7. ECOLOGY

7.1 INTRODUCTION

Limosa Environmental were commissioned by White Young Green Ireland to undertake ecological surveys and assessment in relation to the proposed upgrade of Clonakilty Wastewater Treatment Plant (thereafter referred to as Clonakilty WWTP), located at the head of Clonakilty Estuary (Figure 1.2).

Section 7.0 examines the ecology of the site and the wider environment. Section 7.2 details the methodology used during the study. Section 7.3 presents the results of the literature review and field surveys undertaken and gives an evaluation of the ecological resources within and surrounding the site. Potential impacts of the proposed WWTP upgrade are presented in Section 7.4. Mitigation measures for potential impacts are described in Section 7.5.

7.2 METHODOLOGY

7.2.1 Terrestrial habitat and flora survey

A habitat survey was conducted on the 8th September 2005. The survey area comprised Clonakilty WWTP, Deasy's Quay, Long Quay Pumphouse, the site of the proposed storm holding tank and the route of the proposed pipeline from the pumphouse to the treatment plant.

Terrestrial habitats were recorded and mapped following standard methodology (Heritage Council, 2002; JNCC 2003) and classified according to Fossitt (2000). A list of vascular plant species was drawn up for each habitat. Vascular plant names follow Stace (1997) and their frequency of occurrence within Ireland follows Webb *et al.* (1996). Throughout the text Latin names are given at first mention.

7.2.2 Littoral (intertidal) habitats, fauna and flora

Sampling of the littoral (intertidal) habitats was undertaken on 21st September 2005 and 3rd October 2005 (sediment samples for faecal coliform analysis). Sampling was conduced at five sampling sites (numbered Site 1 to Site 5) (Figure 7.1) following the natural gradient of the estuary (from head to the mouth of the estuary). The location of each sampling site was recorded with a hand-held GPS (Global Positioning System). At each sampling site, sediment samples were taken for granulometry analysis, chemical analysis and the assessment of macroinvertebrate communities.

Granulometry Methods

Sediment cores (10-cm diameter core) were taken to a depth of 5cm for granulometry analysis. The samples were bagged and transported to Mercury Analytical Ltd for analysis. Granulometry analysis consists of a series of wet and dry sieving techniques to determine the proportions of sediment particle sizes present within the whole sample. Results are expressed as % Gravel (particle size > 2mm), % coarse sand (particle size 2mm – 710ųm), % medium sand (particle size 710ųm – 250ųm), % fine sand (particle size 250ųm – 0.063 ųm) and % silt-clay (particle size < 0.063 ųm).

Sediment Chemical Analysis

Sediment cores (5-cm diameter) were taken to a depth of approximately 3cm for chemical and metal analysis. A control sample was also taken (labelled Site 6) – this sample being a duplicate of Site 2. The samples were placed in a cool box and transported to Alcontrol Laboratories (Dublin) for analysis.

The sediment samples were analysed for the following parameters:

Parameter	Units	Method Detection Level
Total Organic Carbon	%	<0.01%
Ammoniacal Nitrogen as N	mg/kg	<0.3mg/kg
Ortho Phosphate	mg/kg	<1mg/kg
Kjeldahl Nitrogen	g/kg	<0.1g/kg
Volatile Organic Compounds	µg/l	1 µg/l
Arsenic	mg/kg	<0.5mg/kg
Cadmium	mg/kg	<0.5mg/kg
Chromium	mg/kg	<1mg/kg
Copper	mg/kg	<1mg/kg
Lead	mg/kg	<1mg/kg
Mercury	mg/kg	<0.3mg/kg
Nickel	mg/kg	<1mg/kg
Zinc	mg/kg	<1mg/kg

Faecal Coliforms

Sediment cores (5-cm diameter) were taken to a depth of approximately 3cm. A control sample was also taken (labelled Site 6) – this sample being a duplicate of Site 2. The samples were stored in a cool box and transported the same day to Consultus Laboratories (Cork) for analysis.

Benthic invertebrates and intertidal flora

Three replicate core samples were taken at each sampling site, totalling 15 core samples for the entire survey.

Core sampling was carried out following standard methodology, each sample taken with a $0.01m^2$ cylindrical core down to a depth of 15cm (Dalkin & Barnett, 2001). The samples were sieved within low-tide channels on site using a 0.5-mm mesh stainless steel sieve before being transported back to the laboratory. Invertebrate identification was carried out using a dissection microscope (10x magnification) and a compound microscope (40 – 400x magnification). Macroinvertebrates were identified to the lowest possible taxonomic level and were subsequently counted and preserved in 70% ethanol. Replicate samples from each site were pooled to give one sample per site. Results are therefore presented as numbers per $0.03m^2$.

In addition to quantitative core sampling, a qualitative assessment was made of each sampling site and the wider habitats following the methodology for *in-situ* biotope recording (Wyn & Brazier, 2001). This included recording the following:

- Sediment type (mud, sandy mud, muddy sand or sand).
- Presence of anoxic layer.
- Proximity of drainage channels/creeks.
- Standing water.
- Notable epifauna (fauna on the sediment surface).
- Presence of mounds/casts of Lugworm *Arenicola marina* (average numbers recorded per $0.25\ m^2$).
- Presence of burrows, holes, tubes.
- Macroalgae - This involved recording the percentage cover of macroalgae within three randomly-positioned quadrats at each site (quadrat area $0.25m^2$).

7.2.3 Wading birds and wildfowl within Clonakilty Bay

Wintering wading birds and wildfowl that occur within the intertidal habitats of Clonakilty Bay were assessed in terms of species diversity, abundance and spatial and temporal distribution in the following ways:

- Review of data from the Irish Wetland Bird Survey (I-WeBS).
- Assessment of previous data collected by Dr L J Lewis (monthly count data for the period July 2000 – February 2002) including species low-tide distribution.

7.2.4 Ecological Evaluation of Habitats and Species and Impact Assessment

Ecological evaluation and impact assessment is based on criteria outlined in Appendix 7.1. Evaluation may apply at different levels and may refer to a site, habitat, communities or species. This will be clarified within the text.

7.3 EXISTING ENVIRONMENT

7.3.1 Site Description

A site description is presented in Section 2.2 and a description of the proposed development is given in Section 2.4.

7.3.2 Designated Areas in the Vicinity of the Site

Designated areas for conservation are areas that are designated under national and/or European laws in order to conserve habitats and species of national or international conservation importance. These include the following examples:

- **Natural Heritage Areas (NHA)**: a national designation given legal status by the Wildlife Amendment (2000) Act.
- **Special Areas of Conservation** (SAC): areas considered of European and national importance whose legal basis is the EU Habitats Directive (92/43/EEC), transposed into Irish law through the European Union (Natural Habitats) Regulations, 1997.
- **Special Protection Areas** (SPA): sites of conservation importance for birds whose legal basis is the EU Birds Directive (79/409/EEC).
- **Wildfowl Sanctuary**: designated under the 1976 Wildlife Act.
- **Ramsar Site**: European designation based on the Ramsar Convention, 1984.

Clonakilty WWTP is located at the head of Clonakilty Estuary (Figure 1.2). Clonakilty Estuary and Inchydoney Estuary together form part of Clonakilty Bay.

Clonakilty Bay has several designations for nature conservation (Figure 7.2).

Clonakilty Bay is a candidate Special Area of Conservation (cSAC) (EU Habitats Directive 92/43/EEC) (Site Code 091) and exhibits six habitats that are listed on Annex I of the directive including mudflats and sandflats not covered by seawater at low tide (Code 1140) and Estuaries (Code 1130).

Habitat encompassed by the whole Clonakilty Bay complex include mud and sandflats (Clonakilty & Inchydoney Estuaries), saline lagoons, freshwater marsh, swamp, wet grassland (Clogheen Marsh and White's Strand) and an extensive dune system associated with the south of Inchydoney Island and Inchydoney beach.

The SAC site synopsis (National Parks and Wildlife Service) is presented in Appendix 7.2.

A similar area is designated as a Natural Heritage Area (Clonakilty Bay NHA).
Clonakilty Bay is also an important habitat for wintering waterbirds and in recognition of its international importance has been designated as a candidate Special Protection Area (cSPA) (EU Birds Directive 79/409/EEC) (Site Code 81). Covering an area of approximately 588 ha, this SPA is an important habitat for wintering waders and wildfowl, largely due to the expanse of intertidal mud and sand flats that provide an abundant invertebrate food source. Designation is based on internationally important numbers of Black-tailed godwits (*Limosa limosa*) and several Annex I species that occur during winter e.g. Golden Plover (*Pluvialis apricaria*), Little Egret (*Egretta garzetta*) and Bar-tailed godwit (*Limosa lapponica*).

7.3.3 Habitats and flora within the existing environment

7.3.3.1 Terrestrial habitats and flora within the existing environment

Terrestrial habitat mapping follows the habitat classification of Ireland (Fossitt, 2000). A terrestrial habitat map is shown in Figure 7.3. Throughout the text, vascular plant names follow Stace (1997) and their frequency of occurrence within Ireland follows Webb *et al.* (1996). Latin names are given at first mention only.

Clonakilty Waste Water Treatment Plant

The site covers an area of approximately 2.2 ha and consists predominantly of **buildings and artificial surfaces** (BL3) set in **amenity grassland** (GA2). Small areas of **recolonising bare ground** (ED3) and **wet grassland** (GS4) were also recorded within the site boundaries. The site is separated from the surrounding environment by either **treelines** (WL2) or **hedgerows** (WL1).

Intertidal mudflats lie to the north and east of the site (described and mapped within Section 7.3.4). A strip of scrub (WS1) separates the site from the intertidal mudflats to the east. Clonakilty GAA ground lies to the west of the site, consisting predominantly of amenity grassland (GA2) (not mapped). Clonakilty Model Railway Village lies to the south of the site and comprises amenity grassland (GA2) and buildings and artificial surfaces (BL3) (not mapped).

Buildings and artificial surfaces (BL3)

This habitat classification refers to all areas of built land and includes the treatment plant control house, all paved or tarmac areas and all sewage treatment tanks and structures. By its nature, few plant species can colonise this un-natural habitat type. The site is well-managed and no colonising 'weed' species were recorded from this habitat.

Amenity grassland (GA2)

The majority of the site consists of well-managed grassland (lawn) that surrounds the sewage treatment tanks, other structures and pathways. The short sward is comprised of a variety of grass species together with a few broadleaved herbs such as Daisy (*Bellis perennis*) and Dandelion (*Taraxacum officinale*). A detailed species list is contained in Appendix 7.7.

Recolonising Bare Ground (ED3)

This category is used for areas of bare or disturbed ground where vegetation cover is greater than 50% (Fossitt, 2000). This habitat occurs in a strip along the eastern boundary of the site with scrub habitat beyond. Near the outfall flume, Hedge Bindweed (*Calystegia sepium*) and Bramble (*Rubus fruticosus* agg.) have grown vigorously over piles of stored material and blend with the scrub habitat beyond the site boundary. A detailed species list is contained in Appendix 7.7.

Recolonising bare ground (ED3)/wet grassland (GS4)

This small area occurs in the north-east of the site near the inlet works and by a garden shed. This patch is a mixture of recolonising bare ground (formerly disturbed and now recolonising) and small patches of wet grassland (characterised by grass species and Soft Rush *Juncus effusus*). Scrub habitat and young saplings (e.g. Sycamore *Acer pseudoplatanus*) occur beyond at the site boundary. A detailed species list is contained in Appendix 7.7.

Hedgerows (WL1) and treelines (WL2)

The entire site is bordered by either hedgerows or treelines comprising a mixture of native, non-native and horticultural species. Willow (*Salix* sp.) dominates in places. A single Sycamore tree stands within an area of amenity grassland close to the control house in the south of the site. A detailed species list is contained in Appendix 7.7.

Beyond the WWTP site boundaries

Scrub (WS1)

Scrub occurs between the site boundary and the high water mark to the north and east of the site and consists predominantly of Gorse (*Ulex europaeus*) and Bramble. Scrub also extends along the seaward boundary of the Model Railway Village. A detailed species list is contained in Appendix 7.7.

Beyond WWTP site boundaries – Deasy's Quay

Deasy's Quay lies to the north of the site beyond the intertidal mudflat area. Two 'creeks' are cut into the grassland habitat and actually represent the remains of former quays at these locations (Deasy's quay and Shipyard, mid 19th century) (Tuipéar, 1988). Two principal habitat types occur today: wet grassland (GS4) and recolonising bare ground (ED3).

Wet Grassland (GS4)

A tall grass-dominated habitat with large swaths of Silverweed (*Potentilla anserina*) also occurring. Saltmarsh species occur close to the creek edges (e.g. Thrift *Armeria maritima* and Sea Beet *Beta vulgaris* subsp. *maritima*) but do not extend to any great degree into the grassland habitat. A detailed species list is contained in Appendix 7.7.

Recolonising Bare Ground (ED3)

This area exhibits varying degrees of colonisation due to obvious disturbance from time to time. A diversity of typical colonisers (e.g. 'weed' species) occurs. A notable species was Pennyroyal (*Mentha pulegium*). This is considered a rare species (Webb *et al.*, 1996) and is recorded in only five 10-km^2 squares within Ireland (Preston *et al.*, 2002). Alien (non-native) species are also represented e.g. Mugwort (*Artemisia vulgaris*) and Japanese Knotweed (*Fallopia japonica*). A detailed species list is contained in Appendix 7.7.

Long Quay Pumping Station

The site of the Long Quay pumping station is classified predominantly as buildings and artificial surfaces (BL3). A narrow strip of amenity grassland (GA2) occurs around the building and supports a few tree and vascular plant species. A detailed species list is contained in Appendix 7.7.

Site of proposed storm water holding tank

This site is an amenity park that supports various tree species and is classified as scattered trees and parkland (WD5) under the habitat classification of Fossitt (2000). Tree species include Ash (*Fraxinus excelsior*), Beech (*Fagus sylvatica*), Birch (*Betula* spp.), Cypress (*Chamaecyparis* spp.), Horse-chestnut (*Aesculus hippocastanum*), Lime (*Tilia* spp.), Oak (*Quercus* spp.) and Sycamore (*Acer pseudoplatanus*), amongst others. The tree-lined boundary to the west also supports Ivy (*Hedera helix*), Hedge Bindweed (*Calystegia sepium*) and Nettle (*Urtica dioicia*).

A small area of artificial surfaces (BL3) in the north-west corner of this site supports a monument. Nearby a small patch of recolonising bare ground has a few weed species such as Broad-leaved Dock (*Rumex obtusifolius*), Nettle and Dandelion (*Taraxacum officinale*).

7.3.3.2 Evaluation of terrestrial habitats and flora

Ecological evaluation is based on criteria outlined in Appendix 7.1. Evaluation may apply at different levels and may refer to a site, habitat, communities or species. This will be clarified within the text.

Clonakilty Waste Water Treatment Plant

The site covers an area of approximately 2.2 ha and the majority of this area is represented by man-made (buildings and artificial surfaces), modified (recolonising bare ground) or managed (e.g. amenity grassland) habitats. These habitats are considered to be of low local ecological value (Table 7.1b, Appendix 7.1).

The area of recolonising bare ground/wet grassland is small and likely to be further modified; this small habitat is also considered of low local ecological value.

