Chapter 10

Independent Reviews

INTRODUCTION

On March 30, 1983, EPA sponsored a conference in Washington, D.C., entitled "Effects of Sea Level Rise on the Economy and Environment." Reviewers from several disciplines were asked to comment on papers that subsequently were revised into Chapters 1 to 7 of this book in light of their experience in areas that would be affected by a sea level rise. Some of these comments follow.

Sherwood Gagliano, president of Coastal Environments, Inc., reviews the case studies of Chapters 4 and 5 and the engineering techniques of Chapter 6. Included in Gagliano's remarks are suggestions for further and improved research as well as a discussion of the planning, public communication, and other efforts undertaken in Louisiana to address coastal erosion and salt intrusion.

Edward. J. Schmeltz, assistant vice president and department manager of coastal engineering for PRC-Harris, discusses some of the problems that must be considered in evaluating the engineering implications of sea level rise. Schmeltz also addresses the ability and willingness of engineers to modify their designs in anticipation of sea level rise.

Jeffrey R. Benoit of the State of Massachusetts Coastal Zone Management Program examines the possible state responses in planning for sea level rise. He discusses four options for effective state response: policy development and/or revision, regulatory reform, legal conflict resolution, and education.

Colonel Thomas H. Magness, III, formerly assistant director for civil works for environmental affairs, U.S. Army Corps of Engineers, discusses the role of the corps in maritime projects and poses a number of questions for further research. Then, Magness highlights some of the corps's research and planning efforts to develop solutions to the problems caused by sea level rise.

Charles Fraser, chairman emeritus of Sea Pines Corporation, which developed Hilton Head Island and other major coastal areas, indicates how difficult it will be to focus attention on an issue such as sea level rise, whose effects are so far in the future.

The comments presented by Lee Koppleman, executive director of the Long Island Regional Planning Board, focus on the near-term problems posed by a potential sea level rise, as well as their political implications. These implications are illustrated using examples from the Long Island coast.

COMMENTS OF SHERWOOD GAGLIANO

I am grateful for the opportunity to comment on the work centered in Chapters 4, 5, and 6, which is both well done and carefully thought out. Part of my assignment was to temper my comments with the experience gained in coastal Louisiana where, for decades, inundation has accelerated as a result of land subsidence and sea level rise. I will first discuss the two case studies-Galveston and Charleston-and then the chapter on engineering techniques. I will conclude with a discussion of the current situation in Louisiana.

Case Studies

The methods used in the two case studies were excellent. They followed a very straightforward historic approach, using what has happened in recent decades as a basis on which to project future conditions. They combined this historic approach with a process form approach, where some adjustments were made based on current knowledge of process response models in the coastal zone. I particularly liked the way the studies used the computer to manipulate large quantities of data and made adjustments based on both judgment and experience.

The results and the projections of both studies are very acceptable. If anything, they are conservative but still provide a basis for making decisions across a wide range of scenarios. Of course, our ability to project shoreline changes can be improved as the method is applied to other areas.

First, as Kana et al. and Leatherman realize, the data base could, as always, be improved. The quality of information available in map form-topographical maps particularly-is insufficient for many coastal areas. In far too many cases, the finest resolution available in contour maps is 5 ft. Many need updating and some of the maps that have been updated are inaccurate.

Measures are necessary to improve the quality of elevation data in all coastal areas. For example, survey lines that have been carried in from stable areas have often not been resurveyed in several years. Assuming that coastal areas are stable is a mistake. In Louisiana we have come to realize that the land surface is like the surface of a waterbed. Some areas are sinking, and others are rising. The loci of these uplifts and subsidences are changing over time, and the rates of both uplift and subsidence are significant in reference to the anticipated rates of sea level rise.

Another factor that needs more consideration is the possible change of coastal river regimes that may accompany sea level shifts. Long-term geographical and archaeological models suggest that during the transition from a standstill to rising conditions and vice versa, changes in the total discharge of rivers, the magnitude of the floods, and the amount of transported sediment can be expected. These changes would result in additional impacts in coastal areas.

The most important conclusion of the case studies is that by using readily available information, state-of-the-art modeling techniques, and an understanding of coastal processes, it is possible to develop in a relatively short time at least a first-cut prediction model for any U.S. coastal area. It would be a mistake to wait until modeling techniques are perfected before we start applying this technique and incorporating its results into the planning cycle.

The results of the case studies for the base conditions and the three scenarios are not surprising. As I understood the two case studies, there are no catastrophic results expected under the continuing base conditions, the low scenario, or the medium scenario through 2025. But if the high scenario should start to unfold, some serious problems can be anticipated as early as 2025 in both of the case study areas. By 2075 there would be serious problems in low-lying coastal areas under any circumstance, with the problems being greatest under the high scenario. Low-lying coastal areas like Louisiana will suffer much more severely from the effects predicted than areas with higher relief.

Both pilot studies and the engineering study considered three types of impact: the changes in shoreline position due to erosion and inundation, the changes in frequency and depth of flooding due to storm surges, and saltwater intrusion in potable aquifers in the coastal zone. Any of the scenarios would decrease the high productivity and the diversity of fish and wildlife in wetlands, estuaries, and such fragile habitats as dunefields. Geological studies reveal that during periods of sea level rise, landforms become simplified and fewer in number, resulting in less diversity in the kinds of habitat that appeared in the coastal zone.

