EFFECTS ON HAWAII OF A WORLDWIDE RISE IN SEA LEVEL INDUCED BY THE "GREENHOUSE EFFECT"

A Report in Response to Senate Resolution 137, 1984

Prepared by the Hawaii Coastal Zone Management Program
Department of Planning and Economic Development

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INTRODUCTION

In the last two decades, numerous studies, committees, and conferences have warned that industrialized nations may be changing the climate of our planet. During this period, debate has shifted from questioning the possibility that the "Greenhouse Effect" would occur to whether the effect will be mild or severe and the timeframe for its imminent occurrence. Among the primary concerns regarding the environmental effects that may result from this change in climate is a rise in sea level.

NATURAL SEA-LEVEL CHANGES

Natural climate and sea level changes have occurred frequently, in relation to geological time, throughout the history of our planet. The past two million years--what scientists call the quaternary or pleistocene epoch--experienced numerous cycles of freeze and thaw. Each produced a fluctuation in sea level, the largest of which was a rise of 130 meters (400 feet) and a fall of 70 meters (230 feet) from the present level. Evidence of this is found worldwide. In Hawaii, for example, the Ewa/Honolulu coastal plain and the drowned reef of Penguin Banks were formed during periods of higher and lower sea levels, respectively.

Sea level changes correlate with global temperature changes for two reasons. First, temperature affects the accumulation of water as ice on or near land masses, particularly at the North and South Poles. During periods of cooler temperatures, precipitation at higher latitudes changes from rain to snow. Moisture in this form does not flow back to the sea but accumulates as glaciers. Over an extended period, the transfer of moisture from the oceans to land causes the sea level to drop. Conversely, as temperatures rise, glaciers thaw and the increase in the volume of water from runoff essentially causes the sea level to rise.

The second effect of temperature change is on water volume. When water gains heat, it becomes less dense and occupies more space. Conversely, a loss of heat will cause water to become more dense and compact. These volumetric changes can result in substantial changes in the sea level.

During the most recent geological period of warming, lasting from 16,000 to about 7,000 years ago, the sea level rose at an average rate of 8 millimeters (one-third of an inch) per year or .8 meters (32 inches) per century (Moberly, et al, July 1984). This rate can be contrasted with estimated extremes of no change and a high of 5-7 meters (16.5 to 23 feet) per century. The last glacial period produced changes of up to 1 meter (three and a quarter feet) per century (Barth, et al, 1984).

INDUCED ATMOSPHERIC WARMING

Theories suggest that previous temperature flunctuations and consequent sea level changes were caused primarily by small changes in the celestial movement of the earth about the sun. Earth occassionally had a more elliptical orbit, or wobbled about its rotational axis, or tilted a little more or less. The smallest of these alterations directly affected the amount of sunlight reaching certain critical latitudes, and precipitated a slow cooling or warming trend over thousands of years.

Theories of the "Greenhouse Effect" attribute recent and ongoing changes in sea level to human activities. According to these theories, global industrialization has altered the relative proportions of atmospheric gases which in turn is affecting the earth's thermal balance.

Research during the last few decades indicate that the relative proportion of atmospheric gases is changing. Atmospheric carbon dioxide, for example, increased 20% over the last 180 years, and 8% since 1958 (Keeling et al, 1976; Rotty, 1979). Increases in other atmospheric gases are also evident. Methane by 1% to 2% annually from 1970 to 1980; chlorofluorocarbons by 6% in toto over the same period; and nitrous oxide by .2% per year since 1975 (World Meteorological Organization).

Scientists believe that although the increase of these gases is not a threat to human health and safety with respect to toxicity, it is significant because of its relationship to global temperatures. The "Greenhouse Effect" is an analogy between the warming achieved in a glass enclosed greenhouse and the higher proportion of so-called greenhouse gases in the atmosphere, notably carbon dioxide which is a major by-product of burning fossil fuels. Like glass, the gases allow sunlight to pass through and warm the earth's surface but retards the radiation of heat back into space, or outside the greenhouse in the case of glass. Thus, heat energy will accumulate until a new equilibrium of heat gain and loss is achieved at higher global temperatures. Corresponding rises in sea level will occur as water volume and the proportion of moisture stored in glaciers or oceans adjust to a higher thermal equilibrium.

