October 2022

Pilot Winter Operation of Ultraviolet (UV) Disinfection at Ringsend WWTP

Assessment of Impact of Winter UV operation at Ringsend WWTP on bathing sites in Dublin Bay

Final Report

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Executive Summary

Overview

Since the 1970s, the EU has had rules in place to safeguard public health and clean bathing waters. The revised Bathing Water Directive (BWD) of 2006 updated and simplified these rules. It **requires Members States to monitor and assess the bathing water for at least two parameters of (faecal) bacteria**.

Bathing water quality can be impacted by a number of factors, including urban wastewater, run-off from agricultural land and roads, nearshore pressures (such as dog and bird fouling) and misconnections from houses and businesses. The EU Bathing Water Directive is implemented in Ireland by the Bathing Water Regulations and the EPA, Local Authorities and the HSE all have a statutory role in the implementation of the Bathing Water Regulations.

In Ireland the Bathing Water Season, as defined in the bathing water regulations, runs from **1 June to 15 September** each year.

As the competent authority for the provision of public wastewater services in Ireland, Irish Water is a significant stakeholder in the context of bathing water quality in Dublin Bay. Particularly with respect to the Ringsend Wastewater Treatment Plant (WwTP), which provides over 40% of Ireland's wastewater treatment capacity and discharges to the Lower Liffey Estuary in Dublin Bay.

In response to concerns raised by both swimmers and public representatives about the quality of bathing water outside of the bathing season in Dublin Bay Irish Water undertook an investigation during which the UV system was operated outside of the designated bathing season for a test period of four months. This pilot winter operation of the UV system was supported by an intensive microbial sampling programme and water quality modelling to assess the likely impacts of the winter operation of the UV system on the bacterial water quality at bathing sites in Dublin Bay.

Methods, Data and Analysis

Water Quality Modelling

Irish Water utilised an existing calibrated water quality model of Dublin Bay to carry out an assessment of the impacts of the winter operation of UV system on bacterial water quality in Dublin Bay.

The results were used to identify the most appropriate locations for bacterial sampling during the UV pilot operation period.

Pilot Operation of the UV System at Ringsend WWTP

Irish Water carried out a four-month operational trial of the UV system from September 16th 2021 until January 12th 2022 in order to measure the real-world impacts on bathing waters of operating the UV system in winter months.

Dublin Bay Microbial Sampling Programme

Irish Water undertook the Dublin Bay Microbial Sampling Programme which involved the collection and laboratory analysis of 3,130 bacterial samples from 15 key locations including popular bathing areas (both designated and non-designated) and rivers.

Twice weekly routine sampling commenced in July 2021 and ended in March 2022. In addition, a number of event-based sampling efforts were undertaken to better understand the effects of tidal, rainfall and UV switch-on/off processes.

Prior to undertaking this work Irish Water engaged with the Dublin Bay Bathing Water Taskforce, UCD Acclimatize project and the SOS Dublin Bay Group on the sampling strategy including methods and locations for inclusion in the programme.

3rd Party Data

In addition to the data collected by Irish Water, historic and current bathing water quality sampling data was obtained from Dublin City Council and Dun Laoghaire Rathdown County Council. These datasets included the weekly samples collected during the bathing season (used to determine the official Bathing Water Quality under the Bathing Water Regulations) as well as the additional routine out-of-season bathing water data collected by both local authorities. This data included samples taken at designated and non-designated bathing waters and rivers.

Further sampling data was also obtained from the UCD Acclimatize project. The Acclimatize project is an EU funded project which aims to work out how bathing waters at the seaside become polluted, in a way that can impact on public health, and how climate change may affect the quality of these waters in the future. This data included samples taken at designated and non-designated bathing waters and rivers as well as flow data for rivers.

Finally hydro-meteorological data was downloaded from Met Eireann, EPA and OPW websites to provide insight into the prevailing weather and flow conditions historically and during the UV pilot operational period and control sampling period.

Analyses

The various datasets were categorised, cleansed and combined into a single database.

Using this database, a statistical assessment of the bathing water quality at various beaches in Dublin Bay was made using the criteria specified in the bathing water regulations.

Statistical assessments were completed for three scenarios as follows:

- Winter Baseline
- UV Pilot Operation Period
- Control Period (No UV)

Event-based sampling data was assessed visually to identify any changes in bacterial concentrations in response to:

- UV Switch Off (Jan 2022)
- UV Switch On (May 2022)
- Storm Barra (Dec 2021)

Conclusion

Irish Water has completed a detailed analysis of the impact of the operation of the UV disinfection system on winter bacterial concentrations at bathing sites in Dublin Bay.

Water quality modelling demonstrated that potential effects of winter operation of the UV system were most likely to be limited to the Lower Liffey Estuary.

A four-month trial operation of winter UV was carried out in conjunction with a comprehensive water quality monitoring campaign. Over 3000 bacterial samples were collected from the Ringsend treatment plant, rivers and bathing sites. Analysis of the collected data failed to demonstrate any material improvement in bathing sites in Dublin Bay as a result of the winter operation of the UV Disinfection System.

These findings are consistent with the analyses carried out by UCD Acclimatize and Dublin City Council, which have identified near-shore pressures on bathing waters as the primary reason for failures in Bathing Water Quality at Designated Bathing Waters.

Introduction

Background

Since the 1970s, the EU has had rules in place to safeguard public health and clean bathing waters. The revised Bathing Water Directive (BWD) of 2006 updated and simplified these rules. It **requires Members States to monitor and assess the bathing water for at least two parameters of (faecal) bacteria**.

The EU Bathing Water Directive is implemented in Ireland by the Bathing Water Regulations and the EPA, Local Authorities and the HSE all have a statutory role in the implementation of the Bathing Water Regulations.

In Ireland Bathing Water Season, defined in the bathing water regulations, runs from **1 June to 15 September** each year. Bathing water quality can be impacted by a number of factors, including urban wastewater, run-off from agricultural land and roads, dog and bird fouling and misconnections from houses and businesses.

As the competent authority for the provision of public wastewater services in Ireland, Irish Water is a significant stakeholder in the context of bathing water quality in Dublin Bay.

Irish Water is continuing to work proactively with all stakeholders to support improvements in bathing water quality, protecting and enhancing our coastal and inland waterways in collaboration with the other agencies including the Local Authorities, EPA, HSE, and industry and academic partners

Irish Water operates an ultraviolet (UV) disinfection system on the final discharge stage at the Ringsend Wastewater Treatment Plant (WWTP) to protect water quality in designated bathing waters during the bathing water season Dollymount Strand.

Concerns have been raised by both swimmers and public representatives about the quality of bathing water outside of the bathing season in Dublin Bay.

In response to these concerns, Irish Water has undertaken an investigation into potential benefits of operating the UV disinfection system outside of the bathing water season through a four-month trial period of winter UV operation and one of the largest microbial sampling programmes completed in Dublin Bay to comprehensively assess the effectiveness of winter operation of the UV system on the bacterial water quality at bathing sites in Dublin Bay. The methods, data and outcomes of the assessment are set out in this report.

Ringsend Wastewater Treatment Plant

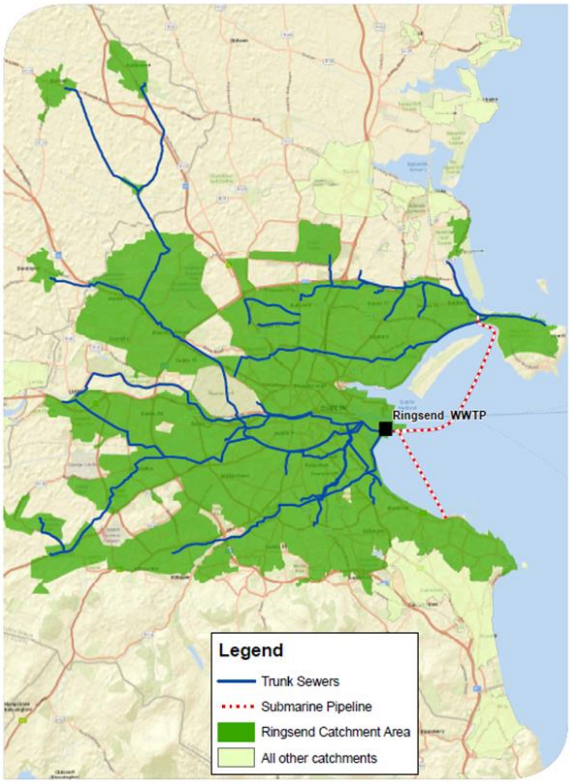

Figure 1: Ringsend Catchment

Wastewater from Dublin has been treated in Ringsend since 1906. Built in 2005, the current plant is the largest in Ireland and was designed to cater for an equivalent of 1.64 million people. The Ringsend Wastewater Treatment Plant (WwTP), which provides over 40% of Ireland's wastewater treatment capacity, is a secondary treatment plant serving the Dublin City and environs.

Ringsend WwTP discharges treated wastewater into the Lower Liffey Estuary via an outfall located approximately 1km from the facility.

The sewer system in Dublin was built in the early 1900s and, as was typical at the time, it carries both wastewater from homes and businesses and surface water that is drained off roads and pavements. When more rain and wastewater than the plant can process arrives, the excess is held in storm water holding tanks. Normally, when the rain has passed, the excess in the storm water holding tanks enters the plant for treatment.

Figure 2. Ringsend WWTP

When there is unusually heavy and sustained rainfall, such as during a yellow weather warning, the amount of water entering the sewer network can be more than the capacity of the plant and the holding tanks. In that case, to prevent the sewer network from backing up and causing flooding of roads and properties, the storm water is released from the holding tanks to the environment. The storm water tank overflow contains wastewater that is highly diluted with rainwater and has been screened and settled to remove debris – a form of primary treatment.

There is an ultraviolet (UV) disinfection system which is operated to ensure compliance with the seasonal emission limit value (ELV) for Faecal Coliforms. In wastewater treatment plants, banks of UV emitting bulbs are provided in modules within concrete channels. These channels are designed to provide hydraulic residence time for the effluent to be irradiated by UV light to achieve a design reduction in bacteria numbers.

Irish Water typically operates the UV disinfection system from mid-May to mid-September. When operational the UV disinfection system provides additional treatment to the primary discharge. It does not treat discharges from the storm tanks.

Methodology

Introduction

Irish Water undertook an investigation during which the UV system was operated outside of the designated bathing season for a test period of four months. This pilot winter operation of the UV system was supported by an intensive microbial sampling programme, informed by water quality modelling and stakeholder feedback to undertake an assessment of the likely impacts of the winter operation of the UV system on the bacterial water quality at bathing sites in Dublin Bay.

Hydro-meteorological data was downloaded from Met Eireann, EPA and OPW websites to provide insight into the prevailing weather and flow conditions.