How sea level rise would affect navigation also warrants careful attention. Flood protection requirements and the potentially increased need for direct surface water to offset effects of saltwater intrusion into aquifers will clearly necessitate many more water control structures in coastal navigation channels. The plumbing in our coastal zones could be very intricate in 50 or 100 years. As we all know, these are very costly structures and represent a major factor in looking at the economic impacts of sea level rise.

We should also think about how sea level rise will affect historic and archaeological sites and recreation areas. South Louisiana has already experienced a dramatic loss of coastal archaeological sites during the last 20 years as a result of shoreline erosion and inundation. Higher priority should be placed on inventories of these kinds of resources.

Engineering Techniques

I find Chapter 6 to be both appropriate and straightforward. The techniques described by Sorensen et al. have been tested and proven in the field. The chapter also presents important and representative cost estimates. The authors present an entire arsenal of hard and soft structural techniques for fighting shoreline erosion. If these sea level rise scenarios really unfold, there will be a need to use every weapon in that arsenal.

Nonstructural alternatives have not really been treated in depth because they were beyond the scope of the work. However, the topic warrants another symposium of this type, involving zoning, floodproofing, abandonment and relocation, and temporary evacuation during storms.

The engineering approaches reveal a strong bias toward working on shorelines with sandy beaches and barrier islands. Relatively little coastal engineering attention has been directed toward muddy and carbonate coasts. For example, how do we manage coastal wetlands in the face of a rising sea level? Our experience in Louisiana has revealed that they are not self-maintaining.

Shoreline retreat measurement alone cannot be used as a basis for predicting coastal wetland deterioration and loss. It is necessary to map the vegetation habitats in great detail and apply a predictive model that uses environmental succession to spot areas where the wetlands are under stress and starting to break up into open water.

We should look at what the Dutch have been doing since about 1200 A.D. to protect themselves against the kinds of problems that are discussed in this volume. This includes the construction of dikes and drainage systems, intricate navigation systems that involve locks, and water control structures that totally manage surface water movement for many purposes. Many situations will require developing polders comparable to those in the Netherlands. These will be very costly, but if we examine the cost-benefit relationship of the Dutch approach, they will prove to be favorable. The Netherlands, which has one of the highest population densities on earth, has consistently enjoyed a good economy and has thrived socially and culturally.

Subsidence in Louisiana

About 15 years ago, we realized that the 5,000 year trend of progradation, resulting from sediment deposited in the Gulf of Mexico by the Mississippi River along the coast of Louisiana, has ended. In its place, we are now experiencing massive shoreline erosion and land loss. While much of the loss is man-induced, subsidence or apparent sea level rise has also been a contributing factor. We have now documented a loss of about one million acres since the turn of the century and a current rate of loss of 129 sq km (50 sq mi) a year. Measurement techniques similar to those presented in Chapters 4 and 5 have been used in determining this rate; we are only now getting to the point of using these findings to project the future shoreline.

Louisiana is a good model for what other low-lying areas can expect as a result of sea level rise. In the last 40 years there has been not only a loss of wetlands, but also a sinking of ridgelands (natural levees). These are the foundations, the high ground upon which most of the development in southern Louisiana is located. Thus, Louisiana faces a very serious problem. When one notes that the highest natural elevation in New Orleans is only 13 ft above sea level and that sinking rates of at least 3 ft per century are occurring in some parts of coastal Louisiana, one begins to realize the enormity of the problem. The barrier islands are breaking up in the washover mode discussed in Chapters 4 and 5. Their loss will result in the shorelines retreating 40 to 48 km (25-30 mi) in some instances and moving into close proximity of some of our urban areas. Also, the Louisiana coast produces about one-fourth of the nation's annual fish harvest. Most of the utilized species depend on the estuaries that are disappearing so rapidly.

Louisiana also provides valuable lessons in responding to the problems associated with sea level change. It took a number of years for the scientific community to recognize and define problems related to sea level effects and even longer to convey these findings in a meaningful way to the public and decision makers. In Louisiana, members of the scientific community have learned that there is a delicate balance between being a harbinger of catastrophe and a rational scientist. It is important to communicate facts and information to decision makers without causing panic. We have had the most success in relating impacts to specific places. For example, when land loss rates of 129 sq km (50 sq mi) per year, in the Louisiana coastal zone were first disclosed, it was newsworthy and of concern. However, it was only after disclosure that a given coastal parish would last only 50 years before it eroded into the sea that the state legislators and the governor enacted a program for coastal erosion protection and shoreline restoration.

In Louisiana we have embarked on a course of responsible planning to deal with these natural hazards. For example, the state has a federally approved coastal management program that is responsible for permitting coastal activities as well as coordinating planning and management. There is reasonably good cooperation between federal, state, and local agencies in dealing with these problems. Some imaginative plans for diverting freshwater, restoring barrier islands, and managing marshes have been developed, and pilot projects are being implemented. A realistic multi-use management approach that recognizes the need for a balance between carefully planned and executed development and conservation management is being taken.

A responsible effort is also emerging in the private sector. A number of developers and landowners in coastal Louisiana are incorporating environmental design features in their new projects. These will not only protect the development areas from future storm surges and flooding but will also ensure that the projects will be compatible with conservation management objectives of adjacent estuarine and marsh areas. Owners of large tracts of wetlands are developing marsh management plans to sustain their properties.

While the potential problems are very large and challenging, the resources and opportunities of coastal areas will continue to attract large populations. It is unlikely that coastal areas will be abandoned because of the threat of natural hazards. In some instances we may be forced to flee to higher ground, but where there are large capital investments and compelling reasons for people to be in the coastal zone, the areas will be maintained.

