

Managing the Coastal Squeeze: Resilience Planning for Shoreline Residential Development

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Climate change now affects almost every facet of California's natural and built environment, and sea level rise will have widespread adverse consequences for California's coastal resources as well as residential development. Threats to residential development will also mean that shoreline structures, including seawalls, revetments, and emergency measures will continue to be proposed to protect existing development. Where shoreline protection like seawalls is the answer to sea level rise, one consequence is the "coastal squeeze"—the incremental loss of recreational beach area and shoreline habitats in front of immovable shoreline structures. The California Coastal Act provides for the protection of existing development from shoreline hazards but also requires that new development (including redevelopment of existing structures) protect public access and recreation, sensitive biological and visual resources, and other coastal resources. While California has a robust planning and regulatory governance framework for addressing coastal hazards, accelerating sea level rise presents a vexing planning challenge. Local governments need policy guidance on providing for future residential development and adaptation to changing conditions while assuring the maximum protection and enhancement of the coastal resource values that lie between shoreline residential areas and the sea. We propose a typology, or systematic classification of types that have similar characteristics, to describe the residential development and hazard conditions found along California's coastline. This typology is useful for guiding the application of alternative statewide sea level rise adaptation policies that are consistent with the Coastal Act. Through six case studies, we demonstrate how six different development contexts illustrate planning challenges related to issues like redevelopment rules, shoreline protection, bluff edge setbacks, and monitoring trigger conditions. While the complexity of development patterns, local geomorphology, and changing ocean conditions do not lend themselves toward any single "silver bullet" for addressing sea level rise, understanding the similarities and differences across communities will support better

proactive planning for sea level rise resilience, and promote sharing of knowledge and experiences along the coast in the coming decades.

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I. INTRODUCTION

Climate change now affects almost every facet of California’s natural and built environment, and sea level rise will have widespread adverse consequences for California’s coastal resources and shoreline development. With 1.4m of potential sea level rise, some studies project over 200,000 Californians and development valued at \$36.5 billion will be at risk in a 100 year

flood event.¹ And these risks will only increase with population growth.²

California's natural and beach recreation coastal resources are also increasingly in danger, particularly as seawalls, rock revetments, and other kinds of shoreline protection are approved to protect development. Beaches, dunes, and wetlands that cannot migrate inland because of seawalls or other barriers will eventually be squeezed out and lost, caught between rising tides and immovable shoreline structures. The loss of California's popular beaches would take a huge toll on the state's economy, much of which derives from coastal tourism and recreation.

California has been a climate change policy leader, including in the area of sea level rise.³ But the next forty years will challenge the limits of the state's coastal management capacity. Planners, decisionmakers and communities are rightly asking for policy guidance on how to plan for, and adapt to, the significant social, economic, and environmental impacts of rising seas. Effective policy, though, must be built on existing authorities and institutional capacity, as well as based on strong science and an understanding of the diversity of California's natural and built environment.

This article focuses on the challenges posed by sea level rise for the many residential development areas along the California coast. Section two provides a background discussion of sea level rise concerns in California, the existing policy framework of the California Coastal Act and Local Coastal Program ("LCP")

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1. MATTHEW HEBERGER ET AL., CAL. CLIMATE CHANGE CTR., THE IMPACTS OF SEA-LEVEL RISE ON THE CALIFORNIA COAST 76 (2009), <http://dev.cakex.org/sites/default/files/CA%20Sea%20Level%20Rise%20Report.pdf>.

2. A recent paper considers projections of population growth through 2100 in determining SLR inundation risk. It finds that while the average US population at risk from SLR at 2100 is ~3 times greater when population growth is considered, the population at risk in California is 5 times greater when comparing future population growth versus current population. Mathew E. Hauer et al., *Millions Projected to Be at Risk from Sea-level Rise in the Continental United States*, NATURE CLIMATE CHANGE, March 14, 2016, <http://www.nature.com/nclimate/journal/vaop/ncurrent/pdf/nclimate2961.pdf>.

3. E.g., CAL. COASTAL COMM'N, SEA LEVEL RISE POLICY GUIDANCE: INTERPRETIVE GUIDELINES FOR ADDRESSING SEA LEVEL RISE IN LOCAL COASTAL PROGRAMS AND COASTAL DEVELOPMENT PERMITS (2015).

implementation, and several key observations about existing residential development patterns in relation to the problem of sea level rise. The discussion highlights that while California has a robust planning and regulatory governance framework for addressing coastal hazards, accelerating sea level rise presents a vexing planning challenge for a residential development pattern that was largely in place before this governance framework was created.

Section three analyzes California's residential development patterns by developing a typology or systematic classification of this development based on common characteristics. Statistical analysis of certain census data and physical setting is used to build a conceptual framework for considering different residential development contexts. This may help represent the complexity of development contexts along the coast as variations on certain core traits, such as development density and geomorphic context, in hopes of informing policy responses to the challenge of sea level rise.

The typology discussion affirms the diversity of development contexts in California, but also provides an entrée for considering six case studies in section four in order to frame the general hazards issues and alternative adaptation responses that local governments should consider in planning for sea level rise and updating their LCPs. As will be shown, this way of framing policy options reminds us that there is no "silver bullet" or magic adaptation template, but it may help promote consistent application of statewide policy to the wide variety of conditions along California's coast.

The article concludes by recognizing that the diversity of potential adaptation approaches mirrors the geomorphic variety of the California coastline, and so no single answer can take the place of a community planning process. This process includes identifying community priorities, conducting vulnerability assessments, choosing acceptable levels of risk, and considering how and where to apply different potential adaptation mechanisms based on community goals, the requirements of the Coastal Act and other relevant laws, and a consideration of the relative social costs and benefits of various adaptation strategies. While some planning insights may be common, such as the need to use best available science on long-term sea level rise projections, other insights may depend on context. For example, redevelopment rules will be critical in highly urban areas. So-

called “soft” or “green infrastructure” strategies such as dune restoration may or may not be effective in certain environments. Planned retreat or rolling easements will depend on the physical and legal options for relocating, transferring or phasing out existing development potential in specific places. In the end, because the right adaptation responses must derive from a strong state and local planning process, continued investment in such “resilience planning” will be required for California to effectively respond to sea level rise over the next forty years.

II. SEA LEVEL RISE, THE CALIFORNIA COASTAL ACT, AND RESIDENTIAL DEVELOPMENT

California policymakers have focused significant attention on coastal hazards in recent years, driven by the emergence of sea level rise as a matter of widespread social, economic and political concern.⁴ But California has a long history of hazards management in the coastal zone. Effective policy responses to sea level rise will need to be informed by an understanding of this history and the existing legal authorities and institutions that are presently charged with implementing coastal management policy. Policy also needs to be based on an understanding of the essential science and physical processes of sea level rise. Following a summary of modern day sea level rise concerns in California, this section highlights some key aspects of California’s coastal hazards management context important to effective coastal planning and management along California’s coast, including for the many miles of urban and residentially-developed shoreline.

A. *Sea Level Rise in California*

Sea level rise (and fall) is a physical phenomenon that has been happening since oceans formed on the earth.⁵ What may be

4. See, e.g., ASSEMBLY SELECT COMM. ON SEA LEVEL RISE AND THE CAL. ECONOMY, SEA-LEVEL RISE: A SLOW-MOVING EMERGENCY, (2014); LITTLE HOOVER COMM’N, GOVERNING CALIFORNIA THROUGH CLIMATE CHANGE REPORT #22 (2014), <http://www.lhc.ca.gov/studies/221/report221.html>; ASSEMBLY SELECT COMM. ON COASTAL PROTECTION, SEA LEVEL RISE: RESILIENCE AND ADAPTATION IN THE COASTAL ZONE (2015).

5. See INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE, CLIMATE CHANGE 2014: IMPACTS, ADAPTATION, AND VULNERABILITY. PART A: GLOBAL AND SECTORAL ASPECTS 1-1132 (Christopher B. Field et al. eds., 2014); M.A. Kominz, *Sea Level Variations Over Geologic Time*, in ENCYCLOPEDIA OF THE OCEAN SCIENCES 2605–13 (Academic Press, 2001), available at

relatively new and challenging for some coastal managers is the realization of the likely future and rapid *acceleration* of sea level rise in this century due to human activities resulting in the release of greenhouse gases into the atmosphere. In fact, the Coastal Commission has been concerned with this physical phenomenon as a causal factor to consider in hazards management since at least 1989, when the agency produced its first report on the topic.⁶

The Commission's early management concern came on the heels of significant public attention to "global warming" in the 1980s, driven by the work of James Hansen, Stephen Schneider and others.⁷ Nearly 25 years ago the Coastal Act was amended to identify sea level rise as an important issue area for the Commission to understand:

The Legislature further finds and declares that sound and timely scientific recommendations are necessary for many coastal planning, conservation, and development decisions and that the commission should, in addition to developing its own expertise in significant applicable fields of science, interact with members of the scientific and academic communities in the social, physical, and natural sciences so that the commission may receive technical advice and recommendations with regard to its decision making, especially with regard to issues such as . . . **the question of sea level rise**, . . . [emphasis added].⁸

In 2001, the Commission produced another report with more specific attention to the implications of sea level rise for California's coastal development and hazards management. Among other things, the report summarized the best available science at the time that projected 1 to 3 feet of sea level rise by 2100 and observed that "[t]he entire coastal zone may be affected significantly by future changes in sea level."⁹

In the 15 years since that Commission report, climate science has become even more sophisticated, and substantial future sea

http://curry.eas.gatech.edu/Courses/5225/ency/Chapter10/Ency_Oceans/Sea_Level_Variations.pdf.

