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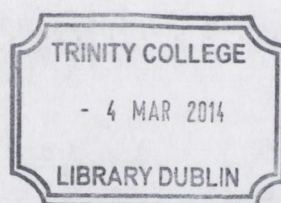
Sustainable Urban Drainage Systems in Dublin:
A Database

By
Gerard Brady

Dissertation submitted to University of Dublin in partial fulfilment of the
requirements of degree masters in engineering (MAI Recurrent Education)

Department of Civil, Structural and Environmental Engineering
Trinity College Dublin

October 2010



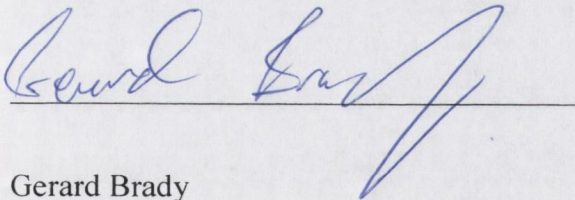
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Gerard Brady

October 2010

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Abstract

The objective of this thesis has been to provide an explanation of the operation of SUDS in Dublin and the development of a system for the recording the use of SUDS. In order to achieve this objective a review of the theory of SUDS, how SUDS works and developed, and how SUDS are currently being used in the Dublin area was performed. A database was then developed to record the use of SUDS in Dublin based on the design criteria for SUDS devices. This SUDS database has been developed to assist Dublin City Council Drainage Division in the planning, maintenance and development of SUDS infrastructure.

Four cases studies have been analysed, each case show how a different SUDS device that have been installed for differing reasons and how each system fulfils their design criteria. Subsequently a SUDS database was developed using a desktop study of planning permission of the years 2005 to 2009 with 95 different SUDS sites and mapped into the Dublin City Council Geographical Information System (GIS). The SUDS database was developed to ensure that it could be integrated into the current system used to map the current drainage infrastructure.

Review of the four case studies showed the benefits of SUDS in relieving hydraulic and water quality issues in Dublin. Development of the SUDS database enabled a review of the patterns of SUDS use in the Dublin area. This showed that the most commonly used SUDS device were attenuation tanks due to the restricted size of development sites in the city. In addition it showed that most SUDS sites are on one-off basis and are private brownfield sites. The benefits of a SUDS database to Dublin City Council have also been reviewed. The DCC SUDS database has shown the importance of recording the use of SUDS devices in Dublin.

Therefore it has been recommended that Dublin City Council update and maintain the SUDS database and use this as a tool for the maintenance, planning and design of the drainage network and future drainage projects.

In conclusion the future use of SUDS in Dublin will become more commonplace and the utilisation of a SUDS database will become an invaluable asset to Dublin City Council Drainage management.

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Introduction

The hydrological cycle is one of the most critical processes in supporting life on this planet. Through the hydrological cycle, water circulates from land to sea to sky and back to land again. The freshwater created by this process in our waterways is essential to human life and culture. The increase in urbanisation can cause an increase in the degradation of our waterways through pollution, resource depletion and construction in flood plans. In recent years we have become more aware of our effect on our waterways and have begun to develop ways to reduce our impact.

New environmental legislation that has been brought in, such as the EU Water Framework Directive, have been enacted in order to encourage better treatment of the environment, by individuals, organisations and governments.

One of the methods that have begun to reduce the impact on our waterways is through the use of Sustainable Urban Drainage Systems (SUDS). The use of Sustainable Urban Drainage Systems has become widespread in the last 10 years throughout Ireland. Dublin City Council has had a Surface Water Drainage policy in place promoting the use of SUDS since 1998. In 2005 a new Stormwater Management Policy for Developers policy was drawn up as part of the Greater Dublin Regional Code of Practice for Drainage Works and SUDS became a compulsory part of development in the DCC's administrative area.

The objective of this thesis is to record the use of and provide an explanation of how Sustainable Urban Drainage Systems operate in the Dublin. This thesis will review how

SUDS work, how the use of SUDS developed, what the main factors for their use and how SUDS are currently being used in the Dublin area. A number of SUDS locations for case studies where different SUDS devices are employed for different reasons will be reviewed and a database will be developed to record the SUDS devices in use in the Dublin City Council administration area and then mapped onto the Dublin City Council GIS system. This database will be populated by a desktop study of planning permission from the last number of years. The benefits of a SUDS database will be discussed and in addition a review of the future maintenance of the SUDS database will be performed. Finally a discussion of the future of SUDS development in Dublin will be presented.

Chapter 2

2. SUDS in Ireland

This Chapter describes how the modern urban drainage infrastructure can have an effect on the environment, the legislation that has been driving the change in the way that we think about the environment and drainage. An overview will be given on how traditional drainage system work and in particular how Dublin's Drainage system developed, its current extent and how the drainage infrastructure is recorded.

This chapter will also explain what Sustainable urban drainage systems (SUDS) are, how and why they were developed in the first place and how SUDS device are used.

2.1 Drainage and the Environment

The development of drainage systems have always had a strong link with the environment, through conveying waste matter away from populations, reducing pollution, preventing waterborne diseases and treating of waste and pollution.

The first modern drainage systems were a reaction to the discovery of the link between water pollution and disease. In the mid 19th century cholera epidemics were common place throughout European cities (World Health Organization, 2010)

“During the 19th century, cholera spread repeatedly from its original reservoir or source in the Ganges delta in India to the rest of the world, before receding to South Asia. Six pandemics were recorded that killed millions of people across Europe, Africa and the Americas.”

2.1.1 The Effect of Urbanisation

The Hydrological Cycle is one of the most critical processes in supporting life on this planet. Through this process water circulates from land to sea to sky and back to land again. The freshwater created by this process in our waterways is essential to human life and culture. The increase in urbanisation can cause an increase in the degradation of our waterways through pollution, resource depletion and construction in flood plains. In recent years as the effect of the human population on the waterways has become more apparent and methods to reduce this impact have been developed.

This increase in urbanisation can cause an increase in the degradation of the waterways through pollution, resource depletion and construction in flood plains. Urbanisation also increases rainfall runoff by the replacement of the permeable land with impermeable roads, rooftops and pathways. Mans activities in these urban areas also give rise to an increased pollution load in surface water flows. The pollution loads can include oils, grits, fertiliser, pesticides, salts, litter and animal waste.

“Mans Activities give rise to large to a larger number of pollutants such as ediments, oil grits, metals, fertilier, pesticides, salts, pathogens and litter that, along with animal waste, can affect public health and cause environmental damage” (CIRIA SUDS Manual, 2007)

“Much of the rainfall in watersheds with forests and pastures is absorbed into the porous soils (infiltration), is stored as ground water, and moves back into streams through seeps and springs. Thus, in many rural areas, much of the rainfall does not enter streams all at once, which helps prevent flooding.” (USGS, 2010)

“Since the economy began to grow in Ireland during the 1990s, there has been a sustained movement of population from rural to urban areas. Cities and towns began to sprawl as a result of development in infrastructure, housing and industry, with growth rates exceeding those of our EU neighbours Ratoath in Co. Meath, for example, is the fastest growing town in Ireland, with a population increase of 54.6% between 2002 and 2006. In addition, the EPA records that artificial surfaces in Ireland grew by 31% between 1990 and 2000, and again by 25% since 2000. (Ask about Ireland, 2009)

“This trend towards urbanisation is causing many rural areas to be reclassified as urban areas, and is having a negative impact on the environment. It creates problems such as air and water pollution, waste management, and damage to surrounding ecosystems. The dramatic increase in road construction in Ireland has the effect of breaking up habitats. Wildlife, such as foxes and badgers, is now a common sight in Dublin, Cork, Belfast and many smaller towns in Ireland”. (Ask about Ireland, 2009)

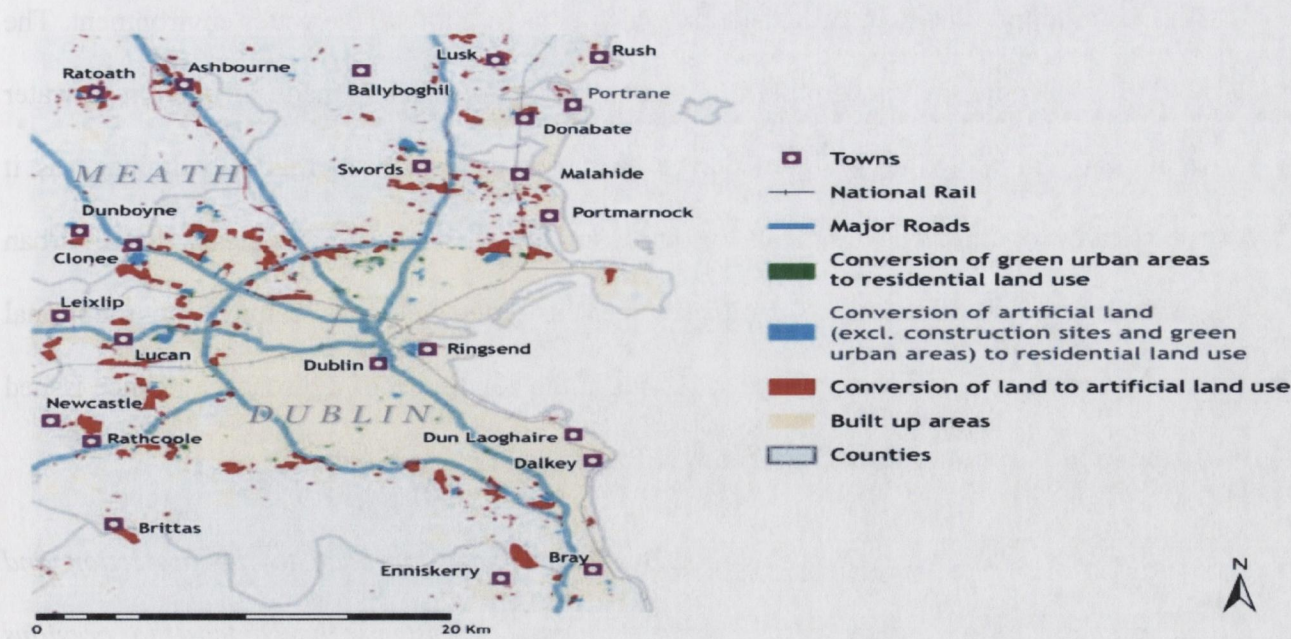


Figure 1 Areas Converted to Residential Use (EPA, 2009)

New environment legislations which have been brought in such as the European Union Water Framework Directive (WFD) have been enacted in order to encourage better treatment of the environment by individuals, organisations and governments.

2.2 Legislation

This section will review how environmental policy and European law have become a major factor in modern drainage system design and a key driver for the use of SUDS in Dublin. An overview will be provided into what effect legislation such as urban wastewater directive and the Water Framework Directive have had, as well as how the Eastern River Basin Study and the Environmental Protection Agency discharge licences effect the use of SUDS in Dublin

2.2.1 European Union Water Framework Directive

The directive establishing a framework for community action in the field of water policy, commonly known as the Water Framework Directive (WFD), was formally adopted by the European Union (EU) Parliament and Council in October 2000 (EP and CEU, 2000). The EU WFD is an important piece of legislation which aims to improve the water environment. The WFD has become the background to all environmental decisions made in relation to water throughout Europe. The WFD encourages a more sustainable approach to drainage as it specifically conditions governments to control surface water runoff. This means that all urban surface water runoff must be mitigated and this effectively has banned the traditional drainage approach. This has now been set out in the conditions of a discharge licence issued by the Environmental Protection Agency (EPA) to Dublin City Council.

“The Water Framework Directive (WFD) marks a new approach to the protection and improvement of our water resources and aquatic ecosystems. In contrast to previous legislation, the WFD aims at protecting all waters and water dependent ecosystems: groundwater, rivers, lakes, transitional waters (estuaries), coastal waters and wetlands. The

objectives of the WFD are demanding and include the prevention of any deterioration in status and the achievement of good status or higher in all waters by 2015.” (EPA Ireland, 2010)

The Water Framework Directive:

- *Considers the full range of the water environment, from "Source to Sea" i.e. groundwaters, rivers, lakes, estuaries, transitional waters and coastal waters.*
- *Considers the impact upon wetlands of the management of water quality and quantity.*
- *Sets environmental objectives, which take account of the full range of pressures upon the aquatic environment (pollution, abstraction, flow regulation/transfer and habitat impact). The emphasis being on ecological quality.*
- *Ecological status is divided into five classes (high, good, moderate, poor and bad) and is derived from measurements of biological, hydro morphological and physio-chemical elements. The measurement of the biological elements includes aquatic flora (plants), benthic invertebrates (small animals that live on the bottom of rivers, lakes and coastal water bodies) and fish.*
- *Promotes sustainable use of water resources.*
- *Defines a planning, management and reporting system based upon River Basin Districts and International River Basin Districts. These are based upon large river basins or a combination of smaller neighbouring basins and include all rivers, lakes, estuaries, coastal waters and associated ground waters.*
- *Involves social participation and transparency. Member States have to involve as many parties as possible (e.g. stakeholders, local and regional authorities, water users and environmental groups) in drafting, discussing and updating River Basin Management Plans.*

(WFD Ireland, 2010)

The WFD is also designed to act as an umbrella directive bringing together other EU directives such as the Urban Wastewater Directive and the Nitrates Directive under it and ensuring that all the directives act in harmony and don't contradict each other which sometimes has been the case in the past . Some of these other EU Directives also have an impact on the how the water environment is to be protected and the use of SUDS has been seen as way of fulfilling this objective.

2.2.2 Urban Waste Water Treatment Directive

“The Urban Wastewater Treatment Directive (UWTD) aims to protect the environment from the adverse effects of discharges of urban waste water and waste water from certain industrial sectors.” (EU UWTD2010)

“The Directive specifies a minimum level of wastewater treatment, based on the urban population size and the receiving water type, to be achieved by 2005” (Butler and Davies, 2004) and also seeks to deal with wastewater collection systems .Butler and Davies (2004), say that the UWTD sets out to *“ensure all urban area with the population equivalent to 2000 or more are provided with collection systems”*.

The pollutants identified for specific attention and reduction include Biological Oxygen Demand (BOD5), Chemical Oxygen Demand (COD), Total Suspended Solids (TSS), Total Phosphorus (TP) and Total Nitrogen (TN) as indicated in Figure 2.

Parameters	Concentrations	Minimum Percentage of Reduction (%)
Biochemical oxygen Demand (BOD5 at 20°C) without nitrification	25 mg/l O2	70 - 90
Chemical Oxygen Demand (COD)	125 mg/l O2	75
Total Suspended Solids (TSS)	35 mg/l	90
Total Phosphorus (TP)	2 mg/l (10,000-100,000 p.e.) 1 mg/l (>100,000)	80
Total Nitrogen (TN)	15 mg/l (10,000-100,000 p.e.) 10 mg/l (>100,000)	70 - 80

Figure2: Concentration values for consent of wastewater (UWWT Directive 91/271/EEC)

In Dublin, the UWWT in setting these criteria for reduction has forced DCC to build large treatment works such as the one in Dublin’s Poolbeg peninsula which are very expensive to build and run. In response to this cost authorities are looking at alternatives to the building of more treatment works. The use of SUDS has been seen as an alternative as it can help reduce the quantity of rainwater entering the system and can also improve the quality of the waters by reducing the quantity of the pollutants listed above from entering receiving waters through both Combined System Overflows and Surface water outfalls.

2.2.3 The Bathing Waters Quality Directive

The EU’s first efforts to improve the quality of bathing waters commenced with the 1976 Bathing Water Quality Directive. The aim of this Directive is to protect public health and the

environment by keeping our coastal and inland bathing waters free from pollution. In 2006 a new Bathing Water Directive was adopted, repealing the old Directive from the end of 2014. Under Article 6 Annex III of the Directive bathing water profiles are established

"Member States shall ensure that bathing water profiles are established in accordance with Annex III. Each bathing water profile may cover a single bathing water or more than one contiguous bathing waters. Bathing water profiles shall be established for the first time by 24 March 2011". (EU Bathing Water Directive 2010)

A bathing water profile is intended to gain an understanding of the faecal sources and routes of pollution and focuses on the indicators for faecal pollution. Under the Directive these indicators are *Escherichia coli* (*E. coli*) 200cfu/100ml and intestinal enterococci 500cfu/100ml.

Dublin as a coastal city has a number of beaches which under the bathing water directive need protection. Dublin's drainage system has a number of outfalls from surface water systems and overflows from combined systems spilling directly to the shoreline as well as into its rivers. DCC has received adverse publicity when Dublin's beaches have failed to meet the Blue Flag status. Again SUDS is seen as a way in which DCC can reduce the number of and improve the quality of the spills to the receiving waters and as a result work towards achieving Blue Flag status for more of Dublin's beaches.

2.2.4 Ground Water Directive

The Ground Water Directive provides a groundwater protection framework *"that requires prevention of the (direct or indirect) introduction of high priority pollutants into groundwater and limiting the introduction into groundwater of other pollutants so as to avoid pollution of this water by these substances"*. (European Union Groundwater Directive, 2010)

Its main aims are to define and characterise groundwater bodies within River Basin Districts, establish registers of protected ground water areas within each river basin districts, and establish groundwater monitoring networks based on the results of characterisation and risk assessment to provide a comprehensive overview of groundwater chemical and quantitative status. Ireland has been divided into eight River Basin Districts with Dublin falling into the Eastern River Basin District.

The limiting of pollutants into groundwater under the Groundwater directive may have an effect on the design of SUDS devices as some devices use infiltration into the ground as a method of reducing overall flow and pollutants into the drainage network.

2.2.5 The Nitrates Directive

“The Nitrates Directive aims to reduce and prevent water pollution caused by nitrates from agricultural sources”. (European Union Groundwater Directive, 2010)

Countries must designate vulnerable zones, which drain into the waters including groundwater, which currently are or in future are likely to be affected by nitrate pollution. These vulnerable zones are receiving waters which contain a nitrates concentration of more than 50 mg/l or are likely to contain such concentrations if measures are not taken. Action programmes under the Nitrates Directive are one of the basic measures of the Water Framework Directive. SUDs is again seen as a way of complying with this directive as the use of SUDs can have a beneficial effect on the Nitrate level in receiving waters

2.2.6 The Integrated Pollution Prevention and Control (IPPC) Directive

“The Integrated Pollution Prevention and Control (IPPC) Directive lays down measures designed to prevent or reduce air, water, or ground pollution.” (European Union Groundwater Directive, 2010)

The Directive allows for the issuing of licences to industrial activities with a high pollution potential. These permits include conditions which set emission limits for pollutants to protect the surrounding area. It is under this directive that the EPA issue DCC's wastewater discharge licence.

2.2.7 EU Floods Directive

“This Directive now requires Member States to assess if all water courses and coast lines are at risk from flooding, to map the flood extent and assets and humans at risk in these areas and to take adequate and coordinated measures to reduce this flood risk.” (European Union Floods Directive 2010). The attenuating of storm water flow through the use of SUDS can have import role in fulfilling DCC responsibilities under this directive.

2.2.8 Eastern River Basin District Project

The Eastern River Basin District Project (ERBD) was one of eight river basin studies started in 2007 as a means of fulfilling Ireland obligations under the WFD. The ERBD is the framework under which DCC must show it is compiling with the WFD. It is a five-year project funded by the Department of Environment Heritage and Local Government. There are twelve local authorities participating in the ERBD Project including the four Dublin Local Authorities. Around *“1.6 million people, 40% of Ireland's population, live in the Eastern River Basin District. The population is growing every decade, partly due to the internal and external migration to live and work around Dublin.”* (ERBD 2010)

“Among the ERBD project goals are to:

- *collect and analyse background information,*
- *characterise the District in accordance with the Water Framework Directive,*

- *develop a river basin management system,*
 - *develop and implement a monitoring system,*
 - *develop a Geographic Information System (GIS) and associated databases,*
 - *prepare a programme of measures,*
 - *implement a public awareness and consultation programme,*
 - *formulate an Environmental Management System (EMS),*
- *work closely with statutory authorities and other stakeholders to ensure the implement-ability of the River Basin Management System,*
- *prepare a River Basin Management Strategy. ” (ERBD 2010)*



Approx 25KM



Figure 3 ERBD Catchment Area (ERBD 2010)

The ERBD project investigates the existing condition of Ireland's water bodies and develops a management strategy based on these investigations. The ERBD management plan has identified and graded all the water body in the catchment area.

"The ERBD contains in total 478 water bodies defined by EPA guidelines (75 groundwater, 356 rivers, 26 lakes, 13 transitional and 8 coastal) which will form the basic units for the study of the ERBD and the prioritisation of a Programme of Measures to ensure GES is met. In ERBD, the combination of heavy agricultural, urban and hydromorphological pressures meant that 84.1% of water bodies, covering 74.1 of the ERBD, are either "At Risk" or "Probably At Risk". Water bodies rated as "At Risk" are done so because there is a high degree of confidence that GES will not be met, whilst a "Probably at Risk" denotes a lower degree of confidence the available data." (ERBD 2010)

SUDS has been identified in the programme of measures in the River Basin Management Strategy as a means by which DCC along with the other Local Authorities in the ERBD area can improve the status of their water bodies.

2.2.9 EPA Discharge Licences

As part of the Irelands responsibilities under the WFD the EPA have developed a Licensing System for all wastewater and stormwater discharges into rivers, lakes and coastal waters. From 2007 all Local Authorities have to apply for a licence to the EPA for permission to discharge wastewater. Part of the EPA discharge licence issued to Dublin City Council has now conditioned Dublin City Council to identify the locations of stormwater and combined overflow, examine the effect these overflows are having on the receiving water, to limit the effects of the overflow on the receiving waters and ultimately try and improve the water quality of the receiving waters.

“The licensee shall, based on the assessment of storm water overflows completed under Condition 4.12.2 and the selection criteria specified by the Department of Environment, Heritage and Local Government prioritise the most significantly non-compliant storm water overflows for improvement works. The prioritisation shall as a minimum consider the frequency of discharge, the duration of discharge, the pollutant parameters within the effluent discharged, and the impact of the discharge on the receiving water (river and estuary)”. (EPA licence to DCC 2010).

As part of DCC’s response to the EPA licence conditions the City Centre Catchment Study has begun. This study includes the monitoring of Combined Sewer Overflow (CSO) in the City Centre for both quantity and quality of spills, the building of a hydraulic and water quality model and development of solutions to hydraulic and environmental issues. SUDS is likely to form a part of the overall solutions considered by this study.

2.3 Drainage Systems

Drainage Systems are used for the collection of foul, combined and stormwater flows from urban populations. Foul flow are purely sewerage flow, stormwater flows are the rainfall runoff from paved such as roads and roofs that enters the drainage network and combined flow are a mixture of both foul and storm water flows.

Irish SUDS defines Sustainable drainage systems SUDS as “*a sequence of conveyance systems and control structures designed to manage the drainage of surface water more sustainably than conventional techniques by providing treatment and reducing flow rates and volumes*”.

SUDS are primarily used to deal with stormwater flows, or the combined sewer overflows. Combined sewer overflows are spills from a combined sewer system which have been overloaded by a heavy rainfall event. They act as a hydraulic release which prevents surface flooding. However some of these spills can have a large pollutant load.

This section will take a look at traditional drainage systems, Dublin Drainage System, and SUDS Drainage Systems

2.3.1 Traditional drainage systems

In conventional drainage systems, excess runoff from built up areas is drained through underground pipes. These systems are designed to ensure that surface water is removed from the area without causing flooding locally. In older sewerage system, surface water runoff has been combined with foul flows into a combined sewer. This surface water flow particularly during periods of heavy rainfall can cause a significant burden on the capacity of the sewerage network and its treatment works.

In certain cases heavy rainfall can trigger untreated combined sewerage to spill into watercourses through combined sewer overflows and can cause pollution. Over the last 50 years drainage networks have been developed on a separate foul and surface water networks. This means the foul flows are piped directly to a treatment works and surface water flow are piped to the nearest watercourse.

However, using the surface water separation approach can cause both environmental and physical damage, due to high flows and the pollution load within the runoff downstream of the site. It has also become impractical and costly to lay pipe of the sizes necessary to take all the surface water runoff for new developments.

“Runoff from impermeable surfaces associated with urban development is often contaminated by pollutants, such as oils, detergents, trace metals, pesticides and herbicides. Any such pollutants will also bypass any available natural treatment processes, such as percolation through the soil, adversely affecting the water quality in receiving waters”.

(GDSDS overall policy 2005)

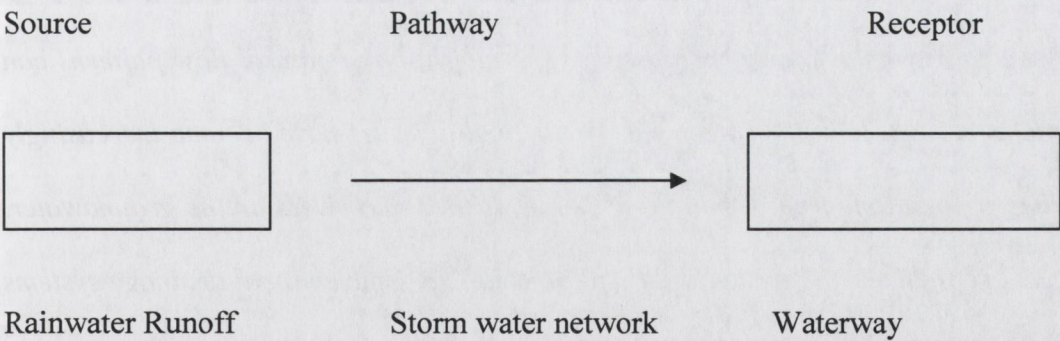


Figure 4: Conventional Drainage System

“Traditional drainage is designed to move rainwater as rapidly as possible from the point at which it has fallen to a discharge point, either a watercourse or soakaway.

This approach has a number of harmful effects:

- *Run-off from hard paving and roofing can increase the risk of flooding downstream, as well as causing sudden rises in water levels and flow rates in watercourses.*
- *Surface water run-off can contain contaminants such as oil, organic matter and toxic metals.*
- *Although often at low levels, cumulatively they can result in poor water quality in rivers and groundwater, affecting biodiversity, amenity value and potential water abstraction.*
- *After heavy rain, the first flush is often highly polluting.*
- *By diverting rainfall to piped systems, water is stopped from soaking into the ground, depleting ground water and reducing flows in watercourses in dry weather.*

As a result, many urban watercourses are lifeless and unattractive, and are often hidden in culverts under the ground.” (UK Environment agency 2010)

“Built-up areas need to be drained to remove surface water. Traditionally this has been done using underground pipe systems designed for quantity, to prevent flooding locally by conveying the water away as quickly as possible. The alteration of natural flow patterns can lead to problems elsewhere in the catchment. Water quality issues have become increasingly important, due to pollutants from urban areas being washed into rivers or the groundwater. Once polluted, groundwater is extremely difficult to clean up. Conventional drainage systems cannot easily control poor runoff quality and may contribute to the problem. The amenity aspects, such as water resources, community facilities, landscaping potential and provision of varied wildlife habitats have largely been ignored. Conventional drainage systems are not designed with these wider considerations in mind. Continuing to drain built up areas with

limited objectives and ignoring wider issues is not a sustainable long-term option causing an impact on the terrestrial and aquatic environments". (CIRIA 2010)

Traditional drainage practices have promoted the rapid collection and conveyance of surface runoff through gullies and pipes away from the site and into watercourses, thus bypassing the natural buffering effect of the natural environment. Consequently, both volumes and rates of runoff increase significantly after development incorporating such drainage systems as gullies and pipes. The resulting problems include flooding, scouring of watercourses and reduced infiltration to recharge aquifers and other sub-soil water bodies. Traditional drainage systems essentially move a number of small local pollution problems downstream through a piped network to a point where a large scale treatment works is required to treat the pollutant. The next sections will look at how one such traditional system in Dublin has developed.