Water Quality Modelling

The existing water quality model is a 3D model built in MIKE3 software originally developed in support of the 2018 planning application for the Ringsend Upgrade project. The model was refined in 2021 and re-validated against updated field data[1]. The model domain in the vicinity of Dublin Bay is shown in Figure 3.

Irish Water utilised this model of Dublin Bay to carry out a comparison of the modelled bacterial water quality in Dublin Bay during winter periods with the UV system on and off. This was used to inform the microbial sampling programme.

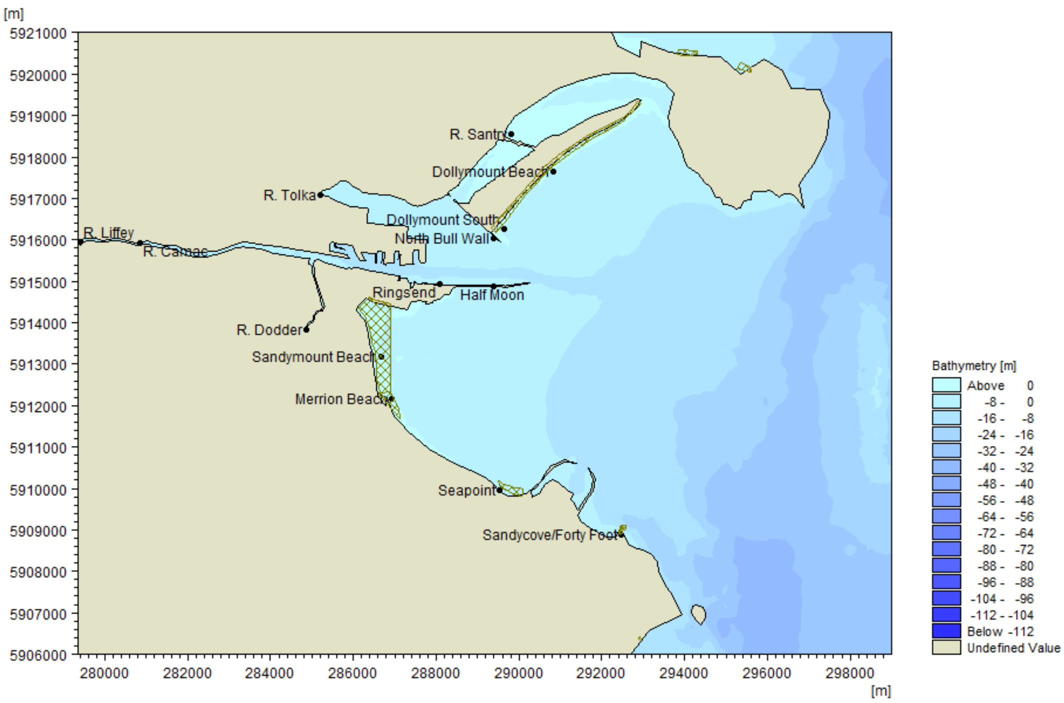

Figure 3. Model domain and bathymetry of the existing MIKE 3 Model of Dublin Bay

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[1] Draft Report - Mike3 Model Refinement and Re-calibration (2021)

A winter baseline scenario and a winter UV operation scenario were modelled as per Table 1 below.

Table 1. Modelled scenarios

Winter Baseline	Winter UV Operation
Average winter effluent flows	Average winter effluent flows
E.Coli Concentration: 106,739 cfu/100ml (based on average winter concentrations)	*E.Coli* Concentration: 21,558 cfu/100ml (based on average summer concentrations)
Dry, calm winter conditions	Dry, calm winter conditions

To maximise the opportunity for observable improvements, the winter UV Operation scenario assumed that the UV disinfection system in winter would achieve the same level of efficacy as summer.

Dry and calm winter conditions were selected as they were the conditions most likely to yield an observable modelled improvement in bacterial water quality during operation of the UV system. A conservative T_{90} value of 43 hours was used to govern the decay of *E.Coli* under winter conditions[2]. Average river flow and concentrations were used.

The results were prepared as follows:

- The results of the two model runs provided bacteria concentration over the 15-day spring-neap tide period.
- 95th percentile plots were prepared as these are in line with the statutory metrics used to determine bathing water quality under the Bathing Water Regulations.
- The difference in the 95th percentile value in each model cell was calculated and a map of the change in bacterial water quality produced (Figure 4).

[2] T_{90} is a measure of the length of time for 90% reduction in the quantity of substance due to natural decay. In the model first-order decay is applied and coefficients are set to ensure the model recreates the effect of decay due to natural UV radiation from sunlight.

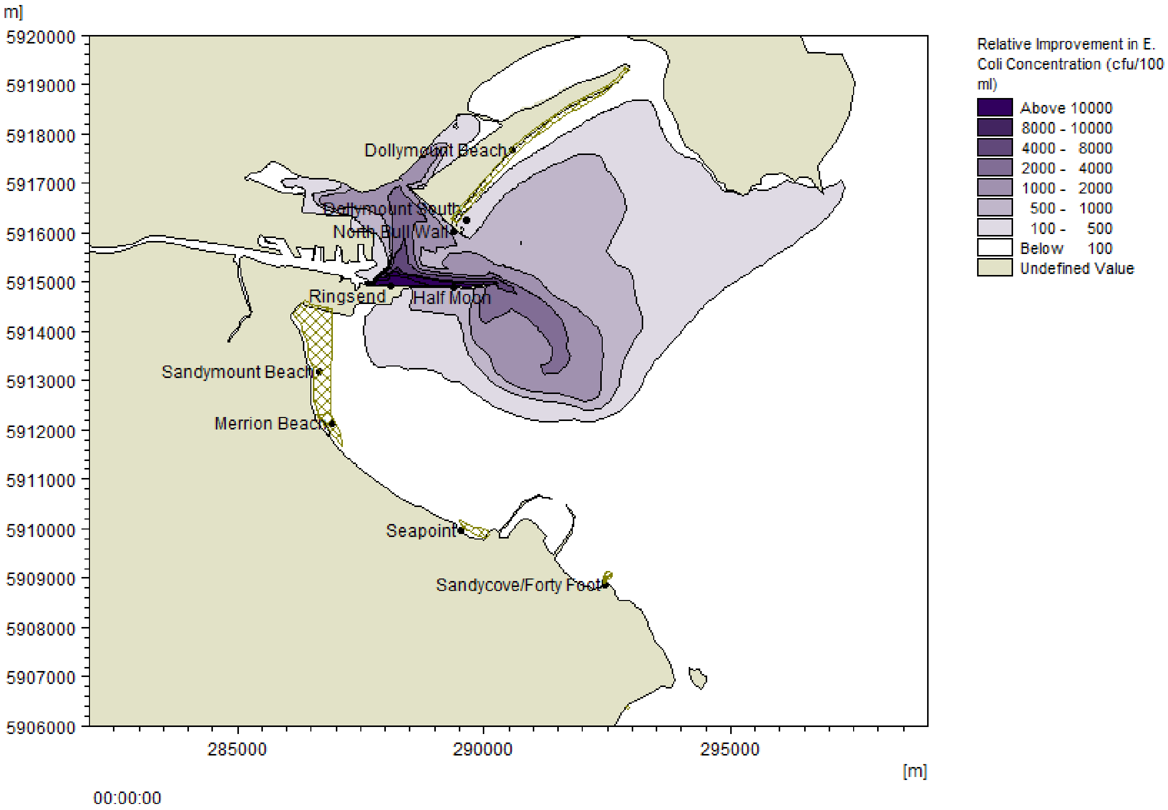


Figure 4. Modelled reduction in 95th percentile Winter E.Coli concentrations due to UV operation under calm, dry conditions.

The results of the model were used to identify the most appropriate locations for the microbial sampling programme in order to measure the real-world impacts of operating the UV system in winter months at bathing sites.

Dublin Bay Microbial Sampling Programme

Introduction

Dublin Bay is a complex system with multiple sources of bacterial load and significant marine and meteorological processes which influence winter bacterial water quality at bathing sites in the bay. A comprehensive microbial sampling programme was undertaken at both designated and non-designated bathing locations as well as key rivers to provide the necessary microbial water quality data for analysis. Routine and event-based sampling was undertaken. The sample locations were identified using the outcome of the water quality modelling and through engagement with stakeholders.

Stakeholder Engagement

Prior to commencing the sampling programme, Irish Water engaged with key stakeholders with an interest in Bathing Waters in Dublin Bay. This included the Dublin Bay Bathing Water Taskforce[3] and the UCD Acclimatize[4] project team. Irish Water hosted a number of workshops with the respective groups. Irish Water subsequently adopted most of the recommendations from the group including the extension of the routine sampling into Q1 2022 to provide a contemporary control dataset and the inclusion of intensive event-based sampling of the UV switch on/off events.

An additional benefit of the engagement was the identification of opportunities to coordinate the respective sampling schedules of the individual organisations to provide mutually beneficial outcomes and maximise the number of sampling days and an agreement to continue to share the collected data across the organisations.

Sampling Locations

Sampling locations included eight bathing sites, five rivers and two locations in the marsh area of the North Bull Island. In addition to monitoring bathing sites monitoring of other potential sources of bacteria was undertaken to understand the wider pressures on bathing sites in Dublin Bay. The monitoring sites are set out in Figure 5.

[3] Dublin Bay Bathing Water Taskforce was established in 2019 and includes DCC, DLRCC, DHLGH, FCC and Irish Water. This group seeks to bring decision makers together to enhance and protect the designated bathing waters in Dublin Bay.

