dedicated to the public need only produce evidence that persons have used the land as they would have used public land. If the land involved is a beach or shoreline area, they should show that the land was used as if it were a public recreation area."[121] In cases where this can be shown, a prescriptive easement by customary use attaches to the dry sand area of the beach.

Such prescriptive easements, much like the easement associated with the area below the mean high tide line in the public trust, should be able to migrate with the beach. Because prescriptive easements established by custom are historically contingent in California, requiring a showing of genuine past public use, they cannot be used generally to preserve broad swaths of the coast. Instead, they can be used as a focused tool to save particular areas of coastline. Fortunately, the restrictive legal test means that areas qualifying for prescriptive easements will be those long used by the public, and thus custom has an important role to play in preserving areas of the coast that are particularly dear to many Californians.

Although custom's application has been interpreted more narrowly in California than in some states, meaning that California's doctrine will be most useful in saving specific popular beaches rather than the shoreline as a whole, its application to moving shorelines in those states may be relevant here as a supporting principle for restricting development. It is therefore worth examining the use of custom-based easements more generally. Custom has been used to open beaches and to prevent development in, among other states, Oregon, Texas, and Hawaii. Hawaii's use of custom is the most expansive.[122] There, where ancient Hawaiian customary law and usage has been imported into state common law, principles of "collective existence and community" have been used to broadly allow access to beaches and to prevent interference with public hunting and gathering rights.[123] But even states without this rich

119. 465 P.2d 50 (Cal. 1970).
120. *Id.* at 56.
121. *Id.*
122. Bederman, *supra* note 117, at 1417–34.
123. *Id.* at 1433–34.

indigenous law have used custom broadly. In Oregon, the state supreme court famously opened the dry sand ocean beaches of the state to the public based on a tradition of customary use.[124]

Texas has applied custom directly to justify moving public easements on public beaches after storm flooding has eroded significant areas of shoreline. In *Matcha v. Mattox*, a Texas court of appeals prohibited the reconstruction of a house that had been damaged by a storm because the storm had also shifted the beach vegetation line.[125] The vegetation line had marked the limit of a declared public easement, which following the storm included the disputed property.[126] As the court held, "the theory of a migratory public easement is compatible with the doctrine of custom and the situations that often give rise to custom."[127] This is because in practice, a public easement "on a beach cannot have been established with reference to a set of static lines on the beach, since the beach itself, and hence the public use of it, surely fluctuated landward and seaward over time."[128] If the public easement is to remain useful and "reflect the reality of the public's actual use of the beach, [it] must migrate as did the customary use from which it arose."[129]

This common sense rationale—that customary use of a moving target must follow the target as it moves—thus also supports the use of the doctrine of custom as a background principle of law to justify imposition of a rolling easement. For beaches or tidelands with long histories of public use, extending well before the Coastal Act, custom may be a useful tool for implementing and defending armoring bans.

c. *Public Nuisance*

Finally, basic nuisance principles can bolster both the argument against armoring and for removing poorly designed or harmful existing armoring structures. A rolling easement can, in other words, be supported as a way of averting or mitigating a public nuisance. California defines nuisances as including, among other things, "an obstruction to the free use of property, so as to interfere with the comfortable enjoyment of life or property, or unlawfully obstruct the free passage or use . . . of any navigable . . . bay, stream, canal, or basin, or any public park, square, street, or highway."[130] This definition clearly encompasses damage to the coast—seawalls that interfere with public use of coastal public lands

124. State *ex rel.* Thornton v. Hay, 462 P.2d 671 (Or. 1969); *see also* Bederman, *supra* note 117, at 1417–25.

125. 711 S.W.2d 95 (Tex. App. 1986)

126. *Id.*

127. *Id.* at 100.

128. *Id.*

129. *Id.*

130. CAL. CIV. CODE § 3479 (West 2006).

would "unlawfully obstruct" such use and "interfere with the comfortable enjoyment of life or property." By articulating the harms caused by seawalls—increased erosion, visual blight, loss of public beaches and ecosystem services, and creation of physically hazardous situations—they could likely be prosecuted as public nuisances.[131] In addition, because waves can refract off barriers, thereby altering the surf's impact on neighboring properties, seawalls also may be a private nuisance due to their effect on nearby coastal properties.

Because "[t]he legislature has the power to declare certain uses of property a nuisance and such use thereupon becomes a nuisance *per se*," governments can also simply define armoring in vulnerable locations as a nuisance.[132] A California court upheld such a legislative definition in a case where the city of Del Mar removed coastal armoring because the city found that a seawall constituted a public nuisance.[133] The court, however, did not reach the question of whether erosion caused by the structures at issue was a nuisance, instead deciding the case on public access grounds.[134] While anchoring an armoring ban in public nuisance law should not be difficult given the considerable damage done by excessive erosion control structures,[135] agencies should support such actions with well-documented findings since many courts will not be familiar with this construction of nuisance.

3. The California Statutory Puzzle: Reconciling the Public Trust and the Coastal Act

Root common law principles—the public trust doctrine, custom, and nuisance—complement, yet may appear at odds with, the statutory provisions of the Coastal Act. The Coastal Commission confronts an unsettled interpretation question that complicates the implementation of rolling easements. The Coastal Act section 30235 provides that "existing structures" should be granted the privilege of armoring if specified conditions are met.[136] Government agencies and nonprofit groups continue to debate the meaning of this provision: does "existing" mean existing as of 1976, when the Act was passed, or existing at the time of the application to build a seawall? The first interpretation would effectively bar seawalls for all post-1976 structures; the second would still bar applications for seawalls for unbuilt structures but leave all built

131. *Id.* § 3480 (defining public nuisance as "one which affects at the same time an entire community or neighborhood, or any considerable number of persons").

132. Scott v. City of Del Mar, 68 Cal. Rptr. 2d 317, 322 (Ct. App. 1997).

133. *Id.* at 319, 322–23.

134. *Id.* at 323 n.6.

135. *See* Griggs, *supra* note 34 (discussing problems caused by armoring).

136. CAL. PUB. RES. CODE § 30235 (West 2006).

structures with at least the possibility of obtaining a permit to armor. The Coastal Commission has historically adopted a version of the second view. However, the Coastal Act itself might be better read to bar new armoring for all structures built after the passage of the Act. The question of statutory interpretation, though important, is ultimately trumped by the public trust doctrine, which extends deeper than any statute. We conclude that no seawall permit can be granted, as discussed above, for any structure that would abrogate the public trust—and, in most cases, this will mean no seawall permits for structures in the way of the rising sea.

Before turning to the statutory dispute's resolution in the public trust doctrine, it is important to understand the nature of the Coastal Act and the constitutional principles that support it. The California Coastal Act is, on the whole, a resource protection and public access statute that allows for economic growth, use, and development of coastal resources where those activities can be harmonized with coastal resource protection and public access. This reflects the fundamental state constitutional emphasis on the public's right of access to the coast, which is codified in, but not limited by, the Coastal Act. The California Constitution provides that no one

> shall be permitted to exclude the right of way to such water whenever it is required for any public purpose . . . and the Legislature shall enact such laws as will give the most liberal construction to this provision, so that access to the navigable waters of this State shall always be attainable for the people thereof.[137]

This theme runs throughout the Coastal Act. For example, section 30210 directs the Commission to work towards "maximum access . . . and recreational opportunities . . . for all the people," albeit taking into account "the need to protect public rights, rights of private property owners, and natural resource areas from overuse."[138] Section 30211 further provides that "development shall not interfere with the public's rights of access where acquired through use or legislative authorization, including, but not limited to, the use of dry sand and rocky coastal beaches."[139] The public's right to the beach is a central California value. That value is reinforced by the public trust principles discussed above, which safeguard and extend the public's rights.

This core value should inform our reading of the apparent conflict between Coastal Act sections 30235, which permits seawall construction for existing structures, and 30253, which limits the location of new

137. CAL. CONST., art. 10, § 4.
138. CAL. PUB. RES. CODE § 30210.
139. *Id.* § 30211.

developments to areas that will *not* require seawalls.[140] The Coastal Commission has not issued a formal rulemaking based on section 30235 but has instead acted on the assumption that the section does grant all threatened coastal structures a qualified privilege to armor—as if, in other words, "existing" structures means structures standing at the time of application. Normally, the Commission will only grant an armoring permit if (1) the structure the protective device is meant to protect exists when the application is filed, (2) the structure is "in danger from erosion" and (3) there are no other environmentally less damaging feasible alternatives.[141] The Commission has, nonetheless, worked to limit the impact of its interpretation of section 30235 by requiring armoring waivers and setbacks for new development. This effort was not structured around the threats of sea level rise, however, and may need to be revisited in light of climate change. Since the meaning of the "existing structures" term has never been judicially resolved,[142] the Commission might also consider undertaking a formal rulemaking to adopt a new administrative interpretation of the term for use in future decisions.