The greenhouse effect, although still minor, has already been measured in terms of rises in global temperatures and the sea level. The ability of water to buffer short-term temperature change has thus far held greenhouse-related temperature increases to only .4 degrees celsius (three-quarters of a degree fahrenheit). This small heat gain, however, has caused ocean levels to rise by 15 centimeters (6 inches). (Gornitz et al, 1982; Barnett, 1983; Lisitzin, 1974) Scientists predict that this change will continue for decades or centuries until the planet again reaches a new state of energy equilibrium.

FUTURE SEA LEVELS

One of the greatest uncertainties society faces today is the location of the shoreline in 50 or 100 years. While natural and human-induced erosion and accretion along the shoreline have long been a concern to coastal communities, changes in sea level present a new and significant variable to be contended with.

Unless there are significant advancements in technology, international cooperation, and financial commitments, scientists conclude that global temperatures and consequently, sea levels will continue to rise. The technology to cleanse the atmosphere of the greenhouse gases or to manipulate climates globally has not yet been developed. Establishing an international organization to cope with this problem and underwrite its enormous cost is a formidable task. The situation continues to be aggravated by the use of fossil fuels for energy generation.

It is generally believed that the effects of greenhouse warming are manifested slowly because of the earth's capacity and, particularly, the ocean's, to absorb tremendous amounts of thermal energy without measurable effect.

Prediction of sea level change remains a controversy. Modern computers provide scientists with a powerful tool for learning more about the complexities of global thermal processes. Computer models have been developed to forecast sea level changes as a response to fluctuations in atmospheric composition and global temperature. The scientific community, however, continues to debate the merits of various predictive methodologies, the relationship of factors which will determine change, and the future of social and technological advancement. As a consequence, decision makers are presented with widely varying estimates of future temperature and sea level.

One key issue on which scientific opinions diverge is the rate by which atmospheric composition will change, particularly with respect to carbon dioxide. Estimates of "doubling time"--the time that it will take to double pre-industrial concentrations of carbon dioxide--currently range from 40 to 100 years from the present (Revelle, 1983; Seidel, 1983). The disparity stems from varying estimates of how rapidly economic development and associated industrialization will occur, and how long and to what degree society will rely on hydrocarbons for fuel.

Predictions of warming are somewhat less debated. The most widely used projection developed by the National Academy of Sciences estimates that a doubling of carbon dioxide would produce a temperature increase of between 1.5 and 4.5 degrees celsius (2.7 and 8.1 degrees fahrenheit). (Charney, et al, 1979; Smagorinsky, 1982) The relatively broad range of temperatures bounded by these figures, however, limits their usefulness. Furthermore, some scientists report that the additive effect of the other greenhouse gases could double the warming induced by carbon dioxide alone (World Meteorological Organization, 1982; Lacis et al, 1982).

The most controversial estimates, however, concern changes in the sea level. Most studies are based on 100 year projections, and while all predict that sea levels will rise, they disagree on magnitude, with estimates varying from as low as 70 centimeters (28 inches) to as high as 6 meters (20 feet) (National Academy of Sciences, 1983; Newsweek, 1981). This variability stems from using different atmospheric and temperature estimates in models and the degree of sophistication among models, some of which provide for newly considered factors such as ocean mixing depth. Between the extremes cited above are numerous moderate estimates.

FOUR SCENARIOS

The significance of these predictions, especially the rise in sea level, is difficult to comprehend from numbers alone. Figures 1 through 4 illustrate the estimated location of the shoreline and coastal hazards that correspond to various increases in the sea levels. These represent what the U.S. Environmental Protection Agency believes are the 1) lowest conceivable, 2) lowest likely, 3) highest likely, and 4) highest conceivable sea levels, respectively, that will exist in the year 2100 (Hoffman, et al, 1983). The scenarios focus on Honolulu since it is both a major population center and the transportation hub upon which the economy of the State depends.