2.3.2 Dublin's Drainage Systems:

Dublin as with many older cities in Europe developed its drainage system around the city's rivers. Most of Dublin's important eighteenth century streets and parallel lanes running behind them had surface drains, which carried the content of chamber pots thrown into the streets and the runoff of cesspools into local waterway and rivers. These rivers, which were also used as a drinking water sources, essentially became sewers. Over time, the surface drains were deepened and improved and in the first quarter of the nineteenth century roof slabs were laid across these creating the first recognisable sewers.

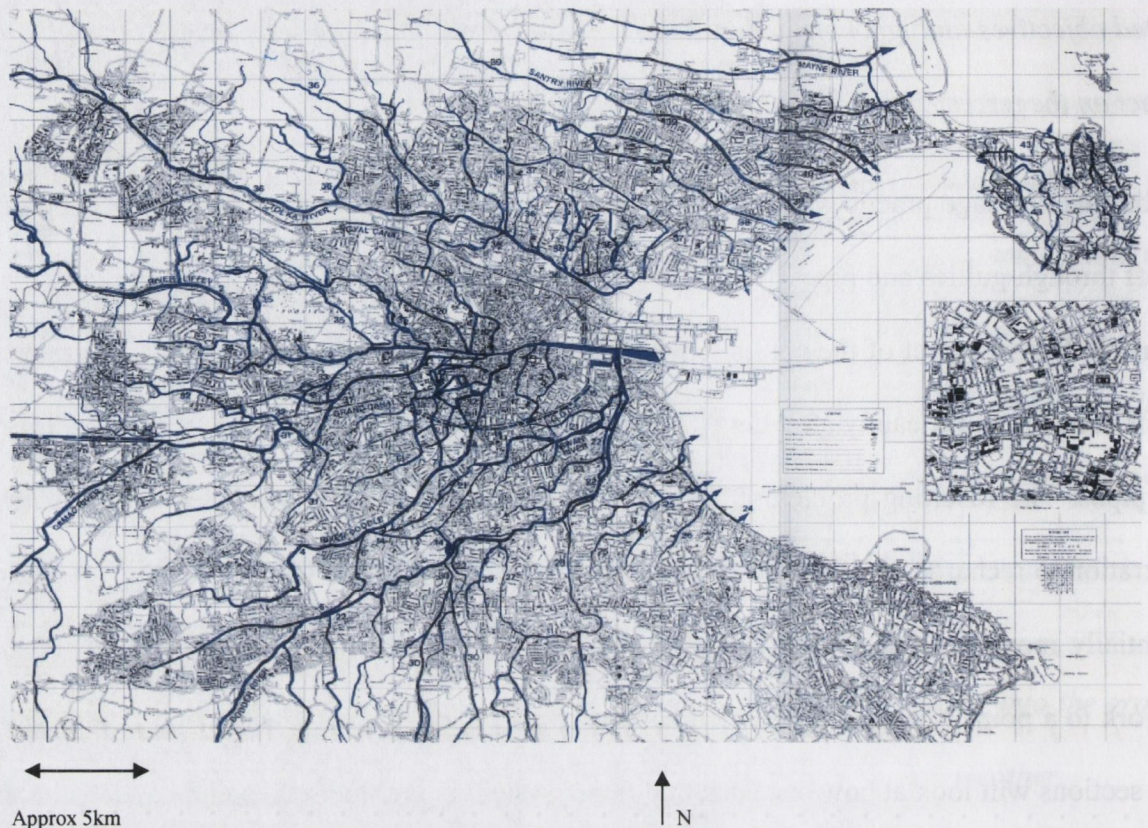


Figure 5 River network of Dublin (Sweeney 1991)

Throughout the mid nineteenth century cholera outbreaks were the scourge of industrial cities such as London and Dublin. In 1854 Dr. John Snow (1813-1858) discovered the link between contaminated water and cholera in London; however it took several years for his theory to become widely accepted. In 1869 Sir Joseph Bazalgette started to build a drainage system in London to intercept the sewerage before it entered the Thames River and divert it downstream, and in doing so prevent it from contaminating London's drinking water.

Shortly after the completion of the London drainage system, Dublin Corporation employed Sir Joseph Bazalgette (1870) to design a main drainage scheme for Dublin. However the first main drainage system to be completed in Dublin was not the Dublin main drainage scheme it was the Rathmines and Pembroke main drainage scheme which started construction in 1877

and was completed in 1881. “The first main drainage scheme to be completed in the Dublin Area was that of the wealthy Rathmines and Pembroke Township”. (Corcoran 2006)

A high level sewer was built along the course of the old Swan River from Harold Cross via Rathmines, Ranelagh Wellington Place and Ballsbridge. From Ballsbridge a sewer followed the banks of the River Dodder to just north west of Londonbridge (Bath Avenue) where it crossed under the river beside another Rathmines and Pembroke sewer coming from Pembroke Road and Shelbourne Avenue. A third low level sewer was laid from Sydney Parade to Lansdowne Road Bridge continuing along the east bank of the River Dodder. A pumping station here raised it to the level of the high level sewer. The sewer ran from here down to South Wall where it discharged.

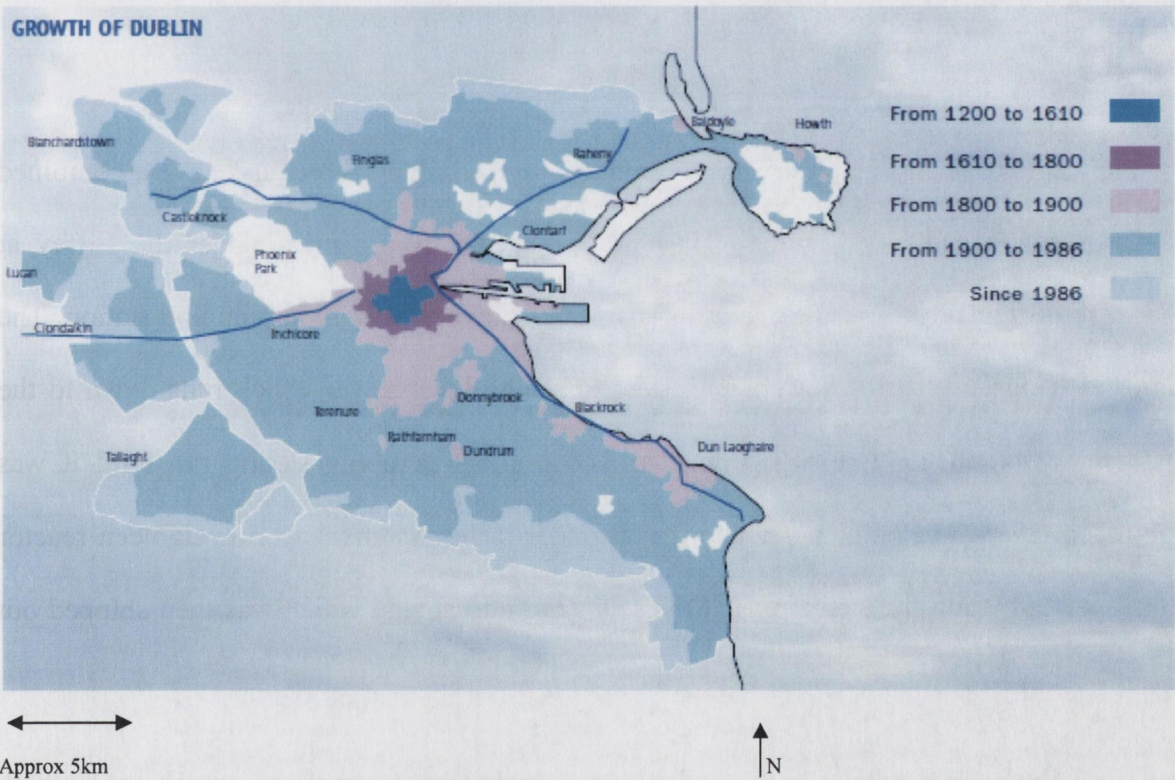


Figure 6 Growth of Dublin: (Dublin Bay Project 2010)

Work started on Dublin Main drainage scheme in 1896. Dublin Corporation designed it to cater for a population of 400,000. “ In 1891 , the corporation engaged George Chatterton of

Sir Joseph Bazalgette's consultancy Colleague and Successor- as adviser for the long frustrated main drainage project" (Corcoran 2006)

"Some preparatory work was carried out at Parkgate Street in Autumn 1895, the long delayed main programme finally starting in 1896" (Corcoran 2006)

The main features of the scheme, which is still in service, are the two interceptor sewers running either side of the River Liffey, a pumping station at Ringsend and a sewerage treatment and discharge works at Pigeon House. The two interceptor sewers pick up all the old drains, which had previously drained straight into the River Liffey. *"the local sewers along the quays which discharged to the Liffey through chambers at existing outfalls now entered the interceptors"* (Corcoran 2006)

The interceptor sewers run from Heuston Station to Wellington Street and have a combined length of seven and a half miles. They are connected by a siphon under the Liffey at Wellington Street and from there, a trunk main runs down to Ringsend pumping station. The pumps at Ringsend lift the sewerage 23 feet to a high level sewer which runs down to the treatment work on the Poolbeg peninsula. The original pumping station ran until it was replaced in 1985. In Poolbeg, prior to the upgrade of the treatment works, eighteen reactor tanks operated using lime precipitated the sewerage into sludge which was then shipped out to sea. This scheme took 10 years to complete.

The main drainage system was extended and enlarged by other drainage schemes which include the North Lotts Drainage Scheme (1912), the North Dublin Drainage Scheme (1952-1959), the Grand Canal Drainage Scheme (1970s), the Dodder Valley Drainage Scheme (1991) and the North Fringe Drainage Scheme (2002).

2.3.3 The Extent of Dublin Drainage System

Today the greater Dublin drainage system now caters for population equivalent of over 1.7 million people. There are over 2,500 kilometres of pipes throughout Dublin, over 50,000 manholes and 18 pumping stations which all drain down to the upgraded Ringsend treatment works (2002), which has a capacity to deal with 2 million m³ of sewerage per day. A large part of the sewerage network particularly in the City Centre, works as a combined flow system.

The Ringsend Wastewater Treatment Works, which was part of the 400 million euro Dublin Bay Project, was completed in 2003. The benefits of the upgraded treatment works included cleaner water in Dublin Bay and in the city's rivers, in addition to more land becoming available for housing and commercial development. Further benefits included two of Dublin's beaches, Dollymount and Seapoint, receiving Blue Flag status, conversion of waste sludge into agricultural fertiliser called Bio-Fert and the conversion of waste to energy to the value of approximately 3 million euro per annum.

2.3.4 Drainage Records

Dublin City Councils drainage database currently includes over 50,000 manholes and 2,500 kilometres of pipelines. The details of this drainage network are recorded in a SUS25 database. The SUS25 database is a Microsoft DOS based program and is used solely to record and update the network. The network itself is displayed in a programme called Mapdrain, which was developed by the Local Government Computer Board for displaying drainage information and is used by a number of Local Authorities around Ireland for this purpose. Mapdrain is based on computer software called Mapinfo and all files imported into it are in .tab format. Dublin City Council along with all the other Dublin Local Authorities in

addition to Kildare, Meath and Wicklow County Council are currently developing the Region Drainage Geographical Information System. This will update the software used for recording the drainage network throughout Dublin. A standard manhole card is used to collect the data that will be used in the manhole database.

2.4 SUDS

2.4.1 A beginning

Stormwater management was a concept developed for dealing with the excessive flow from intense rainfall events. Butler and Balley (2004) state that, *“countries such as Australia, the USA and Sweden have been using these approaches for many years. In the USA SUDS is known as BMP and has been developed since the early 1980's”*

“The significance of storm water runoff in affecting water quality in the United States has become an increasing concern in recent years, as further improvements are made in controlling other point sources such as municipal sewage and industrial waste. EPA conducted a broad analysis of storm water runoff characteristics in its Nationwide Urban Runoff Program between 1979 and 1983. During the 1980's the Agency made several attempts to promulgate regulatory controls for storm water runoff under the statutory framework of the 1972 Clean Water Act.” (US EPA SUDS guidance 2010)

“Following enactment of the Water Quality Act of 1987 in the USA, the EPA began development of a more comprehensive regulatory program. During the course of these actions, the use of best management practices (BMPs) in addressing runoff problems was frequently identified; however it was known that additional research on the performance of BMPs was also needed. The EPA's Engineering and Analysis Division conducted a study on storm water best management practices during 1997 and 1998 as part of its series of preliminary studies in the effluent guidelines program.” (US EPA SUDS guidance 2010)

Butler and Balley state that *“In the UK development of stormwater management policy started in the late 1980s and in 1992 a series of guides with the title scope for control of*

urban runoff was produced by CIRIA". In the 1990s SUDS became more widespread across the UK with acceptance generally more rapid in Scotland than in the rest of the UK

Stormwater management in Dublin began in 1998 with the introduction of the Stormwater Management Policy by Dublin City Council. This policy limited the runoff from a site to 2 l/s/ha. This will be dealt with in more detail in a later chapter.

2.4.2 What is SUDS

SUDS is defined by CIRIA as *"a sequence of Management practices and control structures designed to drain surface water in a more sustainable fashion than conventional techniques"* (SUDS Manual 2007).

SUDS are a way of replicating the natural characteristics of rainfall runoff from any site. To achieve this, requires a decrease in the rate and volume of runoff from developments combined with treating the pollutant loading.

"SuDS involve a change in our way of managing urban run-off from solely looking at volume control to an integrated multi-disciplinary approach which addresses water quality, water quantity, amenity and habitat. When implementing SuDS, it is essential to consider all of these issues.

SuDS minimise the impacts of urban runoff by capturing runoff as close to source as possible and then releasing it slowly. The use of SuDS to control runoff also provides the additional benefit of reducing pollutants in the surface water by settling out suspended solids, and in some cases providing biological treatment. The successful achievement of sustainable urban drainage does not solely rely on the use of engineered techniques to control and treat runoff. 'Good housekeeping' measures, such as safe storage and handling of oils and chemicals, street sweeping and control of sediment run-off from construction sites are an essential

component of SuDS. Public awareness is also an important factor in ensuring the successful implementation of sustainable drainage practices” (GDSDS SUDS Vol 3 2005)

SUDS are designed to address three drainage and environmental issues:

- a) Water quantity
- b) Water quality
- c) Water amenity

These issues are commonly referred to as the SUDS triangle

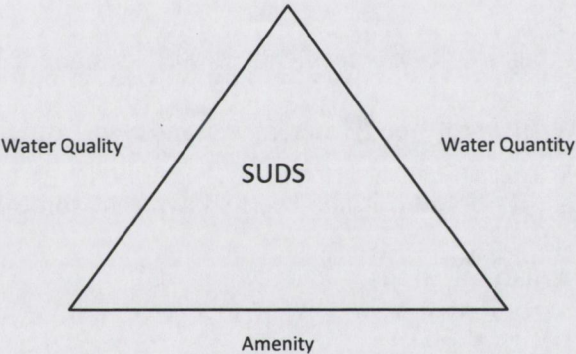


Figure 7: “the SUDS Triangle”

- a.) Water quantity

Rainfall on a Greenfield site generally either soaks away into the ground or runs to the nearest watercourse at a slow rate. When sites are developed, a large percentage of the area becomes impermeable and the rain runoff is piped to the river or storm water drain which causes both the volume and rate of runoff to increase dramatically. This can cause problems in the downstream sewers and rivers and may lead to flooding or an increase in overflows from combined sewers.

b) Water Quality

Heavy rainfall on a traditional drainage system can cause two separate water quality issues in rivers. If the system is combined it is likely that there are a number of Combined Sewer Overflows (CSO) built into the network which will operate in periods of heavy rain. These CSOs' will relieve the network by spilling diluted sewerage into rivers. If it is a separate surface water system the runoff can carry pollutants such as oil, anti-freeze, animal and human waste, decaying leaves, grass or other waste matter to our rivers.

c) Amenity

Water ponds, wetlands and other SUDS devices can, if well designed, be of great amenity value to the local community. Properly constructed wetlands will quickly be colonised by water birds and small animals. In Scotland it has been shown that some SUDS features have higher conservation value than natural ponds

“The SUDS philosophy is simply to mimic natural drainage. When construction takes place the urbanisation of catchments and sub-catchments occurs, and the natural hydrology is affected. This results in reduced supply of rainfall to groundwater by the interception of runoff on areas of hard standing (e.g. roads, roofs and paved surfaces). This in turn means less supply to springs and river network resulting in lower flows and increased likelihood of drought during dry periods.

In addition, by intercepting run-off and routing it through smooth conduits and piped networks, we accelerate the passage of flow to the receiving watercourses resulting in higher peak flows and flooding. Another effect of this is greater erosion and damage to river banks and beds.” (SEPA 2010)

“These systems are more sustainable than conventional drainage methods because they:

- *Manage runoff flowrates, reducing the impact of urbanisation on flooding*
- *Protect or enhance water quality*
- *Are sympathetic to the environmental setting and the needs of the local community*
- *Provide a habitat for wildlife in urban watercourses*
- *Encourage natural groundwater recharge (where appropriate).*

They do this by:

- *Dealing with runoff close to where the rain falls*
- *Managing potential pollution at its source now and in the future*
- *Protecting water resources from point pollution (such as accidental spills) and diffuse sources.*

They may also allow new development in areas where existing sewerage systems are close to full capacity, thereby enabling development within existing urban areas.

Urban drainage is moving away from the conventional thinking of designing for flooding to balancing the impact of urban drainage on flood control, quality management and amenity”.

(CIRIA 2010)

SUDS management principles are way to maximise the beneficial hydrological, environmental and amenity effects of SUDS. The next section looks at what these principles are and how they work.

2.4.3 The Design and Use of SUDS

SUDS like conventional drainage systems are designed using the principles of hydraulic and hydrology. However unlike conventional drainage systems, factors that influence the design

will include runoff water quality, the soil type, the receiving waters be they rivers, lakes, seawater or groundwater, as well as amenity and landscape requirements.

The CIRIA SUDS Manual states 2007 that SUDS management train approach is used to “mimic natural catchment processes as closed as possible” The SUDS management train approach is defined as “The management of runoff through the site using a range of SuDS techniques to maximise the hydraulic and water quality treatment benefits” (Irish SUDS).

In effect, a SUDS management train uses several different types of SUDS in series one after another. This achieves a more accurate mimicking of a Greenfield site as most SUDS devices work better in tandem with another SUDS device than in isolation.

“Effective stormwater management is best achieved from a management systems approach, rather than an approach which focuses on individual practices. Some individual practices may not be very effective alone, but in combination with others, may provide a key function in highly effective systems.” (GDSDS SUDS VOL2 2005)

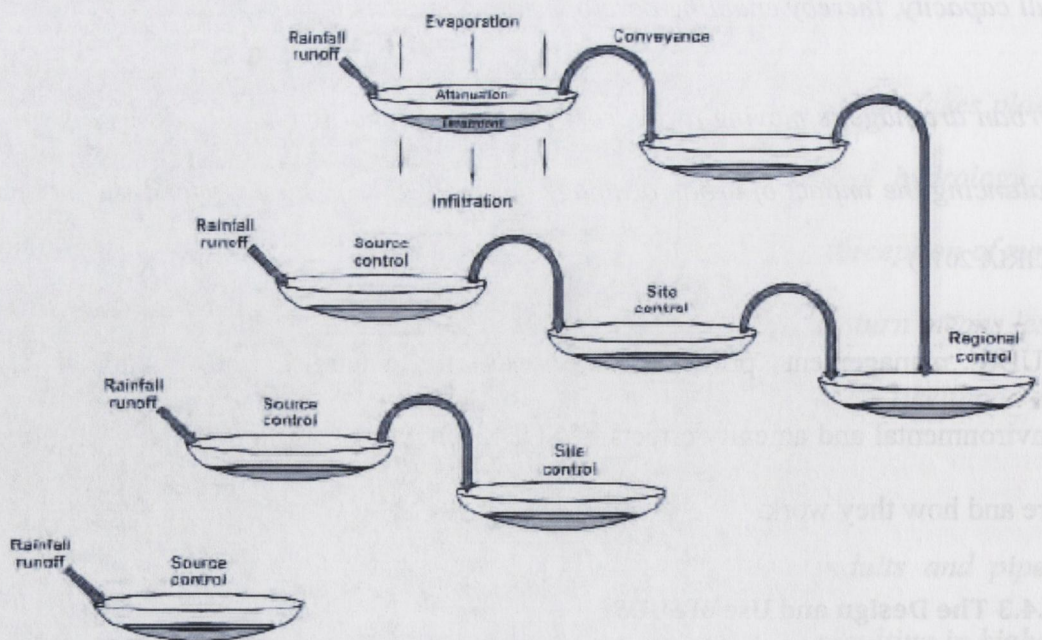


Figure 8 SUDS management train (CIRCA SuDS Manual 2007)

The SUDS management train approach to designing of SUDS as described in the SUDS Manual uses the following hierarchy:

1. Prevention

Utilizing good housekeeping in the design of SUDS to limit runoff and pollution by limiting the hard standing area and preventing spills through the use of bunds, having a regular cleaning regime and the use of rainwater harvesting.

2. Source Control

Controlling runoff at or near the source of the runoff. For example greenroofs, permeable paving, filter drains, soakways, etc.

3. Site Control

Management of the runoff from developed site. Methods of control can include detention basins, and runoff routing.

4. Regional Control

Managing the drainage catchment or local network through the construction of large SUDS infrastructure such as integrated wetlands. The development of regional policies for the use of SUDS and storm drainage in particular

Generally when designing a SUDS system the designer should consider the hydraulic needs (the storage volumes), the long term maintenance need, and the removal of sediment, angle of earthwork banks in a swale or detention basin. In addition the ascetics and amenity value should be taken into consideration (making the SUDS device fit in with its surrounds).

The use of the management principle has lead to the development of a range of different types of SUDS devices which is reviewed in the next section.

2.4.4 Types of SUDS devices

There are a large range of common SUDS devices that are in use. By in large they fall into the following categories:

- Infiltration devices -soakaways, swales, filter strips,
- Basin, ponds and wetland
- Attenuation Devices - attenuation tanks rain water harvesting

Some devices such as permeable paving can either be attenuation device or infiltration devices depending on their design. This section gives a short guide to some common types of SUDS devices in use, how each device deals with the three SUDS criteria of water quantity, water quality and amenity and will also give an example of when this type of SUDS device is most commonly used.

Soakaways

A soakaway is in essence a pit that has been dug and filled with a permeable material such as gravel which facilitates the drainage of excess rainwater into the ground.

“A subsurface structure into which surface water is conveyed to allow infiltration into the ground. Soakaways can be circular perforated manhole structures filled with granular stone or trenches filled with stone, facilitating percolation and separation of solids prior to infiltration. The procedure for soakaway design is set out in BRE Digest 365.” (Suds Wales 2009)

“A pit, usually filled by single sized aggregate, into which surface water is drained to infiltrate into the ground.” (Irish SUDS 2009)

“Soakaways are normally circular structures constructed with concrete rings with holes in, surrounded by granular material. Soakaways constructed for houses usually dispense with the concrete rings and are just filled with shingle.” (Irish suds guidance 2010)

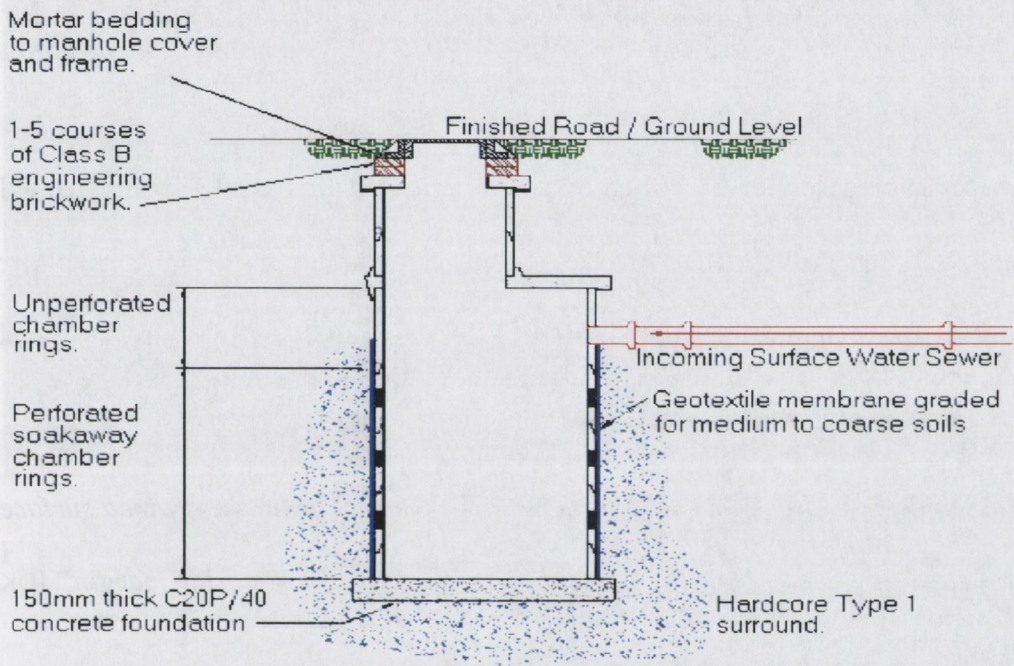


Figure 9 Soakaway (web com systems 2010)

Soakaways are able to provide a reduction in quantity of stormwater runoff from a site as some of the runoff will soakaway into the ground. Soakaways also provide a reduction in water pollution from a site as some of the pollutants are absorbed into the ground and not carried off site into the downstream network. Soakaways have little or no amenity value

Soakaways however are not very useful in dealing with large scale runoff and if the runoff is heavily polluted then there may be issues with the pollution of ground water depending on the local soil type and the level of the local water table.

“Soakaways should be designed to provide a minimum 1m unsaturated zone below the base of the unit to protect groundwater. This can preclude the use of these units as groundwater would generally need to be greater than 3m below ground level.” (Irish suds guidance 2010)

Soakaways are normally thought of as a small scale SUDS measure. They are best used for one off houses and small developments or as a small part of an overall SUDS system where there are small flows with low levels of pollution.