In the absence of a rulemaking, sections 30235 and 30253 work together with regard to future structures. Section 30253 provides that "new development shall," among other things, "assure stability and structural integrity, and neither create nor contribute significantly to erosion, geologic instability, or destruction of the site or surrounding area or in any way require the construction of protective devices that would substantially alter natural landforms along bluffs and cliffs."[143] This seems a straightforward-enough section: to the extent that new development is permitted, it must not be sited so as to damage the coast. This bar is written to include a prohibition on "protective devices"—which includes armoring. This section does not conflict with the armoring privileges for "existing" structures provided for in section 30235 for the simple reason that new development does not yet exist. Note, though, that under a maximally protective alternative reading, in which "existing" structures are only those that were built before 1976, "new development" would include all post-1976 development. The two sections are consistent with each other under both readings. Under either reading, section 30253 requires that new development *must* be built in ways that will not require

140. *Id.* §§ 30235, 30253.

141. *Id.* § 30235.

142. The closest that courts have come to resolution was one unpublished decision challenging seawall approval for a post–Coastal Act structure. The Commission took the position that "existing structures" include post–Coastal Act structures, but the court did not reach the issue, instead dismissing the case on technical grounds. Surfrider Found. v. Cal. Coastal Comm'n, No. A110033, 2006 WL 1530224, at *3–4 (Cal. Super. Ct. June 5, 2006) (holding that Surfrider should have challenged the seawall under the LCP rather than under the Coastal Act itself).

143. CAL. PUB. RES. CODE § 30253 (West 2006).

armoring. As the Commission develops more accurate and comprehensive sea level rise predictions, section 30253 will ensure that new coastal development does not occur in vulnerable areas—preventing economic loss and ecosystem damage.

The armoring privileges provided for in the Coastal Act, whether they are available to post-1976 structures or not, are not absolute. Section 30235 provides that protective devices, including "seawalls, cliff retaining walls, and other such construction that alters natural shoreline processes shall be permitted when required to serve coastal-dependent uses or to protect existing structures or public beaches in danger from erosion, and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply."[144] On its face, then, section 30235 is not a grant of armoring rights but an extension of armoring privileges and only when there is "danger from erosion"—which, under the coastal-protective purposes of the Act will likely be read to mean *imminent* danger—and only when armoring is designed to either eliminate or mitigate shoreline sand supply impacts. The Commission generally interprets "danger" to mean that an existing structure would be unsafe to occupy in the next two or three storm cycles if nothing were to be done. The provision does not contemplate the denial of permits for larger reasons of ecological stability or coastal access protection.[145] In the absence of modifying law elsewhere, section 30235 still provides for an overbroad grant of armoring privileges, particularly if it is read to apply to all existing (e.g., post-1976) structures. Even under a narrower reading, though, limited to pre-1976 structures, the grant of armoring privileges still touches many structures.[146] To address the threat of sea level rise, the Commission would be justified in finding appropriate limits for section 30235 elsewhere in the Act and the law of the state.

As a starting point, note that the Coastal Act itself provides a rule for interpretation. Section 30007.5 explains that internal "conflicts be resolved in a manner which on balance is the most protective of significant coastal resources."[147] As Todd Cardiff argued in a recent note on this subject, that resolution must take limiting coastal armoring as a guiding principle.[148] Section 30007.5 can be read as embodying the underlying public trust doctrine that must guide all coastal decisions: it restates in statutory terms the basic state obligation to safeguard the

144. *Id.* § 30235.

145. *Id.*

146. There is no inventory of the number or distribution of these structures. Creating one would fill one of the many informational gaps that need to be addressed in order to chart a sea level rise policy for California.

147. CAL. PUB. RES. CODE § 30007.5.

148. Cardiff, *supra* note 73, at 269.

public's resources against, among other threats, erosion by private parties.

Cardiff, a proponent of the narrow reading of section 30235, cogently argues that it is meant as a grandfather clause, and that the more natural reading of the provision is that no structures built after the Act's 1976 passage can be said to be "existing" for the purpose of the section.[149] Such an interpretation would bring California into comity with the coastal programs of other states, which grandfather in structures built at the time of passage but do not allow continued armoring.[150] The alternative reading, in any case, offers limited protection against coastal armoring: if the section 30235 conditions are met, along with any other conditions inherent in the base common law, it would allow seawall construction applications for any built structure, giving no independent meaning to the word "existing."[151] In the most liberal reading of the section, new developments could dodge any strictures of the section by building houses first—once the houses are built, they would be "existing structures" and so would be allowed to build coastal armoring.[152]

Even as a textual matter, Cardiff argues, the permissive reading does not square with the restrictive language of section 30235, which invites the court to inquire into the necessity of armoring "required to" protect "existing" structures. The reading also ignores the second sentence of section 30235, which requires that "existing marine structures causing water stagnation" be "phased out, or upgraded when feasible";[153] here, existing structures clearly refer to those in existence at the time of the Act, which legislators intended to be phased out in the future. They surely did not contemplate the construction of new "existing" structures that would then be phased out at a future date, he concludes. Some of the legislative history of the Coastal Act, as collected by Cardiff, supports this understanding of "existing" in section 30235.[154] As he notes, the word "existing" was inserted into the section late in the drafting process, suggesting that it was intended to have a limiting effect upon the original language.[155] Indeed, the term was not present in a more developer-friendly version of the Act also under consideration.[156]

149. *Id.* at 268 (arguing that allowing section 30235 to apply to all "existing" structures, whenever constructed, would mean that "a structure would deserve protection moments after completion").

150. See discussion of coastal acts of Rhode Island, Massachusetts, North Carolina, South Carolina, and Oregon, *infra* notes 192–213.

151. Cardiff, *supra* note 73, at 268.

152. *Id.*

153. CAL. PUB. RES. CODE § 30235 (West 2006).

154. Cardiff, *supra* note 73, at 261–68.

155. *Id.* at 267.

156. *Id.*

Cardiff's evidence, however, is not conclusive. In a recent unpublished case, which did not decide the issue due to a technicality regarding the standard of review, the Coastal Commission pointed out that "existing" is used in other places within the Act's text in ways that clearly indicate it was meant to refer to current conditions, not 1976 conditions.[157] The Commission noted that "existing" was specifically modified with a date in other cases, which at least suggests that the "existing" in section 30235 was intended to refer to all built structures, although the comparison to other, unrelated provisions in the Act is, of course, not dispositive.[158]

Because *both* the broad and narrow readings of section 30235 can be read consistently with section 30253, neither Cardiff nor the Commission clearly has the better of the statutory analysis. Also, importantly, neither reading addresses the problem of pre-1976 structures, which both would allow. We must instead return to the basic trust principles the Act was designed to protect.

As Cardiff notes and as the Act itself states, the essential goal of the Coastal Act is to ensure the long-term future of the coast, not to create an entitlement for destructive development.[159] This principle is embodied in section 30007.5 and in the public trust doctrine: that every apparent conflict in the Coastal Act and between coastal development needs and the public trust must be resolved in the trust's favor. This root principle should be the Commission's guide to reading section 30235: whether its reach is broad or narrow, the armoring privileges that it grants should not be lightly conferred to *any* structure. A legislative change to section 30235's direction that seawalls "shall" be allowed when its conditions are met to a more permissive acknowledgment that seawalls "may" be allowed would make this point clearer.

Indeed, it may be illegal for the Commission to confer armoring privileges even when the conditions of section 30235 are met. This is because where armoring the coast prevents inward migration of the public trust lands—as could be the case under sea level rise—neither the Commission nor the legislature acting through statute has the power to simply cede the state's trust rights. As discussed above, the public trust right is a fundamental principle of law; the state and the Commission would be violating their fiduciary duties if they simply allowed its destruction. Indiscriminate armoring under section 30235 defeats the right in two separate ways. By canceling the reversionary trust interest—that is, by blocking landward migration of the shore—it destroys a

157. Brief of the Cal. Coastal Comm'n at 17–19, Surfrider Found. v. Cal. Coastal Comm'n, 2006 WL 1530224 (Cal. Super. Ct. June 5, 2006) (No. A110033) (on file with authors).

158. *Id.* at 20.

159. Cardiff, *supra* note 73, at 264–66.

portion of the public right. But it also cancels concrete public trust rights: the long-recognized public right to navigation and recreation in the wet sand below the mean high tide line. Indeed, it not only cancels beach access—it cancels the beach itself. By reading the Coastal Act through the lens of the more fundamental law of the public trust doctrine, the Commission can find ample support for appropriate rolling easements for structures of any vintage.