Hedgerow and treeline habitats support a diversity of flora species although many species are non-native (e.g. horticultural shrubs) or considered alien invasive species (Japanese Knotweed). Hedgerows and treelines however, provide good habitats for a range of bird species and other fauna. They provide important sites for foraging, roosting and breeding birds while also providing 'ecological corridors' facilitating bird and other animal movement (Good, 1998). Hedgerows and treelines are considered of low to moderate local ecological value.

Beyond site boundaries

Scrub habitat beyond site boundaries

Scrub occurs between the site boundary and the high water mark to the north and east of the site. Gorse and Bramble are common and widespread species but have some value for wildlife in terms of providing nesting sites for birds, cover for small mammals and foraging habitat for birds and invertebrates. This habitat is not considered rare in the local environment indeed, grassland, hedgerows, treelines and scrub all occur in the agricultural landscape to the north-east and south-west of the site. This habitat is therefore considered of low local ecological value.

Long Quay Pumping Station

The man-made or managed habitats within this site are considered of low local ecological value.

Site of proposed storm water holding tank

This site is an amenity park (known locally as Croppy Park) that supports various tree species and is classified under Fossitt (2000) as scattered trees and parkland (WD5). It is planted with a variety of native and non-native mature broadleaved trees and has an obvious amenity value. In terms of wildlife, the site is likely to support birds (nesting and foraging sites) and invertebrates but is unlikely to have any high value due to its proximity to a major road and levels of human disturbance. In terms of its amenity value and diversity of tree species, this site is regarded as of moderate local importance.

NB Habitats occurring at Deasy's Quay are not evaluated as they lie outside of the zone of influence (area likely to be affected by the proposed development).

Plant Species

None of the plant species recorded within Clonakilty WWTP are listed as Red Data species (Curtis & McGough, 1988) or are listed on the Flora (Protection) Order, 1999. The majority of plant species recorded are considered abundant and widespread throughout Ireland (Webb *et al.*, 1996).

A notable species found within the surrounding environment was Pennyroyal (*Mentha pulegium*). This is considered a rare species (Webb *et al.*, 1996) and has declined since the 1970's, currently recorded in only five 10-km^2 squares within Ireland (Preston *et al.*, 2002). Pennyroyal is listed on the Flora (Protection) Order, 1999 and is a Red Data species. This plant was also recorded from the same location within Clonakilty in 1999 (O'Mahony, 2001) when 50+ plants were recorded.

7.3.4 Littoral (intertidal) habitats, flora and fauna within the wider existing environment – Clonakilty Estuary

Clonakilty Bay historically comprised two arms of a shallow bay (Clonakilty Harbour and Muckruss Strand) separated by Inchydoney Island (Figure 7.4). Due to land claim in the early 1900's the southern arm of the bay is now effectively a separate estuary (Inchydoney Estuary) and receives freshwater input from two small streams. The northern arm of the bay (Clonakilty Estuary) is the estuary of the River Fealge. Together, the two estuaries exhibit intertidal mud and sand flat habitats extending over approximately 270 ha.

The mouth of Clonakilty Estuary is narrow which has the effect of restricting tidal flow, shortening the flood (incoming) tide and lengthening the ebb (outgoing) tide. Tide levels range from 4.1m (MHWST) to 0.7m (MLWST) (Irish Hydrodata, 2000). At low tide, the entire estuary dries out apart from a narrow river channel on the eastern side and various other smaller low tide channels and creeks.

7.3.4.1 Sediment

Granulometry (sediment particle size analysis)

Granulometry results (Table 7.1) show that the sediment of Clonakilty Estuary becomes sandier in nature as one progresses from the head of the estuary towards the mouth. This is a typical sediment gradient for an estuary (Dobson & Frid, 1998).

Table 7.1. Granulometry Results

Sediment Size	Site 1	Site 2	Site 3	Site 4	Site 5
GPS Location Reference	39062 41295	39361 40946	39559 40512	39745 40139	40242 40178
% Gravel	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
% Coarse sand	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
% Medium Sand	31.3	0.6	81	94.7	94.8
% Fine sand	0.3	77.5	2.1	0.3	0.7
% Silt-clay	68.4	21.9	16.9	5.0	4.5
Classification	Fine mud	Muddy-Sand	Muddy-Sand	Sand	Sand

Figure 7.5 shows the distribution of sediment within Clonakilty and Inchydoney estuaries as determined by differential GPS (dGPS) mapping (Lewis, 2003). This map shows that intertidal sediments also become progressively muddier (greater percentage silt/clay) towards the western sea wall. This is due to localised hydrological movements/flow dynamics and the resulting sediment deposition in these areas. Fine muds are therefore characteristic of the inner (northern) estuary head and the western shorelines. In general however, Clonakilty Estuary comprises predominantly sandy sediment particles, i.e. the majority of sediment is influenced by sand to some degree (fine sand, muddy-sand, sandy-mud) (Lewis, 2003).

Sediment chemical analysis

Results of the sediment analyses are shown in Table 7.3a (Appendix 7.3).

Natural Moisture Content

This analysis takes into account the interstitial moisture content of the sediment samples. The results show that moisture content decreases from Site 1 to Site 5 reflecting the natural gradient in sediment from fine silt/clays to coarser sand sediments.

Total Organic Carbon (TOC)

Carbon is a basic constituent of all organic compounds and the carbon in plant and animal tissue eventually breaks down to become organic matter.

In the estuarine environment, there is generally a relationship between the fine silt/clay fraction of sediments and the amount of organic carbon, i.e. fine muds and clays exhibit a greater percentage organic matter.

% Organic Carbon values ranged from 0.07% (Site 5) to 2.19% (Site 1). There is a significant difference between the Site 2 value (0.21% TOC) and the control site (Site 2 duplicate) (0.83% TOC). All recorded values are considered low for an estuarine environment. Organically enriched sediments would have TOC values of 5%+ (e.g. Hansen & Kristensen, 1997). Elevated TOC levels (up to 12%) have been found previously within Clonakilty Estuary within muddy areas affected by algal mats and within areas of the inner estuary (Lewis, 2003).

Ammoniacal Nitrogen and Kjeldahl Nitrogen

Nitrogen enters terrestrial and marine aquatic systems as part of the nitrogen cycle, a significant input to coastal and marine waters being from terrestrial run-off (White *et al.*, 1984). In the surface waters, nitrogen is cycled many times and in contrast to other elements, is not immobilized in the sediments – rather it returns to its atmospheric form by a process called denitrification. Raised concentrations of nitrogen in streams due to fertilizer run-off from agricultural land is linked to eutrophication of freshwater and coastal waters.

Ammoniacal nitrogen is a measure that combines NH^3 (ammonium) and NH_4^+ (ammonia). Kjeldahl Nitrogen is a measure of ammonia plus organic nitrogen. The un-ionised ammonium ion (NH^3) is regarded as the most toxic form of ammonia and generally increases in aquatic environments with lower levels of dissolved oxygen and reduced salinity. The source of ammonia to tidal waters is widely attributed to sewage treatment plants and agricultural run-off.

During the current analysis, levels of Kjeldahl Nitrogen within the sediment samples of Sites 2 - 6 are regarded as within a 'normal' range ($<$0.1 to 0.1 g/kg). A higher value (0.3 g/kg) recorded at Site 1 is comparable with the lower range values found in dredged sediment (0.2 g/kg) (Jones & Lee, 1981) but would not be considered excessively high. Average levels of 1.37g/kg were found within a eutrophic bay in the UK (Montgomery *et al.*, 1985), a considerably larger harbour with greater anthropogenic influences.

Ammoniacal nitrogen is also elevated at Site 1 (69.8 mg/kg) in comparison with the other sites but again would not be considered excessively high.

Ortho Phosphate

Phosphorus is derived principally from the weathering of rock. It generally follows the hydrological cycle in that it is carried from land to the oceans where it is eventually deposited in sediments. Increases due to anthropogenic factors are attributed to the application of fertilizer to land and subsequent run-off; human factors contributing about two-thirds of the annual river flow of phosphorus to the oceans (Ramade, 1981).

The levels of orthophosphate recorded in the current study (ranging from <1 to 2 mg/kg) are considered low and suggest no significant enrichment of the sediment. Elevated levels due to eutrophication may exceed 500mg/kg (Montgomery *et al.*, 1981).

However, in a typical estuary, inorganic phosphate (PO_4^{3-}) is released from the sediment to the water column during the summer months (also coinciding with a release of ammonia) – this may partly explain lower sediment levels at the time of sampling and may also stimulate macroalgal growth at this time of year. In addition, macroalgae store nitrogen and phosphorus in their tissues (Poole & Raven, 1997) and thus take up nutrients otherwise destined for the sediments and water column.

Volatile Organic Compounds

Defined as chemical compounds, based on carbon, that have a high vapour pressure and low solubility. Examples include Benzene, Toluene and Styrene. All recorded levels were low within the current study.

Metals

Metals may be present within estuarine sediments from both natural (e.g. weathering of rocks) and anthropogenic sources (various industries, waste water treatment and agricultural practices). There are currently no Irish sediment quality standards and therefore the results of the current sediment analysis are compared against standards set in the Netherlands, UK and Norway (Table 7.3a, Appendix 7.3). For example, the Dutch limit level shows the level above which sediment contamination is above the maximum acceptable risk; if the Dutch Intervention levels are exceeded the contamination is deemed serious.

The results of the current sediment analysis show that all metal parameters analysed (arsenic, cadmium, chromium, copper, lead, mercury, nickel and zinc) are below the Dutch target values. However, levels of chromium, nickel and zinc within sediment from Site 1 are above the more stringent UK (MAFF) In-house guidelines. Levels of nickel and zinc within sediment from Site 6 (Control Site, duplicate Site 2) although within the Dutch target values, surpass the levels used by the UK (MAFF). Sediment metal levels are generally greater in the Control Site 6 (duplicate of Site 2) than those recorded for Site 2 itself. The method of detection levels for cadmium (<0.5mg/kg) and mercury (<0.3mg.kg) do not allow comparison of the results for these metals with the UK (MAFF) In-house guidelines, although the upper levels detected fall within the Dutch target values.

Faecal Coliforms

Results of the analysis for faecal coliforms are given in Table 7.3b (Appendix 7.3). Total and faecal coliforms within the sediment samples were compared against the mandatory and guideline limits set by EU Directive (76/160/EEC) concerning the quality of bathing waters (transposed by the quality of Bathing Waters Regulations 1992, S. I. No 155 of 1992). All sites fall within the EU mandatory limits. However, total coliforms and faecal coliforms within sediment from Sites 1 and Control Site 6 are greater than the EU guideline limits. Faecal coliforms within Site 2 are outside the EU guideline limit.

General Conclusions of sediment analysis

Measured parameters generally fall within 'normal' or acceptable levels but there was a general trend for higher levels (i.e. total coliforms, faecal coliforms, TOC, Ammoniacal Nitrogen, Ortho phosphate, Kjeldhal Nitrogen and metals: Chromium, Copper, Lead, Nickel and Zinc) within Site 1, just downstream of the WWTP outfall. This suggests that nutrients and pollutants are entering the estuarine water column and sediments from the WWTP although riverine inputs (e.g. run-off) will also be involved. Recorded values for Control Site 6 (replicate of Site 2) were consistently higher than Site 2 (e.g. for parameters TOC, Chromium, Lead, Nickel and Zinc).

A further source of pollutants to the estuary will be from surface run-off from roadways (and other sources) that enters via numerous pipes along the sea walls.

Metals like copper and zinc from sewage can become bound to the sediments and as they are not biodegradable, persist over time. Of most concern in the marine environment are metals that are taken up by fauna (e.g. molluscs) and bio accumulate within their tissues or bio magnify over time; (toxicity of the metal is accumulated and concentrated by a higher trophic level when it is passed up the food chain) (Giller *et al.*, 1997).

7.3.4.2 Benthic macroinvertebrates

The physical characteristics of the core-sampling sites are shown in Table 7.2. All core samples were taken in areas that were free of macroalgal mats (although algal mats were present in some areas at the time of survey). The sediment recorded from the survey transect reflects the natural gradient in sediment from fine muds (silt/clay) at the head of the estuary to the progressively sandier sediment towards the mouth of the estuary. This gradient is well-illustrated by the results of the granulometry analysis (Table 7.1): the percentage silt/clay decreases from Site 1 to Site 5, while the percentage of medium sand progressively increases from Site 1 to Site 5.

Table 7.2. Physical Characteristics of Sampling sites

Site Characteristics	Site 1	Site 2	Site 3	Site 4	Site 5
GPS Location Reference	39062 41295	39361 40946	39559 40512	39745 40139	40242 40178
General Sediment Classification	Fine Mud	Muddy-Sand	Muddy-Sand	Sand	Sand
Average % Algal Cover	0	2%	0	2%	0
Average Number of Lugworm Casts per $0.25m^2$	None	2	4	11	0
Visible sediment surface invertebrates	None. Sediment very black and anoxic, visible leaf litter and detritus	None, but surface signs of *Scrobicularia plana* (benthic bivalve)	Tubes of *Sphiophanes bombyx*	None	None

Benthic macroinvertebrates comprise those species that either live within (infauna) or upon (epifauna) the sediment surface. Table 7.4a (Appendix 7.4) shows all macroinvertebrate species/taxa recorded from Clonakilty Estuary during the current survey and previous surveys (Lewis *et al.*, 2002; Lewis, 2003; Lewis *et al.*, 2003a,b). This table also gives the maximum densities of each species/taxa recorded at any one time and further information with regards to habitat/sediment preferences for each species. Table 7.3 gives the results of the current benthic macroinvertebrate survey.

Table 7.3. Benthic macrofauna recorded from the current core-sampling survey

Species/Taxa	Site 1	Site 2		Site 3		Site 4		Site 5	
		No.	No per m^2	No.	No per m^2	No.	No per m^2	No.	No per m^2
Annelid worms: Class Polychaeta	/								
Hediste diversicolor		3	100			1	33		
Nereis virens		1	33						
Nephtys caeca						3	100		
Scoloplos armiger		3	100	2	66	3	100		
Spiophanes bombyx				6	200	8	267		
Spionid indent.								1	33
Class Oligochatea	/								
Oligochaete spp.		1	33	1	33				
Molluscs: Class Bivalvia	/								
Cerastoderma edule		1	33						
Scrobicularia plana		1	33						
Macoma balthica		2	66						
Molluscs: Class Gastropoda	/								
Hydrobia ulvae				1	33				
Crustaceans: Order Amphipoda	/								
Corophium volutator		64	2133	3	100			1	33
Socarnes erythrophthalamus								15	500
Crustaceans: Order Isopoda	/								
Eurydice spp.								5	167
Crustaceans: Order Decapoda	/								
Carcinus maenas		1	33	1	33				
NUMBER OF SPECIES/TAXA	0	9		6		4		4	
TOTAL INDIVIDUALS	0	77		14		15		22	

The sediment within sampling Site 1 (approx 20m downstream of the WWTP outfall) was black and anoxic and supported no live Macroinvertebrates at all. Further down estuary, previous research has found that organically-enriched sediments between the current sampling Sites 1 and 2 are dominated by the polychaete worm (*Hediste diversicolor*), bivalve (*Scrobicularia plana*) and oligochaete worms (Lewis *et al*, 2002; Lewis *et al*, 2003b). These species are typical within upper-estuarine organically enriched sediments and within this area of Clonakilty estuary may reach densities of over 1200, 500 and 3000 m^{-2}, respectively (Lewis *et al*, 2002; Lewis *et al*, 2003b).