Swales

Swales can sometimes be described as a ditch or a filter strip and are essentially a vegetated dip in the ground with permeable material at the bottom of it. Swales are designed to allow the normal runoff soakaway into the ground and only excess runoff ends up in the piped system

“Swales are grassed depressions which lead surface water overland from the drained surface to a storage or discharge system, typically using the green space of a roadside margin” (UK Environment agency 2010)

“Swales are vegetated surface features that drain water evenly off impermeable areas” (*3 CIRIA Website 2010)

“The term given to a grass channel for stormwater collection with shallow side slopes and gradients to allow ease of maintenance and which is normally dry except during rainfall. The design of the soil and vegetation is important to maximise its operational effectiveness, both hydraulically and for treatment.” (Irish suds 2009)

“Swales are either natural depression or wide shallow ditches which are used to store and route the run-off temporarily. A swale ought to be comprised of a filter strip and is mainly a source control measure”. (D. Sharmal 2008)

Swales are a *“Grass lined channel designed to convey water to infiltration or a watercourse. Delays runoff and traps pollutants via infiltration for filtering effects of vegetation”*. (B Hennelly 2005)



Figure 10: Swale North Carolina USA (Thomas engineering 2010)

“The standard or conveyance swale - is a shallow vegetated channel of around 400mm deep, up to 5m wide at ground level and 1m wide across the base. This receives sheet flow off roads and hard standings and conveys it to a point where it is discharged into a pipe network or other structure. The length of the swale is limited primarily by its conveyance capacity and characteristics, as erosion of the base needs to be avoided” (Irish suds guidance 2010.)

Swales have a beneficial effect in reducing stormwater runoff as some of the runoff will infiltrate into the ground and some of the runoff will be stored in the swale itself. Swales also have an effect on reducing the pollutant load in runoff. The advantage of using swales over some other infiltration devices is that the vegetation removes some pollutants from the runoff prior to it entering the surface water system or the groundwater system.

Swales can have some amenity value as they can be very easily worked into the landscaping and in some case the public may not even know they are there. However if a swale is not maintained or if it is incorrectly designed, be it too small or have too large a gradient into the swale, the swale may not function correctly and may become a quagmire of muddy ground that is both an eyesore and of little use for dealing with future runoff. Swales are commonly used in the stormwater drainage for major roads

Swales

Permeable Paving

Permeable paving is a type of paving surrounded by a permeable material (sand in some cases), above a membrane layer with a pipe underneath the paving. This is designed to slow the runoff from getting into the drainage system and also has the benefits of removing large pollutant matter from the runoff.

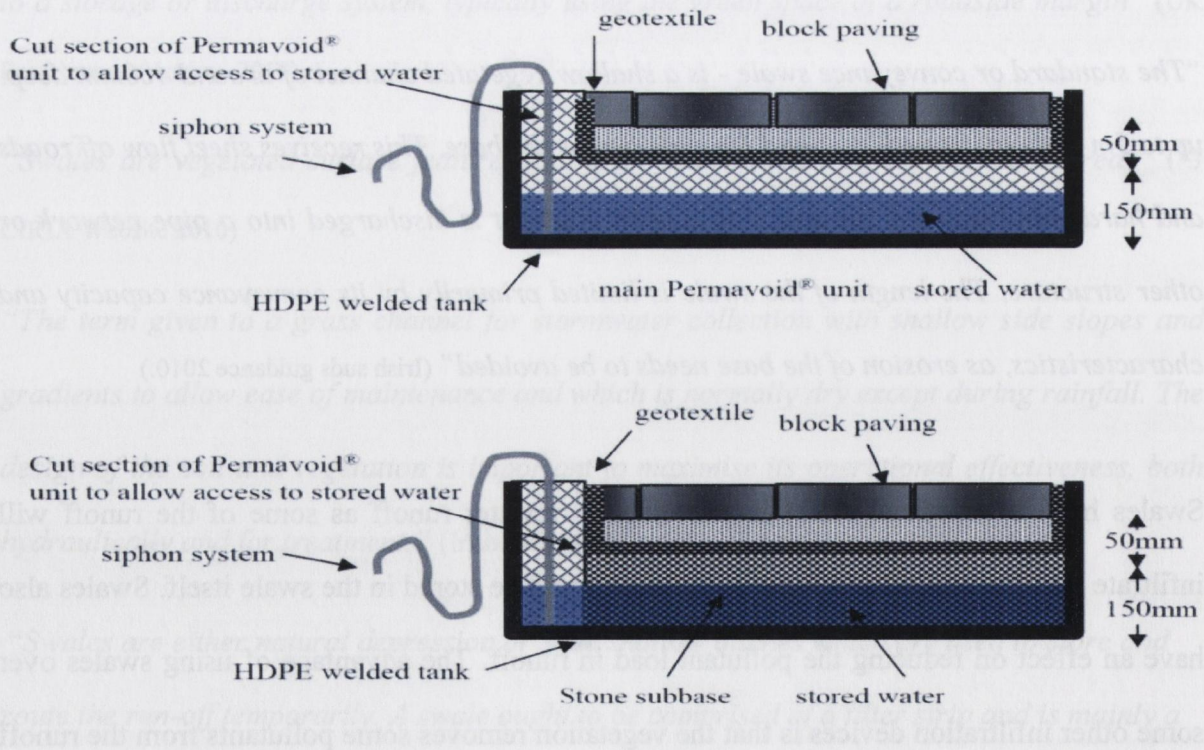


Figure 11 Cross section through permeable paving (Ernest O Nadil 2008)

“A permeable surface that is paved and drains through voids between solid parts of the pavement into a permeable sub-base.” (Irish suds 2009)

“The sub-base normally comprises granular material of specific size grading, but high voids plastic media is used sometimes due to storage volume efficiency gains. The depth of construction is designed to provide structural support as well as provide surface water storage. The granular fill is normally around 350mm deep, although depths can be designed to be more or less than this value.” (Irish suds design criteria 2010)

“Permeable pavements are designed to reduce imperviousness, consequently minimizing surface run-off. They vary in type from porous asphalt, porous concrete, or modular paving (large gaps between impervious areas allows infiltration) and are suited to lightly trafficked areas.” (GDSDS SUDS vol2 2005)

“Use of porous asphalt, porous paving or similar concepts to reduce imperviousness thus minimising runoff. Runoff infiltrates to a stone reservoir where some breakdown of pollutants occurs before controlled discharge to a drain or watercourse or direct infiltration”. (B Hennelly 2005)



Figure 12 permeable paving Thomond park Limerick (tobermore 2010)

Permeable paving has a large effect on the reduction of the quantity stormwater runoff as well as slowing the rate that runoff will enter the downstream surface water network. It also has a beneficial effect on water quality as large pollutant matter gets stuck in the voids in the pavement. The main amenity value of permeable paving is its use in car parks.

Permeable paving is particularly usefully when paving car parks and is used as standard practice by the German supermarkets Aldi and Lidl. The downside of permeable paving is that it is quite maintenance heavy. The top surface itself needs careful maintenance to ensure that the pervious sections between the paving doesn't become clogged. Permeable paving generally has a shorter life than normal paving due to the need to replace the sand and the membrane underneath it more frequently than normal paving. Permeable paving also has an image of being less robust than normal paving and due to this image most road departments

of county and city councils in Ireland are reluctant to take it in charge. Dublin City Council Roads and Paving Department has yet to take any permeable paving in charge and it is predominantly only in use in private development and in some Dublin City Council housing developments. Figure 10 below is from research carried out in Canada and while the results may be more extreme due to Canada very cold winters than could be expected in Ireland, it still demonstrated the reduction in effectiveness of permeable paving over time and the need for regular maintenance.

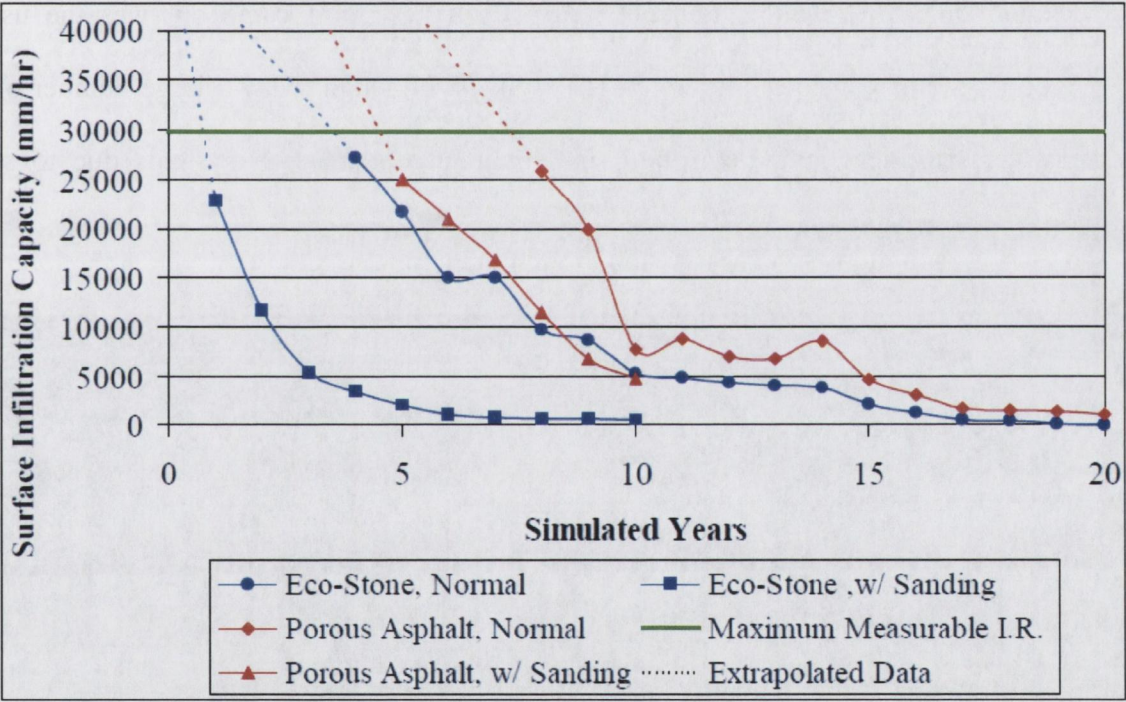


Figure 13 Graph from Characterization of Long-Term Solids Removal and Clogging Processes in Two Types of Permeable Pavement under Cold Climate Conditions (B. van Duin 2008)

Attenuation tanks

The concept of attenuating flow is to reduce the peak flows of runoff in a storm by storing the runoff in a tank or system of pipes, the attenuation tank. The principle is to release storm water only at set rates and to store the additional flow until it can be released over time at a

set rate. In the case of attenuation tanks there is no pollution treatment or amenity value to the attenuation storage. Attenuated storage is not considered a true SUDs device because of this.

“A storage unit designed to attenuate flows by limiting flow rates out of it and storing the difference between the in-flow and out-flow temporarily, and releasing it as in-flows reduce/cease.” (Irish SUDS 2009)

Attenuation storage was one of the first storm water management system used in Dublin and indeed the first storm water policies in Dublin simply asked for attenuated flow. Only after the Greater Dublin Strategic Drainage Study (GDSDS) report came out was the use of attenuation systems consider less preferable to SUDS although today a large number of the storm water management systems built in Dublin use attenuation systems due to space limitations in the city centre.



Figure 14: Attenuation tank Lansdowne rd stadium Dublin 2009

Greenroofs

A greenroof is a roof that has been designed with plant life growing on it on a protective water proof membrane.

“I would describe this as an engineered roofing system that includes vegetation planted in a growing medium above an underlying waterproof membrane material. It has also been referred to as a living roof or eco-roof, to differentiate a vegetative extensive roof specifically from other types of sustainable roofs such as those covered with photo-voltaics or highly reflective roofs (white roofs), which are often included in the broader environmental term of green or sustainable roofing systems.” (Jan Voelz 2006)

The greenroof reduces the amount and slows the rate of roof runoff entering the drainage system by retaining some of the runoff in a the vegetation layer and in the membrane under the vegetation layer

“Green roofs are effective in providing both attenuation and reduction of runoff for small events”. (Irish suds design criteria 2010)

“They play a part in the control of rainwater run-off through three functional characteristics: storage capacity, water consumption through evapotranspiration, delay in flood peak.” (A Baraglioli 2008)

The green-roof also has the effect of reducing the pollution load in the runoff. Green-roofs can retain and bind contaminants that fall on their surface either as dust or dissolved in rainwater. Research by Johnson and Newton, (2004) found that 95% of heavy metals are removed from runoff by green roofs and nitrogen levels can be reduced.

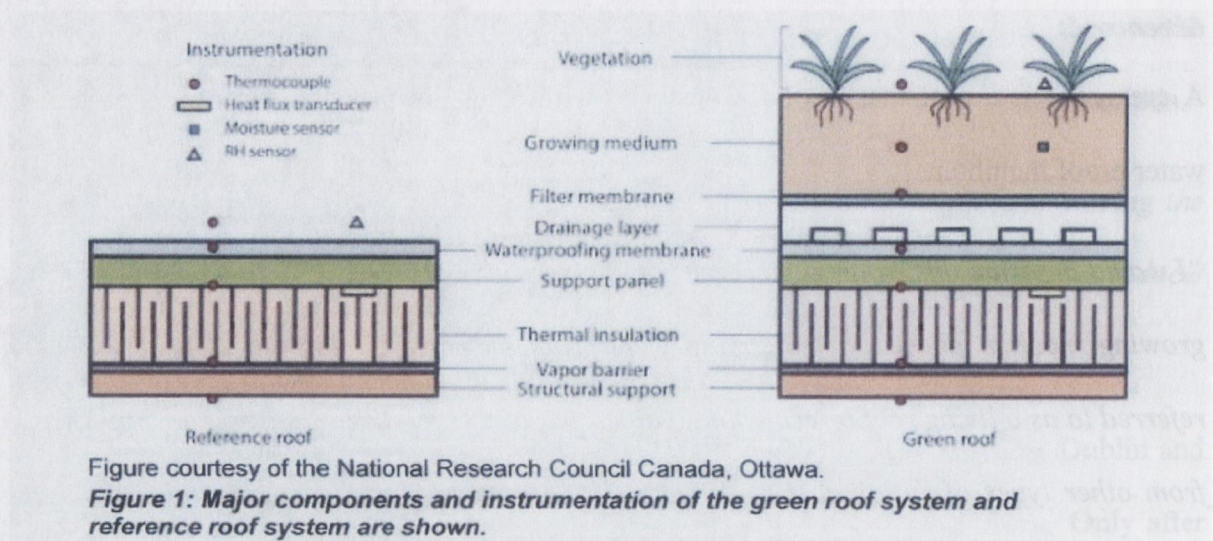


Figure 15: Cross section of a typical green roof (Jan Voelz 2006)

There is also an amenity value to well designed green-roof systems. This is particularly the case in urban areas where there may be limited green space, so the green roof can be used as a leisure area for residents. Dublin City Council now has a Green Roof Policy which promotes the use of green-roofs as a way of not only providing alternative drainage but also increasing biodiversity in the city.

“In urbanized areas, undeveloped land is scarce and storm water management must be retrofitted into the built environment, so green roofs provide a way for roofs to be used beneficially rather than contributing to storm water problems.” (A. Palla 2008)



Figure 16 Extensive green roof in Basel Switzerland (DCC Green roof policy 2008)

Wetlands

A wetland is a shallow pond with vegetation planted throughout the pond. Wetlands can be utilised to provide both a good volume runoff control and pollution treatment if designed and managed properly. The volume of the wetland provides a space for the attenuation of the stormwater flow and the vegetation provides treatment to the runoff as well as providing a community amenity by the way of a habitat for birds etc

“Relatively shallow pond(s) and marshland areas covered almost entirely by aquatic vegetation. Provide good biological treatment and removal of dissolved contaminants and nutrients” (Sniffer 2009)

“A wetland is essentially a pond that has a high proportion of emergent vegetation in relation to open water. Wetlands provide valuable habitat and amenity value as well as attenuating and treating flows that pass through them. The vegetation slows flows and facilitates the settlement of solids within the flow.” (Suds Wales 2010)

“A continuously wet area in which the water is shallow enough to enable the growth of bottom-rooted plants. It has a requirement for a continuous base flow to maintain healthy vegetation. Treatment of stormwater can be very effective, but if used for attenuation, consideration needs to be given to the effect of fluctuating water levels on plant life.” (Irish Suds Glossary)

However if wetlands are undersized the runoff can have the effect of washing away all the vegetation in a storm event and leaving little storage. If the wetland is oversized the wetland can run dry, killing the vegetation in the wetland and therefore the pollution prevention. The key aspect of wetlands is maintenance, if a wetland is not maintained properly alien plant species can migrate into the wetland reducing its pollution treatment. Eventually the wetland will have to be dredged to remove the build up of deposits over the years.

“Maintenance requirements for wetlands are similar to those of retention ponds: Inlets and outlets should be inspected quarterly or after large storms for evidence of clogging or accumulation of debris. During the first two years, it is extremely important that the facilities be inspected quarterly for nuisance vegetation and that these be removed; this will insure a healthy and aesthetically pleasing facility. Other potential problems that should be checked include subsidence, erosion and litter accumulation. Remedial work should be carried out when required. Sediment may have to be removed from the forebay once every 5 to 7 years or when half of the forebay depth is filled with sediment. The wetlands themselves may have to be dredged once every 25 years or less. Stormwater wetlands require frequent maintenance in the first 3 years to establish the marsh. Thereafter, maintenance will be that carried out as in other pond systems. Aquatic vegetation within the wetland should be cut back after flowering, and thinned when necessary, typically every 7 to 10 years”. (Irish SUDS Guidance 2009)



Figure 17: Tolka valley wetland North Dublin May 2009

Rain water harvesting

Rain water harvesting is a system of storing or attenuating rainwater runoff, generally roof runoff. The main difference between a rainwater harvesting tank and an attenuation tank is that stored runoff is used on site after the storm for amenity purposes.

The size of these rain water harvesting systems can range from rain water butts used in household gardens for watering the garden to massive tanks as used in Dublin’s AVIVA Stadium for watering the playing surface. Rain water harvesting can sometime be used to feed a grey water system in a building, this recycled water or runoff used is used to feed devices that require water but not necessarily drinking quality water such as toilets.

“A system that collects rainwater locally (usually from roofs, but occasionally from hard standings) rather than allowing it pass to the drainage system” (Irish suds 2009)



Figure18: Rain water harvesting tank York Street Dublin July 2010

Detention/retention ponds

Retention ponds are large lakes that are used as storm water storage. A retention pond is designed to attenuate the stormwater flow by limiting the outflow from the site and storing the runoff volume in a lake or pond. Retention ponds also provide some water quality benefit through the settling of solids over time.

It is essential that they are sized correctly as the retention pond will only provide water treatment through the settlement of pollutants if the retention time of the runoff is sufficiently

long. Retention ponds, if well designed and landscaped, can also be seen by the local community as an amenity

“A SuDS pond consisting of a significant sized permanent pool of water (up to 4 times V_d) designed to treat surface runoff by detaining the water to provide settling of sediments, and chemical and biological processing as well as provide attenuation. Often used to provide high amenity value.” (Irish SUDS Glossary 2009)

“Permanent water bodies which store excess water for long periods allowing particle settlement and biological treatment. Very effective for pollutant removal but limited to larger developments. Have high habitat and aesthetic benefits.” (B Hennelly 2005)

“Wet detention ponds are storm water control structures providing both retention and treatment of contaminated storm water runoff”. (US EPA 2009)

“The treatment of urban stormwater by retention ponds is known to be effective for water quality improvement as well as storm flow management and in the past two decades has become widely implemented.” (K. Vopicka2008)



Figure 19: Retention pond Pelletstown North Dublin March 2010

2.5 Summary/ Conclusion

The use of traditional systems such as the one that has developed over time in Dublin are no longer able to deal with the effects of urbanisation on the environment. EU legislations such as the WFD and the UWWTD have become also very important drivers for drainage policies and project development.

SUDS was developed in response to the effects of urbanisation and development have been shown to have an impact on the water environment. SUDS is also seen as a way to deal with these developmental, environmental and legislative issues.

SUDS however are not the total answer but if they are carefully designed and managed SUDS will yield acceptable hydraulic and environmental improvements. SUDS devices work best in tandem with other SUDS devices and depending on local conditions the correct SUDS device can vary from site to site depending. Chapter 3 will look into how SUDS are used in Dublin.

“The use of SuDS is now compulsory in the Dublin Region and this is spreading to other parts of the country. SuDS bring enormous benefits in terms of stormwater control, prevention of flooding, removal of pollutants and provision of amenities to local communities. It is unlikely that the water quality requirements of the EU’s Water Framework Directive can be met without greatly increased use of SuDS systems” (B. Hennelly 2005)

Chapter 3

3. SUDS in Dublin

SUDS was first introduced into Dublin in 1998 through the Stormwater Management Policy. The greater Dublin regional drainage strategy 2005 further promoted the use of SUDS and has become the key stone to the use of SUDS in Dublin. The GDSDS Development policy states ***“SUDS is therefore mandatory for all new developments”*** (GDSDS SUDS Vol 2 2005). The GDSDS also set out design criteria for the use of SUDS in Dublin. This chapter tracks the development of SUDS policy in Dublin, sets the criteria under which SUDS must be designed in Dublin and sets out examples of SUDS used in Dublin in four case studies.

3.1 Dublin's Stormwater Policy

SUDS have been an integral part of Dublin City Council's (DCC) storm water planning for a number of years. DCC introduced its *Stormwater Management Policy* in 1998. This policy limited runoff from developed sites to pre-development levels or, in simple terms, runoff from new development was not permitted to exceed 2 l/s/ha with excess runoff being stored on site. Throughout this period developers generally used attenuation tanks with hydro breaks to reduce the storm flows from their new developments to the permitted levels. The 1998 Stormwater Policy was superseded by the GDSDS Regional Stormwater Policy in 2005

3.2 Greater Dublin Strategic Drainage Study

The Greater Dublin Strategic Drainage Study (GDSDS) was commissioned in 2001 with the aim of identifying the drainage issues in the greater Dublin Area and developing a common code of practice for dealing with drainage issues through the Dublin region

“The Greater Dublin Strategic Drainage Study was commissioned in 2001 to carry out a strategic analysis of the existing foul and surface water systems in the local authority areas of Dublin City, Fingal, South Dublin, Dun Laoghaire Rathdown and the adjacent catchments in Meath, Kildare and Wicklow. The objectives of the study were to identify the policies, strategies and projects for developing a sustainable drainage system for the Greater Dublin Region.” (GDSDS overall policy 2005)

The identification of drainage issues involved dividing the drainage network into catchments and the carrying out of large flow surveys of the drainage flow surveys before developing drainage models of the network. These drainage models were then used to assess the drainage system problem and propose some outline solutions. These drainage models were also used in conjunction with the assessment of best international practice to review the local authorities’ practices in five key areas:

- New Development
- Environmental Management
- Climate Change
- Inflow/Infiltration and Exfiltration
- Basements

In the GDSDS policy documents the use of more SUDS is recommended as an integral part of the solutions to future drainage problems.

A whole section of the GDSDS policy document is dedicated to SUDS. The policy on new development goes further than general recommendation in that it states for all new developments SUDS are a mandatory part of the drainage system.

“SUDS is therefore mandatory for all new developments, except where the developer can demonstrate that its inclusion is impractical due to site circumstances. Where SUDS cannot be provided, the developer must provide alternative means of dealing with pollutants”
(GDSDS SUDS Vol 2)

One of the outcomes of the GDSDS recommendations was the development of a regional code of practice.

3.3 Greater Dublin Regional Code of Practice for Drainage Works

In March 2005 the Greater Dublin Regional Code of Practice for Drainage Works (Version 6.0) (GDRCOP) was drawn up by the six local authorities involved in the GDSDS (Meath, Kildare, Wicklow, Fingal, South Dublin, Dun Laoghaire Rathdown County Councils and Dublin City Council). The local authorities used the *GDSDS New Development Policy* and Best Management Practices derived from international experience as a basis for this document. The GDRCOP document does not override the GDSDS policy document; however it does act as a practical day to day summary of the policies.

A new Stormwater Management Policy for Developers was drawn up as part of the Greater Dublin Regional Code of Practice for Drainage Works and SUDS became a compulsory part of development in the DCC’s administrative area in March 2005. In the Stormwater Management Policy, the maximum permitted surface water outfall from any new development is to be restricted to that of a greenfield site before any development took place and SUDS devices are now *“a mandatory requirement of the local sanitary authority”*. Four *“key design criteria”* for stormwater drainage are defined in the code of practise:

1. River Water Quality Protection: The objective of this criterion is the interception/treatment of the first 5-10mm of rainfall runoff to receiving water.
2. River Regime Protection: This criteria limits the discharge rate from a site to 2 l/ha or the rate equal to a 1 year storm on a greenfield site.
3. Level of Service: The purpose of the criteria is to limit the onsite flooding to no flooding for a 30 year 30 minute summer design storm, no property flooding for a 100 year storm and no flooding of an adjacent site in a 100 year storm event.
4. River Flooding Protection: To accommodate long term temporary storage for floodwater on the site for extreme events.

The Stormwater Management Policy does not consider attenuation tanks as true SUDS device as they are not designed to improve the water quality. Attenuation tanks are only permitted as a “last resort”. However, developers have installed a large number these tanks in the DCC area because of the confined nature of the sites under development. This is especially true for the Dublin Docklands Development Area where developers have built some tanks under the public road. SUDS devices mentioned as acceptable in the storm water policy include swales, permeable paving, filter drains, storage ponds, constructed wetlands, roof gardens, soakaways, etc.

3.4 Design of SUDS in Dublin

The Greater Dublin Regional Code of Practise gives a guide to developers regarding the use of SUDS and the conditions that must be complied with. These conditions are shown in Figure 19 which has been taken from the Greater Dublin Regional Code of Practise.

Criteria	Sub criteria	Return Period (Years)	Design Objective
Criteria 1: River water quality protection	1.1	<1	Interception storage of at least 5mm, and preferably 10mm, of rainfall where runoff to the receiving water can be prevented.
	1.2	<1	Where initial runoff from at least 5mm of rainfall cannot be intercepted, treatment of runoff (treatment volume) is required. Retention pond (if used) is to have minimum pool volume equivalent to 15mm rainfall.
Criteria 2 River regime protection	2.1	1	Discharge rate equal to 1-year greenfield site peak runoff rate or 2l/s/ha, whichever is the greater. Site critical duration storm to be used to assess attenuation storage volume.
	2.2	100	Discharge rate equal to 1 in 100 year greenfield site peak runoff rate. Site critical duration storm to be used to assess attenuation storage volume.
Criteria 3 Level of service (flooding) for the site	3.1	30	No flooding on site except where specifically planned flooding is approved. Summer design storm of 15 or 30 minutes are normally critical.
	3.2	100	No internal property flooding. Planned flood routing and temporary flood storage accommodated on site for short high intensity storms. Site critical duration events.
	3.3	100	No internal property flooding. Floor levels at least 500mm above maximum river level and adjacent on-site storage retention.
	3.4	100	No flooding of adjacent urban areas. Overland flooding managed within the development.

