U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

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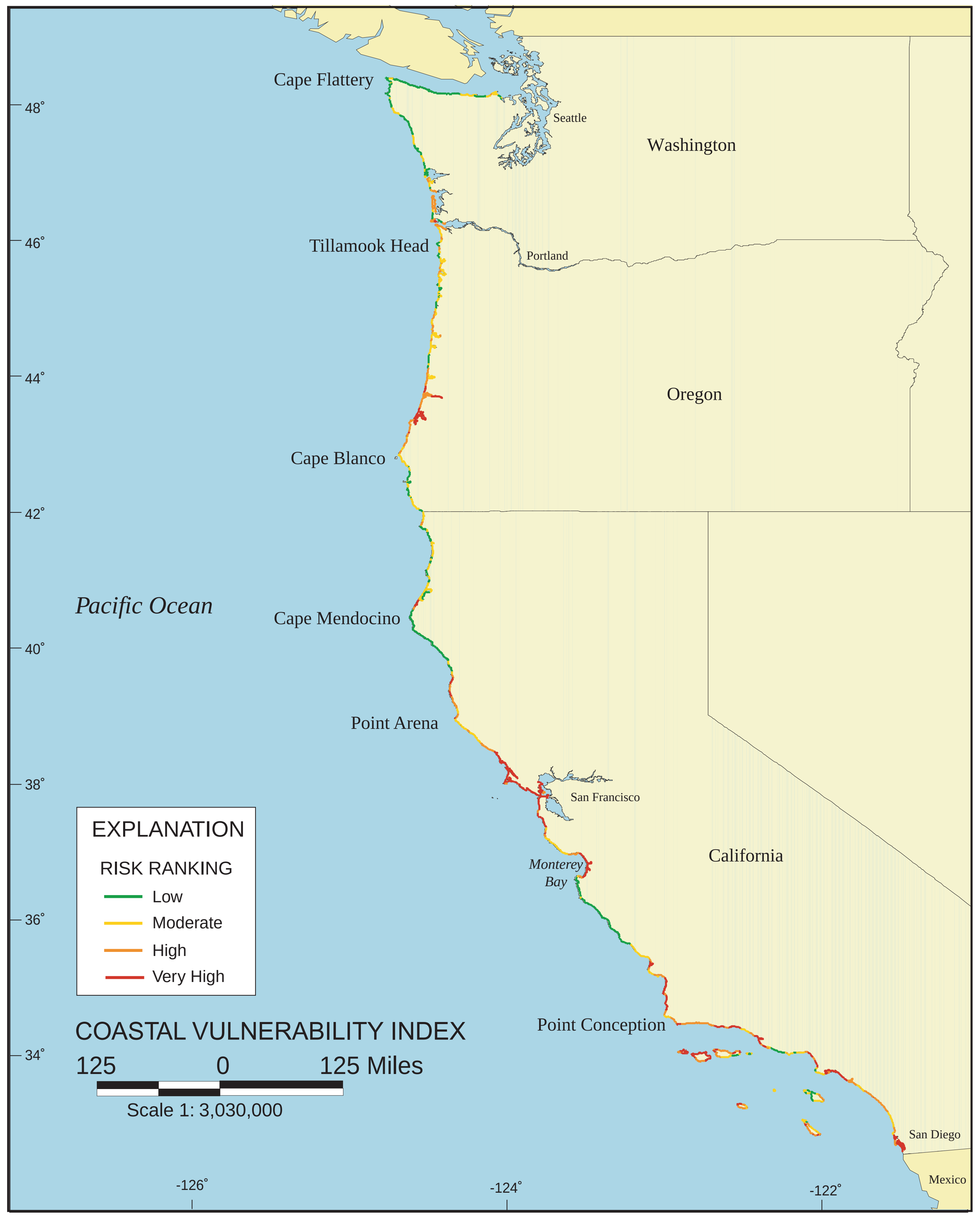

Figure 1. Map of the Coastal Vulnerability Index (CVI) for the U.S. Pacific coast. The CVI shows the relative vulnerability of the coast to changes due to future rise in sea-level. Areas along the coast are assigned a ranking from low to very high risk, based on an analysis of physical variables that contribute to coastal change.

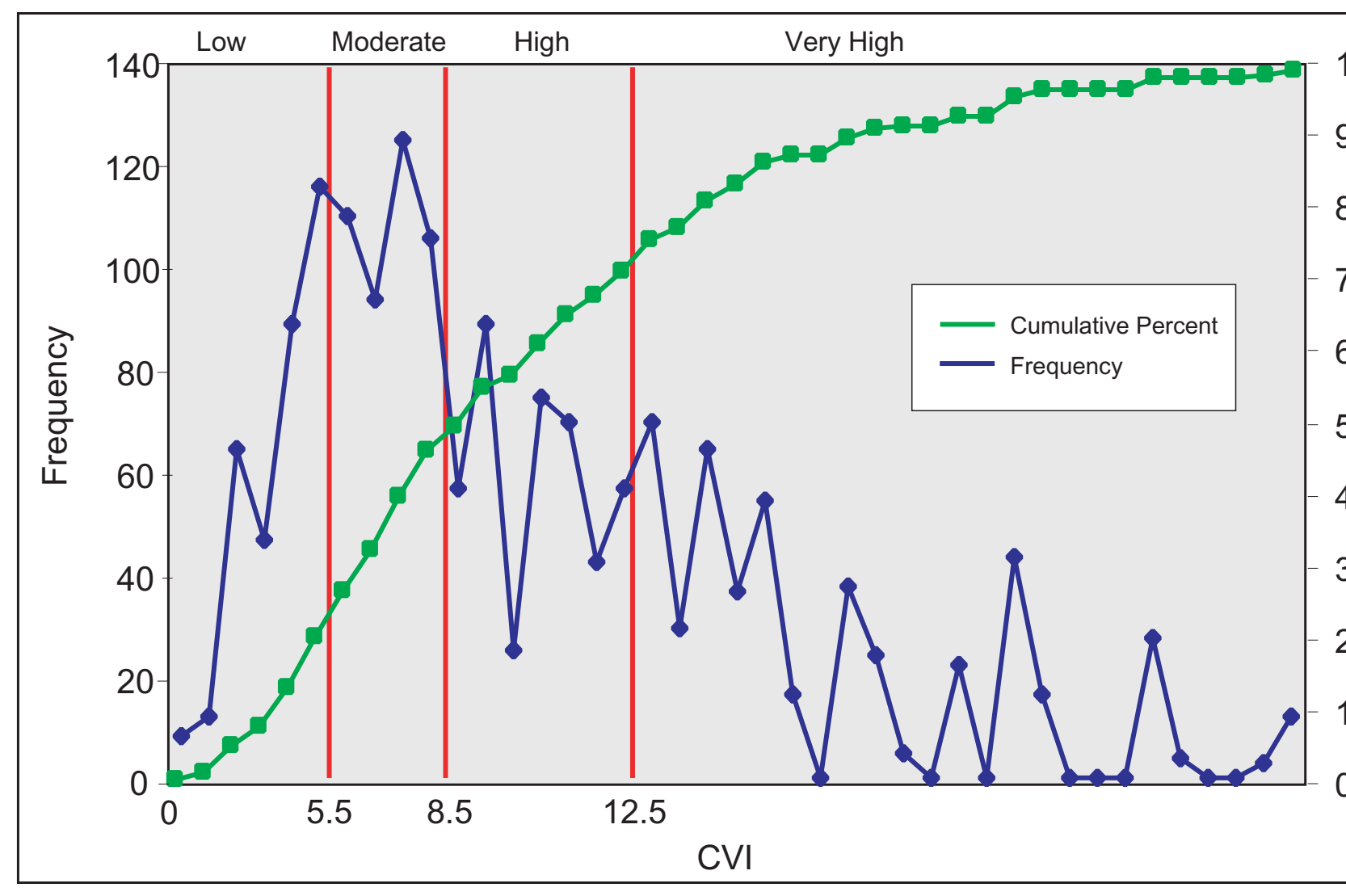

Figure 2. Histograms showing the frequency of occurrence and cumulative frequency of CVI values for the U.S. Pacific coast. The vertical red lines delineate the chosen ranges for low, moderate, high, and very high risk areas.

