

Galway Harbour Extension Project

Strategic Infrastructure Development

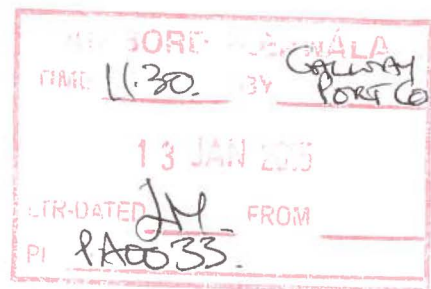
**An Bord Pleanála
Oral Hearing**

Marine Hydrology and Flooding

Brief of Evidence

**of
Anthony Cawley**

January 2015



1. QUALIFICATIONS AND EXPERIENCE

- 1.1 My name is Anthony Cawley. I am an engineering hydrologist and managing director of Hydro Environmental Ltd which is a small specialist hydrological and environmental engineering consultancy company based out of Galway. I specialize in advanced hydrodynamic and dispersion modelling of coastal, estuarine and riverine receiving waters with over 25 years experience in this field. I hold an honours bachelor degree in Civil Engineering and a Post-graduate Masters Degree in Engineering Hydrology from NUI Galway. I am a chartered member of Engineers Ireland. I am a visiting lecturer at the University of Limerick and teach the undergraduate hydrology course to engineering students and supervise in related projects and research in this area.
- 1.2 I have been involved in numerous flood risk assessment and coastal processes studies over the past 25 years with a sample of the more recent and relevant projects are listed as follows:
- ☐ 3D Hydraulic Assessment of the Abbey Weir Navigation scheme on the Shannon Estuary in Limerick for Waterways Ireland (2012 -2013).
 - ☐ Coastal Processes Consultant to An Bord Pleanála on strategic infrastructure projects for the Dublin Port Gateway project (2011) and the Alexandra Basin Redevelopment Project (2014).
 - ☐ Coastal Processes modelling of the Dublin Array (145 Turbine) Offshore Wind Farm project on Kish and Bray Sand Banks in the Irish Sea (2012) involving hydrodynamic, wave climate and sediment transport assessments.
 - ☐ Hydrodynamic and Sediment transport modelling of maintenance dredging proposals for Dunmore East Harbour, Kilrush Creek Marina, Wicklow Harbour, and Fenit Harbour (2013 and 2014).
 - ☐ Narrow Water Bridge Hydraulic model of Carrlingford Lough and the Newry Estuary to predict the impact of a proposed Cable Stay bridge and piled fender protection system on hydrodynamics and sediment transport. (2013)
 - ☐ 2D and 3D Hydrodynamic and dispersion study of the Shannon Estuary for Limerick Main Drainage Scheme Effluent Discharge and an Oil Spill model for Shannon Foynes Harbour) (2010-2012),
 - ☐ Thermal Plume Modelling of the Aghada Combined Gas Power Plant at Whitegate Cork Harbour 3D Hydrodynamic study (2004) and the LNG proposed thermal discharge to the Shannon Estuary using 3-D Baroclinic hydrodynamic and dispersion modelling (2012).
 - ☐ 2D Hydrodynamic and dispersion study of the Fergus Estuary and Lower Reach for a proposed New Outfall for the Ennis Main Drainage Scheme (2002 and 2010) and for the Fergus South Flood alleviation scheme (2013-2014).
 - ☐ Hydraulic modelling and Scour assessment of Arklow Bridge as part of a flood alleviation scheme for Arklow (2011-2013)
 - ☐ cFRAM Flood modelling and flood risk mapping of Avoca River, estuary and coastal waters including wave climate, tidal surge and Fluvial Flooding for the OPW cFRAMs (2014).
 - ☐ A wide range of flood risk assessment projects throughout Ireland and a number in the UK involving hydraulic, hydrodynamic and Wave Climate modelling.
 - ☐ Expert Flood Hydrology Witness to ESB in respect to the November 2009 River Lee flooding of Cork City in current High Court proceedings between UCC v ESB Record No:-2012/129 P

- 1.3 I have been involved in a number of relevant projects in Galway Bay that include Flood Risk Assessment of Southpark, Claddagh Galway City (2008) commissioned by Galway City Council, Mutton Island Sewerage Scheme Outfall Hydrodynamic and Dispersion modeling (2000), Mutton Island Marine Outfall Design (2002), Water Quality Modelling of Kinvarra Bay for the proposed Kinvarra Sewerage Scheme (2002 and 2005) and a number of Wave Climate modeling studies in Galway Bay for site specific Flood Risk Assessments at Oranmore, Spiddal, Cashla Bay and the Aran Islands (Inismore and Inish Meain).

2. INVOLVEMENT IN THE PROJECT

- 2.1.1 I have been part of the Galway Harbour project team since January 2011 bringing coastal process and hydrodynamic modelling related expertise to the project. These hydrodynamic modelling studies have not only fed into the EIS and NIS assessments but also have fed directly into the engineering design that has led to the final Harbour configuration, which is the subject of this oral hearing. Results from the wave climate, hydrodynamic and flood analyses have been used in the design of the various breakwaters, setting of quay wall heights and finish floor levels within the harbour development.
- 2.1.2 I was responsible for carrying out the marine hydrology / coastal processes assessment presented and described in Chapter 8 of the EIS and I am the author of this Chapter.
- 2.1.3 I evaluated the potential impact of the proposed harbour development on the coastal processes of Galway Bay, which included hydrodynamics, salinity, pollutant transport and dispersion, water quality, wave climate, sediment transport and morphology (bed evolution) and coastal and estuarine flooding using advanced computational modelling techniques.
- 2.1.4 The computational modelling was undertaken using the TELEMAC hydrodynamic modelling software programs. TELEMAC was developed originally by the French Electricity Board (EDF) and this software is now under the directorship of an international consortium of organisations including EDF, HR Wallingford, SOGREAH, BAW, ARTELIA and CETMEF. TELEMAC is regarded as one of the leading software packages for free surface water hydraulic applications with thousands of installations of the software worldwide.
- 2.1.5 The study program included
- Fieldwork comprising bathymetric surveys, salinity surveys, water quality surveys, Geotechnical surveys, sediment sampling and analysis and tidal hydrographic surveys to support and develop the computational hydraulic models.
 - Review and compilation of relevant datasets and previous coastal and flood risk studies within the Galway Bay Study Area, including the OPW cFRAMS and the ICPSS studies.