Sites 2 and 3 within the current sampling programme, exhibit greater species diversity and the species are predominantly detritivores (i.e. feeding on detritus or organic matter). Site 4 samples were still dominated by detrivorous polychaete worm species. Interestingly, although Lugworm (*Arenicola marina*) casts were observed on the sediment surface, and in parts of the estuary can form large Lugworm-dominated areas, none were found within core samples. Site 5 was located approximately 900m from the WWTP outfall in sandy sediment. This site is influenced by more marine (rather than freshwater) conditions and species considered more marine in nature were recorded here.

Intertidal habitats can be assessed and mapped in terms of benthic macroinvertebrate distribution and abundance and the distribution of sediment types. A biotope is defined as the physical habitat together with its characteristic community of plants and/or animals. The marine biotope classification of Britain and Ireland was developed by the Marine Nature Conservation Review (MNCR) (Connor *et al.*, 1997 a, b) and has since been updated (version 04.05 being used in this report) (Connor *et al.*, 2004). A biotope map for Clonakilty Estuary (based on current and previous data) is shown in Figure 7.6.

This map shows six major biotopes; additional small or discrete biotopes may occur that were not picked up during sampling and are incorporated within higher biotope classifications. The major biotopes are (following Connor *et al.*, 2004). :

LS.Lmu.UEst Polychaete/oligochaete dominated upper estuarine mud shores – occurs within the upper reaches of Clonakilty Estuary. Biotope typically exhibits anoxic muds and has a freshwater influence. Fauna is species poor dominated by *H. diversicolor* and oligochaetes, the bivalve *S. plana* being common.

LS.Lmu.Uest.Hed.Ol *Hediste diversicolor* and oligochaetes in littoral mud – this area is species-poor and dominated by *H. diversicolor*. *S. plana* may also be present..

LS.Lmu.MEst Polychaete/bivalve dominated mid estuarine mud shores – mud (silt/clay) sediment with a range of polychaete and bivalve species.

LS.Lsa.MUSa Polychaete/bivalve dominated muddy sand shores – a higher biotope classification incorporating muddy sand and fine sand exhibiting a diverse range of polychaetes, bivalves and other taxa.

LS.Lsa Littoral sand and muddy sands – a higher biotope classification incorporating fine, clean sands and muddy sands. The more mobile sand shores are relatively impoverished whereas other areas may be polychaete and/or bivalve dominated.

7.3.4.3 Littoral (Intertidal) Flora and Algae

Flowering plants (angiosperms) are not abundant within Clonakilty Estuary or the wider Clonakilty Bay. Small patches of Eelgrass (*Zostera* spp.) occur in association with small beds of Blue Mussel (*Mytilus edulis*) in the west of Clonakilty Estuary. Glasswort (*Salicornia* spp.) occurs in an extensive patch within Inchydoney Estuary.

Macroalgae are dominant upon the mud and sand flat habitats during the spring, summer and autumn months. These form 'macroalgal mats' and are comprised predominantly of the filamentous green macroalga *Enteromorpha muscoides* (Lewis, 2003). Other species include *E. clathrata*, *E. intestinalis*, *E. compressa* and *Ulva lactuca* (Note that separate genera are still widely used for *Enteromorpha* and *Ulva* although recent evidence suggests that they are one single genera (Hayden *et al.*, 2003)).

Brown seaweeds (Class Phaeophyceae) (e.g. *Fucus* spp) also occur along the shorelines.

Macroalgal mats are considered in more detail in Section 7.3.4.7.

7.3.4.4 Wading Birds and Wildfowl

The Latin names of bird species mentioned in the text are presented in Appendix 7.5 together with bird species conservation status.

Review of Data from Irish Wetland Bird Survey (I-WeBS)

Estuaries and other wetlands of north-west Europe support vast numbers of migratory wading birds and wildfowl each winter that migrate from their breeding grounds in the arctic and north-temperate zones and either over-winter at these sites or stop off (stage) on-route to further destinations. During winter, the main strategy of these bird species is to stay alive and to build up the reserves required to fuel their return to the breeding grounds. High densities of benthic macroinvertebrates (i.e. prey) are therefore the main attraction of these sites although disturbance-free roosting and resting areas are a further important ecological requirement.

Clonakilty Bay has 272 ha of intertidal mud and sand flats that form an important wintering area for migratory birds on the south coast of Ireland. The site qualifies for designation as a Special Protection Area (SPA) (EU Birds Directive 79/409/EEC) (Site Code 081) because it supports wintering populations of species listed on Annex I of the directive and also supports internationally important numbers of bird species. Clonakilty Bay is therefore classed as an internationally important wetland site.

Waterbirds are counted annually during winter as part of the Irish Wetland Bird Survey (I-WeBS). These are high-tide counts. The most recent I-WeBS data for Clonakilty Bay is given in Table 7.6a (Appendix 7.6). This data is for the period 1998/99 – 2002/03 (4 winters) and covers Clonakilty Estuary, Inchydoney Estuary and associated wetland habitats. The current data shows that Clonakilty Bay regularly supports three species that are listed on Annex I of the Birds Directive: Little Egret (*Egretta garzetta*), Golden Plover (*Pluvialis apricaria*) and Bar-tailed godwit (*Limosa lapponica*). Little Egrets were also confirmed as breeding birds within Clonakilty Bay in 2004. As many as 33 adults of this Annex I species have also been observed within the bay (Watson, 2004). Other Annex I species observed at times within the wider Clonakilty Bay habitat complex include Sandwich Tern (*Sterna sandvicensis*), Arctic Tern (*Sterna paradisaea*), Common Tern (*Sterna hirundo*) and Kingfisher (*Alcedo atthis*).

Clonakilty Bay currently supports one species in internationally important numbers - Icelandic Black-tailed godwits (*Limosa limosa islandica*), a four-year average of 958 birds surpassing the international threshold of 350 birds. This species however, can occur in numbers of 1400+ especially during the main migratory (staging) period (L. J. Lewis, pers. obs.).

The average number of total waterbird (wading birds and waterfowl) species found at Clonakilty Bay (based on the four most recent winter counts) is 5285 individuals (Table 7.4). Unfortunately, this data must be viewed with some caution as data collection was not consistent in the latter two years, for example counts in 2002/03 were made in February and March only and therefore are unlikely to represent the whole wintering period.

Table 7.4 Total waterbird numbers for Clonakilty Bay (1998/99 – 2002/03) (BWI)

	1998/99	2000/01	2001/02	2002/03	Mean (1998/99 – 2002/03)
Wildfowl & Waders	8294	7201	4768	877	5285
Wildfowl	1212	1127	606	361	827
Waders	7082	6074	4162	516	4459

The most recent I-WeBS data was therefore consulted (September 2004 – March 2005) and Table 7.5 shows the data for Clonakilty Estuary only. This gives an average number of 1811 birds within the estuary (minimum count 540; maximum count 3276 birds).

Table 7.5 Preliminary I-WeBS Data for the 2004/05 season (Clonakilty Estuary only).

	Sep 04	Oct 04	Nov 04	Dec 04	Jan 05	Feb 05	Mar 05
TOTAL WATERBIRDS	2786	540	1397	1863	3276	2289	526

Peak numbers for each waterbird species during the I-WeBS period September 2004 – March 2005 are also given in Table 7.6b (Appendix 7.6).

Analysis of previous data – wading bird abundance and distribution within Clonakilty Bay

Monthly low-tide bird counts were undertaken within Clonakilty Estuary between July 2000 and February 2002 (L. J. Lewis, unpublished data). The average numbers of birds recorded within Clonakilty Estuary during the low-tide survey period are given in Table 7.6.

Low-tide counts are useful in assessing the use of the estuary by foraging waterbirds. For example, Bar-tailed godwits are recorded sporadically during high-tide counts yet usually occur during low-tide surveys. This is most likely because their high-tide roost sites are not found during high-tide surveys. Similarly Golden Plover do not occur in large numbers during high-tide counts as they move onto fields to forage and roost.

Table 7.6. Average numbers of bird species recorded within Clonakilty Estuary during winter low-tide surveys (July 2000 – February 2002).

Species	No. of counts	Average Number	Peak Number
Black-tailed godwit	23	300	702**
Bar-tailed Godwit	13	13	32
Lapwing	9	65	153
Dunlin	13	96	342
Curlew	23	158	477
Redshank	23	109	223
Golden Plover	8	105	568
Oystercatcher	23	105	209
Black-headed Gull	23	191	582
All Gulls	23	265	678
All Waterbirds (excl gulls)	23	863	1371
Total Birds	23	1128	1804

** indicates number surpassing international threshold.

During the low-tide counts, birds were assigned to survey sections as outlined in Figure 7.7. Calculation of the area of the survey sections (Lewis, 2003) therefore allows densities of wading birds to be calculated for each survey section (Table 7.7).

Table 7.7. The average density of birds per hectare across the survey period (wintering period only) for a range of waterbird species.

Species	No. of counts	Density (birds/ ha)	Maximum Density	Minimum Density
Black-tailed godwit	13	4.8	15.5	0.2
Bar-tailed Godwit	13	1	1	0
Lapwing	9	1.9	5.2	0.1
Dunlin	13	1	1.8	0.1
Curlew	23	1	1.9	0.3
Redshank	23	2.3	6.0	0.0
Golden Plover	8	3	20	1
Oystercatcher	23	1.1	3.0	0.2
Black-headed Gull	23	3.2	11.2	0.7
All Gulls	23	3.8	12.8	0.8
All Waterbirds (excl gulls)	23	13.11	30.38	2.34
Total Birds	23	16.9	32.5	3.9

The density of total birds per ha (17 birds/ha) and all waterbirds (excluding gulls) (13 birds/ha) is within a 'usual' range for estuaries. The UK Low-tide survey of estuaries found densities of waterbirds (excluding gulls) ranging from 2.4 birds/ha (Swansea Bay) to 45.9 birds/ha (Breydon Water), the average across 12 estuaries being 14.1 birds/ha (Banks, 2005).

Dot-density maps are a good way to visualise bird density data and are used in the UK Wetland Bird Survey low-tide atlas. They allow a quick way of determining which sections of an estuary are important for each species (Banks, 2005). Figure 7.7b shows the dot-density map for all bird species combined within Clonakilty Estuary. Interpretation is based on the idea that the closer the dots are together, the more closely placed the birds are (i.e. more birds within a smaller area). Figure 7.7b clearly shows that in terms of density, birds are aggregated within the upper reaches of Clonakilty Estuary.

Dot-density maps have been produced for a range of bird species within Clonakilty Estuary. (Figures 7.8 a-f). Of the species analysed, Black-tailed godwits, Redshank (*Tringa totanus*) and Black-headed Gulls (*Larus ridibundus*), although distributed across a wide area of the estuary, show a tendency to aggregate within the inner reaches of Clonakilty Estuary (within the inner three survey sections). As wading bird distribution is highly correlated with the densities of their prey (Yates *et al.*, 1993) it is likely that this observed distribution is linked to the high densities of worm Ragworms (H. *diversicolor*) and bivalves (*S. plana*) found there (Lewis, 2003). Of note is the observation that Clonakilty Estuary is more important then Inchydoney Estuary for Black-tailed Godwits (Figure 7.8a) probably related to the muddier nature of Clonakilty Estuary. The head of Clonakilty Estuary is also a well-known low-tide roost of Black-tailed Godwits where they roost together with other species beside the low water channel (Hutchinson & O'Halloran, 1994).

In contrast, Curlew (*Numenius arquata*) and Oystercatcher (*Haematopus ostralegus*) are ubiquitous in their distribution, are territorial in behaviour (i.e. space-out during feeding as opposed to flocking birds such as Black-tailed godwits) and their favoured prey species e.g. Lugworm (*A. marina)* and Cockle (*Cerastoderma edule*) (for Curlew and Oystercatcher respectively) are found in sediments with some sand influence (e.g. muddy-sand). This explains their more widespread distribution.

Dunlin (*Calidris alpina*) prefer to feed within muddy-sand habitats (Yates *et al*., 1993) for prey such as ragworms (*H. diversicolor*). Dunlin also prefer down shore areas (Yates *et al*., 1993) and their densities are related to the distance from the high water mark (Austin *et al.,* 1996), occurring preferentially on middle or lower estuaries (Clark & Prys-Jones, 1994). Accordingly, within Clonakilty Estuary they are generally found in the mid to lower estuary, where there are wider study sections and a greater distance to the shoreline.

Low-tide data therefore shows that Black-tailed godwits, Redshank and Black-headed Gulls are strongly associated with the inner, muddy estuarine sediments; Oystercatcher and Curlew while occurring within the inner estuary are widely distributed; Dunlin are not generally associated with the inner estuary (except at times when roosting with Black-tailed Godwits (L. J. Lewis pers. obs).

7.3.4.5 Fish

Fish, together with wading birds, are the top predators of the estuarine ecosystem. Large numbers of several species of fish move up into the intertidal zone to feed when the tide is in, moving off the flats on the ebbing tide (Raffaelli & Hawkins, 1996). Fish species found feeding in the intertidal habitat include Goby species, Plaice (*Pleuronectes platessa*) Bass (*Dicentrarchus labrax*), Flounder *Platichthys flesus*), Lesser Sand Eel (*Ammpdytes tobianus*), Sole (*Solea solea*) and Dab (*Limanda limanda*) and their prey varies from polychaete worms and bivalve siphons (feeding tubes) to epibenthic fauna such as crustaceans.

Intertidal areas are also important feeding and nursery areas for juvenile fish such as Plaice (Costa & Elliott, 1991) and shrimps, prawns, gobiid fish and juvenile flatfish (Raffaelli & Hawkins, 1996).

Migratory species will also be found within these habitats at times (e.g. Salmon *Salmo salar*) as they pass to their freshwater spawning grounds.

7.3.4.6 Mammals

A mammal survey was not requested as part of the current ecological surveys.

Freshwater aquatic mammals

Otters (*Lutra lutra*) are found in a range of aquatic habitats from inland freshwater streams to shallow inshore marine areas. Otters are known to occur within Clonakilty Bay (e.g. Clogheen Marsh) and are likely to forage for fish within Clonakilty Estuary. Otters are a protected species under the Wildlife Act of 1976 as amended in 2000, the European Communities (Natural Habitats) Regulations of 1997, Annex II of the Habitats Directive, 1992 and Appendix II of the Bern Convention. They are also listed as Red Data Species in Ireland (Whilde, 1993).

Marine Mammals

Cetaceans (whales, dolphins and porpoises) are truly marine species but many are recorded within bays and near-shore areas. Irish waters provide some of the most important habitat for cetaceans within Europe and to date 24 species have been recorded (IWDG, 2002). Galley Head, to the west of Clonakilty Bay is a well-recognised location for cetacean-watching. The Irish Whale and Dolphin Group ISCOPE Database lists the following observations for October 2005:

Observed from Galley Head: Common Dolphin (*Delphinus delphinus*), Minke Whale (*Balaenoptera acutorostrata*), Fin Whale (*Balaenoptera physalus*), Harbour Porpoise (*Phocoena phocoena*).

Observed off-shore West Cork: Humpback Whale (*Megaptera novaengliae*), Risso's Dolphin (*Grampus griseus*), Harbour Porpoise. Occasionally smaller species such as dolphins and porpoises venture into shallow areas such as Clonakilty Estuary; larger species may be observed within the wider Clonakilty Bay area (Table 7.8).

