APPENDIX N:
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Harbour Modelling

SAC GREAT ISLAND CHANNEL

The Great Island Channel stretches from Little Island to Midleton, with its southern boundary being formed by Great Island. It is an integral part of Cork Harbour that contains several other sites of conservation interest. Geologically, Cork Harbour consists of two large areas of open water in a limestone basin, separated from each other and the open sea by ridges of Old Red Sandstone. Within this system, Great Island Channel forms the eastern stretch of the river basin and, compared to the rest of Cork Harbour, is relatively undisturbed.

The main habitats of conservation interest are the sheltered tidal mudflats and Atlantic salt meadows, both habitats listed on Annex I of the EU Habitats Directive. These habitats, along with brackish pools and open water, support a rich invertebrate fauna. Cord-grass (Spartina sp.) has colonised the mudflats in places, especially around Rossleague and Belvelly.

The site is also extremely important for wintering waterfowl and is considered to contain three of the top five areas within Cork Harbour, namely North channel, Harper's Island and Belvelly-Marino Point. An Foras Forbartha provided the following description in 1986: waders and wildfowl occur in large numbers during the winter. Shelduck are the most frequent duck species with 800-1000 birds centred on the Fota/Marino Point area. There are also large flocks of Teal and Wigeon, especially at the eastern end. Waders occur in the greatest density north of Rosslare with Dunlin, Godwit, Curlew and Golden Plover the commonest species. A population of about 80 Grey Plover is a notable feature of the area. All the mudflats support feeding birds; the main roost sites are at Weir Island and Brown Island and to the north of Fota at Killacloyne and Harpers Island. Ahanesk supports a roost also but is subject to disturbance. The numbers of Grey Plover and Shelduck, as given above, are of national importance.

The site is an integral part of Cork Harbour which is a wetland of international importance for the birds it supports. Overall, Cork Harbour regularly holds over 20,000 waterfowl and contains Internationally important numbers of Black-tailed Godwit (1,779) and Redshank (2,382) along with Nationally important numbers of nineteen other species. Furthermore, it contains the largest Dunlin (10,912) and Lapwing (14,713) flocks in the country. All counts are average peaks, 1984/85 - 1986/87. Much of the site forms part of Cork Harbour Special Protection Area, an important bird area designated under the Birds Directive.

While the main land use within the site is aquaculture (Oyster farming), the greatest threats to its conservation significance come from road works, infilling, sewage outflows and possible marina developments.

The site is of major importance for the three habitats listed on the EU Habitats Directive that it contains, as well as for its important numbers of wintering waders and wildfowl. It also supports a good invertebrate fauna.

PREVIOUS HARBOUR STUDIES

The report by the EPA entitled *Measurement and Modelling of Nutrient dynamics of Two estuaries in Ireland – Wexford and Cork Harbours (Synthesis Report)* provides information of interest. An extract of the report is below:

"Many studies have been undertaken on Cork Harbour by local authorities, statuary bodies, third level institutions, state and semi-state laboratories, environmental organisations and private companies. The Cork Harbour Report (ERU 1989) was the first report to collate all available data on Cork Harbour and the report by Forbairt and ARUP (1996) built on this. The two former reports and that by Pettit (1992) , documented most of the data on Cork Harbour with the exception of recent studies, notably the unpublished monitoring by the EPA (1994 – 1996). Many of the studies concentrated on a few areas within the estuary and harbour or only analysed a limited number of parameters and were short-term. The reports concluded that the water quality particularly in the upper reaches of the harbour has deteriorated over time. Generally the areas which suffered the most from low dissolved oxygen , high biological oxygen demand, phosphorus, ammonia, and nitrate were the inner estuary (north and south channels of River Lee) and the Lough Mahon area. Phytoplankton causing Paralytic shellfish Poisoning (PSP) have been recorded in Cork Harbour, namely Alexandrium tamarense in 1996 and 1997 (Marine Institute 1999).

The study found that point sources (outfalls) of nutrients are contributing to phytoplankton blooms in both estuaries. Measures to reduce such waste inputs into the inner brackish water part of the estuaries are thus required to reduce the occurrence of harmful algal blooms , especially in Cork Harbour where toxic blooms have occurred and are likely to continue to occur.

Cork Harbour meets several of the criteria for a eutrophic system. Cork Harbour, particularly the area around Lough Mahon appears to be eutrophic. The estuarine circulation in the harbour acts as a focus for the eutrophication-related effects. Increased residence times in the subsurface layer allow more time for algal growth and simultaneously increase the scope for de-oxygenation of the water column Direct nutrient inputs to the surface layers may increase the size of the toxic algal blooms when conditions are appropriate for growth of PSP-causing species.

Within estuaries, eutrophication is better characterised by apparent problems than simple chlorophyll levels. On this basis the deoxygenation in Cork Harbour estuary and toxicity from dinoflagellates, indicate that the estuary is eutrophic."

Cork Harbour Water Quality, 1989, by the ERU had the following findings:

Many of the environmental parameters measured in the harbour show a gradient extending from the upper harbour and estuarine areas, through the lower Harbour to the Harbour mouth. Thus going in this direction, BOD loadings, phosphate, nitrate, and ammonia levels, bacteria levels, and levels of contaminants in the water, sediments and biota all show a general decrease in values as the Harbour mouth is reached. Dissolved oxygen levels, on the other hand, show an increase along the same gradient.

The very steep rise in the levels of nutrients, especially nitrogen, in Cork Harbour is the most outstanding feature of the data collected in the harbour over the last 15 years. This rise is most prominent in the upper harbour reaches particularly in Lough Mahon and the West Passage but it is also marked in the lower harbour. While an increase in phosphate levels relative to 1975 values has occurred, some spurious results mean that the pattern is not clear cut.

Contamination levels measured in the water column, under the priviso of unproven accuracy and precision of the analytical procedures indicate that, in general, metal levels in Cork Harbour are moderate, i.e. they are not low, relative to other, uncontaminated, locations. In particular high levels of zinc and to a lesser extent, nickel have been highlighted. A zinc gradient was shown for the harbour in the late 1970s and was attributed to the disposal of metal wastes at that time. This waste disposal has not taken place for some years now and it has been suggested that this zinc gradient has now dissipated. However this suggestion needs present day confirmation.

"*A synthesis of Existing Information on the Environment of Cork Harbour*" by Ove Arup, 1996, states the following:

The BOD levels in the lower and outer harbour normally range between 1 to 3 mg/l. There has been a general rise in BOD in the harbour between early-mid 1970 and the mid 1980s. BOD levels tend to be highest in Autumn/Summer.

Regarding phosphorus levels, the stage of the tide appears to make a large difference, ranges between 0.03 to 0.14 mg/l are normal.

Orthophosphate levels are normally much lower than phosphorus levels, as the phytoplankton readily use the Orthophosphate.

Ammonia levels were recorded are at their highest when salinity in the harbour is low. The IFI fertiliser manufacturing plant (no longer in operation) was seen to be a major contributor of Ammonia, but when the dispersal effects were modelled, it was found that it only caused a very minor increase in the Ammonia concentration in the surrounding areas. Nitrogen levels were found to be higher in winter; this was put down to runoff from farmland.

Nitrate concentrations have increased significantly since the mid 1970s. Agricultural inputs upstream are seen to be most significant.

HARBOUR MODELLING

1) INTRODUCTION

Cork Harbour is the second largest natural harbour in the world. Its vast size brings it in contact with many users. Sailing and boating is a popular sport, based in Crosshaven, Cobh, East Ferry and other smaller marinas. Fishing vessels use the harbour as their base. Liners stop at the main port terminal in Cobh. The Harbour is classified as a deep multi-modal port. The movement of the larger vessels is controlled by the Port of Cork Company (formerly known as the Cork Harbour Commissioners). The tidal rise at Cork ranges from 3.4m (11 feet) on neap tides to 4.4m (14.5 feet) on spring tides. There are no recognised bathing areas within the harbour.

The Slatty Estuary forms part of the proposed Special Area of Conservation (SAC) no. 1058 known as the Great Island Channel. This SAC contains an important variety of birdlife. Also there is shellfish farming in the channel east of Belvelly Channel, close to Midleton. It is necessary to consider if the discharges allow the Shellfish Regulations to be met at the regions licensed for the shellfish farming.

Since its construction in 1985, the Carrigtohill Wastewater Treatment Plant has been discharging treated effluent to the head of the Slatty Water Estuary via the existing outfall. The adequacy of this form of discharge and treatment for the present and future loadings is to be investigated. Proposed improvements to the discharge regime are to be examined.

For this reason, a hydraulic and water quality model of the relevant parts of Cork Harbour was developed by the Hydraulic and Maritime Research centre, University College of Cork. Bathymetric and coastline data were supplied in digital format by Irish Hydrodata Ltd.

The Department of Marine requested that the model consider if the discharges allow the Shellfish Regulations to be met at the regions licensed for the shellfish farming.

A new treatment plant to treat the waste from Cork City has been constructed at Carrigrenan (on Little Island). This plant shall discharge waste treated to 25:35 BOD:SS standard at Marino Point. The model was set up to deal with both the discharges of Carrigrenan and Carrigtohill to investigate the impact of the combined discharges.

2) PURPOSE OF THE MODEL

The purpose of the model is to estimate the effect on Cork Harbour as a result the existing discharge, and to decide on appropriate discharge location and standards and discharge period in relation to the tidal regimes for the proposed scheme (design population of 45,000 for Phase 1) Our overall aim is to reduce the impact of the combined discharges (from both Carrigtohill and Carrigrenan) rather than the impact of the Carrigtohill discharge alone.

3) MODEL DESCRIPTION

3.1 Introduction

This study involved the numerical modelling of the hydrodynamic and water quality conditions that are prevalent in Cork Harbour and in particular as a result of proposed discharges from the Carrigtohill and Carrigrenan outfalls. The software used to undertake the modelling work is called MIKE21 and was developed by the Danish Hydraulic Institute (DHI). The following two models of the MIKE software were used in the study.

MIKE21 HD (Hydrodynamic module): This software simulates the water level variations and flows due to different forcing functions. A rectangular grid of the relevant area has to be specified and information on such items as bathymetry, bed resistance coefficients, wind field, and the hydrographic boundary conditions need to be provided. The model includes such influences as convective and cross momentum, bottom shear stress, wind shear stress, evaporation, flooding and drying, sources and sinks, Coriolis forces, momentum dispersion and wave induced currents.

MIKE21 WQ (Water Quality Model): This model which runs simultaneously with the hydrodynamic model examines the impact of a pollution source to a water body. The pollution source may be an outfall containing industrial or domestic wastewater, riverine discharges or agricultural run-off. Through the solution of a system of equations involving the various physical, chemical and iological interactions associated with the survival of bacteria the resulting water quality can be determined. Many variables can be modelled, including but not limited to BOD, Ammonia, NH3, Nitrate, NO3, Dissolved Oxygen, DO, Phosphorus, PO4, Faecal coliforms, Total Coliforms.

3.2 Methodology

The approach adopted in this study involved first setting up the model grid and then calibrating/validating the hydrodynamic model, using field measurements to verify the output. Once validated the model input parameters were then varied to examine the effects and implications of various discharge scenarios from the Carrigtohill outfall for both Spring and Neap tidal conditions.

The following sections will outline the methodology in more detail.

3.3 Model set-up/Grid layout

The first major step for the setting up of the numerical model is the input of the bathymetry and the land boundaries. To ensure that the model would run successfully and give reliable results it was necessary to include a very large area extending beyond the area of interest. Therefore, for this study, even though the Slatty water and upper harbour region was the area of interest all of Cork Harbour was included in the model set-up. This approach helped to improve the stability and reliability of the model even though it considerably lengthens the simulation time.

Bathymetric and land data was supplied in digital format by Irish Hydrodata Ltd (see Section 4) which was then imported into MIKE 21 where the discrete randomly located data points were transformed into a regular grid. A grid size of 30 x 30m grid was chosen as it gave sufficient resolution of the relevant processes and gave an acceptable model run time. A complete 15 x 15m grid as well as a nested 15 x 15m section of grid were also set up but it was found that these set ups had a run time in excess of two days, which was considered too long. It was considered that a 30m x 30m grid was sufficiently fine to accurately model the various processes (the model used in the Cork Main Drainage Study had a 100m x 100m grid size).

The interpolated grid was then carefully checked and adjustments were made, by editing the grid, when the data was interpreted incorrectly. This was particularly the case for the land boundaries and relatively small structures such as the piers and islands. Figure 3.1 below shows the extent of the model as well as the bathymetry. Figure 3.2 shows in more detail the most relevant area of the harbour with the locations where data was extracted for analysis.

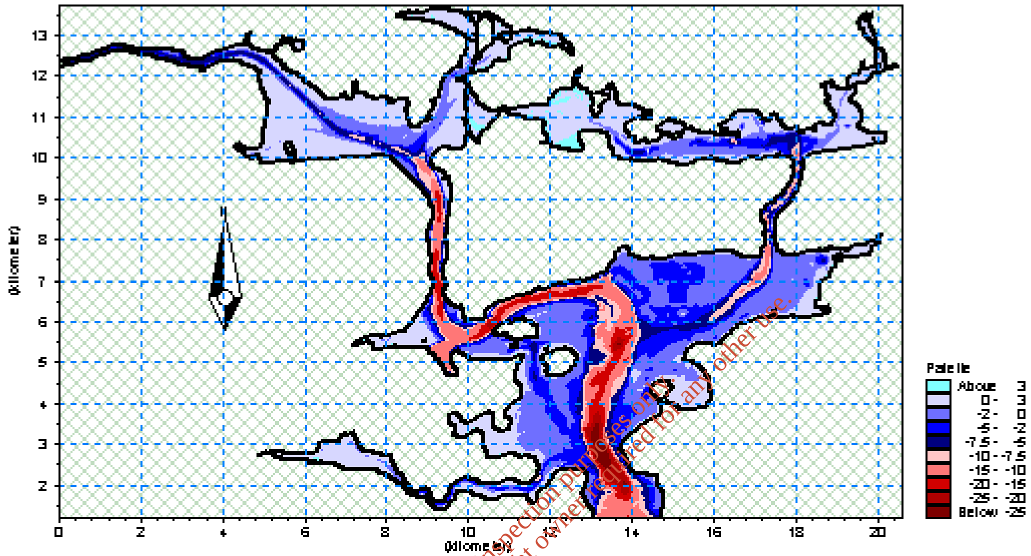


Figure 3.1 Model Area with Bathymetry (Plot Units: m Chart Datum)

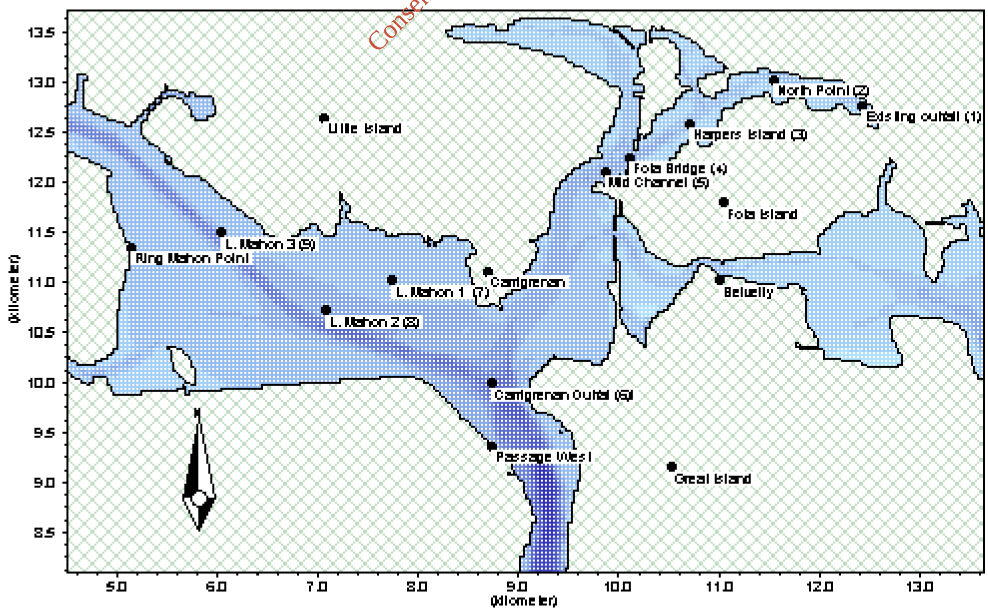


Figure 3.2 Locations of Data Extraction Points (In the simulations where the proposed Outfall is located in the Slatty Estuary)

3.4 Model Calibration/Validation

Before undertaking any design work using the output of numerical models it is imperative that the model is properly calibrated/validated against field measurements. In the case of this study calibration/validation work was carried out in relation to the both the hydrodynamic and water quality models such that the correct flow and dispersion characteristics were substantially reproduced.

3.4.1 Hydrodynamic Model

The calibration process involves running the same simulation until, through adjustment of model parameters, the model satisfactorily reproduces the field conditions. The field measurements used for the calibration/validation of the model included the current speeds and directions as recorded by the recording current meter and fixed station plus the water surface elevations recorded at Fota and Roches Point (see field measurement report for more details). Once the model has been calibrated for one set of input conditions it must be then validated for a different set of field conditions to ensure that it still gives satisfactory results. In the case of this study the model was calibrated for a spring tidal condition and validated on a neap tide. It should be noted that the calibration/validation of a model is a non-trivial task and it often takes considerable time to achieve satisfactory results. In the case of the hydrodynamic model for Cork Harbour good agreement was achieved relatively quickly and this was attributed to the good selection of field measurement points. The methodology followed in the process is described below.

The model grid contained one boundary, located at the southern extremity of the interpolated grid (see Figure 3.1). At this boundary the input condition (driving force) was a water level fluctuation corresponding to the tidal elevations as obtained from the Roches Point field data. For the calibration the simulation lasted for two tidal cycles - the first cycle allowed the model to stabilise whilst data was collected for the remaining cycle. Once the model run was complete comparisons were then made between the measured and simulated data in terms of water surface elevations and current speeds and direction. It required a number of simulations, with adjustments being made to the physical set-up of the model and parameters such as eddy viscosity and bed resistance before satisfactory agreement was achieved. The output plots for the calibration show that the model gives a good representation of the flow at the two measurement points (see figures 3.3 to 3.5).

For the validation of the model a slightly different approach was taken in that the model was run for a total of 9 tidal cycles. Model runs of this length are not normal for validation but given that the field data was available it was considered that the longer run would be a better test of the model. Figures 3.6 to 3.8 show comparisons between the simulated and measured results and in general they agree quite well. It should be noted that both the calibration and validation runs did not include for wind effects and this is partly responsible for observed differences between the measured and simulated results. However these differences are not considered to be significant in terms of influencing the nature of the flow regime in the Slatty Water Estuary.

The completion of the above work ensured that the model could properly reproduce the flow characteristics in the Upper Harbour and thus be used to determine the impact of the proposed outfall from the Carrigtohill treatment plant.

3.4.2 Dispersion Characteristics

The dispersion characteristics of the Slatty Water Estuary were determined by simulating one of the dye releases that was carried out. The model was set up such that a non-decaying substance was introduced at the same location and time as the dye and its subsequent movements were tracked in a similar manner to what was done in the field. The dispersion characteristics as produced by the model were then compared to the field measurements and if they differed then the model was re-run with a different set of dispersion parameters. Figures 3.9 to 3.11 show two comparisons between the model and field data at 3 and 4 hours after the dye release. Note that the dye release was made at high tide.

