Final Report

MARINE INUNDATION LEVELS WITH RESPECT TO A HOUSING DEVELOPMENT AT PORTMARNOCK, CO. DUBLIN: CONTEMPORARY AND FUTURE SCENARIOS

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Marine Inundation Levels with Respect to a Housing Development at Portmarnock, Co. Dublin: Contemporary and Future Scenarios

G. Sutton & A.J. Wheeler, Coastal Resources Centre (April, 2000)

Rationale

This study quantifies estimated maximum marine inundation levels affecting a proposed housing development at Strand Road, Portmarnock, Co. Dublin under contemporary and future scenarios. This assessment takes into account potential sea-level rise due to global warming. It is envisaged that potential flooding is primarily from a marine source although freshwater flooding potential is quantified as part of this study. The study has been carried out at the instruction of Steven Brady of O'Connor, Sutton and Cronin (Consulting Engineers) on behalf of their client Mick Breen of South Dublin Construction Ltd.

The study has arisen due to requirements included in a planning application from Fingal County Council:

“ With regard to the proposed surface and water drainage arrangements the applicant is requested to submit the following:
(i) evidence of possible flood levels to include possible projected increase in tide levels in respect of global warming (finished floor levels should be 1.5m above possible flood level).”

The terms of reference for the study are drawn from the contents of a fax forwarded to Stephen Brady from the Coastal Resources Centre, UCC on 14th April 2000:

“Report producing an estimation of maximum tidal elevations for Portmarnock including an assessment of the following components: HAT, extreme surge, significant wave height and sea-level change. Current scenarios will be primarily modelled moving towards future scenarios based on sea-level rise predictive data. This data will be based on extant empirical data sources of a regional context and, where possible, probability statements.”

It should be noted that the information provided herein is based on data from existing recognised and reputable sources. Whilst every effort has been make to ensure the validity and correctness of the information presented no responsibility is taken by the authors for actions taken, nor any consequences arising from the use or application of this information in any form whatsoever.

It should also be noted that many of the values considered are derived or interpolated from nearest available data points. Thus they are indicative values of likely conditions pertaining in the vicinity of the site rather than representing site specific conditions which would have to be obtained from an extensive period of direct field observations and locally validated high resolution hydrodynamic model.

This final report post-dates a draft report that was submitted to the client. The draft report is a specifically edited version of this report requested by the client to fulfil
their needs with respect to the planning application. This final report is a more comprehensive assessment of the risk-of-flooding at the site.

**Contemporary Tidal Elevations**

To the best of our knowledge, no direct tidal measurements are available at Portmarnock of a significant duration to enable the generation of predicted tidal harmonics or derived tidal variables. Tidal levels at Portmarnock have therefore been extrapolated from the nearest reliable datasets (Admiralty, 2000). These are presented in Table 1 in Chart Datum, note Highest Astronomical Tide levels have not been derived for Howth.

<table>
<thead>
<tr>
<th>Location</th>
<th>MHWS</th>
<th>MHWN</th>
<th>MLWN</th>
<th>MLWS</th>
<th>MSL</th>
<th>HAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dublin</td>
<td>4.10 CD</td>
<td>3.40 CD</td>
<td>1.50 CD</td>
<td>0.70 CD</td>
<td>2.41 CD</td>
<td>4.5 CD</td>
</tr>
<tr>
<td>Howth</td>
<td>4.10 CD</td>
<td>3.30 CD</td>
<td>1.30 CD</td>
<td>0.50 CD</td>
<td>2.34 CD</td>
<td>no data</td>
</tr>
<tr>
<td>Malahide</td>
<td>4.20 CD</td>
<td>3.20 CD</td>
<td>1.10 CD</td>
<td>0.50 CD</td>
<td>2.30 CD</td>
<td>4.7 CD</td>
</tr>
</tbody>
</table>

Portmarnock* 4.10 CD | 3.30 CD | 1.40 CD | 0.60 CD | - | 4.6 CD |

* all predictions for Portmarnock are interpolations (see text)

MHWS: mean high water springs  MHWN: mean high water neaps
MLWS: mean low water springs  MLWN: mean low water neaps
MSL: mean sea-level  HAT: highest astronomical tide

**Table 1. Tidal statistics for relevant ports in chart datum derived from the Admiralty Tide Tables (Admiralty, 2000).**

Chart datum is fixed at each port with respect to estimated lowest tidal levels and is therefore variable around the country. Relationships between chart datum and Ordnance Datum are presented in Table 2 based on conversions presented in the Admiralty Tide Tables (Admiralty, 2000).