In the scenario of a 56 cm (1.9 feet) rise in sea level, Honolulu would be only moderately affected (See Figure 1). The coastal plain, including essentially all of the primary urban area, is above the influence of projected tides and would remain dry under all but storm conditions. The shoreline would be more susceptible to erosion but could be stabilized by shoreline protection structures extending throughout its length. Loss of real estate would probably be limited to a section of quick land on Sand Island. The threat of inundation would be more widely distributed along the shoreline and more frequent than at present. The most significant economic repercussions would be the public cost of shoreline protection, the loss of Waikiki Beach (e.g., to shoreline stabilization projects) and consequent effects on the visitor industry, increased losses of property to storm waves, and occasional but temporary disruptions of transportation at Honolulu Harbor, the International Airport, and along three major surface thoroughfares.

In the scenario of a 144 cm (4.8 feet) rise in sea level, Honolulu would probably have a structurally stabilized shoreline, less developable land, and frequent exposure to waves and inundation (see Figure 2). Loss of developed/developable land might lead the list of serious impacts as the Ala Wai/Moiliili/Ala Moana areas would be inundated by frequent shorefront breaching and diurnal intrusion of tidal waters, and Sand Island would be substantially inundated. Coastal hazards would threaten not only shorefront areas but properties up to a mile inland as well. Economic implications would include, at a minimum, the enormous if not prohibitive cost of stabilizing the entire Honolulu waterfront, loss of valuable urban land, geographic isolation of Waikiki, frequent and prolonged disruption of surface, air, and maritime transportation systems and inestimable property losses. Inundation may render much of the present urban district uninhabitable.