The completion of the above work ensured that the model could properly reproduce the flow characteristics in the Upper Harbour and thus be used to determine the impact of the proposed outfall from the Carrigtohill treatment plant.

3.5 Flow Regime Upper Harbour

Since the discussion of the results will be concerned mainly with water quality it is considered relevant to include a section on the Upper Harbour flow regime at this point. Figures 3.13 and 3.14 show the mid ebb and mid flood flows for a neap tide condition. The plots show that the highest velocities are confined to the main channel (compare with Bathymetry plot – Figure 3.1) and also at the location of constrictions (Belvelly, Fota Bridge etc). It is also relevant to note that there is very little flow interaction between the Upper Harbour and the area north of Great Island, via Belvelly Channel. The shallow depths at Belvelly as well as severe flow constriction at this point ensures that the area north of Great Island floods and ebbs by means of the East Ferry Channel. This is important to note as discharges from both Carrigrenan and Carrigtohill will be shown to have a minimal impact on water quality in this area.

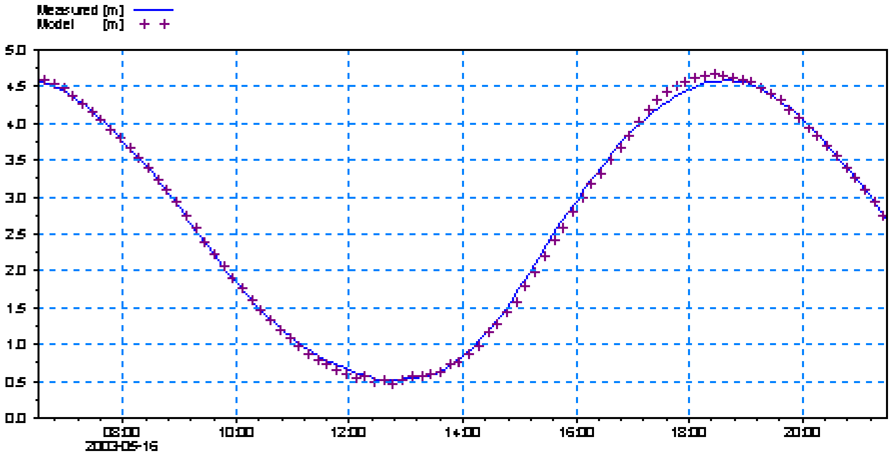


Figure 3.3 Water Surface Elevations (Fota)

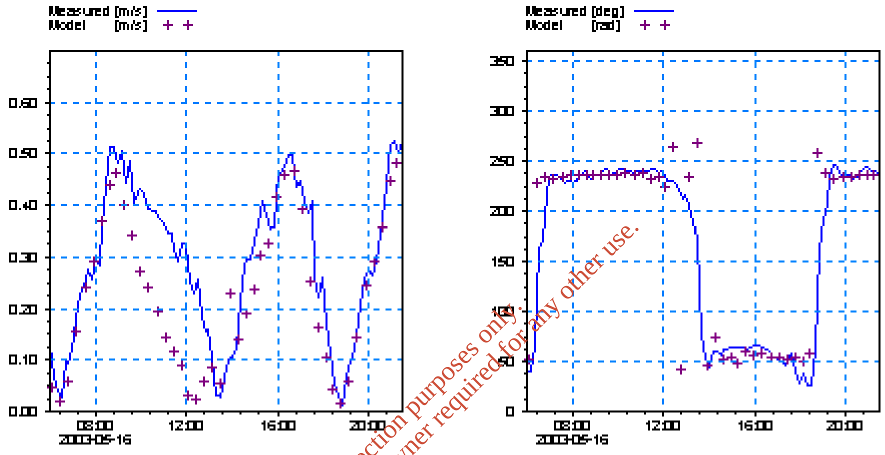


Figure 3.4 ((a) & (b)) Current Speed and Direction (RCM)

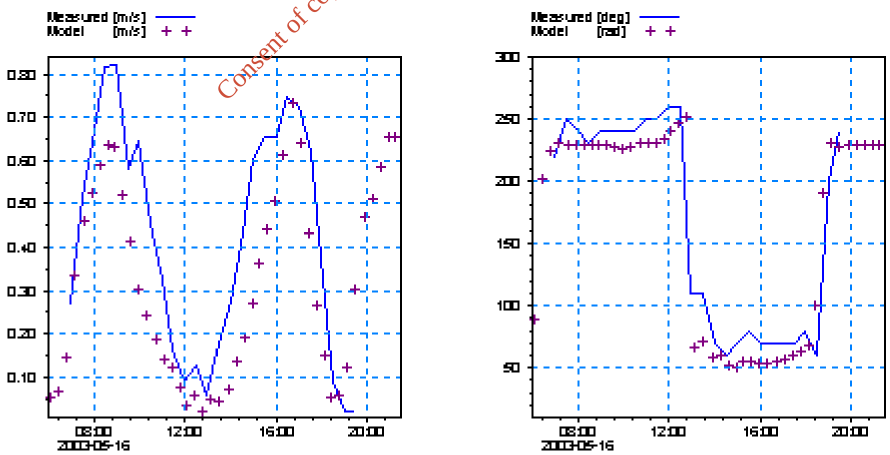


Figure 3.5 ((a) & (b)) Current Speed and Direction (Fixed Station)

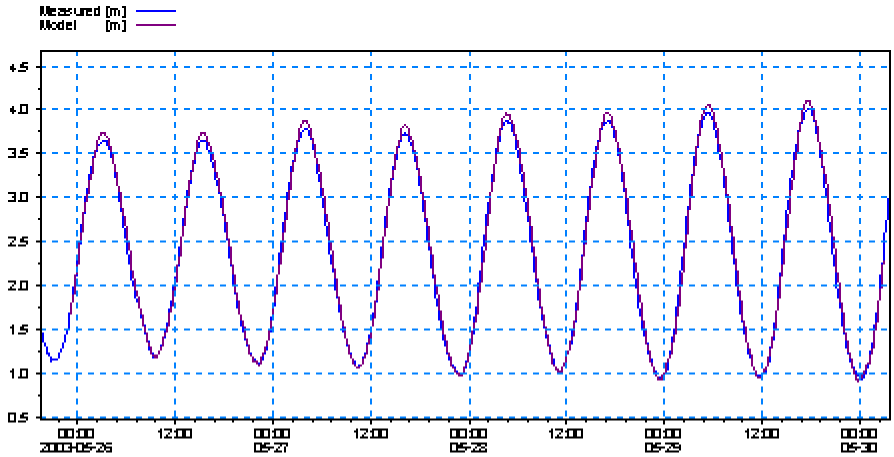


Figure 3.6 Water Surface Elevations (Fota)

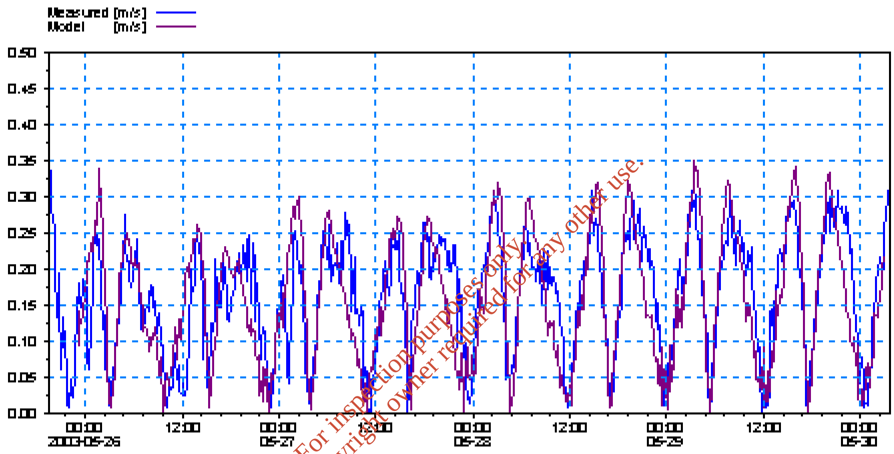


Figure 3.7 Current Speed (RCM)

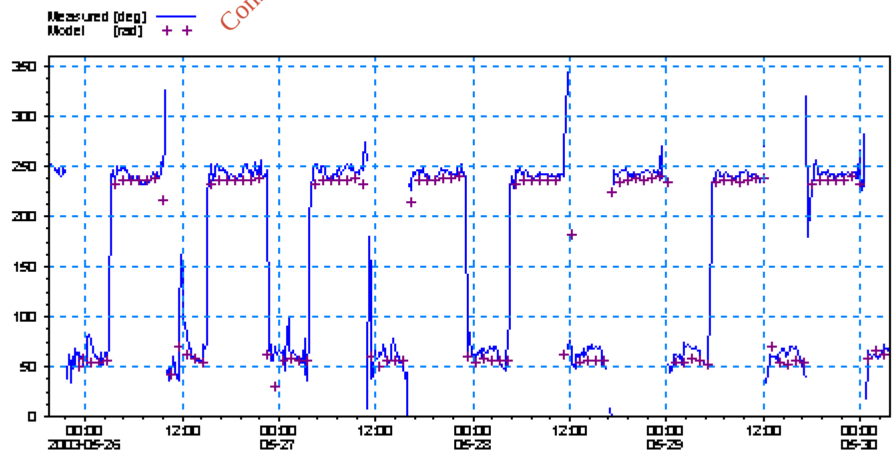


Figure 3.8 Current Direction (RCM)

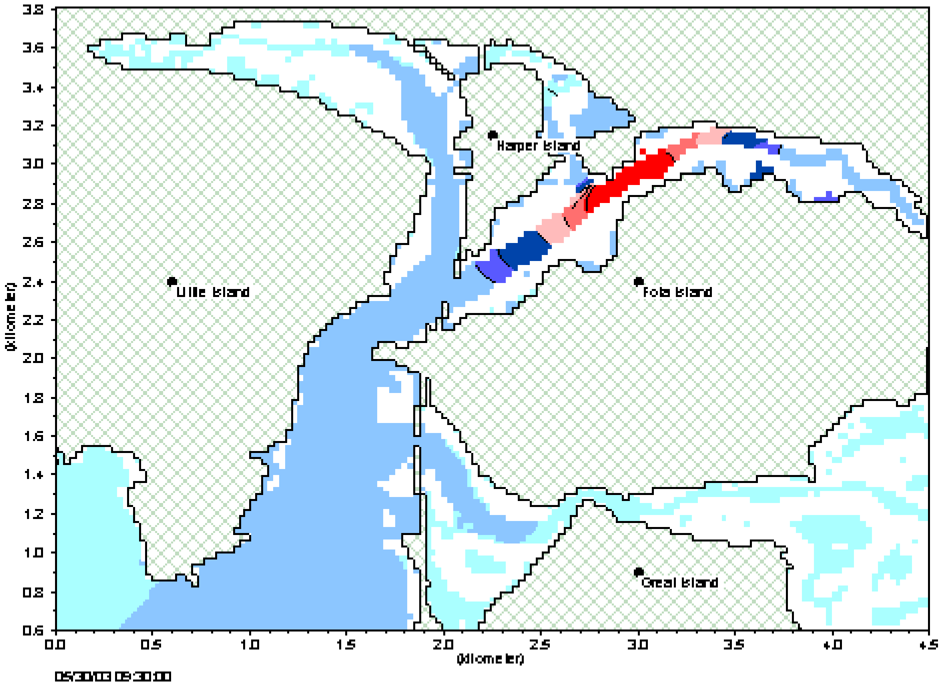


Figure 3.9 Dispersion Model Output HW +3h

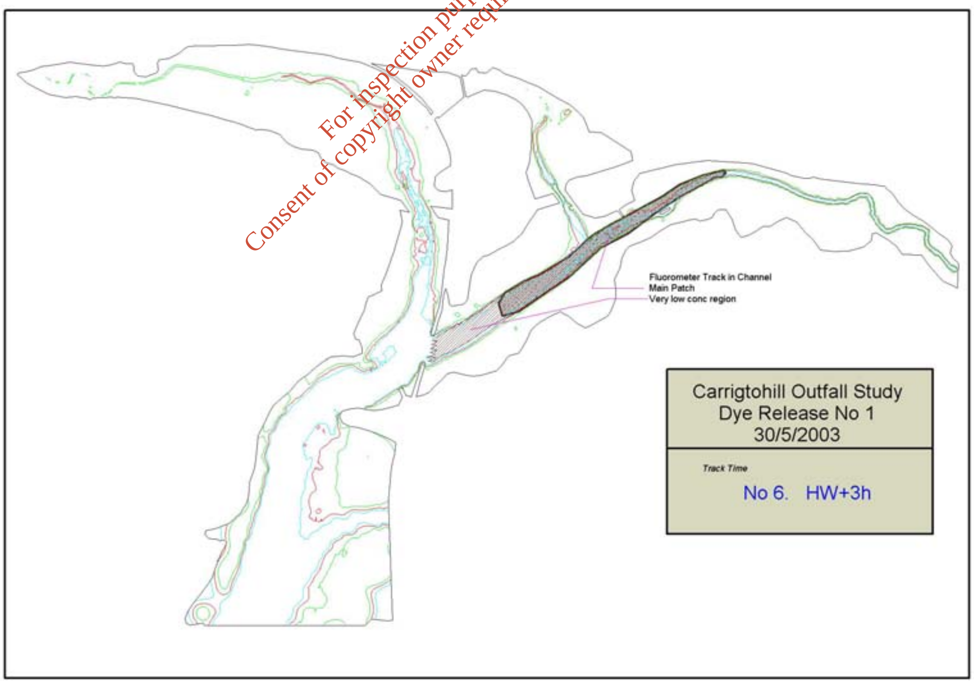


Figure 3.10 Field Measurements HW +3h

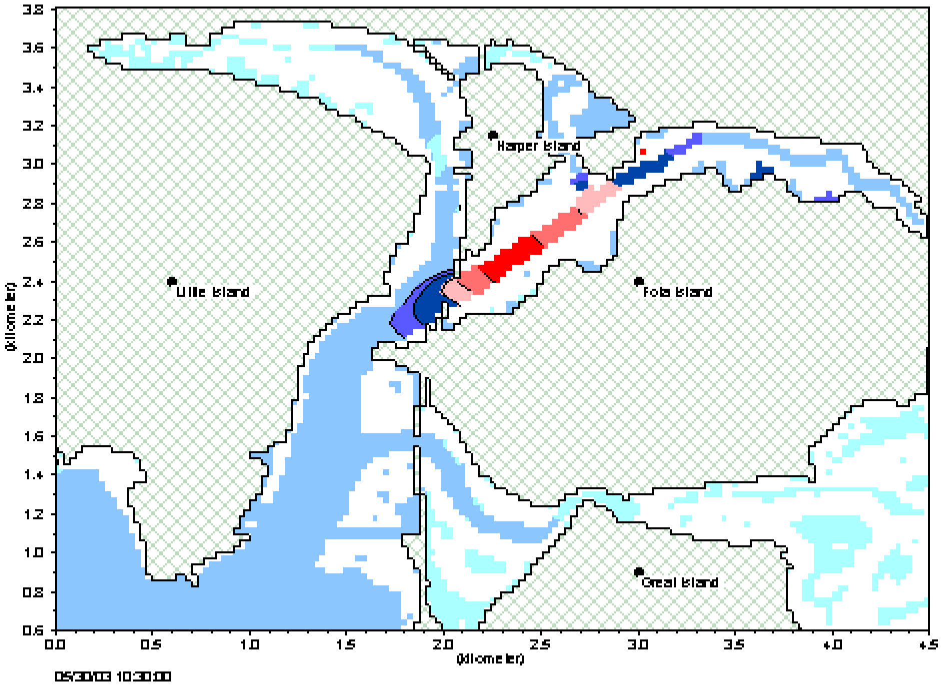


Figure 3.11 Dispersion Model Output HW +3h

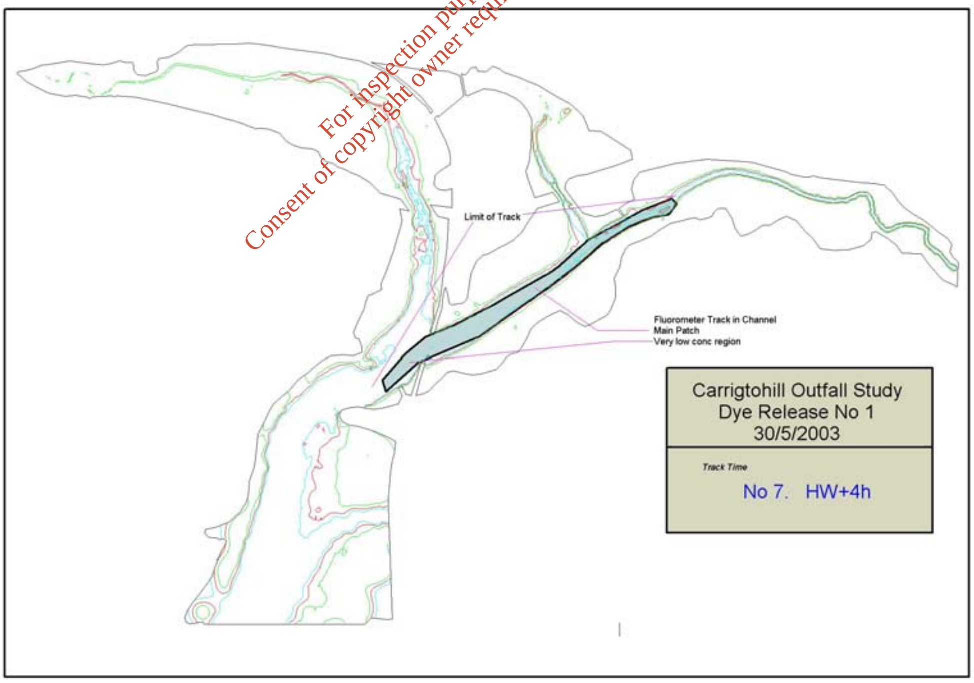


Figure 3.12 Field Measurements HW +3h

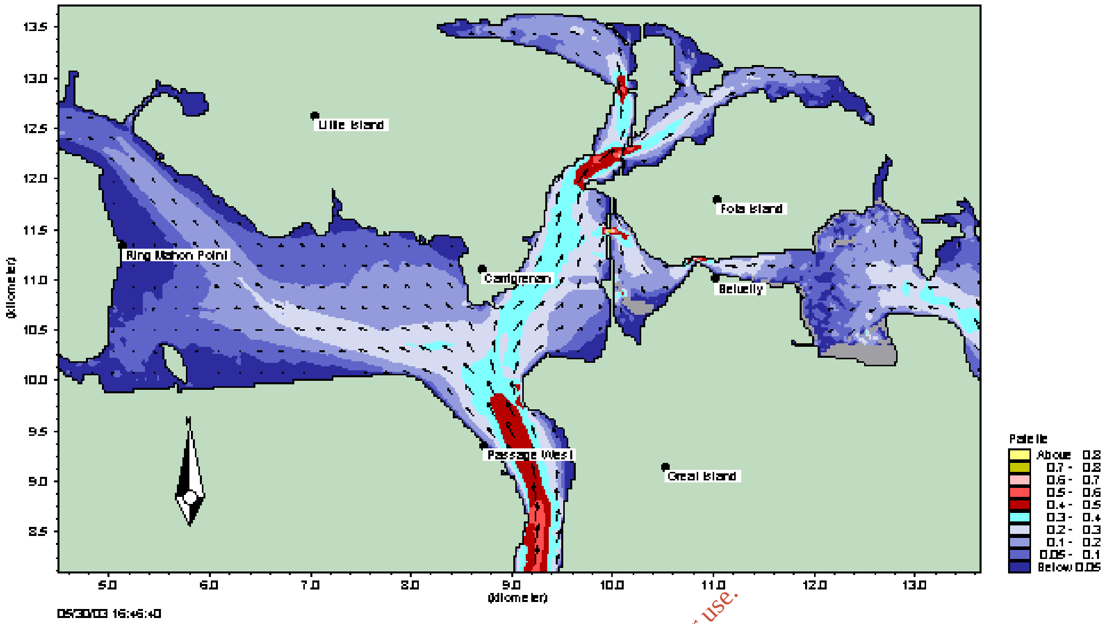


Figure 3.13 Flow Regime, mid ebb tide
(Plot units m/s)