[4] UCD Acclimatize is a research project investigating the sources of pollution on bathing waters. It's research group includes some of the leading microbiological and epidemiological experts in Europe. www.acclimatize.eu

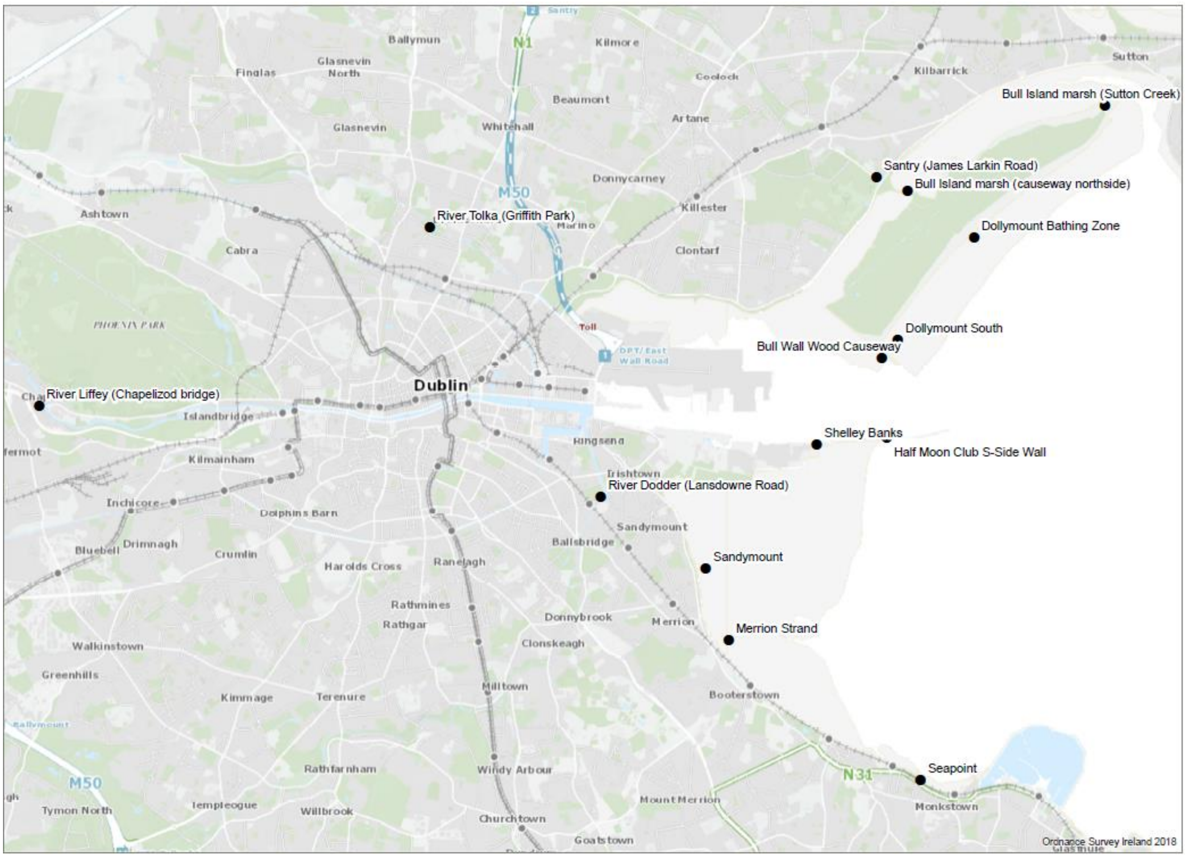


Figure 5. Monitoring Locations

Table 2. Sampling locations

Station Type and EPA/LA Code
Designated bathing water
(40545) Sandymount
(40526) Dollymount Bathing Zone
(40530) Dollymount South
(40561) Seapoint
Non-designated bathing water
(40550) Merrion Strand
(40542) Shelley Banks
(40540) Half Moon Club S-Side Wall
(40535) Bull Wall Wood Causeway
Ambient Sampling Point
North Bull Island marsh area (Sutton Creek)
North Bull Island marsh area (causeway northside)
Rivers
Liffey (Chapelizod bridge EPA site RS09L012350)
Tolka (bridge in centre of Griffith Park EPA site RS09T011150)
Dodder (New Bridge/Lansdowne Road redundant EPA site RS09D011100)
Santry (US of James Larkin Road culvert EPA site RS09S011100)
Camac River Bow Bridge, Mount Brown

Routine Sampling

Twice-weekly routine monitoring commenced during July 2021 and ran until the end of March 2022. The routine sampling period covered part of the bathing season (until September 15th), the 4-month UV operational pilot period as well as an 11-week control period following the UV switch off.

The sampling was carried out on behalf of Irish Water by Capital Water Systems Ltd in collaboration with the Ringsend WWTP operator Celtic Anglian Water. The surveyor's method statement including sampling protocol is provided in the Appendix A to this report.

A report was completed for each sample. Figure 6 shows a completed sample site report for Dollymount South.

Laboratory analysis was carried out by City Analysts using ISO 7899-2 membrane filtration for Enterococci and ISO 9308-2 MPN / Colilert for *E.Coli*.

capital water systems ltd.

Site SP004 Dublin Bay Sampling Report

Date Time	06/01/2022 11:22
Location	(40530) Dollymount South
Lat / Long	53.35357, -6.16083
X Y	322497,235258

Tidal Notes	*Incoming*
Sea Surface Conditions	*Rough*
Rainfall Conditions	*Light Rain*
Solar Radiation	*33.6*
Conductivity	*53125*
Salinity	*34.15*
Temp (C)	*7.85*
Sample Taken	*Yes*
Crew Comments	*Sample collected OK*
Signed	CD

Location Photo

Photo1

Photo 2

Figure 6.Example of a Sampling Sheet for a routine sampling event at Dollymount South

Event-Based Sampling

Several short-term intensive sampling exercises were undertaken as follows:

1. Winter dry weather periods on spring and neap tides;
2. Wet weather event (Storm Barra);
3. Winter UV switch-off (January 12th 2022); and
4. Summer switch-on (May 16th 2022).

These events were selected to assess the effect of these events on bathing water quality and to better understand the within-day variation in bathing water quality in response to tidal and rainfall conditions.

For each of these events multiple samples were collected at each sampling location at intervals ranging from 30 minutes to 3 hours to provide a temporally varying dataset for analysis.

Due to storm conditions in Dublin Bay during Storm Barra, limited data was collected at bathing sites. However, contemporaneous intensive sampling of the discharges from the Ringsend WWTP, including both the primary discharge and the storm tank was undertaken.

Hydro-meteorological data

Data from Met Eireann's synoptic station at Dublin Airport was downloaded from the Met Eireann website and a review of prevailing weather conditions during the survey period was carried out.

For the Pilot UV Operational Period the review noted:

- Drier than normal with observed rainfall totals reaching 77% of 30-year long term average values (LTAV);
- Unusually dry November with rainfall totals only reaching 16% of LTAV.

For the Control Period (UV not operational) the review noted:

- Observed rainfall 103% of LTAV.
- Unusually dry January with rainfall totals 23% of LTAV. The majority of the January rainfall occurred during the Pilot UV Operational Period and there was almost no rainfall for the second half of the month during the Control Period.

Results

Introduction

The results of the samples collected by Irish Water, Local Authorities and UCD Acclimatize was collated into a single database with the hydro-meteorological data for analysis. The available data was categorised to define a number of data horizons for analysis as follows:

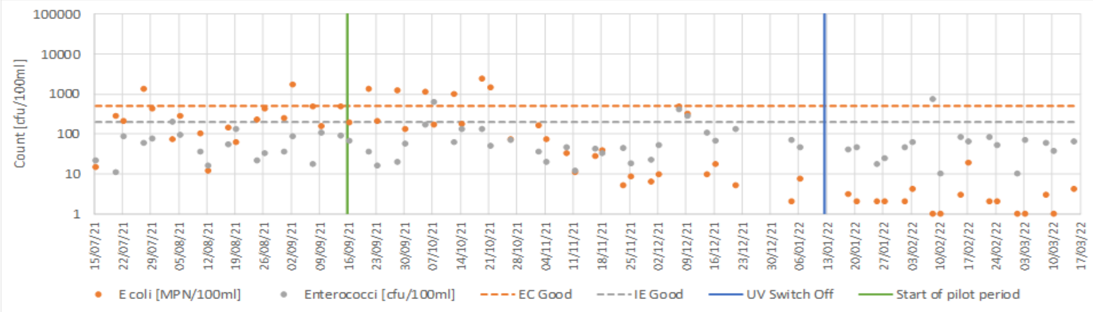
- **Historical Baseline**: All historical data (pre-2021) collected outside of the designated bathing season (16th of September until 31st of May);
- **Pilot UV Operational Period**: Data collected during the pilot operation 16th of September 2021 until 12:00pm 12th of January; and
- **Control Period (UV not operational)**: Data collected between 12:00pm on 12th of January 2022 until 29th of March 2022 representing the winter control period where the UV system was not operational.

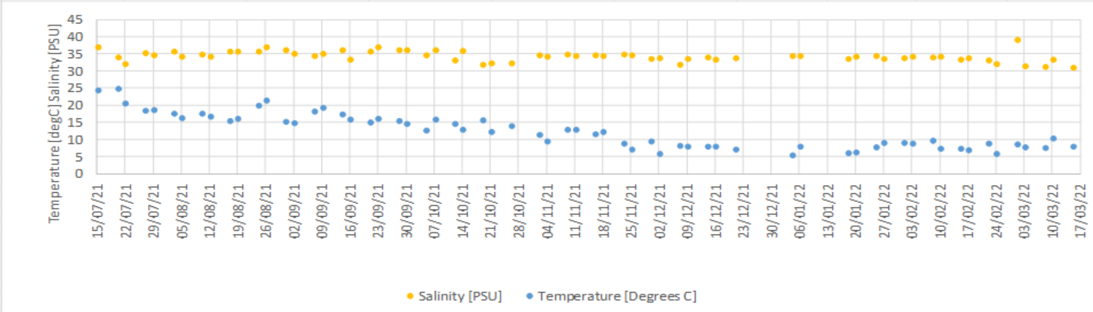
Routine Sampling

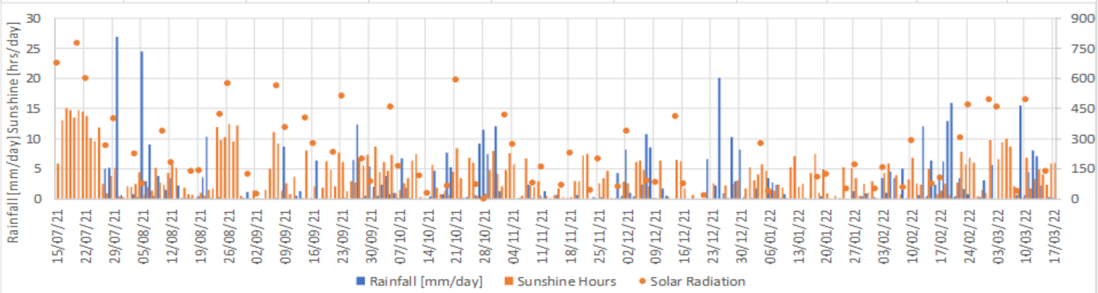
For each sampling location a summary data sheet was produced that summarises the data collected during the 2021 bathing season, the Pilot UV Operational period and the Control Period.

