Appendix A5.1 Assessment of Potential for Reuse of Treated Wastewater from Proposed Regional Wastewater Treatment Plant

Greater Dublin Drainage

Irish Water

Assessment of Potential for Reuse of Treated Wastewater from Proposed Regional Wastewater Treatment Plant

December 2017

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Glossary of Terms

Black water – wastewaters containing sewage waste.

De facto reuse – a situation where reuse of treated wastewater is, in fact, practiced but is not officially recognised (e.g. a drinking water supply intake located downstream from a wastewater treatment plant [WwTP] discharge point, as is the case with the water treatment plant at Leixlip with supply intake from the River Liffey and the WwTP at Osberstown with discharge to the River Liffey upstream of the water treatment plant)

Direct potable reuse (DPR) – the introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a drinking water treatment plant, either co-located or remote from the advanced wastewater treatment system. DPR is not widely undertaken anywhere at present.

Disinfection – removal of pathogens using inactivation (e.g. ultra violet radiation) or oxidation with chlorine or other chemicals.

Grey water – wastewaters generated from kitchens, dishwashing, laundry activities – i.e. not containing sewage waste.

Indirect potable reuse (IPR) – augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes drinking water treatment. IPR is a common practice worldwide.

Integrated Water Resources Management - as defined by the Technical Committee of the Global Water Partnership "*a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems*."

Non-potable reuse – all water reuse applications that do not involve potable reuse.

Planned reuse – is the deliberate (added in direct or indirect way to the water body) reuse of suitably treated wastewater for specific purposes.

Potable reuse – planned augmentation of a drinking water supply with reclaimed water.

Primary treatment – the first major treatment stage following preliminary treatment usually at a sewage treatment works and usually involving the removal of settleable solids.

Reclaimed water – Municipal wastewater that has been treated to meet specific water quality criteria with the intent of being used for a range of beneficial purposes that would not otherwise occur. The term **Recycled Water** is used synonymously with reclaimed water.

Restricted use – the use of reclaimed water for non-potable applications in (i) municipal settings where public access is controlled or restricted by physical barriers such as fencing, or temporal access restrictions; and (ii) to irrigate crops that are either processed before human consumption or not consumed by humans.

Secondary treatment – the treatment of wastewater, usually after the removal of suspended solids, by bacteria under aerobic conditions during which organic matter in solution is oxidised or incorporated into cells which may be removed by settlement. This may be achieved by biological filtration or by the activated-sludge process. May also be termed ‘aerobic biological treatment’.

Advanced treatment – the additional treatment needed to remove suspended, colloidal and dissolved constituents remaining after secondary treatment. Typically this is the removal of organic matter, suspended solids and nutrients to achieve an enhanced quality treated wastewater for stringent discharge limits or to provide more effective disinfection for industrial application wastewater reuse, recharge of groundwater’s or limiting eutrophication to sensitive water bodies. Processes may include filtration, advanced oxidation, membrane treatment.

Unplanned reuse – occurs when treated wastewater is discharged into a water body and subsequently abstracted for beneficial purposes. However, the given beneficial use is not dependent on the wastewater discharge into the water body. Synonymous with ‘de facto reuse’

Unrestricted use – the use of reclaimed water in applications with no restrictions as quality of the reclaimed water is suitable for all reuse applications.

Water reclamation – the act of treating municipal wastewater to make it acceptable for reuse.

Water recycling – generally refers to reuse of wastewater that is captured and redirected back into the same water use scheme. The term can also refer to reuse of wastewaters generated at water treatment plants – e.g. recycling of filter backwash waters in water treatment. On a wastewater treatment plant, recycling of all side stream flows (e.g. sludge liquors from dewatering) back to the works inlet is required to enable treatment to the desired quality standard.

Water reuse – the use of treated wastewater for a beneficial use, such as agricultural irrigation and industrial cooling – as with water reclamation.

1. Introduction

1.1 Title

The official name of the project is *Greater Dublin Drainage – Regional Wastewater Treatment Plant, Marine Outfall & Orbital Drainage System.*

1.2 Client

Up to 31 December 2013 Fingal County Council (FCC) were progressing the development of the project as the Contracting Authority on behalf of Meath, Kildare, Dun Laoghaire / Rathdown and South Dublin County Councils and Dublin City Council. As of 01 January 2014 Irish Water took over responsibility for the project, are now considered the 'Developer' for the scheme and will continue the progression of the project in line with the planning and legislative requirements identified and set out in subsequent sections of this report.

1.3 Project Engineering Consultant

Following a competitive tender process Jacobs Engineering Ireland Ltd. supported by TOBIN Consulting Engineers was appointed to act as Project Engineering Consultant on this project with formal signing of Contract on the 14th March 2011.

1.4 Project Communications Consultant

Following a competitive tender process RPS Project Communications was appointed by FCC to act as Project Communications Consultant on this project.

1.5 Previous Reference Studies

- Greater Dublin Strategic Drainage Study (GDSDS) completed in April 2005, and
- Strategic Environmental Assessment of the Greater Dublin Strategic Drainage Study (SEA of GDSDS).

1.6 Objectives

The primary project objective is to provide a long-term drainage solution that shall cater for existing & future development in the Greater Dublin Area (GDA) by implementing the recommendations of the Greater Dublin Strategic Drainage Study (GDSDS) Final Strategy and the Strategic Environmental Assessment (SEA) of the GDSDS.

The key objectives of the GDD are to safely deliver through the planning process a:

- Regional Wastewater Treatment Plant (WwTP) and associated marine outfall located at a site in the Northern part of the Greater Dublin Area (GDA), and
- An orbital sewer, associated pumping stations and outfall pipeline linking the regional WwTP to the existing regional sewer network and to provide for future connections for identified developing areas within the catchment.

In April 2013, a review of Fingal's Sludge Management Plan (SMP) was completed which recommended that Fingal develop a single Sludge Hub Centre (SHC) to treat all wastewater sludges arising in Fingal and that this SHC should be co-located with the proposed Regional WwTP. During the development of its National Wastewater Sludge Management Plan (NWSMP) in 2016 Irish Water reviewed this proposal and considered it to provide the most appropriate option for a sludge hub in Fingal. The SHC is an element of the treatment process provided by the proposed WwTP, therefore any further reference to the WwTP includes the SHC.

1.7 Commencement Date

The official commencement date of the project was the 14th March 2011.

2. Background

2.1 Introduction

While Europe is largely considered as having adequate water resources, the last two decades has witnessed growing water stress, both in terms of water scarcity and quality deterioration. Further deterioration of the water situation in Europe is expected if temperatures keep rising as a result of climate change.

Population growth and the competing needs of water users will result in an increase of global water demand of 35 – 60% by 2025. This could double by 2050[1]. These trends will be exacerbated by climate change, with serious implications for food security.

Growing concern of water scarcity and drought in Europe has prompted many municipalities to look for more efficient uses of water resources, including a more widespread acceptance of water reuse practices.

Ireland is also recognised on average as having an abundant supply of water, indeed water abundance is recognised as a strategic resource for Ireland, an attraction for investors and a sustainable competitive advantage (IDA Ireland, 2012; DAFF, 2010).

However, at a regional level water abundance is not the case necessarily. The Demand / Supply balance in the Greater Dublin Area (GDA) Water Supply Area is in deficit as the sustainable production of the existing sources is not capable of meeting the Production Requirement for the area. To address this Irish Water is progressing plans to identify a new major supply source to meet the long term water supply needs of the GDA Water Supply Area. When these plans are realised it is likely to see up to 300Ml/d of water being transferred from a reliable source to augment the existing supply sources in the GDA (Water Supply Area) to meet the water supply needs of the GDA (Water Supply Area) up to year 2050.

The new Regional WwTP proposed for the Greater Dublin Area (GDA) under the Greater Dublin Drainage (GDD) project is projected to have an opening year, 2025, treatment capacity requirement of approximately 438,000PE, rising to c.500,000PE at year 2050[2] with the sequential connection of various sub-catchments and catchment growth considerations.

Dry weather flow (DWF) to the proposed Regional WwTP is projected to be in the order of 98,550 m^3/d at year 2025 rising to 112,500 m^3/d by year 2050. Peak inflow at year 2050 is projected to be c. 281,250m^3/d.

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[1] 2011/2012 European Report on Development. http://ec.europa.eu/europeaid/what/development-policies/research-development/erd-2011-2012_en.htm

[2] Greater Dublin Drainage, Assessment of Domestic and Non-Domestic Load on the proposed Regional WwTP (Dec 2017). Jacobs / Tobin

The Key Wastewater Treatment Standards Report dated December 2017 examined treated wastewater treatment standards in accordance with current legislation and identified that the proposed new works will be required to achieve a secondary treatment level with key quality requirements of 25mg/l Biochemical Oxygen Demand, 125mg/l Chemical Oxygen Demand and 35mg/l Total Suspended Solids[3] prior to discharge via an outfall to the marine environment of the Irish Sea.

During the public consultation periods undertaken to-date for the GDD a number of submissions were received relating to the level of treatment proposed for wastewaters at the Regional WwTP and requesting consideration of the potential for reuse of treated wastewater with specific mention that reuse of treated wastewater from the proposed Regional WwTP could solve the future water needs of the GDA thereby obviating the need to potentially transfer water from the River Shannon.

The Fingal County Development Plan, 2011 – 2017, had a stated objective to *"Consider the discharge from the new Regional Wastewater Treatment Plant for reuse in general industry or the agriculture / horticulture industries"* (Objective WT04).

Following from the above Fingal County Council commissioned Jacobs / Tobin (ref. letter 32102900 dated 21 December 2011) to assess the potential for reuse of treated wastewater from the proposed Regional WwTP.

This report entitled "*Assessment of Potential for Reuse of Treated Wastewater from the proposed Regional WwTP*" seeks to deliver on this commission through consideration of the following:

- Terminology associated with treated wastewater reuse
- Types of reuse applications
- European and Global Policy
- Water Scarcity and use – the case for reuse of treated wastewaters
- Current status of treated wastewater reuse in Europe and globally
- Required quality and technology implications
- Planning and Management Considerations
- Public Acceptance
- Specific assessment of potential for reuse with respect to treated wastewaters from the proposed Regional WwTP.

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[3] On a 95%ile basis, upper tier limits are 50mg/l BOD and 87.5mg/l TSS respectively. Other quality parameters include 125mg/l COD (95%ile) and 250mg/l (upper tier).

3. Categories of Water Reuse Applications

3.1 Introduction

This section provides an overview of terminology associated with wastewater reuse and common types of reuse applications.

3.2 Terminology Associated with Wastewater Reuse

As defined in the ‘Glossary of Terms’ at the beginning of this report **water reuse** is the use of treated wastewater for beneficial use. As such water reuse is the terminology used throughout this report for treated wastewater reuse.

In addition to the general terms defined in the ‘Glossary of Terms’ the terminology outlined in Table 1 is generally used to delineate between categories of water reuse applications.

Table 1: Categories of Water Reuse Applications (source: 2012 Guidelines for Water Reuse, USEPA[4])

Category of Reuse		Description
Urban Reuse	Unrestricted	The use of reclaimed water for non-potable applications in municipal settings where public access is not restricted
	Restricted	The use of reclaimed water for non-potable applications in municipal settings where public access is controlled by physical or institutional barriers, such as fencing, advisory signage, or temporal access restriction.
Agricultural Reuse	Food Crops	The use of reclaimed water to irrigate food crops that are intended for human consumption
	Processed Food Crops and Non-food crops	The use of reclaimed water to irrigate food crops that are either processed before human consumption or not consumed by humans
Impoundments	Unrestricted	The use of reclaimed water in an impoundment in which no limitations are imposed on body – contact water recreation activities
	Restricted	The use of reclaimed water in an impoundment where body – contact is restricted.
Environmental Reuse		The use of reclaimed water to create, enhance, sustain or augment water bodies including wetlands, aquatic habitats, or stream flow.
Industrial Reuse		The use of reclaimed water in industrial applications and facilities, power production and extraction of fossil fuels.

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[4] 2012 Guidelines for Water Reuse, USEPA, EPA/600/R-12/618; September 2012

Category of Reuse		Description
Groundwater Recharge – Non-potable Reuse		The use of reclaimed water to recharge aquifers that are not used as a potable water source
Potable Reuse	IPR	Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes normal drinking water treatment
	DPR	The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a water treatment plant, either co-located or remote from the advanced wastewater treatment system.

3.3 Water Reuse Applications

The major applications in water reuse include for irrigation/agriculture, industrial application, discharge to surface waters, groundwater recharge and indirect potable reuse via discharge to water supply reservoirs, as shown schematically in Figure 1. Table 2 expands on the categories of reuse listed in Table 1 and outlines issues related to their use.