Criteria	Sub criteria	Return Period (Years)	Design Objective
Criteria 4 River flood protection (Criterion 4.1, or 4.2 or 4.3 to be applied)	4.1	100	“Long-term” floodwater accommodated on site for development runoff volume which is in excess of the greenfield runoff volume. Temporary flood storage drained by infiltration on a designated flooding area brought into operation by extreme events only. 100 year, 6 hour duration storm to be used for assessment of the additional volume of runoff.
	4.2	100	Infiltration storage provided equal in volume to “long term” storage. Usually designed to operate for all events. 100year, 6-hour duration storm to be used for assessment of the additional volume of runoff.
	4.3	100	Maximum discharge rate of QBAR or 2 l/s/ha, whichever is the greater, for all attenuation storage where separate “long term” storage cannot be provided.

Figure 20 : SUDS Criteria In Greater Dublin Regional Code of Practice for Drainage Works (Greater Dublin Regional code of practise 2005)

All the sites developed in Dublin since the adoption of the GDSDS policies and the introduction of the GDRCOP for drainage works should have SUDS as part of their storm water management for the development and these SUDS devices should fulfill the minimum criteria set out in Figure 19.

The criteria are designed to *“provide a consistent approach to addressing the increase in both rate and volume of runoff as well as providing a mechanism for protecting the*

environment from the pollution that is washed off roads and buildings” (Irish SuDS: design criteria 2010)

However all these criteria are site specific and” In some exceptional cases it may not be feasible to use the above devices and at the discretion of the Local Sanitary Authority, approval may be given to install underground attenuation tanks or enlarged pipes in conjunction with other devices to achieve the required water quality” (Greater Dublin Regional code of practise 2005)

The design criteria recommended by the GDSDS and GDR COP to design SUDS are all based on the best international practice for stormwater design however it is important to recognise there are limitations when used to design drainage systems for urban drainage catchments. All the design calculations are based formulas, coefficients and assumptions developed for the study of rural river catchment. These rural catchment formulas do however provide a good conservative approximation of runoff quantities for the design of storage volumes.

The following sections will look at the way in which these SUDS design criteria are calculated and applied for interception and treatment volume, runoff rate, storage volume long term storage volumes. The importance of amenity value to SUDS design will also be discussed.

3.4.1 River Water Quality Protection Criteria 1

The rainfall runoff from greenfield sites generally only contributes a nominal amount of pollutant and sediment in run-off to rivers. For most rainfall events, which have low rainfall depth and intensity there is little or no direct run-off to rivers, with rainfall filtering away into the ground. The CIRIA SUDS Manual says that “*around 50% of rainfall events are sufficiently small enough that there is no measurable runoff from Greenfield areas*”. This water will over the next period of time find its way into the base flow in the river place.

The rainfall runoff from an urban site when drained by a traditional pipe systems, results in runoff from virtually every rainfall event drained directly to the river. This runoff will carry high levels of pollution, particularly in the first part of the run-off (the first flush), with little or no of the rainfall actually filtering into the ground. There is no support for the base flows in rivers. SUDS Manual states that *“The different means that streams and rivers receiving runoff from impermeable sites become more flashy and groundwater recharge and river base flow are reduced. In addition, development runoff flushes surface pollutants directly into receiving waters with every rainfall event.”*

“Appropriate design criteria to address these differences are therefore:

- *No run-off to pass directly to the river for rainfall depths of 5mm and up to 10mm if possible (interception);*
- *Use of infiltration drainage techniques;*
- *Use of stormwater treatment techniques”* (GDSDS stormwater design 2005)

There are, however a number of practical issues in applying these criteria. The storage volumes required to store 10mm of rain were seen by the GDSDS report as too large for urban sites and infiltration may not be practical in all types of sites in Dublin due to varying soil types and ground conditions. To resolve these practical issues the solution applied requires the interception of the first 5-10mm of runoff or the storage for treatment of an additional 15mm of runoff.

Criteria 1.1 is designed to reduce the first flush effect of rainfall events on the receiving waters from small events. A first flush effect is seen when there is a buildup of sediment and pollutants on surfaces which are then washed into the surface water drainage system when a

rainfall event big or small happens, which causes a higher pollutant effect on the receiving waters.

“Many researchers have reported that pollutants can exhibit higher levels in the initial portion of a stormwater runoff event and this phenomenon is commonly referred to as the ‘first flush’ effect” (D.T. McCarthy 2008.)

“The quality of stormwater runoff is an issue for frequent small events. This is due to the flush of debris and sediment from the catchment surface in the first part of the event together with any sediment deposits in the pipe network”. (The GDSDS Design of SUDS 2005)

The interception volume (V_i) is calculated by multiplying the paved area connected in the site by intercepted rainfall (5mm) by a runoff factor

$$V_i = \text{Rainfall} * \text{permeable area} * \text{Runoff coefficient}$$

The best systems for fulfilling criteria 1.1 are infiltration systems

Criteria 1.2 is designed for larger storms where the interception storage can't be provided.

The treatment storage is for the first 15mm of rainfall and again is designed to reduce the effect of first flush but this time for larger storms. *“The concept of Treatment Storage is to provide a body of water in which dilution and partial treatment (by physical, chemical and biological means) of this runoff can take place”*. (The GDSDS Design of SUDS 2005)

The formula for treatment volume (V_t) is:

$$V_t \text{ (m}^3\text{/ha)} = 9 \times D(\text{SOIL}/2 + (1 - \text{SOIL}/2) \times I)$$

Where:

I = fraction of the area which is impervious (30% impermeable area = 0.3)

D = M5-60 rainfall depth (5 Year Return, 60 minute duration)

SOIL = Soil Classification (Flood Studies or the Wallingford Procedure WRAP map)

“ V_t is thus a function of local hydrological characteristics, soil type and the level of impermeability of the catchment. The presumption is that the treatment volume (permanent pool) is sized to capture runoff from 90% of storms that occur each year.” (GDSDS Stormwater Design 2005).

GDSDS Stormwater Design (2005) states that *“The value for the Dublin region would be an equivalent rainfall depth of around 20mm.”*

In the SuDS Design Manuals CIRIA C521 and C522 it is recommended that up to 4 times V_t is required to provide good treatment of the stormwater volume. Therefore 4 times V_t would be a storage volume of 80mm. This volume is thought by the GDSDS to be impractical to store in an urban environment where they state that

“This is a very large volume of water and recent research suggests that the advantages of large volumes of storage, particularly deep ponds, have limited benefits. It is becoming clear that long residence times can result in the production of high levels of ammonia, due to anaerobic conditions in the sediments, which is very poisonous to river crustaceans and fish.” (GDSDS Stormwater Design 2005).

Shallow ponds however use a greater area and require more maintenance. The GDSDS therefore recommended *“that a figure of 15 mm of rainfall is used for the Dublin region to determine the permanent pool volume, until research provides clear evidence as to what constitutes best practice.”* (GDSDS Stormwater Design 2005).

Taking the GDSDS guidelines into consideration the treatment volume (V_t) is therefore calculated by multiplying the paved area connected to the site by intercepted rainfall (15mm) by a runoff factor

$$V_t = \text{Rainfall} * \text{permeable area} * \text{Runoff coefficient}$$

Retention ponds and wetlands are good examples of systems that could be used to fulfill this criterion

3.4.2 River Regime Protection Criteria 2

In a Greenfield or rural catchment runoff into rivers occurs at a slow rate. In the urban environment, with pipe systems, the runoff is almost immediate and unrestrained. Urban runoff can have high velocities and cause erosion, affecting the morphology of the river channel.

Criteria 2 is designed to protect downstream rivers by limiting the stormwater flow from a site to greenfield flow or 2l/s/ha whichever is greater. This is to ensure that runoff from urban sites is limited to that of a greenfield site and to stop downstream damage of rivers.

“This causes flashy flow in the river that is likely to cause scour and erosion that is likely to seriously affect the morphology and ecology of the stream”. (Irish SUDS: Design criteria 2010)

The Institute of Hydrology in their report¹²⁴ “Flood estimation for small catchments”, (1994) reviewed 71 small rural catchment areas. A regression equation was produced to calculate $QBAR_{rural}$ which is used to determine the mean annual flood.

$$QBAR_{rural} = 0.00108AREA_{0.89}SAAR_{1.17}SOIL_{2.17}$$

Where:

$QBAR_{rural}$ is the mean annual flood flow from a rural catchment in m^3/s .

AREA is the area of the catchment in km^2 .

SAAR is the standard average annual rainfall for the period 1941 to 1970 in mm.

SOIL is the soil index, shown in Figure 21

SOIL	SPR value (% runoff)
1.	0.1
2.	0.3
3.	0.37
4.	0.47
5.	0.53

Figure 21 SPR Values for SOIL (pervious surface runoff factor) (GDSDS Stormwater Design 2005).

The Standard Percentage Runoff value for SOIL types in Dublin are based on runoff models carried out using design storms during the GDSDS. The results of these runoff models are shown below in Figure 22

$QBAR_{rural} = 0.00108 AREA_{rural} SAAR_{rural} SOIL_{rural}$

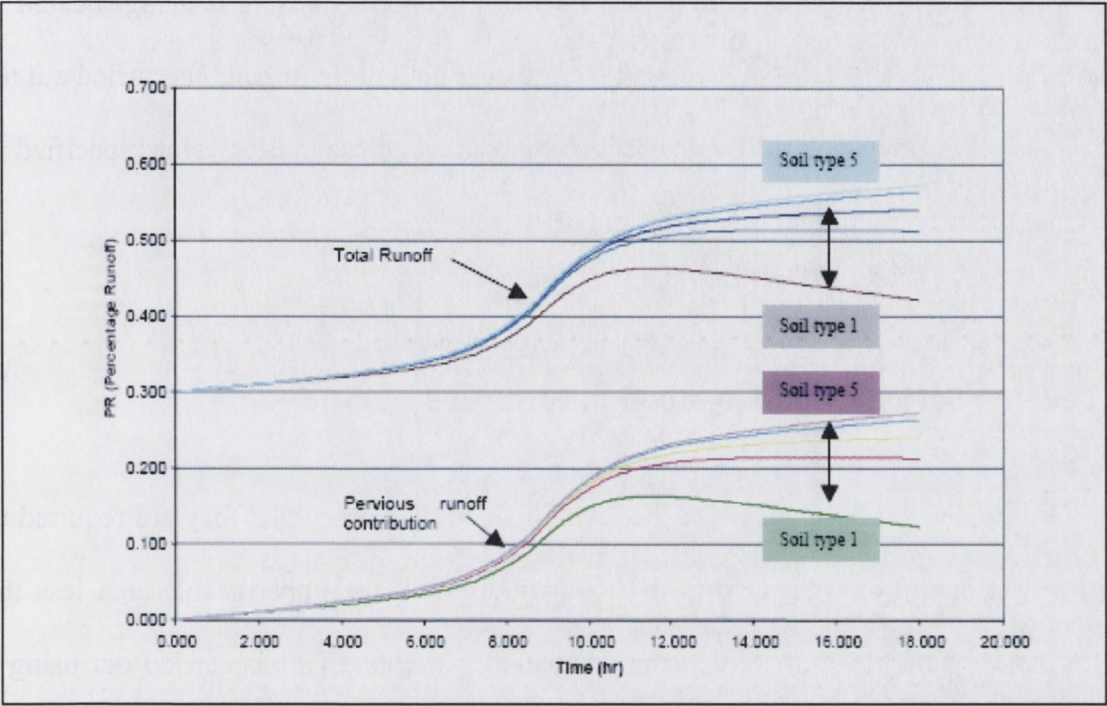


Figure 22 Percentage Runoff as a Function of Rainfall Depth using the New PR Equation (GDSDS FSR Curves 2005).

“The New UK PR model allows for some contribution from pervious areas, which increases with event size. As storms become larger, this is a reasonable premise to make. This pervious term is controlled by the parameter NAPI (Net Antecedent Precipitation Index).

NAPI increases with rainfall depth during the event and therefore PR also increases. Design values for NAPI are a function of SOIL type and selected (usually) on the basis of the mean winter value from analysis of a rainfall time series for attenuation storage analysis.” (The GDSDS Design of SUDS 2005)

It is important to recognise that the SPR value for soil used for calculation of runoff was developed using rural river catchments in Britain and is not necessarily appropriate for SUDS design in urban catchments in Ireland. And indeed the GDSDS report even recognizes the need for further research regarding the soil SPR values. *“It is recognised that further more*

detailed work is warranted to look into this subject, as the implications for drainage design are quite significant". (GDSDS FSR Curves 2005). However until more research is carried out to develop more appropriate soil SPR value, it is recommended to use to SPR values specified by the GDSDS in calculation of greenfield runoff.

3.4.3 Level of Service Flood protection Criteria 3

Criteria 3 provides the developer with the level of flooding storage that they are required to design for. Storage is calculated from the total runoff from the impermeable area less the runoff to the Greenfield runoff or 2 l/s/ha whichever is greater. This is carried out using a hydraulic model for 1 year, 30 year and 100 year storms and for the site critical duration.

Criteria 3 gives limits as to when any surface flooding can take place onsite and where on the site this flooding can occur. No flooding can take place for all 30 year events. For pluvial (rainfall) 100 year events and for river flooding 100 year events no property flooding can take place onsite and the site cannot route flood water to another site unless such routing has been planned for at the planning stage of development. In the case studies that have been reviewed the storage volume is calculated using the rational method to calculate the total flow and limiting the flow to $QBARR_{rural}$ for each storm duration

The rational method for calculating flow is

$$Q = 2.78 * C * I * A$$

Where

Q is the peak flow

C is the runoff coefficient

i is the design rainfall intensity

A is the impermeable area drainage to the network

The rainfall intensity for each for the 10 year, 30 year and 100 year rainfall event for the various durations are based on the Met Eireann rainfall intensity chart in Appendix B

The storage volume is calculated as follows:

$$V = (Q_{\text{total}} * t) - (Q_{\text{limit}} * t)$$

Where

Q_{total} is the total runoff flow onsite

t is the time in seconds

Q_{limit} is the limit to the volume as calculated for Criteria 2

3.4.4 Long Term Storage Criteria 4

Criteria 4 is about designing long term flood storage for the site and limiting the discharge from the site to that of a greenfield site. The idea of long term storage is to allow the developer to separately design long term storage for the site.

“The objective of providing “long term” storage is to protect the river from effects of the increased volume of runoff compared to greenfield conditions. Peak flow rates are addressed by the use of attenuation storage, but it is also important to minimise the additional volume of runoff created by the development.” (GDSDES Stormwater Design 2005).

“The volumetric analysis for “River Flow Protection” is purely a comparison of pre- and post development runoff volumes and can be described as “Long term” storage volume. The objective is to limit the runoff discharged to the river after development to the same as that which occurred prior to development” (The GDSDES Design of SUDS 2005)

“The estimation of the “long term” storage volume is a simple calculation of finding the difference between the runoff volume generated by the development site and that for the greenfield site using the 100 year 6 hour event” (GDSDS Stormwater Design 2005).

The formula for long-term storage is:

$$Vol_{xs} = RD.A.10 \left[\frac{PIMP}{100} (\alpha 0.8) + \left(1 - \frac{PIMP}{100} \right) (\beta.SOIL) - SOIL \right]$$

Where:

Vol_{xs} is the extra runoff volume (m^3) of development runoff over Greenfield runoff.

RD is the rainfall depth for the 100 year, 6 hour event (mm).

PIMP is the impermeable area as a percentage of the total area (values from 0 to100).

A is the area of the site (ha).

SOIL is the “SPR” index from FSR.

α is the proportion of paved area draining to the network or directly to the river
(values from 0 to1).

β is the proportion of pervious area draining to the network or directly to the river
(values from 0 to1

This additional long term storage volume is assumed to only come into effect for extreme events such as 100 year 6 hour storm. In a practical sense this is flood routing to a floodable area of the site (car park, sports field etc)

3.4.5 Amenity Design Criteria

As mentioned in Chapter 2 SUDS is not just about water quality and quantity, a SUDS device should also have an amenity value. The CIRIA SUDS Manual (2007) suggests that the issues that should be dealt with at design stage are visual impact, health and safety and amenity benefit.

The visual impact of SUDS devices should be masked by careful landscaping of the device into the surrounding area. Health and safety has become a major factor in all construction projects and SUDS is no different. There is a perception that some SUDS devices such as wetlands and ponds are unsafe, however with careful design features like shallow slopes these problems can be averted. A risk assessment should be carried out of all SUDS designs prior to construction to minimise the health and safety issues. The amenity benefit of a device should also be reviewed if a SUDS site is to be seen as of benefit to the local area. If a SUDS system is seen as benefit to a local area it is more likely to be maintained and less likely to be damaged through vandalism. Some SUDS device can also have a beneficial effect to the local ecology by increasing biodiversity and reducing pollution

3.5 Use of SUDS in Planning & Development

Dublin City Council Drainage Planning Section (DCCDPS) review the drainage requirements for all developments in the Dublin City Council administrative area and deal with on average 6,000 planning permissions per year. DCCDPS have taken a proactive approach to the use of SUDS in Dublin and in addition to the SUDS requirements set out in the GDR COP, the DCCDPS place additional planning conditions on developers. Developments are dealt with on an individual basis but there are standard approaches used. DCCDPS assess the developer drainage system to ensure that appropriate SUDS devices are used for the developments. In

accessing the suitability of the SUDS DCCDPS check the developers runoff off calculations, check the site location for local water quality, and ground water issues.

In conditioning developments using Soakaways or filter drains DCCDPS uses the following standard condition

“Design and construction of soakaways must comply with the requirements of BRE Digest 365 and CIRIA C522. Calculations to be submitted prior to the submission of the Commencement Notice.” (DCCDPS Standard Condition 2012).

This standard condition requires developers to carry out a percolation test and to design the soakaway to the following standard; CIRIA, 2001 C522 Sustainable urban drainage systems - design manual for England and Wales.

In conditioning developments with a) swales, b) permeable paving, c) retention ponds or d) other SUDS devices that are not primarily used to soak the runoff in the ground but retain and gradually transmit the runoff downstream, the SUDS device and downstream pipes are designed on the basis that all the runoff is retained within the system. DCCDPS approach may be considered a conservative one; however it is probably prudent. One of the councils primary responsibilities is under GDR COP in to prevent flooding downstream from runoff new sites and given the lack of research in the area of soils permeability in Dublin and runoff from SUDS devices such swales and permeable paving it may be difficult to quantify the amount of runoff soaking away and the amount.

3.6 Case Studies

The four case studies have been picked to give as wide a range of different types of SUDS sites and also to provide different reasons for their installation. All the case studies have also had a large amount of Dublin City Council Drainage Division input and therefore the information of the site was more accessible.

Each case study will investigate why SUDS was used instead of traditional drainage, the design considerations and criteria, calculate the flows and interception treatment and storage volumes, discuss the main issues with the use of SUDS at each location and investigate whether or not the SUDS system has been successful and the design criteria have been met.

Case Study 1 in Glendhu Park is a system of swales retro fitted into the exiting urban drainage catchment. It was designed to reduce flooding by allowing excessive surface water runoff to infiltrate into the ground using two large swales.

Case Study 2 in Tolka Valley park is a Wetland build at the end of the Finglasswood river. It is design to treat the urban runoff in the river prior to its entry into the Tolka river.

Case study 3 is in a DCC housing development at York St. The system is design to comply with the GDRCOP. The SUDS system uses both a green roof to treat rainfall runoff and rainwater harvesting tanks to attenuate and recycle rainfall runoff.

Case Study 4 investigates two large development areas in Dublin; Ballymun Regeneration Limited and Pelletstown Development. The SUDS systems for both developments are designed to comply with the GDRCOP and are built on a catchment wide basis rather than on a site by site basis.

3.6.1 Case study 1: Glendhu Park

Introduction

On the 9th of August 2008 an extreme rainfall event hit north Dublin which totalled 76mm of rainfall over a period of five hours, 24.1 mm of rain fell between the hours of 4 pm and 5 pm as recorded in Dublin Airport. This event came at the end of a very wet summer where parts of eastern Ireland had more than twice the normal rainfall level being recorded for the months of June and July and three times the normal rainfall level for the month of August. In the Glendhu estate on August 9th 2008, eight houses experienced flooding; these were Numbers 10-17 Glendhu Park. In addition to this, many other houses within the estate came within inches of being flooded as the entire estate experienced high levels of road flooding. This sub catchment and three others drain into the River Tolka which is located approximately 1 kilometre downstream of Glendhu Park.

House flooding also previously occurred in Glendhu Park on November 17th 2002, following heavy rainfall over a protracted period, which affected houses Numbers 16 and 17. On this occasion the installation of sand bags prevented Number. 15 being flooded. During the 2002 the water level in the two flooded houses was 50mm lower compared to the flooding that occurred 2008 while outside the flood levels were 150mm lower in 2002 compared to 2008. This is consistent with information from the local weather stations which recorded their highest rainfall levels in August 2008.

The houses that experienced flooding in 2002 and 2008 are at a level of 8.8m lower than the estate's entrance at the Navan Road and are also located at the lowest point of the estate. The Glendhu estate and the neighbouring Ashington estate are bordered on the four sides by the

Kempton estate, the Navan Road, the Ratoath Road and the railway line. Within the Glendhu sub-catchment there are 621 houses and a small number of commercial premises. The area of impermeable ground in Glendhu is approximately $82,000\text{m}^2$ and $105,000\text{m}^2$ giving a total area of $187,000\text{m}^2$ to be drained to the River Tolka. Urban creep has significantly increased the impermeable areas since the Glendhu estate was built in the fifties and preventing further urban creep is another recommendation for flood prevention in these estates.



Figure 23 Aerial Shot of Glendhu Park catchment (Bing Maps 2010)

The existing surface water network

The Glendhu Estate is made up of over 4 kilometres of underground surface water drainage while there are 5 kilometres of surface water drainage in the Ashington estate. These pipes are the following sizes in diameter: 225mm, 300mm, 375mm, 450mm, 600mm, and 675mm.

The drainage from these two estates come together and continues under the canal and from here the pipes are 750mm and 1050mm in diameter which continues under the Royal Canal.

In times of very heavy rainfall the local surface water sewers cannot take the excess flood water from the estate at the required rate. This leads to surcharging of the drainage network which results in the discharge of flood waters onto the roadways. Eventually significant volumes of floodwaters flow to the lowest point of the catchment which is Glendhu Park.

In order to help prevent future flooding in this area two large swales in the Glendhu Park area were proposed and are currently being constructed by Dublin City Council.

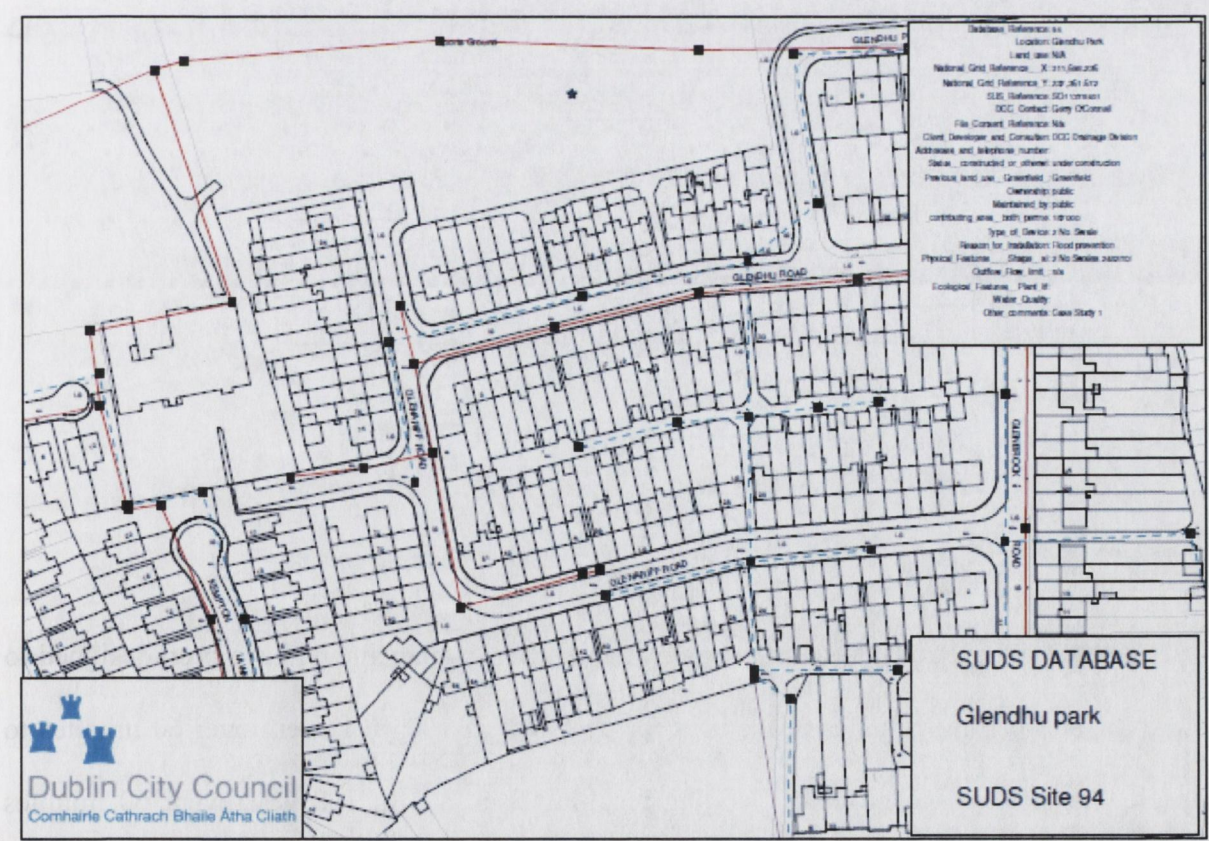


Figure 24: SUDS site 94 Glendhu Park

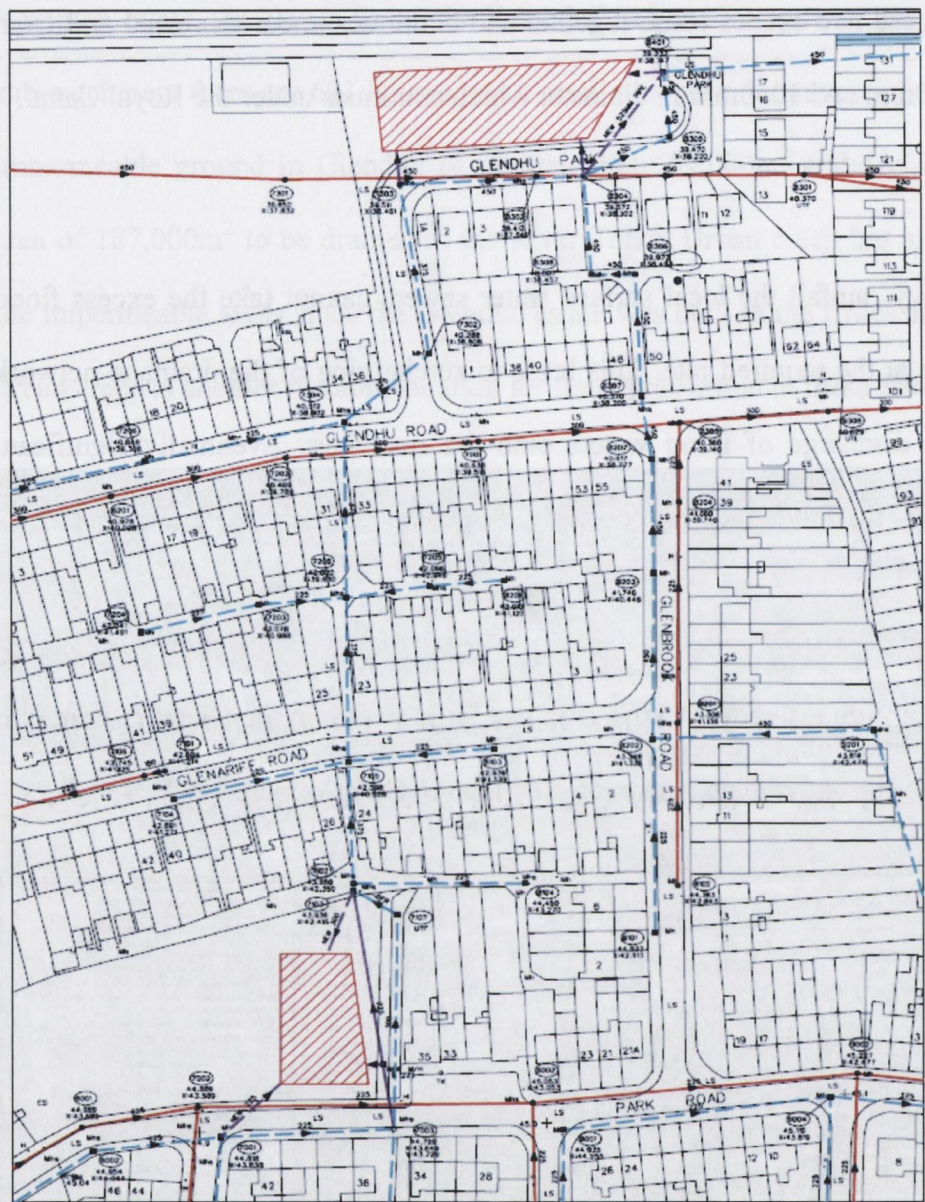


Figure 25: Location of swales in Glendhu Estate

Design Criteria

The Swales are a retro fit system into an existing urban catchment and have been designed to store the storm flow volumes in the area for up to a 1 in 100 year event over 60 minutes to ensure that there is no property flooding resulting from a 1 in 100 year event 60 minutes event and no road flooding in a 1 in 30 year 60 minute event

The following calculations are based on the stormwater design formulas in GDSDS Vol 2 as outlined earlier in this Chapter have been applied to verify if the SUDS device has been effectively designed to prevent future flooding in Glendhu Park

Criteria 1 Interception /Treatment

Criteria 1 is not relevant for the calculations of the swale in Glendhu Park. This swale is a retrofit design into an existing stormwater network to alleviate flooding issues and is not designed to capture the first flush as only excess flows will enter into the swales

Criteria 2 Limit to down Stream flow

The calculation of Greenfield flow

$$QBAR_{rural} = 0.00108 \times AREA^{0.89} \times SAAR^{1.17} \times SOIL^{2.17}$$

Where:

$QBAR_{rural}$ is the mean annual flood flow from a rural catchment in m^3/s .