COMMENTS OF EDWARD J. SCHMELTZ

To a design engineer responsible for the development of various coastal and waterfront structures, the prospect of a significant rise in sea level over the next 50-100 years is a major concern. The implications of such a change in water levels on coastal regions and facilities are numerous.

These remarks will address some of the primary effects of a rise in sea level on factors relevant to the design of coastal structures. A discussion is also presented on the ability and willingness of design professionals to implement changes in design in anticipation of sea level rise.

The Engineering Implications

Significant changes in sea level can have profound repercussions on the planning and design of coastal facilities. Although the factors identified below are not an exhaustive list, they indicate the types of problems that must be considered in evaluating the engineering implications of sea level rise. Prevention, mitigation, and response techniques for a variety of coastal structures have been addressed by Sorensen et al. in Chapter 6.

A critical factor in the analysis of coastal structures is the stillwater level utilized to evaluate design conditions. The magnitude of elevation of the water surface during a storm has a direct bearing on such factors as inundation of low-lying areas, the point of impact of wave action on structures, and the level of wave attack on beach/dune systems.

Less obvious secondary effects may also occur. Examples include increased breaking wave heights, variations in tidal amplitudes and phasing, modifications in storm surge elevations due to increased water depths at a given coastal location, and the effects on water tables.

If ocean temperatures increase as indicated in Chapter 1, the impact on hurricane generation could also be critical. Such storms forming in more northerly latitudes, combined with possible changes in storm tracks, could result in significant modifications to storm surge patterns and wave heights; knowledge of these phenomena is used in the design of various waterfront facilities. In some cases, these consequences could be more critical than the direct effects of sea level rise.

Two basic issues must be addressed, however, in order to assess the response of the coastal engineering community to sea level rise: technological capability and the motivation to institute changes.

Technological Capability

From the standpoint of coastal structures, the technology required to deal with changes in sea level is not new.

The capability exists within the engineering community to deal with variations in water level and the attendant changes in design conditions.

The magnitude of sea level rise, as well as the rate of change is, however, a critical factor. From an engineering standpoint, it is not adequate to predict increases ranging from 2-10 ft. Rather, a more definitive assessment is necessary, keeping in mind that the application has far more practical implications than scientific interest.

A 2 ft rise in the next century would, of course, have far less impact on design than a 10 ft rise. In many areas and for a variety of structure types, a 2 ft rise would probably be of little consequence. For example, some regions of the U.S. coastline are subject to high storm surges. Design stillwater levels on the order of 4.5-6.0 m (15-20 feet) for a 100 year storm are common. A 2 ft increase is not only overwhelmed by other factors but also falls within the combined accuracy of numerical methods of water level and wave height prediction commonly used to establish design conditions. In fact, it is probably safe to say that most structures have sufficient safety margins to withstand a 2 ft sea level rise and resulting increases in wave height. As an example, at a site where waves controlled heights would increase approximately 0.5 m are breaking, (1.6 ft) for a 2 ft increase in stillwater level.

On the other hand, a change of sea level on the order of 10 ft is far more consequential. It is unlikely that most coastal structures could withstand this magnitude of change and still serve their intended function. The effects of inundation are obvious and were discussed earlier. In some areas, a 3 m (10 ft) rise exceeds the total 100 year flood elevations currently accepted. In Long Island Sound, for example, 100 year flood elevations range from 2.4-4.0 m (8-13 ft).

The magnitude of the change in sea level is, therefore, critical in assessing the impact on coastal facilities. Clearly, there are cases where a 2 ft rise is important; in other cases, the change in sea level would have to approach 3 m (10 ft) before significant effects occur. The consequences must be evaluated on a site-specific basis. Reevaluation of existing structures will be necessary to ensure their stability and adequacy to serve their intended function as water levels rise. For new structures, it is a relatively simple proposition to increase design water levels and evaluate other design loading conditions on this basis.

Motivation to Institute Changes

Although the technology exists to address significant changes in sea level, designers of coastal facilities and structures must be convinced of both the probability and the magnitude of future increases in sea level. Approximations and conjecture on the part of scientists may not induce the engineering community to institute necessary design changes.

The credibility of the analysis of possible sea level rise is probably a more critical issue than the actual numerical results of that analysis. In order to understand the engineering profession's attitudes on the subject, one must understand two factors: the engineer's position in the decision-making hierarchy of a project and the consequences of an individual engineer's belief in a significant sea level rise.

An engineer's relationship with the client/owner is a special one. The engineer provides the technological interface between the client/owner and the scientific community. While it is his or her professional responsibility to develop technically adequate designs, he or she must also be sensitive to the project's other needs, such as scheduling and costs. His or her primary function is to translate scientific facts into the hard realities of, for example, a structure. At the same time, the engineer must maintain a proper perspective on such factors as construction cost and start-up requirements. Although the engineer develops and evaluates alternatives, detailed designs, cost estimates, and specifications, the client holds the ultimate decision-making authority. Recommendations made by the engineer are just that and must ultimately be justified to the satisfaction of the owner. This is particularly true of matters that tend to increase project costs.

As Chapter I indicates, coastal facilities tend to be evaluated in terms of their economic life, typically taken as 30 or 40 years, even though their true useful life may be substantially greater. Convincing a client to expend additional monies to accommodate a sea level rise that "may" occur over the next century would at best be difficult. Basing this recommendation on an analysis that results in a range of 0.6-3 m (2-10 ft) stemming from input conditions that could be viewed as conjecture, would be essentially indefensible from the client's standpoint.

