Climate Change

Impacts on Coastal Areas

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Introduction

Coastal erosion and coastal flooding cause serious economic and social disruption and pose serious threats to the coast of Ireland. In the climate change scenarios outlined in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2007), mean sea level is predicted to rise and the frequency and severity of coastal storms is predicted to increase. These consequences of climate change will significantly increase the risks posed by coastal erosion and coastal flooding.

In this paper the threats posed by erosion and flooding are outlined, the effects of climate change on those threats are presented and the measures that can be taken in the immediate and longer terms to respond to those threats are discussed.

Coastal Erosion and Coastal Flooding

Coastal erosion is the progressive encroachment upon the land by the sea. Erosion can be due to a combination of many different factors. A coast may be working its way slowly towards equilibrium with the forces acting upon it, including an underlying slow mean sea level rise of 1.3mm to 2.3mm per annum (Carter, 1991; IPCC, 2007), or the erosion may be the result of human interference such as removal of beach sediment or the placing of structures on the coast that impede sediment movement.

The extent and causes of coastal erosion in Ireland have been documented in the reports of the Royal Commission on Coast Erosion (1911), the National Coastal Erosion Committee (1992), the Eurosion Study (2004), and most recently in reports prepared as part of the National Coastal Protection Strategy Study being carried out by the Department of Communications, Marine and Natural Resources. The findings of these studies all converge to the same general conclusion, i.e. that about 20% to 25% of the 4,850km of Ireland's coastline is at risk from erosion and that erosion rates vary from a maximum of about two metres per annum on parts of the East coast to near zero at sheltered locations.

Coastal flooding occurs when high tides, surges and wave overtopping combine to inundate coastal areas. Astronomic tides on their own do not give rise to coastal flooding concerns but tide levels are rarely exactly as predicted. The difference between a higher than expected sea level and the predicted astronomic tide level is referred to as a surge. A surge occurs when high onshore winds pile the water up on the coast or when an area of low barometric pressure causes the water level to rise. Surges can originate far out in the Atlantic or they may arise from local meteorological conditions. Surges of varying magnitudes occur frequently around our coasts and generally pass unnoticed. They only come to attention in the infrequent event that they coincide with a high spring tide. This is what happened on the East coast of Ireland in February 2002 when a surge of about one metre coincided with one of the highest spring tides of the year. Spring tides occur every fourteen days around the time of new and full moons when the gravitational pull of the sun and moon are

aligned. Three or four particularly high spring tides occur each year. Many of the large urban centres in Ireland such as Dublin, Cork, Waterford and Wexford are built on the coast and are currently at serious risk of surge based coastal flooding.

Tides and surges on their own generate high still water levels and flood low lying areas by simply flowing onto them. Waves on the other hand, when driven by storms, can batter down coastal defences, erode beaches and dunes, run up sea walls and embankments and flood hinterland areas by overtopping. The effect of these storms is greatly magnified when they coincide with high spring tides and surges.

In terms of economic impact, the threats to Ireland's coast can be ranked in order of importance as coastal flooding in the large urban centres, coastal flooding in other areas, and coastal erosion.

Climate Change Impacts

In the climate change scenarios outlined in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, mean sea level is predicted to rise and the frequency and severity of coastal storms is predicted to increase. These consequences of climate change will significantly increase the risks posed by coastal erosion and coastal flooding. At the end of the 21st century, mean sea level is predicted to be 0.18m to 0.59 m above its current level (IPCC, 2007). For the purposes of this paper a mean sea level rise of 0.4m is assumed. This is a modest increase representing about two to three times the current globally averaged rate of mean sea level rise.

The impact of mean sea level rise on coastal erosion can be estimated using the so-called Bruun Rule (Bruun, 1962) which states that,

$S=a*l/h$

Where S is the coastal cut-back, a is the sea level rise, h is the closure depth and l is the closure distance from shore. The closure depth is the depth at which offshore and nearshore sediment exchange effectively ceases. With typical values on an Irish beach of a closure depth of 10m and closure distance of 1000m, a sea level rise of 0.4 metres will lead to a new equilibrium coastline some 40 metres inland of the current position. The work of eroding back to the new equilibrium line will be done by the larger waves that can approach up to the coastline due to the increased average water depths. Mean sea level rise can thus be expected to accelerate erosion in areas that are currently eroding and initiate erosion in vulnerable areas that are currently in a state of equilibrium.

The Bruun Rule is a very simple representation of what is a very complex process. The actual change in the erosion rate on any coast will depend on the particular circumstances of that coast in terms of its exposure, geology, geometric profile and sediment grading. For example, for the stretch of coast from Dublin to Carnsore Point, Co Wexford which is protected by offshore banks, the increased water depths over the banks will allow increased wave energy to reach the coast and will significantly increase the rate of erosion above that predicted by the Bruun Rule. For the purposes of strategic overview, however, the Bruun Rule is useful and it can reasonably be taken that if the rate of mean sea level rise increases by a factor of two to three then the rate of coastal erosion will increase by two to three times also.