AREA is the area of the catchment in km^2 .

SAAR is the standard average annual rainfall (for the period 1941 to 1970 in mm).

SOIL is the soil index, which is a composite index determined from soil survey maps that accompany the Flood Studies Report.

QBAR can be factored by the regional growth curve to produce peak flood flows for other return periods.

$$AREA = 18.7 \text{ ha}$$

SAAR = 750 mm this a typical value for Dublin used in the GDSDS storm water design

Soil runoff %. = 0.3 (assumes the soil type is type 2 which is atypical soil type for the Dublin region type 5)

$$QBAR_{rural} = 0.00108(18.7)^{0.89}(750)^{1.17}(0.3)^{2.17}$$

$$QBAR_{rural} = 2.48 \text{ l/s}$$

$QBAR_{rural}$ (Greenfield flow) is greater than 2 l/s and so is therefore used as the limit to downstream flow.

Criteria 3 Level of Service

The storage volume required for various storm events occurring in the region of the Glendhu Estate are presented in Figure 31. The storage calculations have been carried out using the rational method.

Total flow is calculated as follows

$$Total_{VOL} = C \cdot i \cdot A$$

Where

C is the runoff coefficient

i is the rainfall intensity

A is the area.

The flow out of the catchment is calculated as follows

$$Vol_{out}= Q \cdot t \cdot A$$

Where

Q is the limited flow out of the catchment (from criteria 2)

t is the time in seconds

A is the site area

Glendu Park Storage calculations

Time	time in sec	Duration	Rainfall	Site Area	% runoff to enter system (Impermeable area * runoff ration)	Qbarr	Greenfield vol m3
5 mins	300	1	3.5	18.7	0.48	2.48	13.92
10 mins	600	1	4.9	18.7	0.48	2.48	27.83
15 mins	900	1	5.8	18.7	0.48	2.48	41.75
30 mins	1800	1	7.5	18.7	0.48	2.48	83.49
1 hours	3600	1	9.8	18.7	0.48	2.48	166.99
2 hours	7200	1	12.8	18.7	0.48	2.48	333.97
3 hours	10800	1	15.0	18.7	0.48	2.48	500.96
4 hours	14400	1	16.7	18.7	0.48	2.48	667.95
6 hours	21600	1	19.5	18.7	0.48	2.48	1001.92
9 hours	32400	1	22.8	18.7	0.48	2.48	1502.88
12 hours	43200	1	25.4	18.7	0.48	2.48	2003.84
18 hours	64800	1	29.7	18.7	0.48	2.48	3005.76
24 hours	86400	1	33.2	18.7	0.48	2.48	4007.68
5 mins	300	30	10.7	18.7	0.48	2.48	13.92
10 mins	600	30	14.8	18.7	0.48	2.48	27.83
15 mins	900	30	17.5	18.7	0.48	2.48	41.75
30 mins	1800	30	21.9	18.7	0.48	2.48	83.49
1 hours	3600	30	27.4	18.7	0.48	2.48	166.99
2 hours	7200	30	34.3	18.7	0.48	2.48	333.97
3 hours	10800	30	39.1	18.7	0.48	2.48	500.96
4 hours	14400	30	42.9	18.7	0.48	2.48	667.95
6 hours	21600	30	49.0	18.7	0.48	2.48	1001.92
9 hours	32400	30	55.9	18.7	0.48	2.48	1502.88
12 hours	43200	30	61.3	18.7	0.48	2.48	2003.84
18 hours	64800	30	70.0	18.7	0.48	2.48	3005.76
24 hours	86400	30	76.8	18.7	0.48	2.48	4007.68
5 mins	300	100	15.1	18.7	0.48	2.48	13.92
10 mins	600	100	21.0	18.7	0.48	2.48	27.83

As this is a retrofit design the criteria for the swale was to resolve flooding issues for 1 year, 30 year and 100 year 1 hour events. The storage required in the Glendhu Estate for a 1 year 1 hour duration storm event is 713m³. For a 30 year 1 hour duration event the storage requirement is 2,292m³ while for a 100 year 1 hour duration event the storage requirement is 3,326m³.

The storage volume for the Glendhu Estate is provided by a 1800m³ swale in the green area beside Glendhu Park and a 682m³ swale in the green area beside Park Road at the junction of Kinvara Grove. This design complies with the GDSDS criteria as the design fulfils the requirement that there will be no property flooding for a 30 year event. The additional storage require for a 100 year event is to be provided by the road network in the catchment.

Criteria 4 Long Term Storage

The long term storage requirements were not considered in the design as this was a retro fit system and therefore the Greenfield conditions did not exist prior to the building of the swale. However calculations of the long term storage requirements have been assessed in order help show the difficulties in properly sizing retrofitted systems

$$Vol_{xs} = RD.A.10 \left[\frac{PIMP}{100} (\alpha 0.8) + \left(1 - \frac{PIMP}{100} \right) (\beta.SOIL) - SOIL \right]$$

Where:

Vol_{xs} is the extra runoff volume (m³) of development runoff over Greenfield runoff.

RD is the rainfall depth for the 100 year, 6 hour event (mm).

PIMP is the impermeable area as a percentage of the total area (values from 0 to100).

A is the area of the site (ha).

SOIL is the “SPR” index from FSR.

α is the proportion of paved area draining to the network or directly to the river (values from 0 to1).

β is the proportion of pervious area draining to the network or directly to the river (values from 0 to1).

It is assumed that all the 80% imperious drains directly into the drainage network for α and that 80% of the pervious area drain to the network for β .

The PIMP value is the total area impermeable area =. 18.7 * 60%= 11.22 ha.

The soil runoff coefficient used is 0.3 for soil type 2 which is a GDSDS typical soil type for Dublin

Vol Xs	2201.364
RD	65.4
a	18.7
soil	0.3
α	0.8
β	0.8
pimp	0.6

$$Volxs = 65.4 \times 18.7 \times 10 \left[\frac{0.60}{100} (1 \times 0.8) + \left(1 - \frac{0.55}{100} \right) (0.8 \times 0.3) - 0.3 \right]$$

The V_{xs} (excess volume) required for long term storage is 2,201m³ This excess storage capacity has not been accounted for as this is a retro fit design and additional area was not available to increase the storage capacity

Design of the SUDS System

The SUDS system in Glendhu Park consists of 2 swales, a 1800m³ swale in the green area beside Glendhu Park and a 682m³ swale in the green area beside Park Road at the junction of Kinvara Grove.

Swale 1

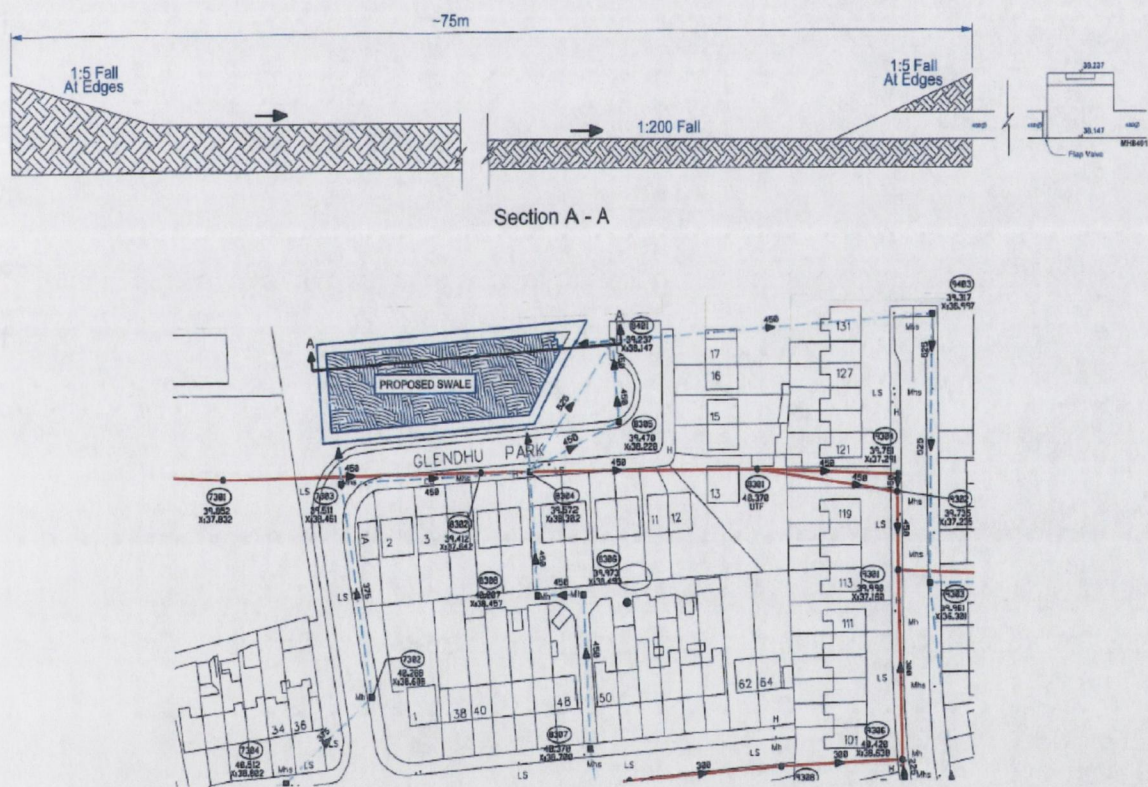


Figure 27 Design Drawing for Swale 1 at Glendhu Park

This swale is located in the green area of Glendhu Park. It has an approximate footprint of 75m x 25m, a depth of 1.5m and has a storage capacity of 1200m³ in times of flood. The

edges have gentle slopes of 1:3 around the perimeter with a smooth transition from sides to base. These details allow mowing of grass without difficulty.

Two manholes immediately before the swale have been be re-constructed to include a weir to allow for the water to enter the swale in times of flood and one manhole has been be re-constructed to allow floodwater to drain from the swale after a flood event. A small earth mound has been formed between the existing footpath and the new swale.

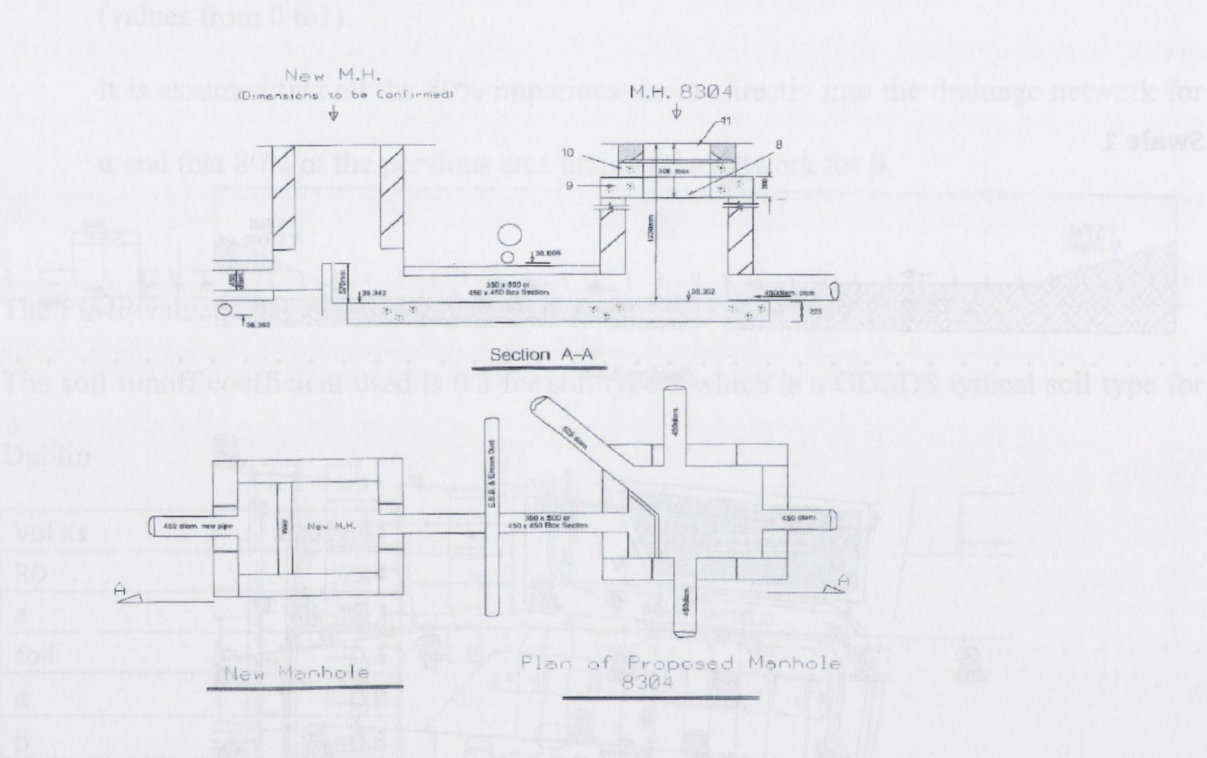


Figure 28: Redesign drawing for Surface water manhole upstream of swale

Swale 2

This swale is located in the green area adjacent Park Road. The storage capacity is 500m³ in times of flood. The edges have gentle slopes of 1:3 around the perimeter with a smooth transition from sides to base also.

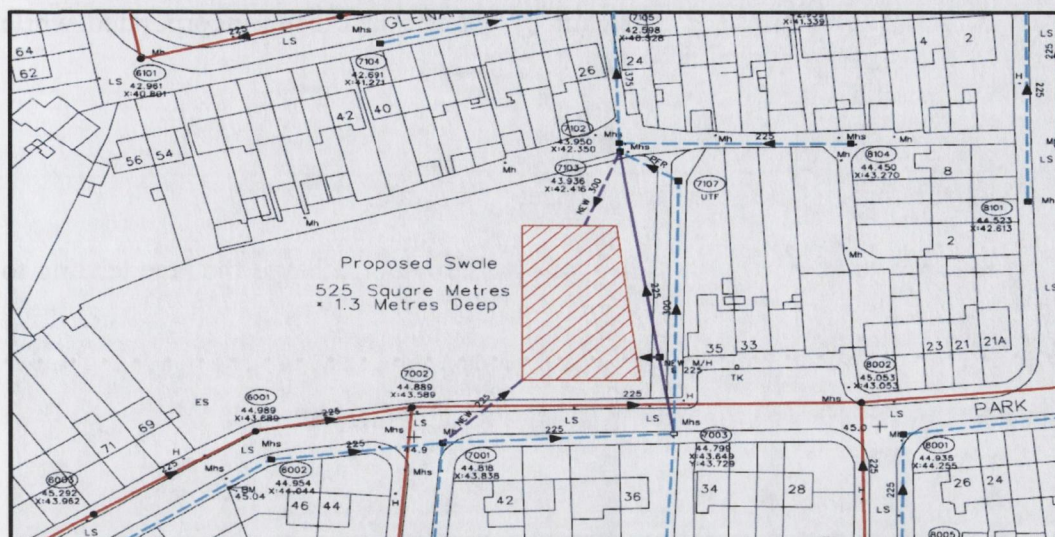


Figure 29 Design drawing for second swale at Park Road

One manhole immediately before the swale has been re-constructed to include a weir. A one new manhole will be constructed with a weir to allow for the water to enter the swale in times of flood while another manhole has been re-constructed to allow floodwater to drain from the swale after the flood event.

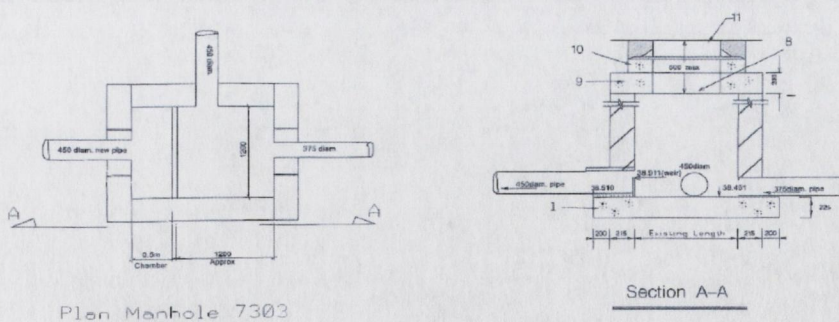


Figure 30: Design drawing for upstream manhole for swale 2

In addition to the new swale some additional improvements have been incorporated while this phase of construction has been ongoing.

- 1) A new footpath through the green area adjacent the swale.
- 2) Two or three new cast iron bollards between the new footpath and the lane leading to Glenariff Rd.
- 3) Re-surfacing of the existing footpath from Park Road to the laneway.

In a 1 in 100 year event the two swales will take approximately one hour to fill up and a further one-hour to drain away. However it will take a 1 in 10 year storm event before any water will flow into the proposed swales.

Construction of the swales, which is now almost complete, started in May 2010 and was carried out by Dublin City Council Drainage Reconstruction Section. Previously these green areas were suitable as play areas for young children and once construction is complete, the swales which will have gentle side slopes, will be grass seeded and maintained by the Dublin City Council Parks Department. This will ensure that the two swales will blend into the existing landscape



Figure 31 Construction of Swale 1 at Glendhu Park

Conclusion

When assessed against the 4 design criteria in the GDSDES Development Policy the design fails to meet both Criteria 1 interception/treatment volume and criteria 4 the long term storage.

The design of the piped network does not intercept or treat the first flush; it allows it to stay within the piped network and does not direct it into the swales. Only the excess volumes overflow into the swales. To improve on the design for water quality treatment/interception

of the first flush for future project perhaps DCC Drainage should look at source control methods such. DCC could work with the local community by trying to reduce the number of misconnections by carrying out a misconnections survey and encouraging local source controls methods such as rain water barrels for roof drainage. The design also does not take account of long term storage however as this is a retro fit design it is difficult to see where such large volumes could be stored. The difficulty in finding areas to retrofit SUDS devices into urban catchment areas shows the importance of SUDS design being incorporated into the early stages of the planning and development of a catchment

The swale design does however meet the criteria 2 and 3 limiting offsite flow and for flood protection and as mentioned throughout this case study, the design for the Swales in Glendhu park is primarily concerned with the flood protection of property. In this regard the design appears to be successful.

Dublin City Council is trialling the use of these two swales in the Glendhu estate as a way of resolving the existing flooding issues in the estate in a cost efficient manner. If the Glendhu estate trial is successful Dublin City Council will be using these types of swale systems in other estates in the DCC area and indeed the design for another estate in Cabra is already well progressed.

Conclusion

When assessed against the 4 design criteria in the ODSDS Development Policy the design fails to meet both Criteria 1 interception/treatment volume and criteria 4 the long term storage. The design of the piped network does not intercept or treat the first flush it allows it to stay within the piped network and does not direct it into the swale. Only the excess volumes overflow into the swale. To improve on the design for water quality treatment/interception

3.6.2 Case study 2: Tolka Valley Wetland.

Introduction

The Tolka Valley Wetland in Finglas was built in 1999 as a way of treating the badly polluted Finglaswood stream prior to it running into the river Tolka. The Finglaswood River or Mount Olive Stream running south west of Finglas Village is a tributary of the River Tolka. It is approximately 2.2 kilometre long and runs from Rathoath Road, Cappagh Road to Tolka Valley Park in Finglas



Figure 32 Map of Finglaswood River (Sweeney 1991)

The Finglaswood River has been badly polluted by misconnections and urban runoff which consisted mainly of

- Domestic misconnections - generally taking the form of incorrectly plumbed washing machines and dishwashers but also includes showers, baths and toilets
- Disposal of household chemicals, paints and solvents
- Diffuse pollution from intermittent road run-off with all the usual pollutants that are carried from trafficked roads
- Car wash run off with detergent, oils and solids
- Disposal of used engine oil into road gullies, most prevalent in summertime
- Disposal of old petrol from lawn mowers
- Disposal of material used in construction such as plaster slurry, cement, lime and concrete container washing
- Fouling by dog and cat litter

“A recent survey of 2602 domestic premises in an area similar to this catchment gave the following misconnections:

Washing Machines	Sinks	Dishwashers	Showers	Baths	Toilets
100	63	22	18	4	3
48%	30%	10%	8%	2%	2%

Figure 33 Misconnection Type

This is a total number of 210 misconnections or 8% of houses surveyed”. (J.Collins 2009)

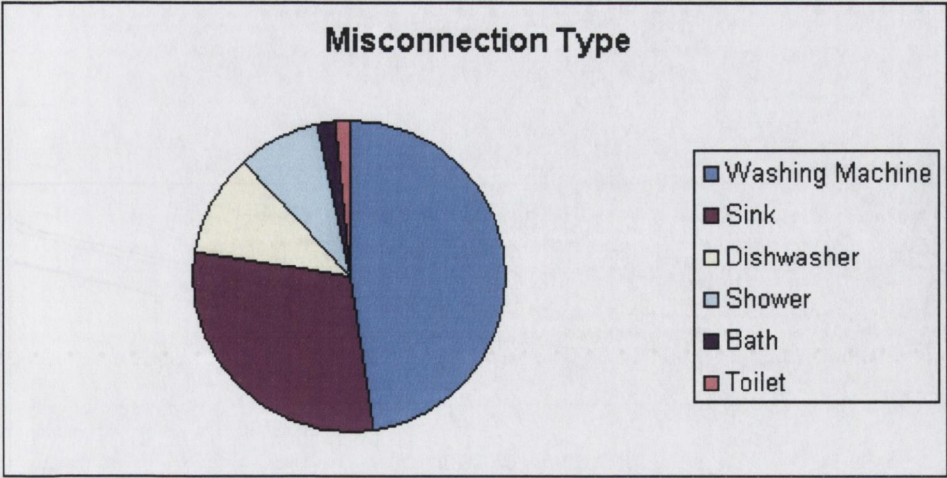


Figure 34 Misconnection type (J.Collins 2009)

It is a common perception that a toilet misconnection is more serious than a domestic appliance misconnection however the table below, which shows a pollutant load from some typical domestic appliances, demonstrates that this is not the case. While only a spot sample it still gives a good indication of the typical pollution load from a misconnection

Appliance	B.O.D. (mg/l)	pH	Solids (mg/l)	Phosphate (mg/l)	Population Equivalent
Washing Machine	1,534 (58.5 litres)	10.0	366	0.53	1.5
Dishwasher	313 (25 litres)	9.2	19	0.32	0.13
Car Wash	3,160 (7 litres)	-	-	0.36	0.36

Figure 35 Domestic Appliance Loading (J.Collins 2009)