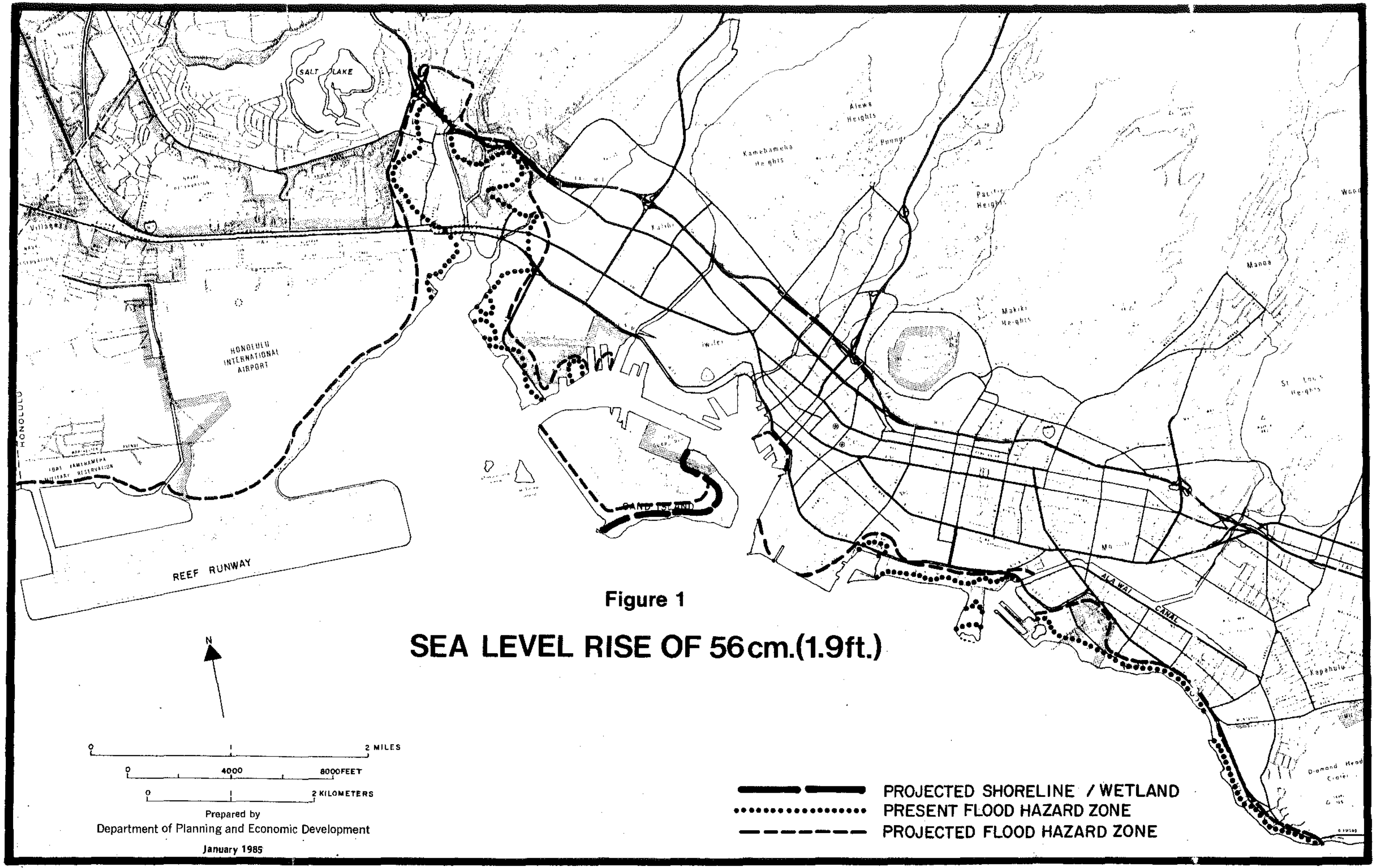

Figure 1

SEA LEVEL RISE OF 56cm.(1.9ft.)

