## 4.4 Discussion on the faecal coliform Time series

We can see from the plots that the proposed treatment plant will lead to significant relative improvements in water quality throughout the harbour.

### 4.4.1 Fountainstown

We can see that there is a reduction in the number of faecal coliforms per 100ml for the repeating spring tide simulation with the introduction of the proposed wastewater treatment plant. It should be noted however that even without the treatment the number of faecal coliforms is relatively minor (< 1/100ml). We can also see that the concentrations of faecal coliforms are higher with the repeating spring tide simulation. The drop in concentration on the 10th of June is attributable to a strong wind from the south west (Fig. 4.61).

### 4.4.2 Myrtleville

We can see that there is a reduction in the number of faecal coliforms per 100ml for both of the simulations with the introduction of the proposed waste water treatment plant. For this location the concentrations of faecal coliforms are higher with the repeating neap tide boundary condition.

### 4.4.3 Roches Point

We can see that there is a reduction in the number of faecal coliforms per 100ml for both of the simulations with the introduction of the proposed waste water treatment plant. Again we can see that the concentrations of faecal coliforms are higher with the repeating neap tide boundary condition.

### 4.4.4 Crosshaven

We can see that there is a reduction in the number of faecal coliforms per 100ml for both of the simulations with the introduction of the proposed waste water treatment plant. There is a significant difference in the concentrations for the repeating spring and repeating neap tides for Crosshaven. We can see that the concentrations for the springs are up to 4 times greater than the neaps for Case 2 (no treatment plant).

### 4.4.5 200m upstream of Existing Outfall

The concentrations at this location are the highest of all the 15 points of interest. We can see that with the introduction of the proposed treatment plant there is a reduction in the number of faecal coliforms per 100ml.

The model does not resolve the near-field of the diffuser and results from our model very close to the diffuser may not be accurate so a point 200m upstream has been chosen to examine the faecal concentrations outside this area.

### 4.4.6 Shoreline Closest to Existing Outfall

We can see that there is a reduction in the number of faecal coliforms per 100ml for both of the simulations with the introduction of the proposed waste water treatment plant. This location is subject to drying out at low tide hence the zero concentrations after each peak in concentration.

### 4.4.7 Spike Island - Proposed Heritage Area

We can see that there is a reduction in the number of faecal coliforms per 100ml for both of the simulations with the introduction of the proposed wastewater treatment plant. For Case 2 the repeating neap tides give a higher concentration of faecal coliforms than the repeating spring tides.

### 4.4.8 Ringaskiddy Ferry

We can see that there is a reduction in the number of faecal coliforms per 100ml for both of the simulations with the introduction of the proposed wastewater treatment plant. It is interesting to note that with the introduction of the proposed wastewater treatment plant the number of faecal coliforms at Ringaskiddy is very close to zero.

### 4.4.9 Monkstown Creek

We can see that there is a reduction in the number of faecal coliforms per 100ml for both of the simulations with the introduction of the proposed wastewater treatment plant. Again we can see that with the introduction of the proposed treatment plant the number of faecal coliforms at this location is close to zero.

### 4.4.10 Cobh - Recreational Area

We can see that there is a reduction in the number of faecal coliforms per 100ml for both of the simulations with the introduction of the proposed waste water treatment plant. With the treatment plant in place the concentrations of faecal coliforms for the repeating neap tides are almost zero.

### 4.4.11 Oyster Farm - Outer Harbour

For both of the Cases we can see that the number of faecal coliforms is relatively minor. There is a spike in concentration towards the end of the simulation, which is attributable to a strong wind from the south west (Fig. 4.61).

### 4.4.12 Marlogue Point

We can see that there is a reduction in the number of faecal coliforms per 100ml for the spring tide simulation with the introduction of the proposed waste water treatment plant. For Case 2 there is a significant difference in concentration between the repeating spring and neap tides.

### 4.4.13 Oyster Farm - North Channel

For both of the Cases we can see that the number of faecal coliforms entering the North Channel is very minor. With a strong wind from the south west however the concentration does increase as we can see with the 'spike' occurring around the 11th of June.

### 4.4.14 West Passage

We can see for both cases that there is a reduction in the number of faecal coliforms at this location with the proposed scheme in place.

### 4.4.15 Lough Mahon

We can see for both cases that there is a reduction in the number of faecal coliforms at this location with the proposed scheme in place.

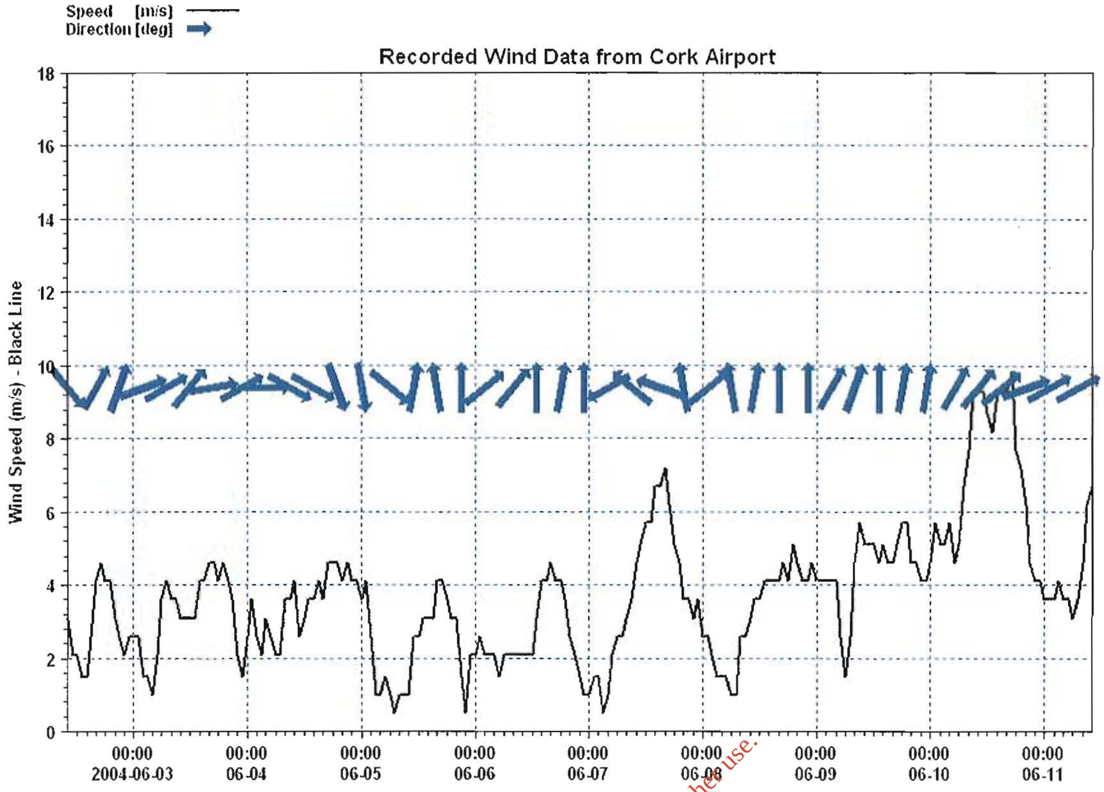

*Fig. 4.44 Recorded Wind data. The wind speed is plotted with the black line on the left-hand axis. The wind direction is indicated with the direction of the blue arrow. We can see a strong wind from the south west acting on the 10th of June.*

## 4.5 Faecal Coliform Sensitivity Analysis

A sensitivity analysis has been carried out as part of this Environmental Impact Assessment for Case 3 with repeating spring tides (PR5). The purpose of a sensitivity analysis is to identify the effect of uncertainties in the model on the results. In this case we wish to determine the highest possible concentration of faecal coliforms that may result when the proposed wastewater treatment plant is operational in 2010. The parameters, which we have varied, are:

1. **The T90 of the faecal coliforms.** We have simulated the faecal coliforms with a longer decay time: T90 of 24 hours.
2. **Wind Forcing.** We have replaced the recorded wind forcing with 4 separate wind forcings. Each of the four has the same wind speed of 10m/s but differ in the direction from which they blow: (1) West, (2) North,

(3) East, (4) South. These wind forcings are constant in space, time, magnitude and direction.

### 4.5.1 Decay rate sensitivity

The results of the decay sensitivity are presented using time series, maximum and averaged values and spatially varying maps of concentrations. By subtracting the spatially varying maps of maximum concentrations for the two different decay rates from each other we can see the difference in concentration between the two. This map is shown in Fig. 4.45. As the concentrations for the slower decay rate are higher we have subtracted the 12 hour decay concentrations *from* the 24 hour decay concentrations. We can see from the figure that the differences in the maximum concentrations range from 1 to 40 fc/100ml. From this we can conclude that if the faecal coliforms were to have a T90 of 24 hours their concentrations would increase by as much as 40 counts per 100ml relative to the case where the T90 is 12 hours.

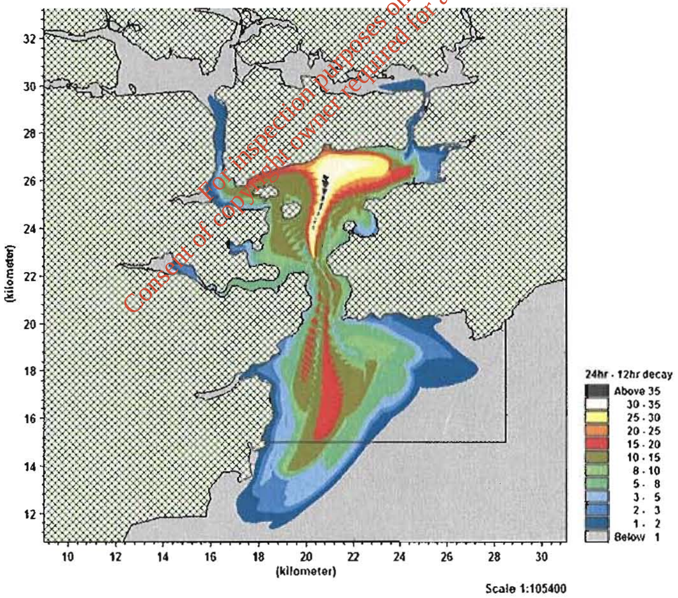

*Fig. 4.45 The numbers in this plot are the differences between the maximum concentrations for the 12 and 24hr decay values.*

The following set of graphs present the results of the decay rate sensitivity for the 15 points of interest in the study. Two plots are included on each of the graphs. The first is the faecal coliform concentrations for the Case 3 (PR5) with a T90 of 12 hours (blue line). The second is the faecal coliform concentrations for

Case 3 with a T90 of 24 hours (green line). The boundary condition is supplied by repeating spring tides.

The maximum and average concentrations for the decay sensitivity (Fig. 4.67) are presented in the following two tables. The corresponding concentrations for the 12 hour decay (as presented in Table 4-4 and Table 4-5) are shown to aid the reader in making a comparison.

| **Year** | **2010** | **2010 - Sensitivity** | **2030** | **2030 - Sensitivity** |
|---|---|---|---|---|
| | MAX | MAX | MAX | MAX |
| **Fountainstown** | 0.2 | 1.2 | 0.3 | 1.8 |
| **Myrtleville** | 0.7 | 2.6 | 1.0 | 3.8 |
| **Roches Point** | 65.3 | 79.4 | 93.5 | 113.7 |
| **Crosshaven** | 3.8 | 11.2 | 5.4 | 16.0 |
| **Ringaskiddy Ferry** | 0.0 | 0.3 | 0.0 | 0.5 |
| **Monkstown Creek** | 0.0 | 0.4 | 0.0 | 0.6 |
| **Oyster F - NC** | 0.1 | 0.9 | 0.2 | 1.3 |
| **Marlogue Point** | 0.3 | 2.0 | 0.4 | 2.9 |
| **Oyster F - Outer** | 0.6 | 3.4 | 0.9 | 4.8 |
| **Cobh** | 23.2 | 40.0 | 33.2 | 57.3 |
| **Spike Island** | 9.1 | 21.5 | 13.1 | 30.7 |
| **Shoreline** | 2.2 | 8.4 | 3.2 | 12.0 |
| **Upstream Outfall** | 333.7 | 357.1 | 477.6 | 510.9 |
| **West Passage** | 1.0 | 4.3 | 1.5 | 6.2 |
| **Lough Mahon** | 0.1 | 0.9 | 0.2 | 1.3 |

*Table 4-6 Summary of 24hr decay sensitivity – Maximum concentrations*

| **Year** | **2010** | **2010 - Sensitivity** | **2030** | **2030 - Sensitivity** |
|---|---|---|---|---|
| | AVG | AVG | AVG | AVG |
| **Fountainstown** | 0.05 | 0.4 | 0.07 | 0.5 |
| **Myrtleville** | 0.14 | 1.0 | 0.20 | 1.4 |
| **Roches Point** | 11.65 | 16.6 | 16.67 | 23.8 |
| **Crosshaven** | 0.95 | 3.6 | 1.36 | 5.1 |
| **Ringaskiddy Ferry** | 0.01 | 0.2 | 0.02 | 0.3 |
| **Monkstown Creek** | 0.01 | 0.1 | 0.01 | 0.2 |
| **Oyster F - NC** | 0.00 | 0.0 | 0.00 | 0.0 |
| **Marlogue Point** | 0.04 | 0.3 | 0.06 | 0.4 |
| **Oyster F - Outer** | 0.00 | 0.1 | 0.00 | 0.1 |
| **Cobh** | 5.32 | 10.6 | 7.62 | 15.1 |
| **Spike Island** | 1.55 | 5.0 | 2.21 | 7.1 |
| **Shoreline** | 0.56 | 1.6 | 0.47 | 2.3 |
| **Upstream Outfall** | 20.12 | 25.7 | 28.79 | 36.8 |
| **West Passage** | 0.08 | 0.6 | 0.11 | 0.8 |
| **Lough Mahon** | 0.01 | 0.1 | 0.01 | 0.1 |