1 cFRAMS – catchment Flood Risk Assessment and Management

2 ICPSS – Irish Coastal Protection Strategic Study

- Development of two-dimensional and three-dimensional hydraulic models of Galway Bay from west of Spiddal on the Galway Coastline and Black Head on the North Clare Coastline inshore to Oranmore. Development of Wave Climate models both large scale coarse mesh and local refined models. The large scale model extends out into the deep Atlantic waters, well west of the Aran Islands.
- Hydrodynamic model simulations of the spring and neap tidal flow regime for existing and proposed (with development) cases under different river inflow and wind conditions, including extreme flood/storm conditions, predicting velocities, depths and bed shear stresses.
- Sediment transport modelling of the proposed capital and maintenance dredging works relating to the navigational channels and the commercial port area, turning circle area and the Fisherman's Quay under varying hydrodynamic conditions.
- Model Simulations of Wave Climate under range of storm conditions local and offshore.
- Model Simulations of the transport, dispersion and fate of the existing Mutton Island outfall and the proposed East Galway sewage outfall under normal and adverse tide and wind conditions, so as to assess the potential impact of the development on the performance of these outfalls and the potential impact on the Water Quality status of inner Galway Bay.
- Morphological simulations of the sediment regime within Galway Bay under tidal flows, river inflows, wind and wave climate varying conditions.
- 3D Baroclinic dispersion modelling of salinity in Inner Galway Bay and the impact of the Development on salinity in Lough Atalia and Renmore Loughs, which are classified as lagoonal habitats.

And finally :

- Flood Risk Assessment of the Harbour development in accordance with the Flood Risk Management Planning Guidelines (2009).

3. SUMMARY OF FINDINGS

- 3.0.1 The findings from the marine hydrology coastal processes assessment can be summarised as follows:

3.1 Hydrodynamics

- 3.1.1 The hydrodynamic modelling predicts a deflection to the west of the ebbing (outgoing) and flooding (incoming) flows of both the tidal and combined freshwater stratified surface flow from the Corrib Estuary. These deflected flows follow the north-south orientation of the new dredge channel to the docks. Immediately to the

east of the development due to the deflection of the Corrib outflow, significantly reduced hydrodynamic conditions are predicted in these more sheltered waters northwards between Hare Island and the harbour extension. There is a predicted slight local increase in tidal velocities past the head of the new proposed southern breakwater to the new commercial port adjacent to Hare Island.

- 3.1.2 The impact on flow velocities inside (upstream) of Nimmo's Pier namely, in the approaches to the Docks, Claddagh basin and Lough Atalia as a result of the development is predicted to be negligible.
- 3.1.3 In the greater bay area to the west of Mutton Island and to the east of Hare Island the effect of the proposed harbour development on tidal hydrodynamics is shown to be negligible.
- 3.1.4 In the vicinity of Mutton Island the ebbing tide and the seaward flowing freshwater surface plume take a slightly more northerly route closer to Mutton Island than the existing undeveloped case due to the westward deflection by the harbour of the Corrib outflow. The impact of this on sediment transport is found to be imperceptible but will deflect the sewage plume from the Mutton Island Outfall slightly more northwards on the flooding tide. Similar initial mixing and outfall dilutions are achieved under existing and proposed development cases for the Mutton Island outfall and the proposed East Galway Outfall.

3.2 Wave Climate

- 3.2.1 Wave climate modelling was carried out to examine the exposure of the proposed development and assist in designing the required breakwater protection for the commercial port area, the Fisherman's Pier and the proposed Marina Area. The wave climate analysis using both spectral and Boussinesq wave models focused on all onshore wave directions from the West through South to East in respect to determining the maximum design wave magnitude along the proposed development and along adjoining shoreline areas.
- 3.2.2 The wave results show that the most exposed section of the development is along the southern breakwater with Atlantic storms from the south-westerly sector (principally SSW, SW, and WSW) capable of diffracting and refracting around Mutton Island to make contact with this breakwater. This is also shown to be the case for the present day existing scenario (i.e. without development). The eastern shoreline of the development (i.e. Commercial Port and Fishermans quay area) is shown to be only exposed to local wind waves from the east to southeast direction. The harbour breakwater protection is not designed to protect the commercial port or the fisherman quay from such wave directions.
- 3.2.3 The western side of the proposed harbour which includes the marina entrance, breakwater and approach channel to the existing Galway Docks is sheltered from local wind waves from the east and southeast sectors. This section remains slightly exposed to local wind waves from the south to southwest sector and Atlantic swell waves from the southwest to west sector diffracting around Mutton Island. The wave climate study shows that the Mutton Island causeway affords great protection to the proposed development against Atlantic Storm Waves. The analysis shows that even under extreme highwater tide conditions when the causeway is underwater it will act as a submerged breakwater, breaking and significantly dissipating the larger Atlantic waves that propagate West and WNW over the causeway towards the Harbour Area.

- 3.2.4 The predicted wave heights from the wave climate simulations have been used to inform the design of the various sections of breakwater protection. The breakwater protection varies in height based on wave climate modelling results with crest level for the southerly breakwater having an elevation of 9.1 to 10.1m O.D. which provides circa 5m wave protection above an extreme storm surge highwater tide level. The westerly breakwater has crest levels of 6.35 to 6.65m O.D. which are sufficient to minimise the risk of overtopping from extreme storm waves combining with extreme high tides along this westerly section of breakwater.
- 3.2.5 The wave climate simulations show that the proposed harbour development impacts only the wave climate environment local to the development through a combination of sheltering via dissipation and reflection off its breakwaters out to sea and diffraction and refraction of the wave field around the development and over the dredged channels. The proposed development is shown to shelter the eastern section of the development and the adjacent Renmore shoreline including Renmore Lough, Ballyloughaun Beach and its westerly headland area against storms from the south to southwest sector. The proposed development protects the Galway Docks entrance and much of the Southpark shoreline against wind waves from the southeast and east directions. Under the existing case the southeast direction generates the highest wave heights at these locations.
- 3.2.6 The wave simulations show that under south and south westerly storm events the wave heights are slightly increased along the south face of Nimmo's Pier and with maximum increases of less than 0.15m predicted at Nimmo's Pier and 0.05m at the adjacent section of Southpark shoreline immediately to the west of the pier. These waves are directed onto a raised shoreline area (entrance to the Walkway at Nimmo's Pier) and a pier wall and across the Corrib channel as opposed to running up along it and will not give rise to any perceptible increase in the flood inundation of Southpark or the Claddagh Quays area. It is noteworthy that these storm directions do not produce the most significant wave heights at this location with the wave modelling showing that the largest waves are produced by wind waves from the SSE and SE Sectors and that the proposed development will significantly shelter this area from such wave directions.
- 3.2.7 The wave simulations show that this increased wave activity in the vicinity of Nimmo's Pier will not impact wave heights within the inner Claddagh Basin area. A positive impact, resulting in reduced wave height and reduced potential for flooding is predicted for the Claddagh Basin as the critical southeast direction which allows wind waves to propagate up the Claddagh Basin against the River Corrib current will also be sheltered by the proposed development.
- 3.2.8 Additional Wave Climate modelling using the SWAN Spectral Wave model in response to the RFI to assess the significance of the change in tidal currents by the proposed harbour development on the resultant wave field showed that the only area of significant wave height change (increase) due to the refraction effect by the opposing Corrib Surface currents was in the proposed navigation channel near the proposed marina entrance. No increase in wave heights by current refraction effects were predicted either inshore at the Nimmo's Pier, Corrib entrance or along the Southpark and Renmore shoreline areas.
- 3.2.9 The Swan model showed slightly higher wave heights of 0.1 to 0.2m along the shoreline areas over the ARTEMIS model due to its ability to simulate local wind wave growth within the model domain. In terms of impact by the proposed development both models generally agree showing small increases in wave heights at Nimmo's Pier section under Atlantic storm directions SSW to WSW and similar sheltering effects for the respective shorelines for the other directions.