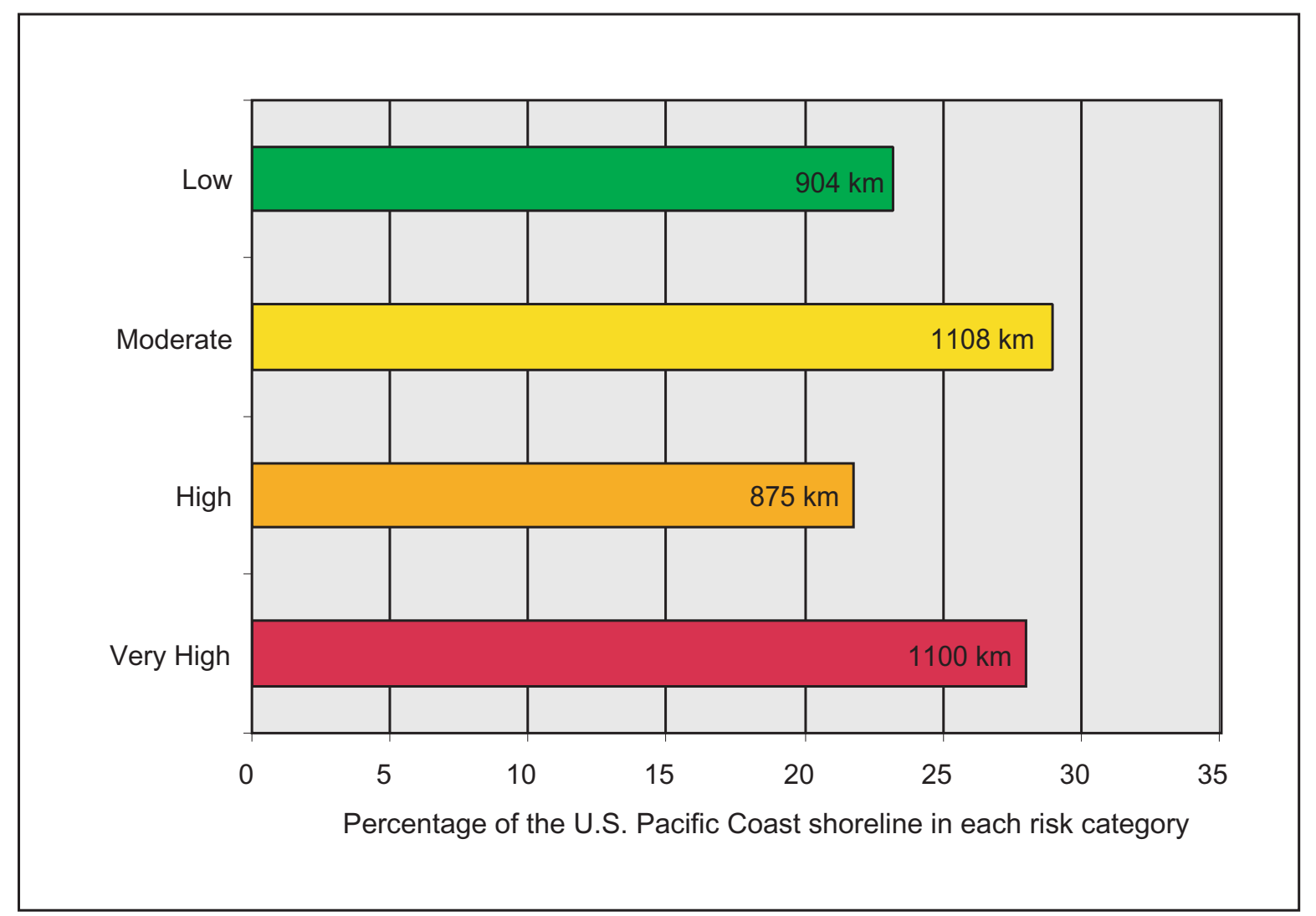

Figure 3. Bar graph showing the percentage of shoreline along the U.S. Pacific coast in each risk category. The graph also shows the total length of shoreline (in kilometers) in each risk category. The total length of mapped shoreline in this study is 3987 km.

Table 1. Ranking of coastal vulnerability index variables for the U.S. Pacific Coast.

	Ranking of coastal vulnerability index				
	Very low	Low	Moderate	High	Very high
VARIABLE	1	2	3	4	5
Geomorphology	Rocky, cliffed coasts Fiords Fiards	Medium cliffs Indented coasts	Low cliffs Glacial drift Alluvial plains	Cobble beaches Estuary Lagoon	Barrier beaches Sand Beaches Salt marsh Mud flats Deltas Mangrove Coral reefs
Coastal Slope (%)	> 1.9	1.3 – 1.9	0.9 – 1.3	0.6 –0.9	< .6
Relative sea-level change (mm/yr)	< -1.21	-1.21 – 0.1	0.1 – 1.24	1.24 –1.36	> 1.36
Shoreline erosion/ accretion (m/yr)	>2.0 Accretion	1.0 –2.0	-1.0 – +1.0 Stable	-1.1– -2.0	< - 2.0 Erosion
Mean tide range (m)	> 6.0	4.1 – 6.0	2.0 – 4.0	1.0 –1.9	< 1.0
Mean wave height (m)	<1.1	1.1 – 2.0	2.0 – 2.25	2.25 –2.60	>2.60

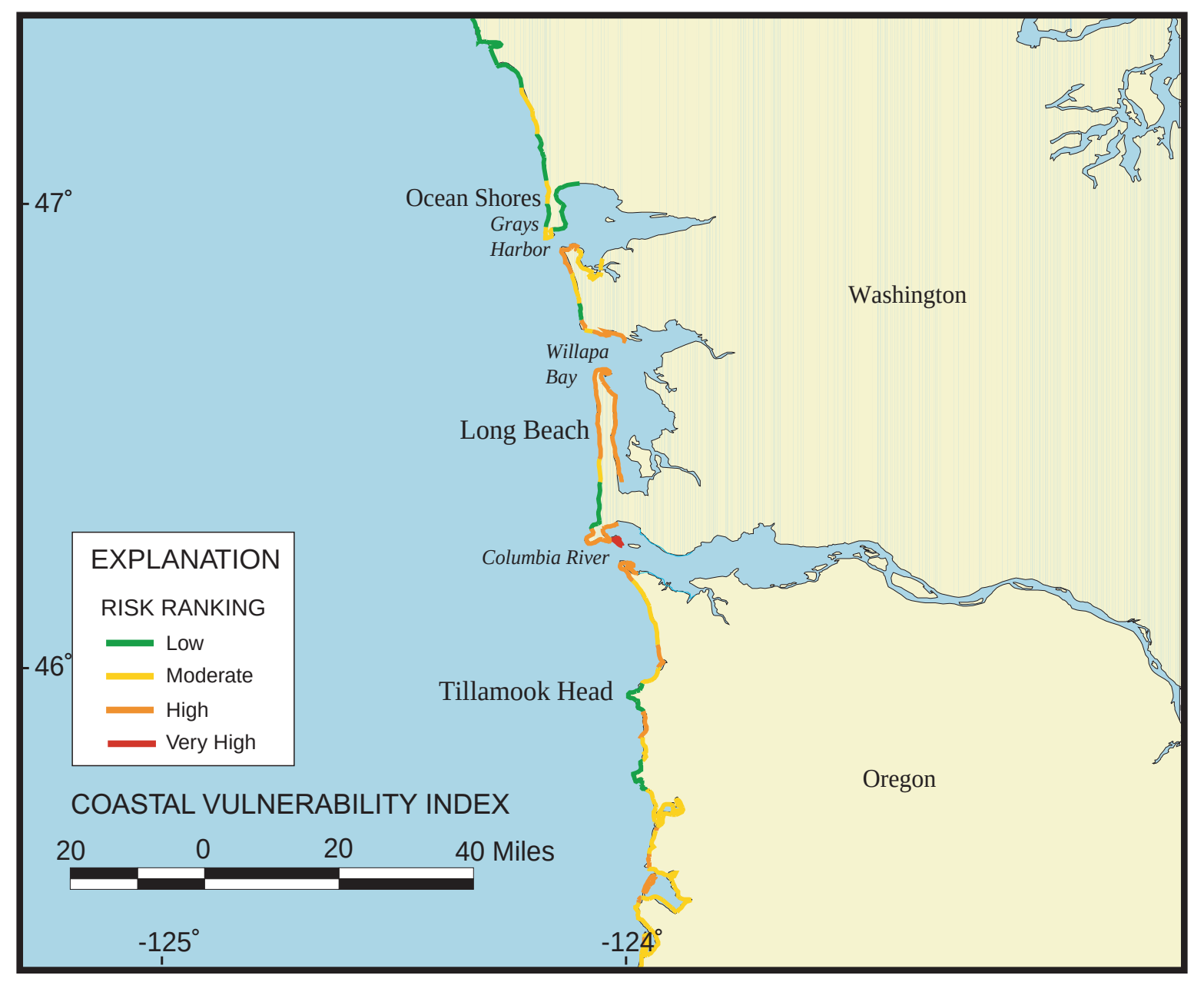

Figure 4. Map of the Coastal Vulnerability Index for the open ocean coast of southwestern Washington and northwestern Oregon.