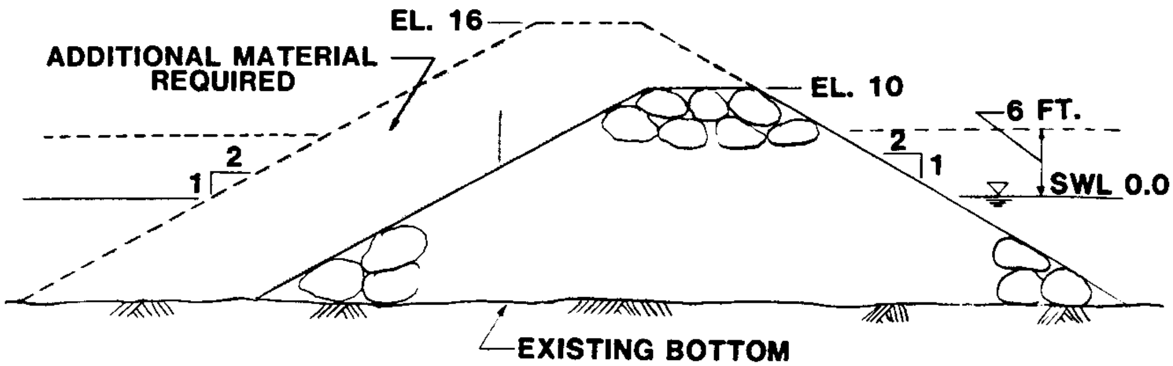

Figure 10-1. Effect of 6 ft (1.8 m) increase in height on breakwater cross-section.

Clearly, a long-term view would be required of both the client and the engineer to modify design conditions to accommodate a substantial sea level rise. Unfortunately, this type of approach would not be in keeping with the economic realities of the times, unless there was firm belief in the probability of sea level rise.

Presupposing that an engineer develops a firm belief in a substantial sea level rise, it is interesting to consider the consequences of this belief. The engineer is placed in the position of convincing not only a client but, in many cases, international lending institutions such as the World Bank. There will also be, in many cases, a considerable impact on a project's initial costs. These costs are critical in the economic decisions that determine a project's viability.

If the engineer's recommendation is not founded on a credible basis that is generally accepted by his or her peers, this task will be difficult. As a simple example of the magnitude of the impact on costs, consider the rubble mound breakwater shown in Figure 10-1. With a crest elevation of 10 ft, side slopes of 1:2H, and located in water depths of 10 ft, it is essentially typical of jetties and groins at many coastal locations. The dashed lines in the figure indicate the shape of the structure for a 6 ft increase in stillwater level, excluding the effects of increased wave heights and run-up. For this simple case, the volume of the structure increases by more than 60 percent for a 30 percent increase in structure height, as indicated by the shaded area in the figure. The cost impact is obvious.

There are other practical effects related to instituting changes in structural design to accommodate future sea level rise. For example, port deck elevations in the future would be higher than those currently in use. If these requirements were incorporated in current designs, new sections of wharfage could be up to 3 m (10 ft) higher than adjacent, existing sections. The movement of cargo along the structure would be complicated by this "step." Convincing the owners of a port where all existing berths are a constant elevation above mean sea level to raise new facilities 10 ft will be extremely difficult without a more credible justification.

Summary and Conclusions

The response of the coastal engineering community to potentially significant changes in sea level is not primarily a technological issue. Rather, it is a question of credibility.

The technology exists for the professional to respond adequately to the phenomenon. Design engineers must be provided with reasonable estimates of the magnitude of the problem. The support for these estimates must be sufficiently detailed to convince the engineer to recommend design changes that may result in significant increases in project costs. Clients and lending institutions who provide the funding for major marine projects must also be convinced of their credibility.

The scientists involved with the evaluation of the phenomenon must remember that there is far more than scientific interest at issue; design engineers must live in a world of cold, hard realities. Project decisions are made on the basis of technical facts and economical considerations. Conjecture and hypothesis are not sufficient, and additional research will be necessary before engineering decisions are likely to incorporate sea level rise.

COMMENTS OF JEFFREY R. BENOIT

The results from Chapter 3 indicate that by the year 2100, the level of the sea could rise over 3 m (10 ft). A rise of this magnitude would result in direct changes in biological, physical, economic, and social systems within the coastal zone. The responsibility for dealing with these changes will ultimately have to be shared by both the private (landowners) and the public (government) sectors.

Coastal states will be faced with many controversial and expensive decisions if the initial results of the EPA study prove true. Individuals responsible for making those decisions should begin to consider what components of a response plan are most suitable for their own state. These comments are intended to provide some preliminary thoughts on this subject and in doing so present a framework of options from which state governments could formulate a comprehensive plan to respond to sea level rise.

Before discussing potential response options, however, a brief look at Massachusetts will reveal several areas of concern that may also be faced by other states.

First, Massachusetts has had a long history of coastal storm damage. The most destructive coastal storm of recent times was the great blizzard of 1978. This northeaster battered the Massachusetts coast for three days. Over 330 homes were substantially damaged or destroyed, and financial losses along the coast were in excess of $180 million. Historically, attempts to protect coastal property relied on the construction of massive structures for shore protection and flood control. Because these types of protective structure were and continue to be designed only for existing sea level conditions, their effectiveness against increased sea levels will be progressively diminished.

Second, the protection of coastal wetland areas has also been of great importance to the citizens of Massachusetts. Strict laws and regulations protect valuable resource areas such as beaches, dunes, salt marshes, and barrier beaches. Changes in sea level will result in rapid spatial shifts of the boundaries of these resources. A revised and expanded regulatory approach will be necessary to ensure their long-term protection.