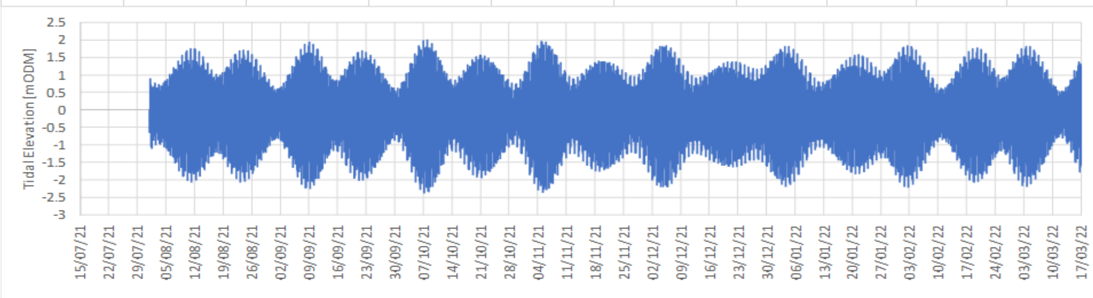
The summary data sheet includes the bacterial sampling data, temperature and salinity data along with daily rainfall and tidal state. The sample summary data sheet for Dollymount South is shown in Figure 7. Datasheets for all sites are included in Appendix B to this report.

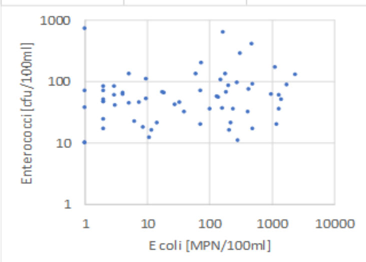
	SP04	(40530) Dollymount South							(South Bay sample)
Statistic	All Data					E coli [MPN/100ml]		Enterococci [cfu/100ml]	
	E coli [MPN/100ml]	Enterococci [cfu/100ml]	Solar Radiation [w/m2]	Salinity [PSU]	Temperature [Degrees C]	UV On	UV Off	UV On	UV Off
Count	64	64	64	64	64	48	16	48	16
Min	1.0	10.0	20.3	30.8	5.2	2	1	11	10
Mean	38.0	52.9	324.3	34.1	12.3	107	2	55	47
25%	4.1	32.0	69.5	33.4	7.8	22	1	32	33
50%	49.2	53.5	182.8	34.1	12.0	160	2	55	48
75%	249.6	83.0	546.8	35.0	15.8	420	3	93	66
90%	1076.0	132.1	925.0	35.9	18.4	1241	4	146	82
95%	1299.7	266.0	990.0	36.6	20.2	1378	6	253	141
Max	2419.6	720.0	1042.0	38.9	24.7	2420	19	620	720

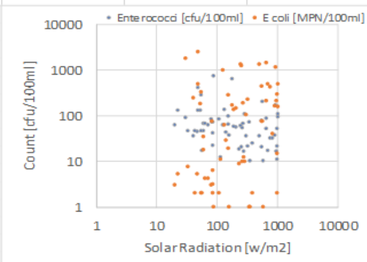












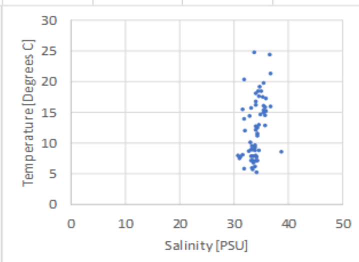


Figure 7. Sample summary data sheet for Dollymount South.

Bathing Sites

Figure 8 shows the bacterial concentrations of samples from all organisations collected over the year, including the UV Operational Pilot period and control period at the bathing sites in closest proximity to the Ringsend WWTP outfall point.

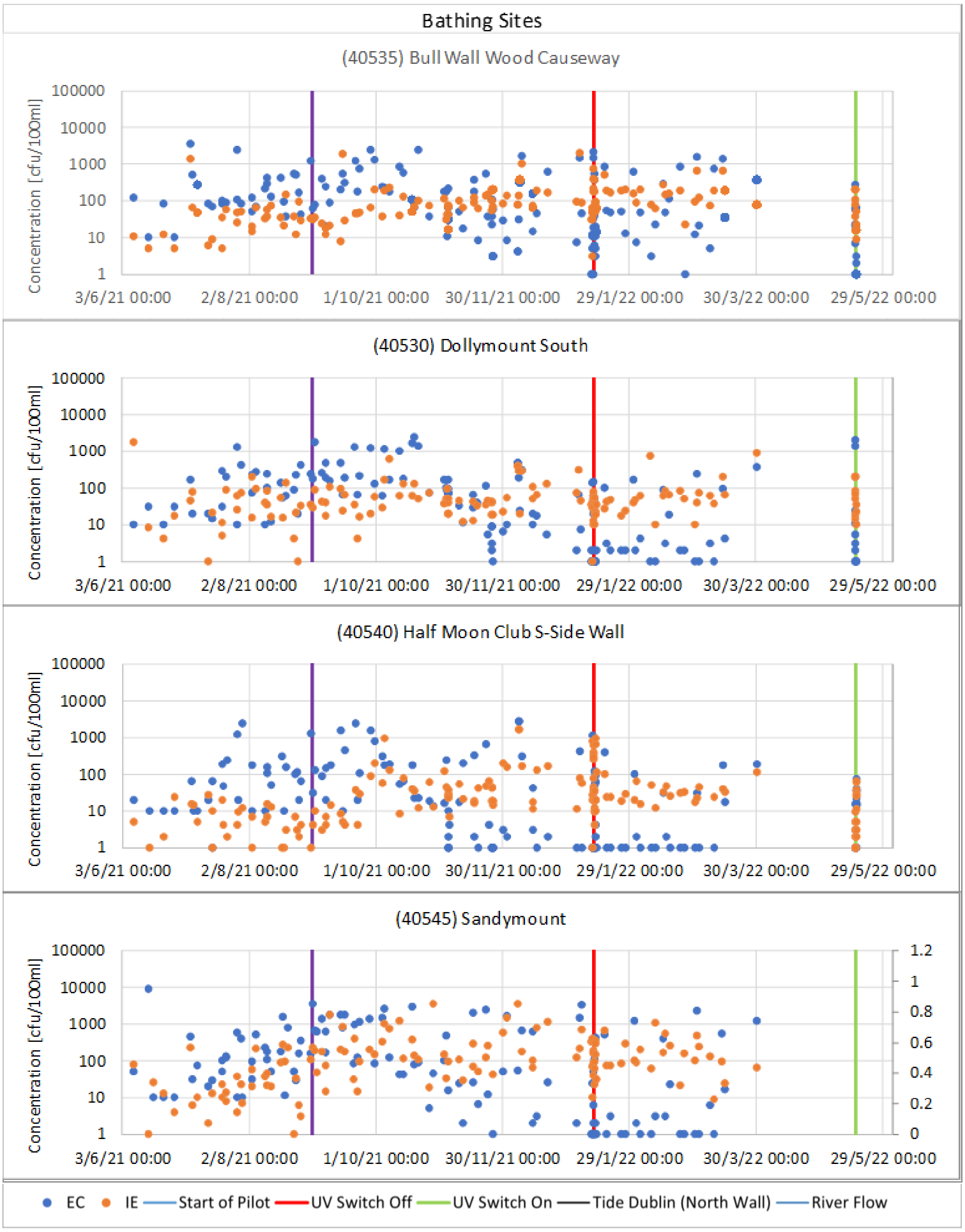


Figure 8. E.Coli and Enterococci Sample Data at selected bathing sites in close proximity to the Ringsend WwTP outfall.

There was no discernible change in E.coli or Enterococci concentrations visible between the Pilot UV Operational Period and the Control period at any of the sampled bathing locations. It is particularly notable that no discernible impact of the operation of the UV system was observable at any of the bathing areas in close proximity to the Ringsend WWTP.

There appears to be a reduction in concentrations in November in particular at Dollymount South, however given the lack of a signal at other locations closer to the WWTP, it is considered likely this is in response to the reduced riverine bacterial loads due to the driest November conditions in 80 years which prevailed during the Pilot UV Operational Period

The 95th percentile concentrations from the routine sampling (in accordance with Bathing Water Regulations) are presented in Table 3.

Table 3. 95th percentile Analyses for bathing sites

Routine Sampling (Bathing Sites)	95%ile concentrations					
	E.Coli			Enterococci		
Bathing Sites	Historical Winter Baseline	Control Period	Winter UV Pilot Period	Historical Winter Baseline	Control Period	Winter UV Pilot Period
(40530) Dollymount South	1,652	233	1,456	570	668	320
(40535) Bull Wall Wood Causeway	8,664	1,366	1,792	2,000	664	378
(40545) Sandymount	3,986	1,200	2,595	1,152	630	1,649
(40550) Merrion Strand	6,105	1,236	5,182	1,107	480	1,520
(40561) Seapoint	524	61	700	239	52	570

The 95th percentile concentrations failed to show a clear trend of improvement in bacterial water quality between the Pilot UV Operational Period and the Control Period.

Rather than showing an improvement, *E.Coli* measurements showed a deterioration in the observed 95th percentile bacterial water quality between the Pilot UV Operational Period and the Control Period at bathing locations. While this outcome is counterintuitive, it coincided with deteriorations in river *E.Coli* concentrations in 4 out of the 5 sampled rivers.

Some improvement in 95th percentile enterococci concentrations was observed at the local bathing sites (North Bull Wall and Dollymount South) however beaches further away reported a deterioration in bacterial water quality between the Pilot UV Operational Period and the Control Period.

The discordance between the outcomes for *E.coli* and Enterococci, reflects the complexity of the Dublin Bay system and the multitude of factors that influence winter bacterial concentrations at bathing sites.

It is also notable that the historic baseline 95th percentile concentrations at bathing sites and rivers all significantly fail the requirements for good bathing water quality for coastal sites (500 cfu/100ml and 200 cfu/100ml for *E.coli* and Enterococci respectively).

River sites

Figure 9 presents time series plots of the routine sampling from the five key rivers sampled during the microbial sampling programme.

The data showed that for the majority of samples taken, concentrations in rivers regularly exceed the bacterial thresholds for Good Bathing Water Quality at coastal bathing areas. In particular the bacterial water quality in the Dodder and Camac rivers is significantly poorer in comparison to the River Liffey.