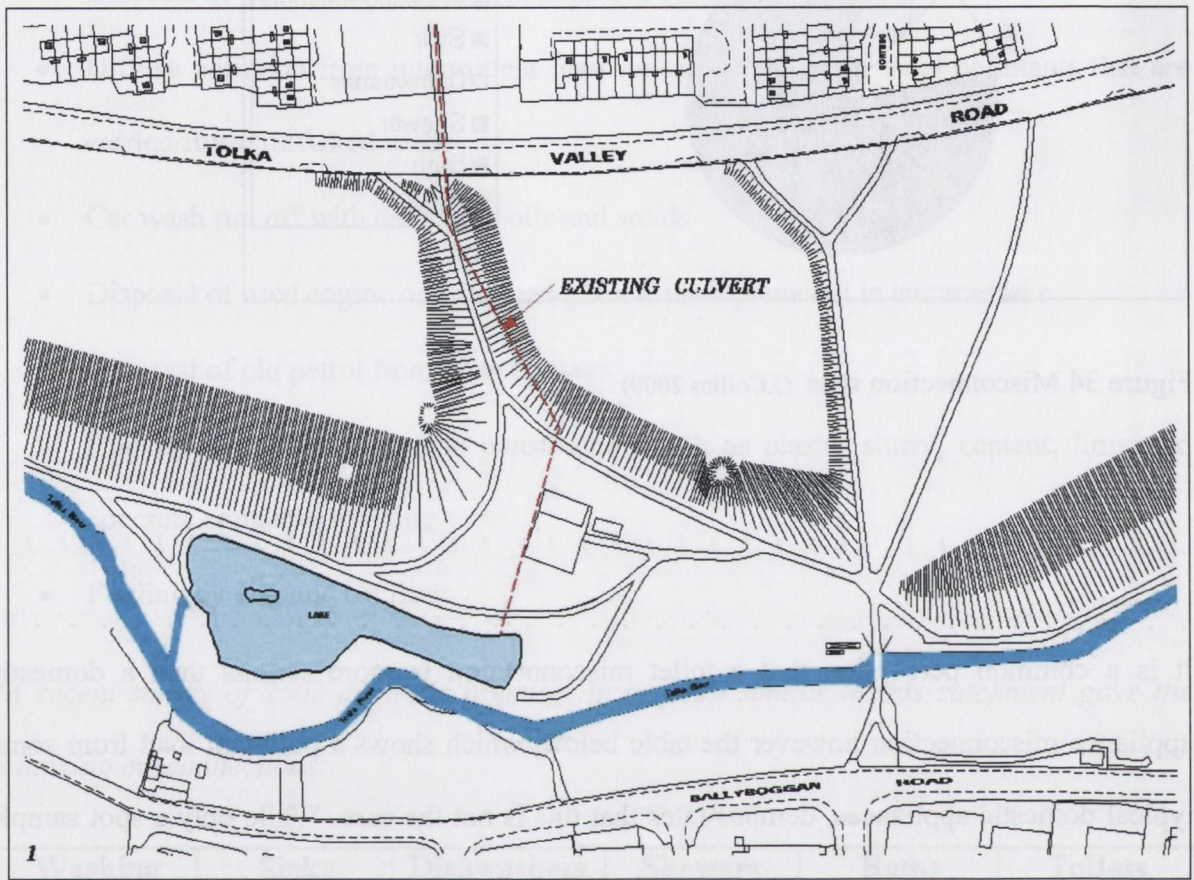


Figure 36 Layout prior to wetland (J.Collins 2009)

The wetland

The wetland composes of two cells, a primary cell and a secondary cell with a length to width ratio of 4:1. The cells are designed to distribute the flow evenly throughout the area to avoid dry patches and make the best use of the area. Unfortunately due to the constricted area onsite the wetland cannot cope with additional storm flow and additional flows are diverted at the weir and bypass the wetland. " At a dry weather flow of 9 l/sec the wetland has a retention time of 49.5 hours however at maximum flow the retention time is just 13 hours." (J.Collins 2009)

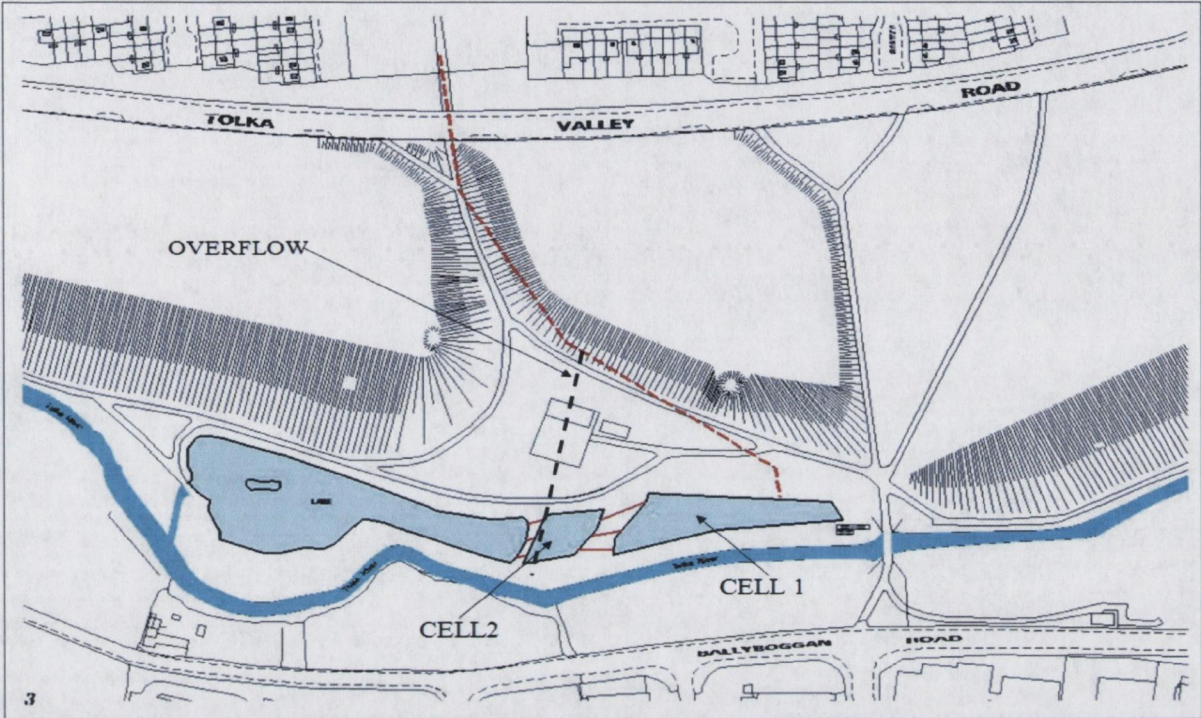


Figure 37 Layout of wetland (J.Collins 2009)



Figure 38 Areal shot of wetland (J.Collins 2009)



Figure 39 Picture of wetland March 2009

To date Dublin City Council has been very pleased with the results of the Tolka Valley Wetland “*between 1999 and 2005 the phosphate levels decreased from an average of 0.296 mg/l to 0.014 mg/l and the ammonia level decreased from 1.080 mg/l to 0.503 mg/l in the receiving lake waters.*” (J.Collins 2009)

The most recent testing carried out between 2008 -2010 by Dublin City Council on the receiving waters are shown in Figure 45. These results over this period show that the improvements have in general been maintained.

Sampling Location	Date	Time	Ammonia (mg/l)	Phosphorus (mg/l as P)
Tolka Inflows, Finglaswood Stream	May 8, 2008	09:40	0.57	
Tolka Inflows, Finglaswood Stream	August 7, 2008	09:40	0.05	0.11
Tolka Inflows, Finglaswood Stream	October 8, 2008	09:40	0.21	<0.13
Tolka Inflows, Finglaswood Stream	October 23, 2008	09:25	0.49	<0.03
Tolka Inflows, Finglaswood Stream	November 20, 2008	09:25	1.00	0.03
Tolka Inflows, Finglaswood Stream	January 7, 2009	10:00	2.59	0.04
Tolka Inflows, Finglaswood Stream	January 28, 2009	09:35	0.95	0.03
Tolka Inflows, Finglaswood St	February 26, 2009	09:30	6.94	<0.03
Tolka Inflows, Finglaswood Stream	April 1, 2009	09:35	2.23	<0.03
Tolka Inflows, Finglaswood Stream	April 23, 2009	09:50	0.50	<0.03
Tolka Inflows, Finglaswood Stream	May 27, 2009	10:20	0.24	0.09
Tolka Inflows, Finglaswood Stream	June 18, 2009	09:55	0.11	0.03
Tolka Inflows, Finglaswood Stream	July 16, 2009	09:00	0.12	0.07
Tolka Inflows, Finglaswood Stream	August 13, 2009	09:50	0.62	0.09
Tolka Inflows, Finglaswood Stream	September 3, 2009	10:00	0.15	0.06
Tolka Inflows, Finglaswood Stream	September 17, 2009	09:50	0.17	0.04
Tolka Inflows, Finglaswood Stream	October 14, 2009	09:45	0.16	0.08
Tolka River, Finglaswood Stream	November 5, 2009	09:35	0.59	0.13
Tolka Inflows, Finglaswood Stream	December 16, 2009	10:50	2.60	0.03
Tolka Inflows, Finglaswood Stream	January 21, 2010	09:10	3.53	0.03
Tolka Inflows, Finglaswood Stream	February 17, 2010	09:35	2.01	<0.03
Tolka Inflows, Finglaswood Stream	March 11, 2010	09:10	1.51	<0.03
Tolka Inflows, Finglaswood St	April 15, 2010	09:20	1.52	<0.03
Tolka Inflows, Finglaswood St	May 19, 2010	09:25	<0.03	<0.03
Tolka Inflows, Finglaswood Stream	June 17, 2010	09:20	0.03	<0.03
Tolka Inflows, Finglaswood Stream	July 8, 2010	09:20	0.11	0.09

Figure 40: Test results from outfall to Tolka River

Figure 41 is a comparison of the pre and post wetland levels for ammonia. As can be seen from the graph the wetland has had a dramatic effect on the ammonia level. Levels of ammonia have dramatically decreased and although peaks are seen in ammonia levels they reduce back within a short period of time.

Figure 42 is a comparison of the ammonia level at the wetland against the Base on Water Framework Directive standard for ammonia (0.065 mg/l) for good water quality. This shows that at times the water quality has improved to a level where it fulfils the criteria for good water quality

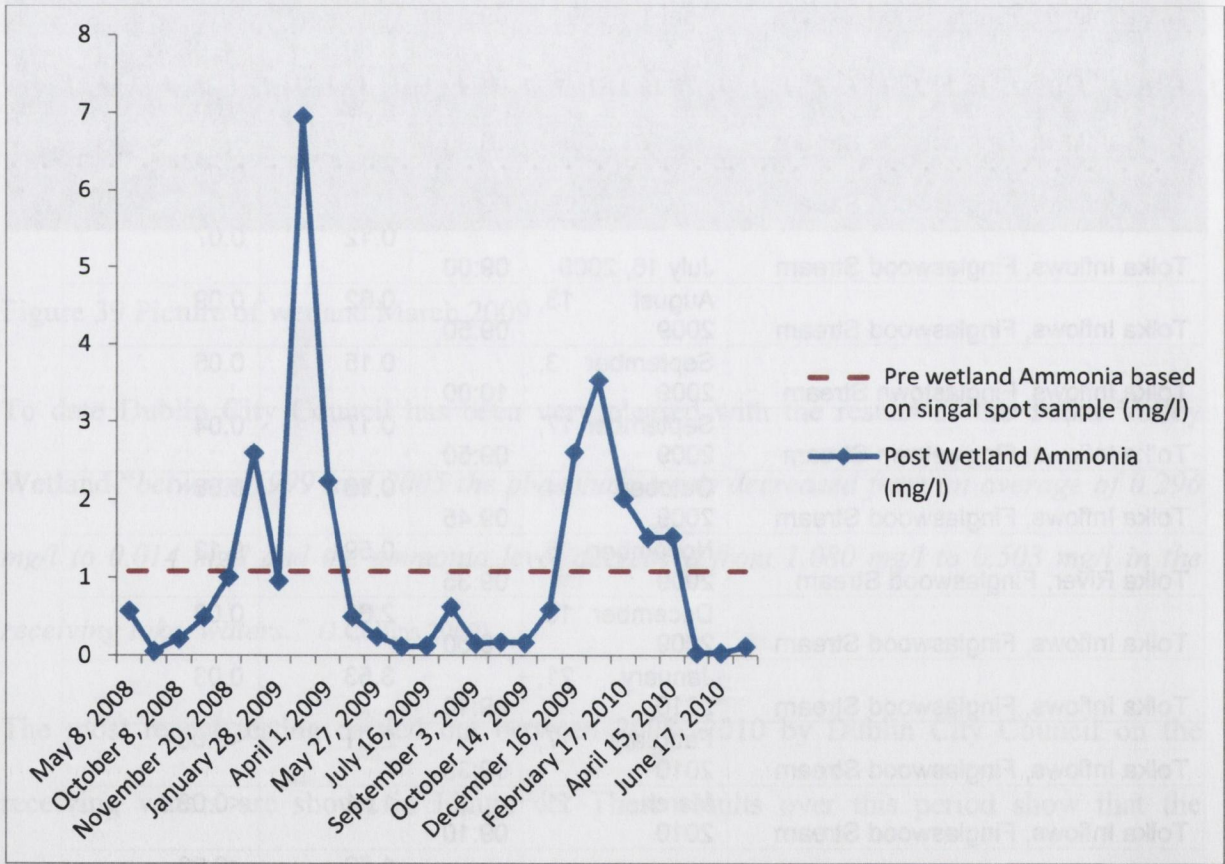


Figure 41: Test result for ammonia pre and post wetland

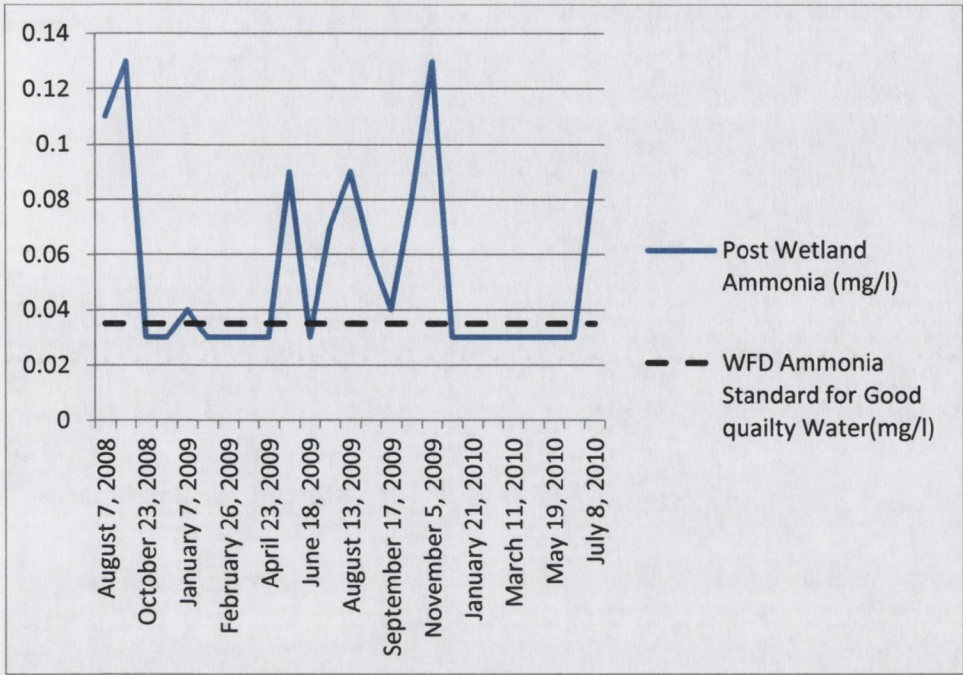


Figure 42: Test result for ammonia at wetland against the WFD standard

Figure 43 is a comparison of the pre and post wetland levels for phosphorus. As with the ammonia level the phosphorous levels have dramatically decreased since the introduction of the wetland.

Figure 44 shows the phosphorous level at the wetland against the Base on Water Framework Directive standard for phosphorous (0.035 mg/l) for good water quality. Having the wetland in place has helped to bring phosphorous levels down to a level where it at times achieves the standard of good water quality.

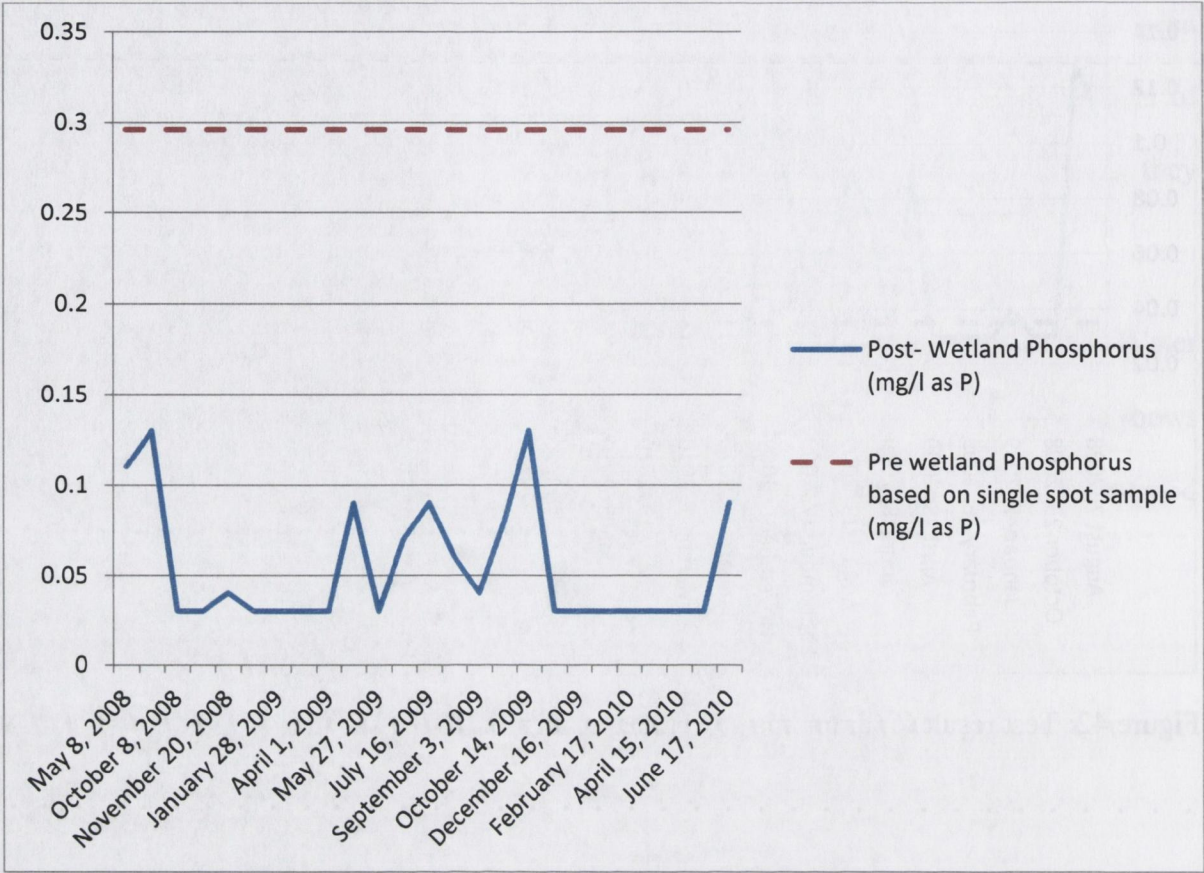


Figure 43: Test result for Phosphorus pre and post wetland

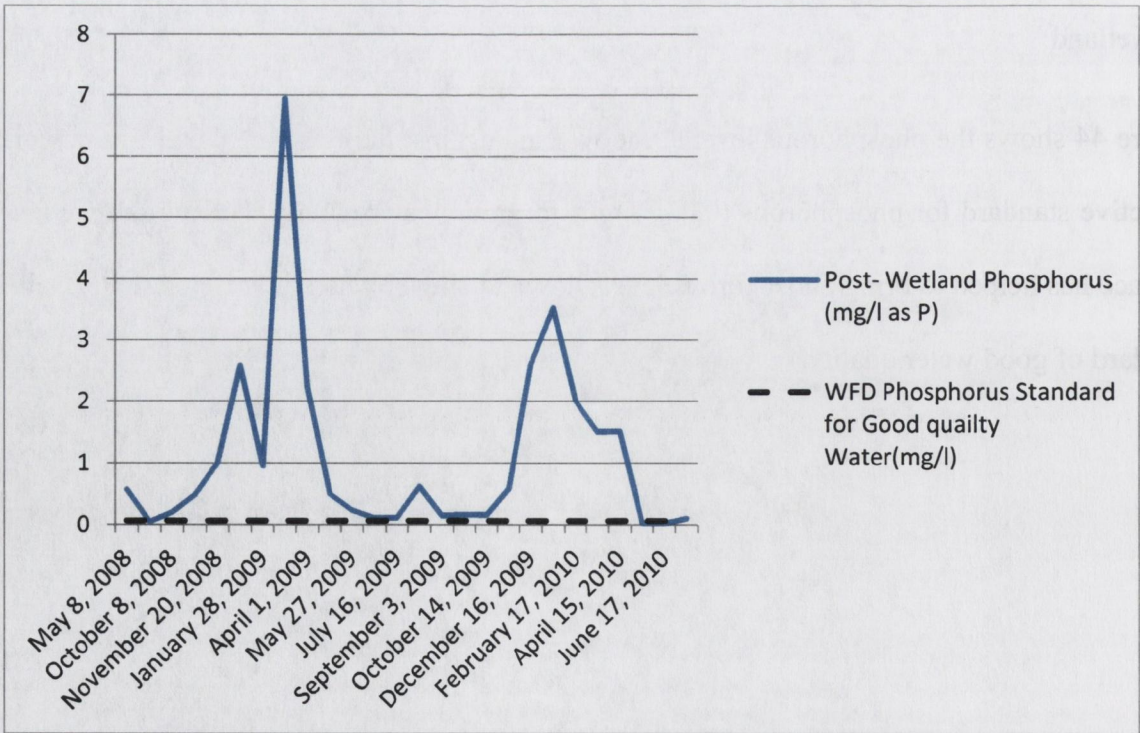


Figure 44: Test result for Phosphorus at wetland against the WFD standard



Figure 45: Tolka Valley wetland May2009

The other part of the success story for this wetland has been the increase biodiversity in both the wetland and the receiving waters. In 2008 Dublin City Council commissioned a biodiversity survey of the wetland. This study concluded that the Tolka Valley wetland as well as reducing the pollution in the area has become a community amenity.

“The establishment of the ICW at Tolka Valley Park is an excellent example of how the forces of biodiversity can be harnessed for the benefit of people – in this case transforming a foetid quagmire into a water purification unit with amenity value” (Openfield Ecological Services 2008)

The study also found that a large number of bird and plant species could now be found in the area and that the wetland even attracted plant, bird and animal species that otherwise would not be found in this area of Dublin

“While only a small number of species were planted at the onset of the project, this survey has found that many other species have since colonised the site and the wetland has even attracted species that would not otherwise be found in the area, even from the banks of the Tolka. These include the Reed Bunting, the Common Frog, a variety of flowers and sedges, and the Banded Jewelwing Damselfly. These colonisers are indicators of the success of the ICW and their variety in turn enhances its capacity to remove pollutants” (Openfield Ecological Services 2008)



Figure 46: Nest of moorhen in wetland (Openfield Ecological Services 2008)



Figure 47: Moorhen in wetland June 2010

Design Criteria

The wetland is not designed to provide any short term or long term storage and is designed purely for pollution prevention. However calculations have been carried out to show the SUDS storage requirements of the catchment

The following calculations are based on the stormwater design formulas outlined in GDSDS vol 2 for the treatment volume required

Criteria 1 Treatment interception Volume

The interception volume of 10mm is required by the GDSDS and/or 15mm treatment volume V_t . Assuming there is 50% impermeable area in the catchment as this is a low density residential, the catchment area is approximately 50 ha.

$$V_t = \text{Rainfall} \times \text{area} \times \% \text{ of impermeable area}$$

$$V_t = 0.015 \times 50\text{ha} \times 0.5$$

$$V_t = 3750 \text{ m}^3.$$

The wetland itself is only approximately $1,000 \text{ m}^3$ which is smaller than the calculations above indicate and therefore a bypass system is required to operate in wet weather.

Criteria 2 Limit to down Stream flow

The calculation of Greenfield flow

$$QBAR_{\text{rural}} = 0.00108 \times AREA_{0.89} \times SAAR_{1.17} \times SOIL_{2.17}$$

Where:

$QBAR_{\text{rural}}$ is the mean annual flood flow from a rural catchment in m^3/s .

AREA is the area of the catchment in km^2 .

SAAR is the standard average annual rainfall (for the period 1941 to 1970 in mm).

SOIL is the soil index, which is a composite index determined from soil survey maps that accompany the Flood Studies Report.

$QBAR$ can be factored by the regional growth curve to produce peak flood flows for other return periods.

$$AREA = 50 \text{ ha}$$

$$SAAR = 750 \text{ mm}$$

this a typical value for Dublin used in the GDSDS storm water design

Soil runoff % = 0.3 (assumes the soil type is type 2 which is atypical soil type for the Dublin region type 5)

$$QBAR_{\text{rural}} = 0.00108(50)^{0.89}(750)^{1.17}(0.3)^{2.17}$$

$$QBAR_{\text{rural}} = 5.95 \text{ l/s}$$

$QBAR_{\text{rural}}$ (Greenfield flow) is greater than 2 l/s and so is therefore used as the limit to downstream flow.

Criteria 3 Level of Service

The storage volume required for various storm events occurring in the region of the Glendhu Estate are presented in Figure 31. The storage calculations have been carried out using the rational method.

Total flow is calculated as follows

$$\text{Total}_{\text{VOL}} = C * i * A$$

Where

C is the runoff coefficient

i is the rainfall intensity

A is the area.

The flow out of the catchment is calculated as follows

$$\text{Vol}_{\text{out}} = Q * t * A$$

Where

Q is the limited flow out of the catchment (from criteria 2)

t is the time in seconds

A is the site area

Tolka Storage calculations

Time	time in sec	Duration	Rainfall	Site Area	% runoff to enter system (Impermeable area * runoff ration)	Qbarr	Greenfiled vol m3
5 mins	300	1	3.5	50	0.4	5.95	89.28
10 mins	600	1	4.9	50	0.4	5.95	178.57
15 mins	900	1	5.8	50	0.4	5.95	267.85
30 mins	1800	1	7.5	50	0.4	5.95	535.70
1 hours	3600	1	9.8	50	0.4	5.95	1071.41
2 hours	7200	1	12.8	50	0.4	5.95	2142.81
3 hours	10800	1	15.0	50	0.4	5.95	3214.22
4 hours	14400	1	16.7	50	0.4	5.95	4285.63
6 hours	21600	1	19.5	50	0.4	5.95	6428.44
9 hours	32400	1	22.8	50	0.4	5.95	9642.66
12 hours	43200	1	25.4	50	0.4	5.95	12856.88
18 hours	64800	1	29.7	50	0.4	5.95	19285.32
24 hours	86400	1	33.2	50	0.4	5.95	25713.76
5 mins	300	30	10.7	50	0.4	5.95	89.28
10 mins	600	30	14.8	50	0.4	5.95	178.57
15 mins	900	30	17.5	50	0.4	5.95	267.85
30 mins	1800	30	21.9	50	0.4	5.95	535.70
1 hours	3600	30	27.4	50	0.4	5.95	1071.41
2 hours	7200	30	34.3	50	0.4	5.95	2142.81
3 hours	10800	30	39.1	50	0.4	5.95	3214.22
4 hours	14400	30	42.9	50	0.4	5.95	4285.63
6 hours	21600	30	49.0	50	0.4	5.95	6428.44
9 hours	32400	30	55.9	50	0.4	5.95	9642.66
12 hours	43200	30	61.3	50	0.4	5.95	12856.88
18 hours	64800	30	70.0	50	0.4	5.95	19285.32
24 hours	86400	30	76.8	50	0.4	5.95	25713.76
5 mins	300	100	15.1	50	0.4	5.95	89.28
10 mins	600	100	21.0	50	0.4	5.95	178.57
15 mins	900	100	24.7	50	0.4	5.95	267.85
30 mins	1800	100	30.6	50	0.4	5.95	535.70

The storage required in the Tolka Valley Park for a 1 year minute duration storm event is 964m³. For a 30 year 2 hour duration event the storage requirement is 4717m³ while for a 100 year 3 hour duration event the storage requirement is 7365m³.