*Table 4-7 Summary of 24hr decay sensitivity – Average concentrations*

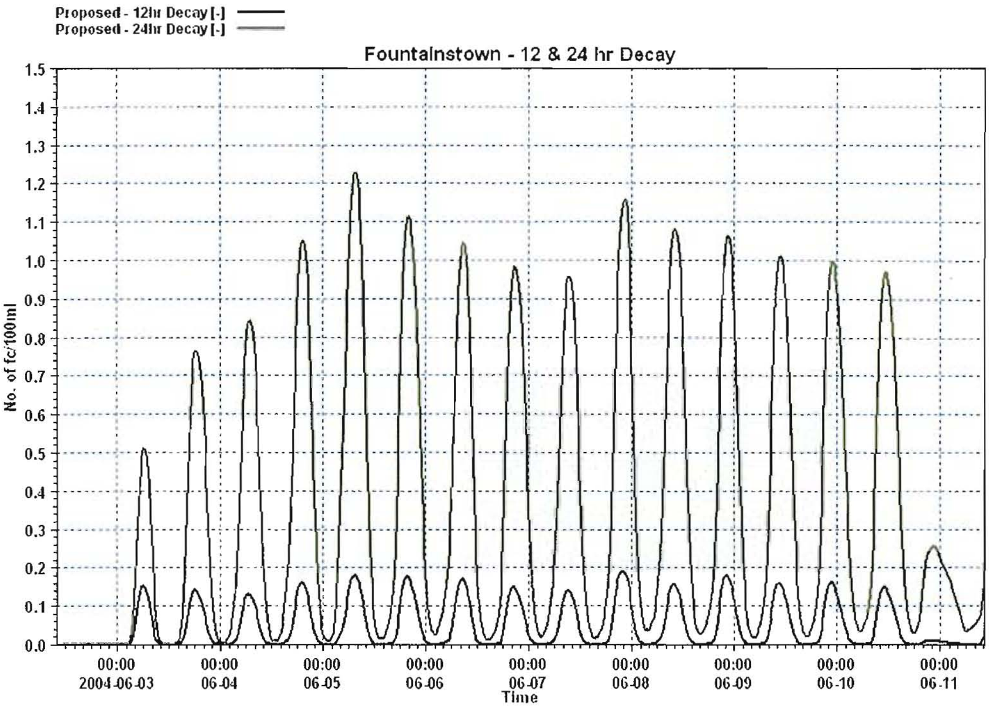

Fig. 4.46 Fountainstown - 24hr decay sensitivity

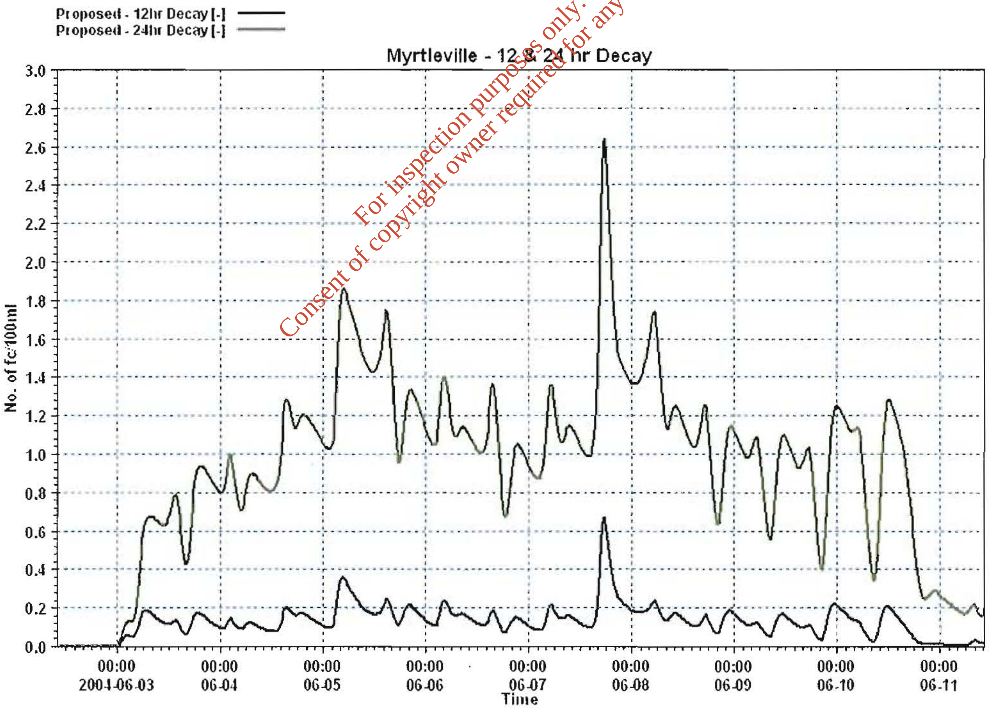

Fig. 4.47 Myrtleville - 24hr decay sensitivity

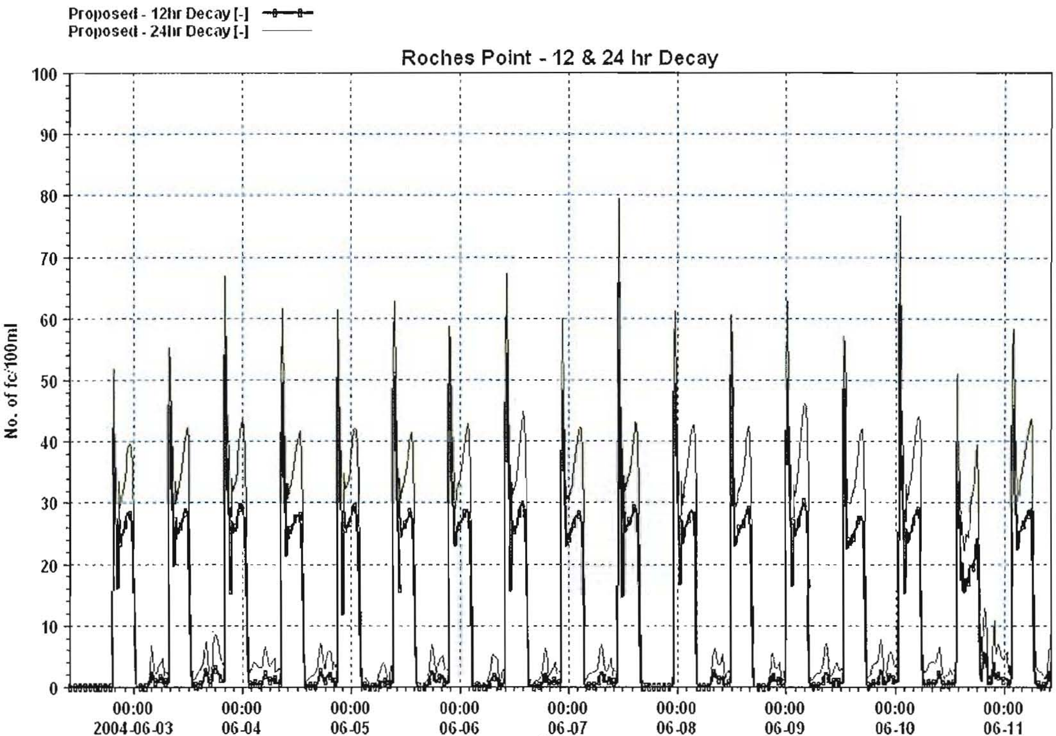

*Fig. 4.48 Roches point - 24hr decay sensitivity*

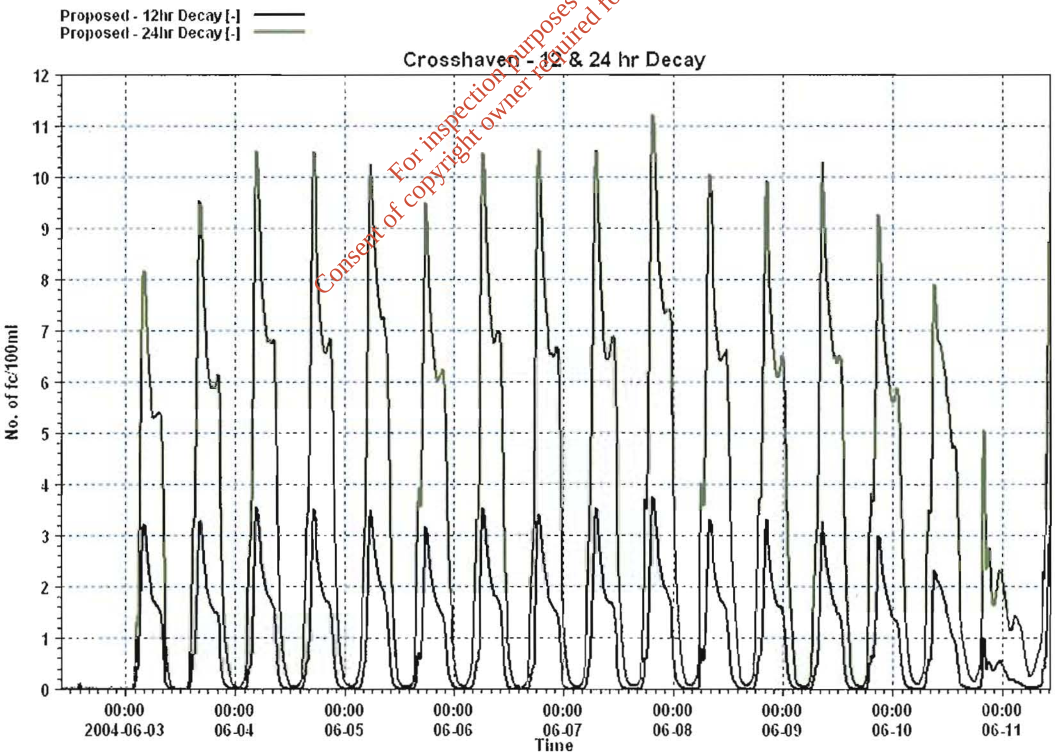

*Fig. 4.49 Crosshaven - 24hr decay sensitivity*

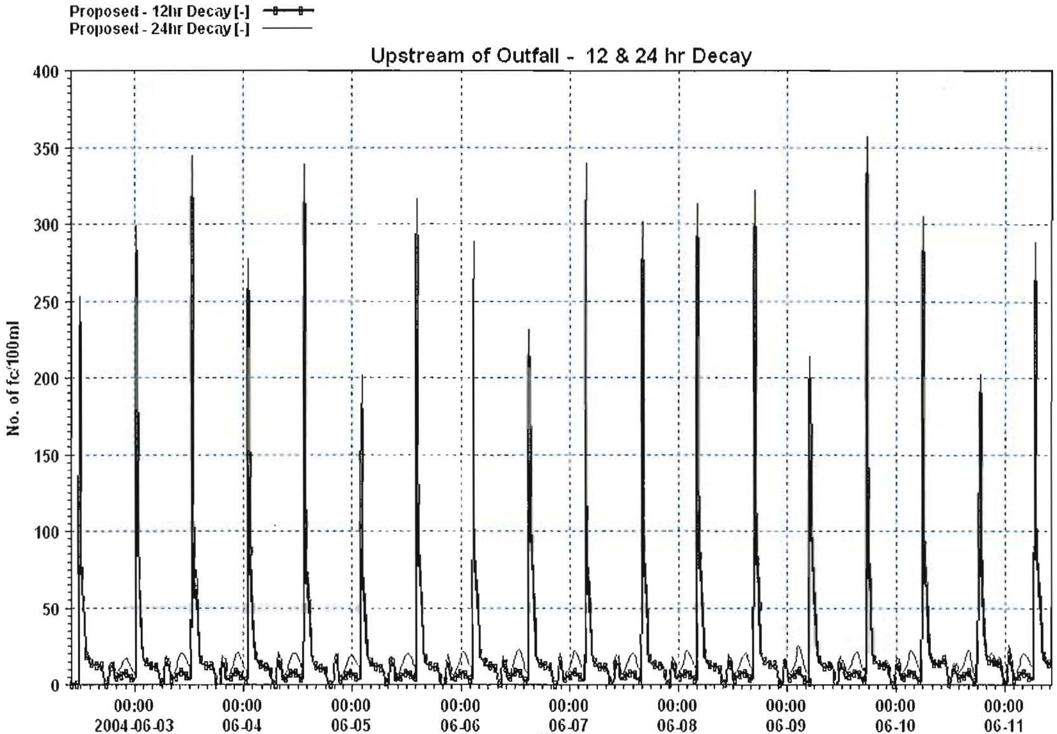

*Fig. 4.50 200m upstream of outfall - 24hr decay sensitivity*

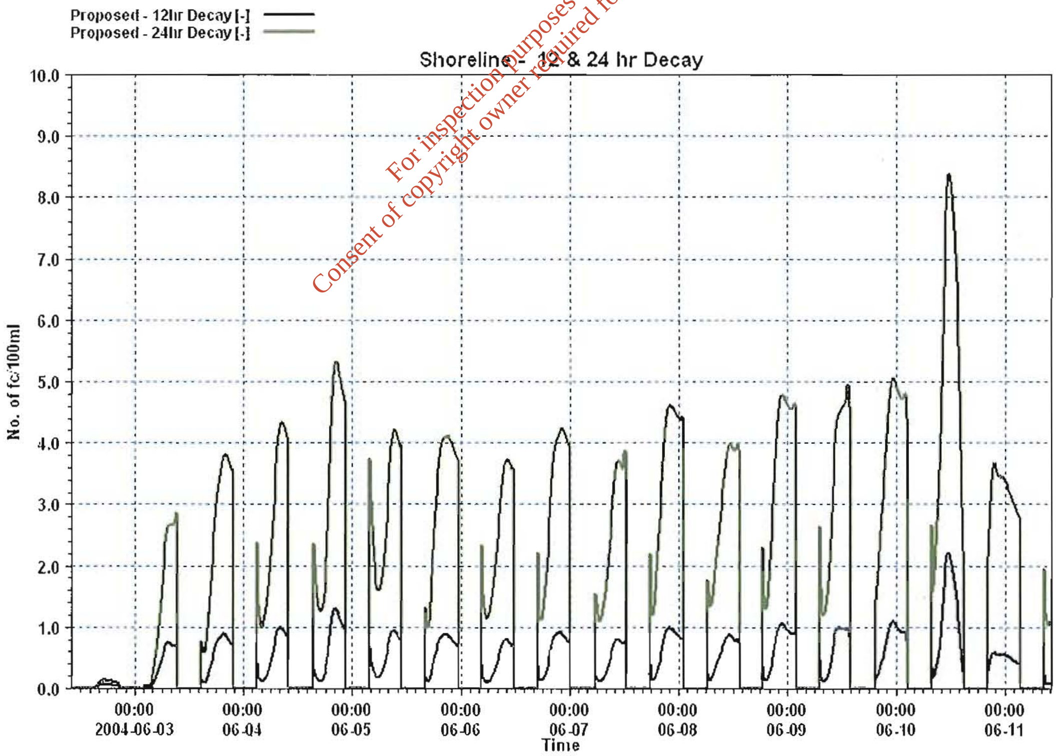

*Fig. 4.51 Shoreline - 24hr decay sensitivity*

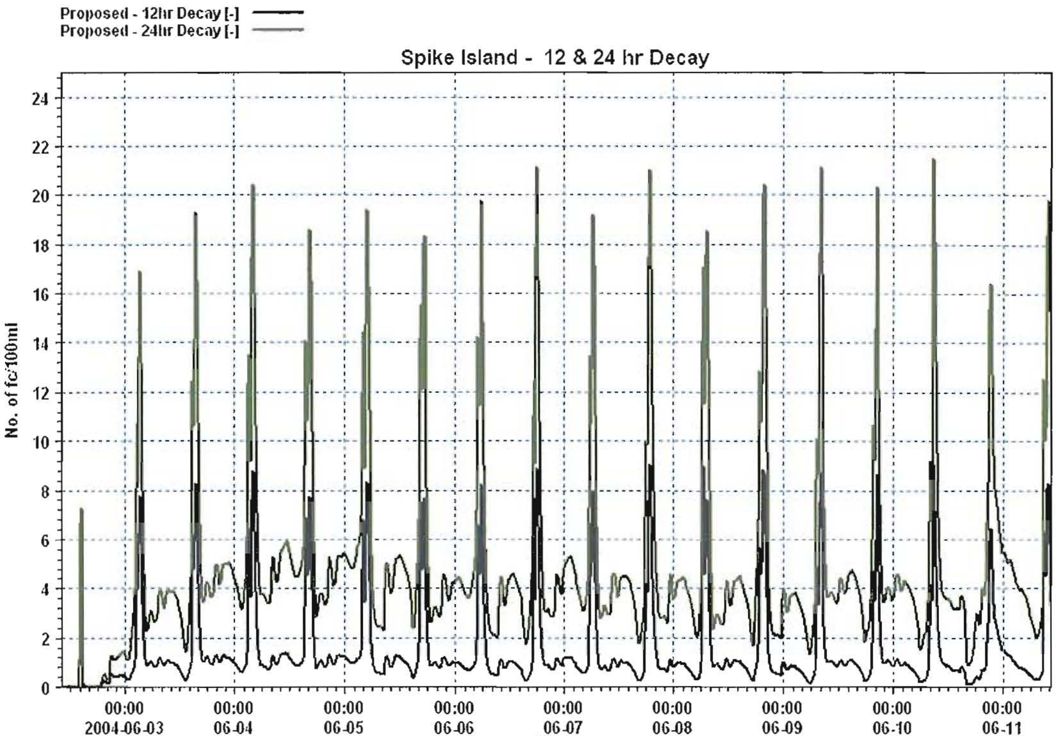

*Fig. 4.52 Spike Island - 24hr decay sensitivity*

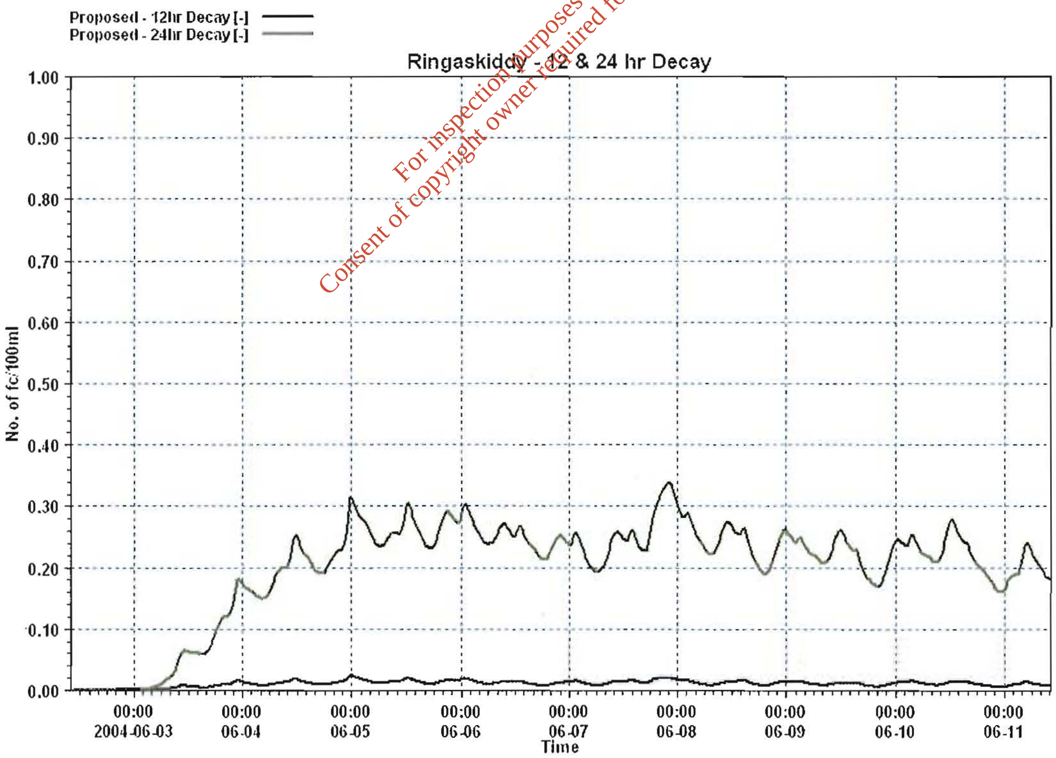

*Fig. 4.53 Ringaskiddy - 24hr decay sensitivity*

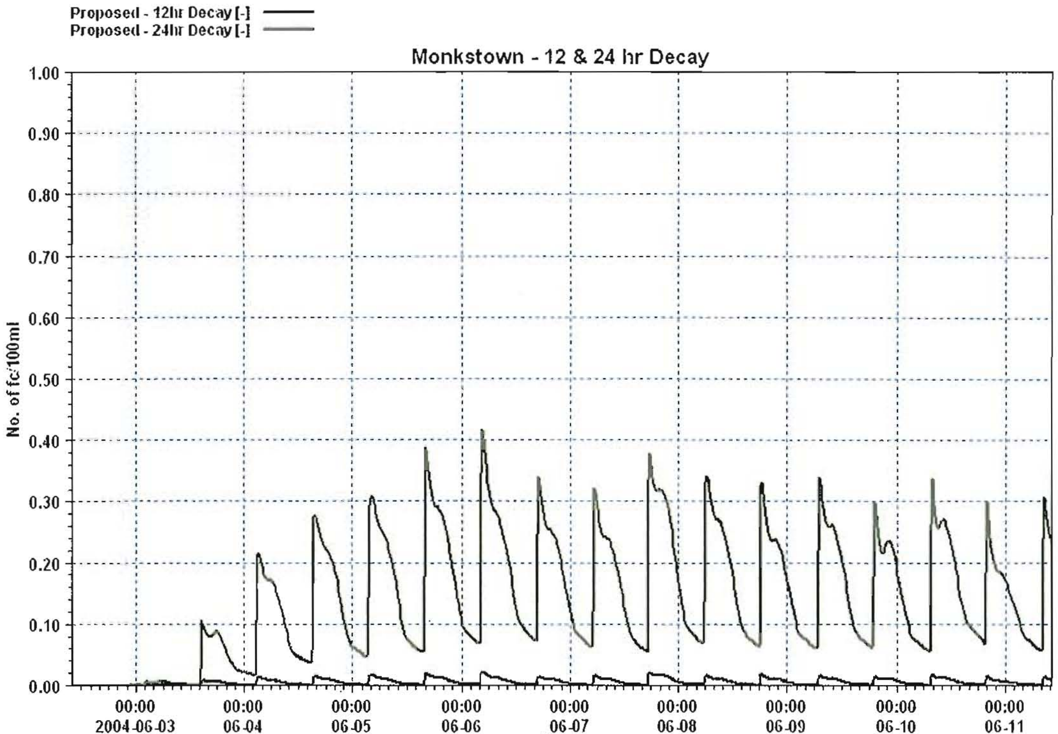

*Fig. 4.54 Monkstown - 24hr decay sensitivity*