3.3 Sediment Transport and Morphology

- 3.3.1 The implications of the development on sedimentation are shown to be minor in respect to impacts from erosion and deposition by tidal flows. The main changes in shear stresses were found to occur along the proposed new dredge channel to Galway Docks and past the head of the southern breakwater protecting the proposed commercial port. The model results show that the proposed development produces shear stresses during spring tides sufficient to erode fine silt and fine sands in these areas. This is considered desirable in respect to maintaining the dredge channels. The simulations show no erosive impact elsewhere as a result of the harbour development and the capital dredge.
- 3.3.2 Under River Corrib flood conditions, the proposed development restricts the area of the erosive flow to the proposed new navigation channel to the Docks. This is considered beneficial in respect to potentially reducing the dredge maintenance requirement as it will mobilise the finer silts and sands laid down during low flow conditions and deposit same to the south of the harbour.
- 3.3.3 The impact of capital and maintenance dredging activity on suspended solids and sediment deposition was assessed using a three dimensional sediment plume model. In addition to the calculations presented in the EIS Section 8.4.2.8 which assessed a dredging rate of 3500m³ per day further sediment transport simulations have been carried out for the peak suction dredging rate of 17000m³ per day which is presented in the EIS addendum. These simulations also include the proposed mitigation measure of restricting dredging in the proposed new Dock navigational channel to the ebbing tide.
- 3.3.4 These model simulations show sediment deposition to be generally localised close to the dredging location. The simulations show that the suspended sediment concentrations are only significantly elevated above background in the immediate vicinity of the dredging works area with the plume enjoying good dispersal and dilution with the tidal flow.
- 3.3.4 Under larger river flows, the sediment plume generated within the Docks navigation channel dredge works will have greater dispersal out to sea resulting in lower more dilute sediment plume concentrations.
- 3.3.5 Simulations show that the sediment plume can enter Lough Atalia from both capital and maintenance dredging activities associated with the new navigation channel to the docks. The critical hydrodynamic conditions for sediment entering Lough Atalia are Spring tides and low Corrib Flow conditions. Mitigation to protect Lough Atalia involving the confinement of dredging activities to the outgoing ebbing tidal flow is proposed for the dredging activities associated with the Marina and Docks navigation channel. Monitoring at the entrance to the Lough Atalia channel will be undertaken during the dredging campaigns to ensure that dredging during ebbing flow is controlled and ceases sufficiently in time before the returning flood flow can discharge directly the dredge sediment plume into Lough Atalia.
- 3.3.6 No mitigation measures are required for the main commercial harbour approach channel, turning circle and berths to the east and south of the Development as the suspended sediment disperses quickly due to the open sea location and the inability of the plume to be directly transported to the Corrib entrance and up into Lough Atalia on the subsequent flood tide.
- 3.3.7 The potential impact of suspended solid concentrations from the proposed dredging activity will, except locally to the dredging works area, achieve salmonid water standards for suspended solid concentration.

3.4 Flood Risk

- 3.4.1 A Flood Risk Assessment (FRA) was undertaken in accordance with the Planning System and Flood Risk Management Planning Guidelines (Nov 2009) for the proposed Harbour Development.
- 3.4.2 Model simulations have been undertaken to determine any change to the flood risk associated with neighbouring areas of Southpark, the Claddagh, Spanish arch, Salthill, Renmore and the Docks area.
- 3.4.3 The assessment shows that the potential source of flood risk to the development and the neighbouring areas is primarily from coastal flooding. This coastal flooding is produced by tidal storm surges and exacerbated by combined effects of wave climate and River Corrib flood flows.
- 3.4.4 The assessment shows that critical maximum flood level for the development and neighbouring areas is produced by a tidal storm surge event. The estimated 200year flood level is 4.146 m O.D. Malin (200year tide with inclusion for statistical error plus twice the statistical standard error)). It should be noted that the recent storm Surge Levels observed in early 2014 achieved a maximum water level of 3.56 to 3.59m O.D. Malin. A medium range climate change scenario of a sea level rise of 0.5m over the next 100years increases the 200year flood level to 4.635m. Both existing and future flood levels inundate a large portion of the city centre as can be seen from the flood mapping presented in Figure 4.10.1 of the Response to the RFI October 2014. The Draft OPW cFRAM mapping shows similar inundation pattern for Flood Zones A (high) and B (moderate) coastal flood risk areas.
- 3.4.5 Hydrodynamic simulations of various combinations of river flood flows, adverse wind conditions and tides including storm surge tides show that the proposed development will not perceptibly impact tidal flooding at the development itself and at the flood vulnerable neighbouring lands of Southpark, the Claddagh, Spanish arch, the Docks Area, Lough Atalia and Ballyloughaun areas.
- 3.4.6 The proposed development site is located within the High Flood Risk Zone (*i.e.* Zone A of the Planning Guidelines). Flood Zone A is the high flood risk zone and represents lands that are below the 100year fluvial flood level or the 200-year tidal or combined (tidal and fluvial) flood level. The FRA shows that the critical condition for the harbour development is the 200-year tidal storm surge event as opposed to a combined fluvial and tide flood event.
- 3.4.7 The proposed development being a Commercial Harbour and Marina with associated dockside activities is classified as a *"water compatible development"* and recognised as appropriate development for Flood Zone A by the Flood Risk Management Planning Guidelines.
- 3.4.8 The quay height and operational ground level in the Commercial Port area are set at 4.7 m O.D. Malin and protected to 5m O.D. Malin by a low concrete quay wall which also functions as spillage containment. This level of protection is sufficiently above the design flood level of 4.635 m O.D. with a freeboard of 300mm for the inclusion for local wave action coinciding with such an event. The minimum finish floor level for all buildings within the Harbour development is set at 5.5 m O.D. which is well above the design flood level providing a freeboard of 850 mm to allow for waves and other factors. This is considered to be a sufficiently safe freeboard for this development. The internal roads within the development are set at a minimum of 4.7m OD.
- 3.4.9 The flood simulations show that the proposed harbour development will not impact on flood risk in the adjoining flood vulnerable areas previously mentioned above. The flood

simulations show no perceptible impact on peak flood levels produced by combined tides, storm winds and river levels within the flood vulnerable areas.