Finally, most coastal communities in Massachusetts accommodate recreational boating and support commercial fisheries. Consideration must be given to the impact that rising sea level will have on the usefulness of piers, docks, and other support facilities. Large urban cities along the coast, like Boston, are also major shipping ports and represent regional commercial and financial centers. As a result, many of these cities contain sizable airports, such as Logan International Airport, located in the middle of Boston Harbor. Logan Airport and much of downtown Boston are reclaimed tidelands, resulting from filling activities that began in the late 1600s. Not surprisingly, Boston's waterfront has little existing freeboard with which to accommodate a rising sea level. Thus, the modification and upgrading of shoreline protection structures will have to be appraised.

Response Options

A variety of options exist through which state governments could effectively respond to increasing sea level. Although all the options may not be suitable for application by each state, collectively they provide a framework for states to choose from. This framework can be divided into four categories: policy development and/or revision, regulatory reform, legal conflict resolution, and education. A brief discussion of each option follows.

If state agencies are to be effective in their long-term planning efforts to mitigate projected sea level rise impacts, new policies must be developed and existing policies revised. A shift in state policies can be achieved in a variety of ways such as gubernatorial executive orders, individual agency response and, interagency coordination. Policy changes can deal with such issues as the elimination of state funding or incentives for new development within areas to be affected by sea level rise; the revision of post-storm recovery policies (evaluating existing rebuilding practices); and the development of criteria to identify, evaluate, and assign priorities to areas for receipt of public funds for construction or modification of shoreline protection structures.

The second category of options consists of changing existing regulatory requirements. A variety of changes could be implemented including the mandatory review and updating of existing coastal wetland inventory maps; coastal resource protection legislation and regulation based on dynamic boundaries as opposed to static mapping products; the revision of state building codes to recognize a progressive landward shift of hazard zones; and the inclusion of sea level rise projections in projects subject to review under state environmental policy acts.

As shoreline positions shift in response to a rising sea level, conflicts over ownership and property rights will arise. Many of these potential conflicts could be avoided prior to their creation if state tidelands statutes were clarified. Specific attention should be directed to the burden of responsibility for impacts on adjacent property resulting from the use of shoreline stabilization structures and to the private right to erect shoreline stabilization structures in contrast to the public right to use the beach.

The fourth, and final, category is education. Introducing a new idea to any audience must be accompanied by an informative explanation. This especially holds true when an idea presents a radical change from accepted concepts. The general public, private investors, engineers, architects, and public officials all must be made aware of the problems associated with sea level rise projections. Accepting the serious nature of the problems is essential if long-term planning measures are to be successfully implemented.

Conclusion

If the high scenario predicting a 4 m (12 ft) sea level rise by 2100 is true, coastal states must begin formulating response plans immediately, but before any action will be taken by legislatures or state agencies, there must exist a strong scientific information base. Without defensible data, it will be extremely difficult to make any substantial changes in state government or to convince the general public that a real problem exists. The extent to which future sea level will change and just what the consequences of the change really mean must be more accurately determined. However, the value of EPNs work in this area is that it will force state agencies, planners, and the public to ask the difficult questions posed by this project. Then we can begin to elicit answers from decision makers via increased research and data gathering efforts.

COMMENTS OF THOMAS H. MAGNESS III

When Chicken Little warns us that "the sky is falling," we in the Corps of Engineers do not worry much. We figure that must be NOAA's or NASA's turf, if you will. But when we get reports that the sea level is rising, we see Chicken Little addressing a water resource problem and take notice.

The Corps of Engineers has had a long and "meaningful" relationship with the sea. The bulk of our maritime involvement has been in the areas of navigation (at ports and inlets), flood control (including floods by hurricane surges), and shore protection (which sometimes involves beach restoration). We plan over the meso-term: longer than a storm event but shorter than a geologic period. Most of our projects in these areas are designed for a useful, functional life of 50-100 years. This is about as far into the future as we can predict, with some certainty, the complex combinations of physical, economic. environmental, and social interactions that will have an impact on a given location. Within that time frame, we are interested in emergency actions, planning, and research on any natural phenomena (such as changes in sea level) that would have an impact on the effectiveness of our ongoing, planned, or existing projects and on the Corps's ability, in general, to carry out its missions.

In order for any of us to examine a change in the sea level relative to the land mass, we obviously must identify each of the processes that could cause such a change, quantify each process, and then re-examine the problem as a whole once the relative importance of each process has been made as clear as possible.

The work presented in this book has certainly accomplished part of this requirement. There is now a more complete list of the individual processes that affect the relative positions of land and sea. We now have a good idea of the present level of knowledge of each of these processes. There is now a first cut at trying to quantify one of these processes, namely, the global warming that results from the build-up of $C0_2$ in the atmosphere. Finally, there is a feeling (though perhaps not yet a consensus) that the relative importance of that process is increasing with respect to other processes.