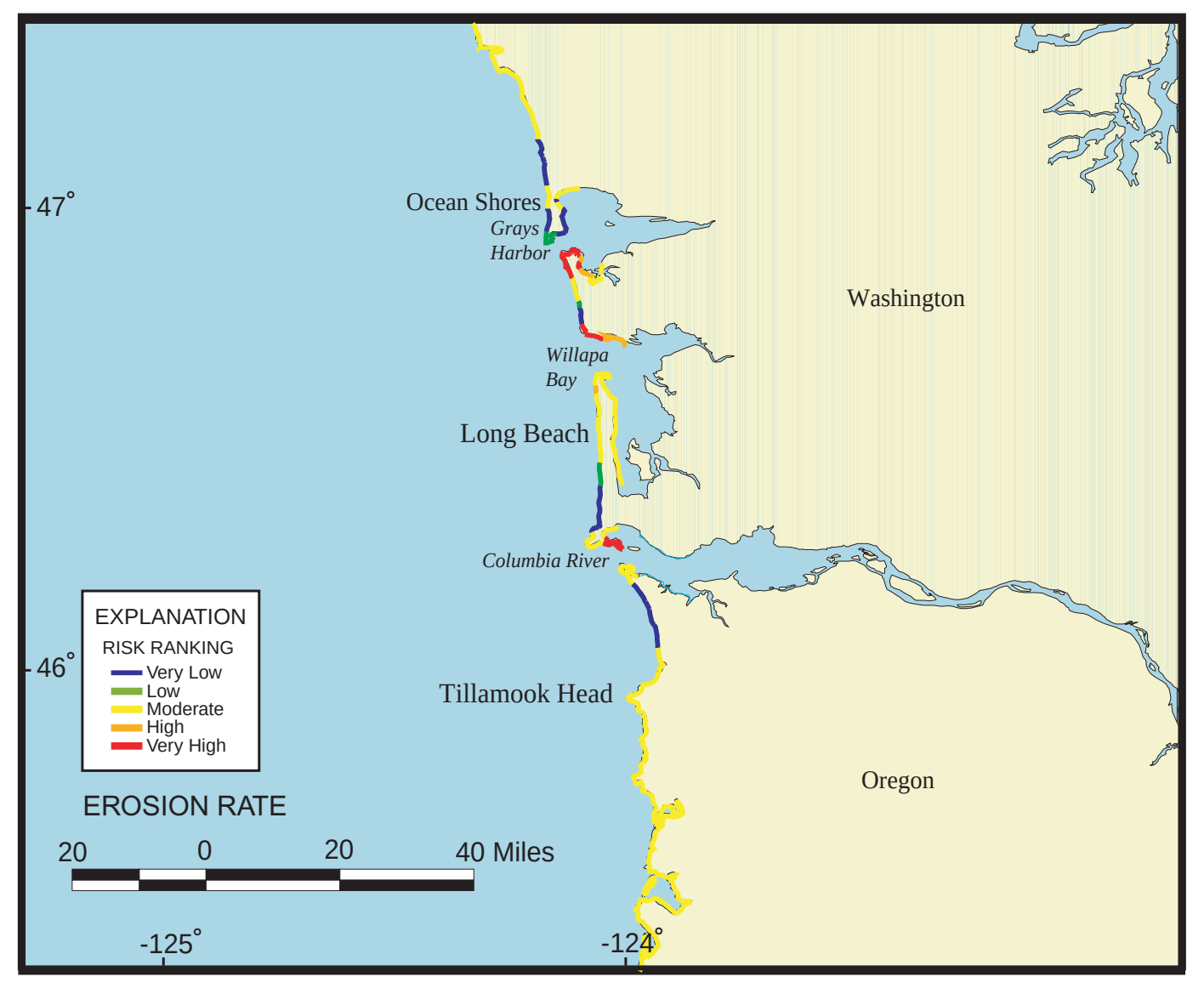

Figure 7. Map of the shoreline erosion/accretion rate variable for southwestern Washington and northwestern Oregon. The smaller-scale variations in the CVI values (see Figure 4) are influenced primarily by changes in shoreline erosion rate.

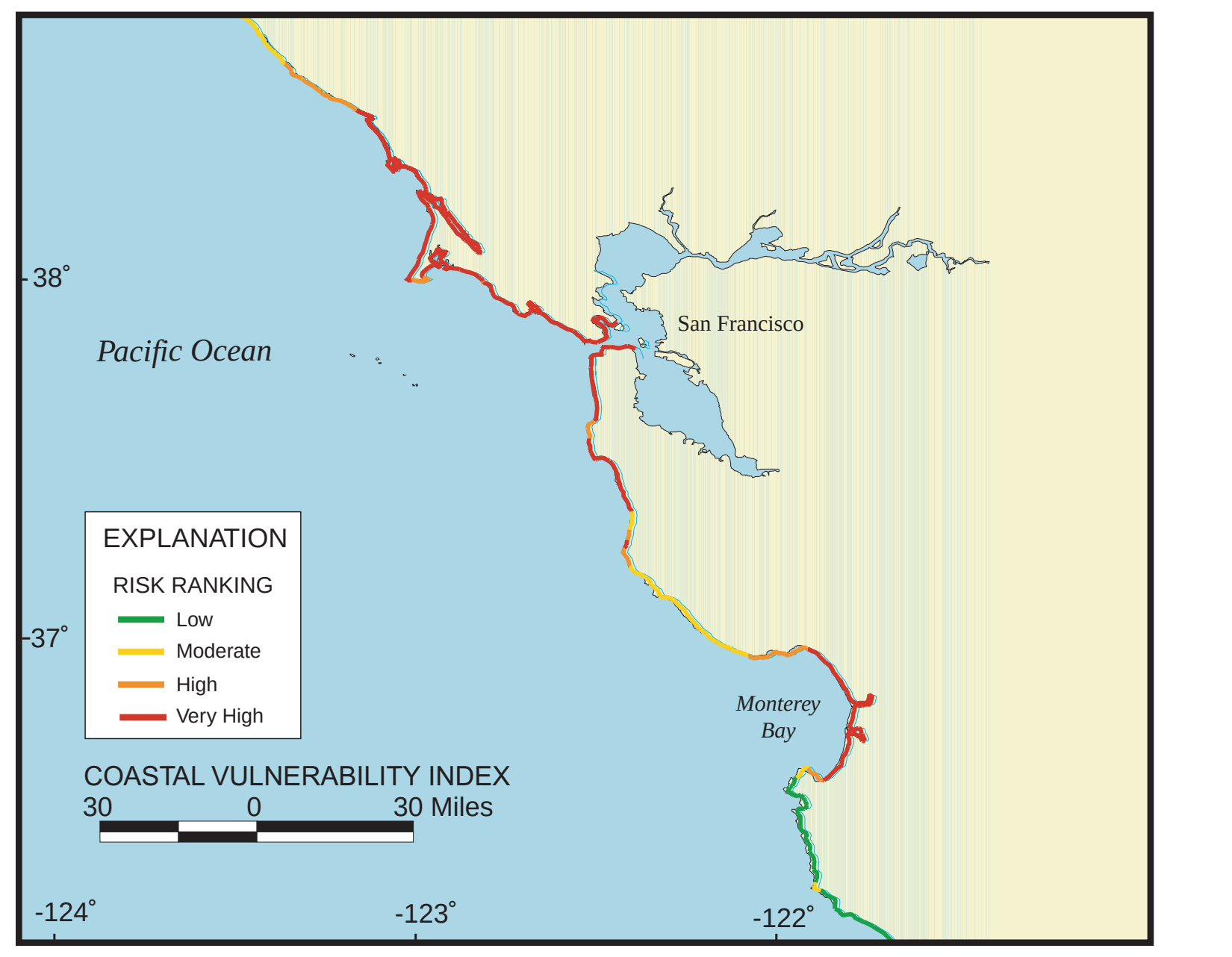

Figure 8. Map of the Coastal Vulnerability Index for the San Francisco - Monterey region.