- 3.4.10 The development will not adversely impact on wave climate and tidal hydrodynamics in respect to flooding and flood risk. The harbour development, generally shelters the shoreline areas along South Park, Nimmo's Pier, the existing docks and the Renmore shoreline area against local and offshore generated waves.
- 3.4.11 Under certain storm wave conditions wave and wind directions from the south to west sector a small increase in wave height is predicted at Nimmo's Pier and the adjoining section of Southpark shoreline immediately west of the Pier. The predicted increase in wave height at this location will not exacerbate the flooding and flood risk in the vulnerable South Park and Frenchville area or in the Claddagh Basin area.
- 3.4.12 In conclusion, the Flood Risk Assessment shows that the proposed development is appropriate development for Flood Zone A. It also concludes that the development will not increase flood risk or alter the flood risk classification in adjacent flood vulnerable lands.

3.5 Water Quality

- 3.5.1 Water quality dispersion simulations, 2D vertically mixed and 3D surface plume, were carried out examining both the licensed Mutton Island outfall discharge and the proposed Galway East Outfall.
- 3.5.2 The 2D dispersion modelling presented in the EIS concluded that the proposed Galway East outfall discharge and the resultant receiving water quality will not be impacted by the proposed harbour development.
- 3.5.3 The 2D dispersion results for the existing Mutton Island outfall show some variation in the plume characteristics to the east of Mutton Island. The overall impact is considered to be local and minor, and importantly the simulations show no impact on the bathing water status along the Salthill/Silverstrand and Renmore shoreline areas or upstream at the existing Galway Harbour where amenity and bathing standards may be considered to apply.
- 3.5.4 There are no perceptible impacts to the more remote bathing waters further west at Silver Strand, Barna or Furbo and no impact to the designated shellfish waters located in the south Inner Galway Bay area as a result of the harbour development.
- 3.5.5 Detailed 3D dispersion simulations were carried out examining the impact from the Harbour Development under worst case conditions, namely, the formation of a surface plume and the transportation of this plume under adverse tide and wind conditions towards the shoreline areas of Galway City. These analyses ignored any initial vertical mixing provided by the 90m long ten port diffuser manifold with risers and horizontal jets. The 3D dispersion simulation released the effluent undiluted in the upper surface layer at the outfall sites. Previous studies by RPS on behalf of Galway Co. Council showed through Monte Carlo statistical simulation that the minimum dilution provided by the Mutton Island diffuser outfall was 1 in 30 dilution and similarly at the proposed Galway East outfall.
- 3.5.6 The 3D dispersion simulations carried out for the Response to the RFI confirm that the predicted plume characteristics from the proposed Galway East outfall and the combined plume effects with the Mutton Island Outfall will not be impacted by the Harbour Development. The simulations tested included adverse southerly wind

conditions to force the Galway East plume northwards towards the harbour, bathing waters and the Mutton Island outfall plume.

- 3.5.7 The 3D dispersion simulations of the licensed Mutton Island outfall discharge show, as expected, changes to the plume pattern in the vicinity of Mutton Island and the harbour development due to changes to the local tidal flow pattern caused by the Harbour Development.
- 3.5.8 The largest predicted changes in plume concentration are shown to occur immediately to the north of the outfall on the flooding tide where the plume trajectory under the proposed case takes a slightly sharper, more northerly route around the island. The higher predicted changes in plume concentration between existing and proposed development cases are shown to occur under slacker wind conditions. The simulations show that under stronger adverse onshore winds higher inshore plume concentrations are generated but that the differences between existing and proposed cases are considerably less.
- 3.5.9 In terms of the receiving water quality chemical parameters (i.e. Ammonia, BOD, DIN, etc.) the impact of the proposed harbour development on these water quality chemical parameters is shown for all simulations to be minor and almost imperceptible / undetectable in terms of change in the concentration magnitude.
- 3.5.10 The critical parameter is shown to be bacteriological impact due to the presence of high coliform numbers in a secondary treated effluent discharge and also due to the close proximity of the Mutton Island outfall to bathing waters along the Galway City Shoreline. Faecal coliform dispersion was simulated to assess and quantify the impact of the development on the receiving waters and in particular bathing water and shellfish water standards. These simulations show that the bacteriological concentration will increase within the waters between the causeway and the harbour development and show very slight increases to the east of the development and into Lough Atalia. Outside of these areas the impact of the Harbour on coliform concentrations is minor to imperceptible.
- 3.5.11 The predicted increases in coliform numbers as a result of the Harbour development does not have a significant impact on bathing waters or the overall bathing water quality status at the existing beaches and amenity areas along the Galway City shoreline.

3.6 Salinity

- 3.6.1 The tide simulations for various freshwater inflows from the River Corrib show the deflection of the Corrib freshwater plume westward due to the proposed harbour structure with the returning mixed freshwater only arriving into Renmore Bay and Ballyloughaun area on the subsequent flooding tide.
- 3.6.2 Under the existing undeveloped case there is a wider area for the freshwater plume to disperse in a fan like pattern on exiting the Corrib entrance at Nimmo's with no physical barrier to prevent the plume migrating east and southeast with the tide. This allows it to avail of a greater area for dispersion and mixing. In the case of the proposed development, the Corrib plume is directed more westward, in a more consistent southerly path with significantly reduced opportunity for the freshwater plume to directly advect and disperse to the east towards the Renmore Bay area on the returning flood tide.

- 3.6.3 The modelling demonstrates significant increases in salinity to the east of development with greatest changes occurring to the northeast of the proposed harbour extension showing an average rise in salinity of between 2.4 and 5.4ppt.
- 3.6.4 Changes in salinity levels (reduction in salinity) are predicted to take place to the west of the structure with very minor changes predicted in Lough Atalia and the waters seaward (west) of Mutton Island. In the approaches to Galway Docks, south of Nimmo's Pier reduction in average salinity concentrations of 1.5 to 2ppt is predicted.
- 3.6.5 Lough Atalia and Renmore Lough fall under the definition of "coastal lagoons" under the EU Habitats Directive and are categorised as a priority habitat, described as being in danger of disappearing and therefore requiring protection. However conservation objectives recently published by NPWS describe the conservation status of Lough Atalia and Renmore Lough as of no conservation value as coastal lagoons.
- 3.6.6 The modelled impact of the Harbour Development on salinity concentrations within Lough Atalia will be to reduce salinities by on average 1.29ppt over the complete range of flow and tide conditions. Given the existing wide range of salinity concentration within the Lough varying from c. 30ppt to almost nil ppt, this reduction of 1.29ppt in salinity represents only 10% of the mean salinity and is not considered significant. The model simulations also demonstrate that the range of salinities (maximum to minimum) within Lough Atalia will not alter as a result of the harbour extension; only the frequency of occurrence will slightly change.
- 3.6.7 Periodic large and extreme flood flows in the Corrib will reduce salinities to practically nil in Lough Atalia for both the existing and proposed cases, principally during neap tides but also on spring tides for a less frequent more extreme flood flow. Over the full tidal range the probability of nil Salinity in a given year occurring within Lough Atalia will increase from 0.08% to 0.21% (7 to 18hours in an average year).
- 3.6.8 It is important to note that the principal source of tidal water that enters and leaves Renmore Lough is from Lough Atalia via a small culvert and drainage channel under the railway line linking the two loughs. The overall impact on salinity within Renmore Lough by the proposed Harbour extension will be to decrease the median salinity within the Lough by 1.22ppt. The overall water balance and inflows to and from Renmore Lough will not be affected by the proposed development as the tidal elevations in Lough Atalia will not be altered by the development and thus the inflow rates to Renmore Lough will remain unchanged.