There are still, however, a number of questions that need to be addressed. Is the list of all the processes involved complete? While it appears to be complete, if we really want to be sure, we need more forums such as this one where all disciplines can interact. What efforts are underway to quantify other processes that affect global warming either positively or negatively? An increased level of effort must be put into research on other, potentially significant phenomena. At this stage, most such studies must still be considered largely speculative. What is the relative accuracy of the quantification of the various other processes? It would do little good to have greater accuracy in quantifying a relatively minor process. This question does not seem to have been addressed yet. What is the relative importance of each of the processes in the "big picture"? How much of the rise in sea level is due to global warming, and how much might be due to something else? There is, as yet, no generally accepted apportionment. How accurate are the measurements of sea level? This has been a continuing problem to many of us, since most tide gauges have historically been installed in bays and sounds. Further, there is also some evidence suggesting that sea level might be responding to geologic-scale oscillations, rather than rising generally and continuously. How do changes in climate and sea level affect the processes that cause beach erosion? The forces required to move beach sand are generated by storms, not by long-term sea level rise. Long-term sea level rise primarily affects the elevation at which the erosive forces act. Long-term climatic changes (such as an increase or decrease in the number of severe storms) would have a far greater effect on local erosion rates. Has anyone yet studied scenarios for estuaries, coastal marshes, and associated freshwater wetlands in response to various sea level rise scenarios?

The Corps' basic missions, of course, are navigation, flood control, and shore protection; these missions dictate the focus and extent of our consideration of sea level rise. These basic missions are, likewise, supported by a considerable amount of applied research by Corps laboratories. The Coastal Engineering Research Center, the Waterways Experiment Station, and the Cold Regions Research and Engineering Laboratory have been working to apply the results of basic research, along with extensive field and laboratory data, to the behavior of inlets and channels, beaches and dunes, and estuaries and wetlands. We must better understand the natural behavior of these features before we can accurately predict their behavior after the installation of man-made projects.

The Corps has already been studying the effects of sea level rise. In 1980 the Coastal Engineering Research Center began a program to increase and refine the basic knowledge of barrier island processes. One of the major ongoing substudies of this program examines sea level elevation changes as they affect barrier island processes, in an attempt to predict future changes.

It is also obvious that beaches have multiple uses, and to plan and design a beach erosion control or hurricane protection project properly, we must consider the local short- and long-term sea level rise (or fall). This book does not address sea level fall; however, it is the Corps's experience that sea level change is very much a site-specific phenomenon. There are many places where a perceived sea level fall has been observed (Astoria, Oregon, and Juneau, Alaska, are well-known examples). At other places, like Texas City, Texas, and Long Beach, California, subsidence has caused a perceived sea level rise. Because the causes of such changes are not well understood, either qualitatively or quantitatively, generalizations about the effect of global sea level rise, from our experience, would be tenuous at best. Yet, we must and do consider sea level changes, however difficult they are to quantify.

The Corps's New Orleans District is currently involved in a study of the Louisiana coastal area, where land subsidence and global sea level rise are but two of several phenomena simultaneously affecting change. In areas such as Louisiana where the relative local change is much greater than the average "global" sea level rise, the Corps was asked to develop solutions to the resultant local and regional problems. While the results of research into global sea level rise will be useful in our planning and design efforts in Louisiana, solutions to these problems should stand us in good stead if we must later address a more general rise.

The Corps's Los Angeles district is currently involved in a regional study of the southern California coast to identify and to quantify all the processes affecting that coast. These regional study results will also be available for future, more localized or broader-scale planning investigations, with research on global sea level rise, or fall, fed into the process models developed in that regional study effort.

The complex hydraulics at inlets, particularly those where there is a navigation interest, has caused the Corps to predict the effects of sea level rise on the basis of the processes occurring there. Not only are navigable waterways affected but also the adjacent beaches, shoals, dunes, and lagoons. We must understand all the processes interacting there and the effects of our navigation works on those processes. Thus, a better capability to predict future sea level conditions is crucial to the adequate planning and design of navigation channels and harbor improvements.

Although our concerns for navigation, flood control, and shore protection form the bulk of the Corps's interest in the coastal zone, we do have some other interests as well. The Corps permit programs, authorized by Section 10 of the 1899 River and Harbor Act and Section 404 of the Clean Water Act, are important ones. Those programs require the Corps to investigate and then certify that an applicant's proposed construction, dredging, or land reclamation in waterways, wetlands, or along the coast would not seriously degrade or otherwise harm water quality, the environment, the property of others, or the public welfare (including navigational interests).

Another all-pervasive concern of the Corps is the individual states' approved coastal zone management plans. We in the Corps do not manage any of the coastal zones per se, but we do conduct our business in concert with state plans and we must certify that our works are not inconsistent with those approved state plans.

We have also been asked by EPA to help in the clean-up of many of the nation's hazardous waste disposal sites. As we have heard, many of the "Superfund" sites are in the coastal zone where a change in sea level would certainly affect where, when, and how we design and accomplish a particular clean-up.

Because of the way Corps studies are authorized and funded, we can say with some certainty that our planning and design process is of sufficient length to allow for the incorporation of any potential general sea level rise in a rational and orderly fashion. And in fact we have already begun.

We plan to share our research results and the findings of site-specific studies with EPA and others. Likewise, we hope that any research results that others develop will be complementary to our own research and planning efforts.

As you may surmise from these remarks, the Corps of Engineers has a very definite interest in sea level rise. We want to and we must better understand all the complex interactions of the phenomena that cause the sea level to rise or fall. Such an understanding will allow us to predict with greater confidence into the next 100 years and therefore to better plan and implement needed water resources projects in the coastal zone. EPA=s start on this program deserves the support and encouragement of us all. To the extent that our resources and mandates permit, the Corps can be counted on to cooperate-and to do so fully and actively-for it would be folly not to believe that Chicken Little only has to be right once.

Note: This paper does not necessarily represent the official position or policy of the Department of the Army.