6. LESLEY EWING ET AL., CAL. COASTAL COMM'N, PLANNING FOR AN ACCELERATED SEA LEVEL RISE ALONG THE CALIFORNIA COAST 1-76 (1989).

7. J. Hansen et al., *Global Climate Changes as Forecast by Goddard Institute for Space Studies Three-Dimensional Model*, 93(D8) J. GEOPHYSICAL RES.: ATMOSPHERES 9341 (1988).

8. CAL. PUB. RES. CODE § 30006.5 (West 2016).

9. CAL. COASTAL COMM'N, OVERVIEW OF SEA LEVEL RISE AND SOME IMPLICATIONS FOR COASTAL CALIFORNIA 1 (2001).

level rise has become a virtual certainty, at least for those familiar with and accepting of the basic science. There is still significant uncertainty surrounding specific projected rates and magnitudes, but most coastal managers in California do not doubt that they should already be planning for rising sea levels.¹⁰

For California, the National Research Council (NRC) has projected that sea level will rise from between 1.4 and 5.5 feet south of Cape Mendocino and 0.3 and 4.7 feet north of the Cape, by 2100, depending on the assumptions one makes about future greenhouse gas emissions¹¹ Projected sea level rise north of Cape Mendocino is reduced due to the tectonic plate transition from a “sinking” coast to an “uplifting” coast.¹²

In addition to factoring in the impact of plate tectonics on future land level, climate science and models continue to be refined based on regional physical and climate factors that may also influence relative future sea level rise in specific locations. Most notably for California, there is concern that sea levels may actually have been suppressed over the last 30 years due to the Pacific Decadal Oscillation—a cycle of warming and cooling in the northern Pacific that influences both sea level and the frequency and strength of storm events.¹³ As we learn more about sea level dynamics, the importance of understanding regional and subregional contexts for effective planning has become increasingly apparent.

More recent examinations of climate change and sea level rise dynamics are also raising the possibility that global sea level rise could be significantly greater than the current NRC projections for California. One study, for example, projects an additional sea level rise of as much as 3 feet by 2100, depending on what happens to the great ice sheets in Antarctica and Greenland.¹⁴ And despite the heralded success of GHG emissions reduction

10. See, e.g., J.A. FINZI HART ET AL., U. S. CAL. SEA GRANT, RISING TO THE CHALLENGE: RESULTS OF THE 2011 COASTAL CALIFORNIA ADAPTATION NEEDS ASSESSMENT 1-29 (2012).

11. NATIONAL RESEARCH COUNCIL OF THE NATIONAL ACADEMIES, SEA-LEVEL RISE FOR THE COASTS OF CALIFORNIA, OREGON, AND WASHINGTON: PAST, PRESENT, AND FUTURE 127-28 (2012).

12. *Id.* Chapter 4.

13. Peter D. Bromirski, *Dynamical Suppression of Sea Level Rise Along the Pacific Coast of North America: Indications for Imminent Acceleration*, 116 J. GEOPHYSICAL RES. (2011).

14. Robert M. DeConto & David Pollard, *Contribution of Antarctica to Past and Future Sea-level Rise*, 531 NATURE 591-597 (2016).

policies in places like California, every day seems to bring new evidence that the planet is well on its way to locking in hundreds if not thousands of years of global sea level rise.¹⁵ This fact counsels for expanding immediate investment in planning for sea level rise, even while many of its effects may not manifest for decades.

B. *Sea Level Rise and Hazards Management Policy*

The looming prospect of a significant acceleration in the rate of sea level rise has put a spotlight on the inherent difficulties of managing coastal hazards along a dynamic coastline. California's hazard management policy system has long dealt with coastal flooding and eroding shorelines, but rising sea level brings the prospect of significantly more coastal flooding, bluff erosion, property damage and coastal resource loss, including loss of recreational, economic, cultural, and ecological beach resources. Infrastructure such as wastewater treatment and energy plants along the coast, and Highway One and coastal rail lines, are increasingly vulnerable to coastal erosion, inundation, and catastrophic failure. Coastal wetlands and habitats will be lost if they cannot adapt to rising seas and changes in climate conditions. And regardless of our reductions in greenhouse gases, many of these future management challenges are irrevocably loaded into the system, and cannot be avoided in our lifetimes and beyond.

An effective coastal management response to sea level rise should be built first on an understanding of past and current management methods. The state of California has been affirmatively managing coastal land use hazards along its outer coast at least since the passage of Proposition 20 ("Prop 20") in 1972.¹⁶ Building on the first four years of experience under Prop

15. For example, as of this writing, "the combined average temperature over global land and ocean surfaces for September 2016 was the second highest for September in the 137-year record, 0.04°C (0.07°F) cooler than the record warmth of 2015 . . . effectively snapp[ing] the 16-month streak of record warm monthly global temperatures." NAT'L OCEANIC & ATMOSPHERIC ADMIN., *State of the Climate: Global Analysis for September 2016*, NATIONAL CENTERS FOR ENVIRONMENTAL INFORMATION, <https://www.ncdc.noaa.gov/sotc/global/201609> (last visited Oct. 20, 2016); see also Sewell Chan, *2016 Likely to Top 2015 as Hottest Year on Record, Scientists Say*, N.Y. TIMES, Nov. 15, 2016, <http://www.nytimes.com/2016/11/15/science/2016-hottest-year-on-record.html>.

16. Proposition 20 required that all development permits ensure that land form alteration and construction of structures minimize the danger of floods, landslides, erosion, siltation and earthquakes (§ 27403(d)).

20, the *California Coastal Plan*—the 1975 blueprint for the Coastal Act called for by Prop 20—includes extensive discussion of issues related to development in hazardous areas, and proposes policies to address the range of typical coastal hazards: flooding, earthquakes, landslides, tsunamis, subsidence and of course, bluff and cliff erosion. The plan went as far as to allow for shoreline structures to protect private development but only if it was determined that the “public interest would be better served by protecting the existing structures than in protecting natural shoreline processes”—a concept that would not be explicitly included in the eventually-adopted Coastal Act.¹⁷ The plan also called for requiring that new development be set back from eroding bluff edges sufficiently to assure the development’s stability for its expected economic lifespan; and that no new structures be built that would increase the need for a shoreline protection structure, such as a seawall or a rock revetment.¹⁸

Except for the public interest language mentioned above, the policy recommendations of the Coastal Plan essentially made it into the Coastal Act through sections 30235 and 30253.¹⁹ In conjunction with other resource protection policies of the Act, these two policies establish a basic shoreline hazards management framework under which: (1) endangered “existing structures” may be eligible for shoreline protection (such as a seawall) if such protection is the least environmentally-damaging feasible alternative; and (2) “new development” should be sited and designed to be safe and to not require shoreline protection in its future.²⁰

17. See CAL. COASTAL ZONE CONSERVATION COMM’N, CALIFORNIA COASTAL PLAN (1975), http://digitalcommons.law.ggu.edu/caldocs_agencies/91 (referring to Policies 19 and 70).

18. *Id.*, 89-90 (referring to Policy 70).

19. PUB. RES. CODE §§ 30235, 30253 (West 2016).

20. PUB. RES. CODE § 30235.

Revetments, breakwaters, groins, harbor channels, 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 . . .

Id. New development must:

- (a) Minimize risks to life and property in areas of high geologic, flood, and fire

Since 1977, the Coastal Commission has applied sections 30235 and 30253 to proposed developments through thousands of permit reviews. With respect to existing structures found to be in danger from erosion, the Commission has approved the construction, reconstruction or maintenance of hundreds and hundreds of seawalls, revetments, and other kinds of shoreline protection.²¹ The Commission also has approved many “new” developments with substantial setbacks from the bluff edge so that future seawalls would not be necessary. And over the last two decades, the Commission has routinely conditioned and deed-restricted new developments to explicitly prohibit the future construction of a shoreline protection device for the development being approved.²²

In addition to its core resource protection and development policies, the California Coastal Act also requires that each local government in the coastal zone (there are 76) prepare a Local Coastal Program (“LCP”) that includes a land use plan, as well as zoning ordinances and programs to implement the land use plan.²³ Each LCP must be reviewed and approved by the State Coastal Commission as consistent with and adequate to carry out the statewide resource protection and coastal development policies of the Coastal Act. Once an LCP is approved, the local government becomes the lead agency for permitting most coastal development above the mean high tide line, subject to a limited appeal authority of the Coastal Commission.²⁴

hazard. (b) 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.

PUB. RES. CODE § 30253.

21. See, e.g., CAL. COASTAL COMM’N, REVISED FINDINGS FOR APPLICATION NO. 3-02-24 (OCEAN HARBOR HOUSE HOMEOWNERS) (2004), <https://documents.coastal.ca.gov/reports/2005/1/Th13a-1-2005.pdf>.

22. See, e.g., CAL. COASTAL COMM’N, ADOPTED FINDINGS, 1-12-023 (WINGET) (2014), <https://documents.coastal.ca.gov/reports/2014/2/W15b-2-2014.pdf>.