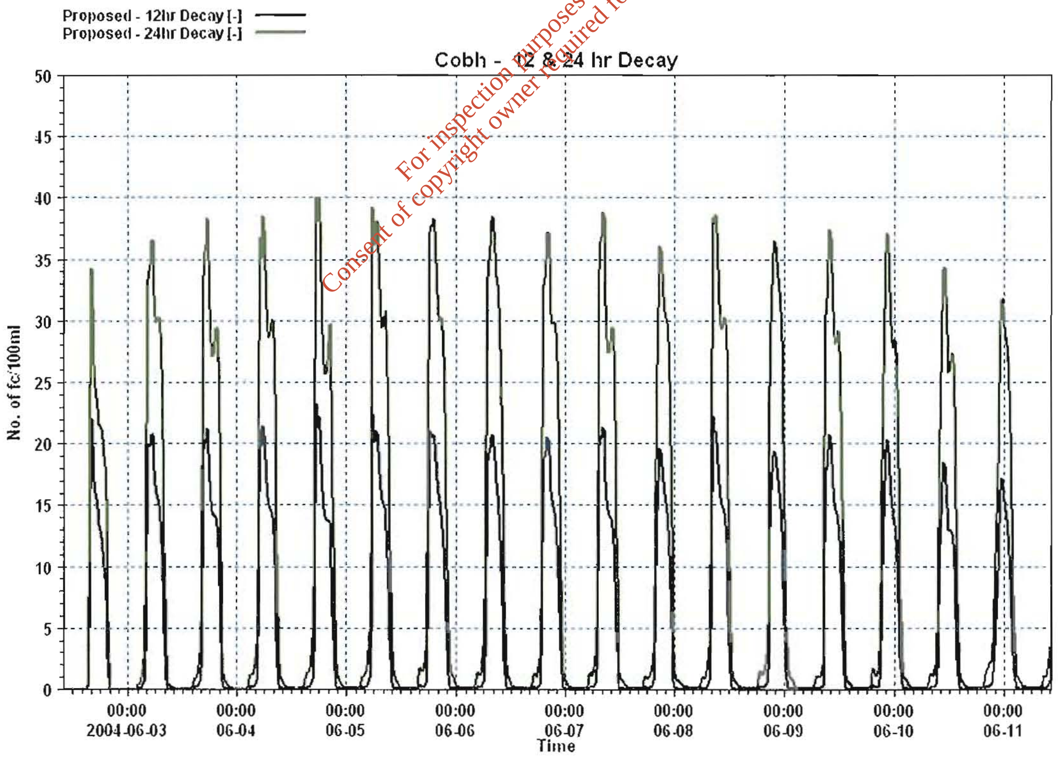

*Fig. 4.55 Cobh - 24hr decay sensitivity*

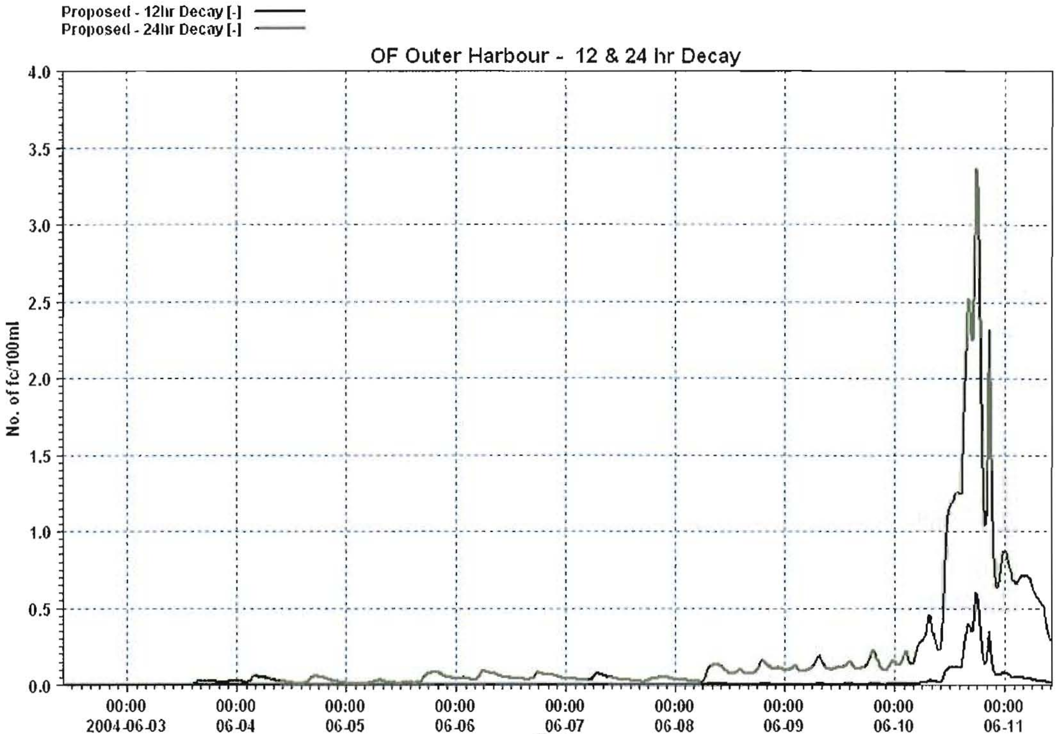

*Fig. 4.56 OF Outer Harbour - 24hr decay sensitivity*

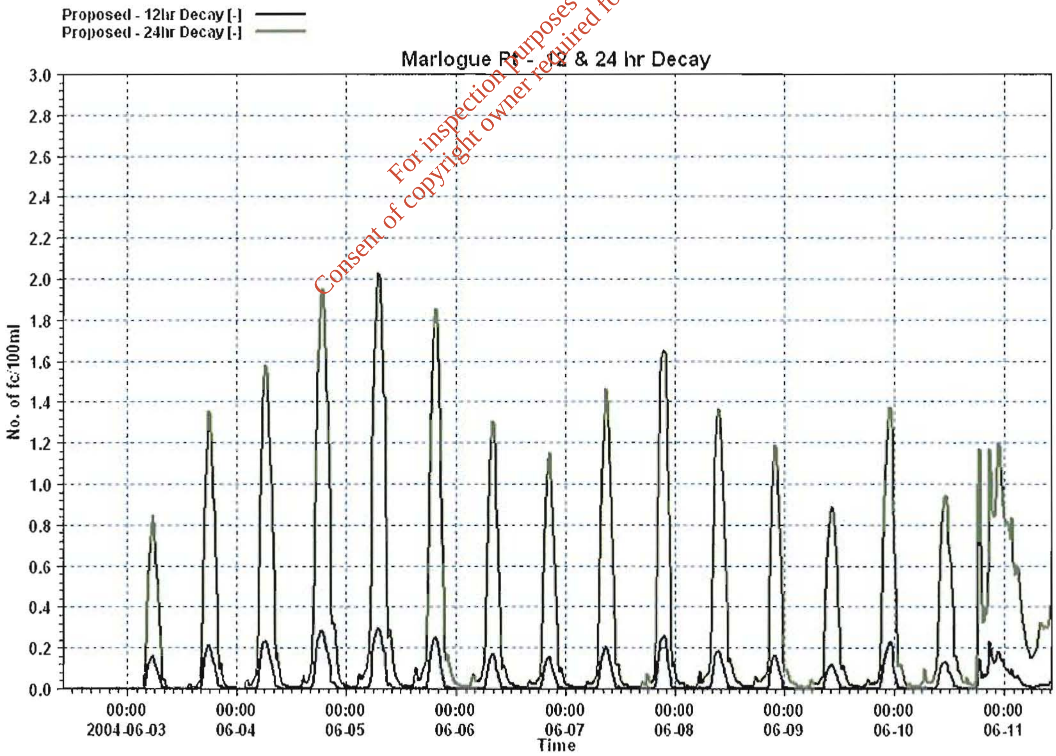

*Fig. 4.57 Marlogue Pt - 24hr decay sensitivity*

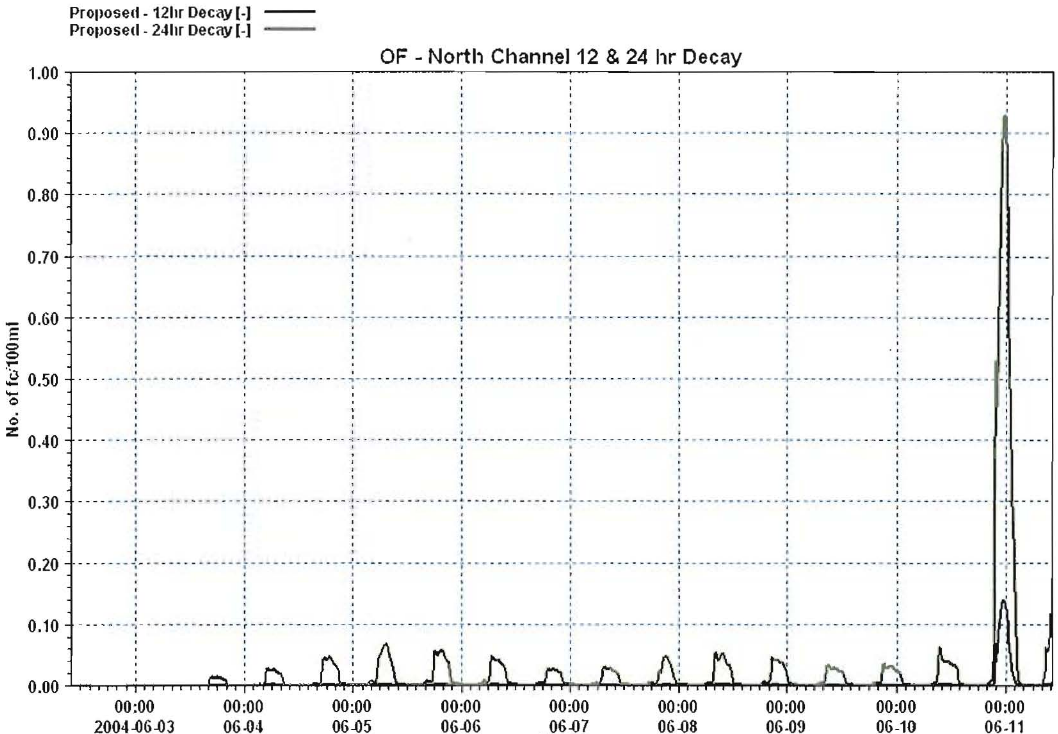

Fig. 4.58 OF North Channel - 24hr decay sensitivity

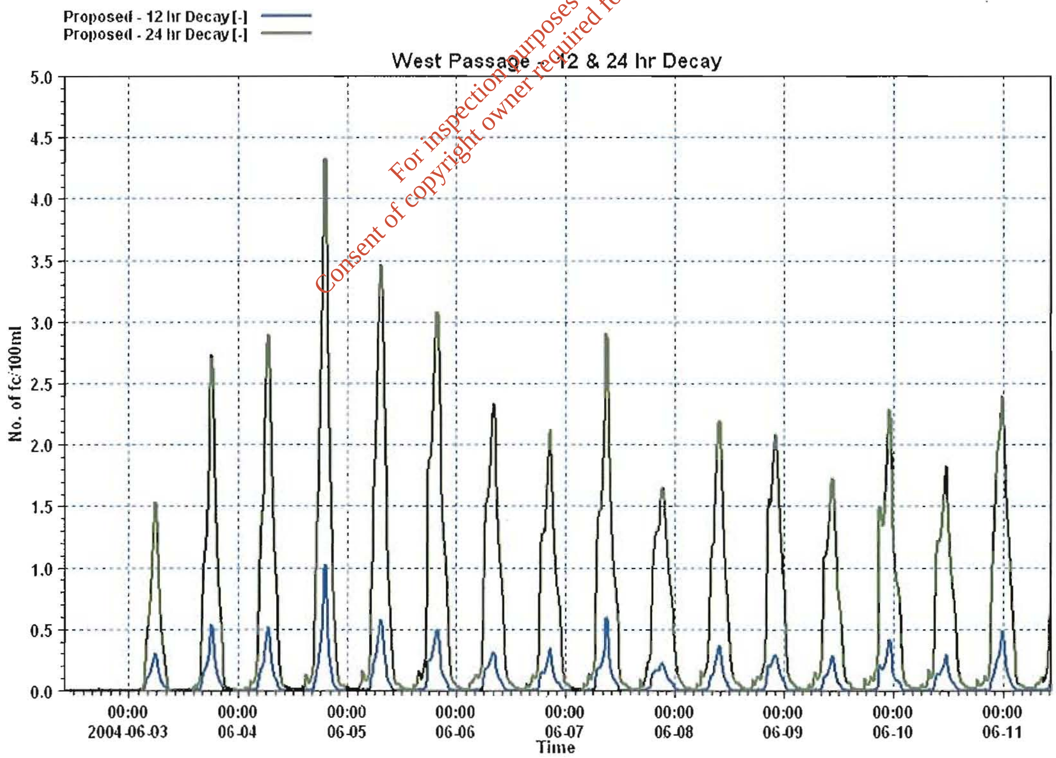

Fig. 4.59 West Passage - 24hr decay sensitivity

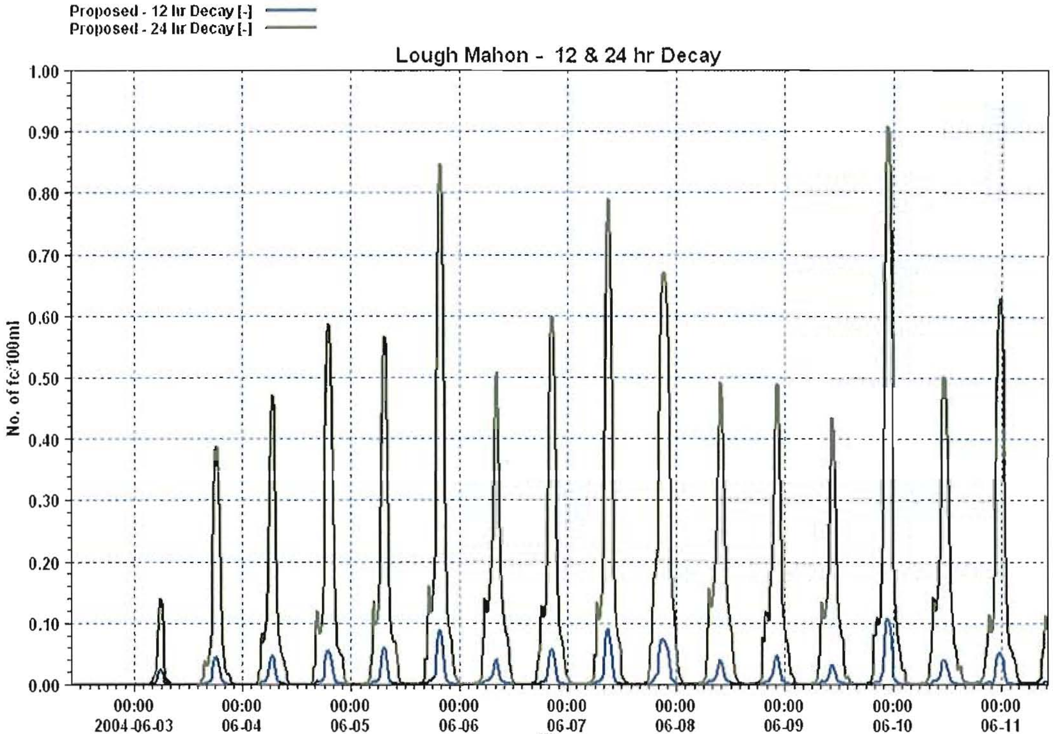

*Fig. 4.60 Lough Mahon - 24hr decay sensitivity*

### 4.5.2 Wind forcing sensitivity – repeating spring tides

The wind forcing sensitivity is now presented. For the repeating spring tides we have replaced the recorded wind with 4 different wind forcings each blowing from a different direction but with the same speed. This sensitivity involved 4 separate model runs each with one of the different wind forcings.