4. *Permit Conditions as Rolling Easements*

The public trust doctrine will also serve as a defense for past and future no-seawall permit conditions. The Commission has used agreed-upon permit conditions to ensure that property owners will never apply for armoring privileges for structures built after 1976, despite the Commission's broad reading of section 30235. The Commission has also used section 30253 to help keep most new structures out of harm's way.

First, the Commission utilizes its authority under section 30253 to require that all new structures are set back from the coast far enough to ensure that erosion will not reach them during the expected economic life of the structure (normally seventy-five to one hundred years for homes, as specified in the relevant LCP). This setback is calculated using historical erosion data and slope stability or, in some cases, is based on the measured geological conditions in the permitted area. However, the Commission's current setback methodology does not take into account dramatic increases in wave forces and erosion due to sea level rise. If future erosion rates are the same as historic rates, the setback will erode at the anticipated rate and the structure will be threatened by erosion only at the end of its economic life. Yet, if erosion accelerates owing to sea level rise, increased storm strength and frequency, or increased wave energy, structures permitted with setbacks will be at risk from erosion many years before the anticipated economic term of the structure. The resulting policy dilemma is that owners of many structures permitted with setbacks may, nonetheless, ultimately be in a position to request armoring.

The Commission has attempted to avoid this possibility by placing "no future armoring" conditions in all recent permits. A sample permit (this one borrowed from the standard language used in modern permitting documents) often specifies, among other requirements, that:

> A. By acceptance of this permit, the applicants agree, on behalf of themselves and all successors and assigns, that no bluff or shoreline protective device(s) shall ever be constructed to protect the development approved pursuant to this Coastal Development Permit, including, but not limited to, the residence with the attached garage, foundations, well, septic system, and driveway in

the event that the development is threatened with damage or destruction from waves, erosion, storm conditions, bluff retreat, landslides, ground subsidence or other natural hazards in the future. By acceptance of this permit, the applicants hereby waive, on behalf of themselves and all successors and assigns, any rights to construct such devices that may exist under Public Resources Code Section 30235 or under Local Coastal Plans.

B. By acceptance of this Permit, the applicants further agree, on behalf of themselves and all successors and assigns, that the landowner shall remove the development authorized by this permit, including the residence with the attached garage, septic system, and driveway if any government agency has ordered that the structures are not to be occupied due to any of the hazards identified above. In the event that portions of the development fall to the beach before they are removed, the landowner shall remove all recoverable debris associated with the development from the beach and ocean and lawfully dispose of the material in an approved disposal site. Such removal shall require a coastal development permit.

C. In the event the edge of the bluff recedes to within 10 feet of the principal residence but no government agency has ordered that the structures not be occupied, a geotechnical investigation shall be prepared by a licensed geologist or civil engineer with coastal experience retained by the applicant, that addresses whether any portions of the residence are threatened by wave, erosion, storm conditions, or other natural hazards. The report shall identify all those immediate or potential future measures that could stabilize the principal residence without shore or bluff protection, including but not limited to removal or relocation of portions of the residence. The report shall be submitted to the Executive Director and the appropriate local government official. If the geotechnical report concludes that the residence or any portion of the residence is unsafe for occupancy, the permittee shall, within 90 days of submitting the report, apply for a coastal development permit amendment to remedy the hazard which shall include removal of the threatened portion of the structure.[160]

Permit conditions also commonly include a waiver of risk and liability and a permanent deed restriction, giving notice to future owners of the parcel in question. Such terms in essence remedy the dangers created by an overbroad reading of section 30235, not by amending the law or altering the Commission's interpretation, but by imposing a series

160. This language is borrowed from a number of public permits issued by the Commission. *See, e.g.*, Staff Report: Permit Amendment 1-88-040-A1 (2006) (on file with authors) (barring seawall construction for single family home on coastal bluff in concert with requiring setback sufficient to likely avoid erosion problems during economic life of the house).

of conditions that remove the threat of future armoring. These provisions have not been tested in court. However, courts have been responsive to other conditions similarly designed to address adverse impacts to public recreation stemming from seawall construction. In September 2006, the Superior Court of Monterey County, for instance, upheld a $2.3 million mitigation fee intended to compensate the public for the lost recreation value of a beach that is expected to completely erode due to shoreline armoring approved for a poorly sited condominium development built before the Coastal Act.[161] The fee covered a total lost future value of $5.3 million.[162] It is worth noting that this fee may have been too low—it took into account only lost recreation value rather than including the loss of other ecosystem services, such as wildlife habitat and lost sand supply to the region's littoral cell[163]—but it demonstrates that even where armoring is allowed, it need not be a simple give-away of public rights to the coast. This case does not, however, serve as a perfect predictor of stronger permit conditions favoring structure removal over large mitigation fee payments.

More importantly, these permit conditions vindicate the public trust rights at stake: they prevent the loss of the public's reversionary interest in the moving shoreline and maintain the public trust navigation and recreation interests on the beaches that would otherwise be lost. They should survive in court because the building permits themselves would be invalid without them. The Commission has no power to violate the public trust or to alienate public trust lands and so has no power to grant seawall privileges in cases where the shoreline is migrating under sea level rise. Thus permit conditions only make explicit what is implicit: the public trust doctrine attaches to all of these transactions.

Because these rights are deeply grounded in the public trust doctrine, working them out in a series of site-specific permit conditions rather than asserting them generally risks being haphazard or underprotective. While it would not be equitable to simply change course without public notice and comment,[164] rulemaking on a statewide basis is

161. Ocean Harbor House Homeowners Ass'n v. Cal. Coastal Comm'n, Case No. M 73109 (Cal. Super. Ct., Monterey County Sept. 2006).

162. *Id.* at 2.

163. *See generally* Alexander Brown & A. McLachlan, *Sandy Shore Ecosystems and the Threats Facing Them: Some Predictions for the Year 2025*, 29 ENVTL. CONSERVATION 62 (2002) (discussing the ways in which beach ecosystems function and how they interconnect with other human and natural systems).

164. Courts frown upon abrupt reversals of agency positions without due process. While agencies are not bound to carry on a bad policy, public reliance upon agency pronouncements mean that agencies are well advised to offer opportunities for notice and comment before reversing course. *See, e.g.*, Ariz. Grocery v. Atchison, Topeka & Santa Fe R.R. Co., 284 U.S. 370 (1932) (seminal Supreme Court case establishing due process requirements for agency position changes); *see also* Motor Vehicle Mfr.'s Ass'n v. State Farm Mutual Auto. Ins. Co., 463 U.S. 29 (1983) (reversals in position are due as much as formal process as adoptions of policy).

a potential long-term solution. Such a rulemaking process would, of course, be politically contentious, but the Commission could reduce the ire of developers by applying its rulemaking prospectively—only to permit applications filed after finalization of the rulemaking. The Commission should seriously consider reinterpreting section 30235 as a grandfather clause, rather than a general grant of power to armor. Alternatively, it might leave section 30235 undisturbed, and simply explain how the public trust doctrine combines with the Coastal Act to bar injudicious armoring. This rulemaking would make clear that the Commission will seek the maximally protective policy, as originally mandated by the Coastal Act upon its passage in 1976 and as fundamentally required by the public trust doctrine.[165]

5. *Takings and Rolling Easements in California*

Could California impose a blanket rolling easement along its coastline without running into takings prohibitions and without being stymied by political opposition? The answer is probably yes, as a constitutional matter, but with serious practical caveats. Few judges, if any, will initially be comfortable with allowing structures built under one understanding of the law to yield to the sea, even if the public trust doctrine would appear to require this result. Because takings lawsuits are most likely if political processes break down, implementing easements in a savvy way is vital. Developing a mixed strategy, including the purchase of rolling easements from existing landowners in appropriate circumstances, will reduce political pressure and is the more equitable course. The cost of rolling easements for existing structures in sensitive areas has the potential to be relatively low if they are implemented within the context of a larger policy. As part of a general strategy including LCP amendments to deflect development away from highly sensitive areas, the imposition of rolling easements in undeveloped areas and requirements to mitigate permitted armoring can provide the lynch pin for sea level rise management.