23. PUB. RES. CODE § 30500.

24. Appealable development generally includes development that is between the sea and the first public road paralleling the sea or within 300 feet of the inland extent of any beach or of the mean tideline of the sea where there is no beach; development located on tidelands, submerged lands, public trust lands, within 100 feet of any wetland, estuary, or stream, or within 300 feet of the top of the seaward face of any coastal bluff; in Counties any development that is not designated as the principal permitted use; and any development which constitutes a major public works project or a major energy facility.

Since 1980, the Commission has approved the incorporation of either the exact or functional equivalent of the language of Coastal Act sections 30235 and 30253 into scores of certified LCPs.²⁵ Approximately 87% of California's coastal zone land area is governed by approved LCPs.²⁶ In addition to addressing coastal hazards, these LCPs establish the allowable land uses, such as residential, commercial, recreational, and open space, along the coast, and provide the policies and regulations to assure that coastal resources of statewide significance, such as public access and recreation, wetlands, sensitive species and habitats, agricultural lands, and scenic landscapes, are protected for the public.²⁷

There are many lessons to be learned from the forty-year history of hazards policy under the Coastal Act, some of which may point to the need for fundamental reforms in the law.²⁸ While a comprehensive hazards policy discussion is beyond the scope of this article, certain general observations are useful for addressing sea level rise and resilience planning in the context of residential development along the coast.

PUB. RES. CODE § 30603.

25. For example, the Marin County LCP, Unit I, originally certified in 1980, includes Policy 5:

The following policy from Section 30235 of the Coastal Act is incorporated into the County LCP: Revetments, breakwaters, groins, harbor channels, seawalls, cliff retaining walls, and other such construction that alters natural shoreline process shall be permitted when required to serve coastal-dependent uses or to protect existing structures (constructed before adoption of the LCP), or public beaches in danger from erosion and when designed to eliminate or mitigate adverse impacts on local shoreline sand supply.

MARIN CTY. CMTY. DEV. AGENCY, MARIN COUNTY LOCAL COASTAL PROGRAM UNIT I 42 (2010).

26. For the status of LCPs statewide, see CAL. COASTAL COMM'N, SUMMARY OF LCP PROGRAM ACTIVITY IN FY15-16 1 (2016), http://documents.coastal.ca.gov/assets/la/FY15_16_LCPStatusSummaryChart.pdf.

27. See, for a broader LCP discussion, Charles Lester, *CZM in California: Successes and Challenges Ahead*, 41 COASTAL MGMT. 219-244 (2013).

28. Little Hoover Commission (LHC). 2014. *Governing California Through Climate Change*. Report #221, July 2014. 98pp. <http://www.lhc.ca.gov/studies/221/report221.html>; MOLLY MELIUS & MARGARET R. CALDWELL, CALIFORNIA COASTAL ARMORING REPORT: MANAGING COASTAL ARMORING AND CLIMATE CHANGE ADAPTATION IN THE 21ST CENTURY ENVIRONMENT AND NATURAL RESOURCES LAW & POLICY PROGRAM WORKING PAPER (2015), <https://law.stanford.edu/publications/california-coastal-armoring-report-managing-coastal-armoring-and-climate-change-adaptation-in-the-21st-century/>.

First, the Coastal Commission has a well-developed regulatory framework for addressing geotechnical issues and analysis. The Commission has long had both professional geologists and a coastal engineer on its staff that have informed the technical assessment of erosion risks and evaluation of alternative responses, such as shoreline protection structure construction and beach replenishment. This technical expertise has been critical, for example, in the development of technically-sound policies and decisions for implementing setback policies for new development proposed on unstable bluffs and cliffs, and for minimizing and mitigating the impacts of shoreline structures that are approved.²⁹ Many local governments likewise require and use geotechnical experts to advise their implementation of LCP policies through the local development review process.³⁰

Second, the Coastal Act's LCP requirement is a proven institutional framework for achieving statewide resource management objectives through local land use planning and regulation. Most local governments have completed an LCP, although a handful (mostly in southern California) have yet to do so. There is a rich history of collaborative and generally successful land use planning and resource management shared by the Coastal Commission and local government in California.³¹ There is certainly still lively debate about whether there are flaws in the basic Coastal Act policy framework that allows shoreline protection for existing development in certain circumstances. But there also exists an effective state-local land use planning framework for addressing hazards management questions.

With these observations as background, what is new and different about the challenge of sea level rise? As suggested

29. Mark J. Johnsson, *Establishing Development Setbacks from Coastal Bluffs*, in CALIFORNIA AND THE WORLD OCEAN 396-416 (2005).

30. For example, Marin County LCP Unit II Shoreline Structure Policy 2 states that:

Before approval is given for the construction or reconstruction of any protective shoreline structure, the applicant for the project shall submit a report from a registered geologist, professional civil engineer, or certified engineering geologist verifying that the structure is necessary for coastal erosion control and explaining how it will perform its intended function.

MARIN CTY. CMTY. DEV. AGENCY, MARIN COUNTY LOCAL COASTAL PROGRAM UNIT II 132 (2010).

31. See Lester, *supra* note 27.

earlier, sea level rise does not create new coastal hazards—California has long experienced, and managed, bluff erosion, landslides, flooding, and so on. Rather, sea level rise is simply increasing the future rates, magnitudes, and likelihoods of these hazards occurring. For example, instead of assuming a constant rate of erosion into the future, based on historic erosion rates, geotechnical analysis must assume increased erosion rates, based on projections of higher water levels and thus greater wave exposure in the future. These higher water levels are particularly important to consider for future coastal storm events, when the most significant flooding, episodic erosion, and storm damage occurs.

The same can be said for coastal land use planning, or what some term adaptation planning. No revolutionary changes have occurred with the tried and true public planning process of identifying community goals, analyzing land use trends and environmental conditions, and evaluating policy and programmatic alternatives to achieve planning goals in light of these trends and conditions. Rather, the environmental conditions related to higher sea levels are changing in previously unanticipated ways, and these new conditions must be projected into the future to support updated plans, including LCPs.

It is important to note that the changing environmental condition of global sea level rise brings considerably more scientific uncertainty to the planning and regulatory decision process. Instead of assuming a constant erosion rate, for example, plans and regulatory alternatives analysis must consider a range of potential erosion rates that are increasingly divergent the further into the future they are projected. This makes planning and regulation more difficult. It also has focused our attention on longer planning horizons, as we cannot assume a constant hazard risk into the future.³²

32. This is not to say that scientific uncertainty has not been an issue in hazards management, only that it has not necessarily been about future condition changes that may affect a future land use. For example, the Coastal Commission approved the Cliffs Hotel in Pismo Beach in 1983 with a bluff-top setback of 100 feet, premised on a geotechnical analysis identifying a bluff erosion rate of 3 inches per year. It was assumed that this setback would render the new hotel safe for at least 100 years without the need for future shoreline protection. During the 1997-98 El Nino, however, the Cliffs placed an “emergency” rock revetment on the shore in an effort to protect the eroding blufftop area above. The subsequent Commission deliberation about whether such a revetment was warranted was driven in part by competing geotechnical analyses identifying erosion rates from 3 inches to 4 feet per year. Ultimately the Commission embraced an erosion

C. *Sea Level Rise and Residential Development*

This article focuses on residential development because it is one of the most prevalent community development patterns along California's coast, and thus poses one of the more frequent hazards management challenges. Before considering the nature of this development pattern, though, three more general observations are important to keep in mind.

First, although the implementation of the Coastal Act hazards policies often has been driven by the distinction between "existing" development (eligible for a shoreline protection) and "new development" (not eligible), the overall pattern of residential-development along California's coast was, for the most part, established before the Coastal Act.³³ Relatedly, within many of these residential areas there is typically a mixture of structures built before and after the Coastal Act. For example, the residential enclave of Broad Beach in Malibu was established well before Prop 20 and the Coastal Act. Within the enclave, there are many houses that were built before 1972, and many that are "new" since 1972 (either entirely new on lots that were vacant in 1972 or new replacement or redeveloped homes).³⁴

Second, many of California's urban coastal areas were built out during the post-WWII development boom that also coincided with a relatively "calmer" coastal period that had fewer, less intense storms.³⁵ The El Niños of 1977-78 and 1982-83 marked the end of the "calm" period and caused enormous amounts of property damage, shoreline erosion, and also often led to necessary emergency shoreline armoring.³⁶ Thus, when the Coastal Act was passed, the State inherited many fixed development patterns in inherently hazardous coastal locations,

rate supporting a conclusion that the revetment was not necessary to protect significant structures, and it ordered the Cliffs Hotel to remove the revetment. The uncertainty in the rates was driven by different analytic methods, not about whether the rates might accelerate in the future. For more detailed discussion of this case, see Charles F. Lester, *An Overview of California's Coastal Hazard Policy*, in *LIVING WITH THE CHANGING CALIFORNIA COAST* 138-162 (Gary Griggs et al. eds., 2005).

33. For more detail, see Lester, *supra* note 27, at 227.

34. See CAL. COASTAL COMM'N, STAFF RECOMMENDATION FOR COASTAL DEVELOPMENT PERMIT # 4-12-043 (BROAD BEACH GHAD) 61 (2015), <https://documents.coastal.ca.gov/reports/2015/10/f8a-10-2015.pdf>.

35. GARY GRIGGS, INTRODUCTION TO CALIFORNIA'S BEACHES AND COAST, 67 (2010).

36. ROBERT G. DEAN ET AL., CALIFORNIA COASTAL EROSION AND STORM DAMAGE DURING THE WINTER OF 1982-83, NAT'L RES. COUNCIL REP. NO. CETS-CND-023 (1984).

perhaps due to an artificially low appreciation of the inherent risks in these locations at the time they were developed.