All cetacean species are protected under the Wildlife Act of 1976 as amended in 2000. Harbour Porpoise and Bottlenose Dolphins (*Tursiops truncates*) are protected under Annex II of the EU Habitats Directive (92/43/EEC); all cetacean species are listed under Annex IV of this directive. Cetaceans are also afforded protection under the Bonn and Berne Conventions.

Table 7.8 Previous Cetacean sighting records for Clonakilty Bay (taken from ISCOPE* Database, IWDG).

Date	Species	Number
8 Sept 2004	Minke whale	4
23 June 2002	Minke Whale	1
2 May 2002	Harbour Porpoise	1
30 Dec 2001	Fin Whale	4
29 Dec 2001	Humpback whale	2
14 Nov 2001	Common Dolphin	200
14 Nov 2001	Fin Whale	4
14 Nov 2001	Minke Whale	4
14 Nov 2001	Humpback Whale	2
14 Nov 2001	Sei, Fin or Blue whale	2
14 Sep 2001	Sei, Fin or Blue whale	3
14 Sep 2001	Minke Whale	2
7 Sep 2001	Common Dolphin	20
29 May 1998	Common Dolphin	7

* ISCOPE – Irish Scheme for Cetacean Observation and Public Education.

7.3.4.7 The effects of organic enrichment on coastal and marine waters and its known or likely impacts on the ecology of Clonakilty Bay

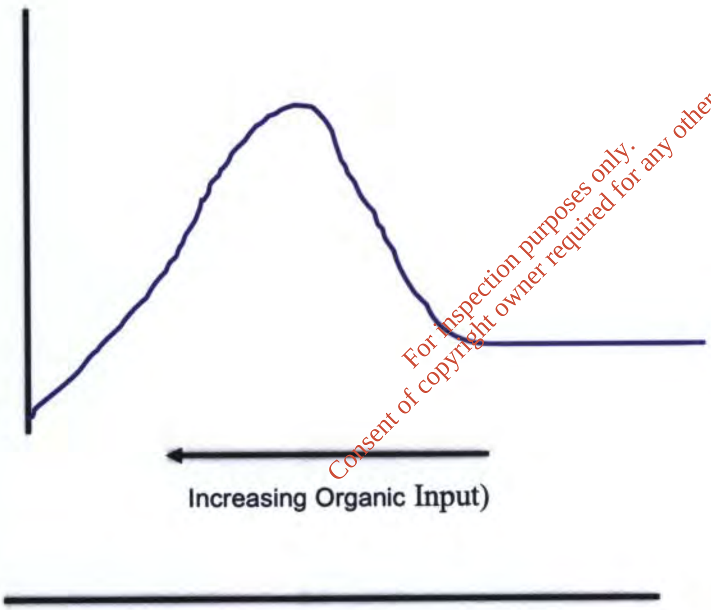
The position of estuaries at the foot of the watershed and their open connection to the sea makes them subject to an almost continuous input of nutrients (Neilson & Cronin, 1981). But although estuaries cycle large quantities of nutrients, the same nutrients, if input in excessive amounts, can be highly detrimental to the estuarine and coastal ecosystem (Neilson & Cronin, 1981). Over half of the Irish population live within 10-km of the coastline and most major towns and cities in Ireland are situated on estuaries (Stapleton *et al.*, 2000). As a consequence, estuaries receive sewage and other wastes from expanding populations and industrial activities. Organic enrichment of marine waters is most often attributed to sewage inputs and is considered one of the most universal of environmental disturbances resulting in a change in chemical, biological and physical factors that in turn have direct or indirect effects of the fauna (Pearson & Rosenberg, 1978).

Benthic fauna

Previous academic research in this area describes a pattern of faunal change along a gradient of decreasing organic enrichment. The extent of this gradient depends on the size of the discharges but can range from a few 100m to over 1000m. The faunal change can be visualised by a macroinvertebrate abundance curve (see below) (Pearson & Rosenberg, 1978) also called an organic enrichment curve.

Sediments in the vicinity of an outfall are usually devoid of benthic macrofauna due to the high enrichment and BOD (Biochemical Oxygen Demand) causing anoxic sediments (low oxygen). The further breakdown of matter by anaerobic bacteria promotes the release of hydrogen sulphide, methane and ammonia.

From about 200 – 600m further downstream, however, a proliferation of macroinvertebrates occurs caused by the aggregation of a few highly tolerant and opportunistic invertebrate species. This gives an 'unnatural' peak in macroinvertebrate densities as seen in the figure below. Following this peak, the invertebrate community gradually returns to a more usual level of species abundance. In terms of diversity, the number of macroinvertebrate species generally increases with increasing distance from the source of the organic input (Pearson & Rosenberg, 1978).



Generalised gradient of invertebrate abundance along a gradient of organic enrichment (after Pearson & Rosenberg, 1978).

Assessment of previous and current macroinvertebrate data for Clonakilty Estuary suggests that there is a macrofaunal response to organic enrichment from Clonakilty WWTP. Areas of black, anoxic mud close within 50m of the sewage outfall are devoid of macroinvertebrate fauna (current survey and previous pers obs, L. J. Lewis). Macroinvertebrate sampling throughout 2000 and 2001 (approximately 200 - 400m away from the outfall) found low species diversity but high densities of three very tolerant macroinvertebrate species: *Hediste diversicolor, Scrobicularia plana* and oligochaete species (See Section 7.3.4.2). Organic enrichment has also been shown to increase growth of the Ragworm (e.g. Hylland *et al.,* 1996).

Further down the estuarine gradient, species abundance appears to return to a more steady state while species diversity increases. However, coupled with organic enrichment is the annual occurrence of macroalgal mats which also exerts pressures on macroinvertebrate fauna causing changes in distribution, abundance and diversity and subsequent knock-on effects on their predators (See '*Eutrophication and macroalgal blooms*' below).

Raw sewage is also believed to enter the estuary at various points (pers. obs) and at these points, a similar increase in BOD, decrease in oxygen and response of macroinvertebrates as discussed above, is highly likely.

Estuarine birds and organic enrichment

Previous research has shown how some bird species benefit from waste matter released in effluent from waste water treatment plants.

Gulls in particular are known as opportunistic feeders and may feed directly on waste matter from outfalls (Cramp & Simmons, 1983). Abundance of Black-headed gulls (*Larus ridibundus*) and Herring Gulls (*L. argentatus*) was related to the volume of sewage discharge (Ferns & Mudge, 2000) in the UK. The association between gulls and human waste causes concerns in relation to the potential spread of disease. Gulls have been associated with Salmonella and Campylobacters and sewage-feeding gulls have been linked to pollution of water supplies where they roost near reservoirs (e.g. Monaghan *et al.,* 1985). Research in Scotland has shown how certain species of wildfowl concentrate near to sewage outfalls or those discharging waste from the food industry (e.g. Campbell & Milne, 1977).

It has long been established that the foraging distribution of wading birds is largely related to the densities and availability of their macroinvertebrate prey (e.g. Goss-Custard *et al.,* 1990; Zwarts & Blomert, 1992; Yates *et al.,* 1993). In terms of the organic enrichment gradient described above, it is therefore most likely that proliferation of tolerant and opportunistic macroinvertebrates downstream of an outfall will benefit wading birds by increasing the abundance of their prey within certain areas (Van Impe, 1985; Burton *et al.,* 2002). This may explain higher densities of some bird species within the head of Clonakilty Estuary (e.g. Black-headed Gulls, Black-tailed godwits) (as outlined in Section 7.3.4.4). At a larger-scale, previous UK studies have suggested potential links between the nutrient status of estuaries and wading bird communities and numbers (Hill *et al.,* 1993) i.e. increases in organic and nutrient inputs may equal increases in bird numbers and may influence species composition.

Organic enrichment (eutrophication) and macroalgal blooms

Eutrophication is defined as '*the enrichment of water by nutrients, especially compounds of nitrogen and/or phosphorus, causing an accelerated growth of algae and higher forms of plant life to produce an undesirable disturbance to the balance of organisms present in the water and to the quality of the water concerned*' (Urban Waste Water Treatment Regulations, 2001).

Organic enrichment or 'eutrophication' may lead to excessive growth of macroalgae within shallow estuaries and coastal areas. The growth of macroalgal mats is attributed to the availability of nitrogen or phosphorus, the major sources of which are sewage and agricultural run-off (Raffaelli *et al.*, 1998). However other factors such as topography, local changes in hydrography (Raffaelli *et al.*, 1998), light attenuation (Lavery *et al.*, 1991), phytoplankton dynamics (Lavery *et al.*, 1991) and degree of exposure (Pihl *et al.*, 1999) all influence macroalgae abundance and spatial distribution.

Whereas organic enrichment may lead to excessive growth of green macroalgae (Chlorophyta), enrichment may also lead to a loss of biodiversity of brown (Phaeophyta) and red (Rhodophyta) seaweeds with the estuarine system (Hardy *et al.*, 1993).

The sheltered nature of Clonakilty Bay, together with its position within a 'basin' surrounded by agricultural land, undoubtedly influences its susceptibility to macroalgal blooms. Macroalgal mats have been observed within the bay for over a decade but their distribution and extent varies from year to year. Previous research at Clonakilty Bay examined the distribution, abundance and ecological effects of macroalgal between 2000 and 2002 (Lewis, 2003). Results include:

- Macroalgal mats start to grow each year during spring, extend through the summer months and begin to decay or break-up during autumn. Autumn storms facilitate mat breakdown. Some macroalgal mats may persist throughout the winter – especially within Inchydoney Estuary.

- Clonakilty Estuary recorded a peak algal cover of 31% of the intertidal area during 2000, an estimated 54 ha of algal cover. Inchydoney Estuary exhibited a peak cover of 44% in 2000, an estimated 44 ha of algal cover.
- Observed algal cover during 2005 was greater than that recorded during 2000 (L. J. Lewis, pers. obs).
- Algal cover is generally confined to muddier sediments although the very head of Clonakilty Estuary has seen a low occurrence of algae in recent years. A typical example of algal cover is shown in Figure 7.9.
- Algal biomass shows considerable spatial and temporal variation but can reach values as high as 650 g dry weight m^{-2}, considerably greater than found in many other research studies in different countries.
- The alga species identified as the major contributor to macroalgal mats within Clonakilty Bay was *Enteromorpha muscoides*.

Algal blooms have a complex and broad range of ecological effects on coastal systems and may completely alter the function and structure of affected ecosystems (Valiela *et al.*, 1997). These effects include:

- Macroalgae may effectively out-compete seagrasses for nutrients and by the effects of shading and so induce the replacement of seagrass beds with macroalgal mats (e.g. Cabral *et al.*, 1999).
- Macroalgae are capable of the fast uptake and storage of nutrients, including those regenerated from the sediments. Acting as 'nutrient sinks' they alter biogeochemical cycles at the sediment-water interface and sequester nutrients that would otherwise have entered the water column (Valiela *et al.*, 1997). Algal burial and decay also leads to higher concentrations of N and C in the sediment.
- Dense algal presence reduces the flow of water at the sediment-water interface, increases sedimentation rates (Hull, 1987) and increases the organic matter content of the sediment (Bolam *et al.*, 2000).
- Algal cover also reduces oxygen exchange between sediment and water column, resulting in anoxic conditions that are accentuated by enhanced bacterial activity during algal decay (Hull, 1987).

These factors all add up to a significant ecological disturbance (Lewis, 2003) with subsequent complex and some negative effects on benthic invertebrates, wading birds and wildfowl and fish. These effects are summarised below:

Benthic Invertebrates

Previous studies have shown the following effects of macroalgal mats on benthic invertebrates:

- Suspension feeding bivalves generally decline under algal mats (Everett, 1994; Peterson *et al.*, 1994; Österling & Pihl, 2001). In particular *Macoma balthica* has restricted mobility and dies under the mats or at the sediment surface (Norkko & Bonsdorff, 1996).
- Algae may filter out pelagic infaunal larvae from the water column, which has the potential to reduce invertebrate juvenile recruitment (Olafsson, 1988).

- Declines of sediment surface feeders such as spionid polychaetes under algal mats (Nicholls *et al.*, 1981; Everett, 1994).
- Rapid reductions in population size and distribution of the crustacean amphipod *Corophium volutator* (Hull, 1987, Raffaelli *et al.*, 1991) in response to algal mats probably due to interference with the feeding behaviour.

Research within algal-affected areas within Clonakilty Bay (2000 – 2002) (Lewis, 2003, 2003b) found:

- The macroinvertebrate community within study sites was generally characterised by low species diversity and by species associated with organically enriched sediments such as *H. diversicolor*, *S. plana*, *Hydrobia ulvae*, oligochaetes and *Malacoceros fulignosus.*
- A high proportion of the macroinvertebrates within algal-affected areas are found within the algae itself (epifaunal species) as opposed to the sediment (benthic species).
- Sensitive species such as bivalve *M. balthica* and amphipod *C. volutator* were generally absent within algal-affected sites.
- Significant negative relationships were found for the densities of *C. volutator*, *S. plana* and *H. diversicolor* with algal cover.
- Some 'black-spots' occur where the biomass of algal cover or the effects of organic enrichment (e.g. anoxia) are so great that the sediment supports no live fauna at all.
- Rapid recolonisation of previously algal-covered areas by some species (e.g. *C. volutator*) and increases in densities of some species (e.g. *H. ulvae*) suggests that the presence of macroalgae (and increased levels of organic matter) benefits some tolerant species after the mats have disappeared.

Estuarine birds

- Wading birds generally avoid areas with algal mats (Tubbs & Tubbs, 1980; Murias *et al.*, 1996; Cabral *et al.*, 1999).
- Some individuals may forage within algal areas to prey on the fauna within the algae (e.g. Redshank at Clonakilty Bay during a short-term study by Lewis & Kelly, 2001). However, longer-term studies (Lewis, 2003) found that this prey source was not utilised to any great extent.
- Habitat selection studies at Clonakilty Bay (Lewis, 2003) found that within patchy algal areas, Black-tailed godwits and Redshank showed a clear preference for clear patches of sediment.
- Avoidance of algal-covered areas therefore amounts to a form of habitat loss. Lewis (2003) calculated that if one excludes areas of Clonakilty Bay that are coarse sand sediment and are less important areas for foraging shorebirds, 63% of the remaining intertidal area was affected by macroalgal mats (Lewis, 2003). This therefore amounts to a considerable, albeit temporary, loss of foraging habitat.
- Foraging distribution of Black-tailed godwits is related to prey distribution (birds perhaps 'learning' that there is a lower prey density beneath algal mats) (Lewis, 2003).

- Foraging distribution of Redshank is negatively related to the amount of algal cover (Lewis, 2003).
- Algal mats negatively affect the foraging success of Black-tailed godwits and Redshank but this negative impact is mitigated to some extent by macroinvertebrate recolonisation of previously algal-covered areas during mid-late winter.
- Macroalgal mats have been linked to declines of Dunlin within estuaries (Lopes et al, in press). An apparent decline in Dunlin between the years 1994/95 and 2001/02 at Clonakilty Bay may be related to macroalgal mats although this is difficult to prove and a national decline is also evident (Crowe, 2005) (Table 7.9).

Table 7.9 I-WeBS Data for Dunlin (*Calidris alpina*) at Clonakilty Bay 1994/95 – 2001/02 showing apparent declines.