James G. Titus of the EPA provides valuable analysis of the takings problems at issue.[166] Under the Supreme Court's decision in *Lucas v. South Carolina Coastal Council*, a taking will occur if a regulation "denies all economically beneficial or productive use of land."[167] Even then, regulations that actualize title restrictions arising from "background principles of the State's law of property and nuisance"[168] do not effect a taking. Under both prongs of analysis, rolling easements—even if

165. CAL. PUB. RES. CODE § 30007.5 (West 2006).
166. Titus, *supra* note 70, at 1354–59.
167. 505 U.S. 1003, 1015 (1992).
168. *Id.* at 1029.

imposed by the state without compensation—would probably not be a taking. As Titus argues, the common law of erosion and the public trust jointly act to "diminish the rights of coastal lowland owners, compared with the rights of noncoastal dryland owners."[169] The public trust doctrine is a background principle of the common law and so would obviate a *Lucas* taking as applied in this case. The easement, simply put, has always been there: it is not an imposition on the property owner but part of the nature of his or her property. This is precisely the reasoning of a U.S. District Court in Texas, upholding that state's rolling easement policy in *Severance v. Patterson*.[170] As Judge Hoyt wrote in that recent decision, issued in May 2007, "the public's rolling beach easement was established long before" the property owner took possession.[171] The extent of the easement depends on the behavior of the ocean, not the caprice of government: "The natural movement of the beach's boundaries may result in a temporary (or long-term) expansion of the physical area covered by the easement, but it may also result in a contraction of the covered area. This natural movement does not work a constitutional wrong."[172]

But even if a case did not involve this background principle, a state's direct imposition of a rolling easement would likely not cause the total loss of economically beneficial uses of land required for a *Lucas* taking. This is because rolling easements impose a future loss that will not occur for decades.[173] Discounted for present value, a rolling easement will not significantly diminish property values. The change in value would be truly minimal for undeveloped land and would likely still be minor for most developed land, except those properties in almost immediate danger of loss.

Easements could also be constitutionally required as permit conditions. The *Nollan/Dolan* line of cases makes clear that all permit conditions must bear an "essential nexus" to the purposes for which the permitting statute was designed, and the burden of the exaction on the permittee must bear "a rough proportionality" to the harm the exaction seeks to prevent.[174] The purposes expressed by the Coastal Act require that state bodies charged with administering the coast "protect, maintain, and, where feasible, enhance and restore the overall quality of the coastal zone," by assuring "orderly, balanced utilization and conservation" of its

169. Titus, *supra* note 70, at 1356.

170. Severance v. Patterson, No. H-06-2467, 2007 WL 1296218 (S.D. Tex. May 2, 2007).

171. *Id.* at *9.

172. *Id.* at *8; *see also id.* at *9 ("[Plaintiff] has not suffered a taking because her right to exclude the public never extended seaward of the dynamic, natural boundary of the beach.").

173. Titus, *supra* note 70, at 1358.

174. *See* Nollan v. Cal. Coastal Comm'n, 483 U.S. 825, 841 (1987) (essential nexus); Dolan v. City of Tigard, 512 U.S. 374, 390 (1994) (rough proportionality).

resources, maximizing "public access to and along the coast," assuring "priority for coastal-dependent" development over other developments, and encouraging state and local cooperation.[175] The state can show (once coastal vulnerability maps are completed) that permitting development would lead to armoring in some areas, and that armoring will reduce access and fail to conserve the critical resources of the land/sea interface. This showing should satisfy the "essential nexus" requirement. The state may also point to existing armored coastlines as evidence of the damage that accelerated armoring would do, as well as to the experience of other states that have successfully prohibited armoring to protect coastal resources.

The "rough proportionality" test may at first seem more difficult to meet—after all, a rolling easement requirement means that the structures may need to be moved or abandoned. However, this is not a total loss in value but rather a limitation on the total economic life of the structure. In present value terms, the burden may be minimal—and because value declines before the structure is built, in the worst case the effect is merely to discourage the building of expensive features. This burden is a small one to bear for the privilege of living in an erosion-prone area where, even with armoring, collapse may be inevitable in the long term. The state is simply readjusting the length of time of occupancy, not prohibiting it, and the permit condition mandates no additional expenses on the part of the property owner.

The sea level rise policy of the state, while rooted generally in the rolling easement concept, will see these easements applied in different ways and with variable frequencies. In urban cores, where ecological losses are likely to be lower and infrastructure replacement costs greater, few easements would be required—and those created (for instance, to protect public beach access) should be purchased, not extracted from unwilling sellers. In more rural areas, where ecological values may trump infrastructure values, easements should also, generally speaking, be negotiated rather than imposed. Here, well-chosen litigation would be more appropriate to defend areas of considerable ecological or public importance. New structures would only be built, under section 30253, in places where no armoring will ever be required—and even they should have "no future armoring" provisions in their permits to deal with the possibility that the sea may rise even faster than anticipated. Such a strategy would use limited state dollars to protect the most important areas, and would allow most existing structures to either armor, if they are in imminent danger and no less environmentally damaging alternative is available, or receive equitable compensation for the eventual property loss. In this way, the state retains its coastal resources and fulfills its

175. CAL. PUB. RES. CODE § 30001.5(a)–(e) (West 2006).

public trust duties. The policy is flexible, allowing "nature to take its course with respect to sea level rise and inland migrations of coastal wetlands," thereby "forcing landowners to incorporate" this risk into land use decisions and providing a dynamic incentive to avoid development of areas subject to loss.[176]

a. *Implementing Rolling Easements: Examples from Other States*

Whether rooted in public trust doctrine, custom, nuisance doctrine, permitting requirements, or statute, rolling easements have been deployed across the country. California lawmakers can take some comfort in the fact that the concept has been successfully implemented to deal with ordinary erosion issues on other coastlines.[177]

The rolling easement concept is most frequently associated with Texas common and statutory law and was first clearly articulated in *Feinman v. Texas*, a 1986 case concerning the rights of property owners after Hurricane Alicia significantly eroded Galveston's West Beach.[178] The facts of *Feinman* help to illuminate the concept. According to Texas' Open Beaches Act, the public trust applies and the public enjoys unrestricted rights in all beaches below the first line of vegetation.[179] The question in *Feinman* was whether the public "easement could shift automatically as the vegetation line moved" as it had during the storm.[180] The court cited to the common law of erosion, which generally awards title over accreting land to shoreline owners and removes title as land erodes, and then extended the concept to hold that "not only can *title* change because of the advances and retreats of the sea, but *the location and extent of easements* along waterways can change because of accretion or erosion to land along a waterway."[181] Put simply, "an easement is not so inflexible that it cannot accommodate changes in the terrain it covers."[182] The interpretation of the beachfront property owners—that the newly reduced beach largely belonged to them because the original easement was now submerged—would "greatly diminish the public's easement. In fact, the easement in some instances eventually

176. Daniel D. Barnhizer, *Givings Recapture: Funding Public Acquisition of Private Property Interests on the Coasts*, 27 HARV. ENVTL. L. REV. 295, 346 (2003).

177. This Article's focus is domestic, but sea level rise is, of course, a global problem. Britain, for instance, has recently adopted a policy of "managed retreat"—essentially a variation on the rolling easements proposed here. There, as here, the social and ecological choices are often wrenching. *See* Elisabeth Rosenthal, *Beccles Journal: As the Climate Changes, Bits of England's Coast Crumble*, N.Y. TIMES, May 4, 2007, at A-4.

178. 717 S.W.2d 106 (Tex. App. 1986).

179. *Id.* at 109; *see also* TEX. NAT. RES. CODE ANN. § 61.011(a) (Vernon 2006) (defining public beach as area "extending from the line of mean low tide to the line of vegetation").

180. *Feinman*, 717 S.W.2d at 109.

181. *Id.* at 110.

182. *Id.*

would disappear," defeating the public trust and public interest.[183] The court somewhat confused matters by relying upon the public's long-term use of the beach to find a (rolling) easement rooted in implied dedication rather than relying upon a broad public trust rationale that would have immediately covered all beaches.[184] Texas courts have continued to employ the rolling easement concept to protect the public's rights on eroding beaches, most recently in *Arrington v. Texas General Land Office*, which upheld a rolling easement that prevented the rebuilding of a beach home when the easement crossed the former building site due to storm erosion.[185] A federal court recently confirmed the constitutionality of the rolling easements endorsed in *Arrington* and *Feinman* in *Severance v. Patterson*, finding that while plaintiffs "may not like this aspect of Texas property law, . . . nothing in the federal Constitution forbids it."[186]

Although *Feinman* established the rolling easement's conceptual outlines, it is important to note a few wrinkles not present in that case. First, it, like *Arrington*, did not involve a refusal to allow armoring, though *Arrington* involved the somewhat analogous denial of a rebuilding permit. Second, the grounding of the easement concept in *Feinman* itself is not entirely clear—it appears to arise from a combination of statutory policy, easement common law, and perhaps, the public trust doctrine.