Finally, given the inherited residential development patterns along California's coast, much of the planning and regulatory work revolves not around permitting of entirely "new" structures or protection of pre-Coastal Act "existing" structures, but rather around "redevelopment". This adds more complexity to the regulatory process because it is often difficult to determine the line between the repair and maintenance of an existing structure that may be entitled to shoreline protection under Coastal Act section 30235, and a renovation, remodel, or significant redevelopment that essentially results in a new structure that should not be entitled to shoreline protection under Coastal Act section 30253.³⁷

III. A TYPOLOGY OF CALIFORNIA'S RESIDENTIAL SHORELINE DEVELOPMENT PATTERNS

Policymakers seeking effective responses to sea level rise in California must confront the inherent complexity of the challenge: California has more than 1100 miles of main coastline, with a diversity of physical environments, ranging from high cliffs to low river mouths; rocky substrates to sandy dunes; high wave energy exposed beaches to lower energy estuarine and bay environments.³⁸ And there are a wide variety of developed areas along this diverse coastline; for example, the U.S. Census Bureau identifies 117 distinct developed "places" on California's outer coast.³⁹

This section considers a typology of California's residentially-developed areas to help frame this complexity for potential policy development. Typologies are systematic classifications of groups that have characteristics in common, allowing complexity to be represented as variations on core traits. Many fields use typologies to facilitate ordering of information for communication and

37. Whereas much policy implementation has focused on the concept of the "economic life" of a structure, the reality is that many structures never really die. Rather, they end up being reborn or renewed in place. *See*, Lester, *supra* note 32, at 148.

38. *See generally*, LIVING WITH THE CHANGING CALIFORNIA COAST (Gary Griggs et al. eds., 2005).

39. U.S. CENSUS BUREAU, *Cartographic Boundary Shapefiles—Places*, CENSUS (2012), available at ftp://ftp2.census.gov/geo/pvs/tiger2010st/06_California/06/tl_2010_06_place10.zip (last visited Oct. 20, 2016).

outreach, from linguistics to natural resource management to climate adaptation.⁴⁰ As shown below, in the case of hazards management, using a typology to describe residential development on the California coastline affirms the diversity of contexts in California, and thus the complexity of the planning challenge, but it may also help frame the variety of key planning issues important for addressing sea level rise in particular places.

Based on the typology, example cases are presented in section four to show the general hazards issues and alternative adaptation responses that local governments might consider in updating their LCPs for sea level rise. As will be shown, this way of framing policy options reminds us that there is no single adaptation plan template that applies everywhere, but it may help promote consistent application of statewide policy to the wide variety of conditions along California's coast.

A. *Methods*

We created a conceptual typology grounded in statistical analysis of census and geophysical data. Cluster analysis of data sets representing housing density, geomorphic shoreline categories, and land use provided an initial categorization of coastal zone residential patterns.⁴¹ Conceptual framing of cluster types was also done by considering qualitative descriptions of shoreline residential development typically brought before the Coastal Commission. We use a conceptual framework to build our typology and empirical data to describe the characteristics of our groups.

The residential land use cluster analysis used 2010 U.S. Census blocks as a unit of analysis to represent neighborhoods. A census block is the smallest geographic unit used by the U.S. Census Bureau for tabulation of 100-percent data (data collected from all

40. Y. T. Maru, J. Langridge & B. B. Lin, *Current and Potential Applications of Typologies in Vulnerability Assessments and Adaptation Science* (CSIRO Climate Adaptation Flagship, Working Paper No. 7, 2011), https://research.csiro.au/climate/wp-content/uploads/sites/54/2016/03/7_Typologies-Adaptation_CAF_pdf-Standard.pdf.

41. A grouping analysis using a clustering algorithm (K means) was used to identify natural clusters in the data set. Grouping analysis functions as an exploratory tool to reveal underlying structure in the data. After we defined the number of groups to create, the algorithm identified a solution where all the features within each group are as similar as possible, and all the groups themselves are as different as possible. We used land use (percent residential and percent commercial), housing density, and distance to shore as the attributes for calculating feature similarity.

houses, rather than a sample of houses).⁴² Housing unit density was the primary variable derived from the census data to reflect intensity of residential use. Using parcel data with land use codes, we attributed a percent land use statistic for each block using its Block Group boundaries to capture a larger neighborhood's mix of land use (typically, Block Groups are statistical aggregations of contiguous census blocks, with populations of 600 to 3,000 people).⁴³ Percent residential and percent commercial land use were then used to characterize concentrations of residential land use and mixed residential/commercial areas. Lastly, distance of the block from shore was calculated to characterize the proximity of the development to potential flooding or erosion that could be exacerbated by sea level rise.⁴⁴

A conceptual shoreline residential land use typology was created using the key variables of 1) elevation to order geomorphic shoreline⁴⁵ context and 2) housing development density to describe a range of urban to rural settings. Using the data sets from the cluster analysis, we were able to describe the range of geomorphic shoreline and backshore settings upon which residential development might be found. Backshore refers to the zone of the shoreline that is normally dry, but might be exposed to waves during extreme storms or very high tides. Backshore descriptions can indicate more information about the landscape behind sandy or rocky shorelines, such as dunes, bluffs,

42. U.S. CENSUS BUREAU, *Geographic Terms and Concepts—Block*, CENSUS (2012), https://www.census.gov/geo/reference/gtc/gtc_block.html (last visited Nov. 11, 2016).

43. Statistical analysis of the outer coast California county parcel datasets shows that parcel sizes vary widely, based on land use and development density of urban locations. For example, the average parcel size for coastal zone residential land use is 0.4 acres across the California outer coast, while commercial land uses average 2.5 acres in size. In more densely developed regions, like Ventura County, shoreline residential parcels average 0.1 acre in size. Data analysis by authors.

44. On land, the coastal zone varies in width from several hundred feet in highly urbanized areas up to five miles in certain rural areas. Cal. Pub. Res. Code § 30103(a). This jurisdiction was established by the Legislature when the Coastal Act was passed. *Id.*

45. Geomorphic shore types correspond to the mapclass field in the HAB_CA_ShoreTypes data set adapted by California Department of Fish and Wildlife (08/25/2005), using the National Oceanic and Atmospheric Administration's Environmental Sensitivity Index (ESI). CA. DEPT. OF FISH AND WILDLIFE, GIS CLEARINGHOUSE, <https://www.wildlife.ca.gov/Data/GIS/Clearinghouse>; NAT'L OCEANIC AND ATMOSPHERIC ADMIN., ENVIRONMENTAL SENSITIVITY INDEX MAPS, <http://response.restoration.noaa.gov/maps-and-spatial-data/environmental-sensitivity-index-esi-maps.html>.

wetlands, or development. This conceptual approach based on expert knowledge adds an additional layer of backshore consideration for discussing sea level rise policies for shoreline residential development.

B. Results

1. Residential patterns.

Cluster analysis of coastal zone census blocks based on housing unit density, percent residential and commercial land use, and distance to shore resulted in five groups (Table 1). These groups include 1) non shoreline-low density, 2) shoreline-low density, 3) shoreline-medium density urban mix, 4) shoreline-medium density residential, and 5) shoreline- high density residential. Of approximately 19,000 census blocks with housing units falling within the state's coastal zone, 58% were less than 500 meters from the shoreline. For each of the five groups, we computed mean values for the four variables used in the cluster analysis (Table 1). Group 1 was composed of 1270 Census blocks with an average distance of 4500 m from shore (this group is considered non-shoreline), and an average 2010 Census housing unit density of 500 units/km. Group 1 represents a low housing density group, so low numbers of parcels in residential and commercial averages are expected. (Many parcels in non-urban areas will be in other land use categories, such as agriculture, miscellaneous, open space, or government land). Medium and low density census blocks accounted for 2 additional clusters (Groups 3 and 4). One cluster of medium housing density, Group 3, was composed of a mix of commercial and residential land use. The other medium density cluster, Group 4, was primarily residential (average 77% residential use per block). The high density blocks corresponded to the closer shoreline locations and, predictably, are found primarily in Los Angeles, Orange, and San Diego counties.

2. Geomorphic patterns.

California's coastline is naturally diverse. From a conceptual standpoint, beaches and cliffs represent the low-lying and high elevation patterns along the coast, respectively. However, there are rivers, marshes, bays and lagoons, as well as low bluffs and dunes that represent a range of geomorphic patterns and

elevations in between. Combining data on residential patterns with data on geomorphic shoreline types, shows the frequency of residential patterns that can be found near each shoreline type (Figure 1). The hardened shores category corresponds to locations such as harbors, as well as stretches of beach protected from erosion by the placement of rock (riprap). However, geomorphic identification as beach or other non-hardened shoreline does not preclude the presence of shoreline protection (e.g., seawalls or riprap).

Because of the diversity of backshore environments that are relevant to planning for development and coastal hazards, we further delved into the concept of geomorphic setting to describe the backshore corresponding to each natural shoreline type (Table 2). This backshore landscape is important to consider because different shoreline types can host similar development contexts. For example, development on bluffs can be adjacent to sandy beaches, rocky shores, or a river bank.