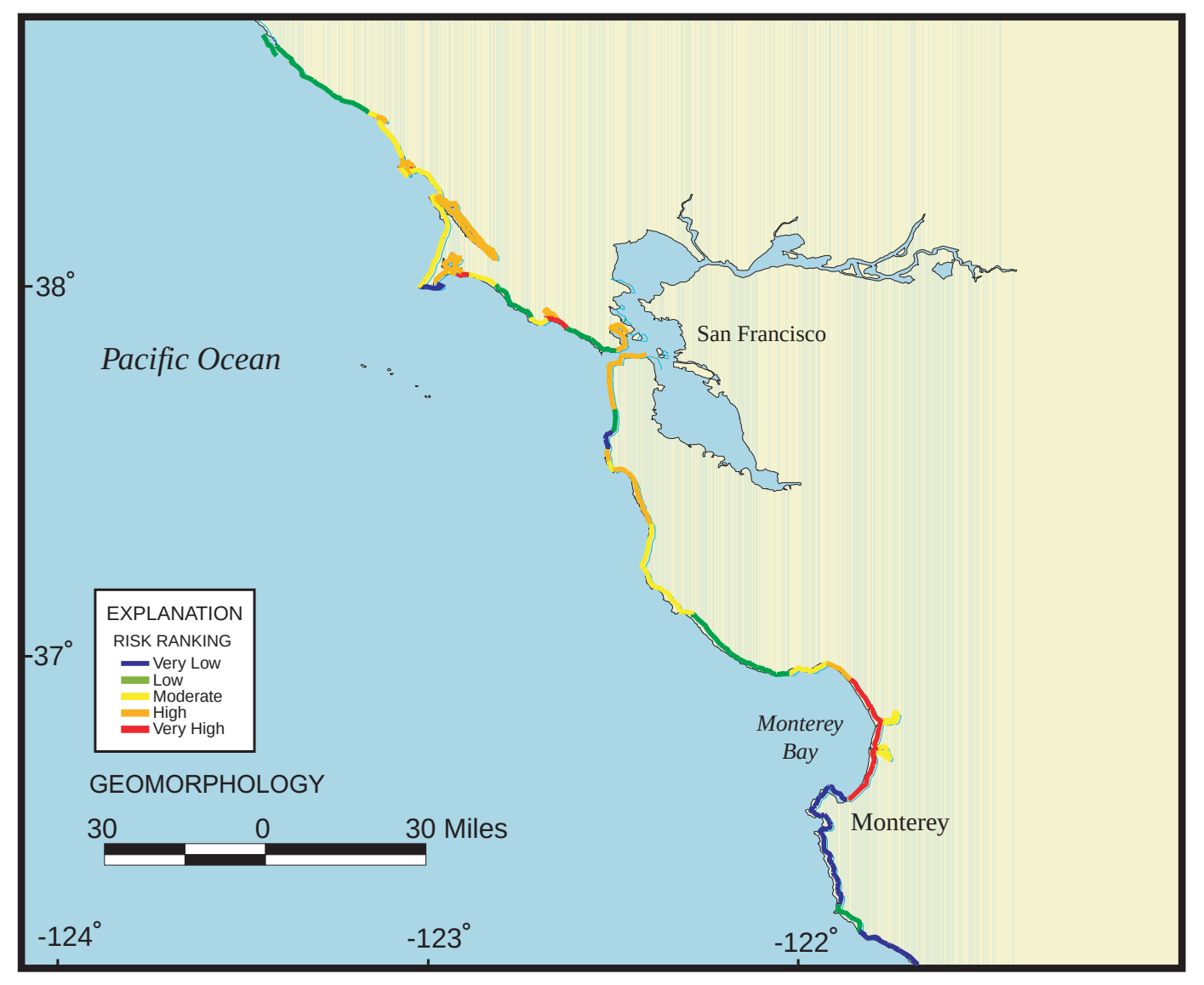

Figure 11. Map of the geomorphology variable for the San Francisco - Monterey region. The shoreline is composed of higher-risk sandy pocket beaches interspersed with lower-risk rocky headlands, as well as areas of low sea-cliffs and high coastal bluffs.

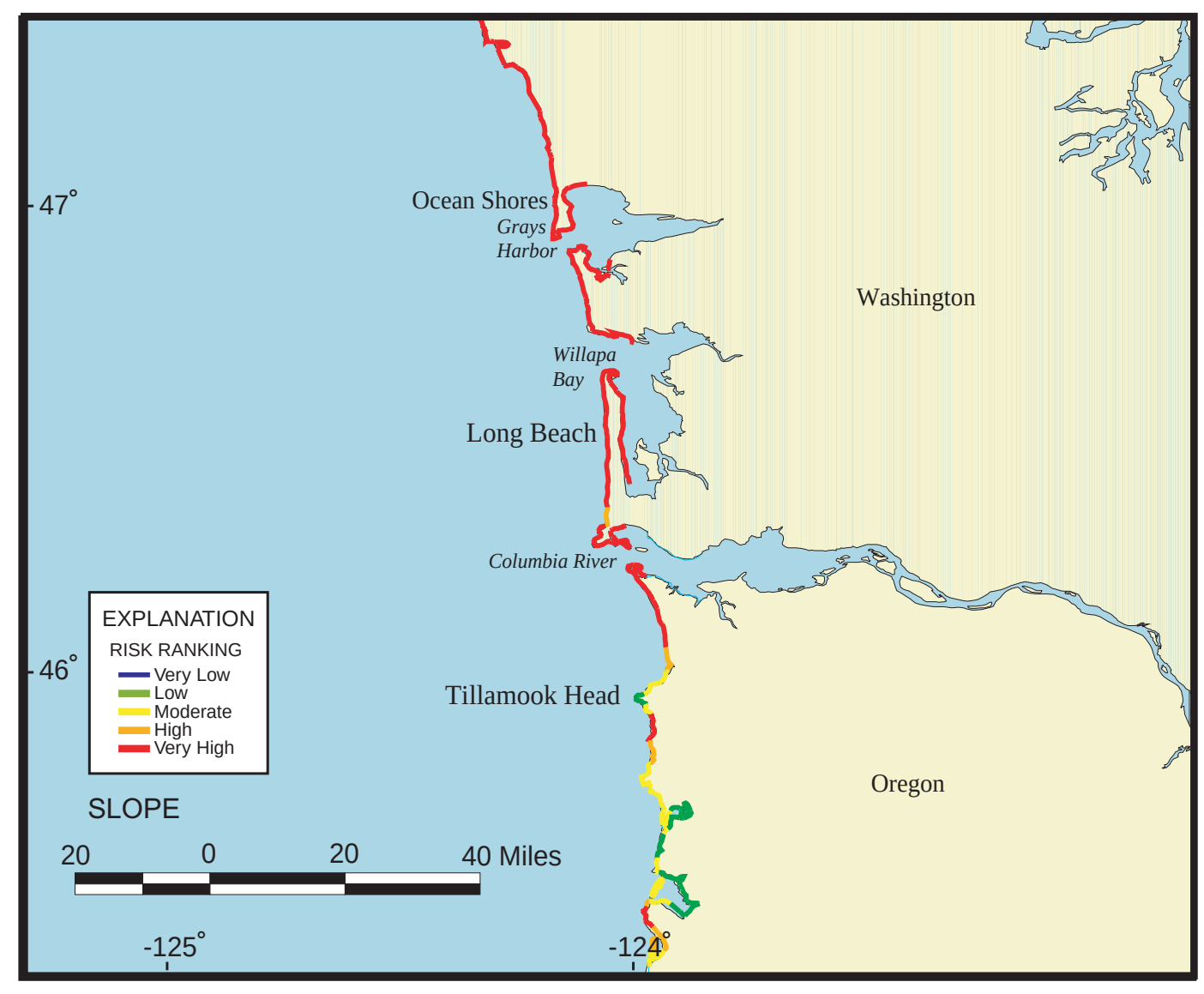

Figure 5. Map of the coastal slope variable for southwestern Washington and northwestern Oregon. The coastal slope is relatively steep (low risk) in northwestern Oregon, but is quite low (high risk) in southwestern Washington.