Criteria 4 Long Term Storage

$$Vol_{xs} = RD.A.10 \left[\frac{PIMP}{100} (\alpha 0.8) + \left(1 - \frac{PIMP}{100} \right) (\beta .SOIL) - SOIL \right]$$

Where:

Vol_{xs} is the extra runoff volume (m³) of development runoff over Greenfield runoff.

RD is the rainfall depth for the 100 year, 6 hour event (mm).

PIMP is the impermeable area as a percentage of the total area (values from 0 to100).

A is the area of the site (ha).

SOIL is the “SPR” index from FSR.

α is the proportion of paved area draining to the network or directly to the river (values from 0 to1).

β is the proportion of pervious area draining to the network or directly to the river (values from 0 to1).

It is assumed that all the 80% imperious drains directly into the drainage network for α and that 80% of the pervious area drain to the network for β .

The PIMP value is the total area impermeable area =. 40 * 50%= 20 ha.

The soil runoff coefficient used is 0.3 for soil type 2 which is a GDSDS typical soil type for Dublin

Vol Xs	3662.4
RD	65.4
a	40
soil	0.3
α	0.8
β	0.8
pimp	0.5

$$Volxs = 65.4 \times 40 \times 10 \left[\frac{0.60}{100} (1 \times 0.8) + \left(1 - \frac{0.55}{100} \right) (0.8 \times 0.3) - 0.3 \right]$$

The V_{xs} (excess volume) required for long term storage is 3662m³

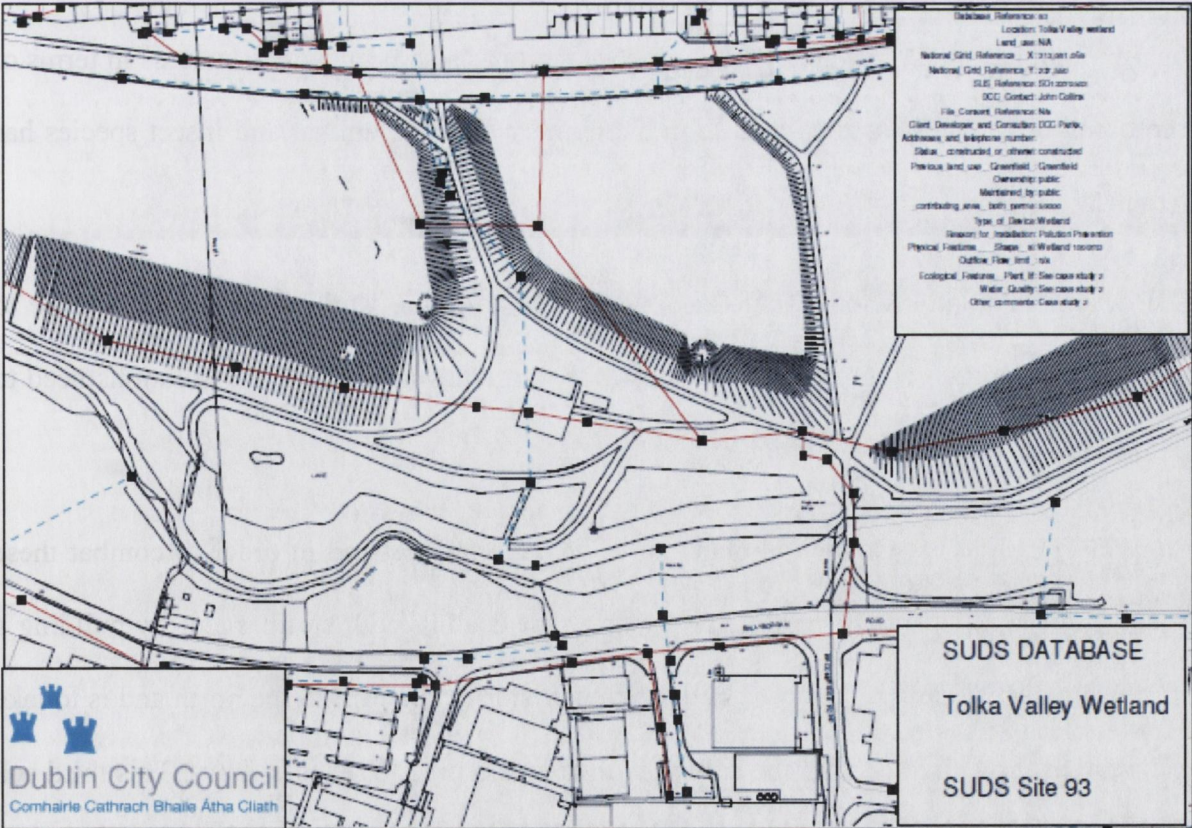


Figure 49: SUDS Site 93 Tolka Valley Wetland

Conclusion

As can be seen in the results in Figures 42 and 44 above the ammonia and phosphorous levels are generally above the WFD standard for good water quality and although there have been some peaks in both ammonia and phosphorus level, these peaks generally coincide with heavy rainfall. As the design criteria calculations have shown that due to the size restriction on the site area available for the wetland a bypass system is required to operate in wet weather. This bypass system and the large catchment area means that during periods of wet weather peaks in both ammonia and phosphorous are seen in the Tolka inflows from the Finglaswood stream. These peaks show the importance of upstream/onsite treatment as the wetland would need to be four times its current size to completely treat the first flush from the catchment area. However despite these peaks the wetland has had a dramatic effect with regard to improvement in water quality. The wetland has also been a great success in terms of improving biodiversity as the increase in the number of plant, animal and insect species has demonstrated

The design calculations for storage also show how large the wetland would have to be to cater for the storage requirements, and show how large downstream SUDS solutions need to be to fully meet all SUDS requirements

Currently Dublin City Council is planning to upgrade the wetland in order to combat these peaks flows and generally improve the capacity for dealing with storm event by building a third wetland cell. This cell is to be built on the far side of the park to the north and is to take dry weather flow directly from the culvert with a bypass pipe for excess flows. This third cell will hopefully double the capacity of the wetland site. Dublin City Council also intend to

carry out a misconnect survey upstream of the wetland which should improve the water quality upstream of the wetland.

3.6.3 Case study 3: York Street apartments

Introduction

The York Street apartments are a housing scheme consisting of sixty-six social housing units which are made up of: 20 – 1 bed, 29 – 2 bed and 17 – 3 bed units. Dublin City Council worked with its energy advisor, Codema in redeveloping the York Street site as a model for sustainable living. The newly-constructed apartments boast excellent Building Energy Ratings, with ratings ranging from A3 to B2. Codema estimates that the energy-efficient measures of this redevelopment will result in a reduction in fuel costs for residents by up to 70 per cent and a reduction of over 50 per cent in both energy usage and CO₂ emissions. This complex is one of the first Dublin City Council housing schemes to incorporate several new, innovative and most importantly, sustainable energy efficient concepts. Some of the concepts include:

- Solar panels for the provision of constant hot water for the residents
- Sedum roofs which have exceptional insulation properties and have excellent rainwater retention properties
- Rainwater is collected in twelve stainless steel water butts for use by the residents in the courtyard area
- Extensive use of sheep's wool in external walls for insulation purposes
- Encouragement of organic waste recycling by the provision of a food digester on site
- Provision of glazed balconies with sliding glass panels, which trap solar heat, for use as winter gardens in winter- time and as extra living space in the summer.



Figure 50 Sedum Roofs July 2010

Dublin City Council social housing scheme was officially opened at York Street, Dublin 4 on Monday 25th May 2009 by the Lord Mayor of Dublin, Eibhlin Byrne and the Minister for the Environment, Heritage and Local Government, Mr. John Gormley, TD.

“I am delighted to welcome this wonderful example of sustainable and energy efficient housing. This reflects strongly Dublin’s commitment to making our city greener which can only improve the quality of life for people as well as ensuring that Dublin’s sustainability is ensured into the future” said the Lord Mayor. (DCC press release 2009)



Figure 51: Roof York Street July 2010

The York Street Housing won an award from the Royal Institute of the Architects of Ireland (RIAI) for Best Sustainable Building. These awards recognise excellence in architectural designs and are made both to the designers and to the commissioning clients.

Dublin City Council issued a draft green roof policy in August 2008 which promotes the use of green roofs in the Dublin City Council area. The York Street housing complex is a good example of how the green roof policy and Dublin City Council storm water management policy could co-exist

“A Green Roof policy could become central to the implementation of SuDs, as Green Roofs reduce the quantity of run-off, improve water quality and provide valuable new habitat in urban areas. It is also important to note that the drainage study recommends that a SuDs system be mandatory in all new developments unless the developer can demonstrate to the

Local Authority that its inclusion is impractical due to site circumstances or that its effect on the control of run-off would be minimal, such as for rural sites. Again Green Roof policy would aid in reinforcing this recommendation” (DCC Green roof policy)

Typical Commercial Green Roof Section

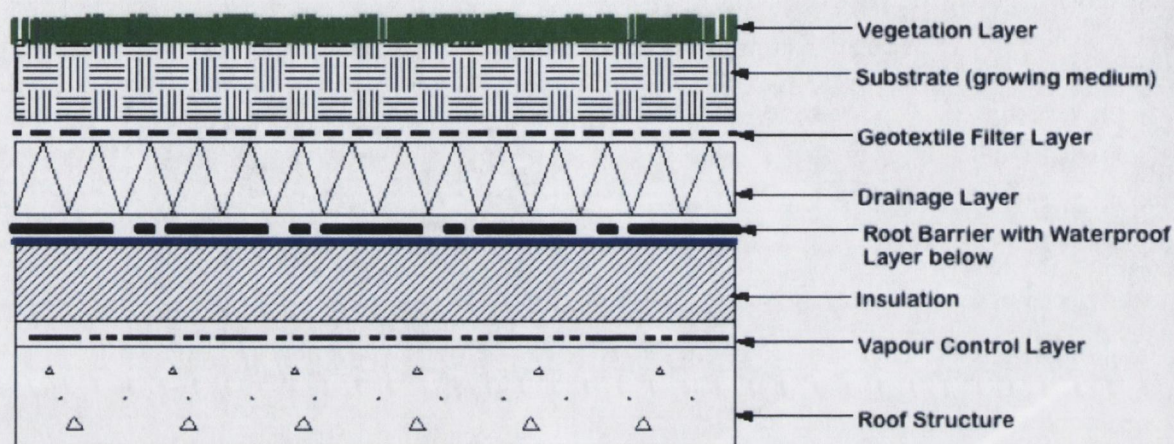


Figure 52: Section through green roof: (DCC Green roof policy)

The development

Figures 52 and 53 show two of the drawings submitted as part of the drainage approval process. These drawings show the surface water drainage pipe work and the water harvesting tanks. The surface water system is developed so that any runoff from the sedum roof is collected into the rain water harvesting tanks and is used by the residents for grey water usage and for use in the communal garden. The overall SUDS capacity on site is provided by approximately 1200 m² sedum roof which has a 100-50 mm depth and 14 rain water storage tanks with approximately 3.6 m³ of storage each. There are also two small roof gardens that are also used for drainage.

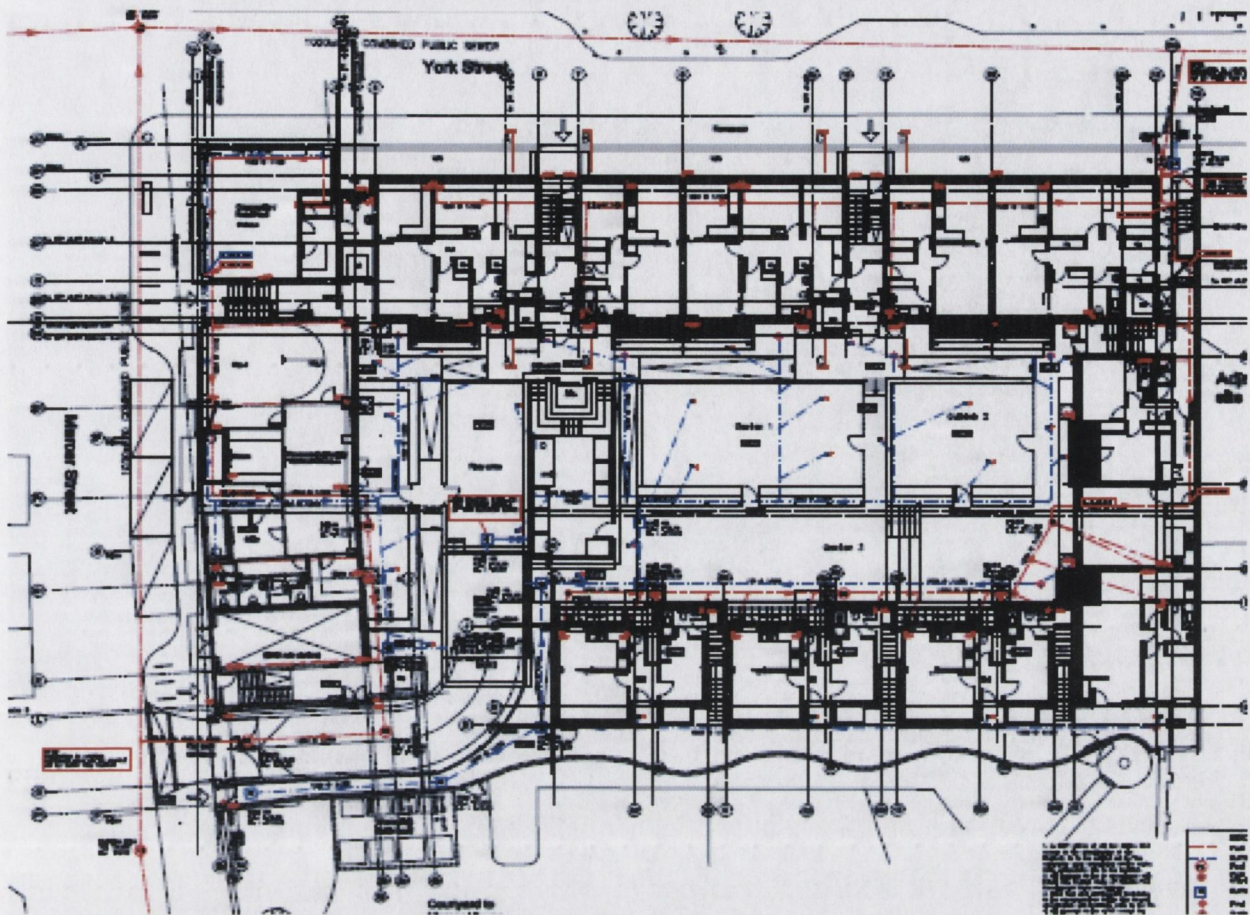


Figure 53: Drainage Drawing from planning file

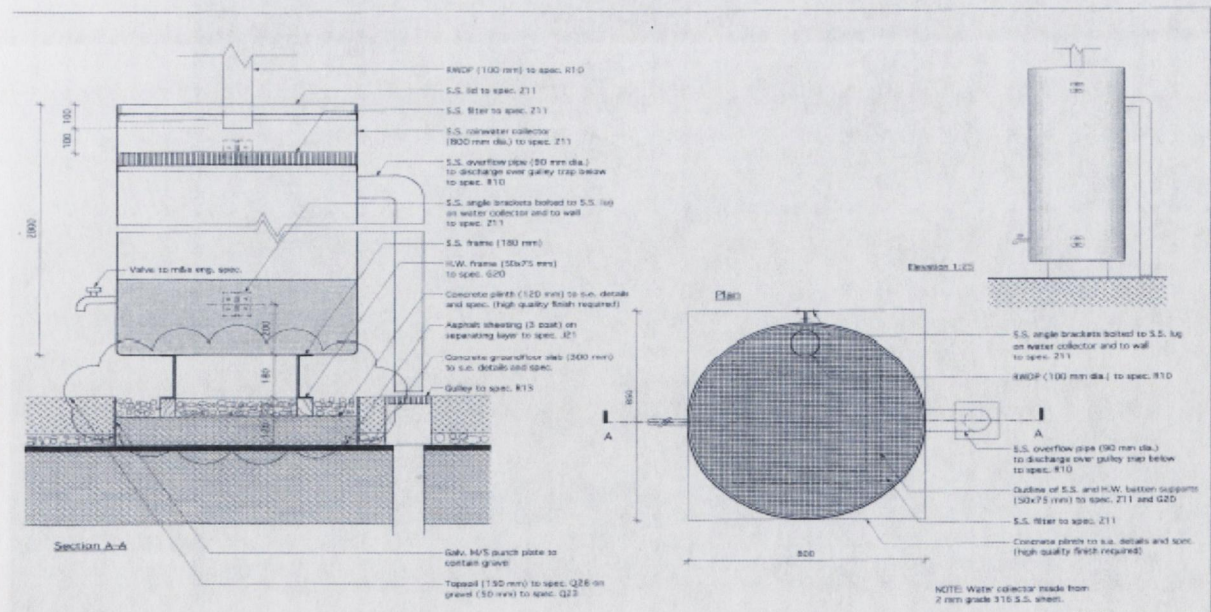


Figure 54: Design Drawing of Rainwater harvesting tanks from planning file

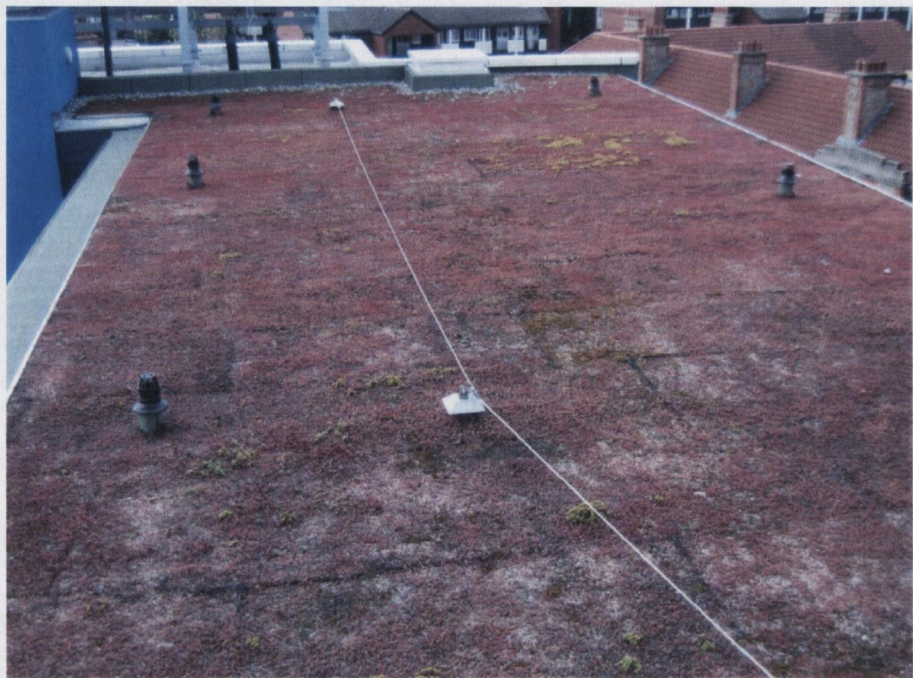


Figure 55: Sedum roof July 2010



Figure 56: Aerial Photo of Construction (bing maps 2009)



Figure 57: Drainage from roof to rain water tank July 2010



Figure 58: Rain water Harvesting Tank York Street July 2010



Figure 59: Roof Garden (part of Green Roof) July 2010

Design Criteria

As with all new developments in the Greater Dublin Area the York St Development must comply with the GDSDS development policy Vol 2 and GDR COP Stormwater Management Policy for developers as outlined earlier in this Chapter.

The following design calculation are based on these design criteria and the information available in the DCC Drainage Planning and DCC Housing Files

Criteria 1 Interception/Treatment volume

The interception volume V_i of 10mm is required by the GDSDS and/or 15mm treatment volume. As this site is in the middle of the city it is assumed that there is no impermeable area.

$$V_i = \text{Rainfall} \times \text{Permeable area}$$

$$V_i = 0.010 \text{ mm} \times 2130 \text{ m}^2$$

$$V_i = 21.3 \text{ m}^3$$

“Green roofs reduce the annual and seasonal rain runoff considerably. The annual runoff coefficient ranged between 23% and 38%. During summer 16%-31 % and in winter 40%-60 % were observed for the runoff coefficient” (M. Uhl 2008)

Taking a conservative yearly value from the above research and assuming that the green roof reduces the runoff by 62% then V_i volume is 8.094 m^3 . Assessment of the treatment volume has not been determined as the interception volume is more than covered by the rainwater harvesting tanks

Criteria 2: Limit to down stream flow

The calculation of Greenfield flow

$$QBAR_{\text{rural}} = 0.00108 \times AREA_{0.89} \times SAAR_{1.17} \times SOIL_{2.17}$$

Where:

$QBAR_{\text{rural}}$ is the mean annual flood flow from a rural catchment in m^3/s .

AREA is the area of the catchment in km^2 .

SAAR is the standard average annual rainfall (for the period 1941 to 1970 in mm).

SOIL is the soil index, which is a composite index determined from soil survey maps that accompany the Flood Studies Report.

QBAR can be factored by the regional growth curve to produce peak flood flows for other return periods.

Area = 0.213 ha

SAAR = 750 mm this a typical value for Dublin used in the GDSDS storm water design

Soil runoff % = 0.3 (assumes the soil type is type 2 which is atypical soil type for the Dublin region type 5)

$$QBAR_{\text{rural}} = 0.00108(0.213)^{0.89}(750)^{1.17}(0.3)^{2.1}$$

$$QBAR_{\text{rural}} = 0.046 \text{ l/s}$$

A runoff rate of 2 l/s is being used here as $QBAR_{\text{rural}}$ (Greenfield Flow) is smaller than the runoff rate and the GDSDS states that the high value should be used

Criteria 3 Level of Service

The storage volume required for various storm events occurring in the region are presented in Figure 65. As the site is located in the city centre it is assumed that the whole site is impermeable. The storage calculations have been carried out using the rational method and total flow is calculated by

$$\text{Total}_{\text{VOL}} = C \cdot i \cdot A$$

Where

C is the runoff coefficient

i is the rainfall intensity

A is the area.

And flow out of the catchment is calculated by

$$\text{Vol}_{\text{out}} = Q * t * A$$

Where

Q is the limited flow out of the catchment (see criteria 2)

t is the time in seconds

A is the site area

Time	time in sec	Duration	Rainfall	Site Area	% runoff to enter system (Impermeable area * runoff ration)	Qbarr	Greenfiled vol m3
5 mins	300	1	3.5	0.213		1	2.00
10 mins	600	1	4.9	0.213		1	2.00
15 mins	900	1	5.8	0.213		1	2.00
30 mins	1800	1	7.5	0.213		1	2.00
1 hours	3600	1	9.8	0.213		1	2.00
2 hours	7200	1	12.8	0.213		1	2.00
3 hours	10800	1	15.0	0.213		1	2.00
4 hours	14400	1	16.7	0.213		1	2.00
6 hours	21600	1	19.5	0.213		1	2.00
9 hours	32400	1	22.8	0.213		1	2.00
12 hours	43200	1	25.4	0.213		1	2.00
18 hours	64800	1	29.7	0.213		1	2.00
24 hours	86400	1	33.2	0.213		1	2.00
5 mins	300	30	10.7	0.213		1	2.00
10 mins	600	30	14.8	0.213		1	2.00
15 mins	900	30	17.5	0.213		1	2.00
30 mins	1800	30	21.9	0.213		1	2.00
1 hours	3600	30	27.4	0.213		1	2.00
2 hours	7200	30	34.3	0.213		1	2.00
3 hours	10800	30	39.1	0.213		1	2.00
4 hours	14400	30	42.9	0.213		1	2.00
6 hours	21600	30	49.0	0.213		1	2.00
9 hours	32400	30	55.9	0.213		1	2.00
12 hours	43200	30	61.3	0.213		1	2.00
18 hours	64800	30	70.0	0.213		1	2.00
24 hours	86400	30	76.8	0.213		1	2.00
5 mins	300	100	15.1	0.213		1	2.00

The GDSDS states that for most small sites a “summer design storm of 15 or 30 minutes are normally critical”. As an Infoworks model is not being used for this design, the storage requirement that is being used is a more conservative 1 hour duration events. The storage required for the critical storm duration of 1 hour for 1 year, 30 year and 100 year events are 19 m³, 57 m³, 79 m³

The green roof is assumed to reduce the runoff by 62% so the storage volume required for no property flood is 30m³. The rain water harvesting tanks provide approximately 50m³ of storage

Criteria 4 Long term storage

$$Vol_{xs} = RD.A.10\left[\frac{PIMP}{100}(\alpha 0.8) + \left(1 - \frac{PIMP}{100}\right)(\beta.SOIL) - SOIL\right]$$

Where:

Vol_{xs} is the extra runoff volume (m³) of development runoff over Greenfield runoff.

RD is the rainfall depth for a 100 year, 6 hour event (mm).

PIMP is the impermeable area as a percentage of the total area (values from 0 to100).

A is the area of the site (ha).

SOIL is the “SPR” index from FSR.

α is the proportion of paved area draining to the network or directly to the river (values from 0 to1).

β is the proportion of pervious area draining to the network or directly to the river (values from 0 to1).

Assuming that all the impervious area drains directly into the drainage network for α .

The PIMP value is the total area – green roof = 0.2130 ha - 0.1200 ha = 0.213 ha.

The soil runoff coefficient used is 0.3 for soil type 2 which is a GDSDS typical soil type for Dublin

RD	65.4
a	0.213
soil	0.3
α	1
β	0.6
PIMP	0.55

$$Vol_{xs} = 65.4 \times 0.213 \times 10 \left[\frac{0.55}{100} (1 \times 0.8) + \left(1 - \frac{0.55}{100} \right) (0.6 \times 0.3) - 0.3 \right]$$
$$Vol_{xs} = 30.78 \text{ m}^3$$

The V_{xs} (excess volume) required for long term storage is 31 m³. Some of this excess storage is provided by the rainwater harvesting tanks, the additional storage is provided by an underground car park which will flood in an extreme 6 hour 100 yr event which would cause no property flooding

Conclusion

The York Street apartments are a successful combination of both Dublin City Council green roof policy and Dublin City Council storm water drainage policy. They are able to meet all the design criteria listed in the GDSDS development policy and the GDR COP Stormwater Management Policy for developers and even have an amenity value in a roof garden for the available for the residents. The rainwater harvesting tanks are also used recycled water to water the plants in the green space in the middle of the housing block. The York Street apartments are an excellent example of SUDS use in a confined site in Dublin city centre.

During a site visit to the York Street apartment, it was discussed with the Dublin City Council housing staff on site whether there had been any issues with SUDS devices onsite. In general it was found that the SUDS systems have worked well and there have been no problems with the green roof. Although there had been some vandalism problems with a couple of the water tanks, these were also functioning well.