COMMENTS OF CHARLES E. FRASER

The world is, unfortunately, filled with examples of tardy responses by citizens affected by significant adverse changes in their immediate work and living environments.

The coastal shoreline of America was of little value, except for occasional ports, in the era when agriculture dominated our economy. In 1900 the 48 km (30 mi) of coastline in South Carolina known today as Myrtle Beach were regarded as worthless. Owned by the Myrtle Beach Farms Company, the sandy land near the ocean was not good for either growing tomatoes or growing good pine trees. It was valued at about $2 an acre, but pine land 10 mi inland was valued at about $10 an acre.

As recently as 1950 on Kiawah and Hilton Head Islands-neither of which had bridge connections-the oceanfront acreage was valued only for the value of the standing timber of those islands-about $100 an acre. Today, 34 years later, as a result of superb land use planning and tight controls in the "golf plantations," oceanfront property sells at $400,000 per half-acre lot, despite threats of hurricanes, rising waters, and high taxes.

For 20 years Congress rejected the idea of buying Cumberland Island for $500 to $1,000 an acre, despite the Mellon Foundation's Vanishing *Shoreline* book of 1954. The U.S. government is assembling the final pieces and is now buying it at $15,000 or more an acre.

Because people freed from the farm and factory burdens of 70 hour work weeks began to visit the seashore, beach railroads became very profitable investments. One could run a railroad on piling and crossties over marshes, out to a beach, load up all the passenger cars available in Atlanta or Philadelphia, and run an excursion express train to the closest beach. The end of the railroad at the station closest to the beach produced a 1920s boom in land values.

A new fad developed after World War II. Tanned skin became a symbol of affluence and leisure. People began to expose their skin to the sun, and the surge of people to the shore increased about fivefold. An interesting bit of trivia is that within the first 5 years of the redevelopment of the ancient Roman bikini in 1947, the summer crowds on the French Riviera increased tenfold.

Predicting trends in the economy of the coast is very difficult. One really does not know what land prices are going to be. They certainly will not plunge downward as a result of this conference. Even though I have been studying the history of coastal values for many years, I have managed to make enough miscalculations to develop a sense of humility. In 1968 I calculated that 10-15 percent a year price increases were at an end at Sea Island, Sea Pines, Hilton Head, and Myrtle Beach and that thereafter they would appreciate at only 5 percent per year, so I sold out. With great wisdom I bought 6 miles of beach in Puerto Rico in 1969. Since I made that then seemingly brilliant decision, the land that I left behind at Hilton Head Island has appreciated 1,000 percent and the land in Puerto Rico has depreciated 80 percent. But I am learning.

As for sea level rise and fall, which are so characteristic of our earth, the concern about another 6 in or even 2 ft rise over the next 20 or 100 years is less today on islands than the current uncertainty about the height of the next hurricane surge tide and the speed of evacuation. Houses at Hilton Head Island are already being built 8 ft above the highest known hurricane wave of the last 300 years. A new computer model-whose authors admit that it contains enormous numbers of gaps in the data-predicts that the next hurricane waves will exceed that record by 10 ft. It's unlikely that a vast program of dealing with an issue that may possibly surface 20-30 years from now is going to attract the attention of a community that is not even willing to deal with the immediate present's problem of overbuilding, which threatens safe hurricane evacuation.

For example, we tried to get the Beaufort County Council for the past 4 years to react to the explosive growth on certain parts of Hilton Head Island. We have both the best and the worst planning in America on Hilton Head Island. Eighty percent is superbly planned, 5 percent is being raped, and a question mark hangs over 15 percent. For 4 years the council has been debating a land-use ordinance that was unanimously recommended by organizations ranging from the Sierra Club to the board of directors of the Chamber of Commerce Hilton Head. So a county government body that cannot even bear limited controls is apt to have difficulty dealing with problems as complex, as subtle, and as far beyond the next five elections as sea level rise. We will vote in a new city government for Hilton Head on August 2, 1983, and tackle such problems locally.*

Similarly, in New York City, you would think all the city agencies would have leaped to support the Rouse Company in the South Street Seaport. It was proposing to carry forward the South Street Seaport development after the brilliant success of the Quincy Market program in Boston and Harbor Place in Baltimore. Yet it took the Rouse Company 10 agonizing years just to get the state and city agencies to agree on a few very simple things for the South Street Southport Connection.

At Hilton Head Island, Sea Island, Georgia, or any of the low-density coastal areas with single-family houses, one might suggest that the owners give up their cherished guarded gates and private drives to get public funds for a seawall to guard against the possible rise of the ocean 10 or 20 years from now. But since many of them are retired, they would say that the sea level would not rise in their lifetimes, so the "Feds" and everybody else should leave them alone.

Similarly, try proposing to the Historic Commission of Charleston that some agency build a 3 m (10 ft) wall around some historic sections of the city. For 22 years a local DAR group resisted restoring the old Exchange Building at the foot of Broad Street, once used to hang pirates. The 22 women on the DAR Board did not want a lot of blacks inside the building 20 years ago and blocked federal funds for years. Imagine the local response to a $50 million bond issue for seawall.

The capacity of institutions to resist complex social or civil engineering projects and the potential for protracted debate over who should pay are almost terrifying whenever action is really urgent. I believe the sea level rise must become more visible before people will take the problem seriously. And I do not think scientific papers are the answer. It will probably take three good hurricanes, which will take us about 50 years. Then, in the rebuilding process, we will address sea level rise. In the meantime, since it will probably take several years to prepare the designs for the creative work you are doing on sea level rise, let's go forward and try to compress a 50-year cycle down to a more meaningful 25-year cycle. At least we will thereby save 25 years, which is not perfect but is better than not saving any time in our inevitably slow reaction to the world around us.