<table>
<thead>
<tr>
<th>Port</th>
<th>CD relative to OD (Poolbeg)</th>
<th>CD relative to OD (Malin)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dublin</td>
<td>0.20m ODP</td>
<td>-2.51m ODM</td>
</tr>
<tr>
<td>Howth</td>
<td>0.20m ODP</td>
<td>-2.51m ODM</td>
</tr>
<tr>
<td>Malahide</td>
<td>0.43m ODP</td>
<td>-2.28m ODM</td>
</tr>
</tbody>
</table>

**Table 2. Relationship between Chart Datum and Ordnance Datum for relevant ports derived from the Admiralty Tide Tables (Admiralty, 2000).**

Table 3 presents the tidal statistics for relevant ports and interpolations for Portmarnock in OD (Malin) based on the contents of Table 1 & 2.

Predictions for Portmarnock are interpolated from trends in tidal statistics heading northwards from Dublin to Howth to Malahide. Portmarnock exists between Howth and Malahide. Dublin and Howth have comparable tidal levels although a rapid increase in tidal levels is experienced immediately north of Howth (Dept. of Energy, 1990). The value of 2.20m ODM for HAT at Portmarnock is therefore seen as a reasonable estimate of HAT based on available data.
<table>
<thead>
<tr>
<th>Location</th>
<th>MHWS</th>
<th>MHWN</th>
<th>MLWN</th>
<th>MLWS</th>
<th>MSL</th>
<th>HAT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dublin</td>
<td>1.59m</td>
<td>0.89m</td>
<td>-1.01m</td>
<td>-1.81m</td>
<td>-0.10m</td>
<td>2.0m</td>
</tr>
<tr>
<td>Howth</td>
<td>1.59m</td>
<td>0.79m</td>
<td>-1.21m</td>
<td>-2.01m</td>
<td>-0.17m</td>
<td>no data</td>
</tr>
<tr>
<td>Malahide</td>
<td>1.92m</td>
<td>0.92m</td>
<td>-1.18m</td>
<td>-1.78m</td>
<td>0.07m</td>
<td>2.4m</td>
</tr>
<tr>
<td>Portmarnock*</td>
<td>1.70m</td>
<td>0.85m</td>
<td>-1.20m</td>
<td>-1.95m</td>
<td>-</td>
<td>2.2m</td>
</tr>
</tbody>
</table>

* all predictions for Portmarnock are interpolations (see text)

Table 3. Tidal statistics for relevant ports in Ordnance Datum (Malin).

**Contemporary Surge Levels**

Tidal levels exist between high and low astronomical tidal level (HAT and LAT) and are regular and predictable. In comparison, storm surges are meteorologically generated and therefore irregular. When superimposed on top of tidal levels, surges can give rise to total still water levels above HAT and below LAT (in the case of negative surges).

The probable indicative 50-year return positive surge value for the Portmarnock area can be taken at **c.1.0m**. This value is based on results from numerical storm surge model adjusted to fit the values derived from observations at reference ports (Dept. of Energy, 1990). This value is also consistent with that supplied by Patrick Opdebeek of John Moylan and Assoc. for developments at Malahide, which was sourced from a Dept. of Marine & Natural Resources hydrodynamic model.

**Coupled Tide and Surge predictions**

A consideration of worse-case marine flooding scenarios for Portmarnock includes the possibility of a large surge coincident with a spring tidal. The 50-year return maximum and minimum total still water level can be estimated from the spring tidal amplitude (STA), the 50-year return storm surge elevation, and factors for reference ports (E50) where the statistical relationships have been established.

The following E50 values have been calculated for the following ports:
- Fishguard =1.11
- Malin Head =1.04

On this basis, a reasonable weighted average of E50 for Ireland’s mid-east coast based on the above values might be **1.07**.

The following calculation for gives an indicative combined surge and tidal value relative to MSL at Dublin:

50-year return max. still-water level = E50 x (STA + 50-year return surge elevation),
then,

50-year return max. still-water level = 1.07 x (1.7+1) = 2.89 (m above MSL).
Since MSL Dublin is -0.1m ODM, then,

50-year return max. still-water level = \textbf{3.22 ODM}.