Courts in other states have been variably receptive to the rolling easement concept. The Supreme Court of North Carolina applied the concept to affirm that a beach access route whose location had shifted due to erosion maintained its easement character.[187] The Nebraska court of appeals imported the concept, in an unpublished decision, to extend an eroding drainage easement, affirming that "erosion to some degree is a natural consequence of the movement of water over soil" and that the easement could, therefore, roll as in *Feinman*.[188] Courts have declined, however, to extend the concept of rolling easement to include public facilities owned by the state based upon reasons other than the public trust doctrine. For example, the Supreme Court of Vermont refused to find a moving easement for a lakefront road that needed to be moved due to erosion, distinguishing *Feinman* because Vermont had no statutory

183. *Id.* at 111.

184. *Id.* at 112–14.

185. *See* 38 S.W.3d 764 (Tex. App. 2001).

186. Severance v. Patterson, No. H-06-2467, 2007 WL 1296218, at *9 (S.D. Tex. May 2, 2007); *see also supra* notes 170–172.

187. Concerned Citizens of Brunswick Co. Taxpayers Ass'n v. North Carolina, 404 S.E.2d 677, 684 (N.C. 1991) (citing *Feinman* approvingly for the proposition that "shifts occurring from time to time in the beach vegetation line due to storm action did not defeat establishment of a prescriptive public easement").

188. Swaney v. City of Bellevue, No. A-98-456, 1999 WL 703548 (Neb. App. Sept. 7, 1999).

policy supporting public access such as had supported the rolling easement in the Texas case.[189] A Delaware court similarly refused to find that a road right-of-way should migrate along with an eroding lakeside riparian boundary because the road in question had been platted at a firm location and was not designed as an easement with the purpose of allowing public access to the water.[190] Although the court acknowledged that the common law of erosion removed title from eroded land, it did not follow that the right-of-way paralleling the water would shift; rather, the road was itself eroded by the changing lake levels.[191] None of these courts addressed the question at issue here of coastal armoring structures.

Several states have codified variations of the rolling easement concept.[192] Maine, the Carolinas, Massachusetts, Rhode Island, and Oregon are among states that have implemented explicit restrictions on shoreline armoring structures. In some states, coastal armoring is flatly barred; in others it is strongly limited or permitted only when it minimizes ecological damage. The strength of these measures vary by state, but all are stronger than the laws that are presently available in California.

In New England, Maine has sought to protect the "fragile, dynamic resources" that comprise its coastal sand dune systems.[193] It anticipates that "sea level will rise approximately two feet in the next 100 years" and has regulated accordingly to prevent damaging its coastal dune system with erosion control structures.[194] It therefore provides that no project may be permitted "if, within 100 years, the property may reasonably be expected to be eroded," and flatly provides that "no new seawall may be constructed."[195] Massachusetts similarly provides that development on coastal dunes may not interfere with "the landward or lateral movement of the dune"[196] and that development on unconsolidated banks will not be allowed to use seawalls to prevent erosion, except for bank structures existing at the time of the law's 1978 passage.[197] Rhode Island bars essentially all erosion control structures along the oceanfront portion of its coast.[198] These policies will allow wetlands, beaches, and the purposes of the public trust to be maintained even as the sea level rises. An

189. Town of South Hero v. Wood, 898 A.2d 756 (Vt. 2006).

190. Scureman v. Judge, 747 A.2d 62 (Del. 1999).

191. *Id.* at 67–69. As the court explained, moving the right-of-way would not roll an old easement but rather create a new one, forcing a right-of-way where one had not previously been. *Id.* at 68.

192. For a broader statutory survey, see James G. Titus, *Does the U.S. Government Realize That the Sea is Rising? How to Restructure Federal Programs so That Wetlands and Beaches Survive*, 30 GOLDEN GATE U. L. REV. 717, 743–44 (2000).

193. Maine Coastal Sand Dune Rules ch. 355.1 (2006).

194. *Id.*

195. *Id.* at ch. 355.5(C)–(E).

196. 310 C.M.R. § 10.28 (2006).

197. *Id.* § 10.30.

198. Rhode Island Coastal Resources Management Program § 300.7(D)(1) (2006).

important exception is that Maine and Massachusetts do not ban armoring on rocky headlands, which are tough, largely granitic rocks rather unlike the relatively weak sedimentary bluffs in California. In California it is precisely these landforms, favored by builders and standing behind many popular beaches, that will be most at risk.

In the Southeast, North and South Carolina have been leaders in coastal protection. South Carolina's legislature found that the dynamic beach/dune system along its coast was "extremely important" to the state as "a storm barrier" contributing to "shoreline stability," by "generating approximately two-thirds of [the state's] annual tourism industry revenue," as "habitat for numerous species [and as] a natural healthy environment for the citizens" of the state.[199] Recognizing that "development unwisely has been sited too close to the system," the legislature found that it was in "both the public and private interests to protect the system from this unwise development."[200] The state legislature found that armoring provided a "false sense of security" but in fact "increased the vulnerability of beach front property" while contributing to the deterioration of the dry sand beach in front of the seawalls.[201] The state has therefore opted to "severely restrict the use of hard erosion control devices to armor the beach/dune system and to encourage the replacement of hard erosion control devices with soft technologies."[202] As a result, the state has barred most new construction and all erosion control structures (except those that protect public highways) seaward of a setback line determined by the crest of the dune system.[203]

North Carolina has taken similar steps. Under that state's Coastal Management Act, no "permanent erosion control structure" may be erected "in an ocean shoreline."[204] The state does allow sandbags to be used on a temporary basis.[205] The administrative rules amplify this, allowing even temporary control structures (e.g., sandbag walls) to be used only to protect "imminently threatened roads . . . and buildings and associated septic systems."[206] These structures may remain in place for a maximum of five years.[207] A structure may only be protected once, regardless of ownership transfers.[208] Structures existing before the Coastal

199. S.C. CODE ANN. § 48–39–250(1) (2006).
200. *Id.* § 48–39–250(4).
201. *Id.* § 48–39–250(5).
202. *Id.* § 48–39–260(3). For discussion of these "soft technologies"—based on living shorelines principles—see Section II.B.v.(c), below.
203. S.C. CODE ANN. § 48–39–280 (establishing setback line); § 48-39-290 (barring erosion control structures and development).
204. N.C. GEN. STAT. §§ 113A–115.1 (2006).
205. *Id.*
206. N.C. ADMIN. CODE tit. 15A, subch. 7H, § 0.0308(2)(A)–(B) (2006).
207. *Id.* § 0.0308(2)(F).
208. *Id.* § 0.0308(2)(L).

Management Act's 1974 passage date are grandfathered in, however, and may be maintained.[209]

Oregon, with a coastal morphology more like California's than the sandy beaches of the Carolinas, has taken similar measures. The state has barred all permits for shoreline armoring for all development built after January 1, 1977.[210] Even permitted structures must be designed to maintain scenic standards, allow for recreation use and access, and avoid or minimize impact to resource values including habitat quality.[211] Oregon's comprehensive statewide planning goals echo these standards and the basic presumption against shoreline armoring.[212] It is also significant to note that the state's comparatively strict laws have not fallen prey to takings challenges. In 1993 the Oregon Supreme Court upheld a seawall permit denial against a takings claim, finding that denying the construction of a seawall did not deny all economic use of the property in question.[213]

b. Rolling Easements as Economic Assets

Across the country, states have taken proactive measures to prevent excessive shoreline armoring, in many cases simply forbidding the practice. Under many of these statutes, property owners must yield to the public's reversionary interest and allow vital beaches and marshes to shift as sea level rises. Admittedly this practice does lead to some private property losses; but because public interest preferences are stated clearly in state code, the practice also prevents losses (both private and public) by steering development away from areas vulnerable to erosion. Such laws acknowledge geologic and climatic reality.

There is also growing evidence that restrictions on armoring improve economic possibilities for coastal towns. Coastal erosion is a major threat nationally; one recent study, which did not even model the effects of climate change, found that a quarter of all homes within 500 feet of the coast may fall prey to erosion within the next sixty years.[214] As a result, there is considerable interest in economically efficient management of coastal erosion. At least two studies have found that the policy of managed retreat promoted by rolling easements (or straightforward statutory prohibitions on armoring) may often produce results

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209. N.C. GEN. STAT. §§ 113A–115.1(b).

210. OR. ADMIN. R. 736–020-0010(6) (2005).

211. *Id.* at 736–020–0015–0030.

212. *See id.* at 660–015–0010(3) (Oregon Statewide Planning Goals & Guidelines, Goal 18) (setting forth very limiting permit conditions for shoreline structures).