Figure 1: Schematic representation of some treated wastewater reuse applications (Asano et al, 1995)

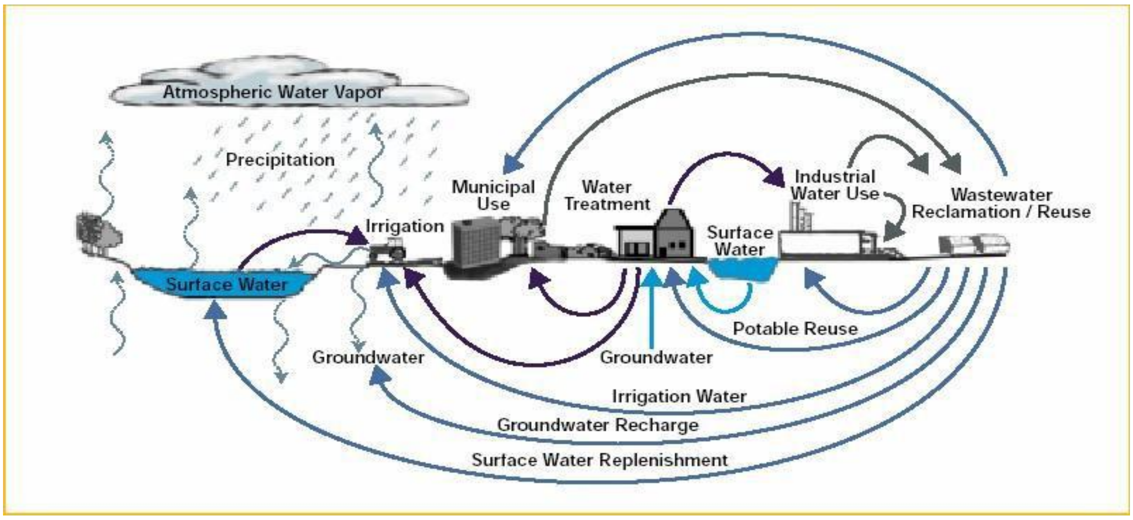

Table 2: Potential applications of water reuse and concerns (Metcalf and Eddy, 2001; AQUAREC, 2006)

Water reuse application	Application	Concerns
Agriculture irrigation	Irrigation of fodder, fibre, seed crops, edible crops, orchards, vineyards, nurseries Irrigation of horticulture	Risk of contamination of surface and groundwater, public health concerns (bacteria, viruses, etc.), marketability of crops, contamination of soils and crops (salts, heavy metals, trace elements, viruses, etc.), storage capacity compatibility with irrigation technique, seasonal demand peaks
Landscape irrigation	Parks, school yards, highway (median strips and shoulders), playing fields, golf courses, cemeteries, greenbelts, residential areas	Risk of contamination of surface and groundwater, public health concerns (bacteria, viruses, organics etc.), contamination of soils (salts, heavy metals, trace elements, viruses, etc.), storage capacity compatibility with irrigation technique, seasonal peak demand
Groundwater recharge	Groundwater replenishment, storage water for future abstraction, saltwater intrusion control (coastal aquifers), control or prevent ground subsidence, provide additional treated wastewater treatment	Contamination of aquifer by chemical and microbiological parameters, land requirements, soil permeability, clogging
Industrial reuse	Cooling water, boiler feed, process water, flue gas wash-down, construction	Scaling, corrosion, biological growth, fouling
Urban reuse (non potable)	Fire protection, toilet flushing, street cleaning, vehicle washing, air conditioning, dust control	Public health concerns (bacteria, viruses, heavy metals, organics etc.), effect of treated wastewater on (a) scaling ,(b) corrosion ,(c) biological growth ,(d) fouling, cross connection of potable and treated wastewater supply, aerosols
Environmental / recreational reuse	Stream flow augmentation (example, rivers), marshes and wetlands, lakes and ponds	Impact to aquatic life, eutrophication, public health concerns (bacteria, viruses, organics etc.)
Direct potable reuse	Water supply reservoirs, water supply mains	Public health concerns (bacteria, viruses, heaving metals, micro organics etc.), aesthetics, public acceptance

The following sections provide additional information for major water reuse applications in order of descending projected volumetric use rates (adapted from Metcalf & Eddy, 2001 p 1352).

(a) Agriculture Irrigation:

Water availability is central to the success of agricultural enterprises with an estimated 60 percent of all the world's freshwater abstractions going towards agricultural irrigation uses. In Europe agriculture accounts for 24 percent of water abstraction[5] and in the United States agricultural irrigation represents approximately 37 percent of all freshwater abstractions (Kenny et al., 2009).

Agricultural use of reclaimed water has a long history and is the most widely used reuse application across the globe (Metcalf and Eddy, 2001). More than 50 countries are involved in agriculture irrigation using treated wastewater (FAO, 2010). The water reuse quality criteria for developing and developed countries are different with a tendency for high water quality requirements in the developed world. The World Health Organisation (WHO) guidelines (WHO, 2006) for irrigation with reclaimed water, widely adopted in Europe and other regions, is a science – based standard that has been successfully applied to irrigation reuse applications throughout the world.

(b) Urban Reuse

Urban reuse applications include recreational field and golf course irrigation, and landscape irrigation. Landscape irrigation is widely used in the USA, Australia, Mediterranean countries and the Middle East. In Europe, golf course irrigation is the most popular reuse application.

(c) Industrial Use:

Traditionally, pulp and paper facilities, textile facilities and other facilities using reclaimed water for cooling purposes, have been the primary industrial users of reclaimed water. Since the mid – 2000's the industrial use of reclaimed water has grown in a variety of industries ranging from electronics to food processing, as well as a broader adoption by the power – generation industry.

The use of water for cooling purposes in energy production is the most water consuming activity, estimated at 44 percent of freshwater abstractions in Europe, and the most widely used application for water reuse for industries (CIWEM, 2007).

(d) Environmental Reuse

Environmental reuse primarily includes the use of reclaimed water to support wetlands and to supplement river and stream flows. Aquifer recharge is also considered environmental reuse.

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[5] The blueprint to Safeguard Europe's Water resources – Communication from the Commission (COM(2012)673)

(e) Groundwater Recharge:

Groundwater recharge to aquifers not used for potable water has been practiced for many years, but has often been viewed as a disposal method for treated wastewater.

Groundwater recharge is a useful application for recovering water levels of streams, aquifers and other water bodies (AQUAREC, 2006). Groundwater recharge can be performed in two ways, through surface spreading via soil (called Soil Aquifer Treatment (SAT)) and subsoil passage or by direct entrance (injection) into the aquifer (AQUAREC, 2006).

Treated wastewater directly injected into the aquifer needs to be of very high standard, as discussed in Section 6. The main benefits include the recharge of groundwater resources and protection of coastal aquifers from saline water intrusion. Groundwater recharge plays an important role in a multi-barrier indirect reuse system as successfully demonstrated on US projects and in Israel, with the percolating of treated wastewater through soil systems providing additional treatment benefits. The quality of groundwater recharged with reused treated wastewater is of potable quality due to the SAT process and the filtration effect from the aquifer in which it is injected (Amy, 2005).

(f) Potable Reuse:

The use of reclaimed water to augment potable water supplies has significant potential for helping to meet future water needs, but planned potable reuse only accounts for a small fraction of the volume of water currently being reused. However, if *de facto* (or unplanned) water reuse is considered, potable reuse is certainly significant to many nations' water supply portfolio. The unplanned reuse of treated wastewater as a drinking water supply is common, with water treatment plants abstracting river waters containing a significant proportion of treated wastewater from upstream communities, especially under low flow conditions, and is widely practiced in Europe in particular for large towns/cities (AQUAREC, 2006). A relevant example of this common practice in the Greater Dublin Area (GDA) is the supply of potable water to north County Dublin by Fingal County Council from their water treatment plant at Leixlip, where water abstracted from the River Liffey contains treated wastewater from Kildare County Council's WwTP at Osberstown, which serves the towns of the upper Liffey catchment including Naas and Newbridge.

Treated wastewater reuse through surface waters is a common practice where public health is protected by water supply standards and river ecology is protected by consent limits on the WwTP treated wastewater. The risks to human health are reduced by dilution, retention time and settlement of contaminants in the river flows (Environment Agency, 2011). The benefit of this improves river flows (particularly during low flows) and allows re-abstraction downstream of the river (ICE, 2006). The treated wastewater quality needs to ensure that there are no adverse effects on the aquatic organisms and ecosystems (AQUAREC, 2006).

(g) Planned Indirect Potable Reuse (IPR)

Planned indirect potable reuse involves a proactive decision by local authorities or water utility companies, to discharge or encourage discharge of reclaimed water into surface water or groundwater supplies for the specific purpose of augmenting the yield of the water supply.

The decision to pursue planned IPR typically involves the following factors (2012 Guidelines for Water Reuse; USEPA):

- Limited availability and yield of alternate sources for water supply
- High cost of developing alternate water sources
- Conscious or unconscious public acceptance
- Confidence in, and some level of control over, both advanced reclaimed water treatment processes and water treatment processes.

In some cases, the level of reclaimed water treatment required to meet water quality standards can be considerable

(h) Direct Potable Reuse (DPR):

Direct potable reuse refers to the introduction of purified water, derived from municipal wastewater after extensive treatment and monitoring to assure that strict water quality requirements are met at all times, directly into a municipal water supply system. The resultant purified water could be blended with source water for further water treatment or could be used in direct pipe-to-pipe blending, providing a significant advantage of utilising existing water distribution infrastructure.

Direct potable reuse is not widely practiced worldwide, mainly due to health concerns. Direct potable reuse is currently practiced in only one city in the world, Windhoek, Namibia where treated wastewater is reused on an intermittent basis (US EPA, 2004). In the USA considerable research and development work has been conducted in the last two decades looking into the potential of direct potable reuse (AQUAREC, 2006).

4. European and Global Policy and Drivers

4.1 Introduction

This section provides an overview of the current legislative and policy drivers for water reuse in Europe and other parts of the world.

4.2 EU Policy and legislation

In Europe, France, Spain, Portugal, Italy, Greece, Hungary and Cyprus are the only countries with national guidelines for specific treated wastewater reuse (*7452-IE-ST03_WReuse_Report-Ed1; 2013*). There are currently no explicit EU wide policy guidelines for the reuse of treated wastewater in the European Union.

There are, however, a number of EU Directives with relevance for reuse schemes including the Urban Waste Water Treatment Directive, the Water Framework Directive and the Surface Water Abstraction Directive. Their relevance is explained below.

4.2.1 Relevant EU Directives

(i) Urban Waste Water Treatment Directive (271/91/EEC)

Article 12 of the Urban Waste Water Treatment Directive states that ‘*treated wastewater shall be reused whenever appropriate’* (European Union Council of Ministers, 1991). The term ‘appropriate’ still lacks legal definition and has been interpreted by the EU countries as per their requirement (FAO, 2010).

(j) Water Framework Directive (2000/60/EC)

The purpose of the EU Water Framework Directive (WFD) is to establish a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater. The Directive requires for EU countries to achieve a ‘good status’ for all European water resources (surface and groundwater) by 2015. It places an emphasis on the hydromorphology, biological and chemical characteristics of watercourses and considers the impacts on these from the *quality* and *quantity* of treated wastewater discharges, with the objective to ensure that these do not compromise the ability of the watercourse to achieve ‘good’ status.

The WFD emphasises the need to integrate health, environmental standards, service provision and financial regulation into the water cycle in order to achieve overall efficiency and protection of the cycle (AQUAREC, 2006).

The concept of integrated water resource management as highlighted in this Directive encourages the integration of water reuse options. This Directive encourages wastewater operating services to investigate water reuse options.

4.2.2 Other EU legislation

Other Directives which may be of relevance are the Nitrates Directive, the Integrated Pollution Prevention Control Directive, the Groundwater Directive, the EU Food Hygiene Regulations, the Bathing Water Directive, the Drinking Water Directive, the Habitats Directive, the Dangerous Substances Directive, the Priority Substances Directive, the Freshwater Fish Directive and the Shell Fish Waters Directive (MWH, 2007; Hochstrat *et al*., 2008).

4.2.3 Way forward – development of EU Policy and Guidelines

In 2006 the AQUAREC project reported on "Integrated Concepts for Reuse of Upgraded Wastewater". This project was funded by the European Commission within the 5th Framework Programme as well as in Australia by the Commonwealth Department of Education, Science and Training. The general objective of the AQUAREC project was to provide knowledge to support rational strategies for municipal wastewater reclamation and reuse as a major component of sustainable water management practices. The project aimed to define criteria to assess the appropriateness of wastewater reuse concepts in particular cases and to identify the potential role of wastewater reuse in the context of European water resources management. Recommendations were for development of European guidelines and increased scale of water recycling to build upon the 200+ municipal water reuse projects currently undertaken in Europe (AQUAREC, 2006).