Is the sea level actually rising today? Despite the $200,000 study reflected at EPA=s sea level rise conference, the issue is very much in scientific debate.

*The results of this election instituted a town government for Hilton Head Island.

COMMENTS OF LEE KOPPLEMAN

After reviewing the previous chapters, I recalled the story of a community suffering a devastating flood. The minister was seen hanging out of the second-floor window of the church. Someone in a passing boat yelled, "Reverend, jump in-we'll save you"! He said, "Go on, fear not, the Lord will save me. Save others." After turning down similar offers and climbing higher and higher in the church, the minister found himself on the top of the steeple, clinging to the cruciform. A rescuer in a helicopter came by, telling him to grab a rope. Again he said, "Fear not, I trust in the Lord." In the next scene the minister was in Heaven. The Almighty welcomed him, and the Reverend said, "You know, I appreciate being here in Heaven, but I'm a bit frustrated. All my life I've served You faithfully, but in my time of need You did not respond." And God replied, "You, frustrated? First I sent one boat, then I sent another boat.... and then I sent a helicopter"!

I believe that the first boat passed us planners by. In fact, I'm afraid the second may have passed us too. In a free society, we only seem to respond politically when faced with crises. Dr. Sherwood Gagliano says we should neither resort to hysteria, nor alarm the public. I thoroughly agree. Government should lead, guide, and comfort its citizens. However, this responsibility does not call for ignoring a crisis when it appears.

Some chapters in this book indicate that perhaps we have no near-term problem. Others mention that sea level rise may increase a few inches or a few feet. When reading them, I was beginning to feel very comfortable, thinking we do not have a problem. But the more I thought about it, the more I realized this interpretation is incorrect and that complacency is the wrong direction. The great value of the papers presented here is that they illuminate the problem.

For example, years ago when I served on the National Coastal Zone Advisory Committee, I remember Dr. Lyle St. Amont saying that there was no conflict between Outer Continental Shelf activity and its impact on Louisiana's wetlands. After all, Louisiana has 3 million acres of wetlands. But with the current annual loss of 13,050 hectares (32,000 acres) of wetlands, in 100 years-just about coincidental with the time horizon of this study-Louisiana may bid its wetlands goodbye.

Thus, the key question is: what are the implications of the work that the very talented people participating in this study have provided in terms of policies for today, not for 100 years from now? The real value of the project becomes manifest here.

A fundamental point is that whether the sea is going to rise 3, 5, or 7 ft is unimportant. The important point is that this study indicates a sense of direction that has absolute relevance today.

For example, my office is now conducting a hurricane mitigation study for FEMA. One thing Chapter I briefly mentions that we did not even consider is that, with the warming of the ocean's surface, the center of hurricanes may gravitate northward and be closer to Long Island. Furthermore, an 8 ft sea level rise would destroy more than $3 billion of industrial and commercial activities there each year. That includes not only fisheries and tourist industries but all the related industries that go with them. And the homes of almost 1.2 million people would be affected. Therefore, the kind of research presented here today forces me to conclude that this work must continue-particularly the meteorological work.

Other policy implications should jump right out at the federal establishment and, incidentally, should be very popular with the current administration. For example, we have been trying to establish a National

Seashore on Fire Island. Since 1964 we have had to deal with New York City people who want to live on Fire Island. They exert their political pressure to keep the Department of Interior from buying up the lands that were originally provided for in federal legislation. The federal government further compounds the problem by issuing insurance to people whose homes may float out to sea. (I have been fighting against flood insurance for years.) In March 1983, five more homes on West Hampton Beach were destroyed by high waters and winds. I cannot say it is because of the rise of the sea; that is a legal question. The citizens who lost their houses said it was flood related and want to get paid. FEMA says it may be an erosion problem. The small print says FEMA will pay if your home is flooded; but they do not pay if erosion causes the loss. I believe these houses were the victims of erosion due to an uncompleted engineering process that started in the 1960s. Suffolk County built 16 out of a planned 21 groin field. Political pressures stopped the project. Of course, the interruption of sand flow downdrift from the sixteenth groin increased erosion.

At Moriches, the barrier beach was broken through. The Corps of Engineers generously helped us fill the breach with a $14 million grant. At the last count, about $5 million worth of that sand has washed back out to sea again. In terms of mitigation for the barrier beach, the latest figure for beach nourishment is $44 million. That does not bother us because most of that is going to be picked up by the Corps. What bothers us is that the county has to maintain the beach at a cost of $8 million every two years. If we can get the Corps to pick up the maintenance costs, we will go ahead with almost any kind of project they wish.

But that policy is not what leads me to my last point. One important area of research is missing in the current study-namely, planning options as an alternative to structural solutions.

The issues presented here have nonstructural solutions. I grant that they are often soft and mushy, but in terms of costs and benefits I think we can benefit from how EPA treats general wastewater management. Looking at the parallel range of nonstructural solutions will provide the full scenario of options in terms of answering questions such as: do you mitigate and stay where you are or, do you take planning steps that allownatural change to take place? This last area of research may fulfill the need for comprehensive general policies. In this fashion we can at least hitch our ride in the helicopter.

As a final comment, I would note that I am very impressed with the harmony and interdisciplinary play among economists, engineers, geologists, geomorphologists, hydrologists, and so on. This is nothing short of remarkable.