213. Stevens v. City of Cannon Beach, 854 P.2d 449, 459–60 (Or. 1993).

214. JOHN H. HEINZ III CTR. FOR SCI., ECON. & THE ENV'T, EVALUATION OF EROSION HAZARDS xxi, 128 (2000).

economically superior to armoring.[215] The economic effect may be best understood as a "coastal tragedy of the commons," with beach access and enjoyment as the common pool resource. Working in the Southeast, economists Warren Kriesel and Robert Friedman amassed empirical data showing that, while the first property owners to armor do capture property value increases, such armoring lowers property values just a few rows of houses inland.[216] If half of all waterfront owners armored, property values for nonwaterfront homes fell 12 percent below parallel contexts where no armoring is present.[217] Although Kriesel and Friedman do not speculate as to why property values declined, this effect is presumably due to the vastly less pleasant shoreline as a result of armoring. The authors do note that their results demonstrate a "classical . . . negative economic externality" and should "give communities pause" before they rely upon armoring.[218]

By contrast, Kriesel and Friedman found that beach nourishment—adding sand directly to beaches—broadly increased property values without the costs associated with armoring.[219] Economist Craig Landry and his co-authors achieved similar results using data based upon Georgia's Tybee Island.[220] They found that the major costs of engineering barriers to erosion were on the same order of magnitude as the property losses that would be sustained under a policy of retreat under a moderate rate of erosion.[221] In other words, armoring costs may often be high enough to make the property losses they prevent negligible.[222] Because the benefits resulting from a broad and unarmored beach are much greater than the management costs associated with such beaches (e.g., the costs of beach nourishment), a policy barring erosion control structures coupled with some degree of nourishment may be the most economically efficient strategy.[223] Landry et al. suggest that in the interests of equity such a policy should offer some payment to the shoreline property owners who bear the additional risk of losing their homes,[224] even if they have no legal right to armor. This compensation could come in the form of the purchase price of a rolling easement.

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215. *See* Craig E. Landry, Andrew G. Keeler & Warren Kriesel, *An Economic Evaluation of Beach Erosion Management Alternatives*, 18 MARINE RES. ECON. 105 (2003); Warren Kriesel & Robert Friedman, *Coastal Hazards and Economic Externality: Implications for Beach Management Policies in the American Southeast*, Heinz Ctr. Discussion Paper (May 2002).

216. Kriesel & Friedman, *supra* note 215, at 2, 12–13.

217. *Id.* at 13.

218. *Id.* at 13, 16.

219. *Id.* at 12–13.

220. *See* Landry et al., *supra* note 215.

221. *Id.* at 121.

222. *Id.*

223. *Id.* at 119–21.

224. *Id.* at 121.

But is compensation appropriate at all? As a matter of expectations, it may be: the changing conditions of sea level rise make clear that previously set assumptions about the stability of the coast and the nature of armoring law must be reexamined. But it is not clear that compensation will always make sense as a matter of policy. For decades, coastal property owners have been allowed to externalize the risk of living in an erosion zone onto the public: they do so by armoring, which imposes public costs for their private benefit. This subsidy—transferring the public trust's value into private hands—is not an entitlement and need not be continued. Although smoothing the transition to the new regime alone may justify a compensation scheme, it is not at all clear that the public need, as a matter of law or equity, pay for maintaining its basic trust rights against transfer to private parties.

Although the experience of rising sea levels and erosion control regulation is relatively new, it is clear that states across the country have taken important steps toward allowing erosion to take its course. Such a policy prevents beach privatization via seawall and maintains ecosystem function. By saving the costs associated with armoring, it may also be the most economically efficient course in many cases. California, which has already armored large swaths of its coast and faces some of the highest erosion risks due to sea level rise should move rapidly to implement rolling easements and related policies.

c. Living Shorelines and Public Access Measures

In some cases, where developments have already been built and a policy of retreat through rolling easements is either financially or legally imprudent, armoring structures will have to be built. In these instances, the Coastal Commission should create and promulgate "living shorelines" and public access design principles for all new coastal armoring structures. The living shorelines movement has grown largely on the eastern seaboard, where fingers of salt marsh are being replaced with concrete walls. The effort is an important one. As the National Academy of Science explained in a 2006 report, replacing natural land/sea transitions with concrete and steel not only destroys beaches, it disrupts "highly diverse and productive plant and animal communities . . . along with the vital ecosystem services they provide."[225] To prevent these losses, the Academy calls for a broad research effort to develop regionally tailored design principles and implement them through a permitting process with a strong preference for minimally invasive

225. NAT'L ACADEMIES OF SCI., REPORT IN BRIEF: MITIGATING SHORE EROSION ON SHELTERED COASTS 3 (2006).

structural solutions.[226] Such an effort is particularly important for California, where technologies developed for salt marshes and low shores will simply be inappropriate for our coast of rocky bluffs and sandy beaches. This is another area where immediate research is essential to prevent the loss of ecosystem function.

Living shorelines guidelines, if developed to fit the California context, will ensure that coastal protection is built in ways that allow some species to continue to move across the land/sea interface, maintaining a degree of ecological function. Social values may also be maintained by requiring armoring structures to provide for public access, such as including public walkways or promenades along the crests of armoring structures.

Design principles will necessarily vary by region. North Carolina has experienced success with replacing seawalls with grassy margins reinforced by low, rocky sills.[227] In California, where El Niño waves batter entire cliffs down, solutions will be different. The Coastal Conservancy, a grant-making agency, should devote substantial research funds to developing a suite of living shorelines options for various coastal situations. Stark bulkheads might, for instance, be replaced by more limited structures that allow for marine mammal haul-outs[228] and some degree of bluff erosion. Rocky revetments that spill across the entirety of formerly broad beaches might be disfavored and we may instead see smaller replacements designed to preserve areas of sand and also provide habitat for tide pool denizens. On many ocean shores, beach nourishment may provide a protective solution, if done with proper care. The goal should be to maintain a substantial degree of ecosystem function when armoring is necessary, rather than simply sacrificing it entirely. Some armoring designs could be regionally planned, ensuring that no beach or stretch of headlands is entirely lost, even if it is fragmented. The goal should be to balance the protection of development with the protection of coastal amenities that first attracted development.

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226. *Id.* at 3–4. One successful effort, at the Jefferson Patterson Park and Museum in Calvert County Maryland is detailed at http://www.jefpat.org/Living%20Shorelines/lsmainpage.htm (last visited Apr. 17, 2007). The museum's website provides a useful taxonomy of living shorelines approaches, from planting specific marsh grasses to careful regard for banks. Also see the Virginia Department of Environmental Quality's guide to techniques used in that state at http://www.deq.state.va.us/coastal/documents/lsfactsheet.pdf (last visited Apr. 17, 2007).

227. N.C. Coastal Fed'n, Living Shorelines Projects, http://www.nccoast.org/Restoration/LivShore (last visited Apr. 8, 2007).

228. Haul-outs are so called because they are sites where marine mammals, like seals or sea lions, "haul out" of the ocean in order to rest, mate, and lounge on land.

CONCLUSION

Protecting coastal access and coastal resources requires developing a sea level rise policy. Climate change will fundamentally reconfigure the California coast; in turn, the Coastal Commission must be ready to plan for a rapidly changing future. Committing California to a responsible sea level rise policy will require more than rolling easement conditions, purchases, and LCP amendments. However, sensible use of rolling easements will allow vital public rights to track the coast more easily as the sea level rises. The Commission can be ready to defend those public rights from premature cancellation by limiting coastal armoring. It will not be a small project, but starting now is preferable to bearing the public costs of inaction later. Even if wholly successful, a more ecologically sensitive coastal armoring policy can only begin to help the coast to adapt to climate change and to mitigate some of its effects. It cannot, on its own, save the coast as warmer waters choke the California Current, bring stronger storms, and destroy marine life.

While the Commission explores its role in addressing climate change's effects—from shifts in coastal fauna and flora to the armoring crisis, it can act to prevent the fortress-like coast that the combination of population growth, coastal development, and climate change would otherwise create. By urging LCP revision to discourage development in erosion-prone or ecologically important areas, implementing rolling easements, preserving access along the shore, and encouraging living shorelines design solutions, the Commission can steward the coast through the difficult years ahead.