In 2007 the Mediterranean–EU Water Initiative (Med-EUWI) Wastewater Reuse Working Group issued a major report on Mediterranean Wastewater Reuse.[6] This report assessed the then current knowledge and experience on treated wastewater reuse in the EU and Mediterranean countries, provided an overview of related benefits and risks (economic, social, health related and environmental), outlined applicable EU environmental legislation and legislative frameworks in several countries, highlighted the importance of treated waste water reuse in the EU-Mediterranean region (with a set of 23 case studies) and provided a set of recommendations. The key recommendation of the MED EUWI Wastewater Reuse Working was to develop a commonly agreed European and Mediterranean guidance framework for treated wastewater reuse planning, water quality recommendations, and applications.

In 2006 and early 2007 the EU Commission carried out an in-depth assessment of water scarcity and droughts in the European Union. Following this assessment the Commission presented an initial set of policy options to increase water efficiency and water savings in a Communication from the Commission to the European Parliament and the Council – *"Addressing the challenge of water scarcity and droughts in the European Union"* (COM/2007/0414 final) published in July 2007. The implementation of this Communication is periodically assessed through annual Follow-up Reports.

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[6] (http://ec.europa.eu/environment/water/water-urbanwaste/info/pdf/final_report.pdf).

In 2012 the EU Commission also compiled a study on wastewater reuse in the European Union which reported in April 2012 under the title *“Wastewater Reuse in the European Union”* (EC-reference: 070307/2009/545394/SER/D1)[7]. This report is an updated report based on the Mediterranean Wastewater Reuse Report, November 2007. This report concluded that *“Wastewater reuse is an accepted practice in Europe and the Mediterranean region and in some countries with limited rainfall and very limited water resources has become already an integral effective component of long term water resources management. However, only a limited number of countries developed comprehensive water treatment and reuse standards, provide direction and encourage and finance wastewater reuse programmes”*. The key recommendation of this report was to develop a commonly agreed European and Mediterranean guidance framework for treated wastewater reuse planning, water quality recommendations, and applications

Based on the periodical Follow-up results of the Communication on water scarcity and droughts, assessment of the River Basin Management Plans and further information, a Policy Review for water scarcity and droughts was completed in November 2012, which is part of the *"Blueprint to Safeguard Europe’s Water Resources"* (com(2012) 673) adopted by the European Commission on 14 November 2012.

The *"Blueprint to Safeguard Europe’s Water Resources"* made clear that one alternative supply option — **water reuse for irrigation or industrial purposes** — emerged as an issue requiring EU attention. Reuse of water (e.g. from wastewater treatment or industrial installations) is considered to have a lower environmental impact than other alternative water supplies (e.g. water transfers or desalinisation), but it is only used to a limited extent in the EU. This appears to be due to the lack of common EU environmental/health standards for reused water and the potential obstacles to the free movement of agricultural product irrigated with reused water.

On 17 March 2015 BIO Deloitte (on behalf of the Commission) undertook an impact assessment entitled *“Optimising water reuse in the EU”*[8] to ensure maintenance of a high level of public health and environmental protection in the EU. The outcome of this assessment was that, in theory, legally-binding EU standards on water reuse (Option 2 below) could be implemented either through a Regulation or a Directive.

Four policy options were investigated, including legally-binding and non-binding options:

- **Option 0** is a ‘no policy change’ option or Business As Usual (BAU) scenario with no further EU policy actions to promote water reuse. However, existing EU policy measures aiming to support water reuse would be continued, in particular support to innovation through the

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[7] (http://ec.europa.eu/environment/water/blueprint/pdf/Final%20Report_Water%20Reuse_April%202012.pdf)

[8] http://ec.europa.eu/environment/water/blueprint/pdf/BIO_IA%20on%20water%20reuse_Final%20Part%20I.pdf

European Innovation Partnership on Water, funding of research projects on water reuse and funding of water reuse projects through the European Structural and Investment Funds.

- **Option 1** is a package of non-binding information, communication and knowledge enhancement measures as follows:
    - Development of a harmonised set of definitions and Key Performance Indicators for the reporting of water reuse data across the MS and improved national reporting of reused water volumes through Eurostat.
    - Awareness raising campaigns, development of awareness raising tools and dissemination of information on the various benefits of water reuse, among all key stakeholders.
    - Development of a good practice reference document on water reuse, resulting from a knowledge exchange between MS and other stakeholders, and of guidelines on how to foster water reuse through economic instruments.
- **Option 2** consists of legally-binding EU standards on water reuse, covering uses for which no EU standards currently exist. Three sub-options are proposed:
    - Option 2A. Legally-binding quality criteria – i.e. defining a range of water quality parameters with minimum thresholds that the water produced from a reuse scheme must meet. These quality parameters would be tailored to specific categories of water use such as irrigation of particular agricultural products or non-potable urban uses.
    - Option 2B. Legally-binding risk assessment and management framework – i.e. defining a planning and management process that reuse scheme operators must undertake in order to obtain approval for their schemes.
    - Option 2C. Legally-binding technological criteria – i.e. defining a set of preapproved or certified treatment technologies for reuse schemes.
- **Option 3** consists of a legally-binding requirement for MS to assess the contribution that water reuse can make to address water stress and, if this contribution is significant, to have agreed targets for use of reclaimed water as part of their river basin management plans (RBMPs). Some flexibility would be left to MS in order to take into account the local geographical and socio economic context of their river basin in their decision to set up the targets (e.g. distance between offer and demand).

In October 2016 *"EU-level instruments on water reuse"* [9] by AMEC FW was issued. This report was intended to support the impact assessment of the policy options identified in the BIO Deloitte report of 2015. This report took into account comments received following consultation of the Common Implementation Strategy Ad-hoc Task Group on water reuse. Policy options have assessed against minimum quality requirements at EU level for water reuse in agricultural irrigation and aquifer recharge.

Before a final decision on EU policy can be made, further work is needed on the economic, environmental and social impacts of the final proposal. Policy and Legislation in Rest of World

The first water reuse standards were published in the USA by the California State Health Department in 1933 and California's Title 22[10] treated wastewater reuse guidelines have informed global practice (Vigneswaran and Sundaravadivel, 2004; FAO. 2010).

Treated wastewater reuse standards across the world are influenced by World Health Organisation (WHO) *"Guidelines for the Safe Use of Wastewater, Excreta and Greywater (WHO, 2006)"*[11] and the US EPA *"Guidelines for Water Reuse (EP/625/R-04/108, September 2004)"*[12], which was updated in 2012.

The following sections provide an overview of policy and legislation in a sample of countries from around the world that are in the forefront of water reuse.

(k) USA

Water reclamation and reuse standards in the United States are the responsibility of state and local agencies – there are no federal regulations for reuse. Recognising the need to provide national guidance on water reuse regulations and programme planning, the U.S. Environmental Protection Agency (US EPA) has developed comprehensive, up-to-date water reuse guidelines in support of regulations and guidelines developed by states, tribes and other authorities (US EPA, 2012).

The first US EPA *Guidelines for Water Reuse* was developed in 1980. These were updated in 1992, 2004 and most recently in 2012 *(EPA/600/R-12/618; September 2012)*[13]. The 2012 guidelines serve as a national overview of the status of reuse regulations and clarify some of the variations in regulatory frameworks that support reuse in different states and regions of the United States.

As of September 2012, 30 states and one U.S. territory have adopted regulations and 15 states have guidelines or design standards that govern water reuse (US EPA, 2012).

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[9] http://ec.europa.eu/environment/water/blueprint/pdf/EU_level_instruments_on_water-2nd-IA_support-study_AMEC.pdf
[10] Title 22 of the California Code of Regulations; Regulations related to recycled water (January 2009)
[11] http://www.who.int/water_sanitation_health/wastewater/gsuweg1/en/
[12] http://nepis.epa.gov/Adobe/PDF/30006MKD.pdf
[13] http://nepis.epa.gov/Adobe/PDF/P100FS7K.pdf

For example, the 2008 Florida State Legislature enacted laws that prohibit ocean discharge of treated wastewater by 2025 except as a backup to a reuse scheme. As a result sixty percent of the water currently discharged in ocean outfalls will have to be reused for a beneficial purpose, increasing reclaimed water use in the state by at least 680Mld by 2025 (US EPA 2012).

(l) Australia

Australia is one of the leading countries in the world in the field of treated wastewater reuse. The Government is actively involved in funding treated wastewater reuse schemes. The National Water Quality Management Strategy (NWQMS) produced guidelines for *Use of Reclaimed Water* (2000) and *Water Recycling* (2006). All states in Australia are signed up to a National Water Initiative to improve the country's treated wastewater management system (CIWEM, 2007). Many of the states have developed their own guidelines, e.g. *Guidelines for the Non-potable Uses of Recycled Water in Western Australia*; (Water Unit, Environmental Health Directorate, Government of Western Australia; August 2011).

(m) Japan

In response to the severe water shortage of 1978, Japan began reusing treated wastewater as an important water resource in urban areas, starting with reuse for toilet flushing in Fukuoka City in 1980. Since then, treated wastewater has also been used for snow melting, environmental and industrial use, sprinkling, etc. In April 2005 the Ministry of Land, Infrastructure and Transport (MLIT) instituted the Guidelines for the Reuse of Treated Wastewater (MLIT, 2005). Japan also has a publicly funded research and development organisation which is called 'Water Reuse Promotion Centre' which supports treated wastewater reuse and desalination technologies (CIWEM, 2007).

(n) Israel

Israel has put wastewater reuse high on its list of national priorities. This is due to a combination of severe water shortage, threat of pollution to its diminishing water resources and a concentrated urban population with high levels of water consumption and wastewater production. Treated wastewater is seen as an integral part of the water resources of the country. National policy calls for the gradual replacement of freshwater use in irrigation with treated wastewater. Treated wastewater used for irrigation must meet water quality criteria set by the Ministry of Health. Today, more than 75% of Israel's municipal wastewater is reused in agriculture irrigation. The objective is to treat 100% of the country's wastewater to a level enabling unrestricted irrigation in accordance with soil sensitivity and without risk to soil and water sources.

(o) Singapore

In order to achieve a sustainable and robust water supply to meet increasing water demand, Singapore has developed a water resources strategy called the 4 National Taps, which consists of the following four elements:

1. Imported water from Malaysia,
2. Local catchment water
3. NEWater
4. Desalinated water

NEWater, a high grade reclaimed water of drinking water standard, is seen as the key to achieving water sustainability in Singapore. NEWater is produced from treated wastewater that is purified further using advanced membrane technologies and ultraviolet disinfection. The U.S. EPA Primary and Secondary Drinking Water Standards (Safe Drinking Water Act) and WHO Drinking Water Quality Guidelines are the benchmarks set for NEWater quality.

In 2012, NEWater was supplied from five NEWater factories in Singapore, with total capacities of 554,600 m^3/day. The total capacity is projected to reach some 873,000 m^3/day by 2020. NEWater is mostly used for direct non-potable use in the wafer fabrication and electronic industries as well as in commercial and institutional complexes for air conditioning cooling purposes. In addition, NEWater supplements Singapore’s potable water supply via planned indirect potable use, where NEWater is blended with raw water in reservoirs and then subjecting the blended water to the same conventional water treatment process as raw water to produce potable water. (H. Seah & C.H. Woo; 2012)

5. The Case for Water Reuse in Europe

5.1 Introduction

While Europe is by and large considered as having adequate water resources, water scarcity and drought is an increasingly frequent and widespread phenomenon in the European Union. The long term imbalance resulting from water demand exceeding available water resources is no longer uncommon.