\textit{Contemporary Significant Wave Height}

Portmarnock exists at the head of a sheltered inlet protected from the open sea by a beach and dune complex that is currently utilised as a golf course. The embayment behind the dunes is c.2.5km in length from the head of the embayment to the opening with the Irish Sea. The embayment trends NNE-SSW and is open to the SSW. To our knowledge, no wave data has been collected from the site of a significant duration to allow estimates of maximum wave heights that may occur over the lifetime of the development.

The potential maximum wave heights that could affect the site are dependent to varying degrees on the contribution of swell in the Irish Sea and the effects of internal wind-wave fetch from within the embayment. A consideration of both of these components is necessary before qualified statements on significant wave height components effecting the site can be made.

\textbf{External significant wave height controls}

An assessment of significant wave height having a 50-year return period ($H_{s50}$) affecting the Portmarnock open coast area is used in this discussion. Significant wave height is the average value of the height of the highest one third of all the crest-to-trough wave heights in a sample or more specifically four times the root-mean-square surface elevation. This is more meaningful that maximum wave elevation which include so-called “freak waves” whose return period is extremely long.

Based on interpolated data for the Irish Sea, $H_{s50}$ for the Portmarnock open coast area c.8m (Dept. of Energy, 1990; Draper, 1992). These interpolations are based on empirical data of which the nearest station is the Kish Lighthouse. Estimates for maximum wave height ($H_{\text{max}}$) for the Irish Sea range from 8 to 15m (Devoy, 2000).

It should be noted that these estimates are values that would be expected if the effects of a detailed bottom bathymetry were unimportant. In the context of Portmarnock, the effects of refraction, reflection, shoaling and wave breaking need to be considered. It is probable that most of the swell wave effecting the site during extreme events would be dissipated although it is anticipated that some component would reach the site. The magnitude of this component is speculative and could be conservatively estimated at 10% of $H_{s50}$. The reliability of this estimate is based on judgement rather than any detailed modeling of the bay.

Estimated external wave component over 50-year return period = 0.80m

\textbf{Internal significant wave height controls}

As well as the influence of external waves entering the embayment, a significant component of the wave energy affecting the site can be produced internally within the fetch of the embayment.
Wind statistics are presented in Table 4 from the nearest major weather station at Dublin Airport.

<table>
<thead>
<tr>
<th>Wind Statistic (Dublin Airport)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum wind speed (gusts) in 50-year return period</td>
<td>38.6 ms(^{-1})</td>
</tr>
<tr>
<td>Maximum 10 minute gust mean (1962-1984)</td>
<td>25.2 ms(^{-1})</td>
</tr>
<tr>
<td>Monthly mean wind speed (23-year return period)</td>
<td>6.3 ms(^{-1})</td>
</tr>
<tr>
<td>Percentage winds from SE</td>
<td>12.3%</td>
</tr>
<tr>
<td>Percentage winds from SE &gt; 10.8 ms(^{-1})</td>
<td>1.4%</td>
</tr>
</tbody>
</table>

Table 4. Wind statistics from Dublin Airport (Rohan, 1986).

From the above statistics, a significant maximum wind speed blowing from the SSE blowing for a duration capable of fulfilling maximum wind-wave heights potential is estimated at 30 ms\(^{-1}\). This figure was estimated on the basis that wind speeds from Dublin Airport for the SE are probably lower than those experienced on the open coast. Mean omnidirectional wind strengths for the Irish Sea are 38.6 although very few strong winds (1.4%) blow from the SE. The Portmarnock site is open to winds from the Irish Sea which may be funneled onto the site as they deflect around Howth. Finally, omnidirectional. The maximum internal fetch that can effect the site is c.3km with waves generated by a wind blowing from the SSE.

Significant wave height that can be internally generate can therefore be calculated from the following equation:

\[ H_{s50} = 0.02013 X^{0.55} U^{0.90} \]

where X = fetch in km, and U = wind-speed in ms\(^{-1}\)

Therefore,

\[ H_{s50} = 0.0213 \times (3)^{0.55} \times (30)^{0.90} = 0.83\text{m} \]

Estimate of significant wave height at the site including both internal and external input = 0.80 + 0.83 = 1.63m

These statistics are derived from datasets collected over the preceding decades and do not necessarily reflect accurate statistics for 2000 AD. Furthermore, future predictions of wave statistics under global climate change scenarios need to take account of changes in the frequency and intensity of storms. It is anticipated that Ireland wave climate will worsen (Devoy, 2000).