4. REPLY TO SUBMISSIONS IN RELATION TO HYDROLOGY AND FLOODING

4.1 Third Party Submissions

4.1.1 Third party submissions raised the following issues in respect to the Marine Hydrology and Flood Risk Assessment presented in Chapter 8:

- Questions were raised whether there would be any significant increase of flood risk in the area as a result of the development.
- Concern was expressed as to what was seen as possible flood and navigational impacts caused by the funneling effect at the Corrib entrance by the harbour development and its proposed new channel and breakwater structures.
- It was suggested that the proposed harbour reclamation will displace flood storage volume which will impact flooding and that this has not been mitigated for.
- Concern was expressed that no consideration was given to improving existing flood defence measures at Southpark to compensate for the changing of the tidal movements and future climate change.
- Concern was expressed that impact to the wave climate from the proposed solid harbour structure piers and quays has the potential to direct waves towards the city. It was suggested that the proposed development pier walls given their massive scale in terms of height and length which are designed not to allow overtopping (unlike the Mutton Island Causeway) will exacerbate flooding upstream at the Docks and in the City Centre.
- Questions were raised in respect to the potential impact of the harbour development on tidal movement and sedimentation within Galway Bay and concerns expressed in regards to potential changes to the longshore drift that could potentially result in changes to sedimentation patterns behind and in front of the proposed piers.
- It was suggested that longshore drift of beach material and sedimentation effects from the River Corrib's waters will be inevitable and such changes could impose a significant cost impact for future maintenance with more regular dredging becoming necessary.

4.2 Reply

Flood Risk

4.2.1 The flood risk assessment presented in Section 8.4.7 of the EIS for the proposed development was carried out in accordance with the Flood Risk Management Planning Guidelines (Nov 2009). This assessment identified in section 8.4.7.3 the existing high flood risk areas within study area of Galway City, which include the neighbouring area of Southpark and Frenchville, Long Walk, Flood Street and the Docks.

4.2.2 The EIS examined all potential sources of flood risk within the study area and concluded the following:

- Inundation from storm surge tides within the Claddagh Basin, the Docks and Spanish Arch and Long Walk areas. It identified wave overtopping combined with high tides as a significant source of flood risk along the Salthill promenade and along Grattan road west of the Mutton Island Causeway.
- The assessment identified urban drainage issues as representing a significant source of flooding in the vicinity of Quay Street and significantly exacerbated by high tides backing up the storm drainage system and causing regular flooding of properties.
- The FRA identified that the River Corrib by itself is not a significant source of flood risk downstream of Wolfe Tone Bridge to the Claddagh Basin area. However, it does play a small factor within the Claddagh Basin Area when combined with tidal surge events.

4.2.3 Hydraulic modelling shows that under extreme tidal flooding of 200year return period (4.146m O.D.) the contribution to flood levels from flood flow in the River Corrib is almost imperceptible due to the large available flood depth and flow cross-sectional area within the Claddagh Basin which reduce flow velocities and the bed resistance against outflow.

4.2.4 As part of the response to the An Bord Pleanála RFI flood risk mapping of the Claddagh Basin and Galway Docks area showing Flood Zone A - High Flood Risk (all areas vulnerable to the 200year tide and combined event) is presented in Figure 4.10.1. Also shown on this mapping is the medium range climate change scenario of 0.5m sea level rise. Both the EIS and RFI response acknowledge the existing Flood Risk that is present at the Claddagh, Spanish Arch and Docks Area and that this flood risk will significantly worsen over the next 100years as a result of sea level rise .

4.2.5 The proposed development should be judged on whether or not it will exacerbate flooding and to address this 2D and 3D hydraulic computer models of the bay including the Corrib entrance, Claddagh Basin and Lough Atalia were developed using the TELEMAC hydraulic software system, which is of International standing in its application to such harbour studies. The models were built for the existing case and for the proposed case which accounted for the volume loss by the proposed reclamation, breakwaters and Quays. A comprehensive series of simulation runs were carried out with various combination of tides, flood flows, storm winds and wave stresses applied in order to investigate the potential impact of the proposed development on flooding and hydrodynamics within the Bay and upstream within the Claddagh Basin and Docks area. These simulations showed no discernible impact by the proposed development on flood levels. Please refer to time series plots in the EIS 8.4.184 to 8.4.208 and the difference plot between existing and proposed peak flood levels presented in the RFI response Figure 4.6.13 that clearly demonstrates the imperceptible impact.

4.2.6 The hydraulic modelling includes the geometry effect of the development and thus includes for the loss of seawater volume as a result of the displacement by the infill. All of the simulations show that such a loss has no discernible effect on flood levels. The loss of sea volume by the infill will not result in displacement of the volume over the remaining water body area through a direct rise in sea level. The main forces generating the tide and storm surges are planetary and atmospheric forces which are large scale forces that dictate the height and shape of the tide almost independently of the available volume to be flooded and therefore the displacement effect at the

scale of the Harbour development will be miniscule in relation to such forces and will not result in any perceptible increase in flood levels locally.

- 4.2.7 The proposed development is shown by the modelling to deflect the Corrib outflow westward along the newly formed northerly approach channel. The depth of this channel and the remaining flow area available westward of the development is sufficiently large not to restrict the outflow. Therefore the proposed development does not produce discernible head loss as to generate a hydraulic effect upstream of Nimmo's Pier or along the shoreline area of Southpark and consequently will not increase flood levels or flood risk along these vulnerable areas through a reduction in conveyance.
- 4.2.8 Simulations were run and presented in the EIS and in the RFI response that examined worst case combined winds, river flood and tidal storm surge. These simulations for the existing and proposed development cases show no funnelling effect at the mouth of the estuary and showed no impact on upstream flood levels in the Claddagh Basin and Docks area. Refer to Figure 4.6.12 and 4.6.13 of the RFI Response which presents a comparison between existing and proposed development cases for a 3.5m Surge tide, a 100year river flood flow and combined with a continuous 20m/s southerly storm wind.
- 4.2.9 The flood risk assessment has included climate change both in respect to recommended factors for sea level rise and increased storm and fluvial flows. The current practice in Ireland and the UK is to use a medium range sea level rise of 0.5m and a 20% increase in peak magnitude for storm and fluvial flood flows. Simulations have been carried out with these factors included to assess the flood risk and the potential flood impact of the development.