Each of the four wind sensitivity runs were simulated for 3 days.

| Run No. | Wind Speed | Wind Direction |
|---|---|---|
| 1 | 10m/s (constant) | From West (270 deg) |
| 2 | 10m/s (constant) | From North (0 deg) |
| 3 | 10m/s (constant) | From East (90 deg) |
| 4 | 10m/s (constant) | From South (180 deg) |

*Table 4-8 List of wind sensitivity runs*

The recorded wind forcing is presented in Fig. 4.61. The wind speed is plotted on the left hand axis (black line) while the direction is plotted using the blue arrows. The direction in which the blue arrow is pointing indicates the direction in which the wind is blowing from.

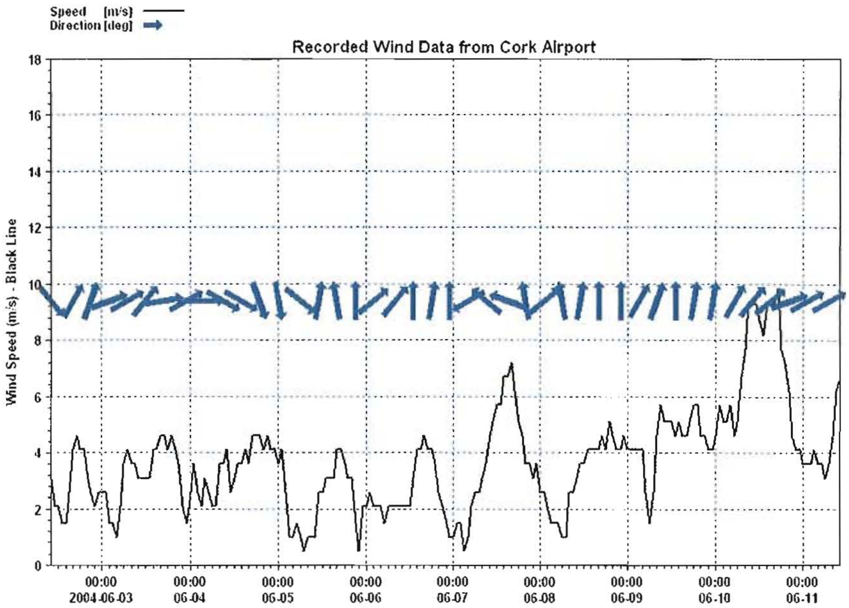

*Fig. 4.61 Recorded Wind data*

The results of the wind sensitivity are presented using spatially varying maps of maximum concentrations. In all 6 maps are presented:

1. Recorded wind simulation maximum concentrations. This plot was already presented in Fig. 4.3 using a different colour palette.
2. Constant 10m/s wind blowing from West
3. Constant 10m/s wind blowing from North
4. Constant 10m/s wind blowing from East
5. Constant 10m/s wind blowing from South
6. The maximum concentrations of the 4 separate wind sensitivity maximum concentration maps. This map presents the maximum value of the four separate wind sensitivity maximum values (i.e. at each grid point the highest of the 4 concentrations from the 4 wind sensitivity simulation runs is presented).

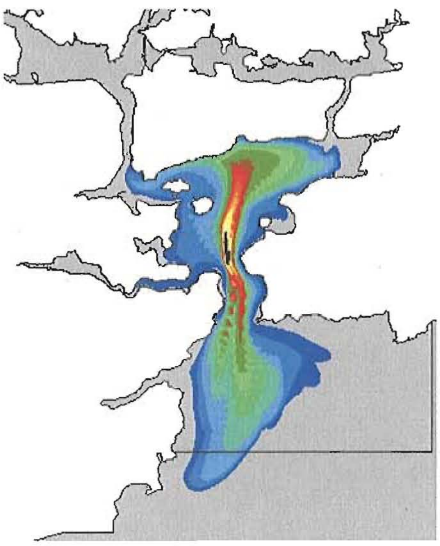

Fig. 4.62 Recorded wind – Base Case

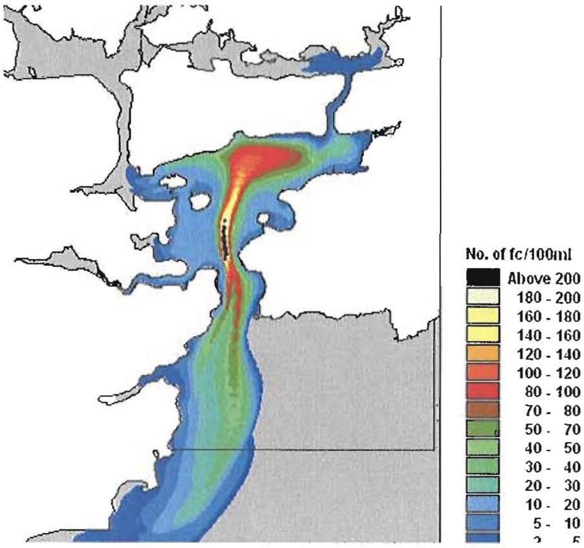

Fig. 4.65 Wind from East

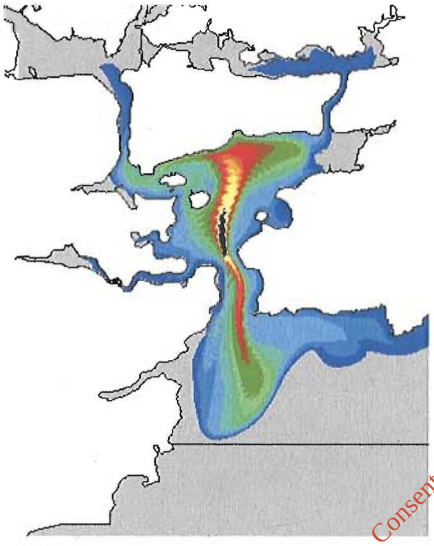

Fig. 4.63 Wind from West

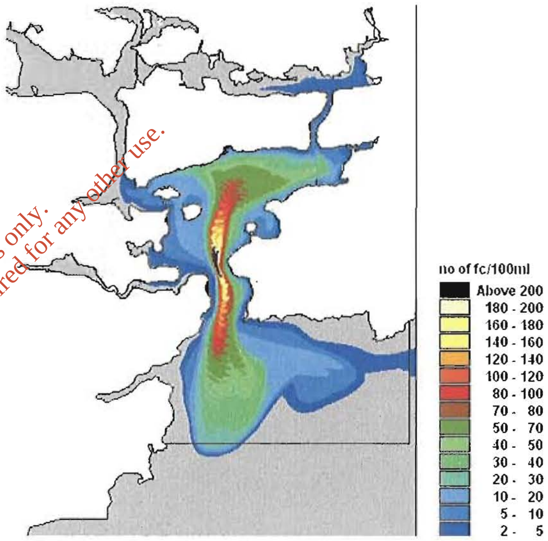

Fig. 4.66 Wind from South

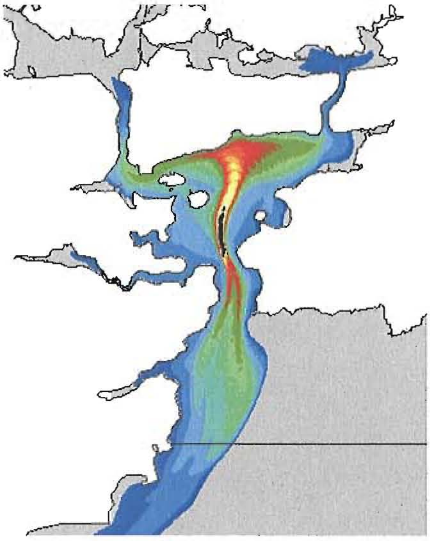

Fig. 4.64 Wind from North

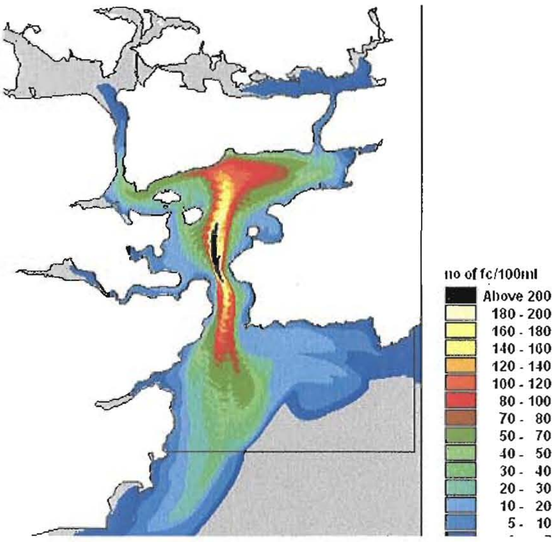

Fig. 4.67 Maximum of wind sensitivities

We can see from the figures that the extent of the plume is different for each of the 4 wind sensitivity simulation runs. In each case the plume extends into the North Channel and has an impact on the oyster farm but not in high concentrations (<10fc/100ml).

The concentrations in the outer harbour are increased with each of the wind sensitivities. We can see from the plots that these increases can be as much as 40-60 faecal coliforms per 100ml in certain areas.

A table presenting the maximum concentrations for each of the 15 points of interest for the combined maximum worse case wind sensitivities (Fig. 4.67) is shown below. The maximum concentrations for the recorded wind case (as presented in Table 4-4) are shown to aid the reader in making a comparison.

| | **2010** | **2010 – Wind sensitivity** | **2030** | **2030 – Wind sensitivity** |
|---|---|---|---|---|
| | MAX | MAX | MAX | MAX |
| **Fountainstown** | 0.2 | 3.5 | 0.3 | 5.0 |
| **Myrtleville** | 0.7 | 3.5 | 1.0 | 5.0 |
| **Roches Point** | 65.3 | 92.0 | 93.5 | 131.7 |
| **Crosshaven** | 3.8 | 11.3 | 5.4 | 16.1 |
| **Ringaskiddy Ferry** | 0.0 | 1.8 | 0.0 | 2.6 |
| **Monkstown Creek** | 0.0 | 0.5 | 0.0 | 0.7 |
| **Oyster F - NC** | 0.1 | 3.4 | 0.2 | 4.9 |
| **Marlogue Point** | 0.3 | 13.4 | 0.4 | 19.2 |
| **Oyster F - Outer** | 0.6 | 10.1 | 0.9 | 14.4 |
| **Cobh** | 23.2 | 67.7 | 33.2 | 96.9 |
| **Spike Island** | 9.1 | 38.1 | 13.1 | 54.5 |
| **Shoreline** | 2.2 | 8.9 | 3.2 | 12.7 |
| **Upstream of Outfall** | 333.7 | 346.4 | 477.6 | 495.7 |
| **West Passage** | 1.0 | 36.4 | 1.5 | 52.1 |
| **Lough Mahon** | 0.1 | 2.4 | 0.2 | 3.5 |

*Table 4-9 Maximum concentrations for the combined maximum worse case wind sensitivities*

## 4.6 Intestinal Enterococci concentrations

We have used the results of our faecal coliform modelling to predict the concentrations of intestinal enterococci in Cork Harbour when the treatment plant is in operation in 2010 and 2030. We have assumed that intestinal enterococci have a T90 of 24 hours and that there are $4.0*10^9$ enterococci in every cubic metre of raw sewage which is equivalent to $4.0*10^5$ enterococci in every 100ml[27]. We have assumed that the proposed waste water treatment plant will remove 90% of the organic matter so that there are $4.0*10^8$ enterococci in every cubic metre of treated effluent which is equivalent to $4.0*10^4$ enterococci per 100ml.

The faecal coliform results (with a T90 of 24 hours) may be used to predict the concentrations of intestinal enterococci owing to the linearity of the partial differential equation that describes the dynamic number-balance of the coliforms. The scaling property is a special case of the principle of superposition. It says the effect of multiplying, or scaling, any individual discharge by a constant positive number, x, is x times the concentration of coliforms in the Harbour due to that discharge before scaling *i.e.* when x is one.

We have assumed that there are $1*10^{11}$ faecal coliforms in every cubic metre of raw sewage and, as stated above, that there are $4.0*10^9$ intestinal enterococci per $m^3$. If we also assume that the removal efficiency of the treatment plant is the same for both we find that in order to rescale the faecal coliform results (T90 = 24hours) to the intestinal enterococci results we need to multiply the coliform concentrations by 0.04 (i.e. $1*10^{11} / 4.0*10^9 = 0.04$).

We are able to rescale in this way as the flow rates from the outfalls are the same for both bacteria. The decay rates (T90 = 24hours) and all other forcings in the model are also the same for both Bacteria. The maximum and average number of intestinal enterococci per 100ml for each of the 15 points of interest is presented in the following table.

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[27] World Health Organization. *WHO Guidelines for safe recreational water environments Volume 1 Coastal and Fresh waters.* Geneva: World Health Organization, 2003.

| **Year** | **2010** | | **2010** | | **2030** | | **2030** | |
|---|---|---|---|---|---|---|---|---|
| **Repeating Tide** | Spring | | Neap | | Spring | | Neap | |
| | MAX | AVG | MAX | AVG | MAX | AVG | MAX | AVG |
| **Fountainstown** | 0.05 | 0.02 | 0.05 | 0.01 | 0.07 | 0.02 | 0.08 | 0.02 |
| **Myrtleville** | 0.11 | 0.04 | 0.19 | 0.09 | 0.15 | 0.06 | 0.27 | 0.13 |
| **Roches Point** | 3.18 | 0.67 | 5.78 | 1.01 | 4.55 | 0.95 | 8.27 | 1.44 |
| **Crosshaven** | 0.45 | 0.14 | 0.37 | 0.06 | 0.64 | 0.21 | 0.52 | 0.09 |
| **Ringaskiddy** | 0.01 | 0.01 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.00 |
| **Monkstown Ck** | 0.02 | 0.01 | 0.00 | 0.00 | 0.02 | 0.01 | 0.00 | 0.00 |
| **Oyster F - NC** | 0.04 | 0.00 | 0.00 | 0.00 | 0.05 | 0.00 | 0.00 | 0.00 |
| **Marlogue Point** | 0.08 | 0.01 | 0.04 | 0.00 | 0.12 | 0.02 | 0.05 | 0.00 |
| **Oyster F - Outer** | 0.13 | 0.00 | 0.20 | 0.00 | 0.19 | 0.00 | 0.29 | 0.00 |
| **Cobh** | 1.60 | 0.42 | 0.30 | 0.02 | 2.29 | 0.61 | 0.42 | 0.03 |
| **Spike Island** | 0.86 | 0.20 | 1.60 | 0.44 | 1.23 | 0.29 | 2.29 | 0.63 |
| **Shoreline** | 0.34 | 0.07 | 0.30 | 0.03 | 0.48 | 0.09 | 0.43 | 0.05 |
| **Upstream Outfall** | 14.28 | 1.03 | 19.18 | 2.91 | 20.44 | 1.47 | 27.44 | 4.17 |
| **West Passage** | 0.17 | 0.02 | 0.01 | 0.00 | 0.25 | 0.03 | 0.01 | 0.00 |
| **Lough Mahon** | 0.04 | 0.00 | 0.00 | 0.00 | 0.05 | 0.01 | 0.00 | 0.00 |

*Table 4-10 Concentration of intestinal enterococci at locations of interest*

We can see from the table that the concentrations are very small with the exception of the area around the proposed outfall.

## 4.7 *Escherichia coli* concentrations

The concentrations of *Escherichia coli* in Cork Harbour may be calculated using the same rescaling technique as for the intestinal enterococci. We have assumed that *E coli* have a T90 of 24 hours and that there are $1.0*10^{12}$ *E coli* in every cubic metre of raw sewage which is equivalent to $1.0*10^{8}$ *E coli* in every 100ml[28]. This is the same concentration as for the faecal coliforms concentrations in raw sewage that were modelled. The results for the coliforms are therefore equivalent to *E coli* concentrations and are not repeated in this section.

## 4.8 Discussion and Conclusion

The OH_2 model has been used to simulate the release and advection of faecal coliforms from the relevant outfalls in Cork Harbour. We assumed that there

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[28] World Health Organization. Op. cit. ante.

were $1.0*10^7$ faecal coliforms in every 100ml of raw sewage. We also assumed that the proposed wastewater treatment plant will remove 90% of the organic matter, so that there are $1.0*10^6$ faecal coliforms in every 100ml of treated effluent.

A comparison between Case 2 (*no* treatment, 2010 population) and Case 3 (*with* treatment, 2010 population) was made for repeating spring and neap boundary conditions. It was shown that there was a substantial relative reduction in the number of faecal coliforms across the entire model area. This improvement in water quality was quantified by expressing the maximum concentrations for Case 3 (with treatment) as a percentage of the maximum concentrations for Case 2 (no treatment). It was found that the maximum concentrations with the treatment plant in place were less than 20% of the maximum concentrations with no treatment for the entire harbour area i.e. there is an 80% relative reduction in the number of indicator organisms. For the inner harbour and the East and West passages they were less than 5% i.e. there is a 95% relative reduction in the number of indicator organisms. This represents a significant improvement in water quality.