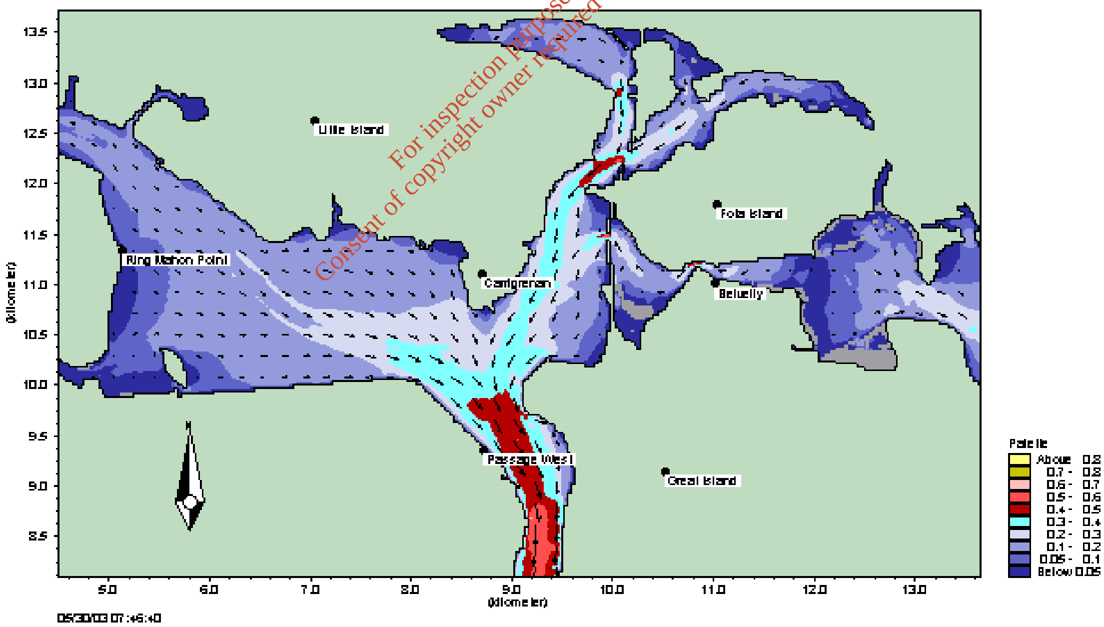


Figure 3.14 Flow Regime, mid flood tide
(Plot units m/s)

3.6 Description of Simulations

The numerical model simulations set out to determine the water quality in the Upper Harbour region as a consequence of the discharges from outfalls from the Carrigtohill and Carrigrenan treatment plants. The Carrigrenan outfall has already been extensively studied (Cork Main Drainage Study) but its impact on the water quality in the Slatty Estuary needed to be included for reference purposes. With regard to the Carrigtohill outfall the objective was to determine the optimal discharge criteria, in terms of both cost and water quality standards, in relation to the following parameters,

- Treatment standard required – impact of various discharge values of coliforms, BOD and nutrients on water quality
- Location of Outfall – consider impact of discharging at different locations in the Slatty Water Estuary
- Discharge type – continuous or tidal

The following sub-sections indicate the variables used in the simulations that were run as part of this study. .

3.6.1 Water levels

Two tidal levels were simulated corresponding to the mean neap and spring tide situations as indicated in the Admiralty tide tables. The high water levels and range for each of these tidal conditions are given below,

Description	High Water Level (Chart Datum)	Range (m)
Neap	3.2	1.9
Spring	4.4	4

Table 3.1 Tidal Conditions

3.6.2 Wind Conditions

Wind can have an impact on the flow conditions within the estuary and to examine this one simulation was run with a wind speed of 15m/s and a wind direction of 225 degrees. It was regarded that winds from a general south westerly direction would most influence the flows in the Slatty Estuary and the Cork Main Drainage Study had shown that this is the most prevalent direction. The input wind conditions would be regarded as being severe with only a bout a 1% frequency of occurrence.

3.6.3 Outfall Discharge Rates

For all simulations the dry weather flow (DWF) was used for the discharge from each of the outfalls. The Carrigrenan outfall had a DWF value of 103,950m^3/day. For Carrigtohill this corresponded to a flow rate of 1050m^3/day for the current situation and 10,125m^3/day for the proposed future condition (45,000 PE). In additional simulation runs, the following flow rates were used for Carrigtohill:

-	55,000 PE	:	12,375 m^3/d
-	62,000 PE	:	13,950 m^3/d
-	82,500 PE	:	18,560 m^3/d
-	100,000 PE	:	22,500 m^3/d

3.6.4 River Discharges

The model included fresh water discharges from the Slatty Pond and the River Lee. The Slatty Pond flow rate was 0.4m^3/s whilst for the River Lee a value of 51m^3/s was used.

3.6.5 Decay Rates

The decay rate for both coliforms and BOD was chosen based on the discussion in Volume 3 of the Cork Main Drainage Report (pg 19). For coliforms the decay rate is specified as a T_{90} (time taken for 90% of the micro-organisms to die) and a value of 6 hours was used. This value is considered to be conservative. For BOD a value of 0.2/day was chosen and this is regarded as being typical of dry summer conditions.

3.6.6 Simulation Length

In general most simulations were run for ten tidal cycles, which corresponded to more that 5 days. This length of simulation was required to allow the coliform and BOD values to stabilise. Two simulations with a 28 day length were also run to examine the build up of nutrients over a longer time period.

3.6.7 Background Values

Background values of coliforms BOD and nutrients (ammonia, nitrate and phosphorous) were set to zero such that the model only predicted the impact of the two outfalls on the water quality in the harbour. Measured values of these parameters should be added to model output to determine the true values.

3.6.8 Preliminary Model Runs

A number of preliminary model runs were carried out to determine the optimum discharge type and location. These simulations are not listed in Table 3.2 below but were useful in showing that the water quality particularly south of Fota Bridge was not that sensitive to either of these factors. Three different discharge locations were simulated corresponding to the existing outfall, a point 300m east of it and the north point of the Slatty Estuary (see Figure 2.1). Water Quality in the vicinity of the outfall was affected but the differences became marginal as the distance from the outfall increased. Similarly with the discharge type, as continuous and various 2, 3 and 4 hour discharges (about high tide) were modelled. It was found that there was less variation in water quality for the continuous discharge condition and peak values occurred around low tide (as opposed to after high tide for the tidal discharge).

3.6.9 Simulation runs

Tables 3.2 and 3.3 below show the input parameters for the model simulations. There are 20 in total and include a variety of different input conditions. They intend to initially show the existing water quality in the Slatty Estuary and follow on to examine the individual impacts of both the Carrigrenan and Carrigtohill outfalls. Even though it is proposed to have a continuous discharge at Carrigrenan one simulation with a tidal discharge was carried out. Following simulations consider the impacts of applying different treatment standards to the effluent. Of note is simulation 14, which considers an alternative discharge location in the Belvelly channel.

In a further stage, additional simulation runs were carried out, again focusing on the discharge locations, but also on the maximum allowable capacity and the discharge standards. Descriptions of these simulation runs are shown in Table 3.4.

The tabled output of the simulation runs is included in Annex 3 (Initial Runs) and Annex 4 (additional Runs). The graphic results of the initial runs are included in annex 5.

Sim. No.	Location	F. Coliforms /100ml	T. Coliforms /100ml	BOD mg/l	S. Solids mg/l	DO mg/l	Amm. mg/l	Nit. mg/l	Phos. mg/l	Discharge Type	Discharge m^3/day	Location	Sim Length days
1	Carrigtohill	1000000	5000000	20	30	1	5	30	8	LW-2 - LW+2	1050	Existing	5
	Carrigrenan	0	0	0	0	0	0	0	0	0	0	Marino Pt.	
2	Carrigtohill	0	0	0	0	0	0	0	0	0	0		5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
3	Carrigtohill	0	0	0	0	0	0	0	0	0	0		5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	HW+.5 - HW+3.5	104198	Marino Pt	
4	Carrigtohill	200000	1000000	10	20	1	5	25	8	Continuous	11145	Existing	5
	Carrigrenan	0	0	0	0	0	0	0	0	Continuous	104198	Marino Pt	
5	Carrigtohill	200000	1000000	20	30	1	2	15	3	Continuous	11145	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
6	Carrigtohill	200000	1000000	20	30	1	2	15	3	Continuous	11145	North Pt.	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
7	Carrigtohill	1000	5000	10	10	1	3	10	1	Continuous	11145	Existing	5
	Carrigrenan	200000	1000000	20	30	1	3	10	1	Continuous	104198	Marino Pt	
8	Carrigtohill	1000	5000	10	10	1	2	15	3	Continuous	11145	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
9	Carrigtohill	200000	1000000	10	20	1	5	25	8	Continuous	11145	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
10	Carrigtohill	200000	1000000	10	20	1	5	25	8	Continuous	11145	Existing	28 (all neap)
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
11	Carrigtohill	200000	1000000	10	20	1	5	25	8	Continuous	11145	Existing	28(real tidal cycle)
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
12	Carrigtohill	1000	5000	10	10	1	2	15	3	Continuous	11145	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
13	Carrigtohill	1000	5000	10	10	1	5	25	8	Continuous	11145	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
14	Carrigtohill	1000	5000	10	10	1	5	25	8	Continuous	11145	Belvelly	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
15	Carrigtohill	1000	5000	10	10	1	3	10	1	Continuous	11145	North pt	5
	Carrigrenan	200000	1000000	20	30	1	3	10	1	Continuous	104198	Marino Pt	
16	Carrigtohill	1000	5000	10	10	1	2	15	3	HW - HW+3	11145	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	

Table 3.2 Input for Neap Tide Simulations

Sim. No.	Location	F. Coliforms /100ml	T. Coliforms /100ml	BOD mg/l	S. Solids mg/l	DO mg/l	Amm. mg/l	Nit. mg/l	Phos. mg/l	Discharge Type	Discharge m^3/day	Location	Sim Length days
17	Carrigtoohill	1000	5000	10	10	1	5	25	8	Continuous	11145	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
18	Carrigtoohill	1000	5000	10	10	1	5	25	8	HW - HW+3	11145	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
19	Carrigtoohill	1000	5000	10	10	1	2	15	3	HW - HW+3	11145	North Pt	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
20	Carrigtoohill	1000	5000	10	10	1	5	25	8	Continuous	11145	North Pt	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	

Table 3.3 Input for Spring Tide Simulations

Sim. No.	Location	F. Coliforms /100ml	T. Coliforms /100ml	BOD mg/l	S. Solids mg/l	DO mg/l	Amm. mg/l	Nit. mg/l	Phos. mg/l	Discharge Type	Discharge m^3/day	Location	Sim Length days
21	Carrigtohill	1000	5000	10	20	1	5	25	8	Continuous	18560	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
22	Carrigtohill	1000	5000	10	20	1	5	25	8	Continuous	22500	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
23	Carrigtohill	200000	1000000	10	20	1	2	8	0.4	Continuous	18560	North Pt	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
24	Carrigtohill	200000	1000000	10	20	1	2	8	0.4	Continuous	18560	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
25	Carrigtohill	200000	1000000	10	20	1	2	8	0.5	Continuous	12375	Existing	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	
26	Carrigtohill	200000	1000000	10	20	1	2	8	0.5	Continuous	12375	North Pt	5
	Carrigrenan	200000	1000000	25	35	1	5	25	8	Continuous	104198	Marino Pt	

Table 3.4 Input for Additional Simulation Runs (Neap Tide)

4) FIELD REPORT

4.1 Introduction

In June 2003 Irish Hydrodata Limited (IHD) were commissioned by the Hydraulic and Maritime Research Centre (HMRC) to conduct a marine survey of the Foaty Channel and adjacent waters in Cork Harbour. The study forms part of a wider investigation into the dispersion of treated wastewaters from the Carrigtohill sewer outfall.

The study methodology was agreed between IHD and HMRC. The various aspects of the study were to include bathymetry, tide level, current profiling, dye tracking and sediment and water sampling. Data and results were to be presented in a format that would facilitate preparation of a numerical dispersion model.

This report documents the study works and includes relevant figures and plots.

All survey position data is to Irish National Grid and vertical control is to Cork Harbour Chart Datum which is 2.57m below Malin Head datum.

4.2 Bathymetric Survey

A bathymetric survey of the Foaty Channel and adjacent waters was conducted over the area shown in Figure 4.1. The survey was completed from a 7m long shallow draft launch equipped with a Knudsen 320m dual frequency echosounder and a Trimble NT300D positioning system. Data was logged on a computer running HYPACK survey software. Tidal levels were recorded manually at Slatty Bridge and bathymetric data subsequently reduced to Cork Harbour chart datum (-2.57m OD Malin).

The shallow waters presented a particular challenge as survey work could only proceed for approximately 1 hour on either side of high water. The survey was completed over a period of four days. Survey lines were chosen to delineate the channels in so far as possible. Limited data was obtained on the shallow mudflats. The tidally reduced survey data was input to a terrain model. Suitable breaklines were manually added to define the channels and xyz data generated on a 5m x 5m rectangular grid. Figure 4.2 shows a colour coded contour plot of this data.

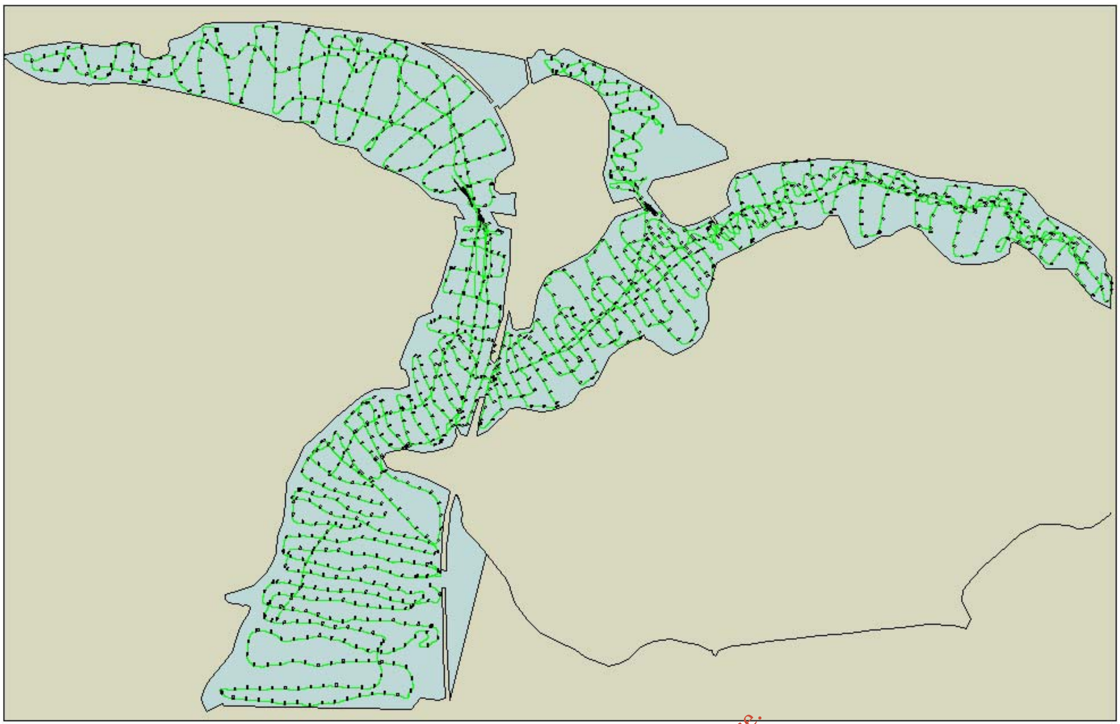


Figure 4.1 – Bathymetric Survey Tracklines

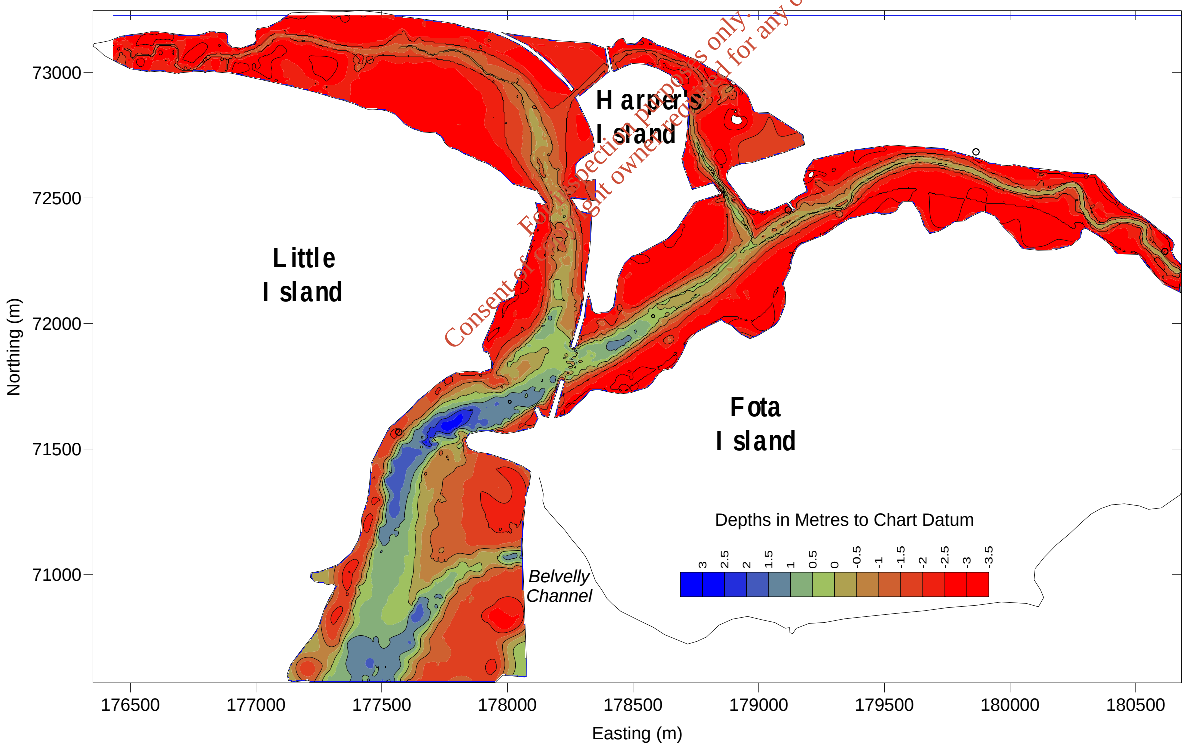


Figure 4.2 –Bathymetry and contours from terrain model

4.3 Tidal level Recording

Two digital tide gauges were deployed for this study; one at the entrance to the harbour near Roches Point and the other within the survey area near Harpers Island. (Figure 4.3). Both were seabed mounted Coastal Leasing Minitide units that recorded absolute pressure (i.e. atmospheric and water) data at 10-minute intervals. Data from the Met Eireann weather station at Roches Point was used to correct for atmospheric pressure variations at the end of the deployment period which lasted for 20 days from 14th May to 5th June. The gauges were levelled into chart datum.