Waves

- 4.2.10 A full series of wave climate analyses using the ARTEMIS Telemac wave model for local (wind wave) and Atlantic storms were carried out for the complete West to East sector of onshore wind directions. The wave climate results are presented Section 8.4.6, Figures 8.4.132 to 8.4.142 of the EIS. These simulations included wave reflection off structures, wave diffraction and wave refraction and showed that generally the proposed development sheltered the flood vulnerable area of the Corrib estuary, Docks and Southpark shoreline area. Under SSW to WSW wave directions the Artemis simulations showed a slight localised increase of less than 15cm in Wave height at Nimmo's Pier and very slight increase of less than 5cm at the easterly most section of the Southpark shoreline adjacent to Nimmo's Pier. Further west along the Southpark shoreline there is no discernible impact. Higher wave heights at the Corrib entrance, up the Claddagh Basin and along the Southpark shoreline are predicted for the SSE and SE wind wave sector and as a positive impact the proposed harbour is shown to provide shelter against these wave /wind directions.
- 4.2.11 To address the RFI additional modelling using the DELFT SWAN wave climate model was carried out to investigate the effect of wind growth within the domain and the effect of tidal current refraction on the resultant wave field, refer to RFI Response Figures 4.4.1 to 4.4.41. In terms of impact by the proposed development both models agree reasonably well showing increases in wave heights in the vicinity of Nimmo's Pier and at the easterly section of the Southpark shoreline for the Atlantic storm directions SSW to WSW. Both models show a reduction in maximum wave height at the Corrib entrance and show no wave impact upstream in the Claddagh Basin as a result of the development. The impacted section of shoreline at Nimmo's Pier and the adjacent easterly section of Southpark have ground elevations in excess

of 5m O.D. can accommodate such minor increases in wave heights and will not increase flood risk to vulnerable Frenchville or Claddagh Avenue residential areas.

Flood Mitigation measures

4.2.12 It is clear given the vulnerability of the Claddagh and Docks area of the City that a flood defence scheme is required to safeguard these vulnerable areas principally from coastal flooding by tides and storm waves. Given the high risk and high number of properties involved it is expected that once the cFRAM process is completed the Galway City and Salthill area will be very high on the OPW National priority list for funding of a flood defence scheme. It is understood that some interim funding has been given by the OPW to Galway City Council for some coastal protection works at Salthill, Southpark and Spanish Arch areas.

4.2.13 I was the hydrologist referred to in the Claddagh residents submission that carried out the Flood Assessment Study of the Southpark area in 2008 and identified that the area was at very high flood risk and recommended a flood defence scheme for the area which included flood embankments, rock armour wave protection, demountable barriers for the Public Road and a number of flood walls to protect this area. Quite a number of the houses within Frenchville have finish floor levels of 3.3 to 3.7m O.D. (i.e. are well below the 200year flood level of 4.146m O.D. or even lesser events including the 50 and 10 year return period flood events) The road levels at Frenchville are at 3.1 to 3.3m O.D. which are highly vulnerable.

4.2.14 What currently protects this area from flooding is the flood storage available within the playing fields at Southpark. This storage accommodates wave overtopping volume and a short period of tidal inundation towards highwater. In the recent coastal flooding of 2014 these pitches were inundated by the tidal surge overflow and protected the surrounding houses and the roadway at Frenchville.

4.2.15 The proposed Harbour development will not increase flood risk in this flood vulnerable area or other adjacent areas and therefore it is not considered necessary for the development to provide flood mitigation in these areas to protect against an existing flood risk. The OPW in association with Galway City Council are the responsible authorities for designing and implementing such a scheme.

cFRAM Study

4.2.15 The cFRAM Galway City Study is tasked with identifying viable flood defence / flood relief options and measures and making a recommendation as to the preferred scheme, integrating environmental and socio-economic factors in the choice of the preferred scheme. The proposed Harbour development location and configuration will not obstruct or impact negatively on any potential future flood defence scheme for this area. The proposed development is not considered premature pending the publication of the cFRAM study in 2015. The flood risk mapping element of the cFRAM has gone to public consultation in early November 2014. The cFRAM flood risk mapping in respect to coastal and fluvial flood risk and areas of flood inundation generally agree with this Flood Risk Assessment.

Sediment transport and Littoral Drift

4.2.16 The sediment load from the River Corrib is small due to the impounded nature of the River and the large upstream lake which provides sufficient resident time for coarse silt and sand to settle out. The river silt that eventually discharges to the harbour waters will be fine silt of which a large proportion is unlikely to settle out on entering Galway Bay due to the high turbulent environment. Sediment transport modelling shows that the a build-up of silt from the Corrib River in the new navigation channel

to the Docks is unlikely as winter flood flows will mobilise this silt and disperse it widely. The main silt load in the Corrib is likely to coincide with large to extreme flood flows and under such conditions the plume on meeting the sea will be transport out into the middle of the Bay well past Mutton Island where it can disperse widely.

4.2.17 The dredging rates and frequency based on dredge volumes removed for the three Campaigns 1978, 1990 and 2001 indicate a relatively low annual dredging volume of < 9000T per annum at a frequency of 12years. The current navigation channel is projected to require maintenance dredging in 2016 with the previous dredging campaign back in 2001, representing a 15year gap. The Mutton Island causeway constructed in 2002 is likely to have reduced the some of the littoral drift heading eastward.

4.2.18 The simulations indicate that the littoral drift, eastward past Mutton Island, is limited and currently the existing channel acts as a sink capturing this littoral drift as it progresses eastward with the main infill occurring at -1 to -4m OD Malin. Under the proposed case the new channel to the Docks will be similar to the existing channel capturing this littoral drift which is likely to build up slightly more southward near the Marina entrance due to the channel velocities. Deeper littoral drift may be captured by the commercial Port navigation channel but this deeper drift is unlikely to be of a substantial volume. Conservatively it is estimated that maintenance dredging is likely to be of a similar frequency to the existing situation of approximately every 12years. The overall dredging volume for removal is likely to be conservatively less than twice the existing dredging requirement (i.e. < 18,000T per annum) allowing for silt build-up within the sheltered waters of the marina and commercial port and turning circle area.