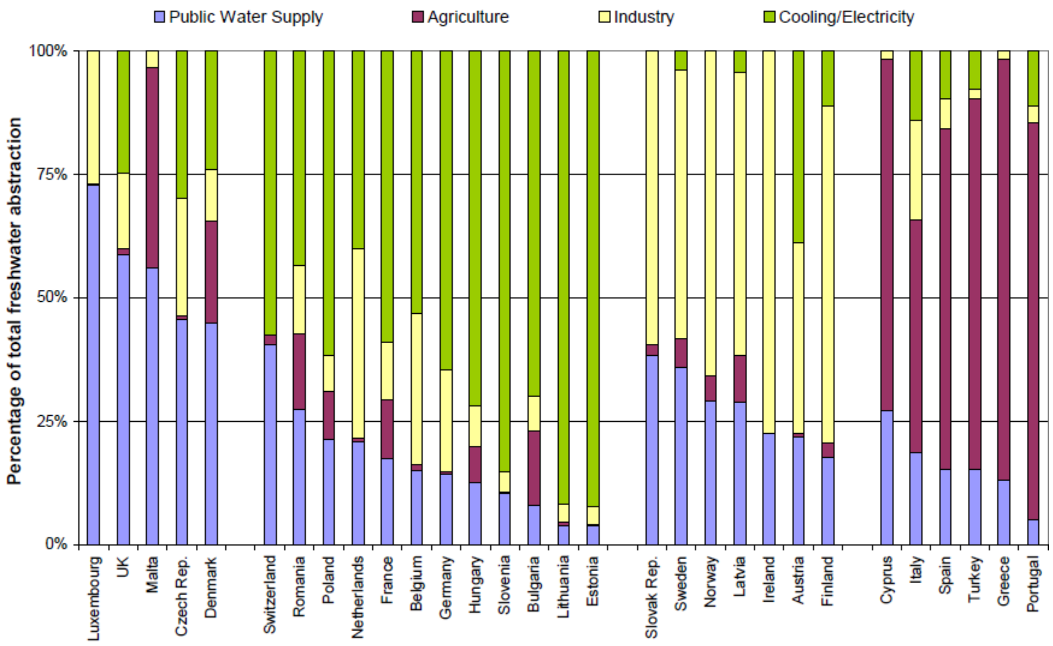
It was estimated that by 2007, at least 11 % of Europe's population and 17 % of its territory had been affected by water scarcity, putting the cost of droughts in Europe over the past thirty years at EUR 100 billion. The Commission expects further deterioration of the water situation in Europe if temperatures keep rising as a result of climate change. Water is no longer the problem of a few regions, but now concerns all 500 million Europeans (EU Commission).

This section provides an overview of water use and scarcity in Europe, identifying broad needs and opportunities for water reuse.

5.2 Water use

The following Figure 2 shows the percentage distribution of water abstraction for various applications in European countries:

Figure 2: Percentage application of sectoral water use for various applications in Europe (Source – AQUAREC, 2006 – figure 1.1).



Ireland's water use is notable in its significant water demand for industry and little or no requirement for agricultural water use. Requirement for cooling/electricity generation is reportedly nil for freshwater abstraction which is unlikely the case and the Irish Academy of Engineering note in their review *Adaptation for Climate Change – Critical Infrastructure* the need to consider the continuing use of water for energy (IAE, 2009). This is best explained by the lack of detailed information and breakdown of water used in Ireland. Since the introduction of non-domestic metering, the collection of this information is gradually improving.

5.3 Water Scarcity and Regional considerations

The ratio of water abstraction to total renewable freshwater resources of a country is represented as the *water stress index*. The lower the water stress index, the lower the risk of over exploitation of water resources and vice versa. Table 2 provides a summary of the index for selected European countries.

Table 2: Water stress index in Europe (Hochstrat et al., 2006a)

Country	Water stress index
Ireland, Norway, Sweden, Finland, Austria	<5%
UK	5 – 10%

France, Greece, Portugal, Poland, Denmark	10 – 20%
Italy, Germany, Spain	20 – 30%
Greece, Belgium, Malta, Cyprus	40 – 60%

The water stress index if less than 10% is considered low, 10 - 20% indicates that water availability is becoming constrained while greater than 20% indicates that necessary measures (for example, increase treated wastewater reuse) are required for balancing supply and demand of water resources (Hochstrat *et al*., 2006a).

Ireland is recognised on average as having one of the lowest water stress indices and indeed water abundance is recognised as a strategic resource for Ireland and a sustainable competitive advantage (IDA, 2012; DAFM, 2010).

However, at a regional level water abundance is not the case necessarily and modelling work in 2008 by Forfas in their study *'Assessment of Water and Waste Water Services for Enterprise'* notes the following with respect to Ireland:

- Areas forecast to have a water supply shortage by 2013 are Athlone, Dublin, Galway and Letterkenny.
- These cities and towns are also forecast to face shortages of wastewater treatment in 2013, along with Mallow and Wexford.

Recent work by Engineers Ireland and others recommends that bulk water transfer mechanisms be established to enable regional sharing to manage deficits (Engineers Ireland et al., 2010). Work is currently ongoing on the Water Supply Project for the Dublin Region.

Likewise, despite the UK rating in water stress index, the index is not regional specific and drought conditions have been experienced in Southern England in recent times, most recently in 2012 when drought was declared for more than half the UK population (Telegraph View, April 16 2012).

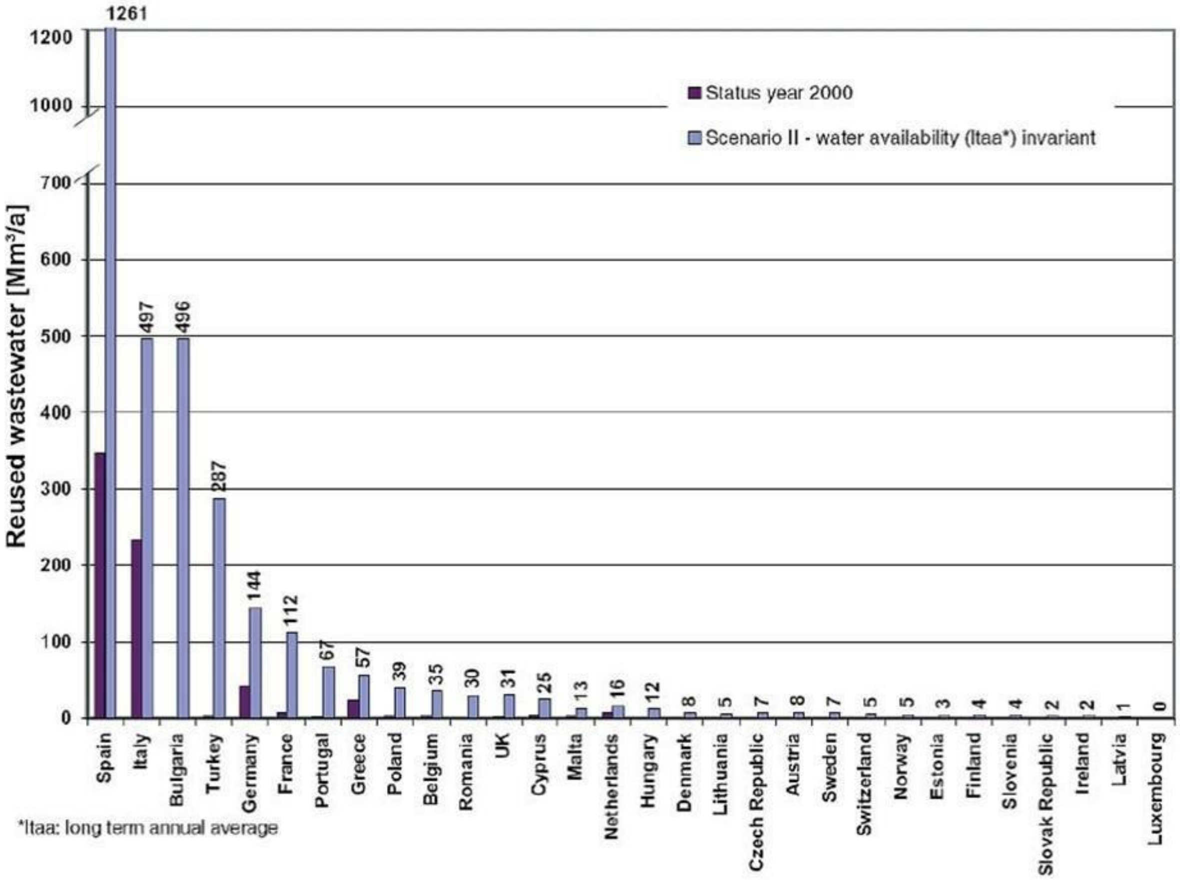
In addition, climate change in Europe has impacted agriculture and freshwater ecosystems and has also contributed to droughts which will impact on water use and reuse considerations (Monte, 2007). Studies on future climatic trends for Europe suggest that temperatures may increase in the range of between 1ºC to 3.5ºC by 2100 (Monte, 2007). Irish predictions for 2050 are for between 1.4 to 1.8ºC with a likelihood of wetter winters and drier summers (Murphy & Fealy, 2009).

Viewed as 'water rich', Ireland may increasingly be seen as a source of water for growing water intensive crops by other water stressed and climate change affected countries, necessitating demand reduction through pricing policies, conservation, harvesting and reuse of non-potable water (Phillips, 2009).

5.4 Projected Treated Wastewater Reuse in Europe

Recent modelling work on an EU funded project has predicted the potential water reuse in Europe for 2025, which is illustrated in Table 3 below.

Table 3: Model output for wastewater reuse potential of European countries on a projection horizon of 2025 (Scenario II), from the AQUAREC project



This modelling work indicates that Spain has the highest water reuse potential for the future, mainly driven by limited water resources availability. The limited or low potential water reuse volumes indicated for Northern Europe and Ireland is mainly due to low demand for water reuse due to the significant amount of freshwater availability.

Again, this looks at a country wide basis and is not regional specific but does not identify Ireland as a country with significant potential for water reuse.

6. Current Status of Water Reuse

6.1 Introduction

As reported by the European Union of National Associations of Water Suppliers and Wastewater Services (EUREAU), the EU depends on the appropriate treatment of wastewater to enhance surface and groundwater resources so that the water can be reused through abstraction for agricultural, industrial or potable uses – and in highly developed regions of the EU many cities rely on **indirect potable reuse** for up to 70% of their potable resource during dry summer conditions (EUREAU, 2004). Indirect potable reuse of treated wastewaters is a common occurrence in Ireland.

The following table summarises the percentage of treated wastewater reused in some countries through dedicated reuse schemes (potable or non-potable planned reuse).

Table 4: Percentage of treated wastewater reused as a share of the total treated wastewater produced (AQUAREC, 2006; Choukar-Allah, 2010; Miller, 2011)[14]

Country	% of treated wastewater reused of total treated wastewater produced
USA	6%
Australia	8% and aiming for 30% by 2015
Kingdom of Saudi Arabia	16% and aiming for 65% by 2016
Singapore	30%
Malta	60%
Israel	>70%
Jordan	85%
Spain	13%
Italy	9%
Greece	5%

Currently, there is no significant degree of dedicated water reuse schemes in Ireland.

This section provides a selected summary of the current state of water reuse in Europe and globally.

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[14] Some values have been derived from graph and approximate.

6.2 European Experience

(p) Ireland

In Europe, with the exception of northern European countries, Ireland has the largest freshwater availability reserves in m^3/head/annum (Angelakis and Bontoux, 2001). This indicates that there are abundant amounts of fresh water resources available in the country; however local deficits are likely to exist for the Dublin Region and other areas (Forfas, 2008).

There are no standards proposed by the Environmental Protection Agency (EPA) for treated wastewater reuse (EPA, 2007).

In recent work on Irish Water reform and supporting studies, key recommendations focus around prioritised investment to accommodate commercial and domestic population growth, reduction of unaccounted for water levels, more effective management on a river basin district basis and introduction of water charging schemes rather than reuse considerations (DoECLG, 2012; Forfas, 2008).

The Department of Agriculture, Food and Marine (DAFM) in 2010 produced a policy document *'Food Harvest 2020 - A vision for Irish agri-food and fisheries'* which recommends funding under the National Development Plan for 'green technology' uptake and the consideration of Water Recycling amongst other options for the horticultural industry (DAFM, 2010). However, there is no evidence of any current water reuse schemes in practice.

Although there is a general absence of dedicated water reuse schemes in the country there is no doubt that a significant degree of unplanned indirect potable, agricultural and industrial reuse occurs already (DoECLG, 2010) as the majority of drinking water in Ireland originates from rivers, reservoirs and lakes (82%).

An example of a recently commissioned dedicated water reuse scheme is outlined below (Celtic Anglian Water, 2012):

- A small water reuse scheme at Ringsend WwTP was commissioned in November 2012 by the plant operator, Celtic Anglian Water (CAW), to replace potable water with treated wastewater in the operation of their industrial processes. The process involves extracting feed water (c. 600m3/d) from the outlet channel and filtering the water to a higher standard using Ultrafiltration (UF) membrane technology and additional Reverse Osmosis (RO) treatment for boiler feed water.

(q) UK

In the UK historically, there have been sufficient water resources available to meet the demand, therefore only a small number of water reuse schemes have been implemented to-date. However, due to prolonged dry periods observed in the last few years, there is now increasing pressure on water companies to evaluate water reuse options.

In June 2011, the Environment Agency released a position statement[15] on water reuse for potable supply, noting significant unplanned indirect water reuse schemes are already in place, advocating indirect potable reuse instead of large scale infrastructure projects and supporting direct water reuse for industrial applications, reducing pressure on potable supplies.