Time series plots for both data sets are presented in Figure 4.4.

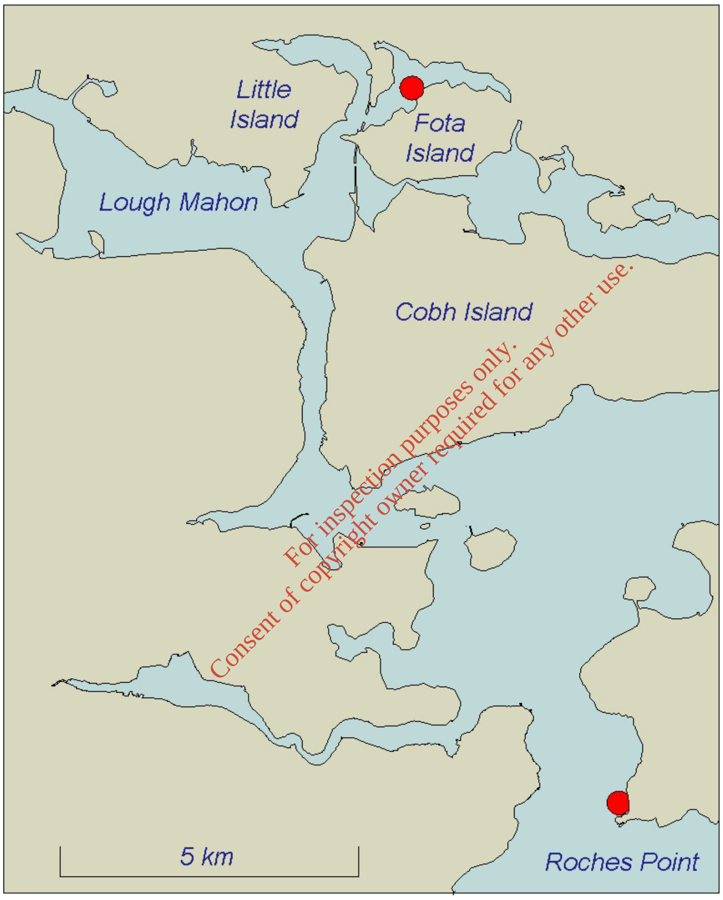


Figure 4.3 – Tide Gauge Locations

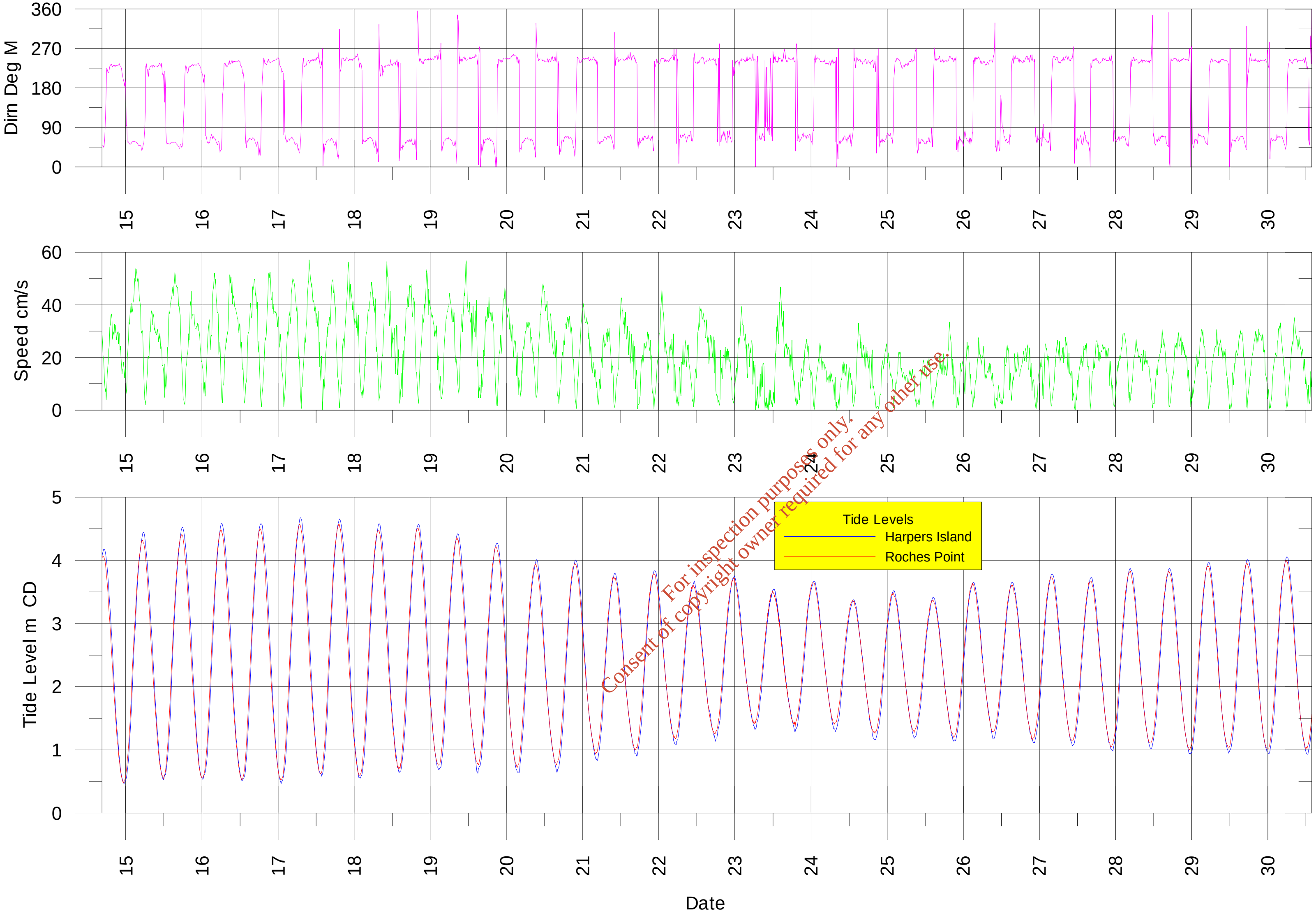


Figure 4.4 – Current Meter and Tidal Data

4.4 Current Metering

Current metering was conducted at the two locations shown in Figure 4.5.

A recording meter was deployed at the north-eastern site for a period of 16 days. This was an Interocean S4 unit which recorded speed and direction data at 10-minute intervals. Fixed station measurements from a moored vessel were made at the western site on two dates. Current data was recorded at ½ hour intervals over a 12½-hour tidal cycle on a spring (16th May) and neap tide (23rd May). Data was recorded at three depths over the water column using a Valeport BFM 008 meter.

The long-term time series plots for the recording current meter are shown with the tidal data in Figure 4.4. Fixed station data for the spring and neap measurements are presented in Figures 4.6 and 4.7. These plots also include RCM and tidal data for the same period.

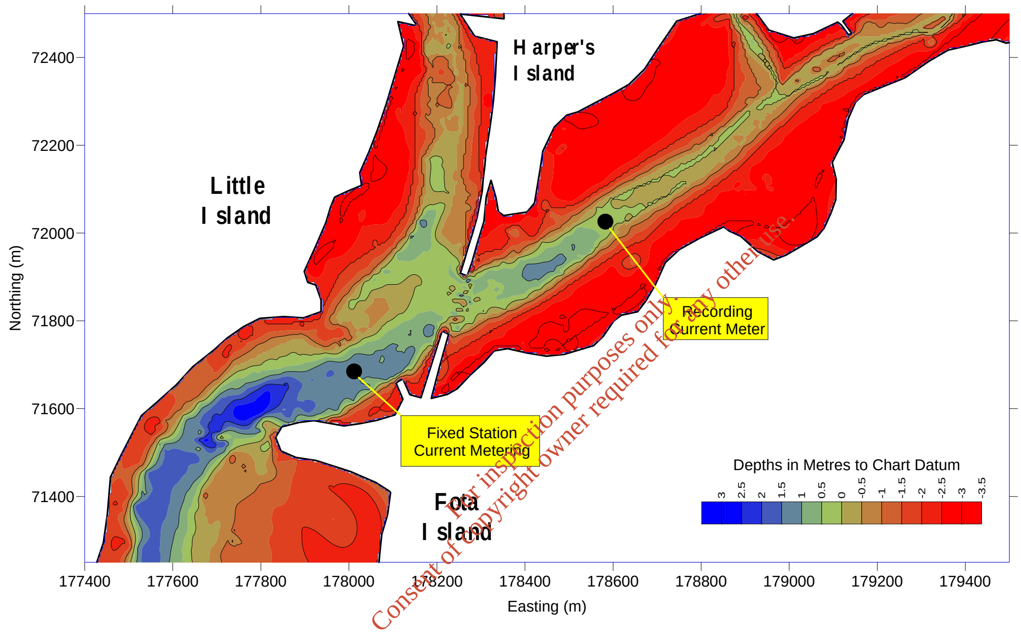


Figure 4.5 – Current Metering Locations

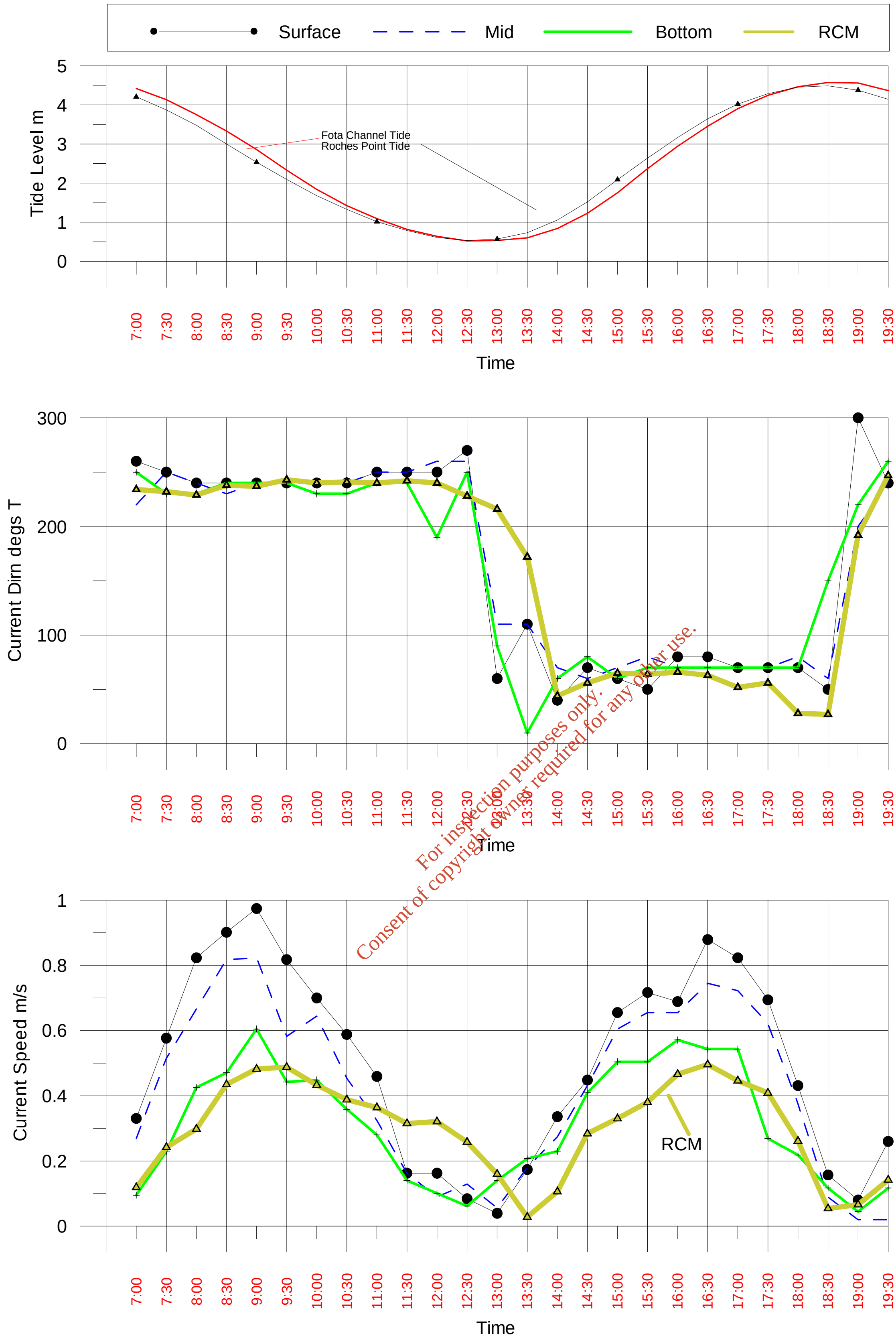


Figure 4.6 – Fixed Station, Spring Tide 16th May 2003

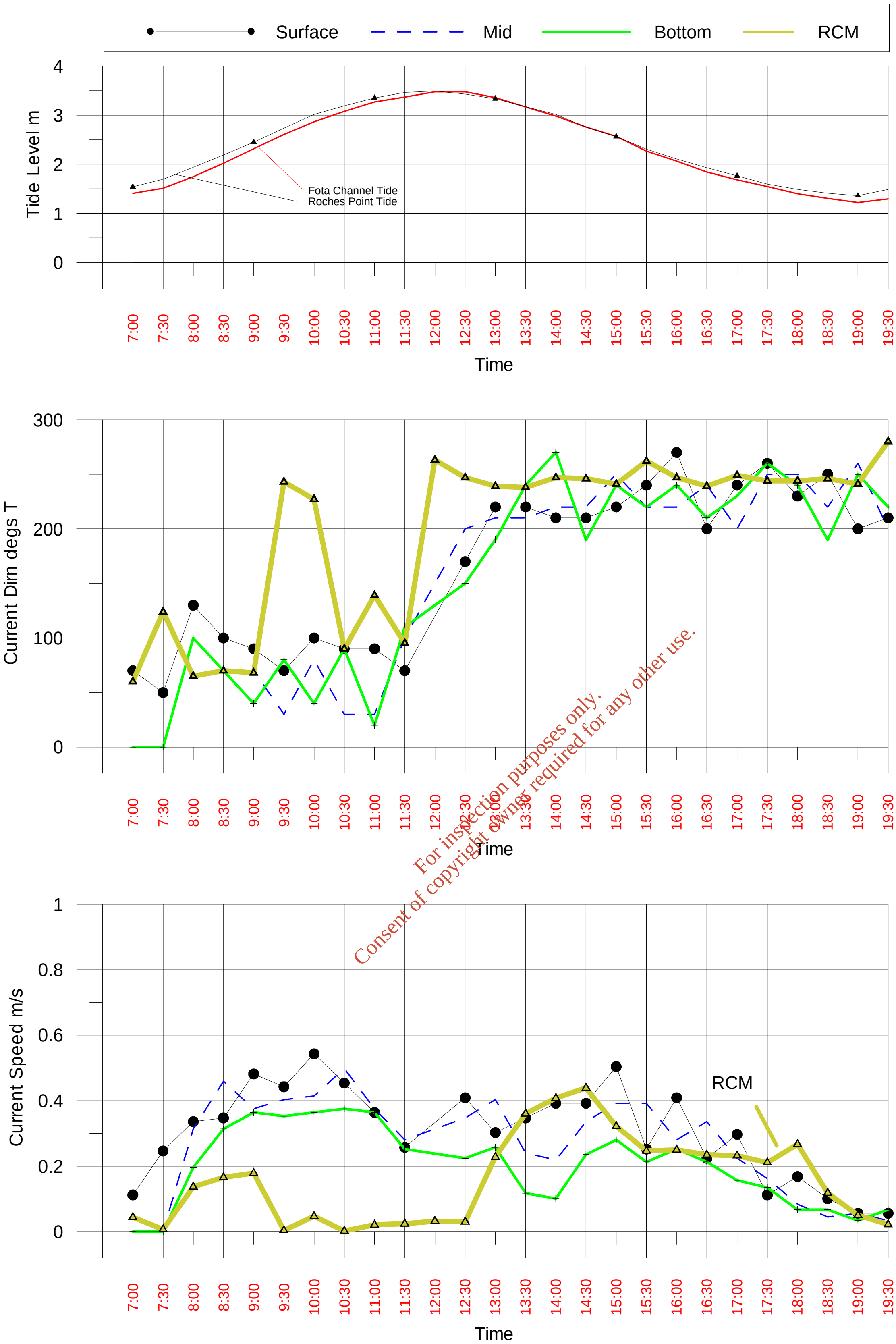


Figure 4.7 – Fixed Station, Neap 23rd May 2003

4.5 Water and Sediment Sampling

Ten water samples were collected at various times during the survey. Three of these were taken from the survey vessel during echo sounding works and the remainder from the northern shore at high and low waters. The sampling locations are indicated in Figure 4.8. Samples were analyzed for salinity and biochemical oxygen demand (BOD) and results are presented in Table 4.1.

Four sediment samples were taken from the intertidal zone at the low water neap contour. The locations were adjacent to the water sampling sites shown in Figure 4.8. Replicate samples were taken with a 50mm core barrel at each site. These were then analysed for sediment oxygen demand (SOD) by the Aquatic Services Unit at UCC. Analysis results are presented in Table 4.2.