4.3 OPW Observations

4.3.1 An Bord Pleanála requested observations from the OPW in relation to two items concerning the Flood Risk Assessment in the EIS, namely:

- the content and conclusions reached in respect to the flood Risk Assessment in the EIS
- how the specific hydrology and hydraulic modelling contained in the EIS compares to similar exercises carried out by the OPW in the CFRAM study for Galway City and Bay.

4.3.2 In the OPW reply to An Bord Pleanála they raised a number of queries regarding the FRA which are summarised and replied to below:

1.2 *The conclusion that the development will not increase flood risk to adjacent lands is not clear from the model results as presented.*

4.3.3 The impact on flood levels by the harbour development under a range of tidal, fluvial and wind conditions was presented at selected key locations (1 to 6) as a full time series comparison between the proposed development and existing cases which represents the best means of presenting impact as it includes duration, phase and magnitude. These time series plots showed no perceptible change in peak flood level for any of the design conditions investigated. It was considered a reasonable extrapolation that if these sites showed no impact then all adjacent locations would also not be impacted. Included in the response to the An Bord Pleanála RFI a hydrodynamic difference plot is presented in Figure 4.6.13 p107 which shows no impact on maximum flood levels throughout the Bay as a result of the Development.

- 1.3 *The model output and results presented in Figures 8.4.152 to 8.4.183 have been truncated along their southern boundary and therefore do not show all of the model predictions.*
- 4.3.4 The full model predictions apply to the entire Galway Bay area but for presentation clarity purposes it was considered best to truncate plots so as to cover the immediate development area where velocity magnitudes are highest and the upstream target areas including the Claddagh Basin and the Corrib entrance. It should also be noted that earlier in the EIS chapter, in the hydrodynamic section, larger scale hydrodynamic plots of the wider area were presented, refer to Figure 8.4.5 to 8.4.15 of the EIS.
- 1.4 *Fluvial flooding has generally been ignored in the FRA and assumed not to be relevant. This source of flooding should be considered in the FRA/EIS e.g. by a review of the preliminary Flood Risk Assessment maps and*
- 4.3.5 Fluvial Flooding from the River Corrib has in no way been ignored in the FRA section of the EIS. In a large number of the impact scenarios the time varying Corrib flood hydrograph has been specified as an upstream inflow flood boundary subject to downstream varying tide conditions. The EIS correctly concludes that the dominant source of peak flood levels within the Claddagh Basin, downstream at the docks entrance and in the coastal areas is tidal flooding produced by extreme Atlantic storm surge conditions.
- 4.3.6 It should be noted that in The OPW cFRAM modelling the fluvial flood simulations specify a 2year high tide level of 3.055m OD Malin at the sea boundary between Long Walk and upstream of Nimmo's Pier for all of fluvial flood risk scenarios examined (i.e. 10, 100 and 1000year return period). Between their sea boundary and the Wolfe Tone bridge at the top of the Claddagh basin the cFRAM modelling shows an increase in flood level of only c. 1cm, 2cm and 4cm for the 10, 100 and 1000year Corrib flood flow peaks, which is negligible in comparison to the tidal range and highwater level. This demonstrates the relative insignificance of the fluvial flow contribution on flood levels and Flood risk in the Claddagh Basin and agrees with the EIS findings. The cFRAM draft flood risk mapping shows the dominance of coastal flooding downstream of Wolfe Tone Bridge being produced by 200year and 1000year tides as opposed to other combined events of lower return period tides and higher return period River flows.
- 1.5 *The design of the Quay at 4.7m O.D. Malin is likely to be adequate, the basis for selecting this finish level should factor in the (a) glacial isostatic adjustment (b) subsidence of reclaimed fill over time and (c) wave overtopping and would be normal practice to allow for finished level*
- 4.3.7 It is noted that the OPW agree that a design level of 4.7m O.D. is likely to be adequate. It is generally acceptable to allow a rounded figure of 500mm to include for the mid range CC Scenario and the glacial isostatic adjustment which is estimated at -0.4mm per annum or -40mm in 100years. The exposed southerly and westerly sections of the development are protected from waves by breakwater structures. The Quay along the easterly section is considered sufficient as statistically is highly unlikely that a 200year Atlantic surge tide would coincide with a severe easterly storm event.
- 4.3.8 In any case for spillage protection a step along the entire Quay front of 0.3m (producing a top elevation of 5m O.D. Malin is proposed which will provide additional

freeboard. The quays, pier walls and buildings etc. will be piled and therefore subsidence will not be an issue in regard to future ground level.

1.6 Modelling of coastal erosion

4.3.8 It is clear visually that the soft glacial till headlands exposed either to Atlantic or locally generated wind waves are prone to erosion from wave impact. In the response to An Bord Pleanála RFI more extensive wave climate modelling using the SWAN spectral wave climate software was carried out and this was coupled with sediment transport model SISYPHE.

4.3.9 The simulations show that development will not impact negatively on the adjacent soft coastline areas the nearest being, Hare Island and its spit and the soft shoreline immediately to the west and east of Ballyloughaun Beach (the east has more recently been reclaimed and protected by Rock Armouring). The simulations show sheltering effect for the shoreline area immediately to the west of Ballyloughaun. To the west of the development there are no soft shorelines areas to be eroded with the Southpark having armour stone and a low concrete wall with embanked grassed area and walkway behind it. The conclusion reached from the additional modelling is that the proposed development will not give rise to an increase in the rate of erosion locally and at adjacent shoreline areas. The soft erosion prone shoreline areas presented in the OPW coastal erosion map also do not show any erosion areas immediately to the west of the development which includes the Southpark shoreline area. Surprisingly Hare Island is not shown as an erosion site, notwithstanding its high exposure to Atlantic storms along its southern and western faces, and should have been included.

1.7 *Wave Climate modelling has been undertaken to assess the impact of the proposed development It has been concluded from this modelling that there will be an increase in wave heights in the vicinity of Nimmo's Pier and to the west of this location. The potential impact of this increased wave climate on flood risk has not been addressed in the FRA.*

4.3.10 The wave climate simulations presented in the EIS and supported by additional SWAN wave climate simulations presented in the RFI response show a small localised increase in wave climate of < 0.15m under certain wave directions (SSW to WSW) in the vicinity of Nimmo's Pier and reducing to < 0.05m along the more easterly section of Southpark shoreline adjoining the pier. The effect of this on flood risk to properties and road infrastructure is negligible as the Nimmo's pier section is a defended section of the shoreline and the easterly section of the Southpark shoreline is a raised area such that wave action will not result in any additional spillage into the Southpark storage area. This shoreline area is well set back from public roads and residential housing with park area acting as a buffer. There may be a minor risk to the public using the Walkway at Nimmo's pier during such events.