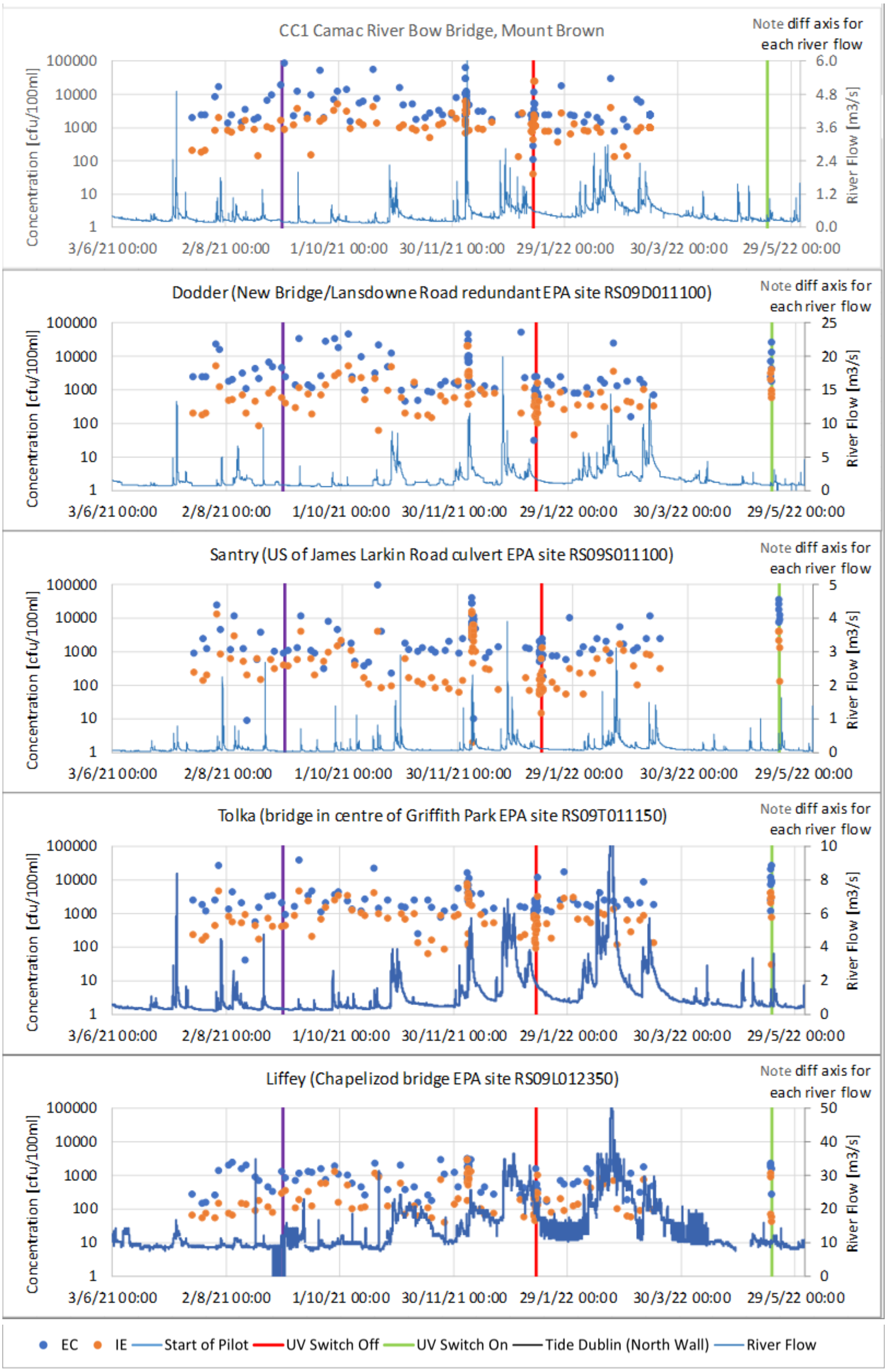


Figure 9. Measured E.coli and Enterococci Concentrations in five sampled rivers.

Assessment of the 95th percentile concentrations from the routine sampling in rivers is presented in Table 4 to provide a measure of the historical winter baseline, Control Period and Pilot Period bacterial water quality in key rivers discharging to Dublin Bay.

Table 4. 95th percentile analyses for river sites

Routine Sampling (River Sites)	95%ile concentrations					
	E.Coli			Enterococci		
Bathing Sites	Historical Winter Baseline	Control Period	Winter UV Pilot Period	Historical Winter Baseline	Control Period	Winter UV Pilot Period
River Camac	29,066	19,586	44,183	4,024	2,992	3,732
River Dodder	31,435	6,820	39,920	3,422	1,512	3,980
River Liffey	2,784	2,420	2,935	1,941	748	1,312
Santry River	11,075	10,338	19,682	2,620	1,220	3,328
River Tolka	7,535	9,911	4,849	3,065	2,768	3,152

The 95th percentile concentrations demonstrated that these rivers are a significant source of bacterial loads, with winter *E.Coli* concentrations in some rivers comparable to wastewater effluent.

Based on the findings of the visual and 95th percentile assessments it is evident that rivers are significant pressures on Bathing Water Quality in Dublin Bay.

Event-Based Sampling – January UV Switch-off

Time-series plots were prepared for key locations to demonstrate any rapid change in bacterial concentration in response to the cessation of the UV system at Ringsend. Figure 10 denotes the concentrations of *E.Coli* and Enterococci through time in the effluent, the South Wall (Liffey Estuary downstream of the WWTP outfall), the North Bull Wall and Dollymount South before and after the UV Switch-off event on January 12th 2022.

It is notable that the ambient conditions for the switch off were ideal for sampling, with zero rainfall and bright sunshine in the 36 hours preceding the UV switch-off.

The data demonstrated an order of magnitude change in the effluent quality, confirming the effect of the UV switch-off however no clear signal of change in bacterial concentrations was detected as a result of cessation of UV operation at bathing sites.

Additional sampling points in the Liffey Estuary were included as part of this sampling event. Data from both the South Wall and North Bull Wall suggested that tidal effects are influencing bacterial concentrations between the South and North Bull walls.

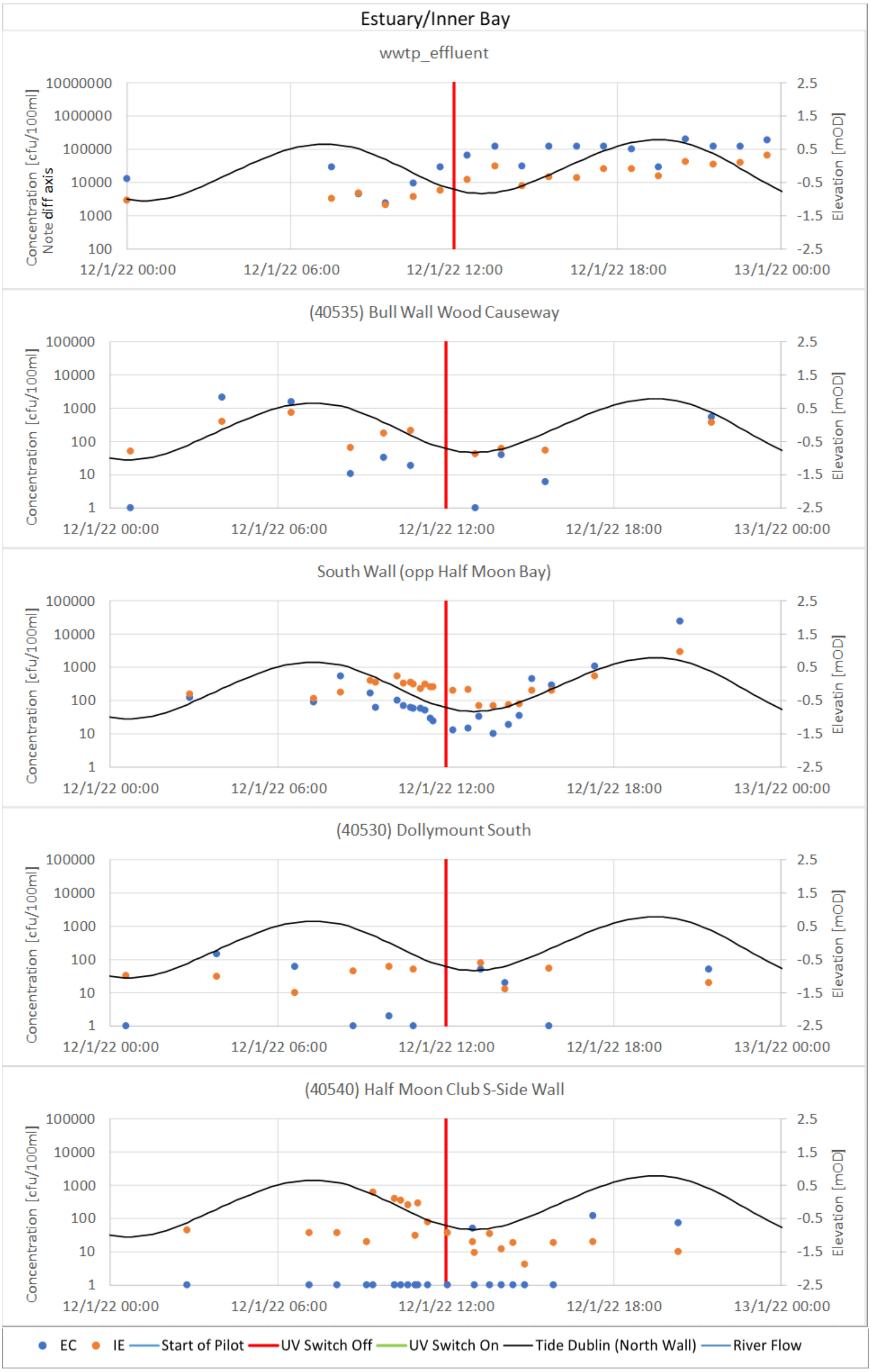


Figure 10. E.coli and Enterococci Concentrations during UV Switch off event (denoted by red line)

Event-Based Sampling – May UV Switch-on

Figure 11 denotes the concentrations of E.Coli and Enterococci through time at the South Wall (Liffey Estuary downstream of the WWTP outfall), the North Bull Wall and Dollymount South before and after the UV switch-on event on May 16th 2022.

The data demonstrated an improvement in the bacterial effluent quality, confirming the effect of the UV switch-on however the data showed no clear signal of change in bacterial concentrations as a result of commencement of UV operation at bathing sites.

An observable degradation in the bacterial water quality at the Half Moon Club (south side of the wall) appeared to coincide with UV switch-on however when considered in the context of the tidal phase this signal is attributable to tidal effects. There also appears to be a tidal signal in the bacterial concentrations at Dollymount South.