	Location	Tide State	Salinity	BOD mg/l
1	Fixed Station Site	HW	27.7	1.97
2	Fixed Station Site	HW+2h	27.6	1.58
3	Fixed Station Site	HW+3h	24.7	1.83
4	Sample Site - S2	LW	11.1	4.28
5	Sample Site - S3	LW	21.8	3.21
6	Sample Site - S4	LW	24.1	1.96
7	Sample Site - S1	HW+1h	18.5	>7.1
8	Sample Site - S2	HW+1h	16.4	3.85
9	Sample Site - S3	HW+1h	20.0	2.25
10	Sample Site - S4	HW+1h	24.7	3.56

Table 4.1 – Water Sample Analysis Results

	Location	Time	SOD $gO_2/m^2/d$
1	1	LW	2.2
2	2	LW	1.7
3	3	LW	2.1
4	4	LW	1.7

Table 2 – Sediment Sample Analysis Results

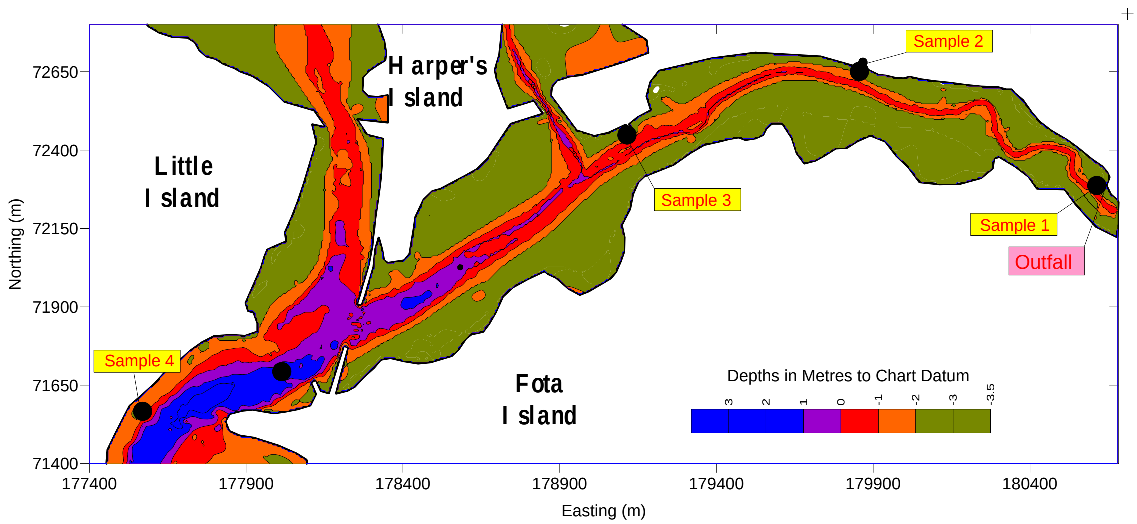


Figure 4.8 – Water & Sediment Sampling Locations

4.6 Dye Tracking

Dye tracking exercises were conducted on two dates, 30th May and 3rd June. On each occasion a slug (250ml) of Rhodamine WT tracer dye was released on the water surface at the outfall location soon after high water. The spreading patch was then tracked as it travelled westwards along the channel. Initially, tracking was visual but as soon as concentrations permitted, tracking commenced with a continuous flow-through fluorometer fitted to the survey vessel.

Plots showing the progress of the patch for Day 1, 30th May and Day 2, 3rd June are presented in Annex 1 and Annex 2.

The tracking was hindered by the shallow waters, which prevented the patch extents and concentrations from being reliably mapped. Subsequent analysis of the data allowed limited descriptive parameters to be established. Details of the patch spreading rates and changing peak concentration are outlined in Figures 4.9 and 4.10. These are similar in feature to typical data observed in other coastal sites.

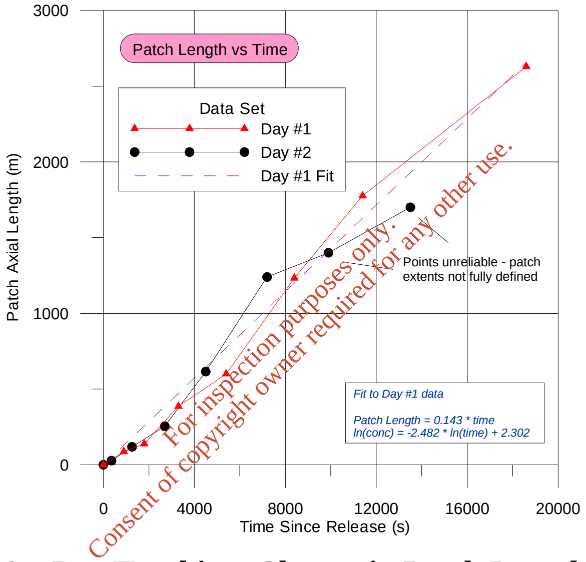


Figure 4.9 – Dye Tracking, Change in Patch Length vs Time

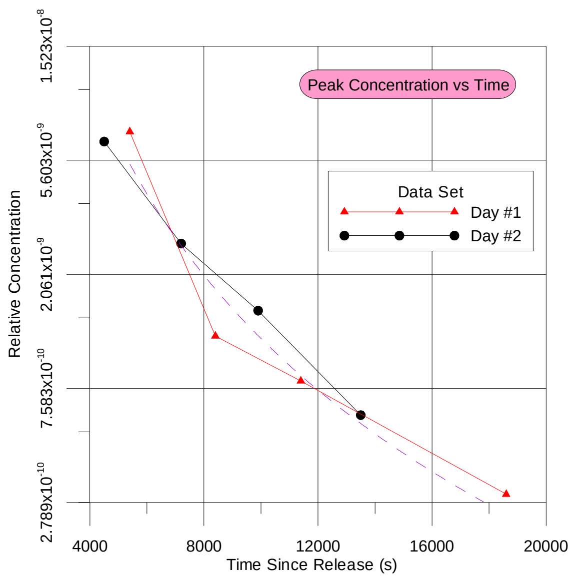


Figure 4.10 – Dye Tracking, Change in Peak Concentration vs Time

5) DISCUSSION OF RESULTS

5.1 Model Calibration and Validation

The model can be stated to be well calibrated. In the CMD PR, it was stated that the peak BOD predicted at the outfall as a result of the discharges from the treatment plant at Carrigrenan would be 0.33 mg/l. We found in our model that the peak BOD at the same outfall would be 0.41 mg/l. Thus we conclude that the models are essentially in agreement, the slight difference may be put down to the sizes of the grids and the improved computing power.

The model assumed the Slatty Water Estuary channel bed to be horizontal so that the depth of the water in the channel to be constant at any specific time in the tide.

The effects of overflows from the treatment work or collection have not been modelled.

5.2 Background values

The following parameter measurements were taken in the Slatty Water Estuary. The estimated BOD values from the model, resulting from the existing Carrigtohill discharges are also stated.

Sample No.	Location	Salinity	BOD	Tide	Model Estimated BOD values	True background values
		%	mg/l		mg/l	mg/l
1	Fixed Station	27.7	1.97	HW	0.07	1.90
2	Fixed Station	27.6	1.58	HW + 2	0.06	1.52
3	Fixed Station	24.7	1.83	HW + 3	0.03	1.80
4	S2	11.1	4.28	LW	0.37	3.91
5	S3	21.8	3.21	LW	0.21	3.00
6	S4	24.1	1.96	LW	0.03	1.93
7	S1	18.5	>7.10	HW + 1	0.50	0.00
8	S2	16.4	3.85	HW + 1	0.06	3.79
9	S3	20.0	2.25	HW + 1	0.01	2.24
10	S4	24.7	3.56	HW + 1	0.01	3.55

Table 5.1 Background Values

The large differences between the measured BOD values and the model estimated values can be explained by the effects of additional untreated discharges to Cork Harbour including the City, Little Island and Belvelly sources.

5.3 Input Parameters

The existing discharge from the Carrigtohill Sewerage treatment works was input (a DWF of 1,050 m3/day was assumed, and the discharge standard of 25:35 was assumed. Note that this standard is not always met). The proposed discharge from Carrigrenan was input along with that from Carrigtohill. It was endeavoured to ensure that the input parameters for the Carrigrenan discharge were as similar as possible to the input parameters used in the Cork Main Drainage Preliminary Report model, for comparison purposes.

Other discharges including those from the City directly into the River Lee and those from the Belvelly into Belvelly Channel were not included in the model. These were excluded on the grounds that the discharges to River Lee will cease when the Carrigrenan plant is operational. The discharges from Belvelly are expected to cease when appropriate treatment is provided at that location. The Belvelly discharges are from a relatively small population equivalent. The Cork Main Drainage Project Office has monitored the Coliforms counts along the Belvelly Channel for several months because of the existence of the shellfish farms.

The flow from the two plants was input at DWF.

The flow from Slatty pond is taken as a discharge over the low tide only as currently occurs.
The flow from the river Lee was input as a constant flow rate of 50 m3/s.

The definition of the North Point is the most northerly location in the Slatty Waters Estuary.

5.4 Receiving Water Quality

The implementation of the EU Water Framework Directive (2000/60/EC) has stimulated intense reviews of practices in relation to the management of all waters in Ireland. As part of this process, the EPA has carried out extensive research on Irish estuarine and coastal waters resulting in the publication of a report entitled "An Assessment of the Trophic Status of Estuaries and Bays in Ireland".

The primary purpose was to identify waterbodies in which eutrophication is occurring or may potentially occur. The Cork Harbour area was one of the waterbodies investigated. A waterbody is classified as eutrophic, when each of the following criteria are breached:

Criteria for nutrient enrichment (N,P);
Criteria for accelerated growth (chlorophyll);
Criteria for 'undesirable disturbance' (DO).

The Slatty Waters and the waters at North Point are determined as intermediate waters (between tidal fresh waters and full-salinity waters). The criteria for eutrophication are set for intermediate waters at:

Dissolved Inorganic Nitrogen	:	1.4	mg/l
Ortho-phosphate (MRP)	:	0.06	mg/l as P

These concentrations are recommended as the maximum concentrations in the receiving water when the impact of the discharge of effluent is considered.

This report contributed to the designation of certain areas as sensitive waters as part of the Urban Wastewater Regulations 2001 (SI No. 254 of 2001). The Lee estuary/Lough Mahon area was designated as a sensitive water and any discharged effluent must meet the standards set in these regulations. The standards set for a treatment plant with a loading between 10,000 PE and 100,000 PE are:

Total Phosphorus	2 mg/l
Total Nitrogen	15 mg/l

The achievement of bathing water quality in the Slatty Water Estuary is not considered an issue, as there are no designated bathing areas in the estuary. Sailing is the predominant water sport within the harbour. Any experienced sailors would be wary of sailing up along the estuary for fear of running aground on the mud flats when the tide goes out. There are no beaches within the estuary and there are no known swimming locations. It is proposed that the Bathing Water Regulations be met only where there is sufficient water over the course of the full tidal cycle for the safe passage of small sailing boats. The first location where there appears to be sufficient water through the course of the tide for such boats is at the channel between Little Island and Foaty Island. This location was titled "Main Channel" in the output tables.

5.5 Model output

The results stated below are for the parameters excluding the background values. The background values are discussed separately above. The figures may thus be compared 'like for like' with the results stated in the Cork Main Drainage Preliminary Report.

Spring tide runs were also run. The full effects of the spring and neap tides are experienced every two weeks. For the spring tide runs, the peaks are expected to be higher and averages are expected to be lower, though this was not the case as shown in the results below for the existing outfall location.

Parameter	Input Value	Output Value	Unit
Design Capacity	**8,000**	**-------**	**p.e.**
BOD	**20**	**1.76**	**mg/l**
SS	**30**	**Not simulated**	**mg/l**
P	**8**	**0.71**	**mg/l**
N	**30**	**2.67**	**mg/l**
DO	**10**	**8.3**	
T. Coliforms	**5,000,000**	**363,946**	**MPN/100mls**
F. Coliforms	**1,000,000**	**83,980**	**MPN/100mls**
DWF	**1,050**	**------**	**m^3/day**

Table 5.3 Discharge Parameters for Existing Carrigtohill WWTW

The existing water quality conditions are considered quite reasonable.

The BOD values remain well below 4mg/l. The BOD standard of 20 mg/l is not always met by the existing treatment works, particularly during period of heavy rainfall, when the dispersion is higher than normal. The oxygen level is at its lowest at 8.3 mg/l. this level of oxygen is not expected to affect the flora or fauna locally.

The nutrient levels drop off rapidly such that at the Mid Channel, phosphorus levels are expected to be 0.01 mg/l and nitrogen levels are expected to be 0.05 mg/l. There is no trace of these nutrients at Marino Point or Lough Mahon. The short retention period of 6 hours on average prevents eutrophication from occurring.

The high coliform counts do not have any noticeable effects, due to the lack of shellfish, bathing or water sports within the estuary. The total coliform counts fall to 1,845 at the Mid Channel.

However the outfall pipe is visible at low tide as is the effluent. The visible nature of the discharge is probably the largest impact.

5.7 Discharge Locations

The first goal of the model was to investigate the most appropriate location of the discharge of the Carrigtohill WWTP. Three locations were considered, namely (i) the existing outfall location near Slatty Bridge; (ii) discharge at North Point (see Figure 5.1) and (iii) discharge east of Belvelly Channel were investigated. This was done with a design population of 45,000 PE.

The goal of minimising the impact of the combined loads from the two plants (Carrigtohill and Carrigrenan), requires that the outfalls are located as far away from each other as possible. However, the dispersion near the existing outfall location is less than would occur further along the Slatty Water Estuary. Discharging at the existing location might hence result in relatively high concentration locally.

An alternative discharge location was examined at the North Point. It was found that the dispersion locally at this point was better. Depending on the final effluent quality, the North Point location can be more favourable than the current location at Slatty Waters. The most critical parameter herein is phosphate. Given the lower levels of dispersion at the existing outfall location the water quality standards as set for intermediate waters may not be achievable.

The option of discharging to the east of Belvelly Channel was examined. This option was only considered with a total coliform discharge standard of 5,000 MPN/100 mls. The peak Total Coliform level is seen to fall rapidly from 469 to 10 at Brick Island and to 1 MPN/100 mls at Brown Island. Thus, there is a reasonable degree of dispersion available in this part of Cork Harbour. However, due to the presence of shellfish farms within the estuary, discharges to this part of the estuary would most likely be unacceptable to the Department of Communications, Marine and Natural Resources.

Thus it is proposed that the optimum discharge location is at North Point.

5.8 Tidal Discharges

Three different tidal discharges were modelled. The first one was a continuous discharge. The second one was form high tide for three hours. The third one was for three hours, beginning one hour before the high tide. In general this was found to be the best locally at the outfall point. The parameters are slightly elevated within the Slatty Waters Estuary as a result of a continuous discharge; this can be seen in the output tables. However it was found that the effect of the tidal discharge was not noticeable by the time the effluent was carried down to the Mid Channel. As the water quality at Lough Mahon and east of Belvelly is under consideration here, thus it appears to be difficult to justify the storage of treated effluent for tidal discharge. It is proposed to discharge continuously.

5.9 Effects of Discharges

The Slatty Waters channel to which the effluent from Carrigtohill WWTW is discharged is an inlet from Lough Mahon. It has a negligible freshwater inflow, hence the water quality entering the channel is effectively that of Lough Mahon. (The channel between Slatty Bridge and Harpers Point feeds into a much larger water mass, Lough Mahon, which discharges to the sea.) The water quality in Lough Mahon has improved substantially in recent years. The proposed enhanced removal of N and P in the Carrigtohill WWTW will ensure that its contribution to the overall nutrient input to Lough Mahon will be insignificant. The effect of any local nutrient enrichment within the confines of the Slatty Waters inlet is greatly ameliorated by the tidal exchange with Lough Mahon, which reduces the average water residence time in the Slatty Waters inlet. The volume of water discharging from the channel is miniscule compared to the volume within Lough Mahon and the impact on the existing Lough Mahon concentrations will be very small. There is a very low level of freshwater discharge into Slatty waters and the dilution and mixing is provided entirely by the ebb and flow of the tides. The tidal nature of the channel results in frequent changes of the water mass indicating that the receiving water in the channel is refreshed on a regular basis. As a result the concentrations of the dispersed effluent parameters are removed from the channel frequently. This "cleansing" of the channel has been taken into account when determining the recommended effluent parameters to strike a balance between the need to minimise the phosphate and nitrogen concentrations within the receiving waters and the need to provide a level of treatment that maximises the efficient use of energy and other valuable resources.

5.9.1 BOD

The model runs with a design capacity of 45,000 PE show that a discharge standard of 25 mg/l is possible when the effluent is discharged at North Point. This results in an average concentration in the receiving water at the outfall point of 2.75 mg/l. If it were discharged at the existing outfall location, the water quality standard of 4 mg/l would be exceeded. At the final design capacity (60,000 pe) a discharge standard of 25 mg/l BOD will result in a concentration of 3.72 mg/l in the receiving water. Therefore a discharge of 25 mg/l (in accordance with the UWTD) is appropriate for both phases of the development.

5.9.2 Nitrogen

From the initial model runs, with a design capacity of 45,000 PE, it became clear that nitrogen removal is necessary to meet the water quality standard. At 45,000 PE and a discharge standard of 15 mg/l N the resulting concentration in the receiving water would be 1.29 mg/l N. At 60,000 PE and a discharge standard of 15 mg/l the resulting concentration in the receiving water would be 1.74 mg/l N. This is above the recommended concentration of 1.4 mg/l N contained in the EPA report so a reduced discharge standard of 10mg/l N would be required for phase 2

The mass of Nitrogen to be discharged from the proposed Carrigtohill WWTW is miniscule when compared to the mass of water in Lough Mahon and would contribute less than 1% of the total nitrogen in Lough Mahon.

Therefore a discharge standard of 15mg/l N (in accordance with the UWTD) is recommended for phase 1 and 10 mg/l N for phase 2 of the development.

5.9.3 Phosphate

Analogous to the model runs on nitrogen, we have investigated the necessary level of phosphorous removal. Discharging at the existing location is not possible without extreme treatment. Although the UWTD sets a standard of 2 mg/l P for the final effluent, this concentration would be excessive in terms of the resulting concentration within the receiving water. As a result, a concentration of 1 mg/l was considered. At 45,000 pe and a discharge standard of 1 mg/l P the resulting concentration of ortho-phosphate in the receiving water would be 0.1 mg/l P at the outfall location. While this is slightly higher than the recommended value (0.06 mg/l P) the concentration will reduce to the recommended value, as a result of the dispersion, before the water reaches Harpers Island, approximately 900 metres downstream of the outfall point.

At 60,000 pe, the resulting concentration in the receiving water would be 0.14 mg/l P. The dispersion would result in the recommended concentration being reached at Mid-Channel, approximately 2,000 metres downstream of the outfall point.

The mass of phosphorus to be discharged from the proposed Carrigtohill WWTW is miniscule when compared to the mass of water in Lough Mahon and would contribute less than 3% of the total phosphorus in Lough Mahon.

The cost of providing phosphorus removal below 1mg/l rises disproportionately when compared to the benefits in terms of the usage of resources such as energy, finance and manpower. Given the large body of water into which the channel feeds, the regular refreshing of the receiving water within the channel, the localised peak at the outfall point and the rapid reduction of the concentration due to dispersion a discharge concentration of 1 mg/l is recommended for both phases of the development.

5.9.4 Coliforms

The model estimates peak coliform counts at Blackrock at 10 MPN/ 100 mls, assuming that there are no sources at the River Lee, and that the nearest source is at Carrigrenan. The corresponding figure stated in the Cork Main Drainage Preliminary Report was 0 MPN/ 100 mls.

Fortunately, with the outfall point chosen above, the discharges from Carrigtohill and Carrigrenan are not accumulative to a significant extent at any location at any time. They do both affect the water quality at the Fota Bridge region, but at different stages of the tide. Thus the effects of either one is dominant at a time, depending on the stage of the tide. When the tide is rising the effluent from Carrigrenan is dominant, when the tide is falling the effluent from Carrigtohill is dominant.

As the Port of Cork do not recognise the Slatty Water Estuary for boating of any significance and as there are no licensed shellfish areas within the Slatty Water Estuary it appears to be unnecessary to treat the effluent to either the Shellfish or Bathing Water standards.