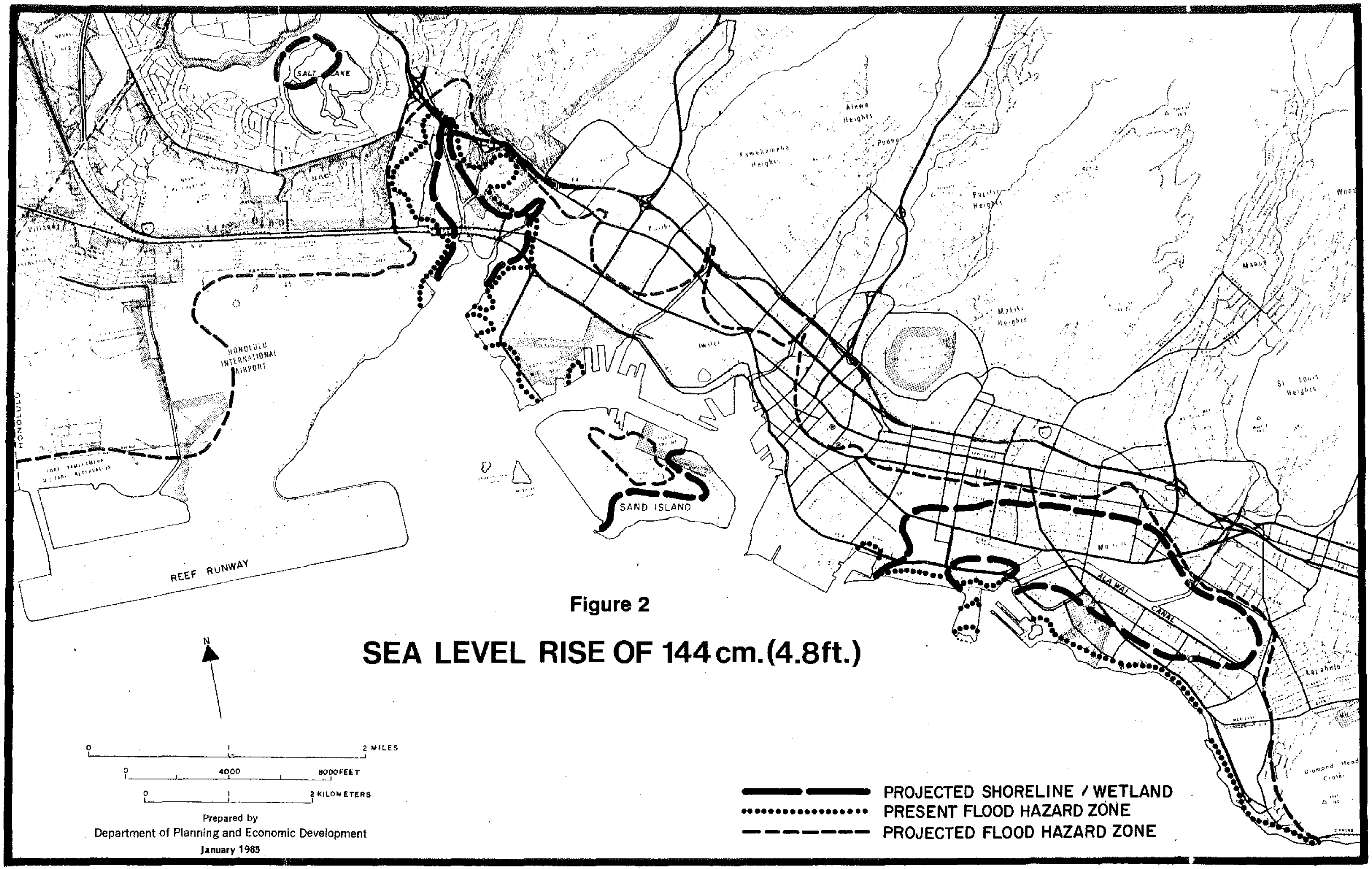

Figure 2

SEA LEVEL RISE OF 144 cm.(4.8ft.)

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The third and fourth scenarios correspond to a rise of 217 cm (7.1 feet) and 345 cm (11.3 feet) in sea level, respectively (see Figures 3 and 4). Although differing in absolute terms, their implications are essentially identical. In both cases, major portions of the city would be submerged and uninhabitable. Use of the harbor, the airport, and most surface streets would be lost due to either inundation or isolation by surrounding water. In neither scenario would efforts to stabilize the shoreline or elevate low-lying areas be economically feasible. If such rises in sea level were to occur today, Honolulu would be rendered non-functional.

At this time, it is uncertain which of these scenarios will likely be realized. Each is based on different assumptions about warming trends and their cause and effect relationships to rises in sea level.

OTHER EFFECTS

Greenhouse warming and a rise in the sea level will also have effects which do not relate directly to coastal hazards and inundation. The most significant of these are likely to be on agriculture and groundwater supplies.

Agriculture can be profoundly affected by climatic changes such as in temperature, rainfall, evaporation, and soil moisture. Of these four factors, only "moderate" temperature increases has been predicted for Hawaii, (________________, 1984). While changes in the other factors are not presently foreseeable, crop diversification toward those which are more heat tolerant or less water consumptive may be necessary to maintain a workable industry.

Groundwater supply and availability will be affected also by a rise in the sea level. Water in Ghyben-Herzberg lenses, for instance, will be closer to the surface and can be more easily tapped as a consequence of greater saltwater infiltration. Offsetting this benefit, however, will be the greater leakage of water to the sea, and the intrusion of saltwater into deep wells and low perched lenses. The overall impact is expected to be a smaller supply of useable groundwater.

Most current projections, including those cited herein, represent averages for the entire planet. Specific locales, however, will experience effects created by unique conditions and circumstances. Temperature increases in Hawaii, for example, will be tempered in comparison to the midwestern United States, due to the stabilizing influence of surrounding ocean waters. Thus, studies considering such variables will be required to interpret what global predictions mean to Hawaii.