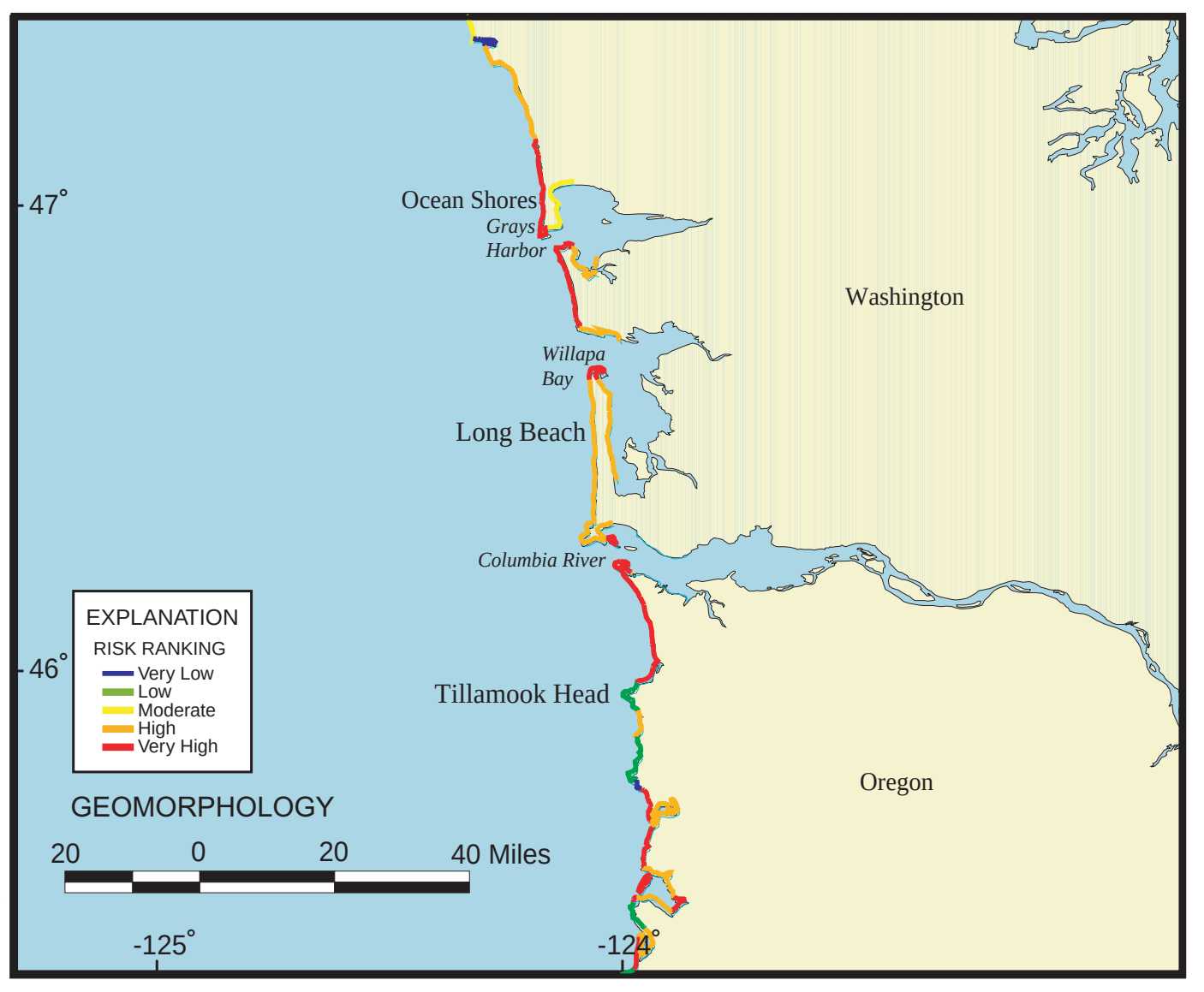

Figure 6. Map of the geomorphology variable for southwestern Washington and northwestern Oregon. The open-ocean shoreline is composed predominantly of high-risk sandy pocket beaches interspersed with low-risk rocky headlands; to the north of Tillamook Head there is a long stretch of very high-risk sandy beach.

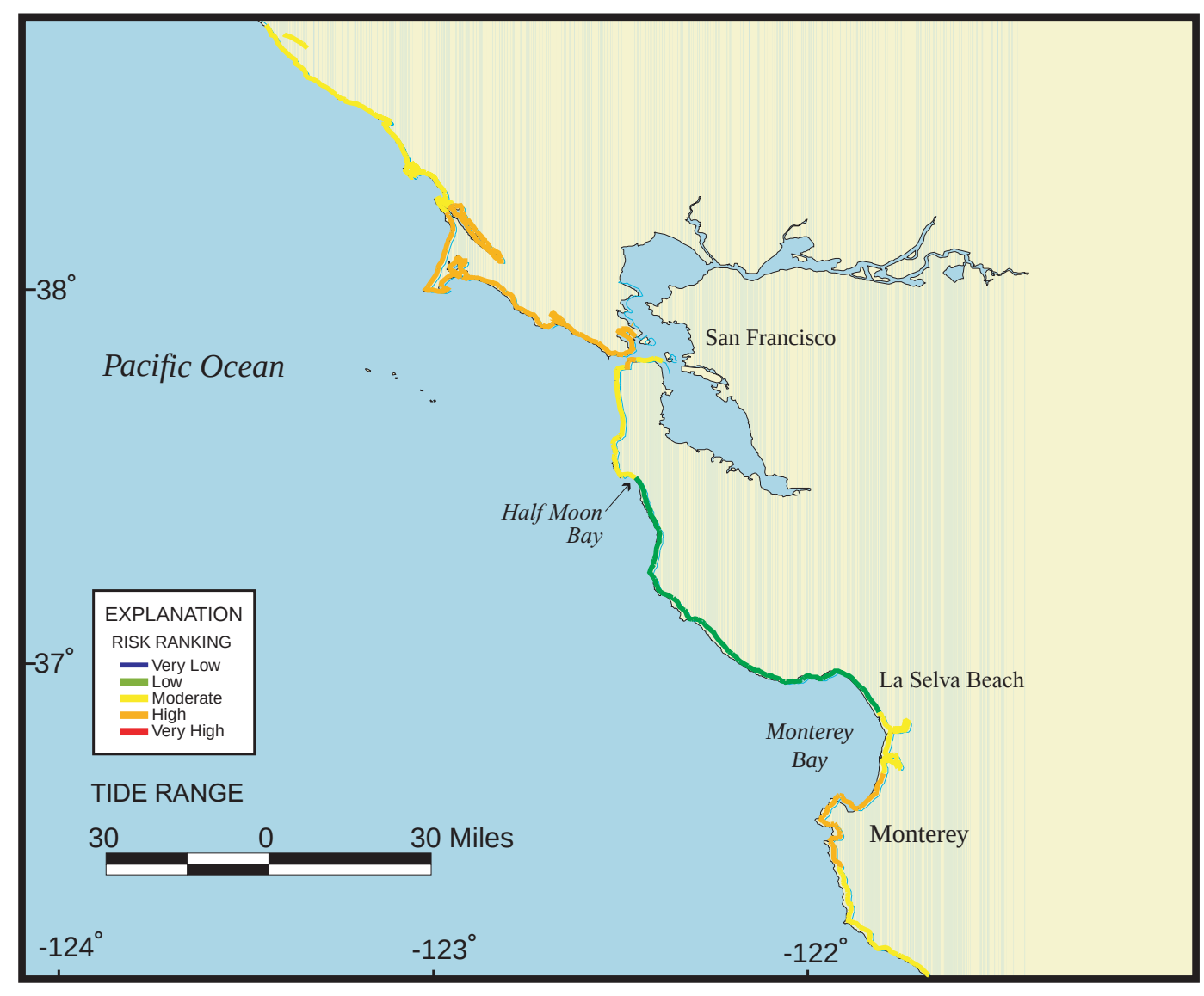

Figure 9. Map of the tide range variable for the San Francisco - Monterey region. The tide range is generally lower than 1.28 m (high to very high risk), except for the area between Half Moon Bay and La Selva Beach where the tide range increases to ~1.5 m.