Modelling of the Faecal Coliform count for the 45,000 pe WWTP with discharge from the proposed outfall at north Point shows that the expected peak at Weir Island (including the dominant effect of Carrigrenan) is only 9 MPN/100 ml. This equates to a maximum daily average of 3 MPN/100 ml. The simulation with the peak wind conditions showed better rather than worse dispersion. It should be noted that the maximum average daily concentration at mid-Channel is 145 MPN/100 ml. This increases by 395% to 573 MPN/100 ml at Carrigrenan as a result of the discharge from the Carrigrenan outfall before reducing to 3MPN/100 ml at Weir Island. The impact of the Carrigtohill WWTW discharge on the faecal coliform levels at Weir Island reduces to zero based on the model results.

Based on these figures it is considered that shellfish farmers operating to the east of Weir Island should have no grounds for concern about discharges from Carrigtohill.

5.10 Sensitivity analysis

A sensitivity analysis was undertaken by changing the grid spacing from 30m to 15m, to show that the results are the same. The size of the model grid is not influential, at this spacing, to the accuracy of the results, though the input parameters are likely to be influential. When the grid size is 30m, the time step associated with that grid size of 30 secs. A simulation with a grid of 15m and 15 secs is to be run, and to be compared with an otherwise identical run, to show that the grid is sufficiently accurate.

Further sensitivity analysis was undertaken with a 28-day simulation. This 28-day run had 56 tidal cycles. It was found that the parameters showed very minor increases except for the nutrients. The nutrient increases found were described above. The expected peak BOD level rose from 2.96 mg/l too 3.03 mg/l. The expected peak Total Coliform levels rose from 276,246 to 291,414 MPN/100mls.

5.11 Wind Effects

The effects of the wind were also modelled. From the wind records at Cork airport over the period 1998 to 2003, it was found that the prevailing wind direction was SSW (225 degrees to the north). Extreme wind conditions were also modelled using wind speed of 15 m/s. This wind speed was exceeded only 1% of the time over the period. The effects of the wind are somewhat exaggerated due to the assumption that the land around the waters is flat. The effect in the Slatty Water Estuary was to decrease the coliforms counts significantly. The BOD vales fell only slightly (from 2.93 mg/l to 2.75 mg/l). The other parameters were no worse at any location as a result of the extreme wind conditions. The coliform count at Belvelly was lower as a result of the wind.

5.12 Proposed Discharge Standard

Based on the results of the model, the following is the proposed discharge standard:

Parameter	Phase 1 Value	Phase 2 Value	Unit
BOD	25	20	mg/l
SS	35	35	mg/l
P	1	1	mg/l
N	15	10	mg/l
T. Coliforms	No specific limit	No specific limit	MPN/100 mls
F. Coliforms	No specific limit	No specific limit	MPN/100 mls

Table 5.1: Proposed Discharge Standards for 45,000 pe and 67,000 pe

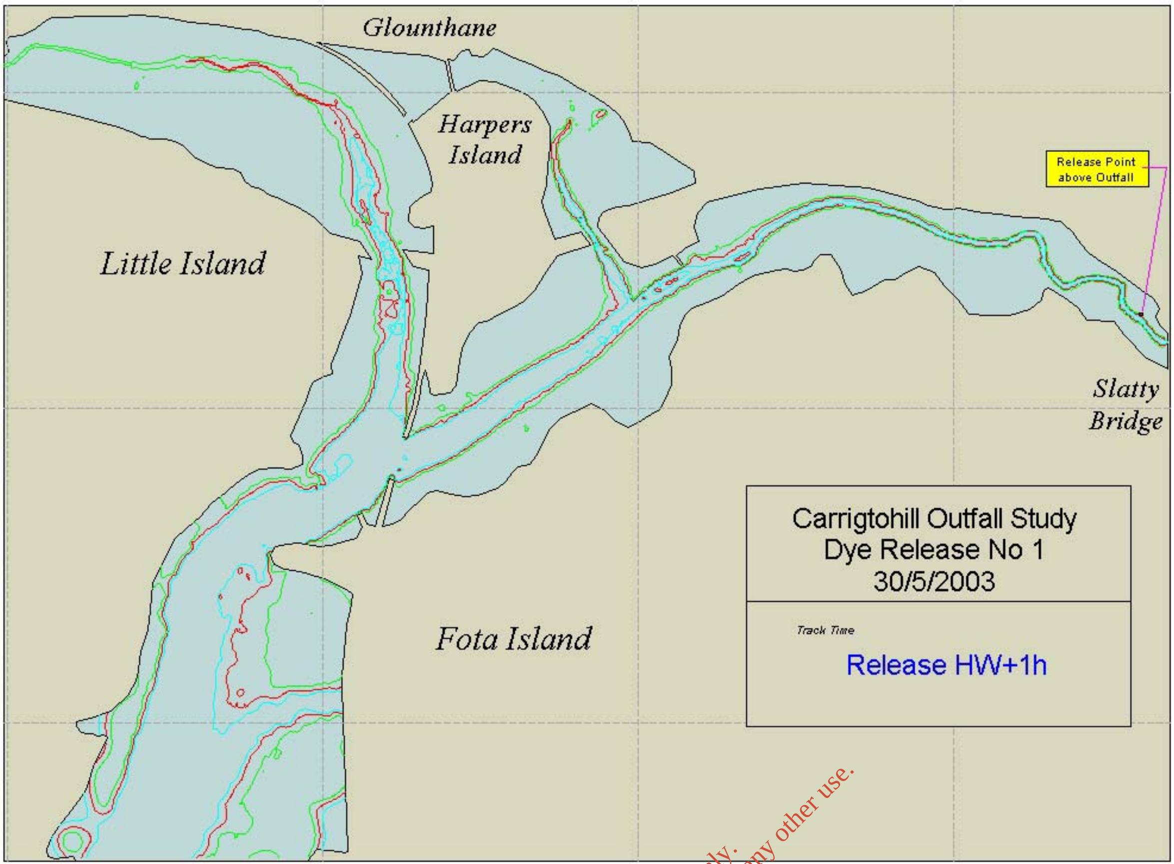
These standards meet the following regulations:

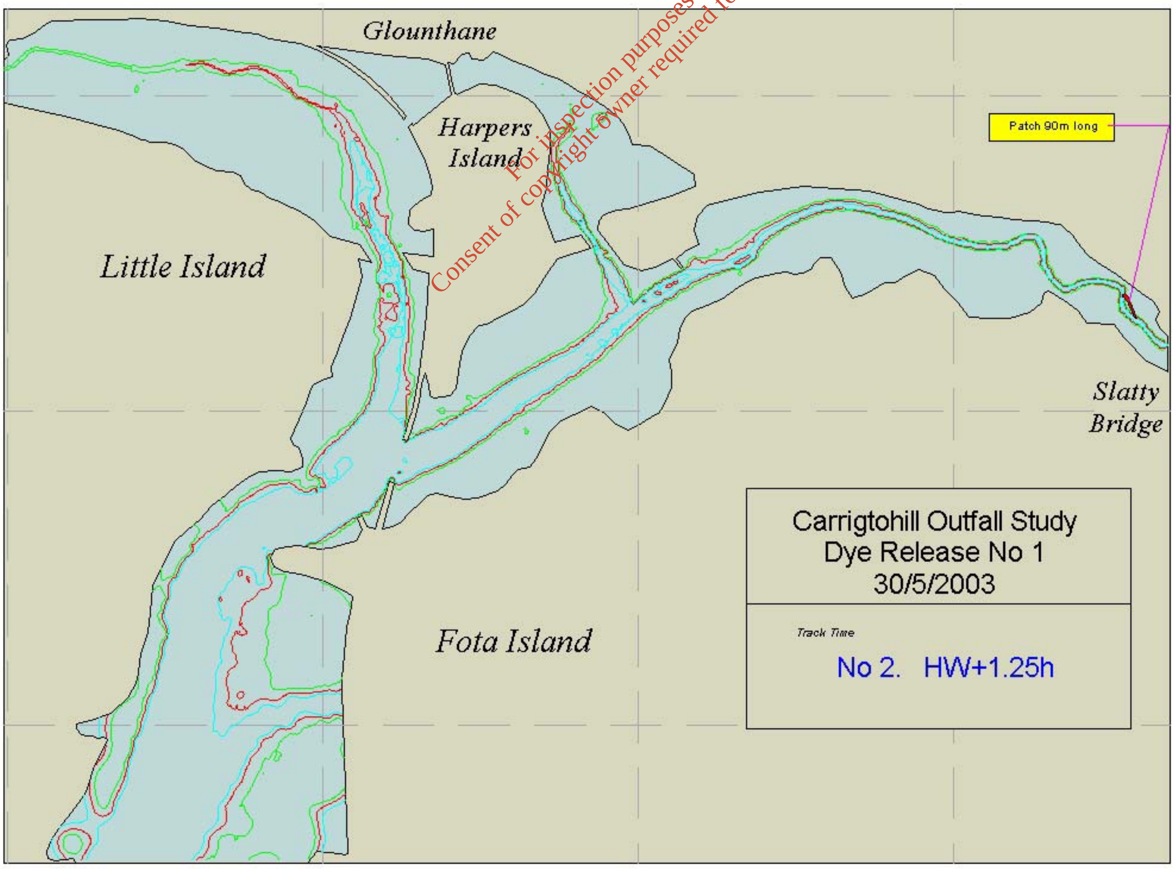
UWWT standard treatment (25:35 BOD:SS)
Shellfish Regulations (100:1000), (with dispersal, at specific locations only)
Bathing Regulations (1000:5000) (with dispersal, at specific locations only)
National Shellfish Sanitary System (at Weir Island Shellfish Farms)

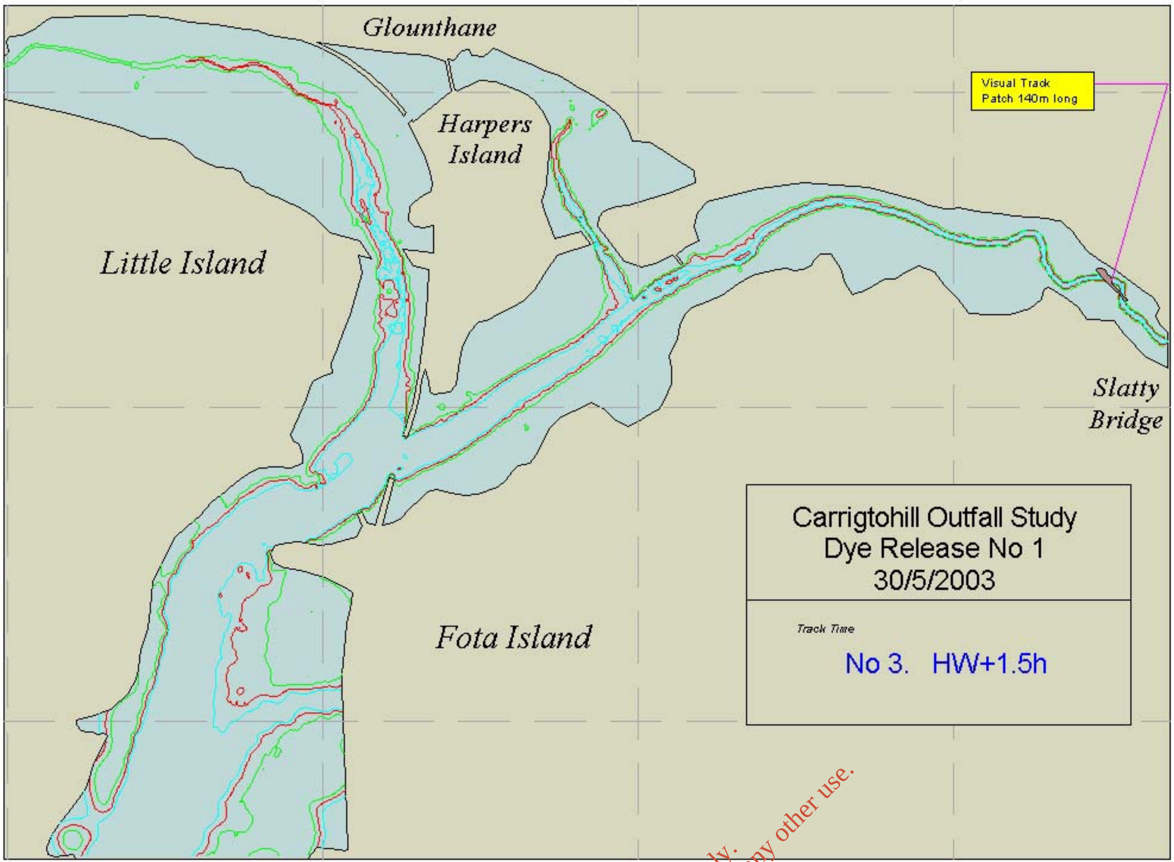
These discharge limits are also in accordance with the recent status of Cork Harbour as a designated sensitive area.
Satisfactory dispersion qualities have been demonstrated at North Point by the hydrodynamic model. The North Point is a suitable discharge location for the Carrigtohill Sewerage Scheme because of the level of dispersion available and the short periods of retention.

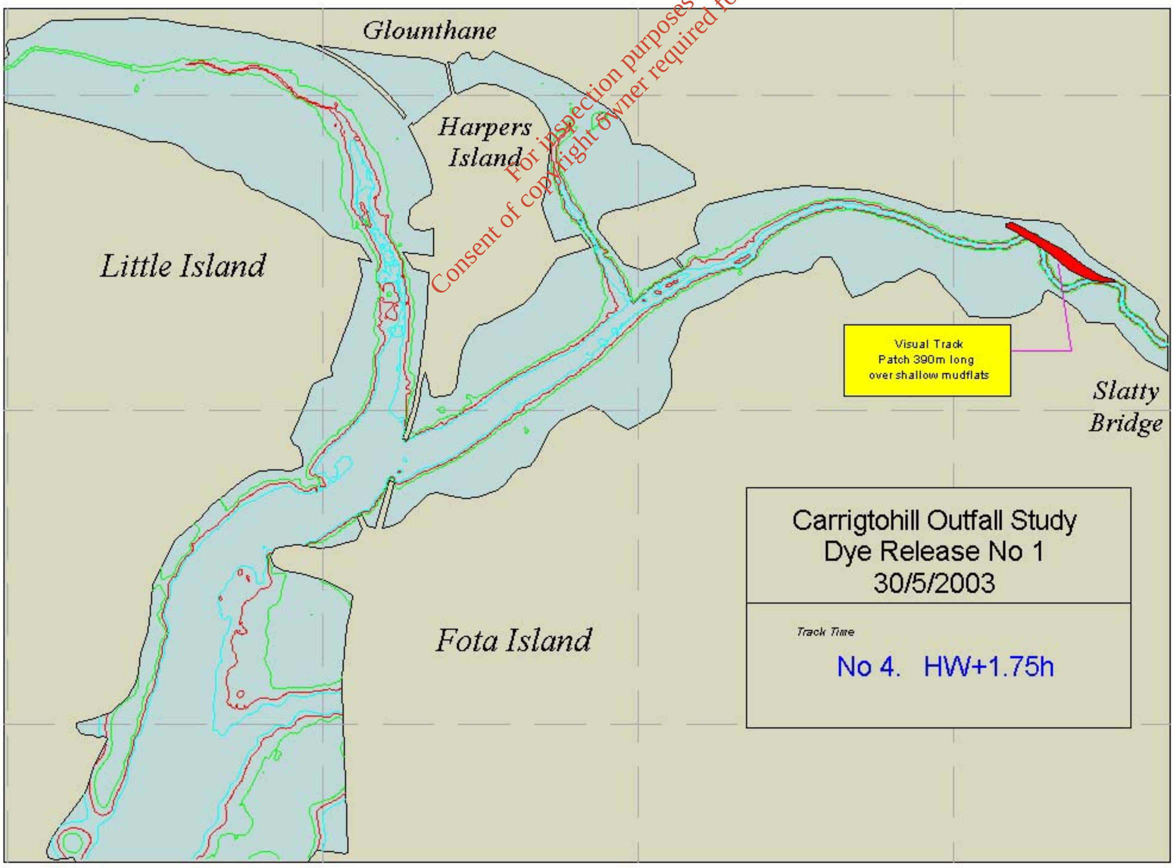
The nutrient concentrations (N, P) will be reduced below the recommended level (EPA Report) prior to discharge into Lough Mahon and the Lee estuary.
The discharge standards recommended will provide adequate treatment for the Carrigtohill WWTW for both phases of the development while complying in principle with all of the relevant standards.