3. *Conceptual typology.*

Considering the backshore landscape and residential intensity patterns from cluster analysis, we created a conceptual typology to describe the most common settings that bound the diverse patterns we might find along the California shoreline. Subtypes represent the backshore landscape for developed neighborhoods that are located on the beachfront, blufftop, or in other low-lying environments (Table 3). The estuary type broadly covers low-lying shorelines characterized by some mixing of freshwater and saltwater, as seen at river mouths, lagoons, bays, and saltmarsh. The shore development type in combination with backshore subtype gives a more useful level of detail to planners who are identifying the policies and ordinances to apply to development in their communities. Most communities have multiple shore types and backshore landscapes. Policies or regulations and potential plan alternatives relevant to floodplain elevation, wetland migration, or setbacks from bluff edges, for example, can be flagged for consideration based on this knowledge of the geomorphic coastal zone landscape. A typology can be created by comparing the gradient of development density of developed places against their backshore elevation in the context of geomorphic types (Figure 2). Backshore bluffs were divided into categories of high and low elevations; beachfronts also have lower

and higher elevation landscapes, referred to by backshore subtype of beaches and dunes, respectively; lastly, estuaries were subtyped according to hydrogeomorphic features of bays, rivers, and marshes.

The backshore subtypes total seven unique categories that can be imagined as the backdrop for development patterns of varying intensity, yielding 14 relatively distinct residential development contexts to be considered by adaptation planning policymakers (Table 3). It is also useful to consider the various residential development patterns across the variables of urbanization and elevation. The urban versus rural density scale reflects the community constraints on adaptation more than the necessary geomorphic characteristics that must be accounted for in a hazards study. The high versus low elevation points yield different policy concerns (e.g. bluff erosion versus flooding) that may be relevant in a specific community.

IV. EXAMPLES OF TYPOLOGY GROUPS AND POLICY ISSUES

The effort to type residential development patterns along California's coast affirms the importance of understanding context when developing policy. It also suggests that it may be difficult to generalize how to implement "adaptation" along the shoreline in specific places. As shown, there is a wide diversity of residential development patterns. This section presents six short case studies of coastal communities (see Figure 3 for photographs) that have some portion of their coastal shoreline fitting into the groups determined by the conceptual typology (Table 3), to explore the implications of diverse context for adaptation planning policy issues.

A. *Urban Blufftop: Solana Beach, San Diego County*⁴⁶

The Solana Beach community is essentially built out along the shoreline, and the beaches below the existing blufftop residential development are highly valuable public access and recreational resources. They are also subject to constant wave attack and long-

46. Archive of Correspondence Regarding Staff Recommendation on City of Solana Beach Major Amend., Cal. Coastal Comm'n San Diego Coast District (Jan. 6, 2014) (on file with Cal. Coastal Comm'n), <http://documents.coastal.ca.gov/reports/2014/1/Th7d-1-2014.pdf>.

term erosional trends.⁴⁷ The cliffs themselves are high and do not provide stable development sites without reliance on significant setback distances of development from the bluff edge, substantial foundation development such as deep caissons (subterranean concrete piers), or beach-level seawalls and mid- and upper-bluff retention structures.⁴⁸ The primary adaptation challenge in Solana Beach has been how to protect existing development, and potentially allow redevelopment of existing homes, while not losing the beach below or the aesthetic of the natural cliff form. Much of this development is in the form of seawalls and upper bluff retention structures. Many of the existing blufftop homes have seawalls, approved since 1972, which prevent natural retreat of the beach and result in loss of beach resources. However, maintaining the existing development pattern will likely lead to long-term loss of beach resources without significant long-term retreat of blufftop development or alternatively, measures such as sand replenishment. Solana Beach developed a Land Use Plan (“LUP”) approved by the Coastal Commission in January 2014 to address these and other issues, including requiring the consideration of accelerated sea level rise in conducting slope stability and safe setback analysis for new development, and laying out specific policies for the redevelopment of existing blufftop residential development.⁴⁹ The Implementation Plan portion of the LUP, which would include more specific development standards, has yet to be completed.

The City of Solana Beach also submitted an LUP Amendment to the Coastal Commission in spring 2016 to incorporate the results of a fee study focused on mitigating adverse impacts to beach recreation from seawall development. This type of effort is a step toward developing strong mitigation policies that can be applied to those private seawall projects that have adverse impacts on the public recreational and ecological values of the beach. The

47. Griggs, *supra* note 38, at 496-98; *see also* CITY OF SOLANA BEACH, SOLANA BEACH LAND USE PLAN (2014), <http://solana-beach.hdso.net/LCPLUP/LCPLUP-COMplete.pdf>.

48. Griggs, *supra* note 38, at 61-65.

49. CITY OF SOLANA BEACH, *supra* note 47 (“Policy 4.57: Siting and design of new shoreline development and bluff retention devices shall take into account predicted future changes in sea level. In particular, an acceleration of the historic rate of sea level rise shall be considered and based upon up-to-date scientific papers and studies, agency guidance (such as the 2010 Sea Level Guidance from the California Ocean Protection Council), and reports by national and international groups such as the National Research Council and the Intergovernmental Panel on Climate Change.”).

Coastal Commission previously has imposed beach impact fees on shoreline protection projects to mitigate for the loss of recreational beach values, using travel-cost and real estate valuation methods to account for the future loss of beach recreation area.⁵⁰ While methods for quantifying and incorporating ecological values into beach impact fees have yet to be endorsed by the Coastal Commission, this area is an active subject of research and requires further work.⁵¹

Given the current conditions in Solana Beach, mitigation strategies for shoreline structure development will be critical to effective long-term protection of the beach environment. The Cities of Solana Beach and Encinitas also are hoping to benefit from a federally-sponsored 50-year beach replenishment effort potentially to begin sometime in 2018-19.⁵² While beach replenishment may be an attractive option for communities such as Solana Beach, it is important to note that these types of projects are expensive and complex, often requiring Congressional approval of projects carried out by the Army Corps of Engineers. These projects may easily take over 10 years to be authorized and funded.⁵³ It is also unclear whether the large investment in such projects will actually result in long-term protection of the beach in places like Solana Beach, where the beaches and cliffs are constantly subject to high wave energy, and thus where the results of sand replenishment may be short-lived.⁵⁴

50. See, e.g., CAL. COASTAL COMM'N, ADOPTED FINDINGS FOR COASTAL DEVELOPMENT, PERMIT APPLICATION NO. 2-10-039 29-39 (2013), <https://documents.coastal.ca.gov/reports/2013/8/Th17a-8-2013.pdf>; CAL. COASTAL COMM'N, REVISED FINDINGS FOR COASTAL DEVELOPMENT, PERMIT APPLICATION NO. 3-02-024 (2005), <https://documents.coastal.ca.gov/reports/2005/1/Th13a-1-2005.pdf>.

51. It is also worth noting that policy options in similar urban blufftops may be determined by other differences in context. For example, the Esplanade area of the City of Pacifica is also a dense urban blufftop, but the substrate is considerably weaker than that of Solana Beach. Consequently, whereas some developments have been able to stem the tides with seawall or revetment construction, others are essentially choosing "unplanned retreat" (i.e. removal) as the highly erodible bluffs continue to collapse and there is no land area readily available for relocation. See, e.g., Renee Schiavone, *Dramatic Video Shows California Coastal Community Literally Falling Into the Pacific*, PACIFICA PATCH (Jan. 29, 2016), <http://patch.com/california/pacifica/dramatic-video-shows-california-coastal-community-literally-falling-pacific-0>.

52. Bianca Kaplanek, *50-Year Sand Project Clears Another Hurdle*, THE COASTAL NEWS GROUP (Oct. 6, 2016), <http://www.thecoastnews.com/2016/10/06/50-year-sand-project-clears-another-hurdle/>.

53. *Id.* (stating that the estimated average annual cost for the proposed Solana Beach project is \$1.6 million).

54. Gary Griggs & Nicole Kinsman, Beach widths, cliff slopes, and artificial

B. *Urban Beachfront: Broad Beach, Los Angeles County*⁵⁵

More than 100 homes sit along Broad Beach just inland of the ocean. Over the last several decades Broad Beach has eroded significantly and placed the homes, backyards and septic systems in danger. A 0.8 mile-long emergency rock revetment was constructed to protect the homes, resulting in the loss of significant beach area and covering many existing public access dedications previously required by the Coastal Commission and now held by the California State Lands Commission. The homeowners have formed a Geological Hazard Abatement District (“GHAD”) to address the shoreline erosion and beach management problem collectively. The GHAD is a type of local assessment district that can enable communities to pool resources to conduct hazards studies and fund adaptation measures. Among other strategies, the Broad Beach GHAD proposes a 20-year beach replenishment program to maintain the beach in front of the revetment, which would be buried under a restored coastal dune complex. Broad Beach is one of the first examples of this mechanism being used for funding sea level rise adaptation measures.

The Broad Beach project raises significant issues about the long-term impacts of the beach homes and associated revetment on the beach; public access and recreation; and ecological value of the dune and beach complex, which will likely require frequent maintenance. There is considerable uncertainty about how long the GHAD’s proposed restoration of public beach seaward of the revetment will last in the face of ongoing beach erosion and sea level rise. Concerns also exist about the potential impacts of the proposed sand replenishment on beach and marine habitats, including sensitive offshore habitats in the Point Dume State Marine Conservation Area. Acknowledging the precedential nature and aspirations of the project, adaptive management relying on a series of monitoring thresholds has been proposed to ensure resources are being adequately protected. The Coastal Commission approved the Broad Beach project in October 2015. However, the approval only extends for 10 years so that it can be

nourishment along the California Coast, *Shore & Beach*, Vol. 84, No. 1, Winter 2016.