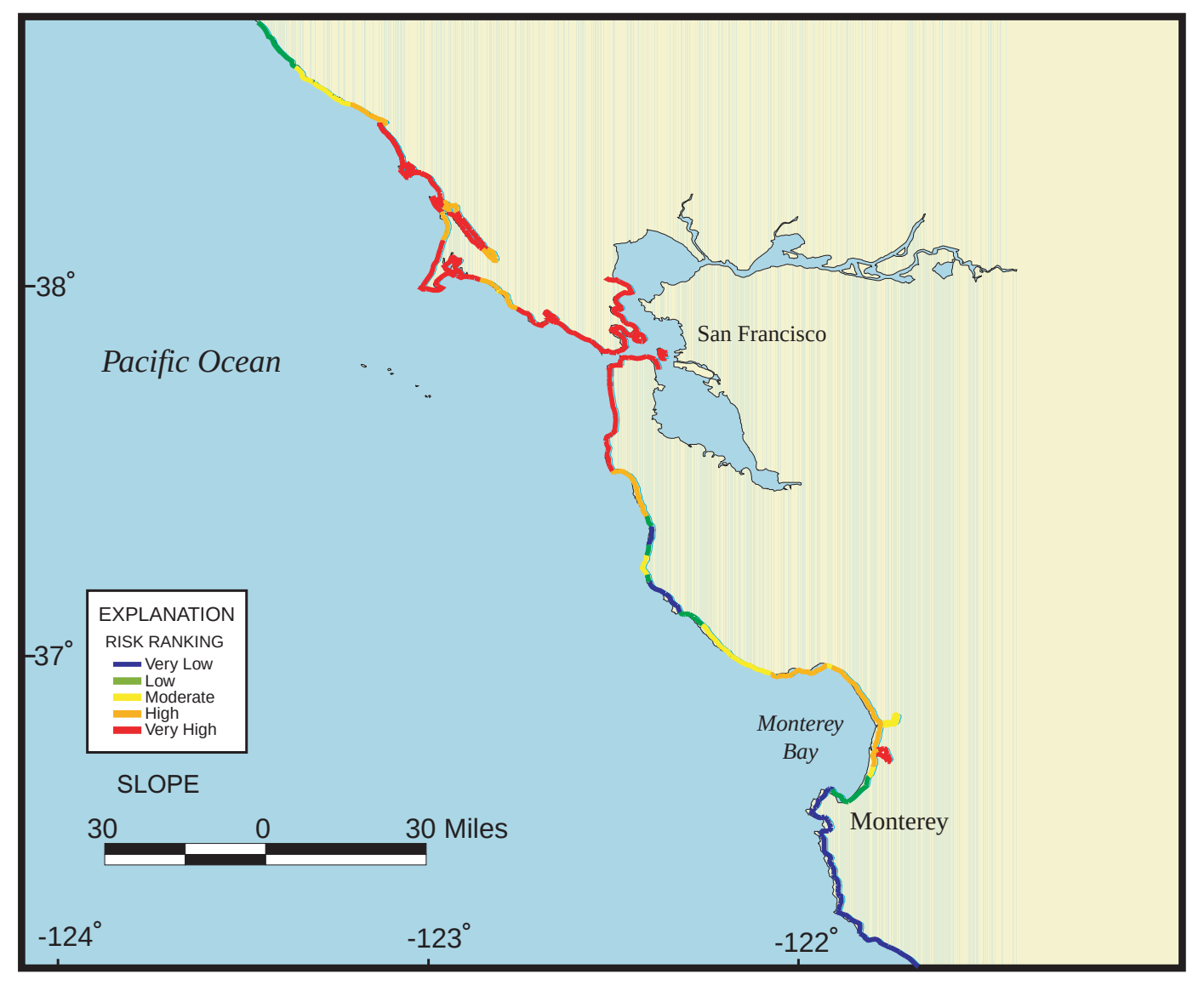

Figure 10. Map of the coastal slope variable for the San Francisco - Monterey region. The coastal slope is relatively steep (low risk) in the Monterey region and at the rocky headlands to the south of San Francisco, but is quite low (high risk) at the open ocean coast at the mouth of San Francisco Bay.

INTRODUCTION

One of the most important applied problems in coastal geology today is determining the physical response of the coastline to sea-level rise. Predicting shoreline retreat, beach loss, cliff retreat, and land loss rates is critical to planning coastal zone management strategies and assessing biological impacts due to habitat change or destruction. Presently, long-term (>50 years) coastal planning and decision-making has been done piecemeal, if at all, for the nation's shoreline (National Research Council, 1990; 1995). Consequently, facilities are being located and entire communities are being developed without adequate consideration of the potential costs of protecting or relocating them from sea-level rise related erosion, flooding and storm damage.

Recent estimates of future sea-level rise based on climate model output (Wigley and Raper, 1992) suggest an increase in global eustatic sea-level of between 15 and 95 cm by 2100, with a "best estimate" of 50 cm (IPCC, 1995). This is more than double the rate of eustatic rise for the past century (Douglas, 1997; Peltier and Jiang, 1997). Thus, sea-level rise will have a large, sustained impact on coastal evolution at the societally-important decadal time scale. For example, Zhang et al. (1997) showed that sea-level rise over the past 80 years at two locations on the U.S. East Coast contributed directly to significant increases in the amount of time the coast is subjected to extreme storm surges. From 1910-1920, the coast near Atlantic City, New Jersey was exposed to anomalously high water levels from extreme storms less than 200 hours per year, whereas during the early 1990's the coast was exposed to high water from storms of the same magnitude 700 to 1200 hours per year. Interestingly, the authors found that although storm surge varied a great deal on annual to decadal scales, there was no long-term trend showing increases in storm intensity or frequency that might account for the increasing anomalously high water levels. Zhang et al. (1997) concluded that the increase in storm surge exposure of the coast was due to sea-level rise of about 30 cm over the 80-year period. This finding suggests that the historical record of sea-level change can be combined with other variables (e.g., elevation, geomorphology, and wave characteristics) to assess the relative coastal vulnerability to future sea-level change.

The prediction of coastal evolution is not straightforward. There is no standard methodology, and even the kinds of data required to make such predictions are the subject of much scientific debate. A number of predictive approaches have been used (National Research Council, 1990), including: 1) extrapolation of historical data (e.g., coastal erosion rates), 2) static inundation modeling, 3) application of a simple geometric model (e.g., the Bruun Rule), 4) application of a sediment dynamics/budget model, or 5) Monte Carlo (probabilistic) simulation based on parameterized physical forcing variables. Each of these approaches, however, has its shortcomings or can be shown to be invalid for certain applications (National Research Council, 1990). Similarly, the types of input data required vary widely, and for a given approach (e.g. sediment budget), existing data may be indeterminate or may simply not exist (Klein and Nicholls, 1999). Furthermore, human manipulation of the coast in the form of beach nourishment, construction of seawalls, groins, and jetties, as well as coastal development itself, may dictate federal, state and local priorities for coastal management without proper regard for geologic processes. Thus, the long-term decision to renourish or otherwise engineer a coastline may be the primary determining factor in how that coastal segment evolves.

Although a viable, quantitative predictive approach is not available, the relative vulnerability of different coastal environments to sea-level rise may be quantified at a regional to national scale using basic information on coastal geomorphology, rate of sea-level rise, past shoreline evolution, and other factors. This approach combines the coastal system's susceptibility to change with its natural ability to adapt to changing environmental conditions, and yields a relative measure of the system's natural vulnerability to the effects of sea-level rise (Klein and Nicholls, 1999). The overall goal of this study is to develop and utilize a relatively simple, objective method to identify those portions of the U.S. coast at risk and the nature of that risk (e.g., inundation, erosion, etc.). The long-term goal of this study is to predict future coastal changes with a degree of certainty useful for coastal management, following an approach similar to that used to map national seismic and volcanic hazards (e.g., Miller, 1989; Frankel et al., 1996; Hoblitt et al. 1998). This information has immediate application to many of the decisions our society will be making regarding coastal development in both the short- and long-term.

This study involves two phases. The first phase, presented in this report for the U.S. Pacific Coast and a previous report for the U.S. Atlantic Coast (Thieler and Hammar-Klose, 1999), involves updating and refining existing databases of geologic and environmental variables, such as that compiled by Gornitz and White (1992). The variables included in this database are geomorphology, regional coastal slope, rate of relative sea-level rise, shoreline erosion and accretion rates, tide range and mean wave height. For all of the variables in this data set, updated or new data exist and are included in this analysis. The second phase of the project has two components. The first component entails integrating model output such as eustatic, isostatic, and short-term climatic sea-level change estimates in order to assess the potential impacts on the shoreline due to these changes. The second component involves developing other databases of environmental information, such as relative coastal sediment supply, as well as including episodic events (hurricane intensity, track, and landfall location, Nor'easter storm intensity data, and El Nino-related climate data such as short-term sea-level rise), and human influences (e.g., coastal engineering such as beach nourishment).

In this preliminary report, the relative vulnerability of different coastal environments to long-term sea-level rise is quantified for the U.S. Pacific Coast. This initial classification is based upon variables such as coastal geomorphology, regional coastal slope, rate of sea-level rise, wave and tide characteristics, and historical shoreline change rates. The combination of these variables and the association of these variables to each other furnishes a broad overview of regions where physical changes are likely to occur due to sea-level rise.