Water companies and in particular those in the south, are considering water reuse as a part of their long-term water resource plans which are to be implemented over the next 10 years (ICE, 2006). There are some examples of water reuse on golf courses, parks, car washing, industrial use, cooling water and road verges (MWH, 2007).

Current examples include (CIWEM, 2007; MWH, 2007, Ilias *et al*., 2012):

- Flag Fen WwTP provides tertiary/advanced treatment to comply with stringent treated wastewater quality limits. The tertiary/advanced treatment includes microfiltration followed by reverse osmosis. About 1,600 m^3/d of treated wastewater is supplied to Flag Fen power station (Peterborough). The treated wastewater is used for producing steam to drive the combined cycle gas turbine plant; and
- Langford Advanced WwTP, treating 40Ml/d, was specifically upgraded with microfiltration and UV disinfection to improve existing treated wastewater discharged from Chelmsford WwTP and to augment river flows upstream of the Hanningfield abstraction. The Hanningfield catchment reservoir provides raw water for potable water treatment and supply – so this reuse application enables indirect potable reuse.

(r) Belgium

Belgium has a high water stress index as shown in Table 3, Section 5 above which is mainly contributed to by prolonged dry periods during the summer. The government is keen to reduce groundwater abstraction and stimulate water reuse. (Monte, 2007). The most important reuse project is located in Wulpen where treated wastewater is reuse for indirect potable water supply (EPA, 2004).

- Wulpen WwTP currently treats 2.5M m^3/annum with tertiary/advanced treatment including microfiltration and reverse osmosis (Monte, 2007). The treated wastewater is injected into an aquifer, to recharge the aquifer, where it is stored for 1-2 months before being abstracted for potable water use – with further treatment required dependent on ground water quality. In addition to water resources

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[15] See the EA Position Statement June 2011 at http://publications.environment-agency.gov.uk/PDF/GEHO0811BTVT-E-E.pdf

augmentation this project provides added environmental benefit in that it provides a hydraulic barrier to saline intrusion into the aquifer.

(s) Spain

Over 70% of treated wastewater in Spain is reused for irrigation/agriculture purposes. Spain is one of the countries in Europe with limited freshwater availability resources. The country has a National Hydrological Plan which encourages the use of treated wastewater for irrigation purposes (Angelakis and Bontoux, 2001).

Current examples include (FAO, 2010):

- Saint Feliu de Llobregat WwTP wastewater is treated to a tertiary level including salinity reduction in a conventional WwTP and is capable of providing 19M m^3/annum of treated wastewater to Canal de la Dreta for irrigation purposes. The treated wastewater is mixed with well water to improve water quality. Treated wastewater reuse only takes place when there is freshwater deficiency. In recent years the water reuse has expanded to include ecological protection, wetland recharge and anti-saline intrusion barrier; and
- Crispijana WwTP (as a part of Vitoria-Gasteiz recycling plan) with filtration and disinfection produces 32M m^3/annum of treated wastewater flows. The treated wastewater is discharged into the river Zadorra, which is used for irrigation purposes.

(t) France

In France interest has grown in water reuse for irrigation in the last few years as the water table has dropped to low levels during prolonged dry summer months. Sainte Maxime WwTP includes advanced treatment comprising filtration, UV and chlorine disinfection and provides up to 10,000m^3/d of treated wastewater for irrigation of golf courses and landscaping (EUWI, 2007).

(u) Italy

Like other Mediterranean countries, Italy suffers from water shortages during the summer months. Southern Italy (particularly Sicily, Sardinia, and Puglia) suffers from water shortages and lacks good quality water sources due to recurring droughts (Barbagallo *et al*., 2001). In 2001 it was reported that 2,400M m^3/annum of treated wastewater was of acceptable quality and could be reused (Angelakis and Bontoux, 2001). In 2001 there were about 16 water reuse projects for producing treated wastewater of suitable quality for the purpose of irrigation (Barbagallo *et al*., 2001).

Current examples include (US EPA, 2004):

- *In Emilia Romagna over 1,250 m^3/d of treated wastewater from the towns of Castiglione, Cesena, Casenatico, Cervia, and Gatteo are reused for irrigation; and*

- *Part of Turin WwTP treated wastewater undergoes advanced treatment (filtration and chlorination) for agricultural and industrial reuse.*

6.3 Rest of the World

(v) USA

Water reuse is practiced widely throughout much of the United States and there is a wide variety of types of application (US EPA 2012). The states of California, Florida, Arizona and Texas produce 90% of the total water reuse in the USA while it is increasing in other states (Miller, 2011). Florida is the leading state in water reuse contributing 49% of the treated wastewater reused in the country (US EPA, 2012).

Research studies on direct potable water reuse is on the rise and more efforts are being made for biologically treated wastewater receiving advanced treatment (microfiltration, reverse osmosis and disinfection) to discharge directly into reservoirs (AQUAREC, 2006). Denver (Colorado), Tampa (Florida) and San Diego (California) are actively involved in research and development work for direct potable treated wastewater reuse.

Appendix D of the US EPA *2012 Guidelines for Water Reuse* contains 68 sample case studies on reclaimed water projects across the U.S. to illustrate the wide variety of water reuse applications currently underway in the U.S., which include, as a sample, the following projects:

- Orange County of southern California is injecting advanced treated wastewater for groundwater replenishment. This is the largest groundwater replenishment scheme in the world;
- Orlando Eastern Regional Reclaimed Water Distribution System provides public access reclaimed water to residential, commercial and industrial users in the city of Orlando, Seminole County, Orange County, the city of Oviedo and the University of Central Florida (UCF);
- Denver Zoo uses recycled water for irrigation, enclosure washing and animal swimming pools;
- Big Spring, Texas is the first water reuse project in the U.S. to directly blend reclaimed water from the Big Spring WwTP with raw drinking water supply in the raw water transmission pipeline to the Big Spring Water Treatment Plant. Reclaimed water will represent up to 15 percent of the blended waters in the pipeline network.

(w) Australia

Australia is one of the leading countries in the world in the field of treated wastewater reuse. An estimated 150,000 – 200,000 Ml of treated wastewater is reused for various applications every year (MWH, 2007). The Mediterranean type climate regions of Australia have set a target of 20% treated wastewater reuse while arid regions set a target of a minimum of 50% treated wastewater reuse by 2012 as the country has encountered frequent drought periods (EUREA, 2004). The majority of schemes are for non-potable use (MWH, 2007) and are located in New South Wales, Queensland, Southern / Western Australia and Victoria. Current examples include (CIWEM, 2007; MWH, 2007):

- Treated wastewater from Kurnell WwTP is providing around 6 Ml/d of reclaimed water to Caltex refinery and Continental Carbon Australia.
- Treated wastewater produced from Fyshwick WwTP is further treated at North Canberra water reuse facility which is then pumped to the receiving water body and then abstracted downstream to Lower Russell Hill reservoir.
- Olympic park in Sydney Olympic Games reused treated wastewater (2.2 Ml/d capacity with advanced treatment) and storm water for non potable purposes.

(x) Japan

Buildings with floor space exceeding 3,000m^2 in Fukuoka city and 30,000m^2 in Tokyo are mandated to provide a treated wastewater reuse system (Gaulke, 2006). Water reuse for non-potable purposes is popular and widely adopted in the cities of Tokyo, Fukuoka, Yokohama and Sapporo (MWH, 2007). About 150,000ML per annum is recycled for environmental use (MWH, 2007).

(y) Middle East and Arab countries

Jordan, Tunisia and GCC (Gulf Cooperation Council) countries (Saudi Arabia, Oman, Qatar, Bahrain, UAE, and Kuwait) are the leaders in the Arab world for treated wastewater reuse (Choukr-Allah, 2010). Irrigation accounts for most of the treated wastewater reuse.

Current examples include:

- Jordan - Wastewater represents 10% of Jordan’s total water supply and up to 85% of its treated wastewater is being reused (Choukr-Allah, 2010);
- Tunisia – There are about 61 wastewater treatment plants producing 240 billion m^3 of wastewater, of which less than 30% is reused for irrigation (Choukr-Allah, 2010);
- In the GCC countries, about 40% of treated wastewater is used for irrigation purposes for landscaping, non-edible crops and fodder (Choukr-Allah, 2010);
- In Kuwait, the Sulaibiya WwTP provides reverse osmosis and ultrafiltration treatment to produce up to 375,000 m^3/d of treated wastewater for reuse (EUWI, 2007); and
- The Dan Region project in Israel is a large scale application of the soil aquifer treatment (SAT) for injecting treated wastewater into the ground water (AQUAREC, 2006).

(z) Central and South Africa

Water reuse is limited with only three countries (South Africa, Namibia and Zambia) accounting for reuse of treated wastewater (MWH, 2007).

Current examples include:

- Namibia – The first country in the world where treated wastewater is reused for direct potable water supply in the city of Windhoek; and
- South Africa – Durban water recycling project provides 7% of Durban with treated wastewater via advanced treatment (filtration, ozonation, granulated carbon filters, chlorination) for water reuse at a paper mill and refinery (EUWI, 2007).

(aa) Singapore

The Government initiative programme, 'NEWater' supports water reuse with significant indirect potable and industrial reuse occurring. Distribution of bottled water in direct potable reuse also takes place to improve public awareness and acceptance. A high public profile of the schemes and large public participation schemes has ensured the perception of reuse is positive and the public are actively involved.

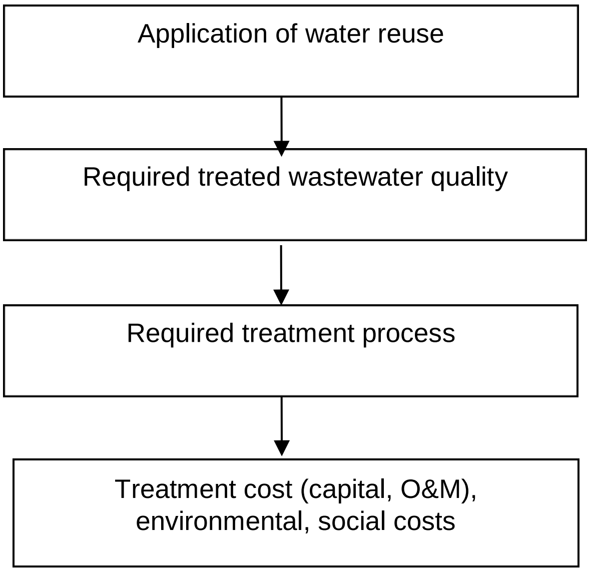
7. Required Quality, Technology and Cost Implications

This section provides a background to the considerations made in assessing the feasibility of a water reuse project with regards to treated wastewater quality required, the treatment processes necessary and the cost implications to achieve this.

7.1 Introduction

The feasibility of a water reuse application requires consideration of suitable demand for water, required water quality standards, required treatment processes to achieve the required water quality standards and the resulting cost assessments as presented below in Figure 3.

Figure 3: Main stages of water reuse feasibility study (Adapted from Sipala et al., 2003)



7.2 Treated Wastewater quality considerations

When considering treatment technologies for reuse applications, the key objective is to achieve a quality of reclaimed water that is appropriate for the intended use and is protective of human health and the environment. Secondary objectives for reclaimed water treatment are directly tied to the end application, and can include aesthetic goals (e.g. additional treatment for colour or odour reduction) or specific user requirements (e.g. salt reduction for irrigation or industrial reuse) (US EPA Guidelines for Water Reuse, 2012).

Protection of public health is achieved by

- Reducing or eliminating concentrations of pathogenic bacteria, parasites, and enteric viruses in reclaimed water;

- Controlling chemical constituents in reclaimed water; and
- Limiting public exposure (contact, inhalation or ingestion) to reclaimed water.

7.2.1 Treatment required to achieve reuse standards

A wide portfolio of treatment options exists to mitigate microbial and chemical contaminants in reclaimed water and meet specific water quality goals (NRC, 2012).

Wastewater treatment is commonly classified into the following levels:

- Preliminary treatment – inlet screening, grit removal from incoming raw sewage;
- Primary treatment – solids settlement in primary settlement or septic tanks;
- Secondary treatment – carbonaceous treatment (removal of solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD)) by biological treatment; can be with or without nutrient removal (removal of nitrogen, phosphorus);
- Tertiary treatment – used to describe common sewage treatment processes downstream of secondary treatment – these are nutrient removal or media filtration to achieve further solids/organic reduction;
- Advanced treatment – used to describe treatment processes commonly used for reuse schemes which may be downstream of conventional sewage treatment (e.g. advanced oxidation, activated carbon filtration, membrane filtration) or in place of conventional sewage treatment (e.g. membrane bioreactor MBR);
- Disinfection – UV or chlorination to achieve pathogen reduction.

