SEA LEVELS AND COASTAL BOUNDARIES

GEORGE M. COLE

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Preface

Humans have always been drawn to the sea and the other great surface waters of the Earth as a source of food, moderate climate, and a medium for transportation and recreation. As evidence of the early attraction of mankind to the sea, remains of some of the earliest human settlements in the United States have been found miles offshore in the Gulf of Mexico. With the limited infrastructure associated with early human life, the dynamic nature of the shoreline, due to long-term sea level change, was not a concern for such settlements. Modern humans are drawn to water for the same reasons as those associated with those early settlements.

Today, it is estimated that over a third of the population and three-fourths of the world's megacities are located in coastal zones. With the more elaborate infrastructure associated with contemporary human development, the constantly moving shorelines associated with long-term sea level change are a topic of considerable interest and concern. As a result, an objective look at long-term sea level change is the primary topic of this writing.

Associated with the issue of long-term sea level change is that of littoral and riparian boundaries and how sea level changes are addressed with such boundaries. The waters of the seas and other major waterbodies have long been considered a public commons. As a result, the boundaries between such waters and the bordering uplands have a special significance as the line between public and private interests. Those lines have been the subject of legal codes since the early Roman civilization. As an example, the early civil code of that era, known as the Institutes of Justinian, reflected the status of the sea as a commons and also defined the boundary between the sea and bordering uplands. This is illustrated by the following translation of a portion of that code.

> The sea shore, that is, the shore as far as the waves go at furthest, was considered to belong to all men . . . . The sea shore extends as far as the greatest winter floods runs up.

Despite the early recognition of the boundary between the sea and bordering uplands, such boundaries remain today as among the most complex in human society due to the complexity associated with the constant movement of the edge of the water.

This writing is an examination of such sea level dynamics and how society deals with the constantly changing sea levels while also protecting the rights of owners of bordering uplands. It begins with a description of how sea level is constantly changing, in both the short and long terms. Then, laws and processes that have evolved for defining the boundary between public waters and bordering uplands are examined for both tidal and nontidal waters. Next, the topic of national and state boundaries in coastal waters and how they are determined is examined. The writing then continues with a review of practices for determining boundaries where shorelines have been altered, followed by an examination of the rights of riparian and littoral property owners and how such rights are defined. The writing concludes with a review of how sea level is changing with interesting conclusions regarding the apparently rapidly changing rates of change along the coastlines of the United States.

Thus, the writing is intended as a guidance in understanding how sea level is changing, how society has defined the boundaries between public waters and bordering uplands as well as national offshore boundaries, and how such boundaries are defined and located. Therefore, the material presented in this writing may be of interest or assistance to practicing boundary surveyors, attorneys, engineers, oceanographers, coastal land managers, landowners, or planners as well as other persons interested in long-term sea level change.

This topic is especially germane at this time due to the public awareness of the possible effects of sea level rise and the frequent sensational coverage of that issue in the popular press. These have increased the need for professionals to understand and be able to deal with such effects. Hopefully, the writing will allow such readers to better understand the overall picture of how sea and other water levels change with time and how littoral and riparian boundaries address such changes. It is also hoped that readers will find the topic as fascinating as it is to the writer even after six decades of practice in this area.

George M. Cole
Chapel Hill, North Carolina
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Sea Level Dynamics

As discussed in the Preface, one of the more complex aspects of water boundaries is the dynamic nature of the land/water interface. A major cause of that variation is constantly changing water level. That fluctuation is due to a variety of causes including the tides, metrological conditions, and global sea level changes. Traditionally, sea level variations are classified by the period of variation, ranging from *surface gravity waves* with periods varying from 1 to 20 seconds; to *seiches* and *tsunamis* with periods of up to an hour; to *astronomic tides* with dominant periods of one-half and one lunar day; to *storm surges* with periods ranging from a few hours to several days; to *long term, apparently nonperiodic trends* caused by geological and climatological effects with periods of thousands of years.

In addition to varying periods, sea level variations also vary considerably in amplitude. Variations range from those associated with seiches and surface waves with amplitudes as small as a few centimeters to tsunamis with amplitudes in the tens of meters.

1.1 Short-Term Sea Level Variation (Other than Tides)

1.1.1 Surface Gravity Waves

Possibly the most noticeable sea level variations are *surface gravity waves* (Figure 1.1), which are generally called either wind waves or swell. *Wind waves* are the effect of wind on water and always travel in the same direction that the wind is blowing. Wind waves continuing for longer than a few hours gain sufficient energy to take on a distinct character known as *swell*, which move across open areas of water even though not under the influence of the wind. Wind waves generally have periods from 1 to 15 seconds. Swell has longer periods,

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