Time series of faecal coliform concentrations were presented for 15 points of special interest. The improvement in water quality was highlighted by plotting the time series for Case 2 and Case 3 on the same graph for the repeating spring and neap tides. The point with the highest concentrations was located just upstream of the outfall where the concentration of faecal coliforms per 100ml ranged from 50 -2300 fc/100ml for the case of no treatment, and 10 - 400 fc/100ml for the case with treatment applied. The points with the lowest concentrations were the centre of the oyster farm in the North Channel and Fountainstown. For both of these locations the number of faecal coliforms per 100ml was less than 1 with no treatment. When the treatment plant was in place it was found to be almost zero. With a strong wind (>10m/s) from the southwest the concentrations in the North Channel increased to over 7 fc/100ml.

A sensitivity analysis was carried out on the OH_2 model for Case 3 (with treatment, 2010 population). It was found that when the faecal coliforms were simulated with a T90 of 24 hours the concentration in the outer harbour increased in by as much as 40 fc/100ml in certain areas. When the model was simulated with adverse wind conditions it was found that the concentrations in the outer harbour increased by as much as 40 - 60 fc/100ml in certain areas. In the area adjacent to the outfall the concentrations increased in by as much as 60 - 90 fc/100ml.

Maximum and averaged concentrations for intestinal enterococci were calculated by rescaling the faecal coliform results for Case 2 and Case 3. It was found that the intestinal enterococci concentrations were very small with the exception of the area immediately around the proposed outfall.

Maximum and averaged concentrations for *E coli* were calculated by rescaling the faecal coliform results for Case 2 and Case 3. As must be the case the concentrations were equal since all inputs were identical in value.

# Chapter 5 *Norovirus* Results

## 5.1 Background

This chapter presents the results of the *Norovirus* modelling. The *Norovirus* or "winter vomiting bug" is the primary pathogen in outbreaks of gastroenteritis following consumption of raw oysters.

The *Norovirus* is endemic in many countries. Outbreaks of "winter vomiting bug" may occur all year round and are often made public in Ireland by the closure of hospitals to visitors. Waters at al.[29] reported that "Since 2002, the burden of Norovirus (NoV) infection in Ireland has increased. Outbreaks in institutional settings are the most common causing widespread disruption to health service delivery". Kelly et al. (2006)[30] reported 226 outbreaks in Ireland during 2004 and concluded: "Results so far indicate that the majority of reported outbreaks in the island of Ireland are associated with hospitals and residential institutions." There is no comment on the probable number of non-reported outbreaks.

The virus is life-threatening to those with post-operative stress in hospital and to the very young and very old. In healthy adults it is not very dangerous.

The *Norovirus* is a colloidal particle 27-38nm in diameter. It is highly infectious especially in the case of projectile vomiting. The minimum infective dose is very low, between one and ten ingested particles. Incubation takes 24 to 48 hours.

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[29] Waters, A., et al. (2006) "Molecular epidemiology of *Norovirus* strains circulating in Ireland from 2003 to 2004" *Epidemiol. Infect.,* Page 1 of 9. Cambridge University Press. http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=420336#

[30] Kelly S., Foley B., Coughlan S., Dunford L., O'Neill H., Smyth B., McKeown P., Lynch M. "Epidemiology and molecular analysis of *Norovirus* outbreaks in Ireland" Abstract p1030

European Society of Clinical Microbiology and Infectious Diseases 16th European Congress of Clinical Microbiology and Infectious Diseases. Nice, France, April 1-4, 2006.

The average infected person may excrete[31] roughly 0.15 billion *Norovirus* particles per day to the sewer system. Roughly 3 to 6% of the population of a town or city may be infected during an outbreak. Asymptomatic excretion from infected persons may persist for a period of up to 2 to 3 months.[32]

The virus has a long survival time in coastal waters from 7 days (summer T90) to 30 days (winter T90)[33]. These T90 values are ten times those for the indicator bacteria, such as faecal coliforms, used in regulatory instruments for the protection of consumers of oysters and the quality of coastal waters where oysters are produced. Consequently, when the infective agent is viral, absence of indicator bacteria does not imply the absence of contamination and health risk. Protection against *Norovirus* may also protect against most other viral pathogens as well.

We have assumed that there are 50 million *Norovirus* in every cubic metre of raw sewage. This is a slightly more conservative value than was used in a study of the *Norovirus* by a team of microbiologists at IFREMER in France[34] where it was assumed that there are 20 million *Norovirus* in every cubic metre of raw sewage.[35] This concentration, multiplied by the flow rate for each town (as listed in Chapter 1) gives the loading for each outfall. Adopting such an approach

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[31] Pommepuy, M. et al. "Sewage impact on shellfish microbial contamination". Water Science and Technology. Vol. 50, No. 1 pp 117-124. IWA publishing, 2004.

[32] Pommepuy, M. et al., 2004, Op. cit. ante.

[33] Pommepuy, M. et al. "Faecal contamination in coastal waters: An engineering approach" Book chapter (p331-359) in Oceans and Health: Pathogens in the Marine Environment. Springer 2006. http://www.springerlink.com, http://www.ifremer.fr/docelec. The T90 time is the time required for 90% decay.

[34] Pommepuy, M. et al., 2004, Op. cit. ante.

[35] No epidemiological data, or models, for the spread of winter vomiting due to *Norovirus* are available either nationally or internationally. Consequently, only relative concentrations are significant in our model *i.e.* the relative change in concentrations due to the new treatment plant and new outfall location. There are no standards for *Norovirus* in recreational or oyster producing waters.

assumes that each and every person living within the catchments experience an identical attack of *Norovirus* gastroenteritis and discharges the same number of *Norovirus* particles to the nearest sewer at a constant rate for the duration of the outbreak of *Norovirus*. We have assumed that an outbreak of *Norovirus* in the population lasts for 20 days[36]. The OH_2 model was therefore simulated for 25 days. In all the time series presented in section 5.3 we can see the concentration of *Norovirus* increase up to a maximum value occurring approximately at the end of the 20 day pulse. The concentrations decrease afterwards. We have therefore used a spring to neap tidal cycle as the boundary condition for the *Norovirus* modelling.

In this study we have assumed that the proposed waste water treatment plant will remove 90% of the organic matter. We have assumed an equivalent removal efficiency of *Norovirus* such that after treatment there are 5 million *Norovirus* in every cubic metre of treated effluent (i.e. 90% of 50 million is 45 million, hence 5 million are left).

In order to determine the worse case scenario in terms of concentration we have assumed that the T90 of the *Norovirus* is 30 days. This slow decay rate is representative of "winter conditions".

The presentation of the results in this chapter follows the same format as in the previous chapter. Spatially varying maps of maximum concentration are presented in the following section. Time series for the 13 points of interest to the study are then given. Unlike the previous chapter where all the concentrations were expressed in number of faecal coliforms per 100ml, all the concentrations in this chapter are expressed as ***Norovirus* per cubic metre.**

## 5.2 Spatially Varying maps of concentration

This section presents the spatially varying maps of maximum concentration over the entire area. Over the course of the model run the number of *Norovirus* at each grid point will, at some specific moment, reach a maximum value. These

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[36] Pommepuy, M. et al., 2004, Op. cit. ante

maxima, at each and every grid point, may be extracted from the result files of a production run and plotted together on a single map. This diagram then illustrates the spatially varying maximum concentrations of the simulation period for Cork Harbour. The time at which the concentrations reach their peak is not considered.

As before the colour palette is the same for each plot in order to aid the reader in making a visual comparison between the different model runs.

The concentrations for Case 2 are presented in Fig. 5.1. We can see from the figure that the maximum concentrations are located in the vicinity of the outfalls. We can also observe that the viral plume extends much further into the Celtic sea than the bacterial plume presented in the previous chapter.

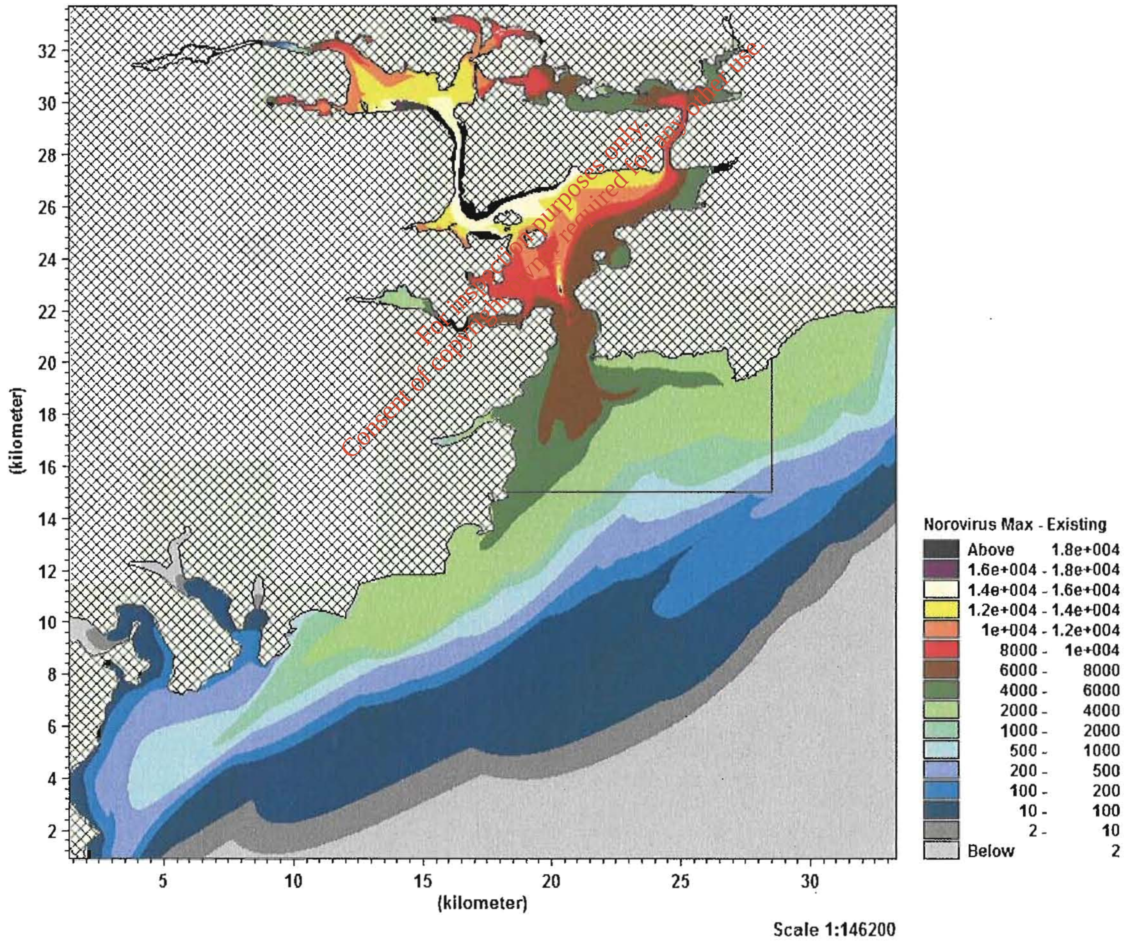

*Fig. 5.1 Plot of maximum concentration for Case 2 (2010 – no treatment)*

Case 3 is presented in Fig. 5.2. We can see from the figure that there has been a reduction in the number of *Norovirus* throughout the harbour. For Case 2 the *Norovirus* concentrations ranged from 2 to over 18,000 viral particles per cubic metre. For Case 3 this range is greatly reduced. We can see that the range is between 2 and 4000 particles per cubic metre if one ignores the very high concentrations in the immediate vicinity of the outfall.

In order to quantify this reduction in concentration we may express the maximum concentrations for Case 2 as a percentage of the maximum concentrations of Case 3 as we did in the previous chapter. This is plotted in Fig. 5.3. We can see from the figure that for Lough Mahon and the Belvelly Channel the concentrations with the treatment plant in operation are less than 5% of the concentrations when untreated waste is being discharged i.e. there is at least a 95% relative reduction in the number of *Norovirus*. For the rest of the Inner harbour they are less than 10% i.e. a 90% relative reduction. For the outer harbour they are less than 20% i.e. an 80% relative reduction.

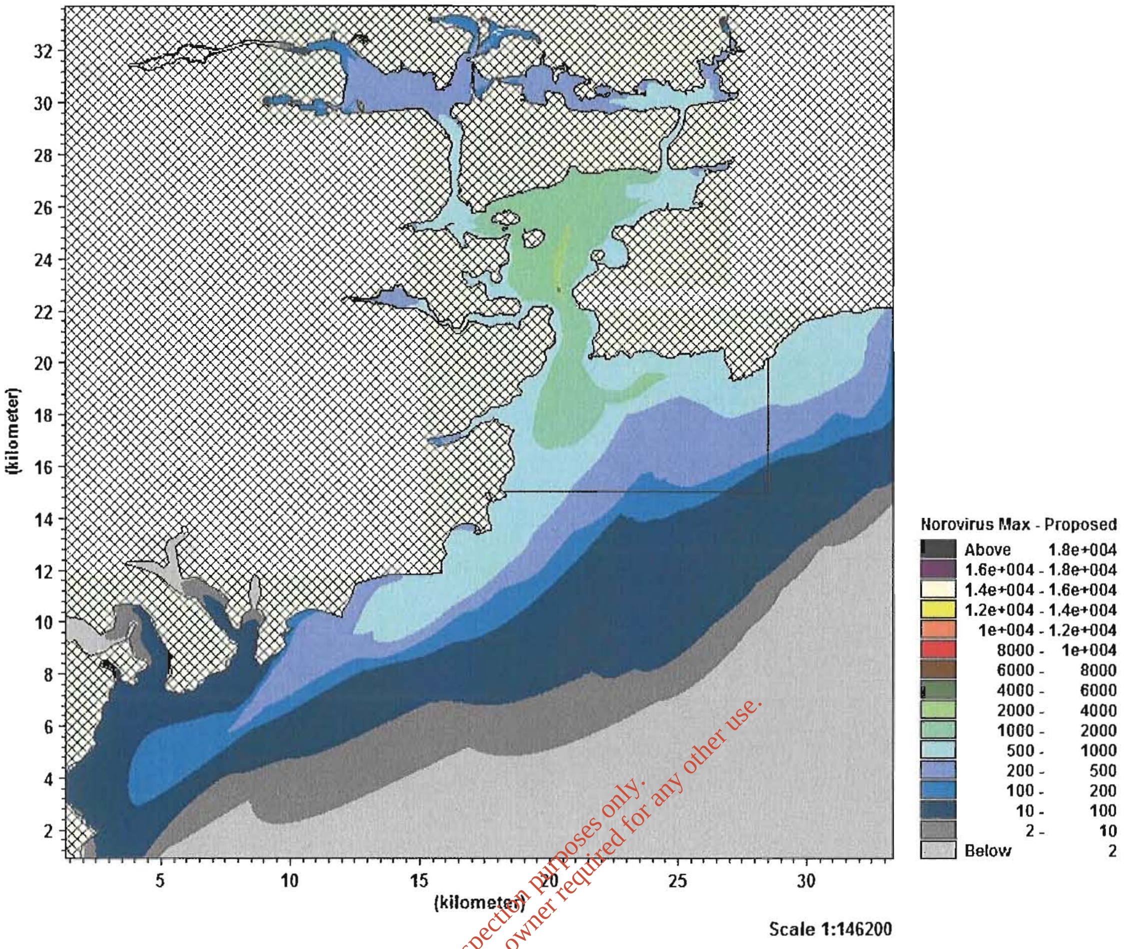

*Fig. 5.2 Plot of maximum concentration for Case 3 (2010 – with treatment)*

The exception to this is the area immediately upstream of the outfall where the concentrations for Case 3 are less than 25% of the concentrations for Case 2 i.e. a 75% relative reduction.

The pattern of relative reduction of *Norovirus* with the introduction of the proposed scheme is very similar to that of the faecal coliforms.