RISK VARIABLES

In order to develop a database for a national-scale assessment of coastal vulnerability, relevant information has been gathered from local, state and federal agencies, as well as academic institutions. The compilation of this database is integral to mapping potential coastal changes due to sea-level rise. This database loosely follows an earlier database developed by Gornitz and White (1992). A comparable assessment of the sensitivity of the Canadian coast to sea-level rise is presented by Shaw et al. (1998).

The input data for this database of coastal vulnerability have been assembled using the original, and sometimes variable, horizontal resolution, which then was resampled to a 3-minute grid cell. A data set for each risk variable is then linked to each grid point. For mapping purposes, data stored in the 3-minute grid is transferred to a 1:2,000,000 vector shoreline with each segment of shoreline lying within a single grid cell.

Table 1 summarizes the six physical variables used here: 1) geomorphology, 2) coastal slope (percent), 3) rate of relative sea-level rise (mm/yr), 4) shoreline erosion and accretion rates (m/yr), 5) mean tidal range (m) and 6) mean wave height (m). As described below, each variable is assigned a relative risk value based on the potential magnitude of its contribution to physical changes on the coast as sea-level rises. The designated ranges are based on previously defined ranges and on histograms and statistical summaries which, for certain variables, describe the regional trends along the U.S. Pacific Coast.

The geomorphology variable expresses the relative erodibility of different landform types (Table 1). These data were derived from state geologic maps and USGS 1:250,000 scale topographic maps, as well as correlated with data compiled in the Cascadia beach-shoreline database, Pacific Northwest Region (Peterson et al., 1994), and with the Living with the Shore book series (Griggs and Savoy, 1985; Terich, 1987; Komar, 1997).

The regional slope permits an evaluation of not only the relative risk of inundation, but also the potential rapidity of shoreline retreat, because low-sloping coastal regions should retreat faster than steeper regions (Pilkey and Davis, 1987). The regional slope of the coastal zone was calculated from a grid of topographic and bathymetric elevations extending landward and seaward of the shoreline. In order to compute the slope from the subaerial coastal plain to the submerged continental shelf, the slope for each grid cell was calculated by defining elevation extremes within a 10 km radius for each individual grid cell along the shoreline. In areas where the shelf/slope break is less than 10 km offshore, the slope was recalculated with a more appropriate radius. For the U.S. Pacific coast, elevation data were obtained from the U.S. Navy ETOPO5 digital topographic and bathymetric elevation database with elevations to the nearest 1 meter for 5-minute grid cells. These data were subsampled to 3-minute (approximately 5 km) resolution to be consistent with our other coastal databases (Thieler and Hammar-Klose, 1999).

The relative sea-level change variable is derived from the increase (or decrease) in annual mean water elevation over time as measured at tide gauge stations along the coast (e.g., Emery and Aubrey, 1991). Relative sea-level change data were obtained for 12 National Ocean Service (NOS) data stations and contoured along the coastline. This variable inherently includes both global eustatic sea-level rise as well as local isostatic or tectonic land motion. Relative sea-level change data are a historical record, and thus show change for only recent time scales (past 50-100 yr).

Shoreline erosion and accretion rates for the U.S. have been compiled by May and others (1983) and Dolan and others (1985) into the Coastal Erosion Information System (CEIS) (May and others, 1982). CEIS includes shoreline change data for the Atlantic, Gulf of Mexico, Pacific and Great Lakes coasts, as well as major bays and estuaries. The data in CEIS are drawn from a wide variety of sources, including published reports, historical shoreline change maps, field surveys and aerial photo analyses. However, the lack of a standard method among coastal scientists for analyzing shoreline changes has resulted in the inclusion of data utilizing a variety of reference features, measurement techniques, and rate-of-change calculations. Thus, while CEIS represents the best available data for the U.S. as a whole, much work is needed to accurately document regional and local erosion rates.

Where higher-quality data are available, we replace and augment the CEIS data with shoreline change data obtained from states and local agencies. In this report, for example, the erosion rate data for the ocean coast of Washington State and Clatsop County, Oregon were provided by the Coastal Monitoring and Analysis Program, Washington Department of Ecology, Olympia, Washington (R. C. Daniels, pers. comm., 2000). These long-term annual erosion rates for the ocean coast are derived from NOS T-Sheets for the years 1926 - 30 and orthophotoquads for the years 1994 - 96; rates for the bays are derived from NOS T-Sheets from 1950 and orthophotoquads for the years 1994 - 96.

Tide range is linked to both permanent and episodic inundation hazards. Tide range data were obtained from the NOS for 160 tide stations along the U.S. Pacific coast; the values were contoured along the coastline.

Wave height is used here as an indicator of wave energy, which drives the coastal sediment budget. Wave energy increases as the square of the wave height; thus the ability to mobilize and transport beach/coastal material is a function of wave height. In this report, we use hindcast nearshore mean wave height data for the period 1956-1975 obtained from the U.S. Army Corps of Engineers Wave Information Study (WIS) (see references in Hubertz et al., 1996). The model wave heights were compared to historical measured wave height data obtained from the NOAA National Data Buoy Center. Wave height data for 182 WIS stations along the U.S. Pacific coast were contoured along the coastline.

DATA RANKING

Table 1 shows the six physical variables described above, ranked on a linear scale from 1-5 in order of increasing vulnerability due to sea-level rise. In other words, a value of 1 represents the lowest risk and 5 represents the highest risk. The database includes both quantitative and qualitative information. Thus, numerical variables are assigned a risk ranking based on data value ranges, whereas the non-numerical geomorphology variable is ranked according to the relative resistance of a given landform to erosion. For the U.S. Pacific coast, regional coastal slopes are considered to be very low risk at values >1.9 percent; very high risk consists of regional slopes <0.6 percent. These ranges are chosen based on the maximum, minimum and statistical variation of the slope values along the Pacific coast. The rate of relative sea-level rise is ranked to reflect the regional to local isostatic or tectonic effects along the Pacific coast, taking into account that these data also reflect the modern rate of eustatic rise (1.8 mm/yr; Douglas, 1997; Peltier and Jiang, 1997). Shorelines with erosion/accretion rates between -1.0 and +1.0 m/yr are ranked as moderate. Increasingly higher erosion or accretion rates are ranked as correspondingly higher or lower risk. Tidal range is ranked such that microtidal coasts are high risk and macrotidal coasts are low risk. Mean wave height rankings range from very low (<1.1 m) to very high (>2.6 m).

In previous and related studies (Gornitz, 1990; Shaw et al., 1998), large tidal range (macrotidal; tide range > 4m) coastlines were assigned a high risk value, and microtidal coasts (tide range <2.0 m) received a low risk value. This decision was based on the concept that a large tide range is associated with strong tidal currents that influence coastal behavior. We have chosen to invert this ranking such that a macrotidal coastline is classified as low risk. Our reasoning is based primarily on the potential influence of storms on coastal evolution, and their impact relative to the tidal range. For example, on a tidal coastline, there is only a 50 percent chance of a storm occurring above mean tide. Thus, for a region with a 4 m tide range, a storm having a 3 m surge height is still up to 1 m below the elevation of normal high tide for half a tidal cycle. A microtidal coastline, on the other hand, is essentially always "near" high tide and therefore always at the greatest risk of significant storm impact.

COASTAL VULNERABILITY INDEX

The coastal vulnerability index (CVI) presented here is similar to that used by Gornitz et al. (1994), as well as to the sensitivity index employed by Shaw et al. (1998). The index allows the six physical variables to be related in a quantifiable manner that expresses the relative vulnerability of the coast to physical changes due to sea-level rise. This method yields numerical data that cannot be equated directly with particular physical effects. It does, however, highlight those regions where the various effects of sea-level rise might be the greatest.

Once each section of coastline is assigned a risk value for each specific data variable, the coastal vulnerability index (CVI) is calculated as the square root of the geometric mean of these values, or the square root of the product of the ranked variables divided by the total number of variables as

$$CVI = \sqrt{((a*b*c*d*e*f)/6)}$$

where, a = geomorphology, b = coastal slope, c =relative sea-level rise rate, d = shoreline erosion/accretion rate, e = mean tide range, and f = mean wave height.

The CVI values reported here apply specifically to the U.S. Pacific coast. Thus, absolute CVI values given for other coasts (e.g., Thieler and Hammar-Klose, 1999) are not directly comparable to the data presented here. In addition to the CVI values, the data ranges are also subdivided using values different from other studies so that the values used here reflect only the relative vulnerability along this coast. We feel this approach best describes and highlights the vulnerability for each of the different continental margin types that make up the U.S. coast.