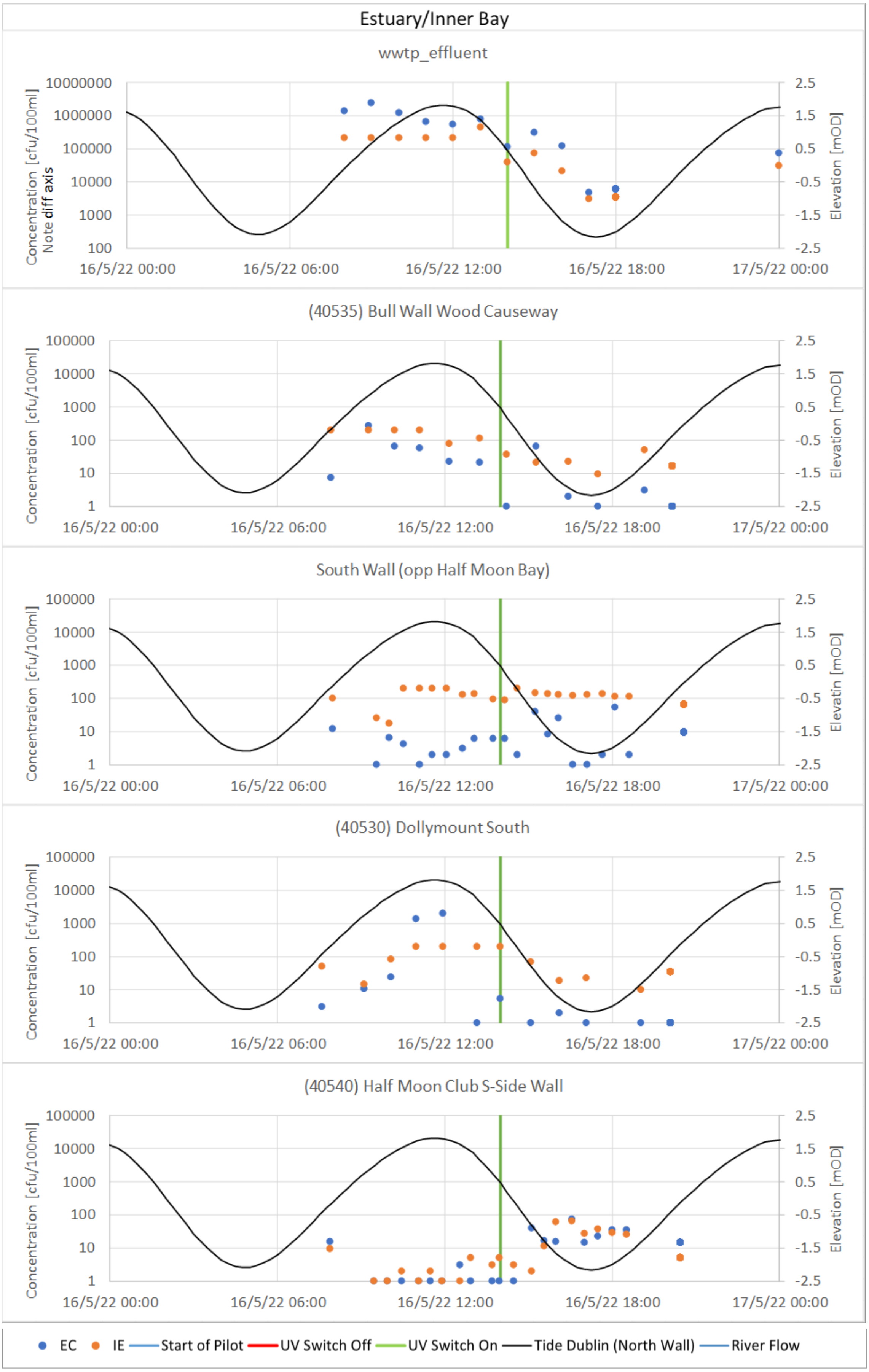


Figure 11. E.coli and Enterococci Concentrations during UV Switch-on event

Event-Based Sampling – Storm Barra

Storm Barra was a significant weather event which provided an opportunity to sample concurrent inputs to Dublin Bay during wet weather conditions. Sampling crews were mobilised on the 7 and 8 of December 2021.

Storm force winds curtailed the sampling at the bathing water sites. River sampling was successfully completed and concurrently intensive sampling was undertaken both the primary discharge to Ringsend WWTP and the Ringsend WWTP storm tank discharge which operated on the 7th during daylight hours.

Sampling data collected during Storm Barra is presented in Figure 12 and Figure 13.

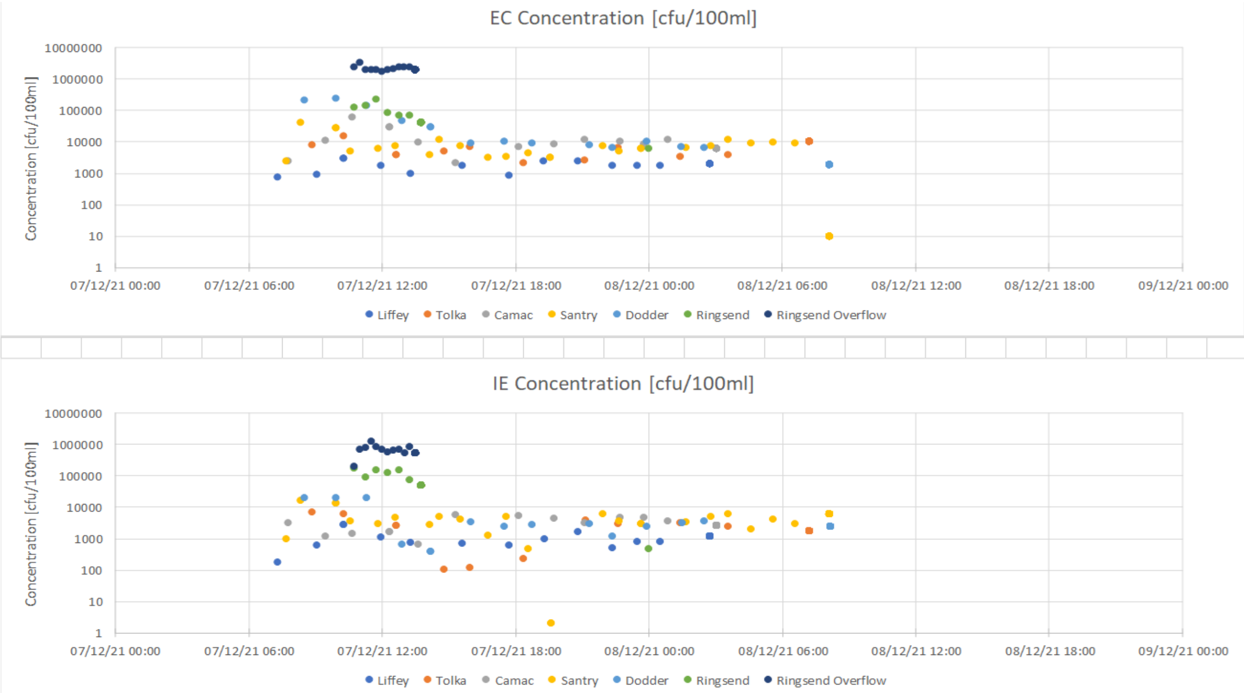


Figure 12. E.coli and Enterococci concentrations during Storm Barra.

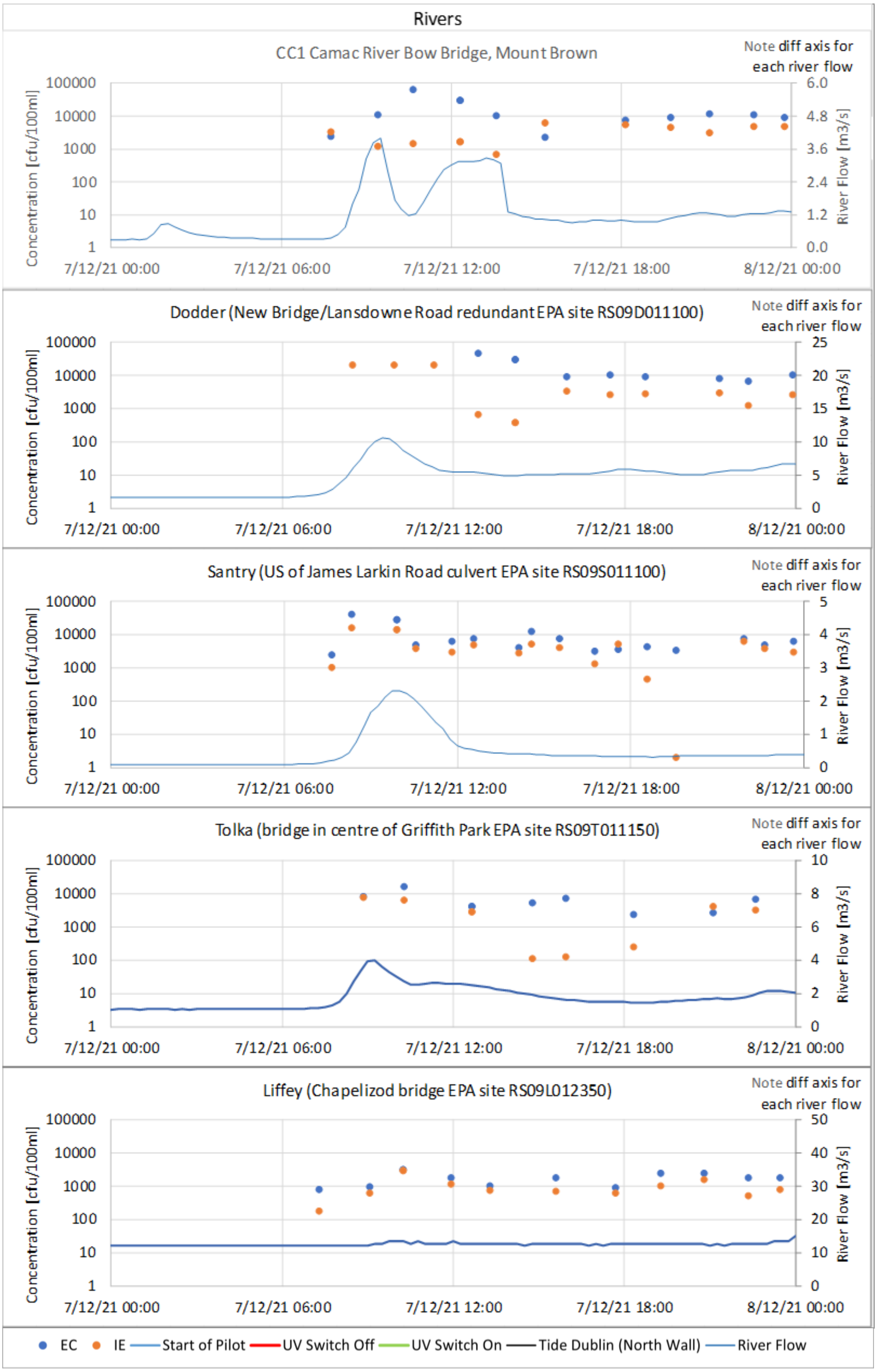


Figure 13. E.coli and Enterococci Concentrations with river flows at 3 rivers during Storm Barra

While the sampling data confirmed that the Ringsend Storm Tank was the largest source of bacterial load to Dublin Bay during this event, the data also demonstrated a major increase in riverine bacterial loads a result of the significant rainfall, confirming the bacterial load contributions from rivers are significant during wet weather conditions.

266 riverine bacterial samples were captured in total across the Liffey, Dodder, Tolka, Camac, Santry, Naniken, Poddle rivers as well as the Brewery and Carrickbrennan Streams.