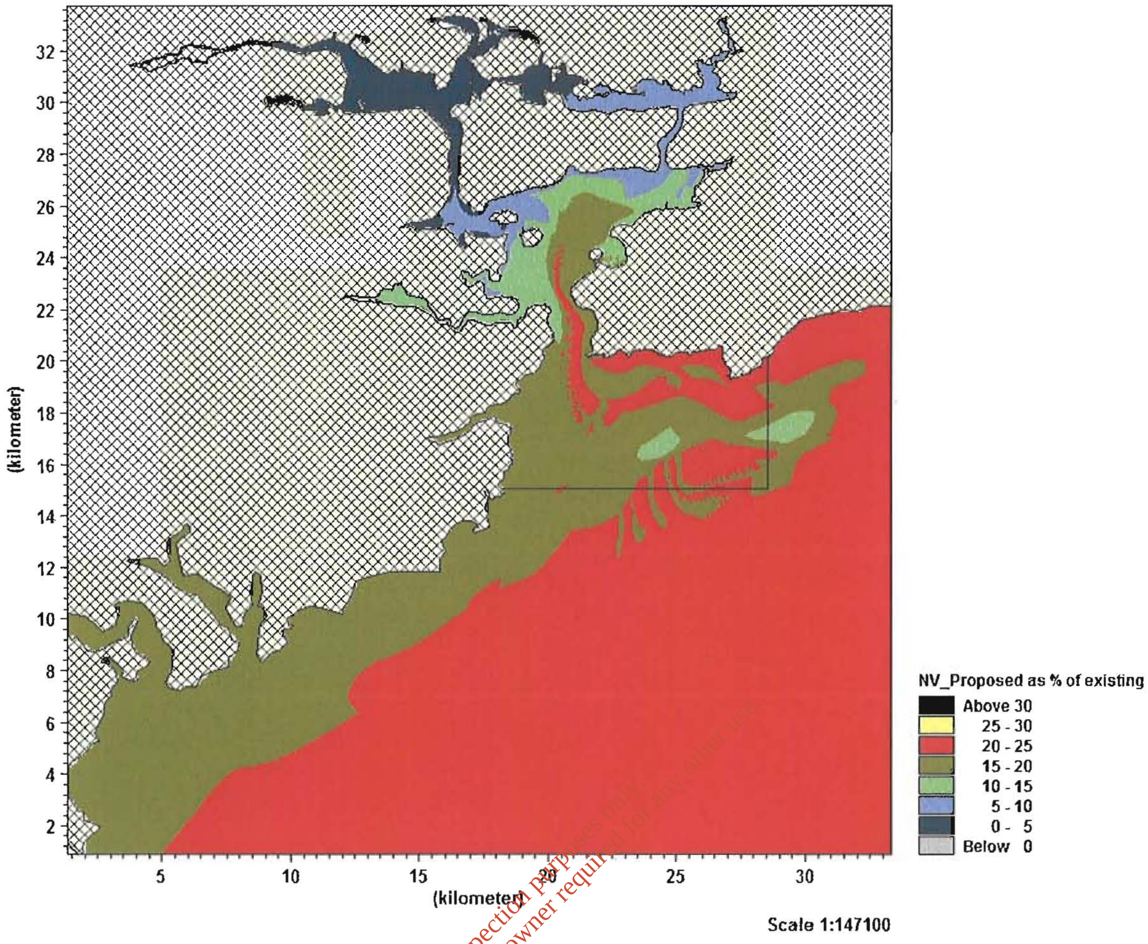

*Fig. 5.3 The 2010 proposed concentrations as a percentage of the existing concentrations*

## 5.3 Time series of concentration of *Norovirus*

The previous section presented spatially varying plots of concentration across the entire harbour area. In order to evaluate the benefit of the proposed scheme at a particular location we must extract the time series of concentration from the locations of interest in the model. For this Environmental Impact Statement 15 points of special interest have been identified and are listed in Table 5-1.

The maximum and averaged concentrations of *Norovirus* for these points of interest are presented in Table 5-2 and Table 5-3.

| Point No | Location | E (UTM) | N (UTM) |
|---|---|---|---|
| 1 | Fountainstown | 547588 | 5736208 |
| 2 | Myrtleville | 548700 | 5737121 |
| 3 | Roches Point | 550651 | 5738138 |
| 4 | Crosshaven | 548497 | 5739695 |
| 5 | Ringaskiddy Ferry | 546466 | 5742772 |
| 6 | Monkstown Creek | 545166 | 5743316 |
| 7 | Oyster Farm - North Channel | 552712 | 5748103 |
| 8 | Marlogue Point | 554291 | 5745574 |
| 9 | Oyster Farm - Outer Harbour | 555451 | 5744826 |
| 10 | Cobh - Recreational Area | 548617 | 5744396 |
| 11 | Spike Island - Proposed Heritage Area | 549349 | 5742451 |
| 12 | Shoreline Closest to Existing Outfall | 547959 | 5741601 |
| 13 | 200m Upstream of Existing Outfall | 550203 | 5740759 |
| 14 | West Passage | 546223 | 5744496 |
| 15 | Entrance to Lough Mahon | 545505 | 5747784 |

*Table 5-1 – Points of interest to the study*

In order to make an assessment of the improvement in water quality resulting from the proposed wastewater treatment plant, Case 2 and Case 3 are plotted against with other in the following graphs. The plots for Case 4 (2030) are not presented. As before one may obtain the concentration for 2030 by simply multiplying the values for Case 3 by 1.431.

One graph is presented for each of the 15 locations. Case 2 is plotted with a black line and is referred to in the legend as “existing”. Case 3 is plotted using blue and is referred to in the legend as “proposed”.

The reader should be aware that the scale on the left-hand axis, which expresses the number of ***Norovirus* per cubic metre**, varies for each of 15 locations.

| | **2001** Untreated MAX | **2010** Untreated MAX | **2010** Treated MAX | **2030** Treated MAX |
|---|---|---|---|---|
| **Fountainstown** | 2816 | 3886 | 695 | 994 |
| **Myrtleville** | 3291 | 4542 | 798 | 1142 |
| **Roches Point** | 4694 | 6478 | 1254 | 1795 |
| **Crosshaven** | 5754 | 7940 | 917 | 1312 |
| **Ringaskiddy** | 8507 | 11740 | 550 | 788 |
| **Monkstown Ck** | 8851 | 12214 | 556 | 795 |
| **Oyster F – NC** | 4254 | 5870 | 550 | 787 |
| **Marlogue Point** | 7806 | 10772 | 933 | 1335 |
| **Oyster F - Outer** | 3967 | 5475 | 545 | 780 |
| **Cobh** | 11704 | 16152 | 1374 | 1966 |
| **Spike Island** | 7281 | 10048 | 1203 | 1722 |
| **Shoreline** | 6498 | 8967 | 1028 | 1471 |
| **Upstream Outfall** | 10863 | 14991 | 3157 | 4518 |
| **West Passage** | 11100 | 15318 | 817 | 1169 |
| **Lough Mahon** | 10674 | 14730 | 471 | 675 |

All concentrations are expressed in no of Norovirus per m3

*Table 5-2 Maximum Norovirus concentrations*

| | **2001** Untreated AVERAGE | **2010** Untreated AVERAGE | **2010** Treated AVERAGE | **2030** Treated AVERAGE |
|---|---|---|---|---|
| **Fountainstown** | 730 | 1008 | 195 | 278 |
| **Myrtleville** | 1091 | 1505 | 285 | 408 |
| **Roches Point** | 1921 | 2650 | 532 | 762 |
| **Crosshaven** | 1816 | 2507 | 368 | 527 |
| **Ringaskiddy** | 5379 | 7423 | 219 | 314 |
| **Monkstown Ck** | 5246 | 7239 | 186 | 266 |
| **Oyster F – NC** | 964 | 1331 | 89 | 127 |
| **Marlogue Point** | 2421 | 3341 | 252 | 361 |
| **Oyster F - Outer** | 1848 | 2550 | 219 | 313 |
| **Cobh** | 6124 | 8452 | 430 | 615 |
| **Spike Island** | 2904 | 4008 | 523 | 748 |
| **Shoreline** | 1601 | 3964 | 496 | 396 |
| **Upstream Outfall** | 2744 | 3787 | 701 | 1004 |
| **West Passage** | 6352 | 8766 | 205 | 293 |
| **Lough Mahon** | 5448 | 7518 | 98 | 140 |

All concentrations are expressed in no of *Norovirus* per m3
The average values are for the 20 day viral pulse

*Table 5-3 Averaged Norovirus concentrations*

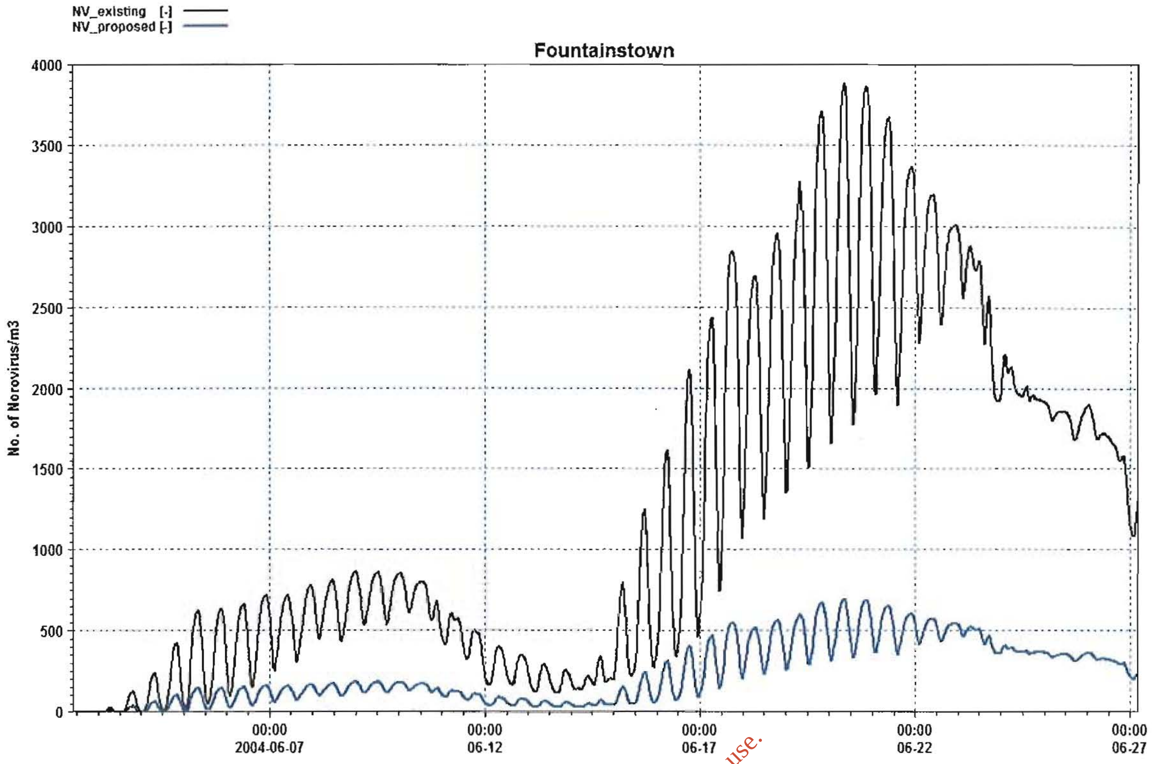

Fig. 5.4 Fountainstown – Norovirus Case 2 & Case 3 (2010)

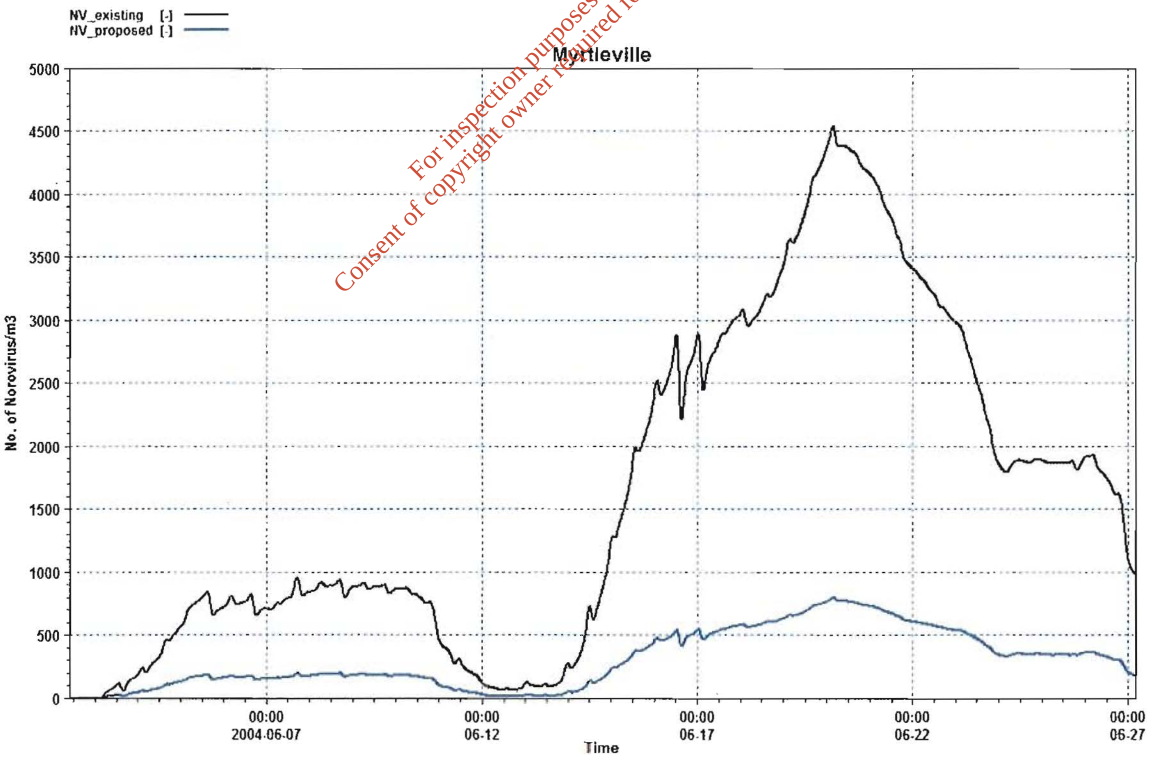

Fig. 5.5 Myrtleville – Norovirus Case 2 & Case 3 (2010)