**Contemporary maximum marine water levels**

Estimates of maximum contemporary tidal levels include the components of astronomical tide, surge effects and wave height. Surge and tide have been statistically integrated based on the probability of a joint-occurrence. Estimates for significant wave height affecting the area have been generated although a probability
of joint occurrence cannot be calculated. It is assumed that maximum water levels will occur when integrated maximum tidal and surge coincide with estimated significant wave height.

Estimated maximum contemporary marine water levels = \(2.79 + 1.63 = 4.42\text{ m ODM}\)

**Global Warming and Relative Sea Level (RSL) Rise**

The following values for a nominal rise in sea-level based on global warming scenarios are presented. These values are based on the work of the Intergovernmental Panel on Climate Change (IPCC) and EU groups (1995-1998) which show scenarios for relative sea-level (RSL) rises of between c.4cm (low estimate) – c.40cm (high estimate) by 2050 for Atlantic Europe, for a CO\(_2\) doubled climate warming. This translates to an increase in the rate of RSL rise to values of c.4-6mm/year by c.2050 (Devoy, 2000).

Analysis of tidal records for the Irish Sea show rising RSL levels of 1.0 +/- 0.15mm year\(^{-1}\) in the last few years. However, this doesn't include the future likely impact of global warming. In considering future scenarios for design purposes in relation to inundation potential, some estimate of the potential rates of change of these values can be taken into account. Depending on the length of records to be considered the potential rate of increase varies from no acceleration (records from this century only) to 0.4 mm yr\(^{-1}\) if longer-term records are included.

It is considered likely that in the next 100 years there may be oscillatory changes in the rate of sea level rise based on the impacts of global warming. Results of modeling studies (GCM climate-ocean coupled models, for standard CO\(_2\) forcing; mid-scale/business-as-usual) give results of a rise in RSL of 8mm yr\(^{-1}\) (0.4m) by 2050.

Combining the current standard rate for the Irish sea of 1.0mm yr\(^{-1}\) with the latter values gives a best-estimate appraisal under probable likely scenarios for Irish Sea coasts of 5-9 mm yr\(^{-1}\) rise in RSL during the next century (Devoy 1999). These are in broad agreement with the range of values shown in Table 5.

<table>
<thead>
<tr>
<th>Source</th>
<th>Estimates RSL rise 1990-2030 (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
</tr>
<tr>
<td>Climate Research Unit, University of East Anglia.</td>
<td>76</td>
</tr>
<tr>
<td>Milkolajewicz et al.</td>
<td></td>
</tr>
<tr>
<td>Europe only</td>
<td></td>
</tr>
<tr>
<td>All recent estimates</td>
<td>49</td>
</tr>
</tbody>
</table>

*Table 5. Estimates of relative sea level rise (1990-2030) in mm as output from various models (source: P. Opdebeek, John Moylan & Associates).*

To examine how these figures might relate to water levels at Portmarnock, Table presents a number of scenarios based on simple extrapolation of the values discussed above. Taking HAT as 2.2 ODM and a median rate of 7mm yr\(^{-1}\) the following
simplified projections are possible. However it should be noted that the effects of rise in RSL may impact on tidal range and Chart Datum in ways that cannot be predicted at present.

<table>
<thead>
<tr>
<th>Time period (years)</th>
<th>Estimated value of HAT including a projected RSL rise of 7mm yr$^{-1}$</th>
<th>Estimated values of maximum marine inundation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>2.27 m ODM</td>
<td>4.49 m ODM</td>
</tr>
<tr>
<td>20</td>
<td>2.34 m ODM</td>
<td>4.56 m ODM</td>
</tr>
<tr>
<td>30</td>
<td>2.41 m ODM</td>
<td>4.63 m ODM</td>
</tr>
<tr>
<td>50</td>
<td>2.55 m ODM</td>
<td>4.77 m ODM</td>
</tr>
</tbody>
</table>

* includes RSL, HAT, significant wave height and surge

Table 6. Estimated maximum marine inundation levels under global warming induced relative sea-level rise.