1994/95	1995/96	1996/97	1997/98	1998/99	2000/01	2001/02
1827	1000	1696	1051	940	807	761

Fish

- Macroalgal cover affects the distribution and foraging behaviour of fish species *'Shallow coastal areas have a high value as feeding grounds and nursery areas for many commercially important fish species; a change in habitat structure (attributed to macroalgae) is likely to have a considerable consequences for these species*' (Isaksson & Pihl, 1992).
- In Sweden, changes in fish species assemblages and reductions in density were related to algal blooms (e.g. Isaksson and Pihl, 1992).
- Macroalgae have been shown to reduce settlement and recruitment of Plaice larvae in shallow bays (Wennhage & Pihl, 1994).
- Feeding success of juvenile fish is significantly reduced as a result of macroalgal cover (Isaksson *et al.*, 1994).

7.3.4.8 Evaluation of littoral (intertidal) habitats, fauna and flora

Clonakilty Bay exhibits over 270 ha of mud and sand flat habitats (Annex I habitat 'mudflats and sandflats not covered by seawater at low tide'; Annex I habitat 'Estuaries') that qualify the site for designation as a candidate SAC (cSAC). In the case of an estuary, evaluation of the habitats should not be judged too harshly on criteria such as naturalness or supposed lack of it (e.g. organic enrichment and human influences) as all estuaries, by their nature, are subject to some degree of organic enrichment (Neilson & Cronin, 1981) and most estuaries are also affected to some extent by human settlement (Stapleton *et al.*, 2000).

The macroinvertebrate species found within Clonakilty Estuary are widely recorded species and are of no major conservation importance in terms of rare or protected species. Benthic fauna however, play a major role within the estuarine ecosystem forming the basis of the estuarine food chain (and thus transferring energy to higher trophic levels) and in the recycling of matter. Birds and fish are top predators within the system and Clonakilty Bay is a major wintering site for migratory birds on the south coast of Ireland.

In addition to a range of Annex I species (including the Little Egret that now breeds within the bay), Clonakilty Bay supports major and internationally important numbers of Black-tailed godwits during the winter months. Black-tailed godwits are the most important qualifying interest of the site for SPA designation. Clonakilty Bay is ranked the 6th most important site for Black-tailed godwits within Ireland. The four-year average of 958 birds within Clonakilty Bay surpasses the international threshold of 350 birds (international threshold is 1% of the total population of the species). This species however, can occur in numbers of 1400+ especially during the main migratory (staging) period (L. J. Lewis, pers. obs.). Given a current national population estimate of 18,003 (Colhoun *et al*, in prep) and an international population estimate of 35,000 (Wetlands International, 2002), 958 birds represents 5.32% of the national wintering population and 2.7% of the total worldwide population. 1,400 birds represent 7.78% of the estimated national population and 4% of the estimated international population.

Icelandic-breeding Black-tailed godwits are one of very few wading birds species that are exhibiting population increases (Gunnarsson *et al.*, 2005). They are covered by the following policies and legislation:

- European status listed as 'vulnerable' (Burfield & Bommel, 2004); largely related to the sub-species *Limosa limosa limosa* that is exhibiting population declines.
- Listed on Appendix III of the Bern Convention.
- Listed on Appendix II of the Bonn Convention.
- Listed as 'least concern' under the world status criteria (Birdlife International/IUCN Red List Assessment).

Low-tide data presented within this report shows that Clonakilty Estuary is more important for Black-tailed godwits than Inchydoney Estuary, probably due to sediment and prey distribution and the organically enriched nature of inner Clonakilty Estuary. The head of Clonakilty Estuary is also the low-tide roost of this species.

In line with evaluation procedures outlined in Appendix 7.1 and given its international designations, Clonakilty Estuary (and Clonakilty Bay as a whole) is considered of International importance.

Additional considerations

Regard should be given to the amenity, tourism and educational value of Clonakilty Estuary in terms of the numerous visitors and students who observe and study the birds, particularly Black-tailed godwits.

2005 has been one of the worst years on record with regards to the abundance of macroalgal mats within Clonakilty Bay and other coastal areas within West cork (e.g. Harbour View, Howe's Strand, Courtmacsherry Bay). Together with negative ecological and environmental effects, macroalgal blooms are also posing problems for the coastal tourism industry and for local authorities. Accumulations of thick algae left on beaches after the tide has ebbed causes considerable visual and olfactory nuisance, while their removal (e.g. by bulldozers) poses problems in terms of finance, method of algae disposal and the long-term physical damage to the beaches themselves.

The EPA have developed a system that aims to establish the trophic status of tidal waterbodies and their sensitivity to eutrophication (ATSEBI: Assessment of the Trophic Status of Estuaries and Bays in Ireland) (Toner *et al.*, 2005). This system is based primarily on water quality and secondly on the distribution and abundance of macroalgae. The initial application of the ATSEBI system was used to designate 'Sensitive Areas in Tidal Waters' under the Urban Waste Water Treatment Regulations, 2001 (S. I. No. 254 of 2001). In order for a water body to be classed as eutrophic they should exhibit each of the following:

1 Enrichment by the stated nutrients
2 Accelerated growth of algae and higher forms of plant life
3 Undesirable disturbance to the balance of organisms present and to the quality of the water concerned.

At present, Clonakilty Estuary is not monitored by the EPA, although the nearby Argideen Estuary (Courtmacsherry Bay) is classed as eutrophic based on macroalgal distribution and abundance (Toner *et al.*, 2005). Given the findings of the current ecological studies of Clonakilty Estuary, review of previous studies (e.g. Lewis, 2003) and with reference to the recent studies on the Clonakilty WWTP outfall (Irish Hydrodata Report, 2006), there is a strong possibility that Clonakilty Estuary is Eutrophic.

Mounded macroalgae on Inchydoney Beach, Summer 2005.

7.3.5 Summary of Ecological Evaluations

Table 7.10. Summary of Ecological Evaluations

Ecological Resource	Ecological Value*
Within WWTP	
Buildings and Artificial Surfaces	F Low Local
Amenity Grassland	F Low Local
Hedgerows and Treelines	Low to Moderate Local
Recolonising Bare Ground/ Wet Grassland	F Low Local
Scrub	F Low Local
Long Quay Pumping Station	F Low Local
Site of Proposed Storm Water Holding Tank	E Moderate Local
Wider Environment – Clonakilty Estuary (incl habitats and species)	A International

* following Table 7.1b (Appendix 7.1).

7.4 POTENTIAL IMPACTS OF THE DEVELOPMENT ON THE ECOLOGY

Impacts are assessed and their magnitudes predicted based on criteria outlined in Appendix 7.1.

7.4.1 Potential Impacts of the development on the existing terrestrial habitats and flora

7.4.1.1 Clonakilty Waste Water Treatment Plant

The proposed development includes the installation of further waste water treatment infrastructure within the existing boundary of the WWTP and includes the following (Table 7.11):

Table 7.11. Proposed additional sewage treatment tanks and the current habitat within the proposed location.

Proposed Installation	Current Habitat
Aeration Tank	Amenity grassland (GA2)
Primary Settling Tank (2)	Buildings and artificial surfaces (BL3), Small areas of recolonising bare ground (ED3) and wet grassland (GS4), amenity grassland (GA2)
Settling Tank	Amenity grassland (GA2)
Sludge Pumping Station	Small areas of recolonising bare ground (ED3) and wet grassland (GS4)
Compressor/dewatering house	Amenity grassland (GA2)
Picket fence thickener	Amenity grassland (GA2)

Development of the additional infrastructure necessarily means permanent removal of the habitats in the proposed locations within the WWTP site (Table 7.11). Location of a proposed Compressor/dewatering house in the south of the site may necessitate the removal of one Sycamore tree. The habitats to be impacted are considered of low local ecological value and are predominantly artificial or managed habitats. This habitat loss is considered of low significance and is predicted to be an Imperceptible Impact.

The hedgerow and treeline habitats that border the site support a diversity of plant species and provide habitats for a range of bird species and other fauna. They provide roosting, foraging and breeding habitat for birds while also maintaining ecological corridors for wildlife. These habitats and the scrub habitat beyond also provide an important barrier between the WWTP and the mudflat habitats to the north. There are no plans to alter the boundary vegetation during development therefore no observable impacts on ecology (no change) are expected.

7.4.1.2 Long Quay Pumping Station

Habitats within the site of the Long Quay Pumping Station are man-made or managed habitats and are considered of low local ecological value. Any ancillary works within this site are predicted to have no observable impacts on ecology (no change).

7.4.1.3 Site of proposed storm water holding tank

This site is a small amenity park that supports a variety of native and non-native mature broadleaved trees. The site is unlikely to have any high value for wildlife due to its proximity to a major road and levels of human disturbance. Similar habitats for birds (i.e. treelines and hedgerows) are abundant in the surrounding environment. In terms of its amenity value and diversity of tree species, this site is regarded as of moderate local importance.

The development of the proposed storm water holding tank will necessitate the removal of some trees and loss of the site as an amenity area. Impacts on wildlife are likely to be imperceptible if the vegetated boundary to the west and as many trees as possible are retained together with tree removal being undertaken at an appropriate time of year (i.e. outside of the bird breeding season).

7.4.2 Potential Impacts of the development on designated sites – Clonakilty Estuary

7.4.2.1 Background

The objectives of wastewater treatment are to reduce BOD_5, reduce TSS, reduce faecal coliforms and to reduce Nitrogen and Phosphates of the incoming wastewater before discharging to a water body (Kiely, 1997).

The impact of a WWTP outfall on a water body depends on the magnitude and treatment level of the discharge, the magnitude of inputs to the system from other sources, background concentrations and the rate of exchange (tidal flushing) (Burton *et al.,* 2002). Therefore in order to make impact predictions, information is required with regards the relative nutrient loads to the estuary from the various sources.

A previous study of the Clonakilty catchment found that nitrate was the most abundant nutrient entering the bay and originated predominantly from riverine inputs (most likely from agricultural run-off). Clonakilty WWTP was found to contribute significant levels of ammonium, total phosphate and orthophosphate (Cork County Council, 1998). A current study of effluent discharges from Clonakilty WWTP calculated contaminant concentrations in the low tide river channel in the inner estuary just downstream of the outfall (Irish Hydrodata, 2006). For example, based on a river flow of 0.075 m^3/s, dissolved nitrogen is calculated as 13mg/l and orthophosphate levels is calculated to be 1,400µg/l mg/l. These levels exceed those considered indicative of nutrient enrichment in tidal fresh waters or intermediate-salinity waters (Toner *et al*, 2005):

	Dissolved Inorganic Nitrogen (DIN) mg/l	**Orthophosphate µg /l P**
Tidal fresh waters	>2.6	>60
Intermediate waters	>1.4	>60

We must consider that the values calculated in the recent study (Irish Hydrodata, 2006) reflect water quality of the low-tide channel only and do not take into account high-tide conditions when greater dilution will take place. This would result in lower concentrations than calculated using river dry 95%ile flows. However, this calculation was based on average background river concentrations of 1 mg/l nitrogen and 0.02 mg/l orthophosphate. Data from Cork County Council (1998) gives nutrient levels for the River Feagle (downstream of Clonakilty Town but upstream of the WWTP) as ranging between 2.8 – 7.6 mg/l for nitrate and 0.02 – 0.33 mg/l for orthophosphate. This suggests that the nutrient levels entering Clonakilty Estuary are much higher than estimated in the assimilative calculations.

This water quality data together with previous ecological research carried out by Dr L J Lewis, results of the current macroinvertebrate sampling and the occurrence of annual and extensive macroalgae within Clonakilty estuary, suggest that the estuary is currently eutrophic.

Clonakilty WWTP is currently operating above its design capacity (e.g. Design Capacity: PE 5,333; Current Loads: PE 15,000) (RPS, June 2006). Therefore it is likely that during times of high wastewater input that the current system is at risk of being overloaded. For example, during times of heavy rainfall, storm overflow may be directly discharged to sea without treatment (RPS, June 2006).

Future design capacity is to provide treatment for a maximum PE of 20,500 with an associated greater flow rate. Treated effluent will at a minimum meet the standard of 25 mg/l BOD_5, 35mg/l SS, 125 mg/l COD as set out in the Urban Wastewater Treatment Regulations 2001. With no reduction in phosphorus (P) and nitrogen (N) levels in the treatment process, the nutrient levels of the effluent will contain significant levels of N and P. Of greater consequence is the potential for increased flow capacity with no nutrient removal which could lead to significantly increased nutrient emissions (N and P) entering the Clonakilty Harbour.

7.4.2.2 Sediment

Measured sediment parameters during the current study were generally within 'normal' or acceptable levels. However, areas of organically enriched and anoxic (low oxygen) sediments have been recorded from Clonakilty inner estuary (Lewis *et al.*, 2002; pers. obs)

Improvements in waste water treatment and reductions in organic loading (reduced BOD) to Clonakilty Estuary are likely to improve dissolved oxygen concentrations in the water column and promote re-oxygenation of sediments in impacted (anoxic) areas. Reduction in BOD generally promotes an improvement in sediment quality (e.g. lower levels of hydrogen sulphide, methane and ammonia). Improvements to Clonakilty WWTP may therefore result in a slight -moderate positive impact upon estuarine sediments within Clonakilty Estuary.

7.4.2.3 Flora

Nitrogen is often identified as the major limiting factor to macroalgal growth (Jeffrey *et al.*, 1995) and sewage treatment plants are identified as the major source of ammonium (NH_4) to estuarine systems (O'Higgins & Wilson, 2005).

Current scientific evidence suggests that only long-term reductions in nutrient inputs to coastal waters will result in significant reductions in macroalgae abundance. This is because other sources of nutrients to the system must also be considered (e.g. river inputs). Indeed, Soulsby *et al.* (1985) suggested that climatic (e.g. optimum temperatures) and physical factors of an estuary together with nitrogen in sea water were sufficient to support the macroalgal standing crop regardless of any changes to sewage effluent outputs. Macroalgal mats themselves also contribute a significant input of organic matter to the estuarine system and macroalgae can also store carbon and nitrogen in their tissues, which on decomposition (break down) enter the sediment. This carbon and nitrogen store therefore contributes to future algal blooms and thus macroalgal mats can be considered as self-regenerating (Lavery & McComb, 1991). It is therefore predicted that only long-term reductions in nutrient inputs to coastal waters will result in significant reductions in macroalgae abundance.

It is therefore predicted that long-term nutrient reductions, that include both nitrogen and phosphorus removal during waste water treatment and a reduction in nutrients in riverine flows, will result in a reduction in algal mats over a long time-scale. Improvement of the Clonakilty WWTP is therefore likely to contribute to a moderate-major positive impact in terms of macroalgal reduction over time with subsequent benefits for habitats and species within Clonakilty Estuary.

Without such long-term reduction in nutrient inputs to the estuary ('do nothing impact') there is likely to be no change in the annual macroalgal cover within the estuary.

If waste water treatment continues without deduction of N and P and increasing volumes of effluent are discharged to the estuary, then increasing N and P inputs to the bay are likely. This will continue the process of eutrophication. In this 'worst-case' scenario, slight – moderate negative impacts are predicted.

7.4.2.4 Benthic Macroinvertebrates

Improvements to waste water treatment and subsequent reductions in organic and nutrient loads to estuaries may promote measurable changes in macroinvertebrate communities, both in terms of species composition, distribution and abundance (Burton *et al*. 2002).

The potential impacts of improvements in waste water treatment can be assessed with regards to the pattern of faunal change along a gradient of organic enrichment away from the polluting source (as described in Section 7.3.4.7).