Significantly elevated bacterial concentrations were recorded in key rivers. In addition, high concentrations were observed in the Poddle, Naniken Rivers as well as the Brewery and Carrickbrennan Streams as demonstrated in Figure 14.

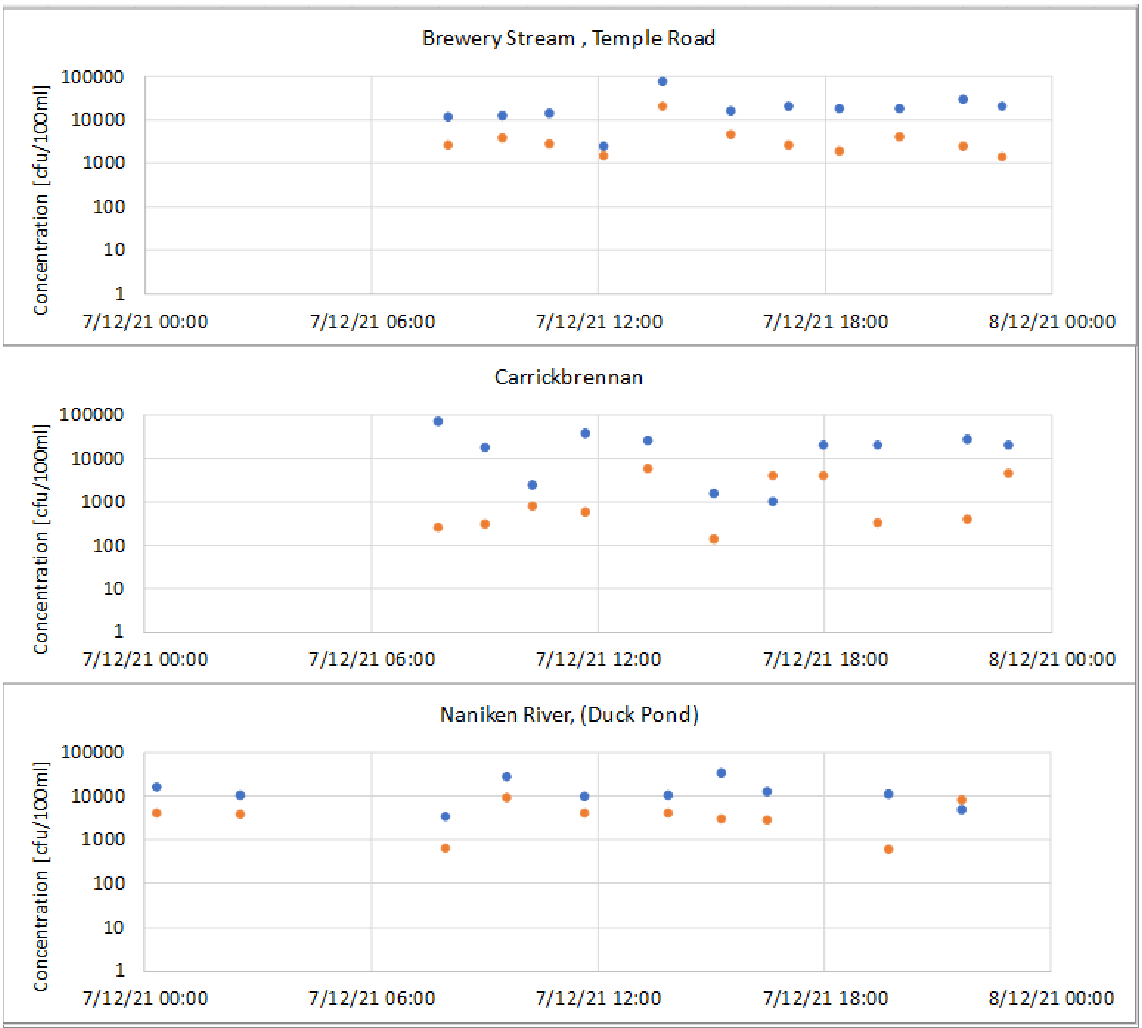


Figure 14. E.coli and Enterococci Concentrations in urban rivers during Storm Barra

This data showed that at times during the storm event bacterial concentrations in rivers were comparable to treated wastewater effluent without UV treatment.

Of particular note was the concentrations in urban rivers which discharge in close proximity to bathing sites. Elevated concentrations at Seapoint were coincident with both elevated concentrations in the Carrickbrennan Stream and stormwater overflows from West Pier Pumping Station.

Telemetry data in Figure 15 from West Pier Pumping Station confirmed overflows were in operation.

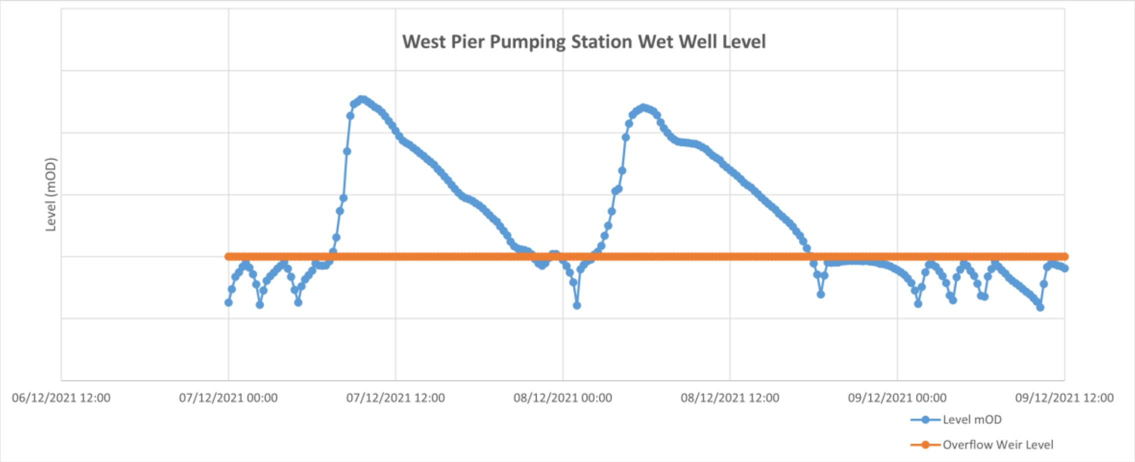


Figure 15. West Pier Pumping Station Wet Well levels

Effect of Tidal Exchange

The findings of the routine and event-based sampling align with the preliminary outcomes of the water quality modelling, which demonstrated that impacts from Ringsend WWTP on bacterial water quality attenuate with increasing distance from the discharge point. This is because of both the favourable dilution in receiving waters and the advection[5] processes which are driven by the significant tidal exchange in Dublin Bay.

To put some context on the level of tidal exchange, under neap tide conditions, ca. 14,600,000m^3 of seawater is exchanged on each tide, twice a day, within the tidal area bound by the North Bull and South Walls. This provides a dilution for the WWTP under normal discharge conditions of 1:33 assuming low flow conditions (95th percentile) in rivers.

Under spring tide conditions, this exchange volume increases to in excess of 26,000,000m^3, which is also exchanged twice a day, resulting in a dilution of 1:121.

These significant levels of dilution coupled with the corresponding advection processes which act to move the plume out to sea on an ebbing tide help to explain why no discernible impacts of the winter operation of UV were observed in the data at the Designated Bathing Waters.

These effects are demonstrated by the winter bacterial plume plots in Figure 16 which show the movement of the enterococci plume from Ringsend WWTP under different stages of the tide under average winter conditions[6].

Yellow areas indicate enterococci concentrations exceed the threshold for Good Bathing Water quality, green indicates concentrations meet requirements for

[5] Advection is the transport of a substance due to the movement of water.

[6] Winter enterococci T_{90} of 86 hours, WWTP discharge of 5.76m3/s and effluent concentration of 35,500 cfu/100ml

Good Bathing Water quality and white represents Excellent Bathing Water Quality. Designated Bathing Waters are shown in Blue for reference.