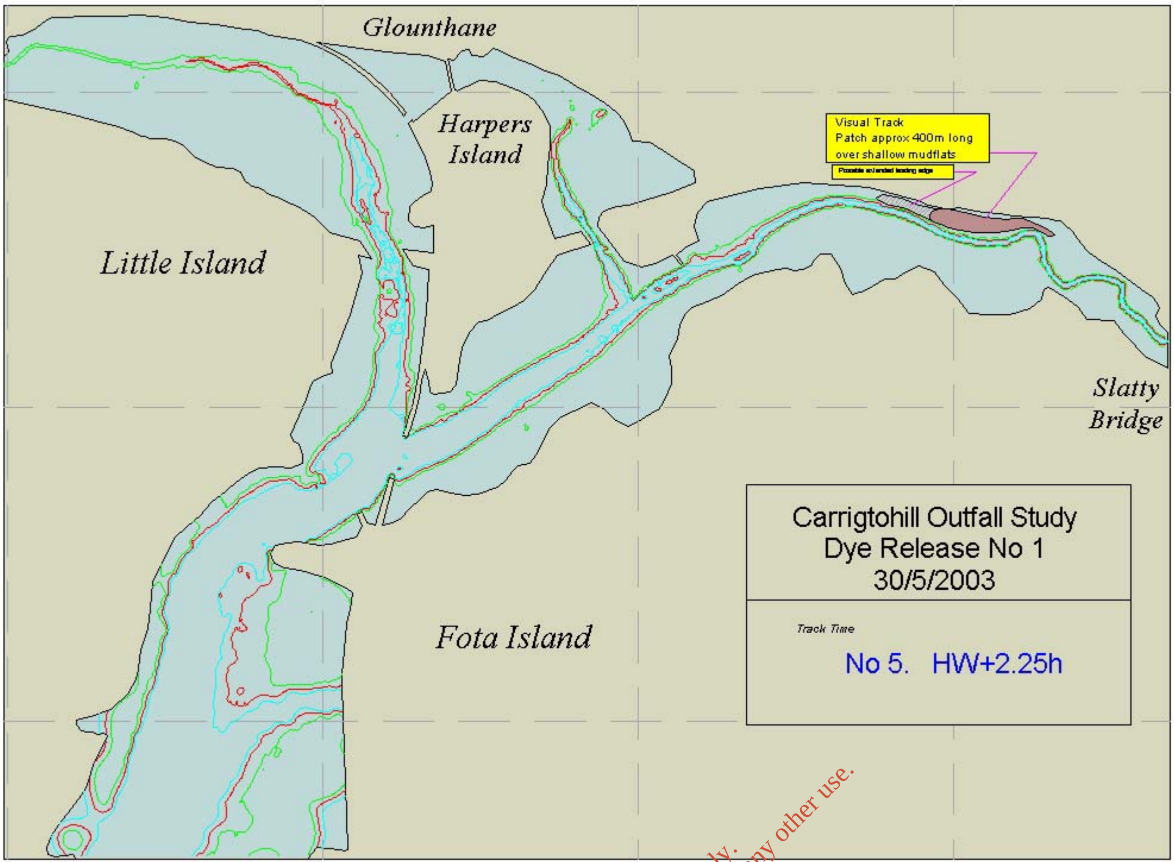
ANNEX 1 DYE TRACK NO 1 30TH MAY 2003

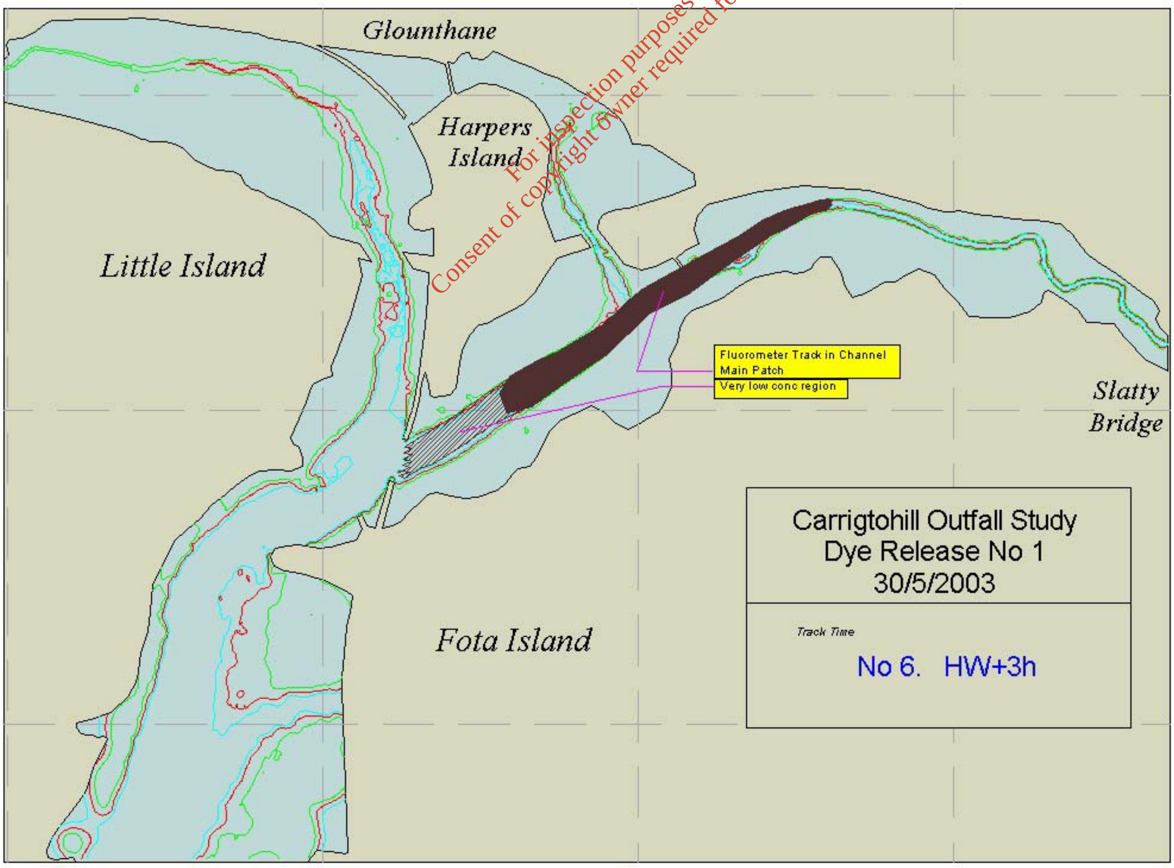

Glounthane
Harpers Island
Little Island
Release Point above Outfall
Slatty Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 1
30/5/2003
Track Time
Release HW+1h

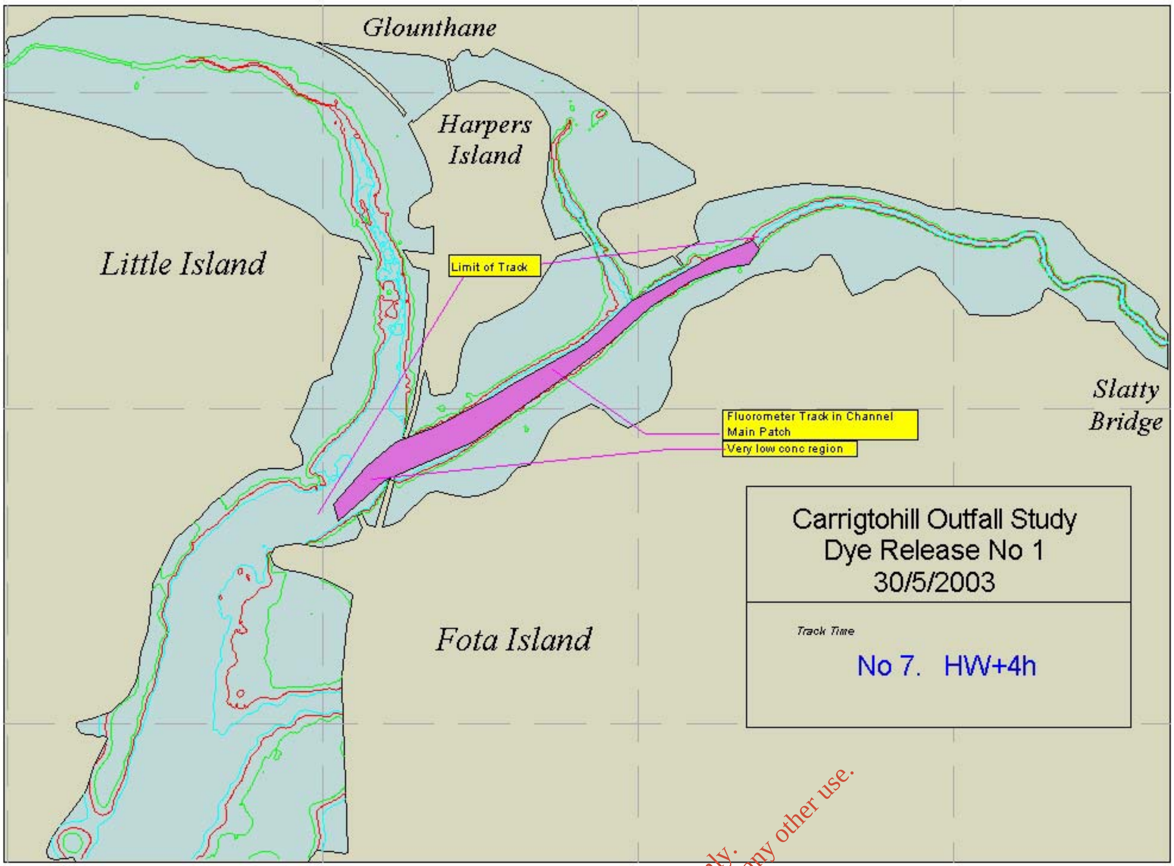

Glounthane
Harpers Island
Little Island
Patch 90m long
Slatty Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 1
30/5/2003
Track Time
No 2. HW+1.25h

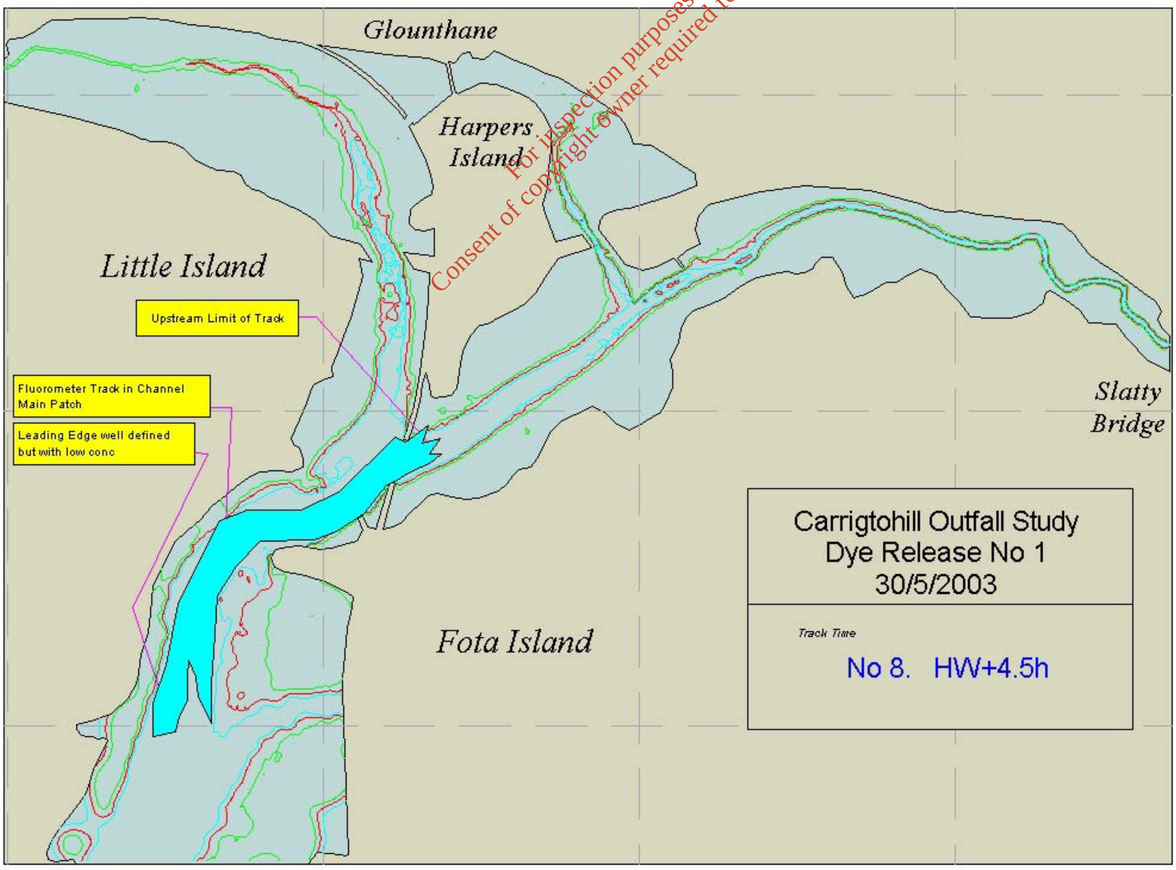

Glounthane
Harpers Island
Little Island
Fota Island
Slatty Bridge
Visual Track Patch 140m long
Carrigtohill Outfall Study
Dye Release No 1
30/5/2003
Track Time
No 3. HW+1.5h


Glounthane
Harpers Island
Little Island
Fota Island
Slatty Bridge
Visual Track Patch 390m long over shallow mudflats
Carrigtohill Outfall Study
Dye Release No 1
30/5/2003
Track Time
No 4. HW+1.75h

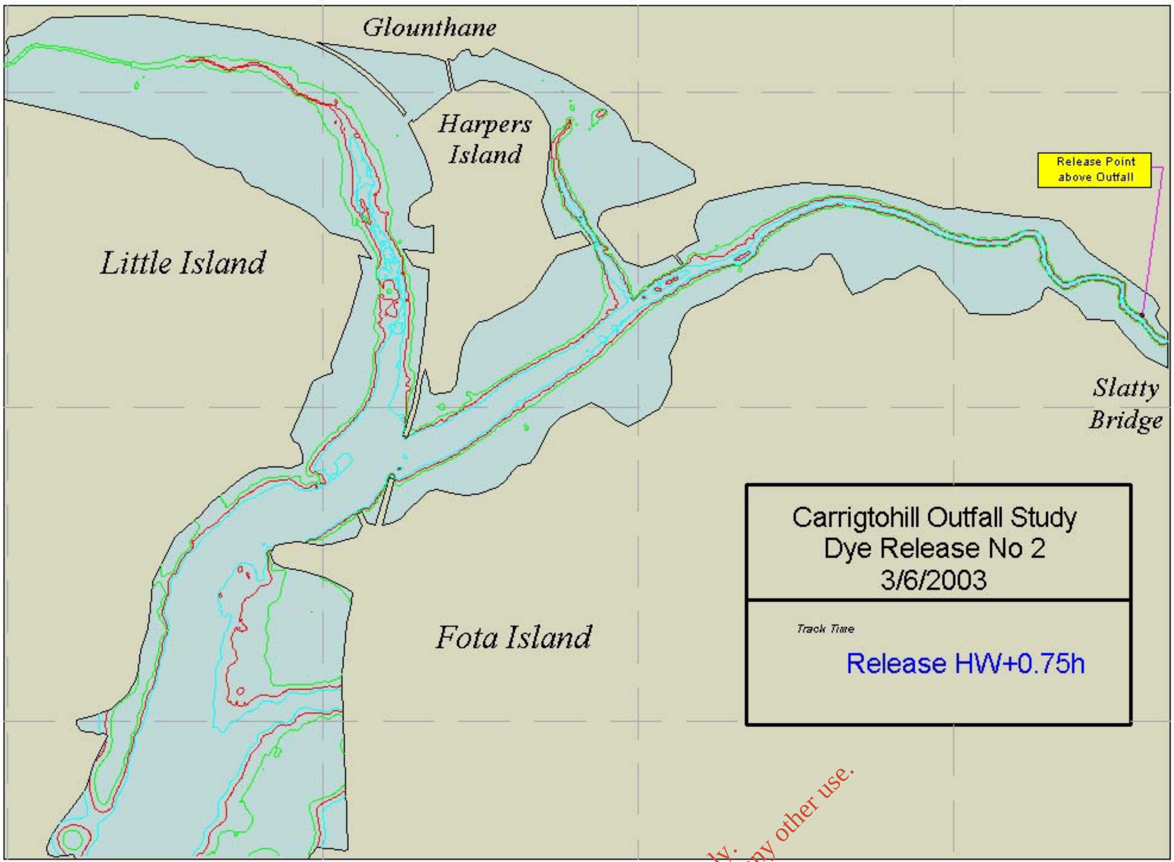

Glounthane
Harpers Island
Little Island
Fota Island
Slatty Bridge
Visual Track
Patch approx 400m long
over shallow mudflats
Carrigtohill Outfall Study
Dye Release No 1
30/5/2003
Track Time
No 5. HW+2.25h

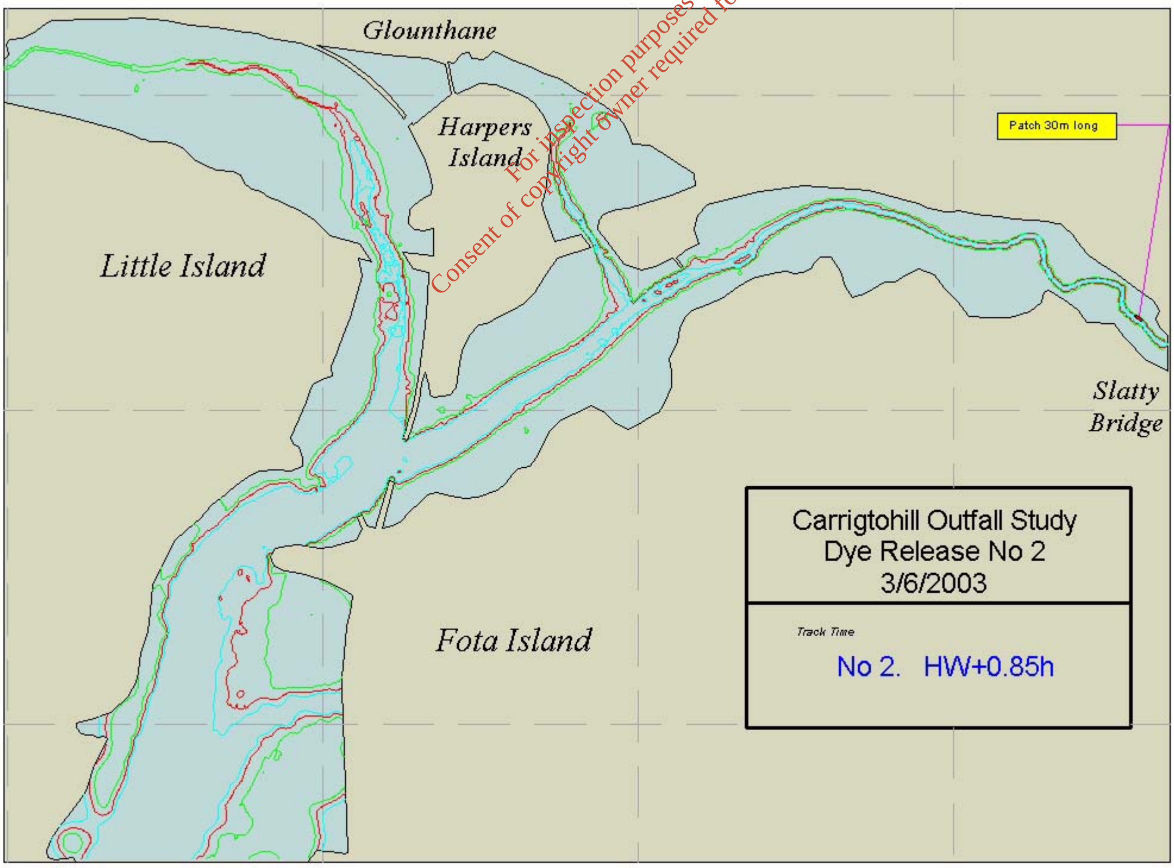

Glounthane
Harpers Island
Little Island
Fota Island
Slatty Bridge
Fluorometer Track in Channel
Main Patch
Very low conc region
Carrigtohill Outfall Study
Dye Release No 1
30/5/2003
Track Time
No 6. HW+3h

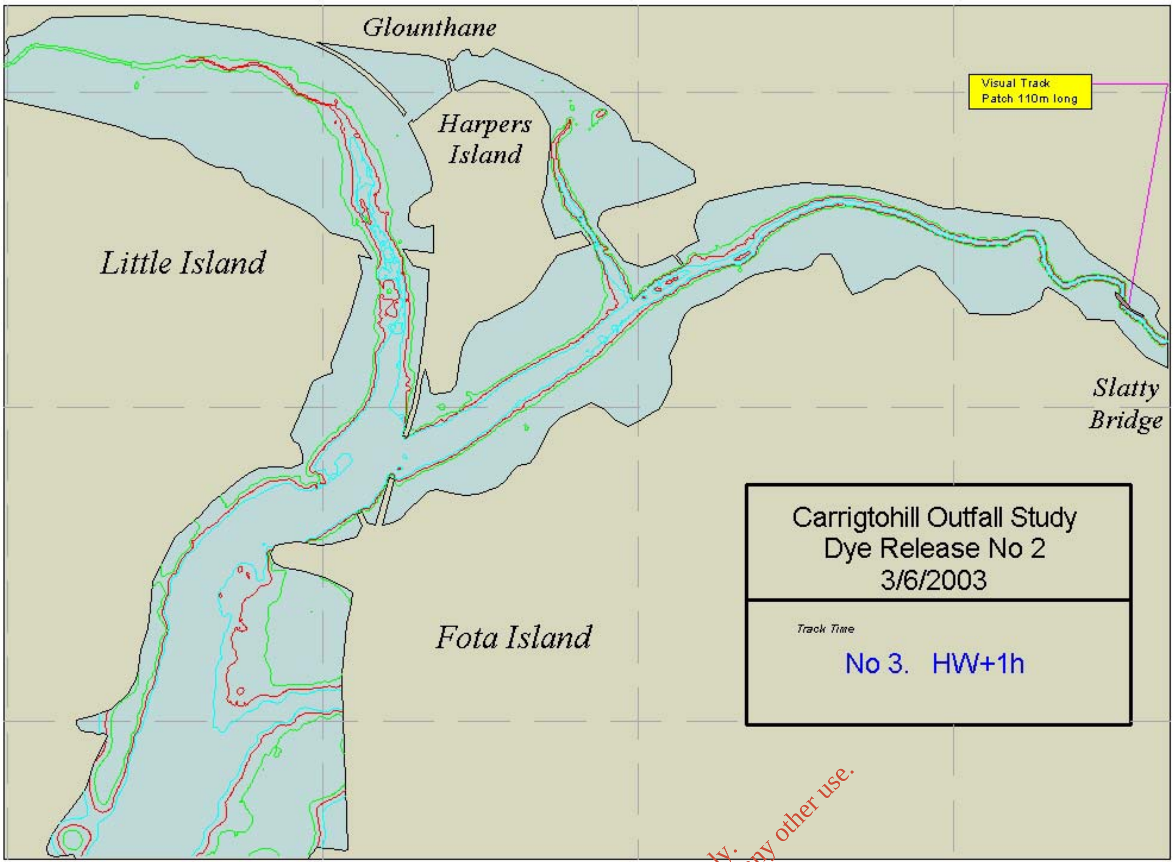

Glounthane
Harpers Island
Little Island
Limit of Track
Fluorometer Track in Channel
Main Patch
Very low conc region
Slatty Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 1
30/5/2003
Track Time
No 7. HW+4h