The required level of treatment for discharge of treated wastewater to marine, estuarine or freshwater watercourses is determined by the licensing procedure depending on quality objectives in relevant legislation. This typically requires quality parameters to be met for biological and chemical constituents. Except where bathing water standards apply, microbiological parameters are typically not applied.

Table 5 provides a general summary of treatment required for achieving a particular water reuse target application for both agricultural and non-agricultural reuse. As different reuse options require different quality treated wastewater, particularly for industrial reuse, the required treatment must be determined on a case by case basis and the following provides some examples only.

Table 5: Types of reuse appropriate for level of treatment provided (adapted from US EPA, 2012; AQUAREC, 2006)

Treatment Processes	Possible reuse application
Preliminary or Primary treatment (sedimentation)	No reuse application recommended.
Secondary treatment for carbonaceous removal only[16]	Very limited reuse applications. Discharge to coastal waters by marine outfall with no bathing water or nutrient sensitive zones. Limited reuse for industrial applications. Suitable for some industries and may be used in power station cooling towers.[17]
Secondary treatment with nutrient removal	*All above applications and,* Indirect reuse for environmental purposes by discharging to water body (rivers) to augment surface flows, marshes and wetlands, wildlife habitat.
Secondary treatment with or without nutrient removal followed by disinfection[18]	*All above applications and,* • Restricted landscape impoundment, for aesthetic purposes, where public contact with the impounded water is not allowed; • Groundwater recharge of non-potable aquifers; • Restricted access area irrigation, where public access is prohibited or restricted or infrequent; • Surface irrigation of food crops commercially processed**[19]**, e.g. orchards and vineyards; • Surface irrigation of non-food crops, e.g. pasture for milking animals, fodder, fibre and seed crops; • Soil compaction, dust control, washing aggregate, concrete making • Industrial reuse dependent on reuse application

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[16] Secondary treatment refers to activated sludge type processes or submerged attached growth processes. The treated wastewater achieves BOD of < 25 mg/l and TSS < 35 mg/l.

[17] Example of reuse: Seabank Power Station in Avonmouth uses Bristol WwTW treated wastewater (secondary treatment with carbonaceous removal only) for cooling tower.

[18] Disinfection may be accomplished by chlorination, UV, ozonation, membrane or other processes. Minimum chlorine residual maybe required for some treated wastewater reuse applications.

[19] Commercially processed food crops are those which have undergone chemical or physical processing in order to destroy pathogens.

Treatment Processes	Possible reuse application
Secondary treatment with or without nutrient removal followed by tertiary filtration and disinfection[20]	*Dependent on type of filtration (e.g. media or membrane) - all above applications and,* • All types of landscape irrigation, golf courses, parks, cemeteries, vehicle washing, toilet flushing, fire protection systems, and other uses with similar access or exposure to the water • Agriculture reuse – food crops not commercially processed including crops eaten raw • Unrestricted recreational impoundment - Incidental (fishing, boating) or full body contact • Industrial reuse - dependent upon industrial reuse application.
Secondary treatment with nutrient removal followed by tertiary filtration, disinfection and advanced treatment[21]	*All above applications and,* • Groundwater recharge of potable aquifer (potentially by direct injection into the aquifer if treated wastewater is of drinking water quality). • Direct potable reuse • Industrial reuse

It is evident from the above table that increasing the level of treatment provided increases the acceptable level of human exposure in reuse applications. However, increasing the level of treatment also increases the levels of cost. Therefore to make reuse cost-effective, the level of treatment must be “fit for purpose”.

Regardless of the reclaimed water use, whether irrigation, IPR, potable reuse or car washing, the most critical treatment objective is pathogen inactivation. The reclaimed water must not pose an unreasonable risk due to infectious agents if there is human contact, which could occur by contact or ingestion (US EPA Guidelines for Water Reuse; 2012).

While the potential human health impacts of reclaimed water is the subject of ongoing research, (e.g. WRRF project 10-07, *Bio-analytical Techniques to Assess the Potential Human Health Impacts of Reclaimed Water,* currently in preparation), additional discussion specific to risk assessment methods

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[20] Disinfection may be accomplished by chlorination, UV, ozonation, membrane or other processes. Minimum chlorine residual maybe required for some treated wastewater reuse.

[21] Advanced wastewater treatment processes include chemical clarification, carbon adsorption, microfiltration, ultrafiltration, reverse osmosis, advanced oxidation and possibly require air stripping and ion exchange. Reverse osmosis is commonly required.

and tools specific to water reuse and exposure to reclaimed water are provided in other recent research reports (WRRF, 2007b; 2010a)

7.2.2 What constituents are present in Wastewater

Untreated municipal wastewater contains a range of constituents, from dissolved metals and trace organic compounds to large solids such as rags, sticks, floating objects, grit and grease. All reuse applications require a minimum of secondary treatment, which addresses large objects and particles, most dissolved organic matter, some nutrients and other inorganics. However, there are some particles, including microorganisms and dissolved organic and inorganic constituents that remain in the secondary treated wastewater and require further treatment before the wastewater can be reused.

The general parameters of concern with regards to water reuse are discussed below (Metcalf and Eddy, 2001; Salgot *et al*., 2006). Some of these parameters which present a significant risk to or via the aquatic environment have been designated under EU legislation as 'Priority Substances' and within these, 'Priority Hazardous Substances[22]' and these require consideration in any treated wastewater discharge or water reuse application.

Methods for their removal from wastewater are also discussed.

(bb) Conventional Parameters

These parameters are those commonly measured in conventional wastewater treatment and often removed to a degree in standard processes such as primary settlement, secondary treatment, nutrient removal and filtration processes. These include organic and in-organic constituents, particulate and soluble and microbial components such as:

1. *Total suspended solids (TSS), colloidal solids*
2. *Biochemical oxygen demand (BOD)*
3. *Chemical oxygen demand (COD)*
4. *Total organic carbon (TOC)*
5. *Ammonia*
6. *Nitrate/nitrite*
7. *Total nitrogen*
8. *Phosphorus*
9. *Microbial constituents such as*
    - Bacteria (example – E coli, faecal coliform, total coliform, salmonella);
    - Viruses (example – bacteriophage, norovirus, enterovirus, hepatitis A);

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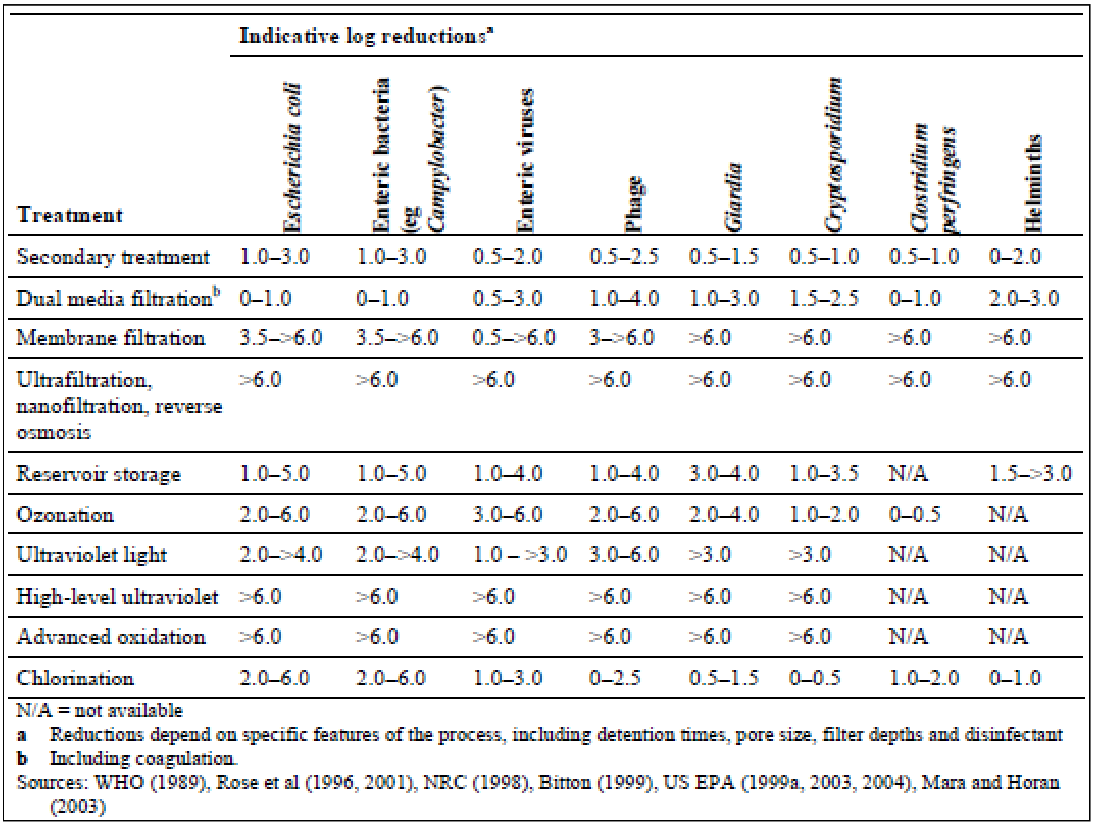
[22] With Priority Hazardous Substances identified due to their persistence, bioaccumulation and/or toxicity or equivalent level of concern.

- Helminths (example – nematode); and
- Protozoa (example – Giardia, cryptosporidium).

Secondary treatment processes will achieve some reduction in all of the above parameters, however the reduction of nutrients i.e. parameters 5 through 8 in the above list, requires additional tertiary (nutrient reduction) treatment processes. Reduction of microbial constituents requires additional treatment by filtration (e.g. membrane) and/or disinfection (e.g. Ultra violet or chlorination).

Removal of microbial pathogens is generally described in terms of log reduction[23], with the log reduction achieved in various treatment processes illustrated below in Figure 4. These are summated to give an overall log reduction achieved. Conventional wastewater treatment offers some removal of microbial pathogens, however high quality reuse for unrestricted agriculture or augmentation of drinking water requires a significantly higher reduction. Generally a 5 to 9.5 log reduction is required which can only be achieved through a multi-stage or multi-barrier treatment process following secondary wastewater treatment.

Figure 4: Indicative log reductions of pathogens and indicator organisms (from NRMMC Australia, 2008)



Treatment	Indicative log reductions[a] *Escherichia coli*	Enteric bacteria (eg *Campylobacter*)	Enteric viruses	Phage	*Giardia*	*Cryptosporidium*	*Clostridium perfringens*	Helminths
Secondary treatment	1.0–3.0	1.0–3.0	0.5–2.0	0.5–2.5	0.5–1.5	0.5–1.0	0.5–1.0	0–2.0
Dual media filtration[b]	0–1.0	0–1.0	0.5–3.0	1.0–4.0	1.0–3.0	1.5–2.5	0–1.0	2.0–3.0
Membrane filtration	3.5–>6.0	3.5–>6.0	0.5–>6.0	3–>6.0	>6.0	>6.0	>6.0	>6.0
Ultrafiltration, nanofiltration, reverse osmosis	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0
Reservoir storage	1.0–5.0	1.0–5.0	1.0–4.0	1.0–4.0	3.0–4.0	1.0–3.5	N/A	1.5–>3.0
Ozonation	2.0–6.0	2.0–6.0	3.0–6.0	2.0–6.0	2.0–4.0	1.0–2.0	0–0.5	N/A
Ultraviolet light	2.0–>4.0	2.0–>4.0	1.0 – >3.0	3.0–6.0	>3.0	>3.0	N/A	N/A
High-level ultraviolet	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	N/A	N/A
Advanced oxidation	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	N/A	N/A
Chlorination	2.0–6.0	2.0–6.0	1.0–3.0	0–2.5	0.5–1.5	0–0.5	1.0–2.0	0–1.0

N/A = not available

a Reductions depend on specific features of the process, including detention times, pore size, filter depths and disinfectant

b Including coagulation.

Sources: WHO (1989), Rose et al (1996, 2001), NRC (1998), Bitton (1999), US EPA (1999a, 2003, 2004), Mara and Horan (2003)

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[23] One log reduction of a pathogen represents the removal of 90% of that pathogen from a sewage source, 2 log reduction represents 99% removal and 3 log reduction represents 99.9% removal

(cc) Non-conventional Parameters

Examples of these parameters include inorganic and organic chemicals such as refractory organics (pesticides, phenols, surfactants), volatile organic compounds, total dissolved solids (TDS), salts, heavy metals (arsenic, mercury, chromium, nickel, lead, cadmium, zinc, copper, manganese, cobalt, vanadium, iron), other metals and surfactants.

Wastewater treatment using existing technology can generally reduce many inorganic trace elements to below recommended maximum levels for irrigation and drinking water.