55. This discussion relies on: Addendum from Cal. Coastal Comm’n South Central Coast District Staff, to Cal. Coastal Comm’rs & Interested Pers., Staff Recommendation on Coastal Development Permit No.4-15-0390 (Oct. 7, 2015) (on file with the Cal. Coastal Comm’n).

revisited and revised if necessary, based on a better understanding of the replenishment project performance, including the implications for public access and natural shoreline resources. In the meantime, the project is mired in continued conflict about the transportation plan and routes for the proposed inland sand supply for the replenishment. As of October 2016 is yet to get underway.⁵⁶

Broad Beach is a good example of a context where a hybrid of hard armoring/rock strategy and soft sand replenishment and dune restoration may work in the immediate term.⁵⁷ The Commission's action also considers the longer-term operation of LCP requirements for redevelopment at Broad Beach, which, similar to the rules for Solana Beach, essentially require redeveloped homes to move inland as far as possible. However, unlike Solana Beach, the Broad Beach LCP also requires homes to be elevated on concrete piers, which potentially removes the need for placing rock at beach level—an option that is not available in the high cliff setting of Solana Beach. Over time, this may allow for the removal of the revetment as a way to further protect shoreline resources from sea level rise. However, there is considerable uncertainty as to whether conditions will allow for such phased retreat. This uncertainty is one of the reasons that the Commission limited its approval to 10 years subject to extensive monitoring and reporting requirements.

C. *Low Density Blufftop: Big Lagoon, Humboldt County*

The Big Lagoon area illustrates how a context where the relatively less dense, more rural development context allows for the use of relocation and planned retreat for both existing and new development. Big Lagoon is in the northern part of

56. See *Broad Beach Residents Still Waiting on Sand*, MALIBU TIMES, Nov. 10, 2016, http://www.malibutimes.com/news/article_fb439ca0-a6d6-11e6-871e-fba60ba84818.html.

57. The Broad Beach neighborhood in this example represents moderate development intensity, especially in contrast to even more urban examples like the Sunset Beach neighborhood of Huntington Beach, which has some of the highest density beachfront development concentrations along the California Coast. Like Broad Beach, Huntington Beach also relies on shoreline armoring and a beach replenishment strategy for protecting shoreline development. Long term planning for all urban beachfront development should consider that the adaptive capacity of beaches may diminish where shoreline armoring prevents the natural erosion and retreat of the beach as sea levels rise (i.e., “coastal squeeze”), even with continued sand nourishment.

Humboldt County, composed of an uplifted marine terrace approximately 40-90 feet above mean sea level. Many of the parcels in the area are used for commercial timber harvesting and rural residences. Bluff erosion and geologic instability currently pose risks to many existing structures located on bluff edges, and climate change will increase erosion rates in the future. Sudden catastrophic bluff failure events have already led to emergency relocations of homes along the bluffs between Big Lagoon and Patrick's Point on several occasions, including emergency relocations of dozens of cabins starting in the 1940s and continuing as recently as 2013.⁵⁸ Development permits for cabin relocations were issued even before the effective certification of the Humboldt County LCP in 1986.⁵⁹ One recent example of planning for retreat and relocation occurred in 2015 when Humboldt County submitted an LCP amendment that would affect a 13-acre lot owned by Big Lagoon Park Company.⁶⁰ The amendment of the North Coast Area Plan segment of the Land Use Plan and the Implementation Plan of the Humboldt County LCP reconfigured the boundary lines between existing Residential Estates ("RE") and Coastal Commercial Timberland ("TC") land use and zoning designations. The zoning change allows managed retreat of 14 existing cabins away from the bluffs.⁶¹

The proactive planned relocation of development in Big Lagoon was also mirrored in a case of proposed new development in this hazardous blufftop area of Humboldt County. On a location just downcoast of the Big Lagoon cabin development, on the same high eroding bluff formation, the Coastal Commission relied on a "takings override" finding to approve a new house in February 2014.⁶² The agency used the

58. CAL. COASTAL COMM'N, HUMBOLDT COUNTY LCP AMENDMENT LCP-1-HUM-15-0011-2 2 (2015).

59. "In January of 1985, prior to effective certification of the Humboldt County LCP in 1986, the Commission approved CDP 1-84-222, which authorized a "master relocation plan" for the adjacent 28-acre Big Lagoon Park Company lot where 76 cabins are now located (APN 517-131-009). Specifically, CDP 1-84-222 authorized the creation of 23 new home sites within the 28-acre property to serve as future relocation sites for existing cabins threatened with imminent bluff erosion risks." *Id.* at 6.

60. *Id.* at 1.

61. *Id.* at 20-21.

62. As discussed in these findings for the Winget CDP, Coastal Act section 30010 mirrors the takings clauses of the U.S. and California constitutions, specifically not allowing the taking of private property without just compensation. When the Commission

best available scientific projections for sea level rise and erosion rates to determine that the proposed house would last about 50 years before it needed to be removed to avoid falling to the beach below. Rather than deny the project entirely, the Commission conditioned it to incorporate adaptive measures that allow for an economic use of the site as long as possible. Before the erosion threat reaches the point of requiring removal, the property owners committed to annual monitoring of the bluff edge and triggers for more thorough geotechnical study as erosion continues to encroach on the development. In this way the property owners can maximize the amount of time possible to safely stay in their residence.⁶³

D. Low/Medium Density Beachfront: Stinson Beach, Marin County

There is significant residential development along the shoreline of Stinson Beach that is subject to long-term erosion, wave run-up, coastal flooding, septic failure, and water distribution pipe failure. Calle del Arroyo, a principal access road to the Calles, Patios, and Seadrift neighborhoods, may also experience increased flooding and eventual permanent inundation, severely limiting access to portions of the community.⁶⁴ Flooding from Bolinas Lagoon and Easkoot Creek already occurs and will likely worsen with future rising sea levels. Stinson Beach is similar to Broad Beach in terms of the density of homes on the immediate beach front. In general, though, there is relatively more beach area in front of the homes as compared to Broad Beach. In the past Marin County has generally allowed redevelopment of beach homes if they comply with FEMA flood elevation rules, but this has resulted in some elevated structures that potentially raise concerns about visual resources and community character, as well as beach access and recreation. Thus, similar to some parts of Malibu and elsewhere in the state, over the long-run there may be a concern that the mean high tide, and thus public trust lands, will migrate to and eventually under

finds that a development is not consistent with the Chapter 3 policies of the Coastal Act, or provisions of an LCP, it may nonetheless “override” this inconsistency and approve it pursuant to section 30010 in order to avoid a taking. CAL. COASTAL COMM’N, STAFF REPORT: REGULAR CALENDAR, APPLICATION NO. I-12-023 24 (2013).

63. *Id.* at 3.

64. BRIDGIT VAN BELLEGHAM, ALEX WESTHOFF, LAUREN ARMSTRONG & NICOLE LE BARON, MARIN OCEAN COAST SEA LEVEL RISE VULNERABILITY ASSESSMENT 6 (2015).

elevated homes. This eventuality demonstrates the looming need to more comprehensively address the potential conflict between coastal hazard mitigation and coastal resource protection, including protection of the public trust interest in tidelands.⁶⁵

Marin is one of the first local communities to go through the process of conducting an extensive climate change vulnerability assessment, beginning work on adaptation planning, and bringing an LCP that attempts to address sea level rise to the Coastal Commission for certification.⁶⁶ While accommodation of vulnerable structures, roads and utilities, primarily through elevation and retrofits, is identified by the County as a short-term priority for Stinson Beach, longer term actions remain to be further studied or proposed. For example, the County's vulnerability assessment concludes that the beach area in front of the Seadrift revetment will be essentially lost by 2100. The County is currently recommending a policy of allowing structures to be raised 3 feet above FEMA's Base Flood Elevation to account for future sea level rise.⁶⁷ In the future, adaptation options might include major beach replenishment, restrictions on rebuilding structures destroyed by storms, and removal or relocation of structures. As of this writing, the LCP was heard by the Coastal Commission in November 2016, but action on the coastal hazards section of the update was deferred.⁶⁸ The Commission staff was recommending approval of the LCP if it was modified to address specific concerns regarding coastal hazards policy and adaptation planning. For example, the staff accepted the County's proposed addition of 3 feet of elevation to new structures in response to sea level rise, but also recommended adding specific triggers for removal of this development in the long run should these projections be exceeded and/or result in the loss of public trust and recreational beach resources. In recognition of the uncertainty of current projections, the staff was also recommending a required revisiting of adaptation measures in 10 years, including the creation of sandy beach management plans to

65. See Meg Caldwell & Craig Hold Segal, *No Day at the Beach: Sea Level Rise, Ecosystem Loss, and Public Access Along the California Coast*, 34 *ECOLOGY L.Q.* 533 (2007).