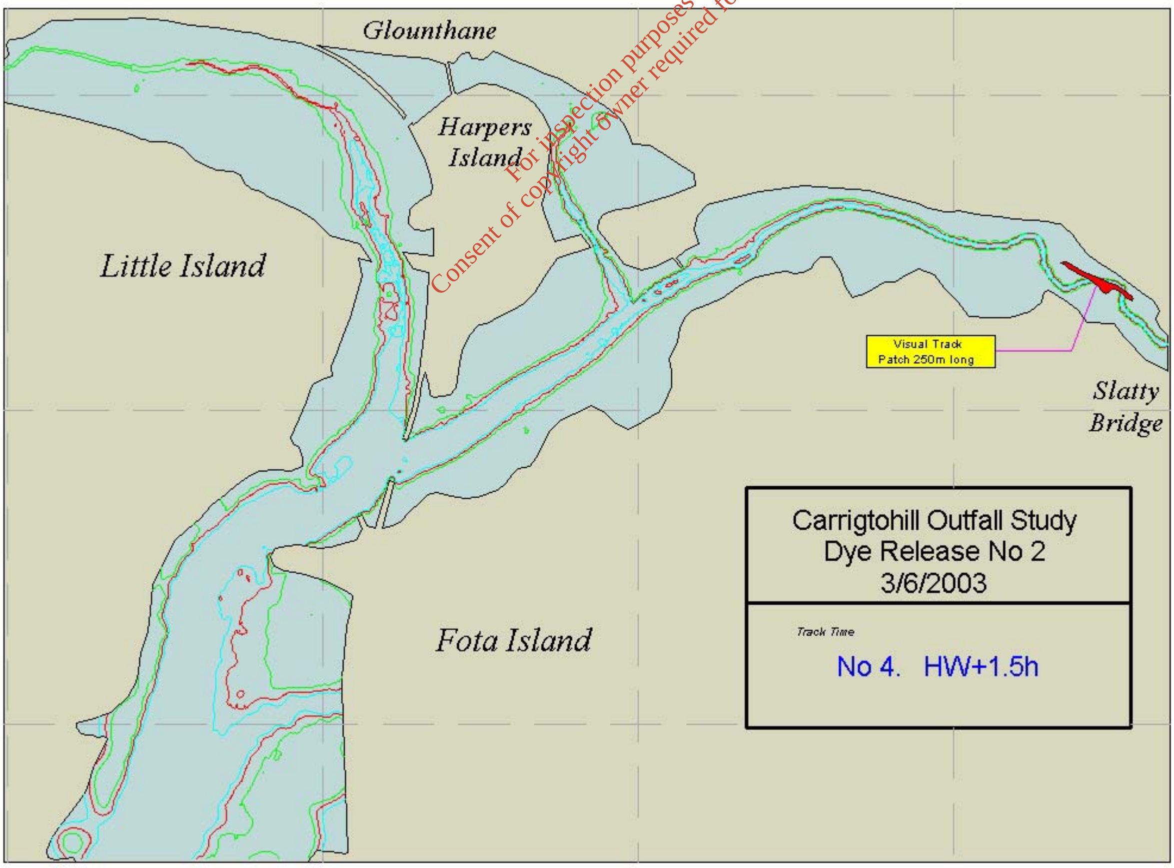

Glounthane
Harpers Island
Little Island
Upstream Limit of Track
Fluorometer Track in Channel
Main Patch
Leading Edge well defined
but with low conc
Slatty Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 1
30/5/2003
Track Time
No 8. HW+4.5h

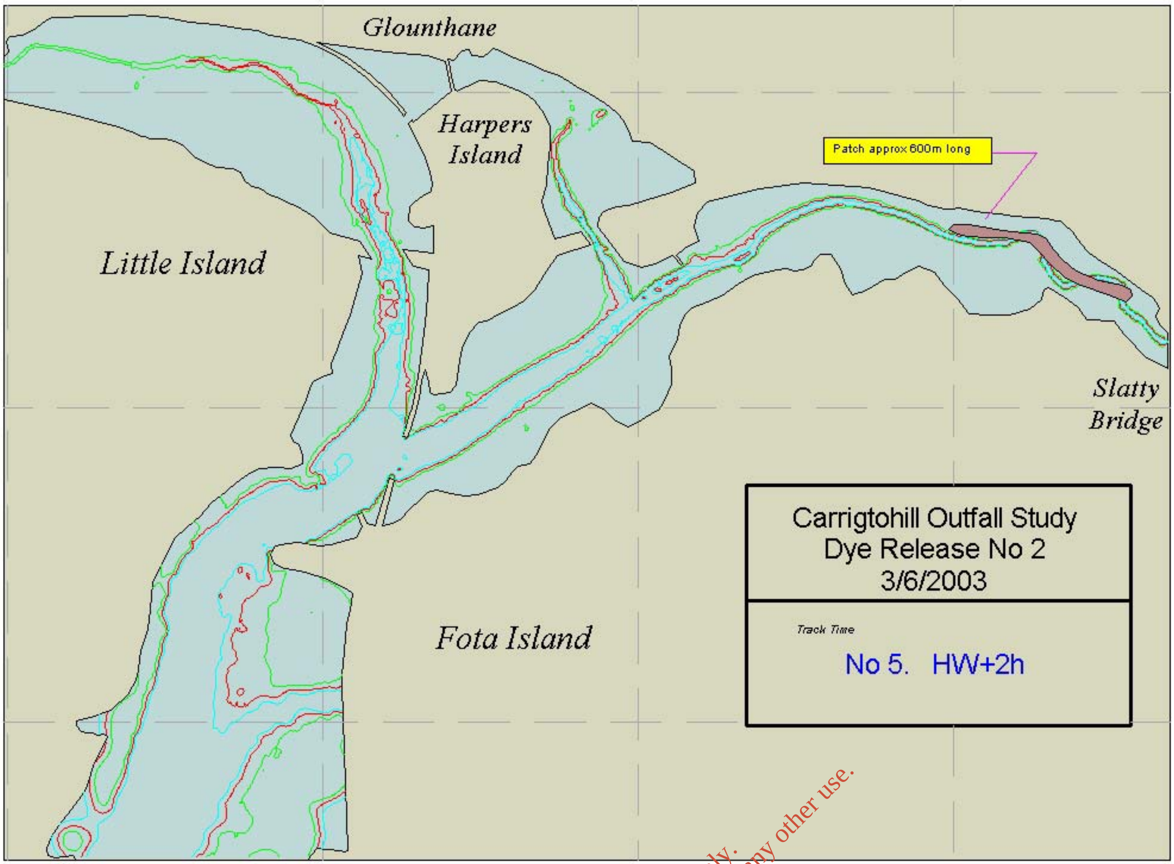
ANNEX 2 DYE TRACK NO 2 3RD JUNE 2003

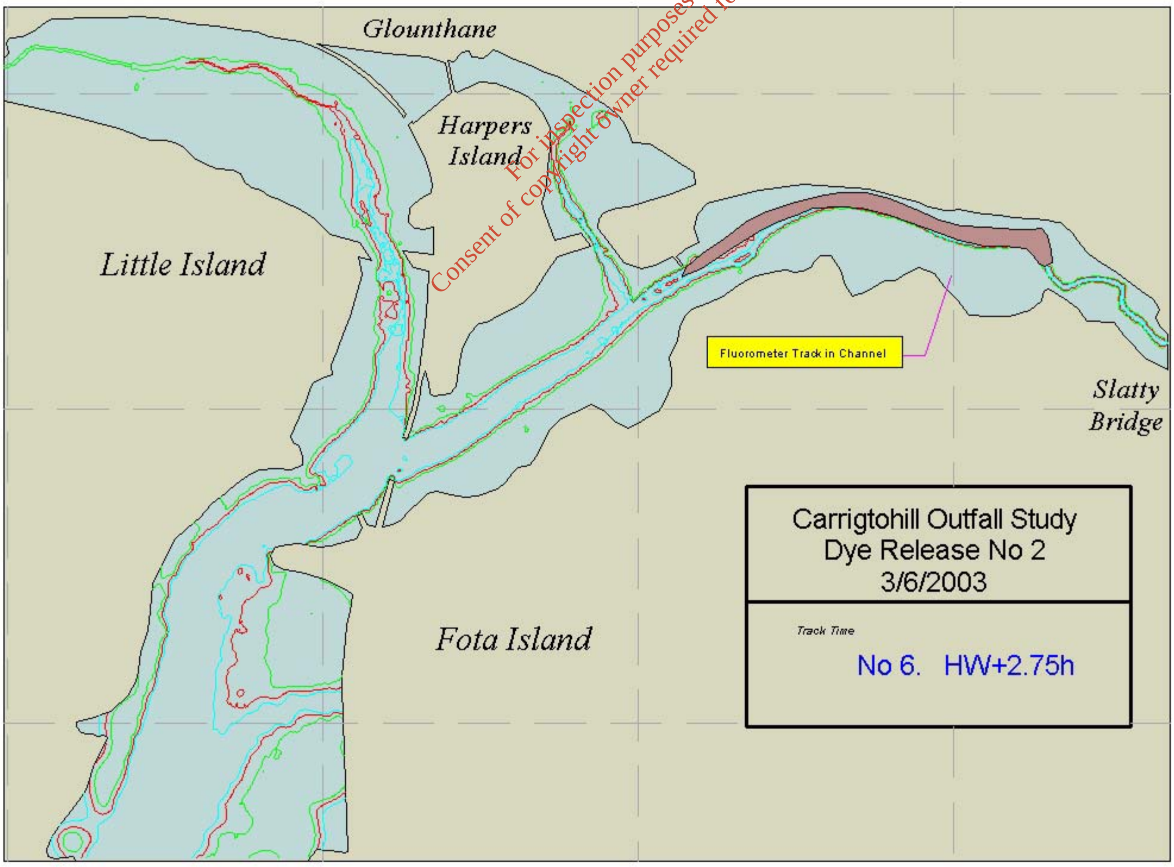

Glounthane
Harpers
Island
Little Island
Release Point
above Outfall
Slatty
Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 2
3/6/2003
Track Time
Release HW+0.75h

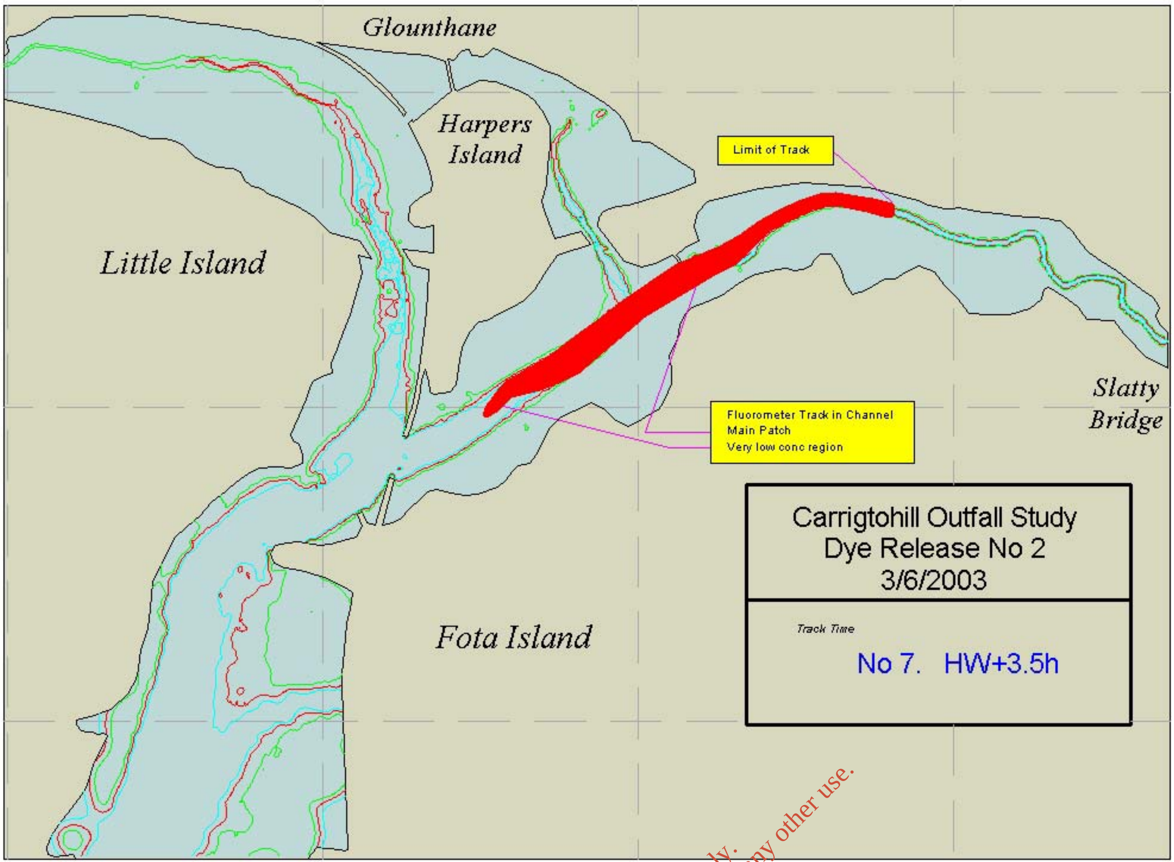

Glounthane
Harpers
Island
Little Island
Patch 30m long
Slatty
Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 2
3/6/2003
Track Time
No 2. HW+0.85h

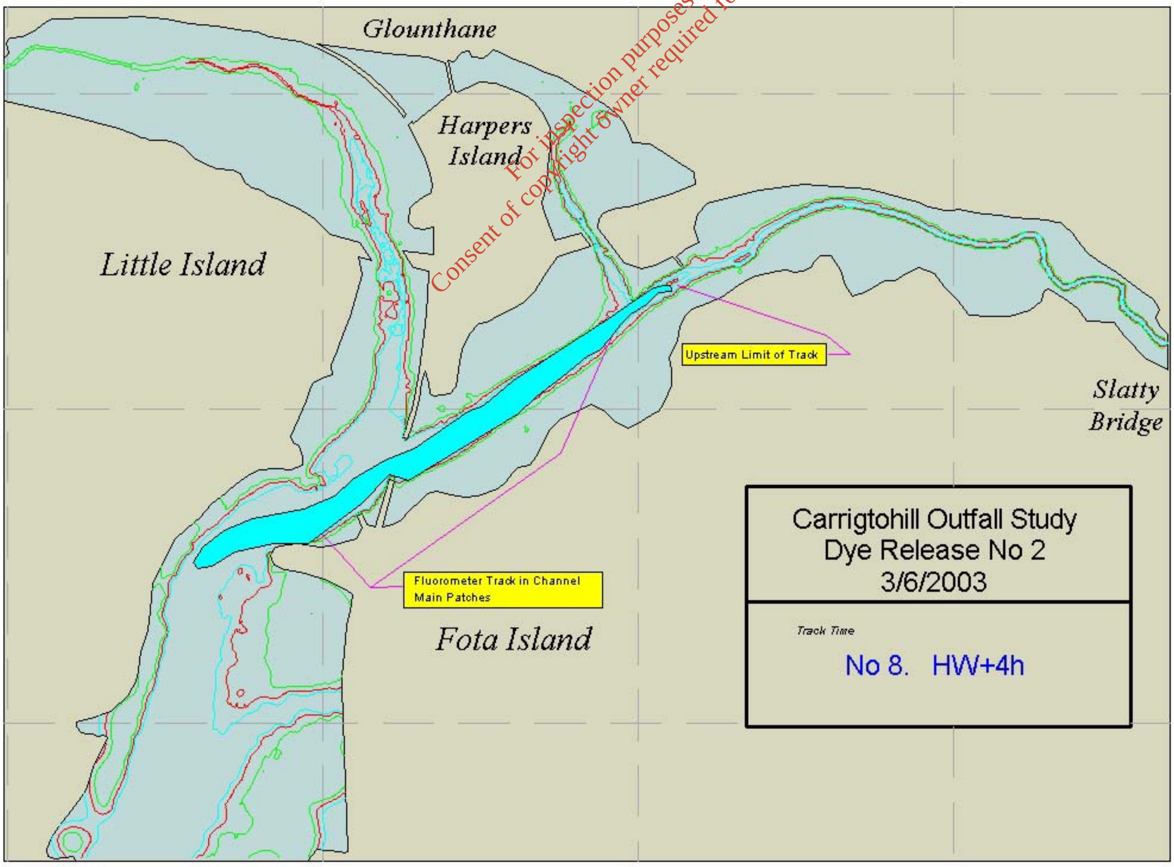

Glounthane
Harpers
Island
Visual Track
Patch 110m long
Little Island
Slatty
Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 2
3/6/2003
Track Time
No 3. HW+1h


Glounthane
Harpers
Island
Little Island
Visual Track
Patch 250m long
Slatty
Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 2
3/6/2003
Track Time
No 4. HW+1.5h


Glounthane
Harpers
Island
Patch approx 600m long
Little Island
Slatty
Bridge
Carrigtohill Outfall Study
Dye Release No 2
3/6/2003
Track Time
No 5. HW+2h
Fota Island


Glounthane
Harpers
Island
Little Island
Fluorometer Track in Channel
Slatty
Bridge
Carrigtohill Outfall Study
Dye Release No 2
3/6/2003
Track Time
No 6. HW+2.75h
Fota Island


Glounthane
Harpers
Island
Little Island
Limit of Track
Fluorometer Track in Channel
Main Patch
Very low conc region
Slatty
Bridge
Fota Island
Carrigtohill Outfall Study
Dye Release No 2
3/6/2003
Track Time
No 7. HW+3.5h


Glounthane
Harpers
Island
Little Island
Upstream Limit of Track
Slatty
Bridge
Fluorometer Track in Channel
Main Patches
Fota Island
Carrigtohill Outfall Study
Dye Release No 2
3/6/2003
Track Time
No 8. HW+4h

Annex 3 Simulation Results