In the case of coastal flooding, adding 0.4m on top of a high spring tide will show no discernable inundation on the coast of Ireland. This simple static analysis is highly misleading, however, as it fails to take into account the impact of mean sea level rise on extreme events. These will be impacted in three main ways by an increase in mean sea level. Firstly, areas that are currently not flooded by an event of a particular occurrence probability will be flooded. Secondly, areas that are flooded to a particular depth will suffer deeper flooding for the same occurrence probability and thirdly, the frequency of flooding at a particular depth will increase dramatically. These of course are all different manifestations of the same effect and can be illustrated using a standard extreme value probability plot. Figure 1 shows a standard plot of flood water levels against annual exceedance probability and return period. This is an actual plot of an analysis of hindcast data from Dublin Bay generated as part of the National Coastal Protection Strategy Study. It can be seen from the plot that a water level of 5.62m has an annual exceedance probability of 1% or a return period of 100 years.

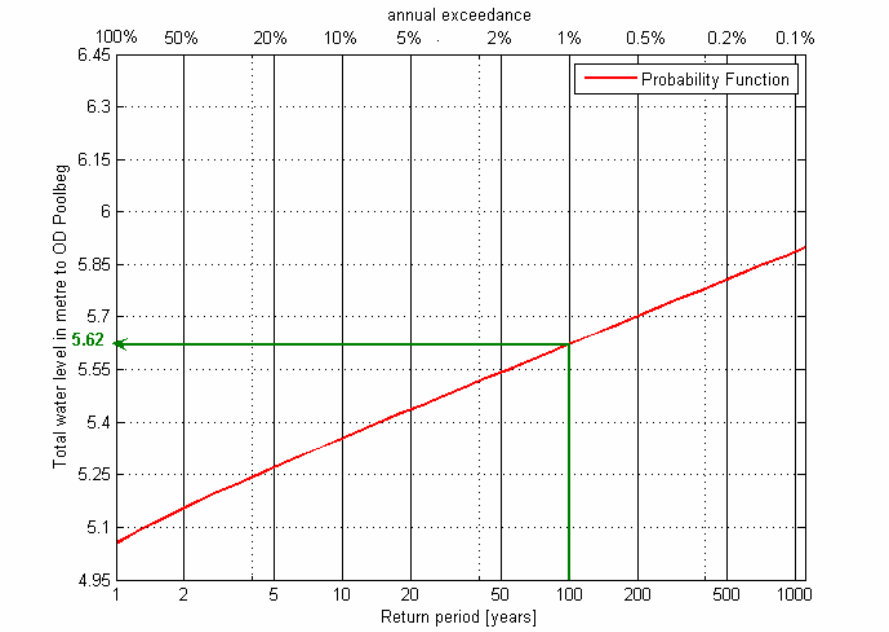

Fig 1: Flood Level Probability Plot

The effect of raising the mean sea level by 0.4m can be examined by simply raising the water level line on this plot by 0.4m. This has been done in Fig 2. It can be seen that at 100 year return period the flood water level is now 6.02m but much more significantly, that the flood level of 5.62m now has a return period of 3.3 years compared to the pre-rise value of 100 years. Thus a modest mean sea level increase of 0.4m has led to a worsening of coastal flooding by a factor of thirty.

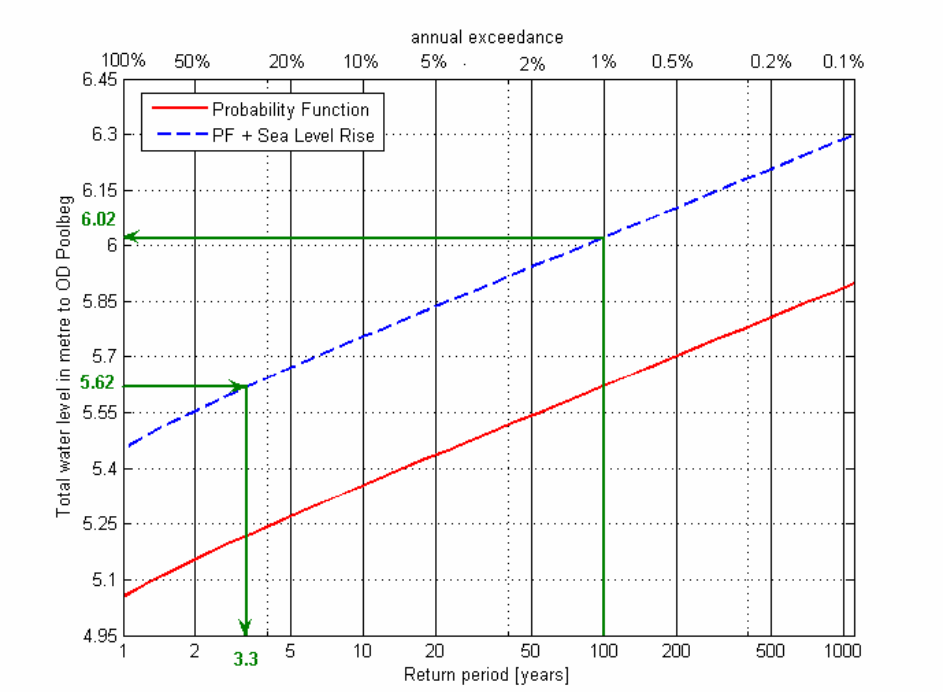

Fig 2: Flood Level Probability Plot with MSL rise of 0.4m

This simple analysis assumes that the underlying surge mechanisms are superimposed unchanged on the higher base level. In fact, it is forecast in the climate change scenarios that storms will increase in frequency and intensity. This effect will increase the probability of occurrence of extreme events, essentially nudging the dashed line to the left and accordingly reducing return periods even further.