- Sediments in the vicinity of an outfall are usually devoid of benthic macrofauna due to the high enrichment and BOD (Biochemical Oxygen Demand) causing anoxic sediments (low oxygen). In these areas, a reduction in organic (BOD) loading to the estuary and subsequent re-oxygenation of the sediments could promote a gradual recolonisation of the sediments by macroinvertebrate species that are tolerant to organic enrichment, most likely mobile and tolerant polychaete worms.
- Further down the gradient, a proliferation of macroinvertebrates occurs due to the aggregation of a few opportunistic invertebrate species that are highly tolerant to organically enriched sediments. In these areas, reductions in organic and nutrient loads to an estuarine system may cause declines in invertebrate densities as the communities return to those more typical of un-enriched sediments. A review by Burton *et al* (2002) concludes that except on grossly polluted sites, improvements to WWTP discharges may lead to reductions in invertebrate abundance, biomass and diversity.

Estuaries are highly dynamic and fluctuating systems. Effects of organic loading to estuaries will vary from site to site depending on various physical, chemical and hydrological factors. Therefore increases/decreases in organic loading to estuaries will influence macroinvertebrate community composition, diversity and abundance over different spatial scales in different estuaries. Indeed, in some systems, a reduction in organic loading may lead to an increase in macroinvertebrate species diversity across some areas of the estuary if species that are less tolerant of organic pollution are able to colonise (Pearson & Rosenberg, 1978).

We must also consider that macroinvertebrate communities will be influenced by organic loadings from other sources (e.g. riverine inputs). If these inputs are significant, they may act as to modify the effects of a reduction in nutrient and organic loading from the WWTP (e.g. Carpenter *et al.*, 1998).

Predicting the impact significance of the Clonakilty WWTP upgrade on macroinvertebrate communities within Clonakilty Estuary is therefore difficult and is considered an indeterminable impact. Further studies would be required to ascertain the relative nutrient/organic loads to the estuary (i.e. from freshwater/river, WWTP and other sources) together with on-going monitoring of macroinvertebrate communities. As Clonakilty Estuary lies within a predominantly agricultural area, organic and nutrient loads from freshwater run-off together with those from natural sources may be significant but their relative effect on estuarine macroinvertebrate communities is unknown.

7.4.2.5 Wading birds and wildfowl

Impacts upon wading birds and wildfowl due to the proposed upgrade of Clonakilty WWTP may arise from:

- Disturbance during construction phase

Some disturbance to estuarine birds may occur during the construction phase (i.e. development of new sewage treatment tanks and equipment within the WWTP site) although the high hedgerow and treeline boundary between the site and the intertidal area provides a good buffer between the site and the intertidal habitats to the north.

Disturbance from the WWTP is not considered to be a major impact upon estuarine birds within the area. The current operations at the site do not appear to effect estuarine birds within the immediate vicinity. Wading birds and wildfowl are thought to habituate to continuous low-level noise (Hill *et al.*, 1997). During the development of the WWTP site, some higher-level noise disturbance may occur but this is likely to be infrequent and of a short-term nature. Even if birds are displaced for a period, they have the potential to return and utilise the habitat (and prey resource) when the disturbance has ceased. It is therefore unlikely that there will be any long-term impacts on the bird species that utilise this inner estuarine area (Gill *et al.*, 2001). The impact of disturbance during the construction phase is therefore predicted to be imperceptible – slight negative over a relatively short time period.

- Disturbance during the operational phase

Current operations at the WWTP site do not appear to effect estuarine birds within the immediate vicinity. Disturbance from the WWTP during its operational phase is not predicted to cause any negative impacts upon estuarine birds within the adjacent intertidal area, as long as codes of good practice are used in the operation of the site.

- Reduction in the number of gulls associated with the sewage outfall

WWTP improvement could result in a reduction in the number of gulls that are directly associated with the outfall and those that currently utilise areas of raw sewage outfall around the bay. Given the health issues surrounding gulls and raw sewage inputs and the ubiquitous and opportunistic nature of gull species, the upgrade of Clonakilty WWTP is unlikely to have a negative impact on gull populations (e.g. Ferns & Mudge, 2000). The impact is predicted to be imperceptible.

- Impacts on birds due to a reduced BOD loading to the estuary

The proliferation of tolerant and opportunistic macroinvertebrates in response to organic enrichment is thought to benefit wading birds by increasing the abundance of their prey within certain areas (Van Impe, 1985; Burton *et al.*, 2002). Studies in the UK have suggested potential relationships between the nutrient status and numbers of wading birds within an estuary (Hill *et al.*, 1993) i.e. increases in organic and nutrient inputs equals increases in bird numbers. This suggests that reductions in the nutrient and organic loading of estuaries and subsequent reductions in macroinvertebrate densities could result in reductions in the number of birds or changes in the species composition of wading birds and wildfowl (see Section 7.3.4.7). Indeed, several studies have postulated links between reductions in organic loadings and declines in bird numbers (e.g. Bryant, 1987) however confounding factors often preclude conclusive associations.

Burton *et al.* (2002) suggest that declines in BOD concentrations and the subsequent changes to macroinvertebrate populations are linked to declines in bird numbers. They suggested that the following species (that also occur at Clonakilty in reasonable numbers) may decline as a result of reductions in organic loading to estuaries: Shelduck (*Tadorna tadorna*), Wigeon (*Anas penelope*), Teal (*Anas crecca*), Oystercatcher, Lapwing (*Vanellus vanellus*), Dunlin, Black-tailed Godwit, Bar-Tailed Godwit, Curlew, Redshank and Turnstone (*Arenaria interpres*) (Burton *et al.*, 2002). More recently, changes to sewage disposal in the Northumbria Coast SPA (UK) have been linked to declines of Turnstone (Burton *et al.*, 2005) and Purple Sandpipers (*Calidris maritima*) (Burton & Goddard, in press).

The following scenarios could potentially result from a reduction in BOD/nutrient loading to the estuary following the proposed upgrade of Clonakilty WWTP:

1. The area of macroinvertebrate proliferation within inner Clonakilty Estuary is characterised by high densities of Ragworm *H. diversicolor*, bivalves *S. plana*, oligochaetes and other invertebrate species, that thrive within the organically enriched sediment (Lewis 2002, 2003b). If reductions in organic loading led to reductions in the densities of these prey species then negative impacts would be placed on bird species that feed on these invertebrates within this area of the estuary. In the case of Clonakilty Estuary, the impact would be primarily upon Black-tailed godwits and Redshank that occur within higher densities within this area (See Section 7.3.4.4). Any significant decline in bird numbers (worst case scenario), especially of Black-tailed godwits would be considered a serious negative impact given the SPA status of the estuary and the qualifying status of the Black-tailed godwit.
2. As discussed in Section 7.4.2.4 above, other sources of organic and nutrient inputs to the estuary may act as to modify the effects of a reduction in nutrient and organic loading from the WWTP, in which case impacts upon birds would be reduced.
3. A reduction in organic matter may bring about changes in macroinvertebrate species diversity or density and may even bring about increases in those species that are intolerant of organic enrichment. This could benefit those bird species that feed upon them.

Impact Prediction:

Scientific studies suggest that reductions in the nutrient and organic loading of estuaries and subsequent reductions in macroinvertebrate densities may potentially result in declines in the number of wintering estuarine birds and/or changes in their species composition. However there is currently no conclusive evidence that allows accurate impact prediction especially when impacts are likely to vary considerably from site to site. We must therefore conclude that the current impact potential upon birds is undeterminable without on-going studies.

- Knock-on effects due to changes in the abundance and distribution of annual macroalgal mats within the estuary

Macroalgal mats have been shown to have negative effects on the foraging and distribution of most estuarine bird species studied (e.g. Tubbs & Tubbs, 1980; 1983; Cabral *et al.*, 1999; Lewis, 2003). More recently, long-term studies have linked increases in numbers of Dunlin to decreases in macroalgal cover (Lopes *et al.*, in press).

Given that a long-term reduction in nutrient loadings to an estuary may lead to a reduction in macroalgal biomass and cover, a reduction in nutrient loadings could have knock-on beneficial effects for birds. Areas of the estuary that are currently affected by high macroalgal biomass and cover and experience the greatest negative effects (anoxic sediments, defaunation of sediments) could undergo an improvement in sediment quality and subsequent re-colonisation by macroinvertebrates. This could increase foraging habitat for birds across some areas of the estuary while partially mitigating any decrease in invertebrates brought about by a reduction in BOD loading, as discussed above.

A reduction in macroalgal cover could also lead to increases in prey species such as the amphipod *Corophium volutator* and bivalves (e.g. *Macoma balthica* and *Cerastoderma edule*) that are generally absent or present in low densities in algal-affected areas. These species are important prey items for wading birds.

As described above (Section 7.4.2.3), it is predicted that only long-term reductions in nutrient inputs to coastal waters will result in significant reductions in macroalgae abundance._Macroalgae within Clonakilty Bay is undoubtedly influenced by other factors in addition to the WWTP. Nutrient loading may be sufficient from other sources to result in their continued growth within the estuary. However, any reduction in macroalgal growth as a result of reduced/improved nutrient loading to the estuary would be considered a moderate positive impact for birds.

7.4.2.6 Fish

As higher predators in the estuarine food chain, fish are likely to be affected by any changes in macroinvertebrate densities brought about by a reduction in organic loadings. Effects are species -specific and although some species may benefit from increased nutrient loadings (due to effects on their invertebrate prey), species such as Plaice, Flounder, Dab and salmonids benefit from improved water quality (Burton *et al.*, 2002) and species diversity and abundance may increase (Pomfret *et al.*, 1998). Any reduction in the abundance of macroalgal mats due to reductions in nutrient loadings will also have positive effects on fish. The proposed upgrade of Clonakilty WWTP and potential reductions in organic and nutrient loadings are predicted to have a slight - moderate positive impact upon fish species.

7.4.2.7 'Do nothing' Impact

Given no change to the current operations of Clonakilty WWTP, nutrient and organic loadings to Clonakilty Estuary would be expected to remain at current levels and to increase over time as the population levels expand. Over time, the water and sediment conditions within the estuary could potentially decline, as the estuary became more eutrophic in nature. A greater proportion of estuarine sediment could become anoxic and devoid of all macroinvertebrate life. Annual growths of macroalgae are predicted to continue and have the potential to increase. The estuary would become a mosaic of good and poor feeding areas for wintering wading birds and wildfowl.

7.4.3 Consideration of impacts in light of a potential barrage construction within Clonakilty Estuary and consideration of outfall location

Conclusive impact prediction is not possible however the following scenarios are presented based on the tidal barrage being open after construction (i.e. not impounded):

- If the barrage is built and no change occurs with regards Clonakilty WWTP.
  It is predicted that the barrage construction could lead to increased sediment deposition within the inner harbour with a subsequent increase in organic matter content of the sediments. Organic matter and nutrients could potentially be concentrated within the sheltered upper estuary as a result of decreased flushing. This could add to the eutrophic potential of the estuary. In a 'worst case' scenario, a greater area of sediments could become anoxic and subsequently defaunated leading to a loss of prey for birds.

- If the barrage is built and WWTP treatment continues without treatment of N and P and increasing volumes of effluent are discharged
  There is a potential that the effects of eutrophication will be magnified (potential cumulative impact). In this 'worst-case' scenario there could be a more profound effect of organic enrichment on sediments and macroinvertebrates (See Section 7.3.4.7). In an extreme case, a greater area of sediments could become anoxic and subsequently defaunated leading to a loss of prey for birds.

- If the barrage is built and BOD and nutrient loading to the estuary are reduced (including N & P removal during treatment)
  Effluent outputs from Clonakilty WWTP have the greatest impact on nutrient levels within the inner estuary and channel area (Irish Hydrodata, 2006).

  Inner Clonakilty Estuary is shallow and sheltered and building of a tidal barrage will increase the sheltered nature of this area, potentially promoting poorer mixing of waters and decreased tidal flushing as a consequence of altering the natural tidal flow and circulation. It is predicted that the barrage construction could lead to increased sediment deposition within the inner harbour with a subsequent increase in organic matter content of the sediments. Despite improvements in waste water treatment, organic matter and nutrients could still potentially be concentrated within the sheltered upper estuary as a result of decreased flushing. Without N and P removal during treatment, processes of nutrient enrichment and eutrophication could be enhanced.

  The full impacts upon habitats and species are difficult to predict. Output from the WWTP together with organic and nutrient loading from riverine sources could still potentially lead to an organically over-enriched inner estuarine area. This could maintain high densities of tolerant macroinvertebrates such as detrivorous worms that are an important food source for birds.

Growths of annual macroalgal mats may be maintained in the short-term but a long-term reduction of nutrient inputs (including from freshwater sources) is likely to result in a reduction in growth over time.

In order to address the problem of eutrophication by substantially reducing nutrient/BOD loading to the estuary, the WWTP outfall would be best placed outside of the estuary i.e. a marine outfall, where there would be greater dilution. However, due to the location of the Inchydoney Blue Flag Beach and concerns over human health issues, results of a current study recommend that the optimum location in terms of minimising bacterial contamination is the existing location at the head of the estuary (Irish Hydrodata, 2006).

7.5 RECOMMENDED MITIGATION MEASURES

7.5.1 Mitigation measures for the existing terrestrial habitats and flora

7.5.1.1 Clonakilty WWTP

It is recommended that development activities be restricted to within the site boundaries only and not encroach into surrounding habitats so as to not impact, alter or cause deterioration to the surrounding habitats or fauna.

The boundary hedgerows, treelines and associated scrub between the site and the adjacent intertidal habitats to the north act as a good natural buffer against noise and are an important ecological corridor. These habitats should not be removed or physically disturbed and could be enhanced by the planting of appropriate native shrub species for the area (i.e. gorse).

The development of the site should be managed (e.g. Environmental Management System) in such a way so as to minimise all potential impacts on the surrounding habitats and species. Management systems need to consider the coastal environment in terms of dust and noise emissions. Conservation of the surrounding habitats and minimisation of disturbance to the adjacent SPA/SAC should form part of the Environmental Management System and should also be taken into consideration during the operation of the site.

Permitting and licensing bodies of the WWTP should set appropriate noise levels within which the WWTP will operate during both the development and operational phases. These should take into account the proximity of the SPA.

7.5.1.2 Long Quay Pumping Station

No mitigation deemed necessary.

7.5.1.3 Site of proposed storm water holding tank

Vegetation removal should be minimised during the building of the storm water holding tank. Where possible, the developer should endeavour to relocate the trees that require removal, particularly native species.

With regards vegetation removal, the developer should take into account the Wildlife (Amendment) Act 2000 Section 46, amending Section 40 of the Wildlife Act, 1976 with regards to the timing of vegetation removal and habitat destruction with regards to potential breeding birds on the site.

7.5.2 Mitigation measures for designated sites

7.5.2.1 Estuarine water and sediment quality

Estuarine water and sediment quality has a profound effect on the ecology of the estuarine system. Accurate and site-specific impact predictions for the proposed WWTP upgrade development upon Clonakilty Estuary are difficult to make without further information with regard to the relative nutrient/organic loads to the estuary (i.e. from freshwater/river, WWTP and other sources).