66. See generally CA. COASTAL COMM'N, MARIN COUNTY LOCAL COASTAL PROGRAM AMENDMENT NUMBER LCP-2-MAR-15-0029-1 (2016).

67. See *id.* Ex. 9 at 1-14.

68. See Samantha Kimmey, *Bulk of LCP Moves Forward as Hazards Chapter Stalls*, POINT REYES LIGHT, Nov. 10, 2016, <http://www.ptreyeslight.com/article/bulk-lcp-moves-forward-hazards-chapter-stalls>.

protect the valuable beaches of Marin County.⁶⁹

E. Developed Estuary: Newport Beach, Orange County

Estuarine environments present a different set of sea level rise policy concerns compared to developed bluffs or beaches. The development of Newport Bay Harbor was authorized in 1934 and carried out by the Army Corps of Engineers. Islands within Newport Bay were built-up using dredged sediments within the estuary and now residences and small piers are common in the bay. “Sea level rise is expected to lead to increased erosion, loss of coastal wetlands, permanent or periodic inundation of low-lying areas, increases in coastal flooding, and salt water intrusion into stormwater systems and aquifers.”⁷⁰ Structures on islands within Newport Bay and the bayside of Balboa Peninsula typically rely on bulkheads, retaining wall structures similar to seawalls but typically not designed for wave impacts, to ensure protection against coastal flooding and shoreline retreat. Most immediate sea level rise adaptation measures in Newport Bay will be to reinforce and elevate those existing bulkheads. However, protection of the public tidelands seaward of the bulkheads for public use is a primary concern and must be addressed on a comprehensive scale.⁷¹

The Coastal Commission approved an Implementation Plan (“IP”) submitted by the City of Newport Beach in September 2016.⁷² As approved the IP adds requirements to the LCP that sea level rise be addressed in Coastal Hazards Reports and Geologic Stability Reports for new development applications, and that shoreline management plans be created for existing development. These management plans must include evaluation of adaptation options exploring the feasibility of hazard avoidance, beach replenishment, and planned retreat. The City also requires property owners to record a waiver of future shoreline protection for new development. In the case of bulkheads, applicants must waive rights to future protection, including repair or

69. CAL. COASTAL COMM’N, *supra* note 66, at 5.

70. CAL. COASTAL COMM’N, CITY OF NEWPORT BEACH IMPLEMENTATION PLAN LCP-5-NPB-15-0039-1 53 (2016).

71. *Id.* at 60.

72. *Id.*; CAL. COASTAL COMM’N, MEETING AGENDA (SEPT. 2016) <https://www.coastal.ca.gov/meetings/mtg-mm16-9.html> (indicating that the Implementation Plan was approved with modifications).

maintenance, enhancement, or any activity affecting the bulkhead, that results in any encroachment seaward of the authorized footprint when public lands (tidelands or sandy beach area) are present seaward of the existing bulkhead. In this way, redevelopment of the existing pattern of bulkhead-reliant areas includes measures that allow for landward relocation of new development and bulkheads in the future, not unlike the redevelopment standards for Solana Beach.

F. Low Density Estuary: Bodega Bay, Sonoma County

The Sonoma County coast supports agricultural lands, timber preserves, open space areas, recreational lands, and low-density community development. In contrast to Newport Bay, Bodega Harbor is a small shallow natural harbor in Sonoma County, protected from the larger expanse of Bodega Bay to the south by a narrow spit of land. The area has low levels of residential development, and large expanses of natural habitat, both in tidal mudflats and salt marsh, presenting different policy questions than the urban context of Newport Bay. For example, in one recent coastal permit application, the Coastal Commission found that there was a policy conflict and applied the conflict resolution provision of the Coastal Act to provide protection of Environmentally Sensitive Habitat Area (“ESHA”) wetlands in Bodega Bay while allowing redevelopment of an existing residence.⁷³ The residence was moved out of ESHA and special conditions put in place to mitigate the impacts from the development. These conditions included a revised habitat restoration and monitoring plan; restrictions on future development, including a prohibition on development within sensitive habitat areas; and a restriction on future shoreline protective devices.

The Lundberg residence relied on design plans that accounted for 55 inches of sea level rise and waves during a 100-year storm. It was also found to be elevated sufficiently to withstand a tsunami wave during its 75 year expected life. However, as with the Marin County LCP and the Winget project in Big Lagoon, the inherent uncertainty associated with coastal hazards and sea level rise projections means that the residence

73. CAL. COASTAL COMM’N, STAFF REPORT ADDENDUM FOR W16A, CDP APPLICATION NUMBER 2-14-0673 29-36 (2015).

might face threats sooner than expected. To mitigate this future risk, the permit contained a requirement to remove the proposed development when the residence is no longer safe to inhabit or is threatened with coastal hazards that would require a response beyond ordinary repair and maintenance.

V. SYNTHESIS AND CONCLUSIONS

Recent discussion of sea level rise adaptation planning has generally focused on three categories of adaptation strategies: protection, accommodation, and retreat.⁷⁴ And in the call for new policy to address sea level rise, and reduce uncertainty, there is always a risk of oversimplifying the challenge by calling for one strategy over another: protection of development with seawalls, elevation of development in place, or removal of development altogether.

Effective policy must be attentive to the diversity of the physical and built environment along California's coast. On one hand the typology considered in section three affirms the high diversity, and thus complexity, of residential development contexts along California's coast. Yet statistical cluster analysis and consideration of geomorphic conditions also help to frame the adaptation planning challenge by presenting distinct types of cases for the consideration of policy development. The six cases summarized in section four, based on the typology, are a small sampling of the broader diversity of residential development contexts along California's coast. But they touch upon both the similar sea level rise adaptation challenges faced up and down the coast, and the need to address different specific policy challenges, as driven by the varied geomorphic and development settings in California.

The historic post-WWII development pattern along California's coast has set up a significant adaptation planning challenge for the next forty years of coastal management. For all development contexts in California, sea level rise brings to the fore the inherent tension in the Coastal Act between existing and new development that has informed decision-making under the Coastal Act since the beginning. It also shines a spotlight on the potential long-run ephemeral nature of all development along the

74. CAL. COASTAL COMM'N, CALIFORNIA COASTAL COMMISSION SEA LEVEL RISE POLICY GUIDANCE CH. 7 125 (2015).

immediate shoreline, and thus on the need to engage in adaptation planning that considers not only consistency with the Coastal Act, but the specific trade-offs between various management options that may result in protection, accommodation or retreat of development on the coast in any given case.⁷⁵ Each of the cases summarized above represent efforts to provide for ongoing development while protecting coastal resources. And they each entail decisions about not only which social costs and benefits may be acceptable to a community—such as the costs of beach replenishment, the impacts of seawalls on public access, or the benefits of protecting existing community development in place—but also the distribution of these costs and benefits to different members of the community over time. So, notwithstanding the diversity of development contexts along the shoreline, all California communities share the common challenge of maintaining resilient communities that protect coastal resources and that are environmentally just.⁷⁶

Going forward it will be important that all local governments undertake vulnerability assessments and begin the adaptation planning process to allow for continued growth of their communities in a way that also protects coastal resources and public access to the maximum extent feasible as sea level rises. As a general matter all communities should embrace the best available science and include high projections of sea level rise in their planning for coastal hazards. Development should be required to be as resilient and safe as possible, while assuring the protection of beach recreational resources and ecological values—no easy task. All communities should also be considering longer planning horizons and phased approaches that inform property owners and the public about planned adaptation through such mechanisms as deed restrictions, real estate disclosures, and assurances or waivers of rights based on defined triggers sensitive to the specific planning context.

It will also be important for communities to look to each other to see if there are lessons to be learned from common contextual factors and experiences. For example, even this short overview

75. See, e.g., THE NATURE CONSERVANCY, SCC CLIMATE READY GRANT NO. 13-107 ECONOMIC IMPACTS OF CLIMATE ADAPTATION STRATEGIES FOR SOUTHERN MONTEREY BAY 8 (Nancy Steinberg, eds., 2016).

76. See CAL. COASTAL COMM'N, CALIFORNIA COASTAL COMMISSION SEA LEVEL RISE POLICY GUIDANCE CH. 4 (2015)

and consideration of the typology suggests the following:

- Planning for redevelopment that protects coastal resources while minimizing and avoiding coastal hazards will be a common challenge in higher density areas. As in Solana Beach and Marin County, specific attention should be paid to the detailed rules that govern how and to what extent redevelopment can occur, and what triggers may be needed to provide for coordinated adaptation at the community level.
- Policies for different geomorphic contexts may differ in the type of technical studies and triggers that are appropriate for the hazard of concern. For example, beach width and high water marks might be important triggers for beachfront development such as at Broad and Stinson Beaches, while bluff stability measures and distance of the structure to bluff edge will be relevant for blufftop residences in places like Solana Beach and Big Lagoon. Regardless of whether it is beachfront or bluff edge distance between a development and the sea, policies should establish the priority and timing of the adaptation measures planned for each area of concern.
- A long-term adaptation approach that includes deed restrictions on armoring, rolling easements for new development, and the use of more comprehensive planned retreat strategies, such as transfer of development rights or buyout programs, may be necessary to phase redevelopment in a community for eventual conformance with an LCP policy for protection of coastal resources and the public trust.⁷⁷ This will depend on the evaluation of long-term resource and development trends as weighed against the state Coastal Act.
- Soft solutions such as dune restoration or beach replenishment may be preferred over hard armoring, but these will not work everywhere. In addition, further research and understanding of the potential adverse impacts of certain strategies, such as beach replenishment

77. For example, the recent Coastal Commission staff recommendation on the Marin County LCP contemplates the development of sandy beach management plans that might include zoning overlays with development standards to facilitate protection of public beach resources. CAL. COASTAL COMM'N, MARIN COUNTY LOCAL COASTAL PROGRAM AMENDMENT NO. LCP-2-MAR-15-0029-1 EXHIBIT 12 AT 56 (2016).

and impacts to shoreline ecology, are also needed so caution is warranted. Cases like Broad Beach, with such alternatives, including ecological monitoring built in, could be important bellwethers for policy performance.