RESULTS

The calculated CVI values range from 2.0 to 28.3. The mean CVI value is 9.92; the mode is 7.74; and the median is 8.48. The standard deviation is 5.45. The 25th, 50th, and 75th percentiles are 5.54, 8.54, and 12.52, respectively.

Figure 1 shows a map of the coastal vulnerability index for the U.S. Pacific Coast. The CVI scores are divided into low, moderate, high, and very high-risk categories based on the quartile ranges and visual inspection of the data. CVI values below 5.5 are assigned to the low risk category. Values from 5.5-8.5 are considered moderate risk. High-risk values lie between 8.5-12.5. CVI values above 12.5 are classified as very high risk. Histograms of the CVI values are shown in Figure 2.

Figure 3 shows a bar graph of the percentage of U.S. Pacific shoreline in each risk category. A total of 3987 km of shoreline is evaluated in the study area. Of this total, 27 percent of the mapped shoreline is classified as being at very high risk due to future sea-level rise. Twenty-two percent is classified as high risk, 28 percent as moderate risk, and 23 percent as low risk.

In the calculation of the Coastal Vulnerability Index, certain variables add more weight to the index than others. For example, in a region where most variables score low in the risk ranking (1-3), but one variable scores high (4 or 5), the high variable adds the most weight to the index. This variable is said to dominate the index. In most cases along the U.S. Pacific Coast, one or two variables dominate the index, whereas the other lower ranking variables have little impact on the index value.

The mapped CVI values show numerous areas of very high vulnerability, particularly in the San Francisco - Monterey Bay area and in southern California from San Luis Obispo to San Diego, where the coast is most highly populated. The highest vulnerability areas are typically lower-lying beach areas; their susceptibility is primarily a function of geomorphology and coastal slope. On the northern Pacific coast, wave energy is a dominant variable (adds weight to the index), whereas to the south, tides and relative sea-level dominate the index. In general, the CVI values for Washington, Oregon and northern California are defined by variable geomorphology over small spatial scales (~ 10 km). Rocky headlands and cliffs with sandy pocket beaches characterize this coastline, with only a few long stretches of sandy beach. In contrast, the southern coast of California has long stretches of both rocky cliffs and sandy beaches, where geomorphology typically varies at a longer length scale (from 50 to 100 km).

The low risk, least vulnerable areas generally occur at rocky headlands along cliffed coasts where the coastal slope is steep, relative sea-level is falling, tide range is large and wave energy is lower. Examples of these areas are the northern coast of Washington, Monterey, California and Cape Mendocino, California (Figure 1).

DISCUSSION

The data variables underlying the CVI show variability at several spatial scales. The rate of sea-level rise and tide range vary over a spatial scale of ~100 km. For sea-level rise, this variability represents the large-scale patterns of isostasy and tectonism along the Pacific continental margin of North America (Peltier, 1996; Komar and Shih, 1993). Changes in tide range generally reflect changes in the configuration of the continental shelf as a whole (e.g., continental shelf width).

A second group of variables, consisting of geomorphology and wave height, vary on a ~10 km spatial scale that reflects primarily the alongshore changes in environments and distribution of energy in the coastal system. For example, the high energy coast of Washington, Oregon and northern California stands in sharp contrast to the lower-energy coast of southern California.

The shoreline erosion/accretion rates vary on a spatial scale equal to the minimum size of our grid, which is 3-minutes or ~5 km. It is this variable that generally adds the greatest variation to the CVI values. As described above, however, erosion rates are the variable in our data set that is the least well-documented. On the U.S. Pacific coast, the erosion rate variable is of great importance because shoreline erosion and cliff retreat rates are controlled to a large extent by the cliff material, as well as geologic structure such as jointing and faulting (Komar and Shih, 1993) which can vary significantly over this spatial scale. The effect of well-documented erosion rate data on CVI rankings is visible in the area to the north of Tillamook Head where the variation in erosion rates is reflected in the variation of the CVI.

Regional Examples

To highlight the nature of the CVI and its underlying data, different index variables from two geographic regions are presented below.

Tillamook Head, Oregon to Ocean Shores, Washington

The CVI values near Tillamook Head, Oregon indicate a low vulnerability to future sea-level rise (Figure 4). To the north, however, the CVI values increase to a "very high" ranking. Three variables (tide range, rate of sea-level rise, wave energy) provide a relatively uniform "background" vulnerability for this region, since they have consistent values over the entire region. The change in CVI ranking is thus reflected primarily in the remaining three variables: coastal slope, geomorphology and erosion rate. The regional coastal slope diminishes greatly to the north of Tillamook Head (Figure 5). Whereas at Tillamook Head the coastal slope is very steep, the slope decreases at the Columbia River entrance and along the beaches to the north. Similarly, the geomorphology at Tillamook Head -- cliffs and rocky headlands -- is ranked as low vulnerability, whereas to the north the sandy beaches of Long Beach and Grays Harbor are ranked as high and very high vulnerability, respectively (Figure 6). Finally, this region of the Washington/Oregon coast has a spatially varying erosion rate that is also well-documented. Tillamook Head is stable (neither eroding nor accreting more than 1.0 m/year); to the north, the erosion rate data indicates both rapidly eroding and accreting coastlines are present around the Columbia River mouth (Figure 7).

San Francisco and Monterey Bay

The San Francisco and Monterey Bay areas reflect variability in CVI rankings that is quite different from the regions to the north, with high susceptibility to the north decreasing to lower susceptibility south of Monterey Bay (Figure 8). In the San Francisco - Monterey Bay region relative sea-level is rising at 2.29 mm/yr. In contrast to the northern Pacific coast, wave energy here is moderate to high and decreases to low towards southern California. Similarly, the variation in tide range yields larger scale variability (Figure 9). The erosion rate data for this region is poorly documented, with the entire region classified as stable. In contrast to the Tillamook Head area, the combination of two moderate ranks (erosion rate and wave energy) and one high vulnerability ranking (rate of sea-level rise) gives the region a "background" of high vulnerability.

As in the Washington/Oregon region, the variables that provide the variability to the index in this region are geomorphology and coastal slope. In general, the coastal slope and the geomorphology closely mimic each other. The cliffed rocky headland at Monterey has a very steep coastal slope. Within Monterey Bay, however, the sandy beach has a low coastal slope (Figure 10). In the San Francisco region, the geomorphology variable reflects rocky headlands interspersed with sandy beaches (Figure 11). The regional coastal slope, however, is very low along the open ocean coast. Within the San Francisco region the relatively low coastal slope adds weight to the index, whereas the geomorphology adds alongshore variation. Thus, the combination of high risk associated with coastal slope, erosion rate, and geomorphology leads to a much higher overall vulnerability ranking than the areas in the Pacific Northwest.

SUMMARY

The coastal vulnerability index (CVI) provides insight into the relative potential of coastal change due to future sea-level rise. The maps and data presented here can be viewed in at least two ways: 1) as a base for developing a more complete inventory of variables influencing the coastal vulnerability to future sea-level rise to which other elements can be added as they become available; and 2) as an example of the potential for assessing coastal vulnerability to future sea-level rise using objective criteria.

As ranked in this study, coastal geomorphology and coastal slope are the most important variables in determining the CVI. Wave height, relative sea-level rise, and tide range provide large-scale variability to the coastal vulnerability index. Erosion and accretion rates, where complete, contribute the greatest variability to the CVI at short spatial scales. The rates of shoreline change, however, are the most complex and poorly documented variable in this data set. Most of the rates used here are based on a dated, low-resolution data set, and thus far, corrections have been made only on a preliminary level. To best understand where physical changes may occur, large-scale variables must be clearly and accurately mapped and small-scale variables must be understood on a scale that takes into account their geologic and environmental influences.

Acknowledgments

The shoreline position and rate of change data used in this report for the ocean coast of Washington were provided by the Coastal Monitoring and Analysis Program (CMAP), Washington Department of Ecology, Olympia, Washington. CMAP's data collection and development costs were funded in part or in their entirety by the Department of Ecology, U.S. Geological Survey, or the National Oceanic and Atmospheric Administration in support of the Southwest Washington Coastal Erosion Study. CMAP reserves the right to revise or modify this data without notice.

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By

E. Robert Thieler and Erika S. Hammar-Klose

U.S. Geological Survey
Woods Hole, Massachusetts

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