All future emissions from Clonakilty WWTP should meet the minimum standard of 25 mg/l BOD_5, 35mg/l SS, 125 mg/l COD as set out in the Urban Waste Water Treatment regulations, 2001. As described in Section 6.5.2, it is recommended that the WWTP provide nutrient reduction in order to meet the limit of 15mg/l N and 2mg/l P in the treated effluent. This will result in significantly reduced levels of nutrients entering the estuary. It is also recommended that ongoing monitoring of nutrients levels in the Clonakilty Estuary, following the EPA's ATSEBI System, be carried out. (see Section 7.3.4.8) so that any improvements in water quality resulting from the upgraded WWTP can be observed.

Nutrient inputs to the estuary from freshwater sources are likely to improve over time due to the implementation of the Nitrates Directive, Water Framework Directive and improved water quality requirements. These, together with improvements at Clonakilty WWTP (including removal of N and P), will lead to overall improvements in sediment and water quality in Clonakilty Estuary and will be in line with the wider objectives of the Water Framework Directive.

7.5.2.2 Macroinvertebrates and wading birds and wildfowl

A European conservation priority is to protect and maintain internationally important populations of migratory shorebirds that over winter on estuaries of north-west Europe. To this end, qualifying sites are designated as SPAs which requires member states to undertake measures to 'preserve, maintain or re-establish a sufficient diversity and area of habitats for all species listed (Article 3). In terms of the Habitats Directive, member states are required to 'take appropriate steps to avoid...the deterioration of natural habitats and the habitats of species, as well as the disturbance of the species, for which the areas have been designated.'

There is thus conflict between (1) the EU Birds and Habitats Directives and (2) the EU Urban Waste Water Treatment Directive (Directive 91/271/EEC) and the Bathing Water Directive (EU Directive 76/160/EEC); the latter aiming to maintain the quality of bathing water and protect public health and the environment. Further the objectives of the Water Framework Directive may be in conflict with the Birds Directive due to the potential impacts on birds as a result of improvements in estuarine water quality.

Estuaries are important for migratory wintering birds because of the abundance of prey (macroinvertebrates) found within the mudflats (McClusky, 1981). Previous research however, suggests there is a potential for negative impacts upon wading birds and wildfowl due to reductions in prey densities brought about by reductions in organic loadings to estuaries. Given that the impacts are likely to vary considerably from site to site, definitive impact prediction is also difficult. Further, there are currently no European or national guidelines that give recommendations for the mitigation of this potential deterioration of intertidal habitats for birds. The Ramsar Convention Bureau made reference to this issue in 1994 and stated that the importance of organically-enriched areas for birds should not prevent the upgrading of treatment in the interests of the wider environment (Ramsar Convention Bureau, 1994) but there are no updated reviews or guidelines. There are also no straightforward or direct measures that can mitigate for a potential reduction in prey density. An example of progressive mitigation would be the use of constructed wetlands that could provide wastewater treatment but also offer potential in terms of wildlife habitat (examples provided in Merritt, 1994). Constructed wetlands are not considered to be an option for the Clonakilty WWTP due to the wastewater load and the extent of area required for the wetlands.

Monitoring of the SPA/SAC is therefore strongly recommended, particularly in relation to the Black-tailed Godwit. As prey density is one of the most important factors determining estuarine bird distribution and abundance, it has been suggested that baseline monitoring of estuarine SPAs should involve monitoring of macroinvertebrate densities and diversity (dit Durrell *et al.*, 2005). However, it is also known that macroinvertebrate densities alone cannot determine how many birds can be supported (Goss-Custard, 2003). A combination of macroinvertebrate sampling, low-tide bird counts with distribution studies and nutrient studies would ensure adequate sampling. A Before-After-Control-Impact study (i.e. both before and after the proposed WWTP upgrade) would be the best approach (e.g. Lewis *et al.*, 2002) in order to assess impacts conclusively.

7.6 RESIDUAL IMPACTS

Clonakilty Waste Water Treatment Plant

Development of additional infrastructure within the site necessarily means some permanent removal of habitats within the site. However as these habitats are considered of low local ecological value (predominantly artificial or managed habitats) the impact is deemed to be imperceptible. If development activities follow the recommendations given and are undertaken with due consideration of the adjacent areas of conservation importance, then residual impacts should be imperceptible.

Long Quay Pumping Station

Habitats within the site of the Long Quay Pumping Station are man-made or managed habitats and are considered of low local ecological value. Development within this site is predicted to have no observable impacts on ecology and therefore no residual impacts are predicted.

Site of the proposed storm water holding tank

This site is a small amenity park that supports a variety of native and non-native broadleaved trees. The development of the proposed storm water holding tank will necessitate the removal of some trees but the site is considered unlikely to have any high value for wildlife. If development activities follow the recommendations given, then some wildlife (e.g. birds) would be expected to return to the site following development and to utilise the remaining available habitat (e.g. trees, vegetated boundary). The residual impacts are predicted to be imperceptible-slight.

The development of the site is expected to lead to the permanent loss of the site as an amenity area.

Impacts on designated sites – Clonakilty Estuary

The proposed upgrade of Clonakilty WWTP and subsequent changes in the organic/nutrient loading to Clonakilty Estuary are predicted to lead to a complex range of positive and negative impacts on the flora and fauna associated with the estuarine ecosystem. Some of these predicted impacts are contradictory e.g. a reduction in nutrient/BOD loading to the estuary, while potentially leading to a reduction in the occurrence of algal mats (over a long-time period) (positive impact), may also lead to a reduction in macroinvertebrate densities (a negative impact upon estuarine birds).

If the proposed development leads to long-term reductions in nutrients (N and P) entering the estuary then reductions in macroalgal blooms (mats) are predicted over time. This could lead to a moderate-major long-term positive impact but is also strongly related to the amount of nutrients entering the estuary from other sources which are largely undetermined. However, nutrient removal during treatment would be a major step in tackling the problem of eutrophication and has a long-term beneficial effect.

Impacts upon wading birds and wildfowl in terms of disturbance during the construction or operation phases, is deemed to be imperceptible - slight. Residual impacts are not expected.

Changes in the organic/nutrient loading to Clonakilty Estuary will result in indeterminable impacts upon macroinvertebrates and wading birds and wildfowl. Current scientific evidence does not allow accurate impact assessment and this document discusses the different possible impact scenarios. Residual impacts are therefore impossible to predict although these may be determined as a result of the on-going monitoring recommended.

7.7 INTERACTIONS

The main interaction of ecology will be with water quality. As discussed in Section 7.4.2, a change in nutrient/BOD loading to Clonakilty Estuary may induce a range of ecological impacts that range from positive to negative depending on the changes that occur in the WWTP emissions. This document has discussed the potential conflicting impacts upon ecology of an improvement in estuarine water quality i.e. improvements may result in a decrease in macroalgal mats (positive impacts upon ecology); improvements may lead to a decrease in macroinvertebrate densities which could result a significant negative impact upon birds. In general however, a reduction in the potential eutrophic status of Clonakilty Estuary is viewed as beneficial to ecology.

The impact of habitat loss in relation to the WWTP site itself, Long Quay pumping station and the site of the proposed storm water holding tank are considered to be imperceptible.

Ecology may interact with noise during the construction phase (See Section 7.4.2.5) whereby some disturbance may be placed upon wading birds and wildfowl. However, the potential impact of noise (during construction) upon birds is predicted to be imperceptible-slight over a relatively short time period.

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8. AIR QUALITY

8.1 INTRODUCTION

This assessment of the anticipated impact on air quality from the development of the proposed upgrade to the Clonakilty wastewater treatment upgrade has been undertaken in accordance with the *Draft Guidelines on the Information to be contained in Environmental Impact Statements* (Environmental Protection Agency, 2002) and also *Advice Notes on Current Practice in the Preparation of Environmental Impact Statements* (Environmental Protection Agency, 2003).

To characterise the existing air quality on the proposed development site and assess the impacts of both the construction and operational phases of the proposed development, the following approach has been adopted:

- Identification of potential pollutants
- Assessment of the impacts of the proposed development for both the construction and operational phases
- Propose mitigation measures to minimise or ameliorate any identified impacts

Details of the receiving environment including the location of the facility are presented in Section 2.0 of this environmental impact statement.

8.2 EXISTING ENVIRONMENT

Based on the preliminary site visit and the nature of the proposed development, it was not considered necessary to undertake a baseline air quality assessment at the Clonakilty wastewater treatment plant. The main impact on air quality arises from odorous emissions from the plant and traffic emissions from cars entering/leaving the plant and travelling along the adjacent N71 national primary road. With regard to odour, it is not common practice to undertake ambient odour sampling to determine baseline conditions due to large variations due to changes in meteorological conditions such as wind speed and wind direction. A more appropriate approach is to assess odorous emissions from the plant by dispersion modelling techniques.

Regarding emissions from traffic, the current volume of site related traffic is considered low with a maximum of five vehicles per day currently entering/leaving the plant. Therefore, the main impact on air quality in this area is from traffic on the N71. However, as the plant is set back 50m from this road, emissions from road traffic will not have an adverse impact at the wastewater treatment plant.

With the exception of odour and based on the location of the wastewater treatment plant, it is considered that the air quality in this area is 'very good' as defined under the EPA air quality index which expresses complex air quality data in simple terms. The index is based on criteria including limit values and assessment thresholds in the relevant EU Directives and comparison with existing European and North American indices. For air quality classified as 'very good', concentrations of the pollutants presented in Table 8.1 are expected at the Clonakilty wastewater treatment plant and hence compliance with the relevant limits as stipulated in the Air Quality Standards Regulations 2002:

Table 8.1: Air Quality Index and Concentrations Ranges for Various Pollutants

Index	SO_2 (ug/m^3)	NO_2 (ug/m^3)	PM_{10} (ug/m^3)
Very Good	0-49	0-36	0-49

The predominant impact of the plant on the local air quality is potentially from odour which may arise as a result of the activities from the water treatment process and sludge dewatering activities.

8.3 ASSESSMENT CRITERIA

The main impact on air quality will arise from odorous emissions from the existing and proposed upgraded plant. Commonly used odour annoyance criteria for the UK, Netherlands, Germany and Ireland are presented in Table 8.2 for different types of industry.

Table 8.2: Odour Annoyance Criteria for Dispersion Modelling

Odour Concentration Limit (ou_E/m^3)	Percentile Value	Application
UK (WWTP, ADMS Model) ≤5.0	98	Used as a planning guideline for the upgrade of WWTP
≤1.5	98	DEFRA Code of Practice on Odour Nuisance from Sewage Treatment Works, 2004
Germany ≤4.0	98	WWTP level at which odour nuisance experienced, Frenchen 1995
Netherlands ≤1.5	98	WWTP existing site, residential dwellings in area
≤3.5	98	WWTP existing site, rural area or industrial estate
Ireland (EPA) (pig, mushroom compost and tanning industry) ISC ST and Complex 1 Model ≤3.0	98	Limit Value for New Facilities
≤6.0	98	Limit Values for Existing Facilities

References: EPA 2001, Frenchen 1995, McIntyre et al. 2000, Newbiggin-by-the-sea planning appeal document

An odour threshold of 1 ou_E/m^3 is the level at which an odour is detectable by 50% of the screened panellists. According to research on wastewater treatment works, the odour recognition threshold is approximately 3-5 times this concentration and is liable to cause offence (3-5ou_E/m^3), (Keddie et al. 1980, Chapter 11 – Dispersion of Odours – A Concise Guide).

In the UK, an odour impact criterion of ≤5.0ou_E/m^3 as a 98 percentile has been unofficially adopted by the wastewater industry as acceptable at the site boundary. This guideline is taken from a landmark planning case for a treatment plant at a seaside resort at Newbiggin-by-the-sea. However, as there is a history odour of complaints at the Clonakilty WWTP, it is recommended that the more stringent odour annoyance criterion of ≤3.0ou_E/m^3 for the 98th percentile at sensitive receptors should be adopted for the purposes of this proposed upgrade.

8.4 POTENTIAL IMPACTS

There are two phases of this development which have the potential to impact on local air quality. These are:

- Construction Phase
- Operational Phase

8.4.1 Construction Phase

8.4.1.1 Generation of Dust

During the construction phase, the main potential impacts on air quality will arise from the generation of dust caused by the movement of construction traffic at the site.

The main sources of dust that may potentially be generated during the construction phase include:

- Stripping of topsoil
- Construction of the primary settlement tanks, aeration tank, the new dewatering house
- Removal of demolition waste
- Excavation, stockpiling and movement of topsoil and subsoil during landscaping
- Construction of temporary hard standing areas
- Soil exposure after re-seeding
- Formation of embankments on the site boundary

The impact of fugitive dust emissions generated from these operations will, to a certain extent depend on surface characteristics, wind direction, wind speed and other meteorological conditions such as rainfall. Dust generation will be greatest during dry windy weather and least during calm wet conditions. Furthermore, the dust effects will be localised and will not to extend beyond the site boundary of the development with mitigation measures in place.

The potential for dust construction impacts is also dependent on the proximity of sensitive receptors. The zone of impact can be reduced substantially with adequate mitigation measures.

8.4.1.2 Construction Related Traffic Emissions

The movement of machinery and construction vehicles during the construction phase will generate exhaust fumes and subsequently contribute to potential emissions of sulphur dioxide (SO_2), oxides of nitrogen (NO_x), carbon monoxide (CO), particulate matter (PM_{10}) and organic compounds. The following additional traffic volumes will be generated during the construction phase:

- A maximum of 40 staff vehicle movements per day. This is based on a workforce of 20 and assuming each person travels to work separately
- The majority of demolition waste will be removed over a two month period and will not exceed 4 HGVs per hour or 40HGVs per day during this period
- The deliveries of broken stone and ready-mix concrete up to a maximum of 4HGVs per hour for short periods of time.

While pollutant concentrations are expected to increase during the construction phase, strict adherence to 'good site/engineering practices' will minimise the generation of any unnecessary air emissions. Notwithstanding this, the level of air pollution generated will be of minimal significance and will occur over a duration of 12 months.

8.4.1.3 Existing WWTP

The Clonakilty WWTP will be fully operational during the construction phase of the proposed upgrade. However, there may be some disruption to the operations. Air emissions are not expected to change during this period.

8.4.1.4 Plant Related Traffic Emissions

It is anticipated at this stage that there will be no change in routine traffic during the construction phase of the project. The existing site traffic entering/leaving the facility is not considered significant and consists of the following vehicles:

- 2 site visits per day from the caretaker
- 2 to 3 visits per week for sludge removal
- 1 visit per fortnight for the removal of screenings
- 2 visits per week for the removal of grit

8.4.2 Operational Phase

8.4.2.1 Proposed Facility

8.4.2.1.1 Main Potential Emissions

Odour will be the main potential emissions to air from the proposed WWTP upgrade. The predominant odour sources, as discussed with the client, are presented in Table 8.3:

Table 8.3: Source of Emissions at the Proposed Facility

Parameter	Source of Emissions
Odour	Odour Control Units 1 and 2 3 No. Secondary Settlement Tanks 3 No. Aeration Tanks

The proposed odour control units will extract and treat odorous air from the various sources detailed in Table 8.4. The type of abatement technology has not been decided. However, the selected technique will be required to remove 98% of the incoming extracted odour.

Table 8.4: Treatment of Odorous Air

Abatement	Plant Treatment
Odour Control Unit 1	Proposed Sludge Dewatering Building Existing and Proposed Picket Fence Thickener
Odour Control Unit 2	Existing and Proposed Inlet Works Proposed Primary Settlement Tanks

To predict the impact of the above emissions from the proposed facility during the operational phase, air dispersion modelling techniques have been used.