2.2 *The coastal modelling outputs undertaken as part of the ICPSS and ICWWS do not appear to have been reviewed in any detail in the preparation of this flood risk assessment and there are therefore inevitable differences between the modelled outputs for the existing situation. An example of this would be the extreme water levels in the vicinity of the site.*

4.3.11 The ICPSS Study (extreme Sea levels and Flood maps) was reviewed and more recently through the cFRAM public consultation process held in November the shoreline areas vulnerable to wave overtopping and associated wave climate were

reviewed including the ICWWS. The tide and wave climate studies presented in the EIS and in the response to the RFI would generally agree well with the CFRAM / ICPSS studies in regard to shoreline locations of potential overtopping both tide and storm. The areas vulnerable to wave overtopping in proximity to the Harbour development is described in the Flood Risk Assessment section of the EIS and does not contradict the cFRAM/ICPSS study mapping.

- 4.3.12 It is understood that the extreme sea level estimate from the OPW ICPSS model gives a 50year tide level of 3.56mOD and a 200year tide level of 3.77m OD for the Galway City area. These estimates would appear to be on the low side given that the tide level in inner Galway Bay reached 3.49m OD in 1995, 3.48m OD in February 1997, and recently 3.56m OD on the 3rd Jan 2014 and 3.59m O.D. Malin on the 1st February 2014. The Harbour Study uses similar magnitude quantiles derived from statistical frequency analysis of nearby tidal gauges. However these tide level quantiles are adjusted upwards to include for statistical sampling error yielding a 50year estimate of 3.83m O.D. Malin and a 200year year estimate of 4.146m O.D. Malin. The harbour study provides higher more conservative estimates for tidal flood levels, which is considered appropriate for ensuring safe sustainable development.

2.3 *Different types of coastal models were used in each case and different modeling methodologies were adopted consistent with the different objectives of the respective studies / assessments which will inevitably account for differences in the model outputs. The OPW express the view that modelling comparisons between the ICPSS / ICWWS and EIS are not considered appropriate as the ICPSS / ICWWS did not seek to model the impact or changes in coastal processes associated with this proposed new development.*

- 4.3.13 The ICPSS study was focused on the national coastline scale as opposed to high refinement for local site specific study areas such as the models developed for the Galway Harbour development project. In terms of the governing equations and solution schemes they are generally similar and the differences apply in their respective applications. The local scale models were developed primarily as a computational tool for predicting hydrological impact due to geometry and bathymetric changes arising from the proposed Harbour development. The ICPSS models were used to propagate inshore extreme offshore conditions generated by combining global tide models with meteorological storm models including movement of such storms across the domain and the variation in space and time of atmospheric pressure.

4.4 Galway City Council

4.4.1 The submission from Galway City Council regarding the proposed Harbour Development raised a number of observations in respect to the marine Hydrology and the Flood Risk Assessment. These are summarised as follows:

- *Critical that ABP Consult with the OPW on CFRAMS and the ICPSS for Galway Bay Area*

4.4.2 An Bord Pleanála has consulted with the OPW in respect to the Flood Risk and the cFRAM and ICPSS studies and a submission from the OPW was received and has been replied to as outlined in the previous section of this evidence.

- *If studies indicate that revised assumptions are necessary, then ABP should seek a review of impact on flood vulnerability.*

4.4.3 Following the OPW submission and the An Bord Pleanála further information request revised assumptions are not required in respect to flood vulnerability and flood risk.

- *ABP should be confident of adopted sea level rise of 0.5m*

4.4.4 The medium range future scenario climate change allowance of 500mm for sea level and 20% increase to the peak river fluvial flow meets current best practice for Ireland. An adjustment for isostatic rebound/ for the Galway Bay Area is -40mm. This isostatic rebound adjustment has not been included as there is sufficient freeboard allowance in the 200year surge tide flood level with the addition of twice the statistical standard error to cater for this further small adjustment. The overall 200year coastal flood level with MRFS climate change for the Harbour Site is higher than the current OPW (draft) cFRAM figure.

- *Concern raised regarding potential to exacerbate erosion at Kelly's Field and causeway to Hare Island.*

4.4.5 The model simulation show no impact on hydrodynamic, wave and sediment transport processes along and in the vicinity of the Hare Island Causeway. Consequently changes to the morphology resulting in increased erosion as a result of the Harbour development are not predicted at these locations.

4.4.6 The proposed development will afford some protection to Kelly's Field from the Atlantic Storm waves and wind waves from the west to SSW sector. The Shoreline at Kelly's field remains vulnerable to south to east Sector wind waves with the shoreline easily being eroded as it consists of a glacial till / Boulder clay with a mix of fine silt, sand, gravel, cobbles and boulders.

- *Concern regarding potential undermining of Nimmo's pier due to increase in wave activity*

4.4.7 A visual condition survey of Nimmo's Pier along its exposed sea face indicates generally a stable slope of cobbles and boulders at the base of the pier with little evidence of any current erosion/scour problems. The structure itself appears to be in reasonable condition and stable. There is evidence of some repairs to the structure having been carried out historically, which is not unusual given that it is a marine

structure exposed to the elements of the sea. It is expected that ongoing future repairs to the structure will be required with or without the development.

4.4.8 The predicted increase in wave climate along the exposed (south) face of Nimmo's pier is 0.15m for southwest to south sector storm conditions which does not represent a significant increase over the existing wave heights for these directions. Significant reduction in wave conditions as a result of the development are predicted for the southeast to east sector wind waves. The overall impact is likely to be an increase in the wear and tear of the structure which can be monitored for and maintained on an on-going basis.

4.4.9 Monitoring and maintenance of marine structures is an important on-going activity so as to protect the structure from future deterioration and undermining by providing timely local repairs to the bed/toe protection and to the stonework.

- *Need to review impact of Galway Eastern Environs WWTW*

4.4.10 A detailed water quality assessment has been carried out to assess the impact of the harbour on the performance of the Mutton Island Outfall and on the Proposed Galway East Outfall. This assessment shows that the proposed Harbour development will not impact on the performance of these outfalls and will not affect the Water Quality Status of Galway Bay in respect to Shellfishery, Water Framework Directive and Bathing Water standards.

5. CONCLUSIONS

5.1.1 The proposed Harbour Development meets the requirements of the Flood Risk Management Planning Guidelines for Ireland as follows:

- being an appropriate water compatible development for a high flood risk zone,
- being designed to meet the Irish flood risk standards of a 200year flood level, climate change allowance and suitable freeboard allowance for uncertainty in respect to finish levels for the proposed buildings, quays and road areas,
- it will not impact on the flood risk of adjacent flood vulnerable areas through either increases in flood levels, wave climate or the duration of Flooding, both present day and future climate change conditions and
- will not result in coastal erosion of soft vulnerable shoreline areas within the bay.

5.1.2 The impact of the Harbour development on Coastal Processes is shown to be localised and not significant in terms of its impact to the water quality status, the sediment transport regime, siltation and hydrodynamics within the inner Galway Bay and the Galway Bay SAC complex including the lagoonal waters of Lough Atalia and Renmore Lough.