- As illustrated by the Big Lagoon context, planned retreat options and recommended larger setbacks for redevelopment are, predictably, more immediately feasible in less constrained areas (e.g., lower density, larger parcels) than in highly developed urban places. Where retreat options are viable, a precautionary approach—avoiding and moving out of hazardous areas—should be taken to avoid creating new problems in the long-run. In other highly urban places, like Solana Beach, retreat of existing structures, as opposed to retirement of structures, will be less feasible, starkly framing the coastal squeeze challenge. In still other places, like the high bluffs of Pacifica or Gleason’s Beach in Sonoma County, “unplanned retreat” and removal of structures (as well as cleanup of debris), will become the de facto, feasible “alternative” if there are insufficient private or public funds to do anything but remove structures, once it is too late to save them.
- As in the Winget case from Big Lagoon, an adaptive approach based on triggers and clearly defined future actions can improve resilience in many situations, provide for continued productive use of developed areas, and account for some level of uncertainty in the timing of sea level rise impacts. Again, the specific timing and mechanisms will depend on context.
- Improving mitigation strategies for shoreline structure development, such as the beach recreational fee in Solana Beach, will be critical to effective, coordinated, and fair long-run protection of the beach environment in coastal communities where such shoreline protection is unavoidable in the near term.
- Related to mitigation, financing adaptation measures at the neighborhood scale will grow in importance in the future. For example, the Broad Beach GHAD pooled homeowner resources to fund their adaptation project. Still, significant state and federal resources likely will be needed to fully fund adaptation strategies. For example,

tens of millions are necessary for the recently approved sand replenishment project at Solana Beach.

The California Coastal Commission recently awarded a third round of grant funding to support local governments in completing or updating LCPs with special emphasis on planning for sea-level rise and climate change.⁷⁸ And building on the prior two rounds of Coastal Commission planning grants, each supported by important budget augmentations from the state, more LCP planning products are becoming available for other local governments, providing examples of vulnerability assessments and adaptation policies and ordinances that will assist communities in developing sea level rise resilience.⁷⁹ The Coastal Commission also continues work on next steps following the Sea Level Rise Policy Guidance adopted by the Commission in August 2015.⁸⁰ As part of the Commission's effort, the Coastal Commission may soon produce additional policy guidance and model ordinance language for resilient shoreline residential development in hazardous areas affected by sea level rise. This type of guidance will help local governments address policy and management issues in a proactive way that allows for protecting coastal resources while minimizing and avoiding coastal hazards, as required by the California Coastal Act.

In the end, because the planning process will include identifying how and where to apply different adaptation mechanisms based on the Coastal Act; geomorphic context; social, economic and legal consideration of the built

78. CAL. COASTAL COMM'N, ADDENDUM TO ITEM F5: ROUND 3 LOCAL COASTAL PROGRAM LOCAL ASSISTANCE GRANT AWARDS 1 (2016).

79. *See, e.g.*, CITY OF GOLETA, RESOLUTION NO. 15-55 COASTAL HAZARDS VULNERABILITY AND FISCAL IMPACT DRAFT REPORT (2015) (example of a planning product).

80. As argued herein, the Commission's sea level rise guidance also recognizes that there is no one solution to the challenge of adaptation:

For purposes of implementing the Coastal Act, no single category or even specific strategy should be considered the "best" option as a rule. Different types of strategies will be appropriate in different locations and for different hazard management and resource protection goals. The effectiveness of different adaptation strategies will vary across both spatial and temporal scales. In many cases, a hybrid approach that uses strategies from multiple categories will be necessary, and the suite of strategies chosen may need to change over time.

CAL. COASTAL COMM'N, *supra* note 78, at 122.

environment; and environmental justice, exactly how every LCP addresses sea level rise will differ. There is no shortcut for undertaking such a community-level planning process, in conjunction with the Coastal Commission and other stakeholders, to identify the right strategies and implementation timing for each context. The diversity and thus complexity of California's natural and built environment does not lend itself toward any single "silver bullet" for addressing sea level rise. Still, understanding the similarities and differences across communities will support better and more consistent proactive planning for sea level rise resilience, and promote sharing of knowledge and experiences along the coast in the coming decades.

APPENDIX

Table 1. Groups from R clustering analysis on housing unit density, percent residential and commercial, and distance to shore

Group	Description	# of blocks	Group mean			
			HDEN10 (units/km)	Dist. from shore (m)	Commercial (%)	Residential (%)
1	Non Shoreline– Low Density	1270	500	4,500	9%	18%
2	Shoreline– Low Density	7015	900	570	4%	17%
3	Shoreline– Medium Density Urban Mix	2627	2,100	510	59%	26%
4	Shoreline– Medium Density Residential	7003	2,000	510	8%	77%
5	Shoreline– High Density Residential	1131	8,400	270	20%	48%

Table 2. Typical natural shoreline type and backshore categories

<i>Shoreline</i>	<i>Backshore landscape</i>
Sandy Beach	Low/High Bluff, Dunes
Rocky	Low/High Bluffs
Marsh	Wetland
Tidal/Bay	Bluff, Tidal Mudflat, Wetland, Dunes

Table 3. Shore development typology groups with associated backshore subtypes

Shore Development Type		Backshore Subtype		
1	Urban blufftop	Low	High	
2	Urban beachfront	Beach	Dune	
3	Low density blufftop	Low	High	
4	Low density beachfront	Beach	Dune	
5	Urban estuary	Bay	River	Marsh
6	Low density estuary	Bay	River	Marsh

Figure 1. Frequency of residential density patterns found with geomorphic shoreline types

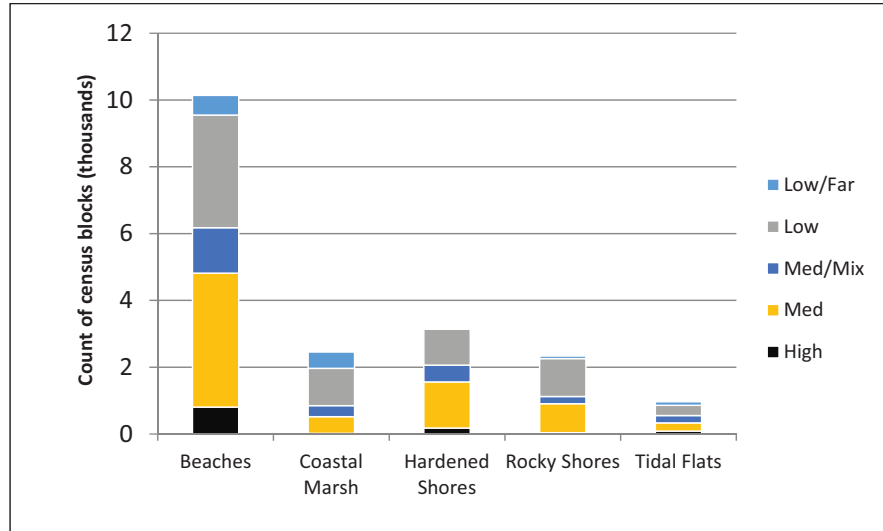


Figure 2. Example typology graph describing residential development patterns

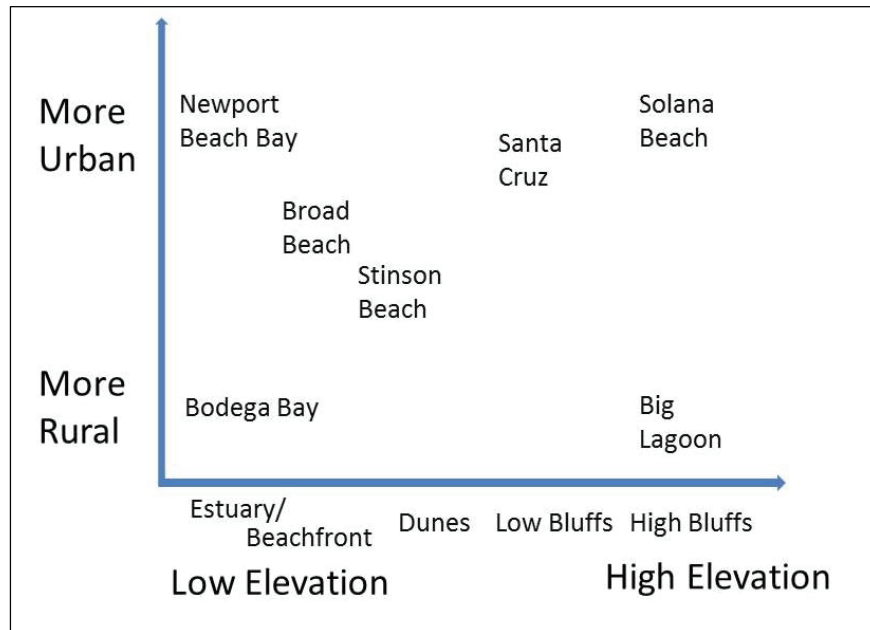


Figure 3. Photographs of six case studies



A. Solana Beach, courtesy of California Coastal Records Project



B. Broad Beach, courtesy of Lesley Ewing



C. Big Lagoon, courtesy of California Coastal Records Project



D. Stinson Beach, courtesy of California Coastal Records Project



E. Newport Bay, courtesy of California Coastal Records Project



F. Lundberg residence in circle, Bodega Bay, courtesy of Google Earth