AERMOD Dispersion Modelling Package Description

The AMS/EPA Regulatory Model (AERMOD) is the current US EPA regulatory model used to predict pollutant concentrations from a wide range of sources that are present at typical industrial facilities.

The model estimates the concentration or deposition value for each source and receptor combination for each hour of input meteorology and calculates user-selected short term averages. Since most air quality standards are stipulated as averages or percentiles, AERMOD allows further analysis of the results for comparison purposes.

Percentile analysis for emissions is calculated for the maximum averages using the AERMOD-percent post-processing utility. This utility calculates the maximum concentration of a pollutant from all receptors at a specific percentile, for a specific period. Employing the percentile facilitates the omission of unusual short-term meteorological events that may cause elevated pollutant concentrations and hence a more accurate representation of the likely average pollutant concentrations over an averaging period.

The following information was input into the model for the prediction of maximum ground level ambient concentrations of odour from the proposed WWTP upgrade.

Terrain Description

Terrain data was supplied by the Ordnance Survey of Ireland (OSI) in DTM format (X, Y and Z) at 50m intervals. The data was imported into the model and pre-processed using the in-built AERMAP pre-processor for use in the AERMOD dispersion model.

Meteorological Data

Five years of hourly sequential meteorological data (Cork Airport, 1999-2002 and 2004) was used for the AERMOD dispersion modelling assessment. This allows for the determination of the predicted worst case overall impact of emissions from the proposed facility.

Site Map and Cartesian Grid

The site layout map was supplied by the client in dwg format. This was converted to a shp format for import into the model. The map included the site boundary and all relevant buildings and tanks. The boundary, all relevant structures were traced and emission sources were included. The site map was grid referenced, imported into the model and a 50m x, y Cartesian grid receptor constructed with south-west corner co-ordinates Easting 137950, Northing 40250. The total constructed grid size was 2km x 2km.

Sources

The site layout map was used as a template for the source locations, all relevant structures and the boundary of the facility. On-site sources were modelled as either point or area sources.

Point Sources

A point source is one that releases pollutants from a limited opening, such as a stack or vent. The AERMOD package uses the steady state Gaussian plume equation for a continuous elevated point source. The proposed abatement unit outlets were modelled as point sources.

All tanks were modelled as area sources. They are used to model low level or ground level releases with no plume rise. For this type of source, the odour emission rate is defined as the quantity of odour emitted per m^2 of surface area per unit time.

When one or more buildings in the vicinity of a point source interrupt wind flow, an area of turbulence known as a building wake is created. Pollutants emitted from a relatively low level can be caught in this turbulence, affecting their dispersion. This phenomenon is called building downwash. In order to conduct an extensive analysis of downwash effects of all point sources, the dimensions (including heights) of all significant buildings on-site were obtained from drawings supplied by the client and inputted into the model. The downwash effects are determined using the building profile input programme (BPIP-Prime) which is run prior to all modelling runs.

Emission Rate Calculations

The rate of production of a pollutant emission is best quantified as an emission rate. For a chimney or vent, this is equivalent to the odour concentration (ou_E/m^3) multiplied by the air flow rate (m^3/s). It is the mass of odorous pollutant emitted from a source per second and often expressed in ou_E/second.

Odour Emission Rates

Table 8.5 represents the odour sources including odour emission rates at the existing Clonakilty WWTP. All emission data was obtained from published sources detailed below. A worse case emission scenario was implemented i.e. all plant was operational 24 hours a day, 7 days a week.

Table 8.5: Estimated Emission Rate for the Existing Clonakilty WWTP

Source	Exposed Surface Area (m^2)	Specific Odour Emission Rate ($ou_E/m^2/sec$)	Process Emission (ou_E/sec)
Inlet Works	66.1	18 Note 1	2,378
Grit Containers	12	19 Note 2	228
Aeration Tanks (2 of)	660	2.9 Note 1	3,828
Secondary Settlement Tanks (2 of)	227	1.7 Note 2	772
Picket Fence Thickener	50.2	16 Note 2	803
Sludge Lifting Wheel	$25m^2$	Note 3	Note 1
Sludge Dewatering Building	$5.4m^3/sec$	$3{,}500ou_E/m^3$ Note 2	18,900
Sludge Skip	12	4 Note 2	48
Total			34,966

Note 1: Assessment of Odour Emissions from Sewage Treatment Plants, 1989, by T Graafland
Note 2: Published Irish data for Mullingar Sewerage Improvement Scheme EIS, 2002
Note 3: No published data available

Table 8.6 presents the odour emission rates for sources at the proposed upgraded WWTP including odour abatement, the details of which are presented overleaf:

- A second inlet screen/lysep unit will be installed adjacent to the existing one which will double inlet capacity. The entire inlet works will be covered and extracted air will be treated via an odour abatement unit
- A grit classifier will be installed to separate the grit from other materials. The relatively dry grit will be conveyed to an adjacent covered skip and reduce odour to insignificant levels
- A third aeration tank will be installed using diffused aeration technology
- A second picket fence thickener tank will be installed and both tanks will be covered and extracted air will be treated via an odour abatement unit
- The sludge lifting wheel chamber will be replaced by a covered submersible sludge pump sump which will not be an odorous source
- A new purpose built sludge dewatering building will be constructed. Air will extracted from this building and treated through an odour abatement unit
- It is proposed to house the sludge skip within the dewatering building and therefore will be eliminated as an odour source
- It is proposed to install 2 odour abatement control units at the Clonakilty WWTP both with an odour removal efficiency of 98%

- The first abatement unit will extract and treat air from the sludge dewatering building and the existing and proposed picket fence thickeners. It will be located to the south of the site and adjacent to the dewatering building
- The second abatement unit will extract and treat air from the inlet works and proposed primary settlement tanks. It will be located to the north of the site adjacent to the settlement tanks

Table 8.6: Estimated Emission Rate for Proposed WWTP Upgrade with Odour Abatement

Source	Exposed Surface Area (m^2)	Specific Odour Emission Rate ($ou_E/m^2/sec$)	Process Emission (ou_E/sec)
Inlet Works (2 of)	0	-	47.6
Grit Containers	0	-	<5.0 Note 1
Primary Settlement Tanks (2 of)	0	-	45.8 Note2
Aeration Tanks (3 of)	660	2.9	5,742
Secondary Settlement Tanks (3 of)	227	1.7	1,158
Picket Fence Thickener (2 of)	0	-	32.2
Sludge Dewatering Building	$5.4m^3/sec$	2% of original odour emission rate (Table 8.4)	378
Sludge Skip	0	-	0.96
Total			7,405

Note 1: The installation of a grit classifier and covering the skip containing the grit eliminates this as a significant odour source
Note 2: Assessment of Odour Emissions from Sewage Treatment Plants, 1989, by T Graafland

Table 8.6 shows that with the proposed abatement, the predominant odour sources include the aeration and settlement tanks. It is well established that for an efficiently working treatment plant, aeration tanks exhibit an 'earthy' odour which is not considered to be unpleasant. Secondary settlement tanks have a character similar to that of natural sources. Odour emissions from both these sources can be considered a locally raised background concentration i.e. odour treatment part plus background as can occur in the immediate vicinity of a pool or canal.

Input Data

Based on the information presented in Tables 8.5 and 8.6, the following data has been input into the dispersion model to assess the impact of odorous emissions on the receiving environment.

Table 8.7: Modelling Input Data

Odour Source	Emission Rate/Flux	Release Height (m)	Stack Temp. (°C)	Exit Velocity (m/s)	Diameter (m)
Odour Control Unit 1 Note 1	805ou_E/s	8	293	10	0.5
Odour Control Unit 2 Note 2	183.3ou_E/s	8	293	10	0.5
Secondary Settlement Tank (3 of)	1.7ou_E/m^2/s	6	-	-	17.4
Aeration Tanks (3 of)	2.9 ou_E/m^2/s	6.5	-	-	-

Note 1: Proposal to cover, extract and treat air from sludge dewatering building and proposed and existing picket fence thickener
Note 2: Proposal to cover, treat and extract air from inlet works and proposed primary settlement tanks

Results of Dispersion Modelling Assessment

The results of the odour dispersion modelling assessment are presented in Table 8.7:

Table 8.8: Air Dispersion Modelling Results for the Boiler Emission Point

Parameter	Averaging Period	Maximum Predicted Ground Level Concentration (GLCs) ou_E/m^3	Maximum Predicted GLC Location (Grid Reference Points)
Odour	1 hour, (98%)	2.11	139050, 41450

Discussion of Modelling Results

The dispersion modelling has predicted that the proposed upgrade which includes the installation of the proposed abatement units will not have an odour impact above the odour annoyance criterion of ≤3.0ou_E/m^3 for the 98th percentile as illustrated in Figure 8.1. The maximum 1 hour odour ground level concentration of 2.11ou_E/m^3 is predicted to occur approximately 145m to the north east of the plant boundary along the Ring road. The plotted odour concentrations of ≤1.5ou_E/m^3 and ≤1.0ou_E/m^3 for the 98th percentile are approximately circular. There is no ≤3.0ou_E/m^3 contour as the maximum predicted odour concentration is predicted to be below this level. The maximum plume spread in a north-south direction for odour concentrations of ≤1.5ou_E/m^3 and ≤1.0ou_E/m^3 is approximately 430m and 625m respectively. The ≤1.5ou_E/m^3 contour is centred to the north and east of the WWTP and extends south to the Model Railway Village. The ≤1.0ou_E/m^3 contour extends to the houses north-east of the WWTP, to the Model Railway Village to the south and includes part of the GAA pitch to the west. Neither contour extends as far as Clonakilty town to the north-west of the WWTP.

The dispersion modelling assessment has demonstrated that the adopted odour annoyance criterion of $\leq 3.0ou_E/m^3$ for the 98^{th} percentile will not be perceived at any sensitive receptor beyond the plant boundary. Therefore, with the covering and abatement of odorous sources, the impact of odour emissions from the proposed upgraded plant will not be of significance.

8.4.2.1.2 Plant Related Traffic Emissions

When considering the likely environmental effects that an increase in traffic will have on the existing environment, guidelines are provided by the Institute of Environmental Management and Assessment (IEMA). The IEMA Guidelines indicate that a significant impact on the perceptible environment is only likely to occur if there is an increase of 30% in the opening year as a result of the development traffic.

There will be a marginal increase in traffic during the operational phase of the development entering/leaving the proposed upgraded WWTP as shown below:

- 2 site visits per day from the caretaker
- 3 to 4 visits per week for sludge removal
- 3 per month for the removal of screenings
- 1 visit per week for the removal of grit

Based on estimated traffic figures for 2006 detailed in Table 11.1 of Section 11 (Traffic), a total of 1,541 vehicles (including cars, LGVs, HGVs, buses) pass the WWTP over a 12 hour period (07.00 – 19.00). As a worst case scenario, a maximum of 5 vehicles will access the proposed upgraded WWTP which is considerably less than 1% of the total traffic volume along the Inchdoney road.

In summary, the proposed development upgrade will have negligible impact on the receiving environment from traffic emissions.

8.5 MITIGATION MEASURES

To ensure that any impacts arising from the development will not have an adverse affect on the receiving environment, the following mitigation measures for both the construction and operational phases have been proposed.

8.5.1 Construction Phase

8.5.1.1 Generation of Dust

During the construction phase the following dust minimisation measures will be implemented to reduce the potential for dust migration from the site and from construction traffic using public roads. This will involve the following good site/management practices:

- Implementation of a dust minimisation plan to be agreed by all parties prior to commencement of site works
- The use of construction equipment designed to minimise dust generation
- A temporary truck wheel wash will be installed a the entrance/exit to the construction site and all trucks exiting the site will have their wheels and undercarriage washed down to avoid leaving any soil etc. on the public road
- A mobile bowser/dust suppression spray will be used during dry periods to dampen vehicle route ways
- During dry periods, stockpiles of soil and hardcore will be kept moist using rotary sprinkler heads
- Public roads will be regularly inspected for cleanliness and cleaned as necessary
- The use of site speed limits to prevent the unnecessary generation of fugitive dust emissions
- Lorries/trucks will be properly covered or enclosed during transportation of friable construction materials and debris to prevent their escape along public roads
- The contractor will be required to put in dust mitigation measures
- All plant machinery will be regularly maintained and comply with all relevant legislation relating to emissions
- Adherence to good site engineering practices which will assist in reducing dust generation

8.5.1.2 Construction Related Traffic Emissions

Good site practices will be implemented to minimise the emissions from vehicles. It will be requested that all site vehicles and machinery are switched off or throttled down to a minimum when not in use to eliminate any unnecessary emissions.

8.5.2 Operational Phase

8.5.2.1 Plant Emissions

- Cork County Council will comply with all conditions stipulated in S. I. No. 787 of 2005 for the prevention of causing nuisance through odour generation
- A grit classifier will be installed to separate out the grit from other materials. The relatively dry grit will be conveyed to an adjacent covered skip
- The existing and proposed picket fence thickener will be fitted with airtight covers. Headspace air will be extracted through an odour abatement unit (Unit 1) before emission to atmosphere
- The inlet works and proposed primary settlement tanks will be fitted with airtight covers. Headspace air will be extracted through an odour abatement unit (Unit 2) before emission to atmosphere

- A new sludge dewatering building will be constructed. Odorous air will be extracted through an odour abatement unit (Unit 1) before emission to atmosphere
- The dewatering building will include an enclosed sludge storage tank with a 3 day sludge storage capacity
- Introduction of a diffused aeration system in the proposed aeration tank to aid and improve aerobic conditions
- Replacement of the rotors in the existing 2 No. aeration tanks with submersible mixers to improve aeration
- The installation of a selector tank at the west end of aeration tank No. 2 to allow primary effluent and return activated sludge to be combined. This tank will alleviate the current problem of Nocardia foam and hence odour from the secondary settling tanks
- Preparation and implementation of an odour management plan for the plant
- On-site good house keeping and raw material handling practices will be improved
- Control and minimise odours from residual materials and waste
- Screening equipment will be regularly cleaned
- The primary sedimentation process will not be overloaded
- Maintaining the effluent aerated other than in processes that are specifically anaerobic
- Avoiding anaerobic conditions and minimising septicity
- Implementation of an odour complaints register to be integrated into the odour management plan
- Implementation of plant maintenance and inspection programme
- Training of staff having duties relating to the management, operation, maintenance or repair of odour critical processes

8.5.2.2 Plant Related Traffic Emissions

The proposed development will include the following measures to ensure traffic emissions are minimised. These are

- Adherence to site speed limits
- Switching off idling engines or throttling down to a minimum
- Excess or unnecessary revving of engines will not be permitted

In summary, dispersion modelling, used to assess the impact of odorous emissions from the proposed upgraded plant on the receiving environment has predicted ambient ground level odour concentrations below the odour annoyance criterion of $\leq 3.0 ou_E/m^3$ for the 98th percentile and therefore will not be perceived at any sensitive receptor beyond the site boundary.

8.6 INTERACTIONS

Odour emissions from the proposed plant have the potential to interact with human beings. However, emissions are not predicted to be perceived at any sensitive receptor beyond the site boundary. There is a potential risk of negative impact on human beings and habitats from dust generation during the construction phase. However, the implementation of stringent mitigation measures will ensure that any impact will be minimised. Interactions of air emissions with other elements addressed in the environmental impact statement are not relevant.

8.7 REFERENCES

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