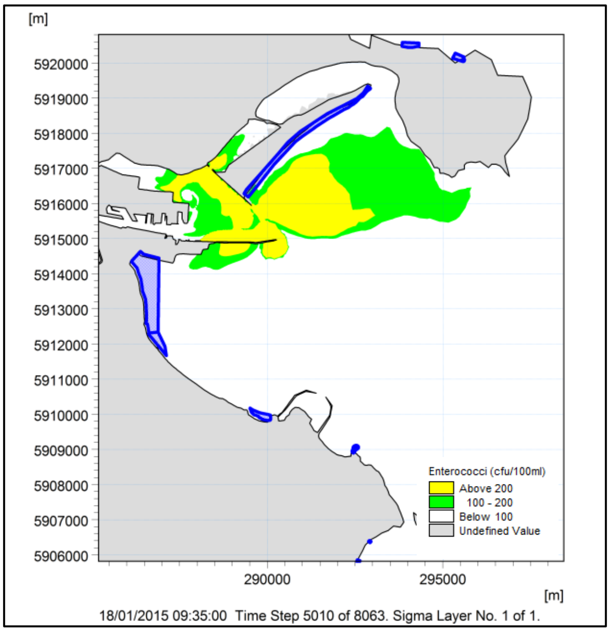


Figure 16a – High Water

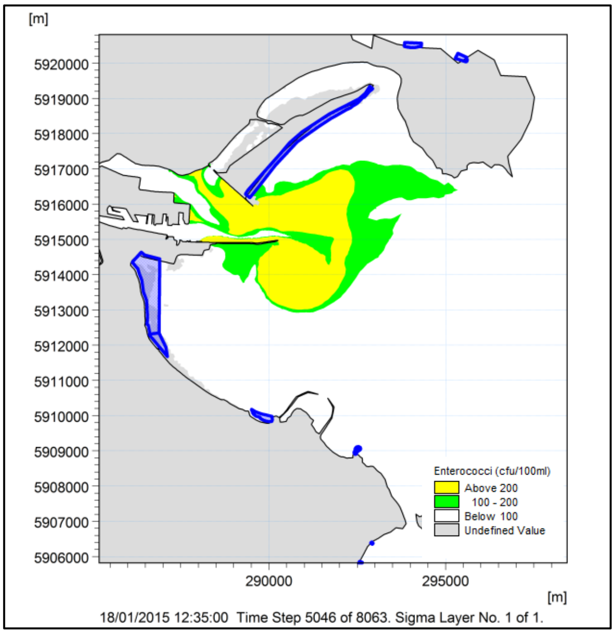


Figure 16b – Mid-Ebb

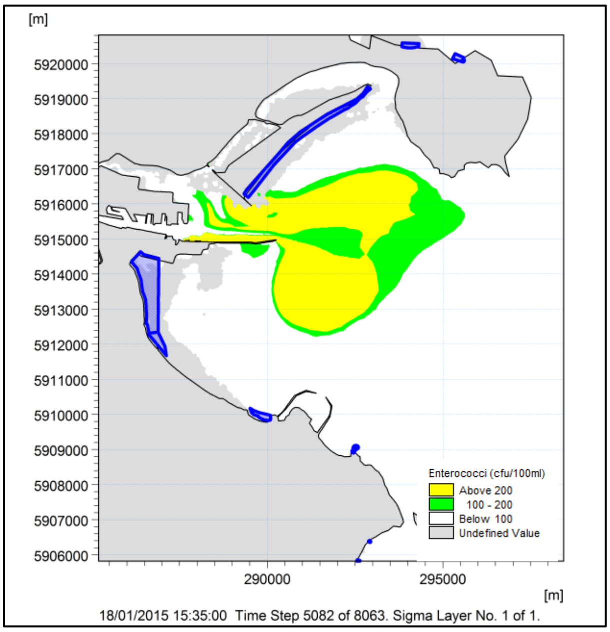


Figure 16c – Low Water

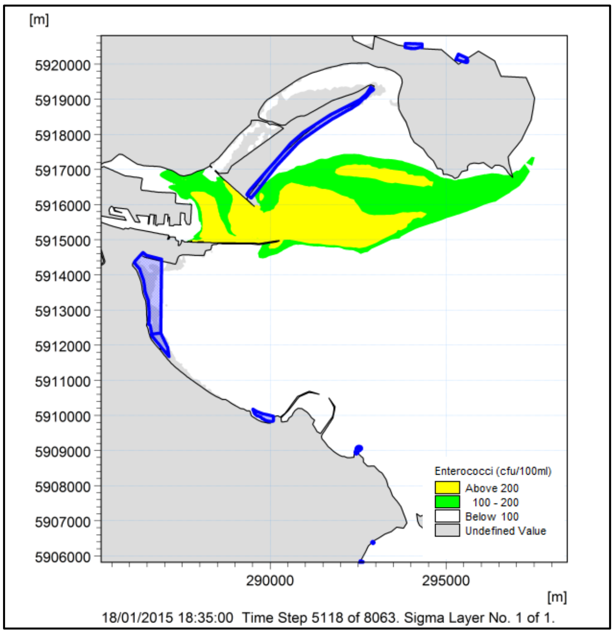


Figure 16d – Mid-Flood

Figure 16. Winter bacterial plume plot showing the extents of impact of Ringsend WWTP discharge on surface enterococci concentrations under winter conditions through various stages of the tide.

The plume plots demonstrate that natural movement of water due to tidal exchange significantly constrains the ability of the Ringsend WWTP to influence bacterial water quality at Designated Bathing Sites.

There are some modelled interactions between the winter bacterial plume at non-designated bathing sites at the North Bull Wall and to a lesser extent at the Half Moon bathing area, however these are limited to certain tidal states.

In summary the modelling demonstrated that there is limited hydraulic connectivity between the discharges from Ringsend WWTP and the Designated Bathing Sites, which is consistent with the findings of the microbial sampling programme.

These finding are also consistent with the outcomes the preliminary findings of the UCD Acclimatize project which, after extensive sampling of Merrion and Sandymount bathing sites as well as nearby rivers, found that the sources of bacterial pollution were driven by near-shore pressures[7] and that the failure to achieve good bathing water quality is not driven by discharges from Ringsend.

[7] Reynolds LJ, Martin NA, Sala-Comorera L, Callanan K, Doyle P, O'Leary C, Buggy P, Nolan TM, O'Hare GMP, O'Sullivan JJ and Meijer WG (2021) Identifying Sources of Faecal Contamination in a Small Urban Stream Catchment: A Multiparametric Approach. *Front. Microbiol*. 12:661954. doi: 10.3389/fmicb.2021.661954

Conclusion

Assessment Outcomes

Dublin Bay is a complex system with multiple sources of bacterial load and significant marine and meteorological processes which influence winter bacterial water quality at bathing sites. Irish Water has undertaken a detailed analysis of the impact of the operation of the UV disinfection system on winter bacterial concentrations at bathing sites in Dublin Bay. A bespoke sampling programme was developed in consultation with stakeholders to incorporate a four-month UV operational pilot period, an 11-week Control period and a range of event-based intensive sampling campaigns to develop a comprehensive water quality database including over 3000 bacterial samples.

The assessment has made the following conclusions:

a) Water quality modelling demonstrated that potential effects of winter operation of the UV system were likely to be limited to the Lower Liffey Estuary and were unlikely to be observable at designated bathing sites. Based on these model outputs, subsequent sampling sites were targeted to bathing sites in closest proximity to Ringsend WWTP, and the sampling programme confirmed the findings of the water quality modelling.

b) **The pilot operation of UV demonstrated there will be no discernible benefit to winter bathing water quality at Designated Bathing Waters, based on year-round operation of the UV system at the Ringsend WWTP.** Analyses of the collected data failed to demonstrate any material improvement in bathing sites, including non-designated sites, in Dublin Bay as a result of the winter operation of the UV Disinfection System.

c) Routine and event-based sampling identified that during winter months rivers are significant sources of bacterial loads into Dublin Bay.

d) The outcomes of the microbial sampling programme were consistent with the findings of the water quality modelling exercises which provides further confidence in the conclusion.

e) The findings of the assessment are consistent with the previous analyses carried out by UCD Acclimatize and DCC, which have identified near-shore pressures on bathing waters as the primary reason for failures in Bathing Water Quality at Designated Bathing Waters.

Recommendations

Based on the above conclusions the following recommendations are proposed:

- The UV system at Ringsend WWTP should only be operated during Bathing Water Season in accordance with the requirements of the Wastewater Discharge License. It should be noted there is significant OPEX and carbon cost of running the UV system all year-round and the energy consumption associated with operating the system is enough to supply power to 600 homes.

- Irish Water will continue to assess risks in Irish Water network assets which directly and indirectly influence bacterial water quality at bathing sites in winter months via the Drainage Area Plan Programme, with network improvements being delivered under the Irish Water Capital Investment Plan.

- Irish Water will continue to support inter-agency collaboration via data sharing and the development of the predictive bathing water quality forecasting system in conjunction with the Dublin Bay Bathing Water Taskforce. Irish Water will utilise the collected bacterial data to support validation of the forecasting system.

- Irish Water will continue the roll-out of real-time monitoring of key overflows and will continue to work in partnership with key stakeholders including Dublin Bay Bathing Water Taskforce and the National Bathing Water Expert Group to support the protection of public health in the context of winter bathing activities.

Glossary

Term	Explanation
Bathing Water	The general term used for designated locations for bathing that are safe to swim in. Designated beaches and lakes are known as identified bathing waters.
Bathing Water Directive	A law called the EU Bathing Water Directive is implemented in Ireland by the Bathing Water Regulations. The EPA works with the HSE and local authorities to ensure that designated beaches and lakes in Ireland are safe to swim in. Water quality is monitored and assessed at designated bathing waters during the bathing water season to keep swimmers safe and healthy.
Bathing Water Notices	Notifying the public of bathing water incidents by means of beach signage and notices on local authority websites and on the dedicated website. Notification can also include media broadcasts.
Bathing Water Season	The period, which runs from 1 June to 15 September each year, during which time local authorities take water quality samples at regular intervals.
Drainage Area Plan	A comprehensive study of an entire drainage catchment, which uses asset and performance data on the condition, performance and future capabilities of the sewers in that area. The goal of these studies is to build a model that allows Irish Water to prioritise sewers in need of upgrading and to ensure that wastewater infrastructure is in place to support population and economic growth.
E. coli / intestinal enterococci (EC/IE)	These are two types of bacteria found in both human and animal faeces in large numbers. They are used as indicators of the possible presence of other harmful micro-organisms like viruses.
Effluent	Wastewater - treated or untreated - that flows out of a treatment plant, sewer, or industrial outfall. Industries that discharge wastewater (typically referred to as trade effluent) to a sewer or waters, are required to obtain the relevant discharge licence in accordance with the Water Pollution Act 1977, as amended.
Emission limit values (ELVs)	Effluent releases to waters require a licence from the Environmental Protection Agency. A range of water quality parameters including pH, BOD, ammonia, nitrogen and phosphorus must be met. A limit value for each parameter may be set in the discharge authorisation/licence. ELVs must be achieved, and performance reported regularly to the regulator.

Term	Explanation
Identified Bathing Waters	This is the legal term used for those beaches and lakes managed under the Bathing Water Regulations. Local authorities are responsible for identifying bathing waters within their area. These are generally the waters considered to be the most popular. These are reported to the European Commission each year. The public can propose that new bathing waters be identified under the Bathing Water Regulations. Guidance on this is available from www.beaches.ie
Misconnections	Misconnections are wastewater pipes from toilets or household appliances such as dishwashers and washing machines, that have been incorrectly connected to surface drains, rather than sewers. They can be a source of pollution because the wastewater from these pipes is untreated.
Population Equivalent (PE)	Wastewater treatment plants are described in terms of their designed treatment capacity, which is generally expressed as population equivalent (PE). The Population Equivalent is not simply the population of a catchment area, rather it includes the combined capacity from homes, businesses, tourism, schools, hospitals, etc. This is a measurement of total organic biodegradable load, including industrial, institutional, commercial and domestic organic load, on a wastewater treatment plant, converted to the equivalent number of population equivalents (PE). One person is considered to generate 60g of BOD per day (BOD is the 5-day biochemical oxygen demand); and 1PE is defined as being equivalent to 60g of BOD per day.
Pollution	This is defined (for bathing water purposes) as the presence of microbiological contamination or waste affecting water quality and presenting a risk to the health of bathers.
Stormwater Overflows	Stormwater overflows are standard features of older combined sewer systems, mainly constructed before 1970, when it was common practice for wastewater and surface water to be collected in the same pipe. During times of heavy rainfall, when the sewers and pumping stations become overwhelmed, stormwater overflows enable excess flows to be discharged into the sea, rivers or watercourses in a controlled and regulated manner. This is to protect homes, gardens, roads and open spaces from wastewater flooding.
Surface Water Run-Off	Water flow over the surface of roofs and ground surface to a drainage system.
Surface (or Storm) Water Drain	The drainage collection system that carries the surface water run off in a dedicate network including from road gullies and roof drainage. This system is not intended to convey foul wastewater.

Term	Explanation
Wastewater Infrastructure	This includes sewers, pumping stations, storage tanks, wastewater treatment plants, and outfall pipes.
Water Quality	Water quality refers to the chemical, physical, and biological characteristics of water based on the standards of its usage.
Water Quality Monitoring	Water quality monitoring is defined here as the sampling and analysis of water constituents and conditions.

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