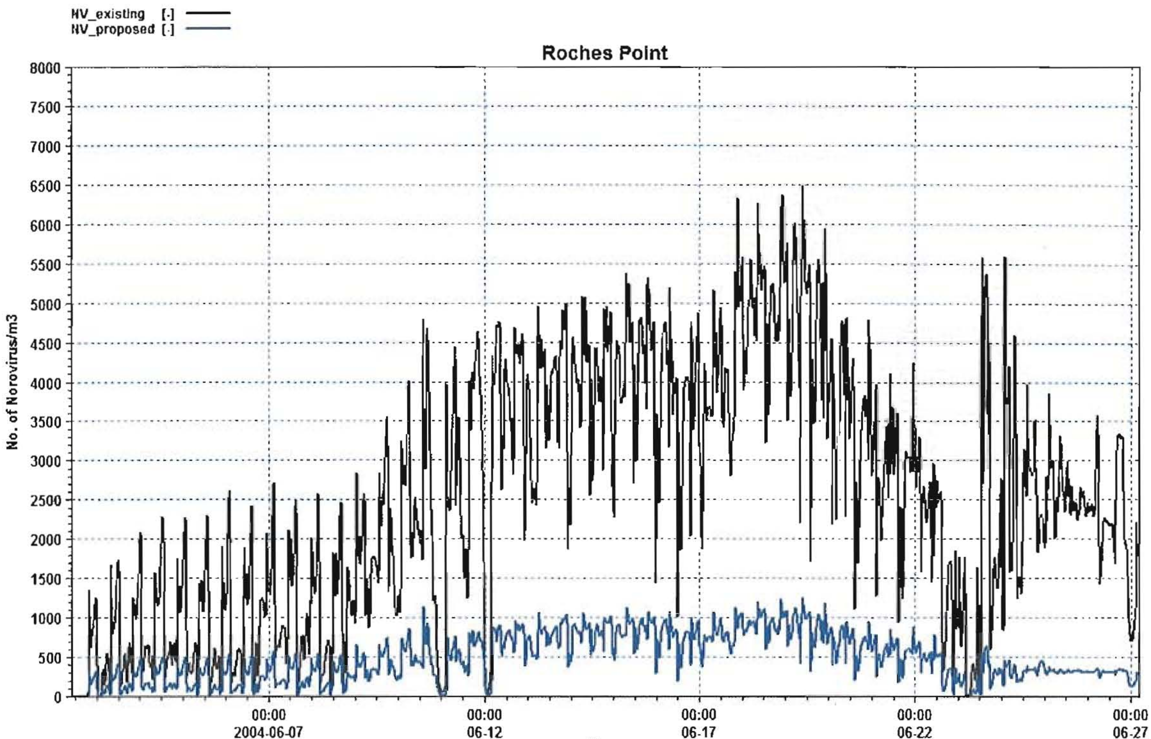

*Fig. 5.6 Roches Point – Norovirus Case 2 & Case 3 (2010)*

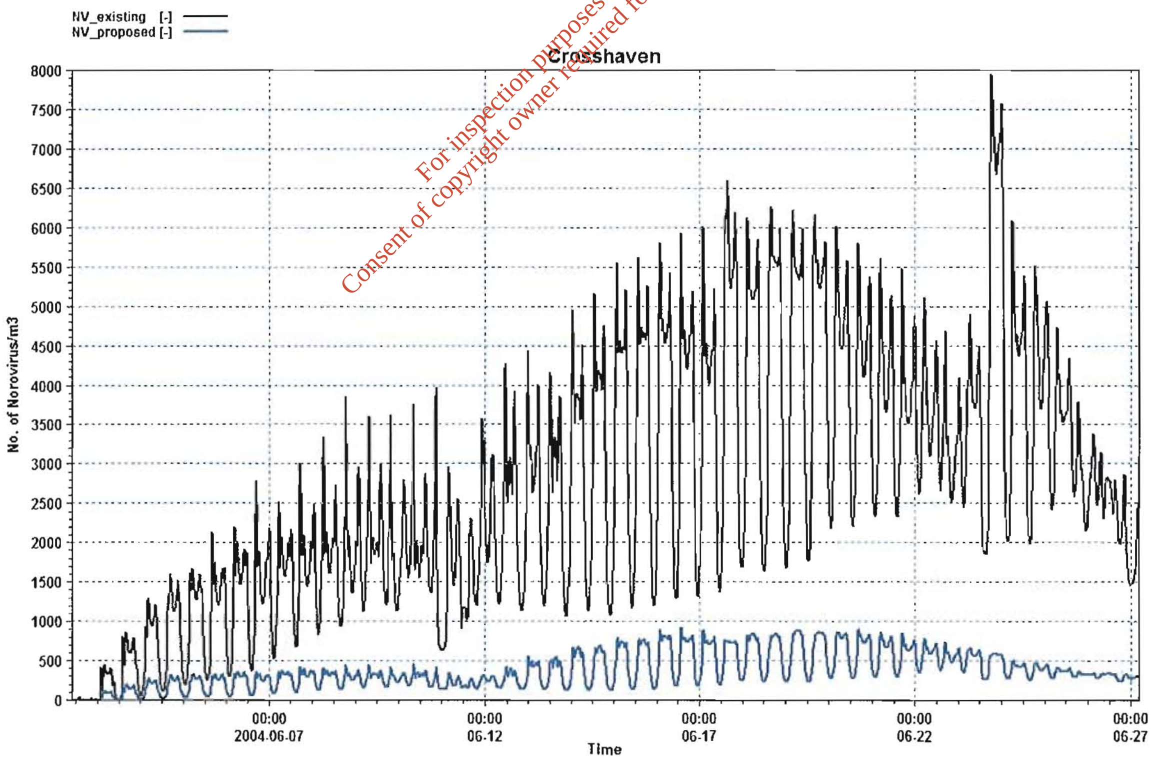

*Fig. 5.7 Crosshaven – Norovirus Case 2 & Case 3 (2010)*

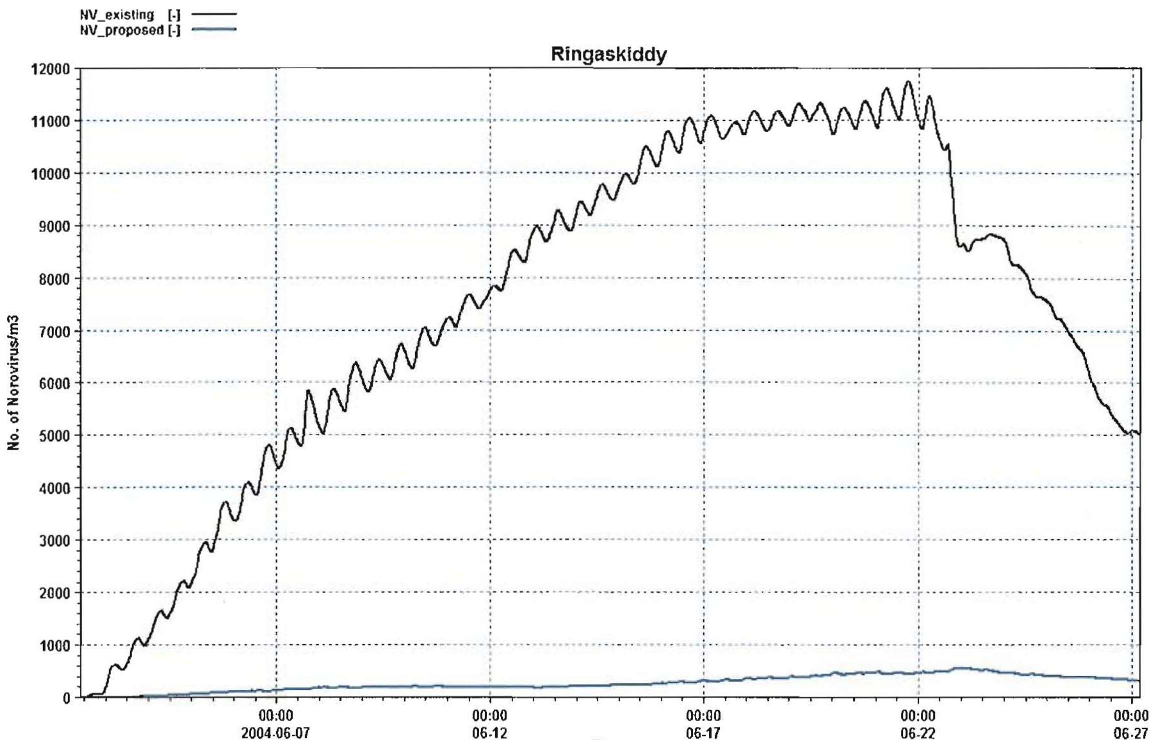

Fig. 5.8 Ringaskiddy – Norovirus Case 2 & Case 3 (2010)

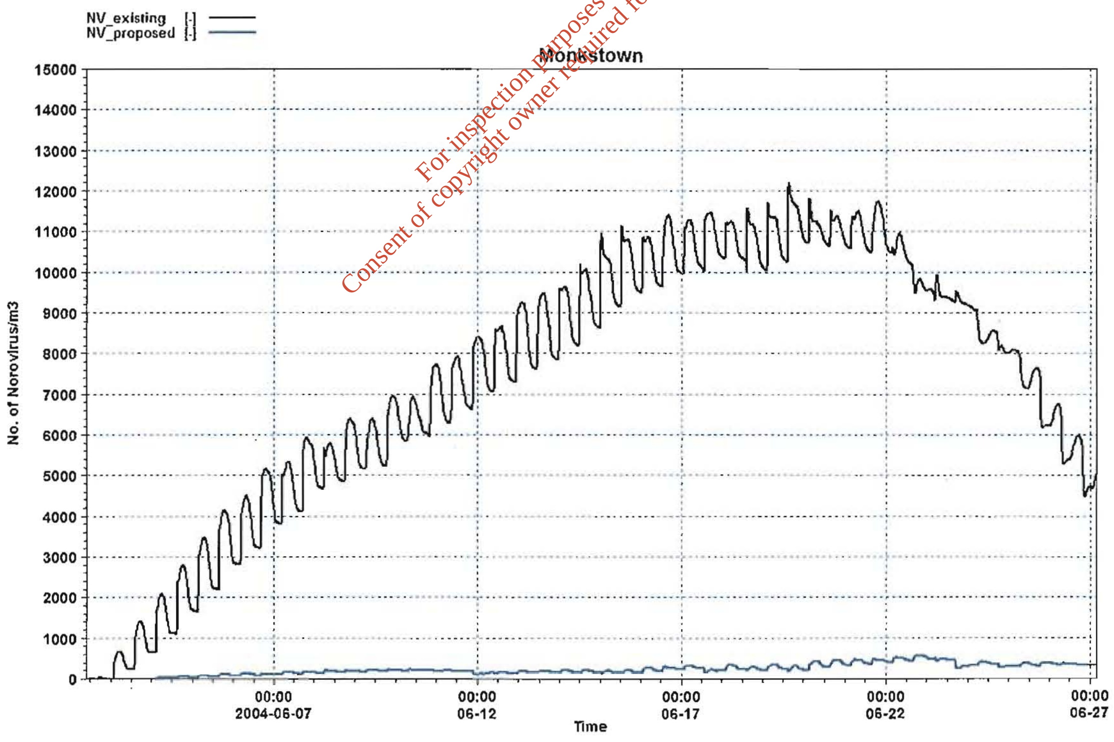

Fig. 5.9 Monkstown – Norovirus Case 2 & Case 3 (2010)

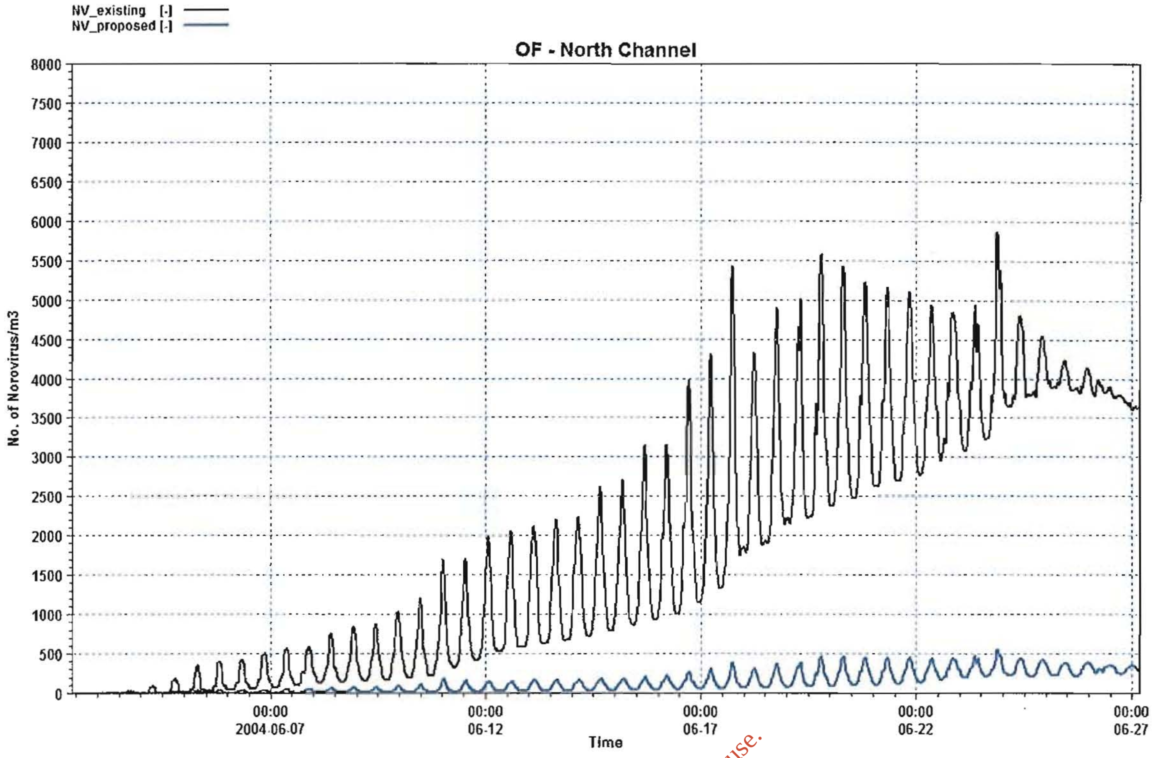

Fig. 5.10 OF - North Channel – Norovirus Case 2 & Case 3 (2010)

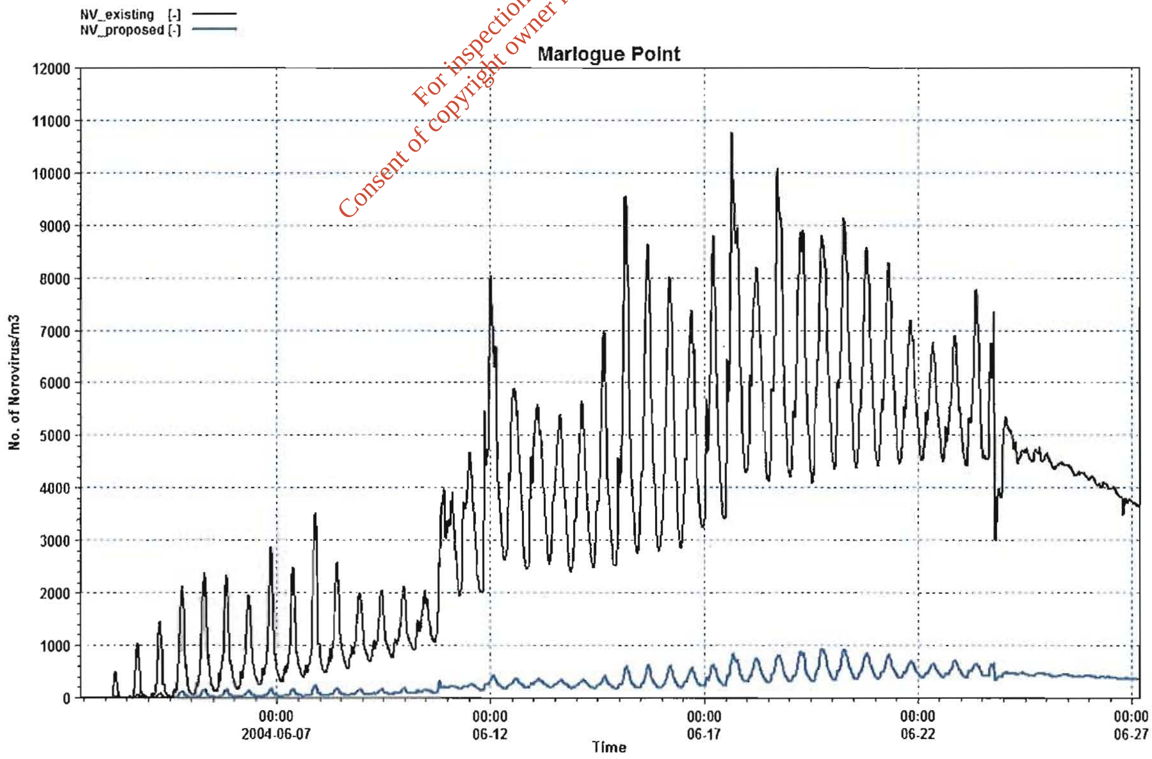

Fig. 5.11 Marlogue Point – Norovirus Case 2 & Case 3 (2010)

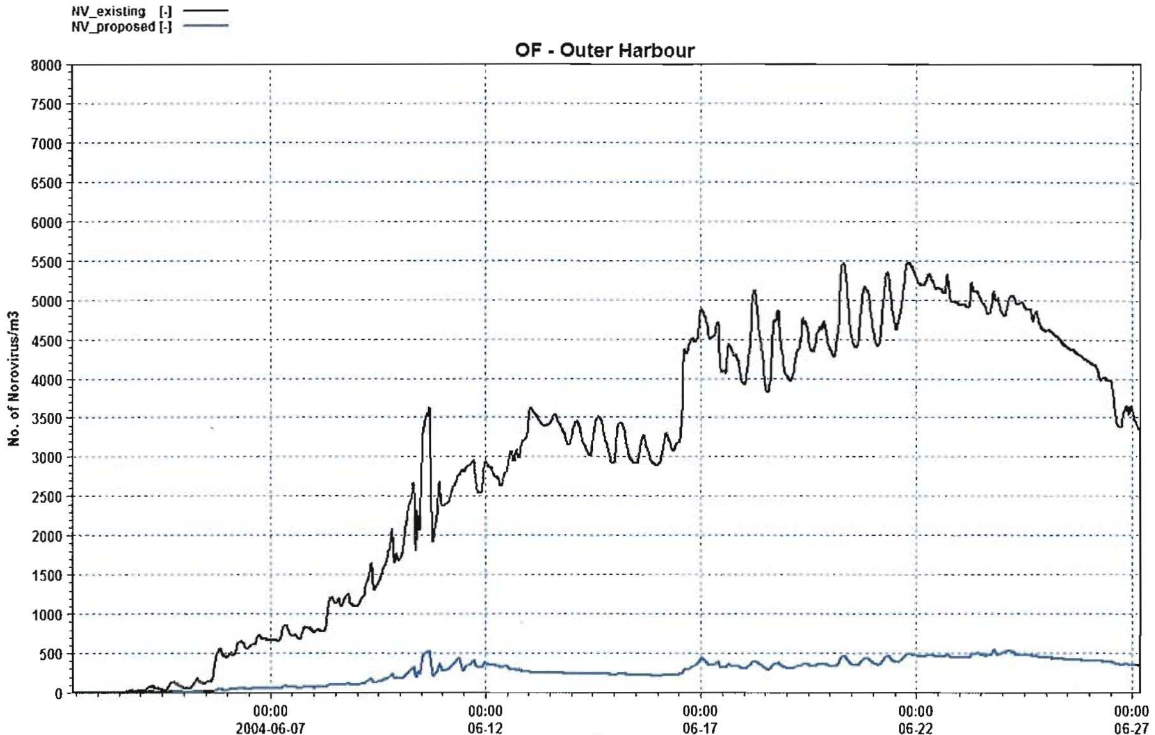

Fig. 5.12 OF – outer harbour – Norovirus Case 2 & Case 3 (2010)