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Monday, April 10, 2006

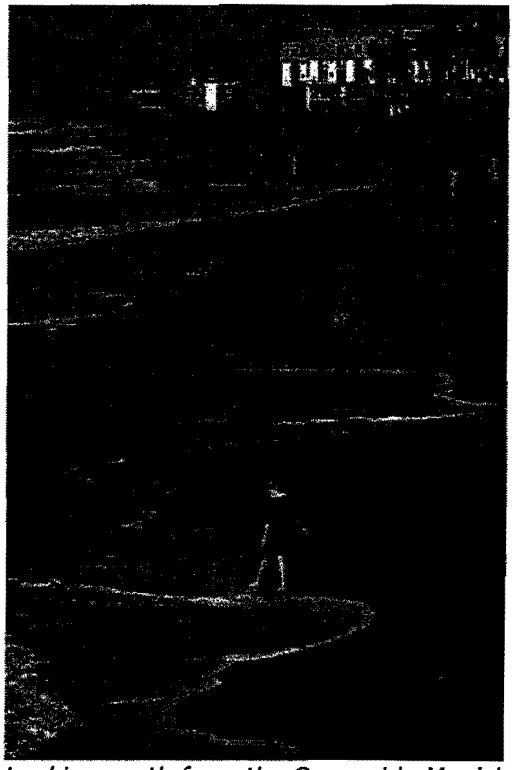
Last modified Saturday, April 8, 2006 7:36 PM PDT

The making of a natural sandy beach

By: CHRISTINA S. JOHNSON - For the North County Times

It is a common belief that naturally flowing rivers in Southern California are a major source of beach sand, replenishing grains washed to sea by heavy surf and high tides. As a corollary, dams and other human activities changing the natural course of rivers have been seen as robbing beaches of new sand, contributing to beach erosion and intensifying the need for replenishing beaches through engineered beach nourishment projects.

The long-standing canon of beach dynamics, that rivers supply beaches with sand, may be overstated and overly simplistic, says Escondido resident Neal Driscoll, a professor in the Geosciences Research Division at Scripps Institution of Oceanography, who has California Sea Grant support to study sedimentation patterns in San Diego and Orange counties.



Looking north from the Oceanside Municipal Pier on Tuesday morning during high tide, surf washes up high on Oceanside's sandy beach.
***BILL WECHTER** Staff Photographer*
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"I am not saying rivers are an unimportant source of sand," Driscoll said. "I am saying they may not be a major source of sand."

As a result, dams and urbanization may not have altered the region's sand budget in the way, or to the degree, that researchers had previously imagined.

Past studies of beach processes led scientists to estimate that rivers bring as much as 90 percent of sand to beaches and that dams, therefore, cut off an equal amount of the coveted material. This estimate, Driscoll said, may be too high.

Driscoll is not alone in his theory that rivers have been ill-cast as the lead player in maintaining sandy beaches. Coastal engineers at UC San Diego led by professor Scott Ashford, a resident of Encinitas, recently used laser-imaging techniques to create highly detailed digital maps of the shape of coastal bluffs in San Diego County. Analyses of the changes in the bluffs' shape over time let them compute the volume of material shed by the cliffs.

Assuming that all eroded cliff material was sand and went to beaches, coastal cliff erosion could supply more

than half of all sand on some beaches in Southern California, they reported. That would make coastal bluff erosion the single most important natural sand source, and it would imply that sea walls, riprap and other hard structures built to halt bluff erosion contribute to the narrowing of sandy beaches and might be doing so faster than thought.

This discovery, which is being more fully explored in an ongoing collaborative project with Sea Grant, is fully consistent with Driscoll's theory, since its basic message is that coastal bluff erosion has been an overlooked sand source.

Driscoll is taking the science of sediment dispersal a step further by re-examining the role of rivers in supplying beaches with sand.

"People have oversimplified many things about beach dynamics," he said. "I am going back to square one."

Rivers are akin to conveyor belts, he explained. They shuttle sediments to the coast. Think of the prominent granite boulders of inland North County being slowly scoured by water and the reddish clay soils of the scrublands melted away. A lot of sediment is transported, but this is not the same as saying this sediment ends up ---- let alone stays ---- on beaches, he said.

Instead, Driscoll believes that the precious sand may be destined for the bottom of the sea. A compelling piece of evidence for this idea comes from stream gauge data along rivers in semiarid climates such as Southern California, the flows through the San Luis Rey River mouth being a prime example.

"Most of the time, there is no water coming out of the San Luis Rey," Driscoll said. "But when it 'goes,' it goes big. If sand is coming from the river, it has to be coming in huge pulses."

These sand pulses increase the density of river water, potentially making it more dense than seawater, which is normally heavier than freshwater because of its salt. This means that at the coast, the water coming out of the river might not float atop the saltwater and drop its sediments into shallow water, where waves and tides can return sand to beaches. Instead, the water-sand slurry may sink to the bottom and move to deeper water, bypassing the near-shore system, effectively eliminating the river's ability to serve as an input of new sand.

"It is like having molasses move through the water," Driscoll said. "Something heavy sinks and moves along the bottom."

Southern California is prone to molasseslike river discharges, known scientifically as gravity currents, because there is not much vegetation to grip the soil in place during heavy rains. When it rains hard, the water is very effective at picking up sediments. There is a lot of erosion, and because the rivers are flowing fast, a lot of sediment can stay suspended in the water column.

The theory that sediments carried by rivers might be bypassing the beach zone was first put forth by geologist Jonathan Warrick of the U.S. Geological Survey in Santa Cruz during studies of the Santa Clara River in Ventura County. He and colleagues who placed instruments on the continental shelf to acoustically and optically measure sediment concentrations and water velocities showed that the flows from the river did indeed sink to the seabed.

"We saw these gravity currents moving offshore from the river mouth," Warrick said. A gravity current is a highly concentrated flow of water and sediment. "It is analogous to a mudflow on land."

In a published paper on the research, Warrick hypothesized that the gravity currents observed at the Santa Clara River might be characteristic of river dynamics in general in Southern California, and that as a result, much of the sediment load in the region's rivers might be deposited directly on the adjacent continental shelf, thus representing a "loss" of a potential sand source.

Warrick's field work, conducted in winter 2004, focused on documenting a gravity current in the region, at the time a first. The field studies did not attempt to examine the logical follow-up question for those interested in understanding beach-building processes: How much sand is actually contained in these currents?

"We proved these flows exist," Warrick said. "But we don't know how much sand is within them. I can guarantee that there is a lot of mud. We don't know about the sand."

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Sifting county's shifting sands

Bluff erosion primary source, studies show

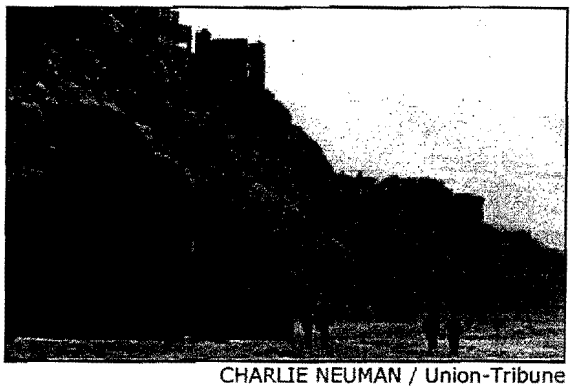
By Terry Rodgers
UNION-TRIBUNE STAFF WRITER

October 13, 2005

UCSD scientists have completed two studies showing that cliff erosion produces far more sand for local beaches than previously estimated.

A six-year study by engineering professor Scott Ashford and graduate student Adam Young found that bluff erosion accounted for 68 percent of the fresh sand that nature provides to the county's eroding beaches.

A second study by geology professor Neal Driscoll and graduate student Jennifer Haas used a "mineralogical fingerprinting" technique to compare grains of sand on local beaches with the types of sand found in bluffs and rivers, and from material dredged offshore.



CHARLIE NEUMAN / Union-Tribune
Homes on South Sierra Avenue in Solana Beach sit atop eroding bluffs above Fletcher Cove Beach Park. Two new studies by scientists at UCSD found that erosion of Southern California's sea cliffs is the primary source of the region's beach sand.

Driscoll and Haas concluded that 50 percent of the sand came from erosion of the bluffs, also known as sea cliffs.

The combined studies were released yesterday. They rebut the conventional wisdom often heard at public hearings that cliff erosion accounts for only 10 percent to 15 percent of the sand that nature supplies to local beaches.

The findings immediately rekindled the debate over sea walls, the "armoring" of the coastline that has pitted private-property owners against opponents of such walls.

"This is huge for us," said Marco Gonzalez of the San Diego chapter of the Surfrider Foundation, which views erosion as a natural process necessary to maintain sandy beaches. "It spotlights the true impact of sea walls, which are a bad long-term solution to the effects of sea-level rise and the natural processes of erosion."