The level of treatment for organic chemicals in wastewater is related to the end use of the reclaimed water. The detection of a variety of organic chemicals in municipal wastewater treated wastewater has raised concerns about the potential presence of wastewater-derived chemical contaminants in reclaimed water as well as their health effects. Organic compounds in wastewater can be transformed into disinfection by-products (DBP) where chlorine is used for disinfection purposes. There are strong associations between DBP exposure and cancers of the bladder, liver and kidney. As chlorination of wastewater is still the most commonly used form of wastewater disinfection, research to further address the challenge of DBP in *de facto* reuse is a critical need (US EPA 2012 Guidelines for Water Reuse). To address concerns associated with DBPs and other trace organics in reclaimed water, several utilities in California are using reverse osmosis (RO) followed by ultra violet – advanced oxidation processes (UV-AOP) in the treatment train for reclaimed water.

(dd) Emerging Parameters

Examples of these include prescription and non-prescription drugs, personal and home care products, industrial and household products, steroidal based hormone therapies and endocrine disrupting compounds (EDCs). These are of concern where subsequently ingested by humans in an indirect reuse application and to the environment and aquatic eco-systems where discharged. This broad group of individual chemicals and classes of compounds present at trace concentrations are sometimes termed contaminants of emerging concern (CEC).

EDCs are a cause of increasing concern, these are compounds which are present in treated wastewaters, agricultural and industrial treated wastewaters which mimic natural hormones and which can inhibit the action of hormones or alter normal regulatory function of the immune, nervous and endocrine systems in humans and the environment, including aquatic life and wildlife (Crisp, et al. 1997). EDCs can also be produced as disinfection by-products (DBPs) in wastewater treatment through the oxidation of organic components by chlorination. .

UK and USA research has shown adverse impact on aquatic life such as ‘feminization’ of male species and with improved measurement and monitoring of parameters, awareness is increasing with significant funds committed to research. A recently released report commissioned by the EU *State of* *the Art Assessment of Endocrine Disrupters*[24] confirms the potential for widespread and irreversible human and wildlife impacts of EDCs and the need for additional regulation.

As reclaimed water is considered a source for more and more uses, including potable water uses, the treatment focus has expanded far beyond secondary treatment and disinfection to include treatment for other contaminants, such as metals, dissolved solids and trace chemical constituents. In 2010 the US EPA reported on the results of an extensive literature review of published studies of the effectiveness of various treatment technologies for CECs. The results of this literature review are also available in a searchable database*, "Treating Contaminants of Emerging Concern – A Literature Review Database"* (US EPA, 2010). This information was developed to provide an accessible and comprehensive body of historical information about current CEC treatment technologies.

Given the wide range of properties represented by trace chemical constituents, there is no single treatment process that provides an absolute barrier to all chemicals. To minimize their presence in treated water, a sequence of diverse treatment processes capable of tackling the wide range of physiochemical properties is needed (Drewes and Khan, 2010). Pilot and full-scale studies have demonstrated that this can be accomplished by combinations of different processes: biological processes coupled with chemical oxidation or activated carbon adsorption, physical separation (RO) followed by chemical oxidation, or natural processes coupled with chemical oxidation or carbon adsorption.

7.3 Cost Implications

The cost involved for upgrading a WwTP for water reuse is generally divided into three categories (FAO, 2010):

- Capital cost for upgrading the WwTP;
- Installation of new infrastructure for the transfer of treated wastewater; and
- Reoccurring operation and maintenance cost.
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One of the key considerations in water reuse are the costs associated with the treatment processes which are required to comply with treated wastewater quality and the economics of the end use of treated wastewater; e.g. how much an existing industrial or agricultural water user pays and is willing to pay.

There may be challenges in showing whole life benefits when this depends on the sale of treated wastewater to a private user unless long term contracts can be agreed.

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[24] http://ec.europa.eu/environment/endocrine/documents/4_SOTA%20EDC%20Final%20Report%20V3%206%20Feb%2012.pdf

The EA position statement[25] refers to commissioned work in 2007 by MWH which concluded that it is technically feasible to implement reuse schemes cost-effectively and with no deterioration in water quality – however costs are scheme specific and must be assessed on a case by case basis.

In 2010 the Food and Agriculture Organisation (FAO) published an economic analysis of water reuse in the agriculture sector (FAO, 2010), which discusses cost-benefit analysis of water reuse schemes.

7.3.1 Capital Cost

The capital cost depends on the required quality of reclaimed water and the distance the distance the end user is from the reclaimed water facility.

The key factor in determining the level of treatment required is the intended end use of the reclaimed water. The level of treatment required increases as the level of human exposure increases and increasing levels of treatment will entail increasing levels of cost.

Installation of new infrastructure (i.e. separate piped systems) for the transfer of treated wastewater will also require capital expenditure, which increases with distance from the reclaimed water facility.

7.3.2 Infrastructure for Transfer of Reclaimed Water

For most reuse applications a dual distribution system, that is a separate piped system for reclaimed water to that for potable water, is required. The American Public Works Association (APWA) Uniform Colour Standard was updated in 2003 to add purple as the colour for reclaimed water pipe systems.

The following are the main infrastructural items required:

- Pipework from WwTP to Water Reclamation Facility (WRF) and from the WRF to the end user.
- Reclaimed water storage tanks to ensure flows are available during low flow conditions, time of reclaimed water application and during peak demand;
- Installation of monitoring equipment;
- Pumping stations; and
- Control and instrumentation system for transferring the flows and operation measures when reclaimed water is not meeting the required quality.

7.3.3 Operation and Maintenance Cost

The following are O&M considerations:

- Highly skilled operators;

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[25] Refer Position Statement online at http://publications.environment-agency.gov.uk/PDF/GEHO0811BTVT-E-E.pdf.

- Chemicals for dosing;
- Power cost for operating units;
- Maintenance cost associated with units;
- Reclaimed water monitoring cost (laboratory cost); and
- Monitoring cost of parameters (laboratory cost);

Advanced filtration and treatment processes have significant additional power demands beyond conventional secondary wastewater treatment and often necessitate interstage pumping, further adding to operational costs.

8. Planning and Management Considerations

8.1 Introduction

With increasing restrictions on conventional water resource development and wastewater discharges, reuse has become an essential tool in addressing both water supply and wastewater disposal needs in many areas. This growing dependence on reuse makes it critical to integrate reuse programmes into planning initiatives.

In Europe the Water Framework Directive (WFD), established a framework for the protection of inland surface waters, transitional waters, coastal waters and groundwater, based on the concept of integrated water resource management. The WFD encourages the integration of water reuse options.

8.2 Planning Reclaimed Water Systems

Planning of reclaimed water systems should be consistent with the overall integrated water resources management objectives. As part of an integrated water resources plan, a reclaimed water master plan can identify acceptable community uses for reclaimed water, potential customers and their water demand, and the quality of water required.

The volume of reclaimed water available for distribution must also be determined with particular attention paid to the diurnal discharge curve at the WwTP. Balancing the daily and/or seasonal demand for reclaimed water with available supply from the WwTP may require storage options to be considered to resolve any supply/demand imbalance.

The *WateReuse Association Manual of Practice* (WRA, 2009) details the following project planning steps for reclaimed water projects:

A. Identify quantity of reclaimed water available
B. Screen all existing and potential future uses and users
C. Identify potential users
D Determine if users will accept reclaimed water
E. Compare supply to potential demand
F. Prepare distribution system layout
G. Finalize customer list
H. Determine economic feasibility
I. Compile final user list and distribution
J. Prepare point-of-sale facilities

K. Obtain regulatory approval

L. Preform on-site retrofits

M. Preform cross-connection test

N. Begin delivering water

8.3 Managing Reclaimed Water Supplies

Managing and distributing reclaimed water supplies is significantly different from the management of traditional water sources. Traditionally, a water company drawing from groundwater or surface water impoundments uses the resource as both a source and a storage facility. What is not used on any given day is simply left for future use. However, in the case of reuse, the reclaimed water is continuously generated, and what cannot be used immediately must be stored or disposed of in some manner. Depending on the volume and pattern of projected reuse demands, in addition to operational storage considerations, seasonal storage requirements may become a significant design consideration and have a substantial impact on the capital cost of the system.

Each water use in a traditional system has a distinctive demand pattern and thereby, impacts on the need for storage. The same is true for a reclaimed water system. When considering reclaimed water distribution storage systems it is essential to consider the types of users, potential peak demands (daily and seasonal), potential for concurrent peaks, time of day restrictions for irrigation with reclaimed water and whether the reclaimed water system will be designed to meet fire protection requirements.

From an operational perspective, maintaining a chlorine residual in the reclaimed water system is as important as maintaining a residual in the potable water system. Public health decisions should control design decisions.

8.4 Operating a Reclaimed Water System

In order to protect public health and enhance customer confidence, water of a quality that is safe and suitable for the intended end uses must be reliably produced and distributed, regardless of the source water. The same high standard of design, construction, operation and reliability as applies to a traditional potable water system is required for a reclaimed water system.

Well-designed quality assurance/quality control and monitoring programmes must be implemented to protect public health. An important element of such programmes is a well-defined and rigorously-enforced procedure for responding to system failures.

9. Public Acceptance

9.1 Introduction

This section discusses the social and environmental concerns surrounding water reuse.

9.2 Social impacts

The social barriers of treated wastewater reuse are well established globally and although the public are generally unaware that indirect reuse of treated wastewater for potable drinking water occurs widely, specific reuse projects are likely to be met with significant negative feedback and fear often exacerbated by media coverage.

Significant public education and engagement may be required for reuse schemes with a key public element; for industrial reuse in private industry there is likely to be less concern although any agricultural reuse application is also likely to gain public interest.

Past experiences show that even when faced with drought conditions and the scientific proof of sufficient treatment to meet all quality standards, the consumer may be unwilling to agree to planned treated wastewater reuse schemes, one such example was in the case of Toowoomba residents in Australia who voted no to a referendum on indirect potable reuse[26].

Past experience also shows the importance of considering all stakeholder groups - – e.g. in the above scheme, farmer groups voted ‘no’ to the same indirect treated wastewater reuse scheme knowing it would divert treated sewage flows from watercourses from which they abstract for agriculture, subsequently suing the State following plans to sell the treated wastewater to the mining industry[27]. Upstream and downstream ‘users’ must be considered as with any water allocation project.

For any treated wastewater reuse scheme, consultation with the public should commence at the early stages of the project. Often, perception of wastewater as a source of reclaimed water is minimal (Hartley, 2006). The general public can be educated by providing non-technical project summary reports, press advertisement, community information sessions, fact sheets, internet (Urkiaga *et al*., 2006). The main factors which contribute to the degree of public acceptance of treated wastewater reuse are: degree of human contact, protection of public health and environment, type of treatment and expected treated wastewater quality and benefits of treated wastewater reuse (Hartley, 2006; Urkiaga *et al*., 2006).

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[26] See wesite http://www.wme.com.au/categories/water/FEB5_06.php).

27 See website http://www.couriermail.com.au/news/features/mine-buys-out-water-allocation/story-e6freoyo-1111114905752).

The majority of people tend to feel less favourable towards treated wastewater reuse as its application comes closer to them, this is generally based on their perception of what the final treated wastewater quality is (Toze, 2004). It has been noted that people have less of a concern about using untreated storm water which is usually of a lower quality standard than treated wastewater (Po *et al*., 2003).

Given Ireland’s ‘green’ image any proposal to reuse reclaimed wastewater for irrigation purposes, particularly of food crops, is likely to mobilise significant opposition. A number of food scares around the world in recent years, many of them associated with the agricultural reuse of treated wastewater, has shaken public confidence in the safety of the food supply chain and in the ability of the regulatory agencies to police the industry. Public concern over potential damage to our ‘green’ image and loss of export markets for our produce would be difficult to overcome requiring significant resources to be expended in public education and engagement.

9.3 Environmental impacts

Treated wastewater reuse schemes may produce either positive or negative environmental impacts (MWH, 2007). Consideration should be given to both capital environmental impacts i.e. plant, equipment and pipelines and ongoing environmental impacts i.e. continuous discharge of treated wastewater to watercourse, carbon impacts of pumping, transport and maintenance. To fully quantify these impacts an environmental assessment and whole life carbon costing exercise combined with required environmental impact assessment processes would be necessary.

Assessment of environmental impacts requires consideration of construction phase environmental impacts as well as ongoing environmental impacts – e.g. environmental quality impacts of continued discharge of treated wastewater to watercourses or the removal of treated wastewater previously discharged to watercourse, hydromophological impacts and changes to aquatic ecosystems and processes (e.g. impacts on fish migration).