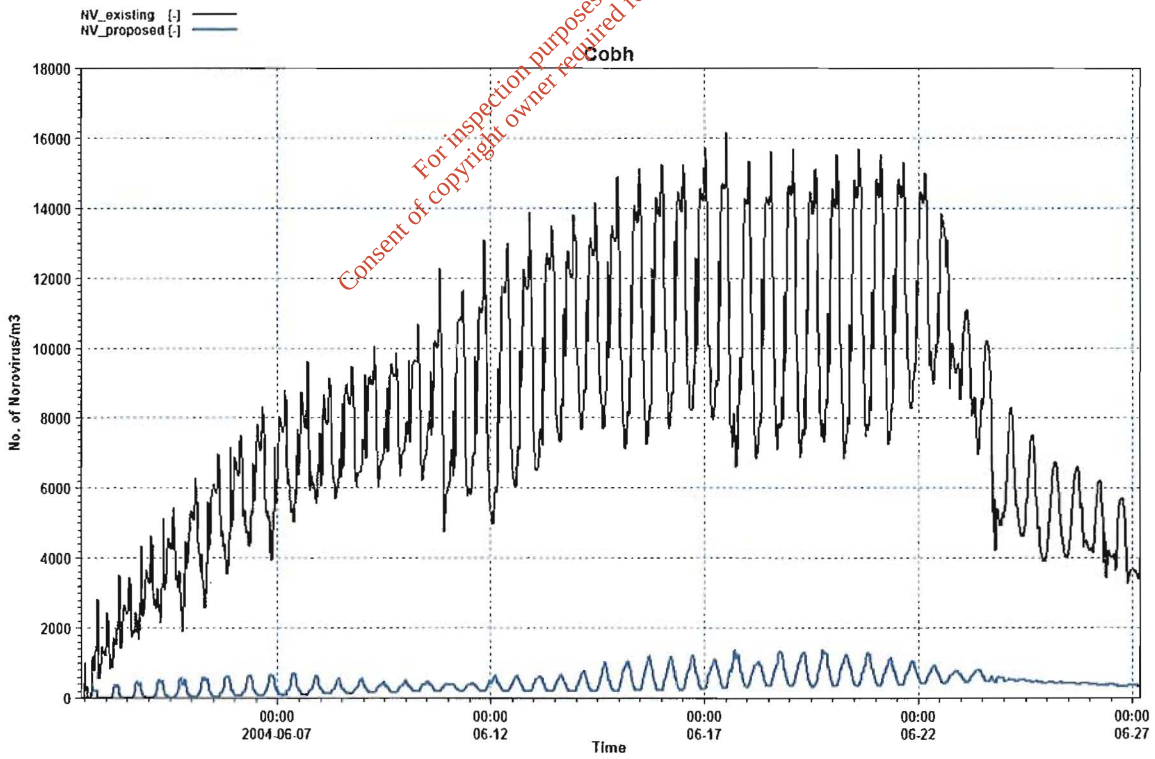

Fig. 5.13 Cobh recreational area – Norovirus Case 2 & Case 3 (2010)

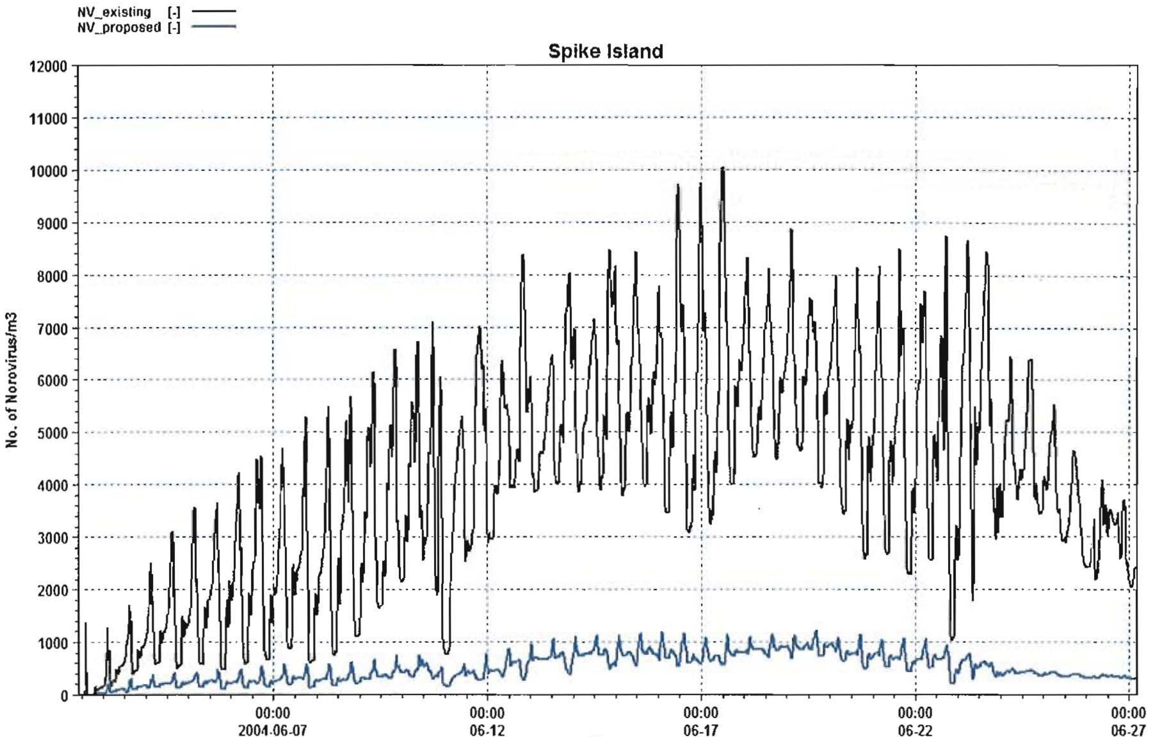

Fig. 5.14 Spike Island – Norovirus Case 2 & Case 3 (2010)

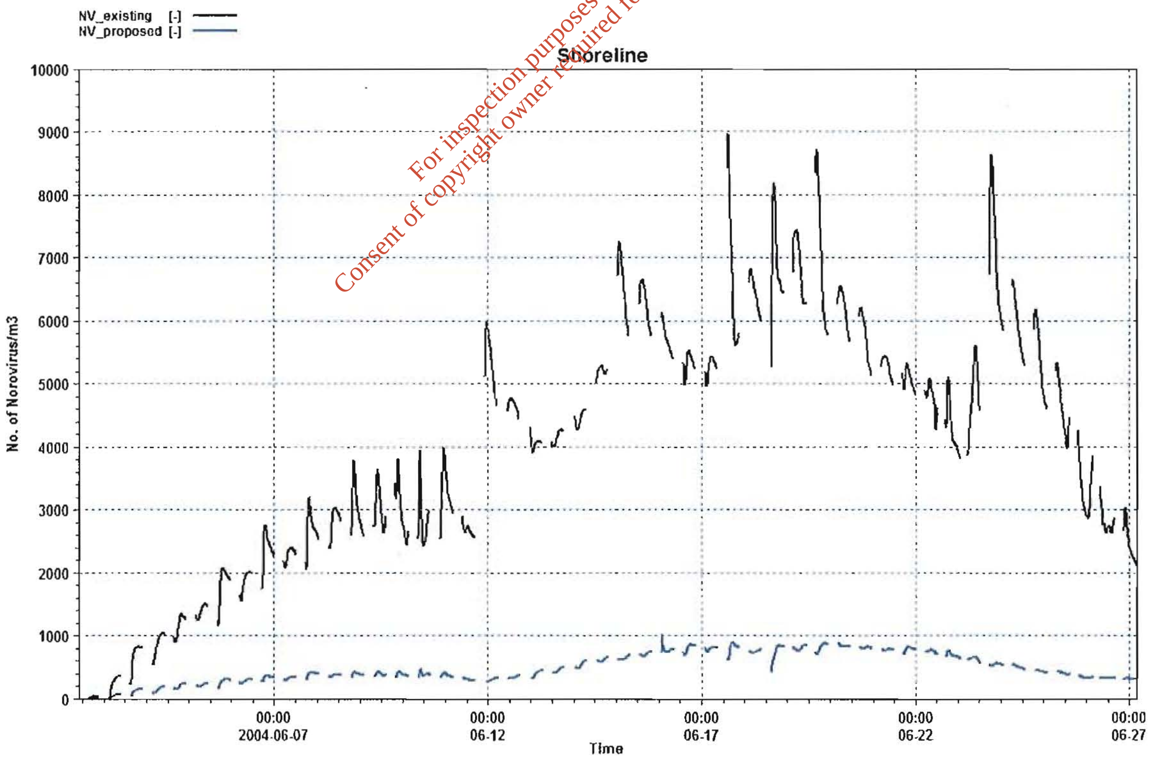

Fig. 5.15 Existing Shoreline closest to the outfall – Norovirus Case 2 & Case 3 (2010)

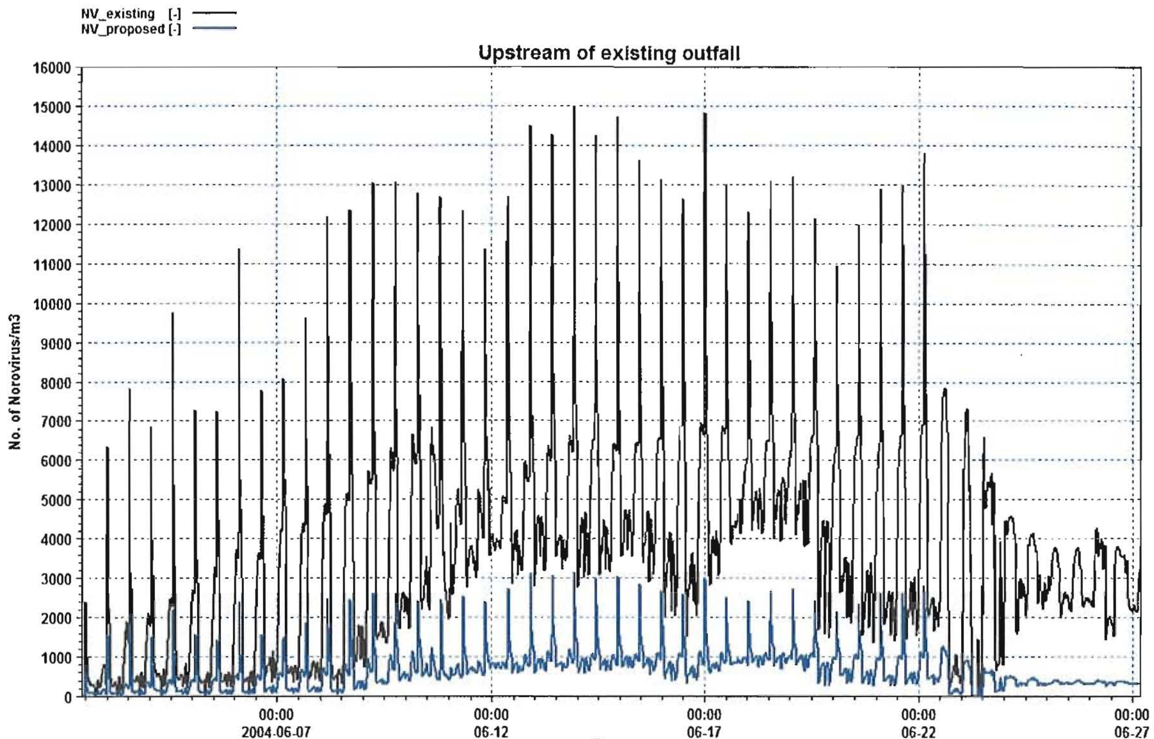

*Fig. 5.16 200m upstream of the existing outfall – Norovirus Case 2 & Case 3 (2010)*

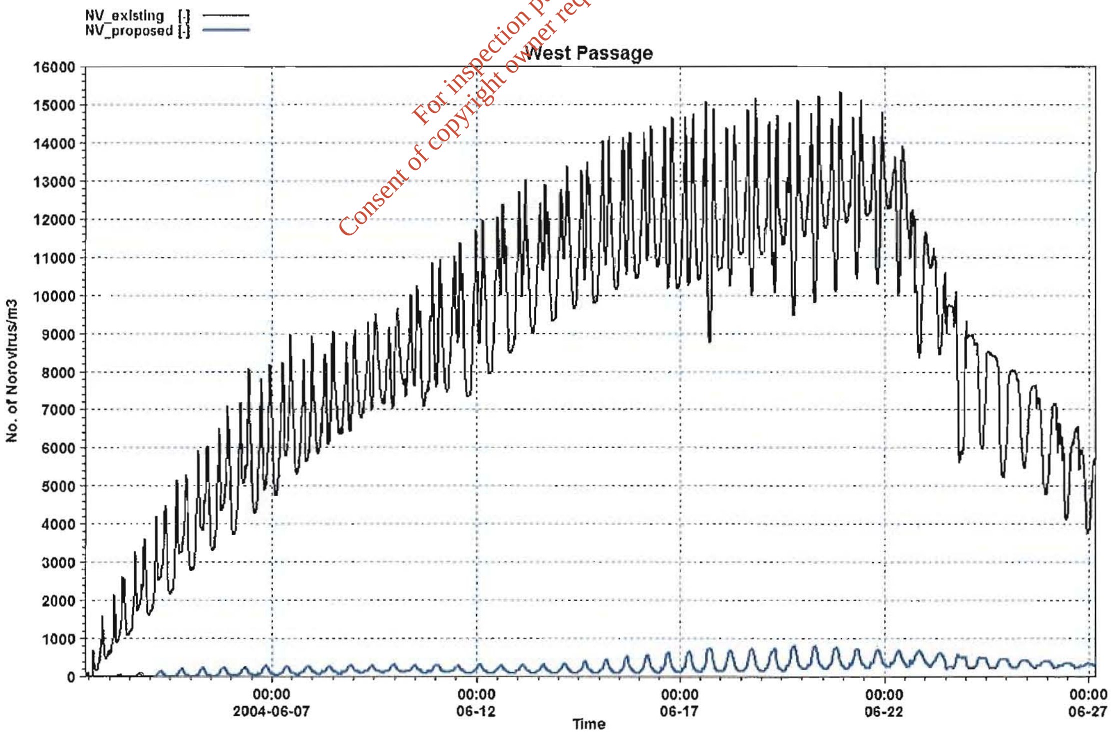

*Fig. 5.17 West Passage – Norovirus Case 2 & Case 3 (2010)*

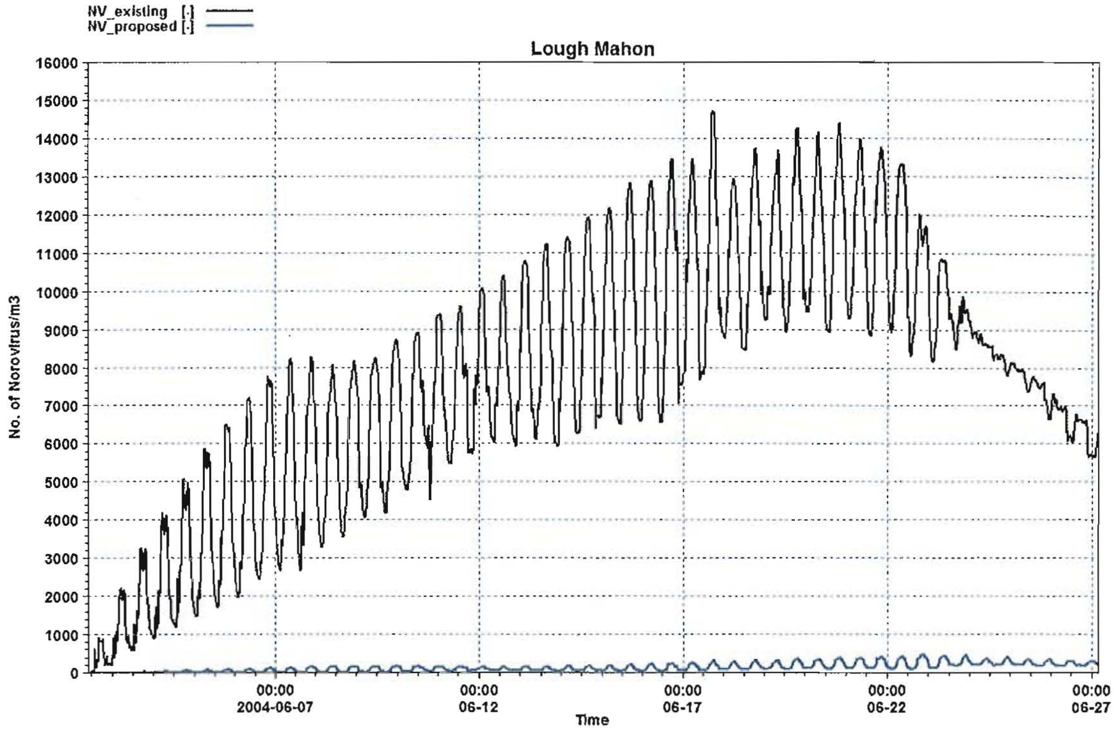

*Fig. 5.18 Lough Mahon – Norovirus Case 2 & Case 3 (2010)*

## 5.4 Discussion and Conclusion

The OH_2 model has been used to simulate the release and advection of *Norovirus* from the relevant outfalls in Cork Harbour. *Norovirus* was included in this Environmental Impact statement in order to assess the changes in concentration at the oyster farms and water-contact recreation areas present in the harbour.

We assumed that there was 50 million *Norovirus* in every cubic metre of raw sewage during a 20 day outbreak of "winter vomiting". We also assumed that the proposed wastewater treatment plant will remove 90% of the *Norovirus* so that there are 5 million *Norovirus* in every cubic metre of treated effluent for 20 days. We assumed a T90 of 30 days, a typical value for winter conditions leading to maximum concentrations in the harbour.

A comparison between Case 2 (*no* treatment, 2010 population) and Case 3 (*with* treatment, 2010 population) was made for a spring to neap to spring tidal cycle for a 25 day period. It was shown that there was a reduction in the number of *Norovirus* across the entire model area. This was quantified by expressing the maximum concentrations for Case 3 (with treatment) as a percentage of the maximum concentrations for Case 2 (no treatment). It was found that the maximum concentrations with the treatment plant in place were less than 20% (i.e. an 80 % relative reduction) of the maximum concentrations with no treatment for the entire harbour area with the exception of the area immediately adjacent to the outfall. For areas of the Inner harbour the improvement was much greater with the maximum concentrations for Case 3 being less than 5% of those for Case 2 (i.e. a 95 % relative reduction).

Time series of *Norovirus* concentrations were presented for 15 points of special interest. The improvement in water quality was highlighted by plotting the time series for Case 2 and Case 3 on the same graph.

From this we can conclude that the burden of *Norovirus* on Cork Harbour is reduced with the construction of the proposed wastewater treatment plant.