The increase in rates of coastal erosion and the increase in probability of coastal flooding, in particular, point towards extremely serious economic implications for Ireland.

Response to Threats-What can be done?

There are quite a number of reasonably modest and measured steps that can be taken now to prepare for the threats to the coast that may emerge in the decades ahead. These are:

Identification and Quantification of Threats.

Down scaling of global analyses to an Irish context is the first step in identifying and quantifying the threats posed by climate change. This work has been ongoing for some time (McWilliams, 1991; Sweeney et al, 2003; Boelens et al, 2005; McGrath et al, 2005 and McElwain and Sweeney, 2006). The next step is the conversion of the downscaled data into impacts on coastal erosion and coastal flooding. This work also has already commenced as part of the National Coastal Protection Strategy Study being carried out by the Department of Communications, Marine and Natural Resources.

Integration of the Erosion and Flooding data into the Planning and Development and National Spatial Strategy Systems.

Integration of the data on coastal erosion and coastal flooding into the Planning and Development and National Spatial Strategy systems is the single most important step

that can be taken now to prepare for the threats posed by climate change to the coasts of Ireland. Permitting development to take place in an uncontrolled way in vulnerable areas will impose unreasonable burdens in relation to coastal protection spending requirements on future generations. That does not mean that all development should be prohibited in coastal areas. Rather it means that development be organised in a fully informed way in relation to existing and reasonable future threats. In this regard the Department of Communications, Marine and natural Resources is working with the Office of Public Works and the Department of Environment, Heritage and Local Government on the preparation of Guidance on Consideration of Flood Risk in Planning and Development management.

Development of Strategies to respond to Threats in Developed areas

There are essentially three approaches to responding to erosion and flooding threats on developed coasts. Defences, such as seawalls, rock revetments or beach nourishment works can be constructed; the threats can be accommodated, for example, by allowing flooding to occur but flood proofing buildings; or the coast can be re-aligned and defended at a more sustainable landward location. The decision on which approach to adopt will have to be taken on a case by case basis with sustainability and economic considerations to the fore but issues such as social cohesion also given serious weight. With limited funding, difficult decisions may arise and it will be important that objective and transparent procedures are in place at a national level for scheme prioritisation.

Development of a Coastal Flood Warning System

Ireland does not currently have in place a system for surge forecasting and for disseminating coastal flood warnings. Thus the flooding that occurred in Dublin in February 2002 largely took all authorities by surprise. Computer models are currently available that, when combined with the good quality meteorological forecasts put out by Met Eireann, can give two to three days advance warning of coastal flooding. These warnings can allow emergency measures to be put in place and can lead to significant reductions in flood damage and social disruption. Identification and development of such a flood warning system is proposed under the National Coastal Protection Strategy Study.

Data Collection, Research and Design Guidance

There are a number of areas that need to be addressed in relation to coastal data collection, research and design guidance. Three priority areas are highlighted below.

A reliable, quality controlled tide-gauge network with a quality controlled data processing and archiving system needs to be established in Ireland. The Marine Institute is currently examining this matter and in 2006 the Department of Communications, Marine and Natural Resources installed a tide-gauge to GLOSS (Global Sea Level Observing System) standard at Castletownbere, Co Cork. A comprehensive network is required to monitor sea level changes and provide data for numerical model calibration and real time feedback to a coastal flood warning system. Such a system would also provide information on tectonic and isostatic movements of the Irish coast.

Research is needed on the identification and quantification of sediment pathways and sediment reservoirs around the Irish coast. Availability of sediment is one of the key factors underlying coastal resilience, that is, the inherent ability of the coast to

accommodate changes such as those induced by mean sea level rise. This research is particularly important in the light of the possibility that marine sediment sources may be sought to replace contracting land based supplies.

Guidance is required for engineers working in infrastructure areas where design event probability may change in an uncertain way over the life of the structure being designed. Flexibility is probably the key in this area but this requires guidance also in relation to, for example, how much design should be incorporated to permit inexpensive retro-fitting if design upgrades are required at a future date.

Disclaimer

This paper was prepared by Dr Gerard Farrell, Chief Engineer, Department of Communications, Marine and Natural Resources, for presentation at a workshop on "Ireland at Risk", for the years 2050 and beyond, to stimulate discussion on the potential issues relating to coastal erosion and coastal flooding. The views expressed are solely those of the author.

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