Other relevant implication of global warming
Under a global climate warming scenario, natural impact of wave action in coastal change is likely to worsen. It is therefore important to consider the effects of global warming on significant wave height. Results of recent studies of storms affecting European Atlantic coasts (EU Environment Programme project, Storminess) show a significant pattern of changes over the last c.40 years. The number and frequency of storms recorded in the North Atlantic have followed a quasi-decadal (8.5 years) cyclical sequence of increases and decreases, with storms increasing particularly in number in the late 1980s - early 1990s (Fig.1).


This pattern correlates strongly with cycles in the North Atlantic Oscillation (NAO) – regional pressure anomaly index, which overall has intensified progressively during this period. In spite of this distinctive pattern of periodic increases in storminess, the longer-term trend in the North Atlantic has been for a small but progressive decrease
in storm numbers (Fig. 1). However, at the inter-annual level the storms have become seasonally more polarised. For Irish western coasts the records show more intense individual storms, with storms concentrated increasingly in the winter months, followed more generally by quieter summers.

Comparing these storminess trends based upon observed data with the outputs from ocean – atmosphere coupled models (the ECHAM 4A GCM was used in the Storminess project work), shows a strong degree of agreement with the modeled patterns for this period. Predictions from the models for future storm changes under climate warming to 2030 shows a continuation of these established trends. Whilst storm frequency is likely to continue to reduce for Ireland, and with a slight northward shift in storm tracking, the magnitude of individual storms will continue to increase. The significance of this at the coast will be in the impact of destructive individual storms upon the environmental thresholds maintaining coastal stability. These model predictions are consistent with other GCM studies for climate warming scenarios (Sweeney, 1997).

If this expected increase in storm size is linked to an accelerating background sea-level rise under climate warming, then the implication for coastal flooding is clear. Marine generated coastal flooding under storm conditions is likely to become more common. The principle involved is simple: bigger storms mounted on top of a rising sea level will be able to reach higher against the land surface.

More important than direct marine inundation may be the repercussions of storm changes on rainfall distribution, affecting throughputs of water in river catchments, leading to impacts upon seasonal water budgets and flooding inland. Sweeney (1997) states, “all GCM models predict higher annual precipitation in the high and low latitudes and higher winter precipitation in mid latitude locations such as Ireland”. Analysis of precipitation data for Ireland with GCM outputs indicates that average winter precipitation is likely to increase by 5-10% for 2050, whilst average precipitation in summer may decrease by similar amounts (5-15%). A projection of the regional distribution of these seasonal variations in precipitation is more problematic. This level of detail (for Ireland) hasn’t yet been resolved from GCM work, though analysis suggests that eastern Ireland will experience the greatest reductions in summer rainfall. It is possible, given the seasonal changes in the positioning and extent of the controlling pressure systems over Europe under climate warming, that cyclonic and easterly derived storms for Ireland will result in increased average rainfall over southern and eastern areas; the details remain unclear though.

**Relationship between marine inundation levels and flooding at the site**

Estimates have been presented that suggest values for maximum marine flood levels that can be calculated to the best of our ability based on data and interpolation tools available. Within the context of the proposed building development, the area proposed exists behind raised sea defences which also carry roads. The ability of the site to be flooded therefore depends on the capability of the sea defences to withstand these levels.
Based on recent leveling at the site (O’Connor Sutton Cronin, pers. comm) the minimum height of these defences is c.2.30m ODM. Behind the sea defence is raised land at c.2.90m ODM that offers further protection to the site. Should this rise in land be breached then flooding will continue up the stream by the edge of the site. Most of the site is situated above c.3.30m ODM but the lowest levels of the site are at c.2.50m ODM. Based on the above assessment, the risk of over-topping of the defences under a worst-case scenario would seem probable and some flooding of the field adjacent to the site is possible. This statement however does not take into account the robustness of the defences to withstand coastal erosion under present or projected conditions. Increased flooding risk for the site may also result from a reduction in the area of free-draining land caused by the development itself.

The actual flooding levels at the site are not only dependent on flooding inputs but also on the ability of the site to drain away flood waters that could become ponded behind the sea defence. This is primarily dependent on the efficiency of sluiced drain near to the site, which is only operational at low tide, as well as ground permeability and evaporation rates.

**References**