As previously discussed, the environmental and health impacts on humans must also be considered. Whilst pathogen risks and reduction methods are well understood, new emerging compounds, as outlined in Section 7.2.2(c) above, present in treated wastewater are currently being investigated in detail for their effect on aquatic life and public health. These compounds are very likely to have limits in the future and require special treatment processes. For example, adsorption processes, membrane filtration, reverse osmosis and advanced oxidation processes (combination of UV, ozone, hydrogen peroxide) are efficient in removing some micro-pollutants and emerging contaminants but are energy intensive with high operating and maintenance costs.

10. Assessment for Potential for Reuse of Treated Wastewater from Regional WwTP

10.1 Introduction

This section assesses the potential for reuse of treated wastewater from the Regional WwTP against the categories of water reuse applications illustrated in Table 1 of this report.

a. Available Water for Reuse

As stated in section 2, DWF to the proposed Regional WwTP is projected to be in the order of 98,550 m^3/d at year 2025 rising to 143,440 m^3/d by year 2050. This amounts to potentially 98MLD (Mega Litres per Day) of wastewater that could be diverted away from the new marine outfall to alternative sources if demand is shown to be present.

b. Water Reuse Standards

As stated previously in this report there are currently no explicit EU wide policy guidelines for the reuse of treated wastewater in the European Union. There are also no standards currently proposed by the Environmental Protection Agency (EPA) for treated wastewater reuse in Ireland.

Therefore, prior to consideration of any water reuse scheme, standards and guidelines for water reuse would have to be developed with the EPA. Significant public education and stakeholder education would also be required.

10.2 Urban Reuse (non-potable)

a. General Applications

Urban reuse applications would typically involve landscape irrigation of parks, school yards, roads / highways (median strips and shoulders), playing fields, golf courses, cemeteries, greenbelts and residential areas. Other non-potable urban reuse includes fire protection, toilet flushing, street cleaning, vehicle washing, air conditioning and dust control. In the USA urban reuse is one of the highest volume uses of reclaimed water.

b. Potential Applications for the Regional WwTP treated water

Within 5 km of the proposed regional WwTP, there are number of potential urban reuse options. These include approximately 10 GAA clubs, 9 golf courses and 3 cemeteries. Further study would be required to evaluate the demand for reclaimed water amongst these areas.

However, to use treated wastewater for this application it would be necessary to treat the reclaimed water to high standard involving secondary treatment (potentially with nutrient removal) followed by tertiary filtration and disinfection as identified in Table 5 in Section 7. Should identified customers be willing to use reclaimed water the other main obstacle is the lack of any infrastructure to deliver the reclaimed water directly to such customers. Transmission of the reclaimed water to these customers would require development of transfer pipelines, pumping stations and reclaimed water storage tanks.

10.3 Agricultural Reuse

a. General Applications

This is the reuse of treated wastewater in the irrigation of agricultural produce including fodder, fibre, seed crops, edible crops, orchards, nurseries and horticulture.

b. Potential Applications for the Regional WwTP treated water

Fingal is home to a significant horticultural industry. The potential for use of reclaimed water for this industry is considered under direct and indirect application.

Direct Application

If direct application of the reclaimed water was proposed, it would be necessary as a minimum to treat the reclaimed water to high standard involving secondary treatment (potentially with nutrient removal) followed by tertiary filtration and disinfection as identified in Table 5 in Section 7. As well as this, consultation would also be necessary with the Food Safety Authority of Ireland (FSAI) to ensure they are satisfied with the level of treatment proposed. It would also be necessary to install a new transmission and storage system as outlined in Section 10.2 above.

However the main obstacle to overcome would be public perception and the potential damage to Ireland’s green image as outlined in Section 9. It is considered unlikely that horticultural producers would be willing to receive reclaimed water and risk the potential damage to their industry.

Indirect Application/Groundwater Recharge

A potential alternative to direct application would be to use the treated wastewater to recharge a groundwater source from which the agricultural industry could then draw water.

Any discharge to groundwater would be subject to the Groundwater Regulations and agreement with the EPA (as the responsible agency). Under Regulation 4 of the Groundwater Regulations all reasonable steps would have to be taken to:

“(a) prevent or limit, as appropriate, the input of pollutants into the groundwater and prevent the deterioration of the status of all bodies of groundwater

The discharge to a groundwater source would be subject to a Tier 3 assessment under the Groundwater Regulations. This would involve significant investigation and modelling of any potential aquifer identified for recharge to determine if there is a potential to reuse.

As stated in the “Guidance on the Authorisation of Discharges to Groundwater” it should also be noted that currently there are no discharges to groundwater in Ireland greater than 90m3/d. There are also no current standards regarding water reuse so it is likely that significant consultations with the EPA would be required.

It should also be noted that the soil type in North County Dublin is predominantly heavy clay and as such direct injection is likely to be required to enable any potential recharge.

Although less so than with direct application, there is still a concern regarding public perception and the potential adverse impact to the horticultural industry.

10.4 Impoundments

a. General Applications

The use of reclaimed water for maintenance of impoundments range from water hazards on golf courses to full-scale development of water-based recreational use involving incidental contact (fishing and boating) and full body contact (swimming and wading).

b. Potential Applications for the Regional WwTP treated water

They are no large scale impoundments in the vicinity of the proposed Regional WwTP other than those associated with golf courses previously discussed in Section 10.2. It is worth noting that any discharges to such a development could be subject to compliance with the groundwater regulations and are likely to require a Tier 3 assessment as outlined above.

10.5 Environmental Reuse

a. General Applications

The use of reclaimed water to create, enhance, sustain or augment water bodies including wetlands, aquatic habitats, or stream flow.

b. Potential Applications for the Regional WwTP treated water

There are no water bodies within close proximity to the Regional WwTP that require augmentation or any proposals to create new water bodies in the area.

10.6 Industrial Reuse

a. General Applications

The use of reclaimed water in industrial applications and facilities, power production and extraction of fossil fuels.

b. Potential Applications for the Regional WwTP treated water

Existing Industrial Developments

There are currently no major industries within close proximity to the proposed Regional WwTP with significant water demand. However, a significant water using industrial concern is located on the outskirts of Leixlip which presents an opportunity to explore the potential of supplying appropriately treated wastewater from Leixlip WwTP to them as a replacement for some of the potable water they are currently supplied with.

New Industrial Developments

New industrial development may locate within the catchment of the Regional WwTP which could be willing to use reclaimed water instead of potable water. In particular, there are IDA lands situated immediately to the south of the proposed Regional WwTP and consideration should be given to potential water reuse opportunities which may be available depending on the development proposals being considered for the area. A whole life cost analysis should be undertaken to determine the feasibility of any such scheme upon the identification of a suitable industrial client. Consideration would need to be given to the significant capital cost involved in upgrading the treatment works, constructing a new transmission system to provide reclaimed water at a discounted rate to any potential user.

Proposed Regional WwTP water demand

The proposed Regional WwTP will have a significant demand for potable water. Water is required throughout the process including the following processes:

- Screen washing
- Screenings transportation
- Grit/Screenings washing
- Polymer make up for sludge thickening/dewatering processes
- Sludge re-wetting
- Cooling water
- Site washwater

As has been demonstrated at Ringsend WwTP, discussed in Section 6.2(a), it is possible to use highly treated wastewater for a significant amount of these applications. As there will be no duplication of an existing potable main, it is likely that significant additional capital investment would not be required to install this infrastructure at the Regional WwTP during the initial phase. However, it is recommended that further investigation is undertaken to identify the volume and required standard of treatment should such a process be considered for implementation at the Regional WwTP.

10.7 Groundwater Recharge (non-potable reuse)

a. General Applications

The use of reclaimed water to recharge aquifers that are not used as a potable water source.

b. Potential Applications for the Regional WwTP treated water

This has been discussed under 10.3 (b).

10.8 Potable Reuse

10.8.1 Indirect Potable Reuse

a. General Applications

Augmentation of a drinking water source (surface or groundwater) with reclaimed water followed by an environmental buffer that precedes normal drinking water treatment.

b. Potential Applications for the Regional WwTP treated water

Indirect potable reuse currently occurs in an unplanned manner in the Greater Dublin Area (GDA) on the River Liffey where the supply of potable water to north County Dublin as abstracted from the River Liffey at Leixlip contains treated wastewater from the WwTP at Osberstown, which serves the towns of the Upper Liffey Valley catchment including Naas and Newbridge.

Consideration should be given that this practise be reviewed and that a proactive decision be taken for the planned indirect potable reuse of the treated wastewater flows from Osberstown WwTP to augment the yield of the water abstraction at Leixlip WTP. This should include a review of the standard of treatment applied to the wastewater at Osberstown WwTP to minimize potential risk to the downstream abstraction at Leixlip. The proposed development of Water Safety Plans by Irish Water would be a first step in achieving planned indirect potable reuse.

Leixlip WwTP currently discharges to the River Liffey downstream of the ESB dam at Leixlip and consequently downstream of the abstraction point of the Leixlip WTP and consideration could be given to using Leixlip WwTP treated wastewater flows in the following reuse schemes:

- To augment the flow to the WTP by using the treated wastewater from the WwTP as a proportion of the river compensation flow required to be released by the ESB at Leixlip dam In lieu of main river flow.
- For planned indirect potable reuse by pumping an appropriately treated wastewater back to the head of the Leixlip impoundment for subsequent abstraction at Leixlip WTP. The proposed development of Water Safety Plans by Irish Water would be a first step in achieving planned indirect potable reuse.

The nearest WTP to the proposed Regional WwTP is the groundwater source of “Bog of the Ring”. However, this source is not close enough to consider as a potential recharge even if issues such as compliance with groundwater regulations and required treatment standards could be overcome.

10.8.2 Direct Potable Reuse

a. General Applications

The introduction of reclaimed water (with or without retention in an engineered storage buffer) directly into a water treatment plant, either co-located or remote from the advanced wastewater treatment system.

b. Potential Applications for the Regional WwTP treated water

There is likely to be no potential for this application in Ireland due to the expected adverse public reaction. It is unlikely that even advanced treatment, control and quality processes would allay concerns over perceived increases in the risk to human health.

11. Conclusions and Recommendations

This report has provided an overview of treated wastewater reuse policy, practice and aspects in the European and global context and undertaken an initial assessment of the potential for reuse of treated wastewater associated with the proposed Regional WwTP.

With increasing focus on the cost of water, integrated water resources management and increasing water stress in many European countries, it is likely that reuse will receive increasing attention and support and planned reuse schemes will increase in Europe.

EU and resulting Irish legislation and policy currently lacks explicit direction or guidelines with regards to treated wastewater reuse - however there are numerous global examples of reuse projects which could be used as reference if a water reuse scheme was considered viable. However, prior to consideration of any water reuse scheme standards and guidelines for water reuse would have to be developed with the EPA and other key stakeholders.

While treated wastewater from the Regional WwTP of secondary treatment quality is of suitable quality for marine outfall discharge to the Irish Sea it will not be suitable for potential reuse applications without additional treatment, with the possible exception of limited industrial reuse applications. At a minimum disinfection is likely to be required and in most reuse applications, tertiary or advanced treatment will be necessary.

Public perception is likely to limit the potential for any reuse scheme with a key public element and significant public education and stakeholder engagement would be required.

The initial assessment of the potential for reuse of treated wastewater from the proposed Regional WwTP has identified the reuse schemes listed hereunder as having potential subject to further studies being undertaken.

Proposed Regional WwTP

- The potential reuse at the new Regional WwTP itself in the form of process water for various elements of the works. Further investigation is recommended to identify the required volumes and required standard of treatment
- Use of the treated wastewater to supply potential future industrial customers on the IDA lands situated immediately to the south of the proposed Regional WwTP.

In addition, this initial assessment has identified, subject to further studies being undertaken, potential reuse schemes for treated wastewater from the wastewater treatment plants at Leixlip and Osberstown, as listed hereunder:

Leixlip WwTP

- Use of the treated wastewater as a proportion of the dam compensation flow required at Leixlip, thereby allowing additional abstraction at Leixlip WTP, or
- Use of the treated wastewater in a planned indirect potable reuse scheme by transferring appropriately treated wastewater to the head of Leixlip impoundment.; or
- Use of the treated wastewater as an alternative supply to the significant water using industrial facility located on the outskirts of Leixlip.

<u>Osberstown WwTP</u>

- Convert the current unplanned indirect reuse of the treated wastewater into a proactively planned indirect reuse scheme to augment the abstraction for potable use downstream at Leixlip. The proposed development of Water Safety Plans by Irish Water would be a first step in achieving planned indirect potable reuse.

If suitable end users could be determined, a whole life cost analysis of the additional treatment required for treated wastewater reuse schemes would be required in order to determine the feasibility of such a scheme. This must take into consideration the requirement for additional transmission costs to any potential end users. It is recommended that, in analysing the feasibility of any such reuse scheme, the project planning steps outlined in the *WateReuse Association Manual of Practice* (WRA, 2009) and in Section 8.2 above are followed.

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