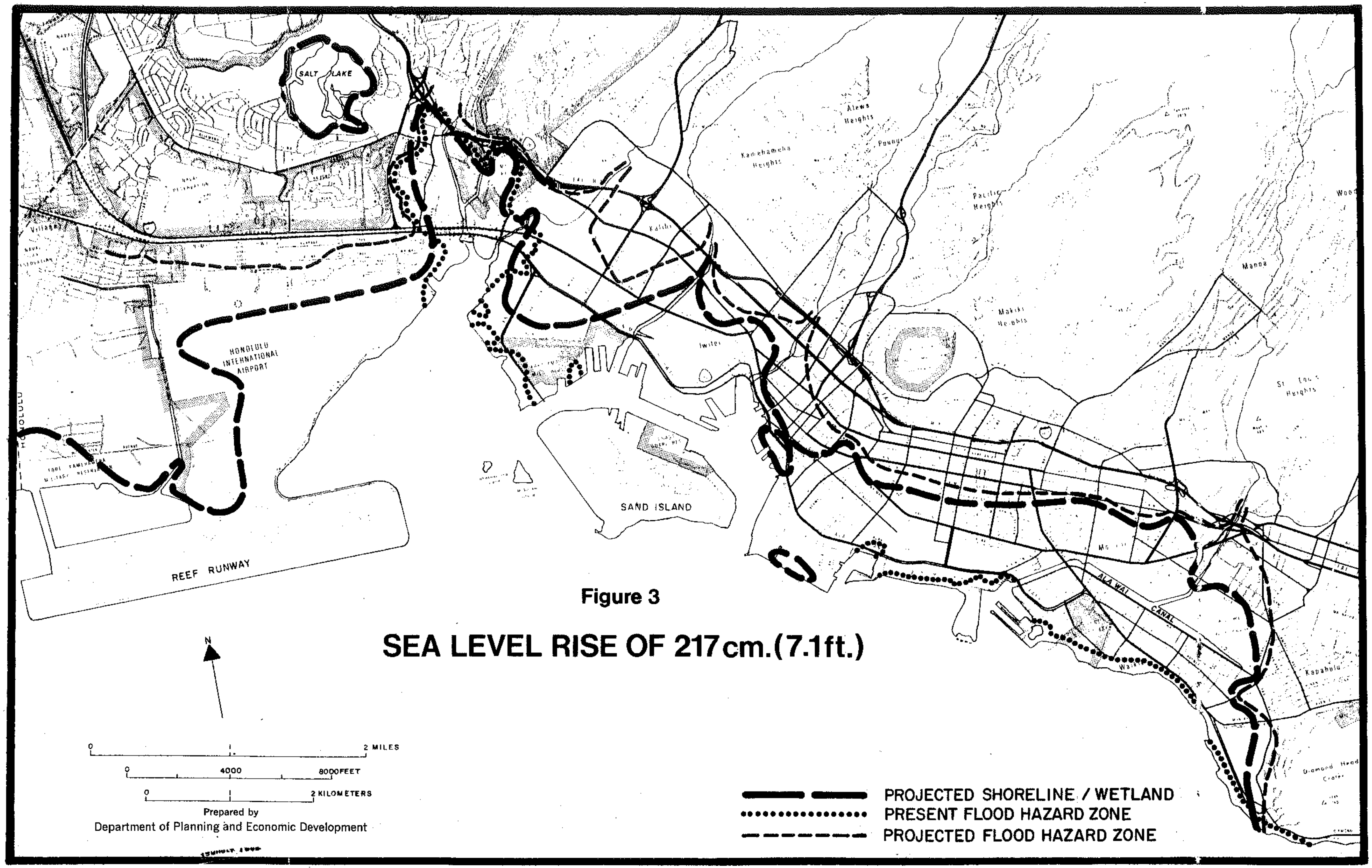

Figure 3

SEA LEVEL RISE OF 217 cm. (7.1 ft.)