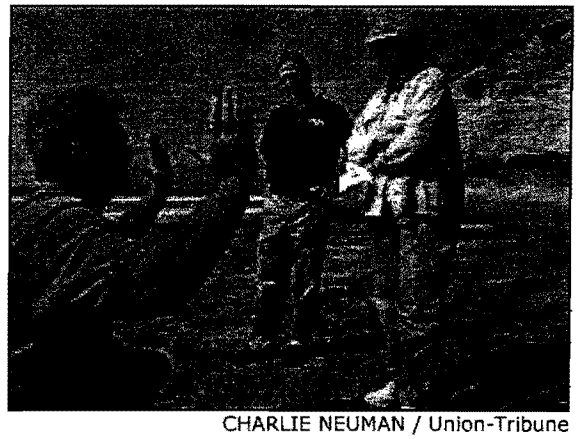
But Walter Crampton, a coastal engineer who represents oceanfront property owners, said the studies merely reinforce previous scientific estimates of how natural processes contribute sand to the beaches.

"All it does is reaffirm everything we've said in the last five years," Crampton said. "Everything is the same."

Leslie Ewing, a staff engineer for the state Coastal Commission, applauded the UCSD scientists for using "cutting-edge science and technology."

However, Ewing said the new findings are unlikely to trigger major changes in coastal policy, including a 10-year-old fee the commission charges residents who want to build sea walls.

Ashford and Young were able to more precisely calculate the amount of bluff erosion by comparing three-dimensional images made from a laser scanning device called LYDAR, an acronym for "light detection and ranging."



CHARLIE NEUMAN / Union-Tribune
UCSD scientists Neal Driscoll (left) and Scott Ashford shared their findings on where local beaches get their sand with former Solana Beach Mayor Margaret Schlesinger.

The same type of scanners was used to measure the crater after debris was cleared from the World Trade Center disaster in September 2001. It is also employed by forensics teams to calculate the spray from bomb blasts.

Ashford agreed with other scientists that the amount of sand being supplied from eroding bluffs – the study estimated it at 76,000 cubic yards annually along about 50 miles of shoreline – is probably far less than what is needed to stabilize beaches that are already too narrow.

The U.S. Army Corps of Engineers recently issued a report saying that to stop further erosion of the cliffs, 825,000 cubic yards of sand needs to be placed on the beaches in Encinitas and an additional 450,000 cubic yards in Solana Beach.

▪Terry Rodgers: (619) 542-4566; **terry.rodgers@uniontrib.com**

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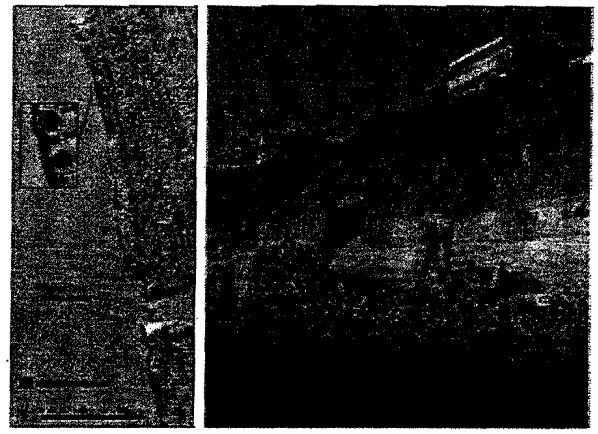
Source: University of California - San Diego

Posted: October 22, 2005

Coastal Bluffs Provide More Sand To California Beaches Than Previously Believed

Coastal geologists have assumed for years that sediment-laden rivers that enter the Pacific Ocean along the Central and Southern California coast supply up to 90 percent of the sand on the region's beaches. However, new research by two independent groups of UCSD scientists indicates that what had been thought to be a minor source of sand -- erosion from coastal bluffs and cliffs -- could account for about half of the region's beach sand.

Various types of concrete surfacing and reinforcement of bluffs as well as layering large boulders as rip-rap along the base of bluffs tend to "armor" them, slowing or preventing such erosion. Determining the source of sand, according to the researchers, is the logical first step in any effort to preserve Southern Californian beaches.



Jacobs School of Engineering professor Scott Ashford and Ph.D. candidate Adam Young used a highly accurate laser scanning technology to measure the contribution of coastal bluffs to the supply of beach sand in a 50-mile stretch of Southern California beach. (Image courtesy of University of California - San Diego)

In a paper to be presented October 12 during the annual meeting of the American Shore and Beach Preservation Association in San Francisco, Adam Young, a Ph.D. candidate in UCSD's Jacobs School of Engineering, will report the unexpectedly high contribution of coastal bluffs and cliffs to the supply of beach sand. Young, who has also submitted his results to the Journal of Coastal Research, used laserscanning technology to generate a series of 3-D topographical maps that quantified coastal bluff erosion with a high degree of accuracy during the past six years.

Based on the volume of material that has fallen from the bluffs during the study period, Young concluded that half of the beach sand in the Oceanside Littoral Cell, a 50-mile stretch of California coast from La Jolla north to Dana Point, was likely derived from the bluffs.

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In recognition of his research, which was funded by California Sea Grant, the University of California's Coastal Environmental Quality Initiative, and UCSD's Center for Earth Observations and Applications, the American Shore and Beach Preservation Association on Oct. 11 will present its 2005 Education Award to Young. In addition, the California chapter of the association will present its 2005 Robert L. Wiegel Coastal Studies Scholarship to Young, also in recognition of his bluff erosion research.

"While keeping in mind that six years is only a brief snapshot in the life of the Southern California coastline, our results call into question the conventional wisdom that coastal bluffs don't contribute much to the beaches," said Scott Ashford, a professor of structural engineering at UCSD and Young's faculty advisor. "Adam's results should alert all groups interested in the preservation and development of Southern California's beaches that the assumptions they have been using to identify the supply of beach sand should now be re-examined."

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Ashford said decades-old photographs of the Southern California coast taken from the ground and the air also have documented the steady pace of erosion. However, he said the photographs lack the precision and accuracy of the laser scanning technique called LIDAR, an acronym for light detection and ranging. Ashford said the 3-D maps generated by LIDAR permitted Young to calculate the unexpectedly high volume of bluff material that has fallen onto beaches during the study period.

"A new question we're interested in now is 'What if we stopped armoring the bluffs and cliffs and allow them to erode naturally?' " Ashford said. "Would such a moratorium be enough to replenish the beaches? We need to do more work to address a range of questions like that."

At the wave washed western edge of the campus, Neal Driscoll, a geology professor at UCSD's Scripps Institution of Oceanography, and graduate student Jennifer Haas have studied the same 50-mile stretch of beach north, but with a completely different technique. The Scripps team used a mineralogical fingerprinting technique. They compared sand grains collected from beaches in the study area to grains taken from coastal bluffs, rivers, and from dredged material that the San Diego Regional Beach Sand Project used to replenish the region's disappearing beaches.

After examining the population of sand grains on beaches in the La Jolla area, the Scripps team determined that sea cliffs must be an important source of sand to those beaches. Based on their observations, Haas and Driscoll concluded that 50 percent of the sand came from erosion of the bluffs and cliffs. Haas successfully defended her master's thesis in spring 2005.

"What is exciting to me is that both our engineering group at the Jacobs School and the geology group at Scripps took completely different approaches, but arrived at the same conclusion, which is that bluffs and cliffs appear to be a much more important source of sand in the Oceanside Littoral Cell than had been previously believed," Ashford said.

The Scripps team found a type of clear-quartz grains in the coastal cliffs, but collected predominantly frosted quartz sand grains in the rivers and offshore borrow sites from which sand has been dredged for placement on erosion-prone beaches. "In La Jolla, the beaches have a large proportion of clear quartz, which indicates that the cliffs are a significant source of beach sand," Driscoll said. "There's just no other way around it."

Driscoll and Ashford agree that Central and Southern California rivers carry a huge amount of sandy sediment to the Pacific Ocean during seasonal downpours. "When the rains come, the majority of the sediment discharge occurs during an extremely small percent of the time," Driscoll said. "Often, the sediment-laden river water is denser than seawater, so when this slurry reaches the coast, it sinks and follows the bottom, escaping the shallow water region near the shore where it could replenish sand to the beaches."

In dry years there is very little sediment in Southern California rivers flowing into the Pacific. "In wet years," Driscoll said, "the rivers flow like fire hoses, with most of the sediment ending up offshore in deeper water."

California Sea Grant, the largest of the 30 Sea Grant programs nationwide and administered by the University of California, recently awarded $200,000 to Ashford and Driscoll to collaborate and expand their investigation of the relationship between bluff erosion and beach sand supply in the Oceanside Littoral Cell.

The Center for Earth Observations and Applications at UCSD, which partially funded Young's bluff-scanning project, was formed in 2005 with a grant from UCSD Chancellor Marye Anne Fox. John Orcutt, deputy director of scientific affairs at Scripps Institution of Oceanography, directs the center.

Editor's Note: The original news release can be found here.

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