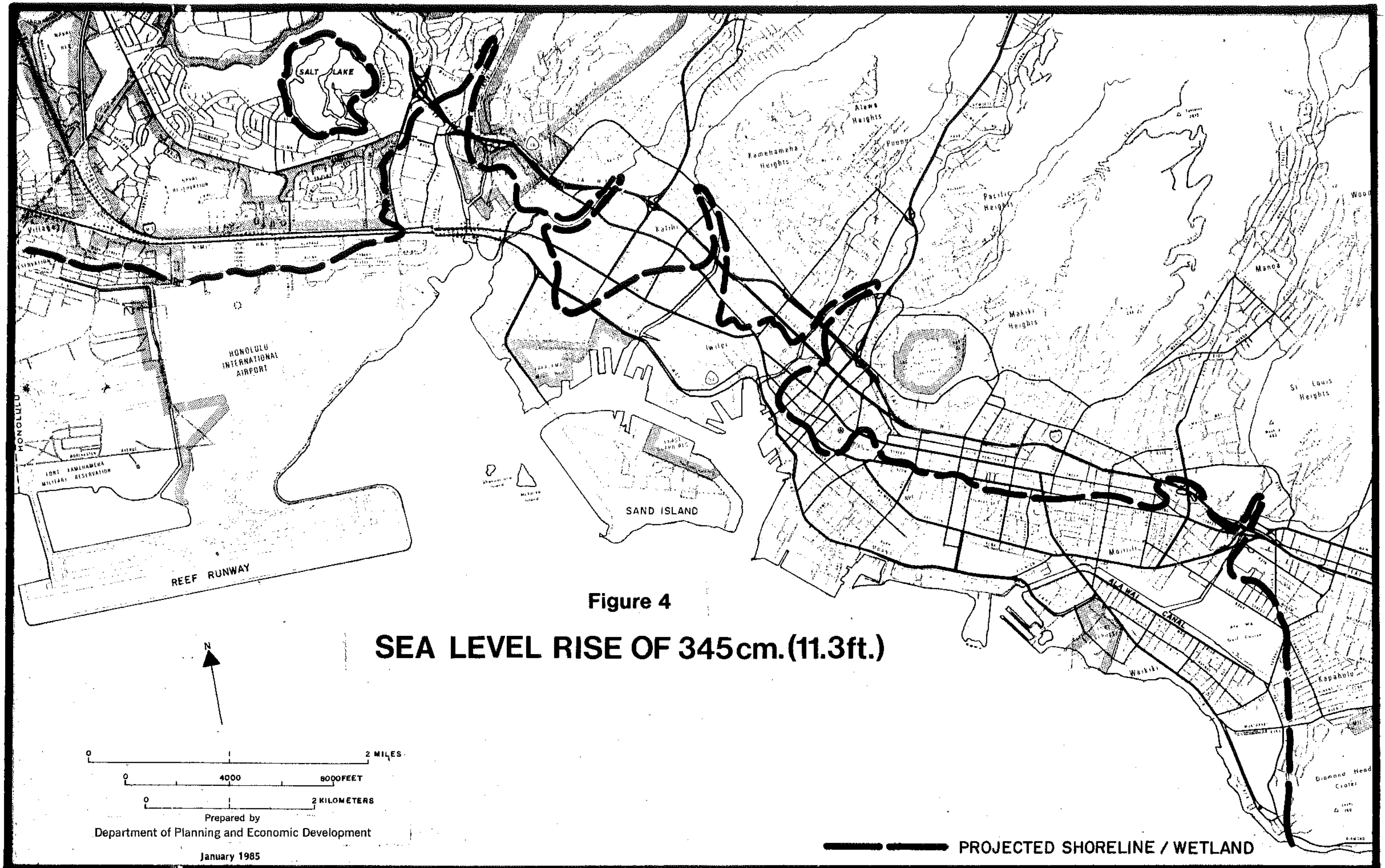

Figure 4

SEA LEVEL RISE OF 345cm.(11.3ft.)

CONCLUSION

The current uncertainty regarding the magnitude and rate of sea level rises, evident in the preceding scenarios, hampers the planning of specific measures to mitigate the inconveniences or, possibly, the serious threats to property and the State's economy that may arise within the lifetime of structures and infrastructures started today. Thus, we believe there is insufficient basis for formulating a long-range plan at the present time. We believe, however, that the information now available provides reason enough to mount a vigil of the scientific community's current research and refinement of predictive capabilities to determine both the timing and scope of a long-range plan.

RECOMMENDATIONS

There should be a continuing effort to better understand Greenhouse warming trends and their correlation with rising sea levels. It is recommended that the Hawaii Institute of Geophysics closely monitor the refinement of the international scientific communities' predictive capabilities, and by July 1, 1989, confer with the Department of Planning and Economic Development on the "state of the art," it's accuracy and application to predict potential impacts in Hawaii. At that time, more specific recommendations for a long-range plan aimed at mitigating the impacts can be developed. At a minimum, the plan would address the following considerations:

1. The rising sea level projections for Hawaii to adopt for planning purposes based upon the best data and scientific predictions available.

2. Review and revision of the adopted sea level projections at regular intervals (i.e. intervals of ten years).

3. The plotting of approximate locations of shorelines and coastal hazards based on the adopted or amended sea level projections.

4. The use of projected shoreline and coastal hazard maps in the design and location of new public facilities and in the improvement and alteration of existing facilities, based on their lifespan and safety features.

5. Locating new infrastructural facilities as a means to attract development to "safe" areas away from zones of projected hazard. Considerations may include the maintainance or non-maintainance of the existing infrastructure.

6. Adopting more innovative uses of the economic incentives of the National Flood Insurance Program to encourage appropriate changes in existing patterns of development.

7. A stricter adherence to existing prohibitions against shoreside development (e.g. shoreline setback, special management permits, and conservation district uses) by approving fewer variances, waivers, and exemptions.

8. More serious consideration of requests for replacing structures lost to natural forces and situated within areas subject to impact from rising sea levels (i.e. shoreside structures rendered inhabitable as the result of ocean storms, related flooding, and tsunami).

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