Introduction

Limitations



Figure 61 Courtyard above car park York Street July 2010

3.5.4 Case Study 4: Large Scale developments: Ballymun Regeneration Limited/ Pelletstown

More and more development in Dublin is now happening on an area by area basis rather than piecemeal. This gives Dublin City Council an opportunity to design a catchment wide drainage plan for the development. Two recent examples of this are Ballymun Regeneration Limited and Pelletstown

Ballymun Regeneration Limited

Ballymun Regeneration Ltd (BRL) is a Dublin City Council company, set up in 1997, to plan and implement a regeneration programme which will result in a new town centre with new and improved facilities for the 30,000 people who will live there. BRL is working with the community to develop and implement the Masterplan for the physical, economic and social regeneration of Ballymun.

The seven fifteen-storey tower blocks, nineteen eight-storey blocks and ten four-storey blocks of flats have been demolished. They are being replaced by at least 5,000 new homes in a variety of styles and sizes in five existing neighbourhoods.



Figure 62 BRL Aerial shot of catchment (BRL 2010)

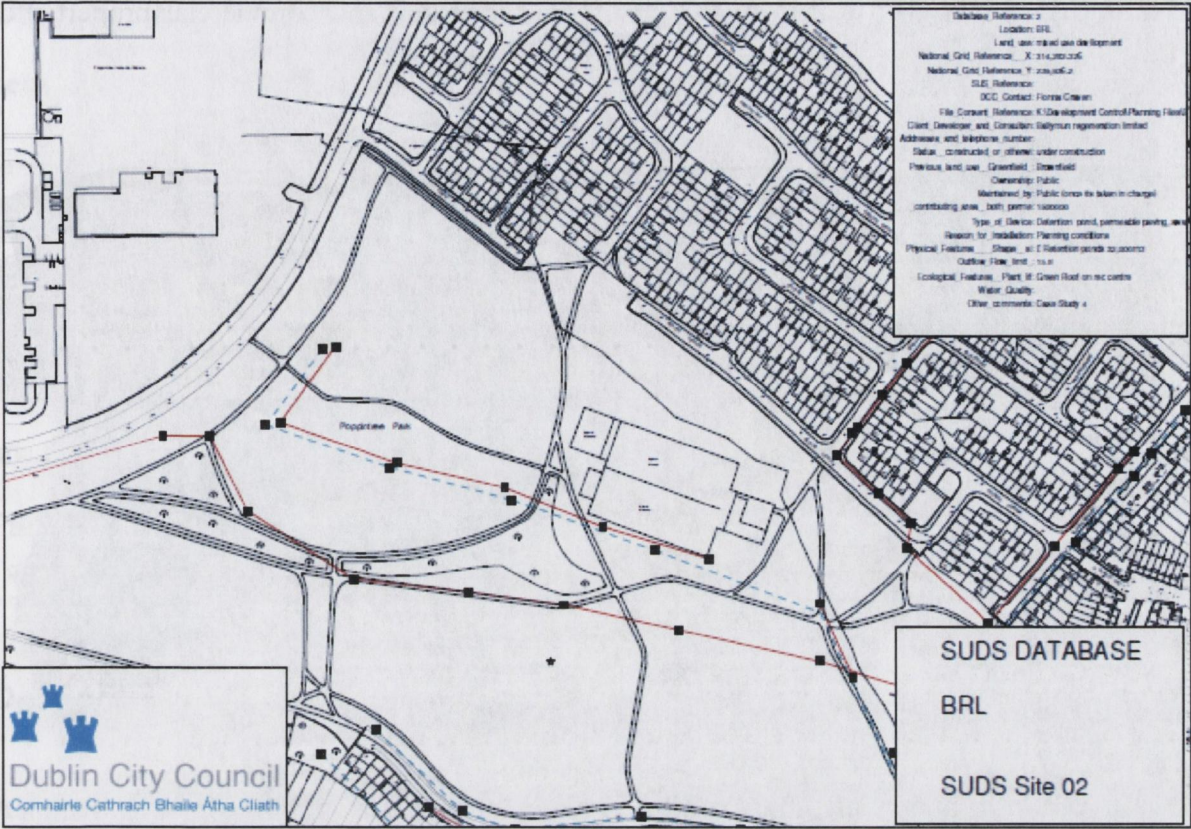


Figure 63 SUDS Site 02 BRL

The unique aspect from a SUDS viewpoint is that this redevelopment in Ballymun gave Dublin City Council an opportunity to use SUDS on a catchment wide level rather than the piecemeal development by development approach. As part of the plan to redevelop the Ballymun suburb BRL were asked to attenuate the storm water flows within the project area.

This plan involved the use of SUDS on a development level and a large storm water attenuation pond on a catchment wide level. The overall Storm water Masterplan (Figure 69) has three large attenuation ponds in Poppintree Park, Whitepark and Shangan Court (shown in black in the drawing below). The storage available at each location is as follows:

Poppintree Park: 30,000 m³, Shangan Court 800 m³ and Whitepark 1200 m³.

This storage is designed to avoid flooding in the residential and commercial property for extreme storm events.

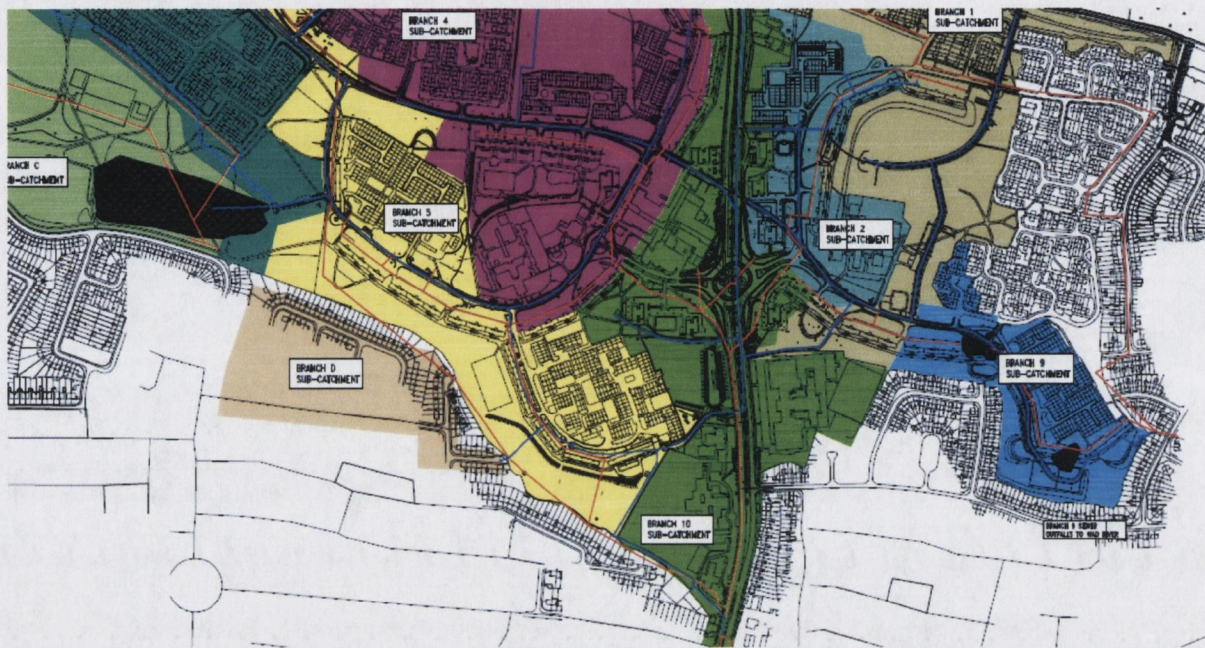


Figure 64 BRL Stormwater Masterplan (BRL 2010)



Figure 65 Poppintree Park Retention Pond(BRL 2010)

The 2007 BRL Masterplan promotes the development of SUDS technology in the building of new developments such as soakaways, rain water harvesting, green roofs and permeable paving. Most of the older BRL housing developments use filter drains in their back gardens, while the newer developments use permeable paving, green roofs and rain water harvesting. A couple of examples of this is the development located around Balcurris Park where the local surface water drainage from hard standing area and roof drainage from local buildings are to be drained into swales in the park and rain water tanks for use by Dublin City Council Parks department and the Ballymun Recreation Centre which has had a green roof installed

Design Criteria

As with all new developments in the Greater Dublin Area the SUDS design for the BRL area are based on the stormwater design formulas outlined in GDSDS vol 2 and GDR COP Stormwater Management Policy for developers as outlined earlier in this chapter. These SUDS design criteria have been applied to the following calculations.

Criteria 1 Interception/Treatment volume

The interception volume of 10mm is required by the GDSDS and/or 15mm treatment volume V_t . As this site is a middle density urban area it is assumed that there is 70% impermeable area.

$$V_t = \text{Rainfall} \times \% \text{Impermeable area} \times \text{total area}$$

$$V_t = 0.015 \text{ m} \times 0.7 \text{ m}^2 \times 100 \text{ ha}$$

$$V_t = 10,000 \text{ m}^3$$

Criteria 2 Limit to down Stream flow

The calculation of Greenfield flow

$$QBARR_{\text{rural}} = 0.00108 \text{AREA}_{0.89} \text{SAAR}_{1.17} \text{SOIL}_{2.17}$$

Where:

$QBARR_{\text{rural}}$ is the mean annual flood flow from a rural catchment in m^3/s .

AREA is the area of the catchment in km^2 .

SAAR is the standard average annual rainfall (for the period 1941 to 1970 in mm).

SOIL is the soil index, which is a composite index determined from soil survey maps that accompany the Flood Studies Report. $QBARR$ can be factored by the regional growth curve to produce peak flood flows for other return periods.

Area 150 ha

SAAR = 750 mm this a typical value for Dublin used in the GDSDS storm water design

Soil runoff %. = 0.3 (assumes the soil type is type 2 which is atypical soil type for the Dublin region type 5)

$$QBARR_{\text{rural}} = 0.00108(150)_{0.89}(750)_{1.17}(0.3)_{2.1}$$

$$QBARR_{\text{rural}} = 15.82 \text{ l/s}$$

$QBARR_{\text{rural}}$ (Greenfield flow) is greater than 2 l/s and so is therefore used as the limit to downstream flow.

Criteria 3 Level of Service

The storage volume required for various storm events occurring in the Ballymun region are presented in Figure 71. The storage calculations have been carried out using the rational method.

Total flow is calculated by

$$\text{Total}_{\text{VOL}} = C \times i \times A$$

Where

C is the runoff coefficient

i is the rainfall intensity

A is the area.

The flow out of the catchment is calculated by

$$\text{Vol}_{\text{out}} = Q \times t \times A$$

Where

Q is the limited flow out of the catchment (see criteria 2)

t is the time in seconds

A is the site area

Time	time in sec	Duration	Rainfall	Site Area	% runoff to enter system (impermeable area * runoff ration)	Qbarr	Greenfield vol m3
5 mins	300	1	3.5	150	0.56	15.82	712.09
10 mins	600	1	4.9	150	0.56	15.82	1424.17
15 mins	900	1	5.8	150	0.56	15.82	2136.26
30 mins	1800	1	7.5	150	0.56	15.82	4272.51
1 hours	3600	1	9.8	150	0.56	15.82	8545.03
2 hours	7200	1	12.8	150	0.56	15.82	17090.06
3 hours	10800	1	15.0	150	0.56	15.82	25635.09
4 hours	14400	1	16.7	150	0.56	15.82	34180.12
6 hours	21600	1	19.5	150	0.56	15.82	51270.17
9 hours	32400	1	22.8	150	0.56	15.82	76905.26
12 hours	43200	1	25.4	150	0.56	15.82	102540.35
18 hours	64800	1	29.7	150	0.56	15.82	153810.52
24 hours	86400	1	33.2	150	0.56	15.82	205080.69
5 mins	300	30	10.7	150	0.56	15.82	712.09
10 mins	600	30	14.8	150	0.56	15.82	1424.17
15 mins	900	30	17.5	150	0.56	15.82	2136.26
30 mins	1800	30	21.9	150	0.56	15.82	4272.51
1 hours	3600	30	27.4	150	0.56	15.82	8545.03
2 hours	7200	30	34.3	150	0.56	15.82	17090.06
3 hours	10800	30	39.1	150	0.56	15.82	25635.09
4 hours	14400	30	42.9	150	0.56	15.82	34180.12
6 hours	21600	30	49.0	150	0.56	15.82	51270.17
9 hours	32400	30	55.9	150	0.56	15.82	76905.26
12 hours	43200	30	61.3	150	0.56	15.82	102540.35
18 hours	64800	30	70.0	150	0.56	15.82	153810.52
24 hours	86400	30	76.8	150	0.56	15.82	205080.69
5 mins	300	100	15.1	150	0.56	15.82	712.09

From Figure 71 the critical storm duration is 1 hour for a 30 year and 100 year event and the critical storm duration is 15 minutes for the 1 year event. The storage required for the critical duration storm 1 year, 30 year and 100 year storms are 2,736 m³, 14,470 m³ and 23,207 m³. This storage requirement is accounted for by the three retention ponds with a total storage capacity of 32,000 m³

Criteria 4 Long term storage

$$Vol_{xs} = RD.A.10 \left[\frac{PIMP}{100} (\alpha 0.8) + \left(1 - \frac{PIMP}{100} \right) (\beta.SOIL) - SOIL \right]$$

Where:

- Vol_{xs} is the extra runoff volume (m³) of development runoff over Greenfield runoff.
- RD is the rainfall depth for the 100 year, 6 hour event (mm).
- PIMP is the impermeable area as a percentage of the total area (values from 0 to100).
- A is the area of the site (ha).
- SOIL is the “SPR” index from FSR.
- α is the proportion of paved area draining to the network or directly to the river (values from 0 to1).
- β is the proportion of pervious area draining to the network or directly to the river (values from 0 to1).

It is assumed that all the 80% imperious drains directly into the drainage network for α and that 55% of the pervious area drain to the network for β. This is to account for all the filter drains in use in Ballymun development

The PIMP value is the total area impermeable area =. 150 * 55%= 52.5 ha.

The soil runoff coefficient used is 0.3 for soil type 2 which is a GDSDS typical soil type for Dublin

RD	65.4
a	150
soil	0.3
α	0.8
β	0.5
PIMP	0.55

$$Vol_{XS} = 65.4 \times 150 \times 10 \left[\frac{0.55}{100} (0.8 \times 0.8) + \left(1 - \frac{0.55}{100} \right) (0.5 \times 0.3) - 0.3 \right]$$

$$Vol_{XS} = 11722.95 \text{ m}^3$$

The V_{xs} (excess volume) required for long term storage is 11,723 m³. This excess storage capacity is accounted for in the remaining capacity of the retention pond (approximately 9000 m³) and the other onsite SUDS systems. This additional storage will operate in an extreme 6 hour 100 year event and will prevent property flooding.

Pelletstown Development

Pelletstown is located in the north west of Dublin between the River Tolka and the Royal Canal, just north of Ashtown and previously was undeveloped area formally known as Pelletstown House. The development was carried out by two private companies Ballymore Homes and Castletorn Properties and is approximately 40 ha which includes approximately 2,500 housing units and a town centre.

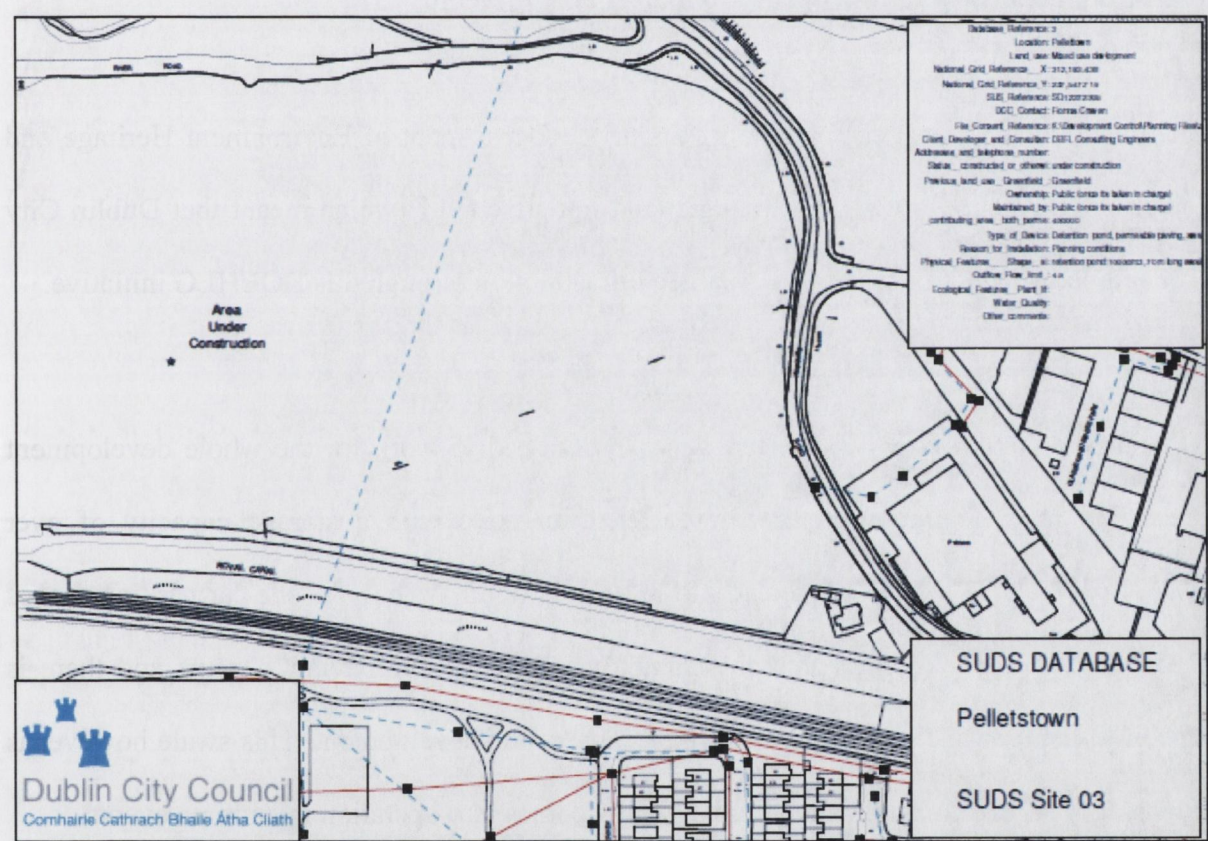


Figure 67 SUDS site 03 Pelletstown



Figure 68: Pelletstown Master plan (from the planning record)

The development qualified for funding under the Department of Environment Heritage and Local Government (DOEHLG) Strategic land initiative (SLI) which meant that Dublin City Council part funded the water and drainage infrastructure through this DOEHLG initiative.

The surface water system in Pelletstown was designed to work for the whole development area. The main feature is a three level retention pond with a storage capacity of over 10,000m³ which is located at the end of the surface water system. All the car parking spaces throughout the development area are drained using permeable paving systems and there is also a 70 metre swale running through the centre of the development. This swale however is bypassed by a traditional piped system and only comes into operation in extreme events.



Figure 69: Design drawing of retention pond in Pelletstown from planning files



Figure 70: Retention pond in Pelletstown March 2010



Figure 71: Retention pond in Pelletstown March 2010



Figure 72: Swale in Pelletstown March 2010

Design Criteria

As with all new developments in the Greater Dublin Area the SUDS design for the Pelletstown area are Based on the stormwater design formulas outlined in GDSDS vol 2 and GDRCOP Stormwater Management Policy for developers as outlined earlier in this chapter. These SUDS design critrea have been been applied to the following calcualtions.

Criteria 1 Interception/Treatment volume

The interception volume of 10mm is required by the GDSDS and/or 15mm treatment volume V_t . As this site is a middle density urban area it is assumed that there is 70% impermeable area.

$$V_t = \text{Rainfall} \times \% \text{Impermeable area} \times \text{total area}$$

$$V_t = 0.015 \times 0.7 \times 40$$

$$V_t = 4,200 \text{ m}^3$$

Criteria 2: Limit to down stream flow

The calculation of Greenfield flow

$$Q_{BAR_{rural}} = 0.00108 \text{ AREA}^{0.89} \text{ SAAR}^{1.17} \text{ SOIL}^{2.17}$$

Where:

$Q_{BAR_{rural}}$ is the mean annual flood flow from a rural catchment in m^3/s .

AREA is the area of the catchment in km^2 .

SAAR is the standard average annual rainfall (for the period 1941 to 1970 in mm).

SOIL is the soil index, which is a composite index determined from soil survey maps that accompany the Flood Studies Report.

Q_{BAR} can be factored by the regional growth curve to produce peak flood flows for other return periods.

Area = 40 ha

SAAR = 750 mm this a typical value for Dublin used in the GDSDS storm water design

Soil runoff %. = 0.3 (assumes the soil type is type 2 which is atypical soil type for the Dublin region type 5)

$$QBAR_{rural} = 0.00108(150)^{0.89}(750)^{1.17}(0.3)^{2.1}$$

$$QBAR_{rural} = 4.88 \text{ l/s}$$

$QBAR_{rural}$ (Greenfield flow) is greater than 2 l/s and so is therefore used as the limit to downstream flow.

Criteria 3 Level of Service

The storage volume required for various storm events occurring in the region are presented in Figure 78. The storage calculations have been carried out using the rational method.

Total flow is calculated by

$$Total_{VOL} = C * i * A$$

Where

C is the runoff coefficient

i is the rainfall intensity

A is the area.

The flow out of the catchment is calculated by

$$Vol_{out} = Q * t * A$$

Where

Q is the limited flow out of the catchment (see criteria 2)

t is the time in seconds

A is the site area

Time	time in sec	Duration	Rainfall	Site Area	% runoff to enter system (Impermeable area * runoff ration)	Qbarr	Greenfiled vol m3
5 mins	300	1	3.5	40	0.56	11.00	132.00
10 mins	600	1	4.9	40	0.56	11.00	264.00
15 mins	900	1	5.8	40	0.56	11.00	396.00
30 mins	1800	1	7.5	40	0.56	11.00	792.00
1 hours	3600	1	9.8	40	0.56	11.00	1584.00
2 hours	7200	1	12.8	40	0.56	11.00	3168.00
3 hours	10800	1	15.0	40	0.56	11.00	4752.00
4 hours	14400	1	16.7	40	0.56	11.00	6336.00
6 hours	21600	1	19.5	40	0.56	11.00	9504.00
9 hours	32400	1	22.8	40	0.56	11.00	14256.00
12 hours	43200	1	25.4	40	0.56	11.00	19008.00
18 hours	64800	1	29.7	40	0.56	11.00	28512.00
24 hours	86400	1	33.2	40	0.56	11.00	38016.00
5 mins	300	30	10.7	40	0.56	11.00	132.00
10 mins	600	30	14.8	40	0.56	11.00	264.00
15 mins	900	30	17.5	40	0.56	11.00	396.00
30 mins	1800	30	21.9	40	0.56	11.00	792.00
1 hours	3600	30	27.4	40	0.56	11.00	1584.00
2 hours	7200	30	34.3	40	0.56	11.00	3168.00
3 hours	10800	30	39.1	40	0.56	11.00	4752.00
4 hours	14400	30	42.9	40	0.56	11.00	6336.00
6 hours	21600	30	49.0	40	0.56	11.00	9504.00
9 hours	32400	30	55.9	40	0.56	11.00	14256.00
12 hours	43200	30	61.3	40	0.56	11.00	19008.00
18 hours	64800	30	70.0	40	0.56	11.00	28512.00
24 hours	86400	30	76.8	40	0.56	11.00	38016.00
5 mins	300	100	15.1	40	0.56	11.00	132.00
10 mins	600	100	21.0	40	0.56	11.00	264.00

As can be seen from the Figure 78 the critical storm duration is 15 minutes for the 1 year event, the critical storm duration is 1 hour event for the 30 year event and 2 hours storm duration for a 100 year event. The storage required for the critical duration storm 1 year, 30 year and 100 year storms are 903 m³, 4,554 m³ and 7,292 m³. This storage requirement is account for by the retention pond which has a total storage capacity of 10,000 m³

Criteria 4 Long term storage

In Figure 78

$$Vol_{xs} = RD.A.10 \left[\frac{PIMP}{100} (\alpha 0.8) + \left(1 - \frac{PIMP}{100} \right) (\beta.SOIL) - SOIL \right]$$

Where:

- Vol_{XS} is the extra runoff volume (m³) of development runoff over Greenfield runoff.
- RD is the rainfall depth for the 100 year, 6 hour event (mm).
- PIMP is the impermeable area as a percentage of the total area (values from 0 to100).
- A is the area of the site (ha).
- SOIL is the “SPR” index from FSR.
- α is the proportion of paved area draining to the network or directly to the river (values from 0 to1).
- β is the proportion of pervious area draining to the network or directly to the river (values from 0 to1).
- It is assumed that all the 80% imperious drains directly into the drainage network for α and that 50% of the pervious area drain to the network for β. This is to account for all the permeable paving in use in Pelletstown development

The PIMP value is the total area impermeable area =. 40 * 55%= 22 ha.

The soil runoff coefficient used is 0.3 for soil type 2 which is a GDSDS typical soil type for Dublin

RD	65.4
a	40
soil	0.3
α	0.8
β	0.5
PIMP	0.55

$$Vol_{xs} = 65.4 \times 40 \times 10 \left[\frac{0.55}{100} (1 \times 0.8) + \left(1 - \frac{0.55}{100} \right) (0.6 \times 0.3) - 0.3 \right]$$

$$Vol_{xs} = 3,126.12 \text{ m}^3$$

The V_{xs} (excess volume) required for long term storage is 3,126 m³. This excess storage capacity is accounted for in the remaining capacity of the retention pond (approximately 2,700m³) and the 70 m² swale. They will operate in an extreme 6 hour 100 year event and will prevent property flooding.

Conclusion

The two examples of Ballymun and Pelletstown show a coordinated approach to storm water design and SUDS use. There is use of small scale filter drains, permeable paving at the source level combined with downstream retention. Both the Pelletstown and BRL systems are heavily dependent on infiltration through the permeable paving, filter drains, swales and retention ponds and this dependence for the proper operation of the SUDS devices on infiltration highlights the need for further research into the effect of infiltration on groundwater quality and soil type on the rate of infiltration into the ground particularly with such large volumes of runoff

Both catchment areas also show some of the reasons why a SUDS database is needed. When investigating the SUDS in use in Pelletstown there was confusion and conflicting details on how exactly the SUDS system works. During review of the SUDS system it was revealed that the large swale in the middle of the site is effectively bypassed by the piped system and that the swale only operates in extreme events. The normally operating storm water SUDS consists of just the retention pond.

In Ballymun filter drains have been installed in the gardens of most of the residential development. The use of these filter drain not widely known and if this information is not record and passed onto the Drainage Planning engineers, future planning permissions such as house extensions could cause a gradual degradation of the overall SUDS system.

3.5.5 Summary Of Case studies

The four case studies have shown a sample of the range of different types of SUDS devices in Use in Dublin. They have highlighted the issues in applying the GDSDS and GDR COP Design Criteria in a practical setting such as

- The area restrictions of a SUDS retro fit to an existing urban catchment,
- The problem of using downstream solutions to resolve water quality issues,
- The design of SUDS for new developments in the city centre
- The creation of catchment wide stormwater systems.

The four case studies have also show the volume of information needed as well as some of the key factors in assessing a SUDS system and its effect on the surrounding catchment.

Factors listed below are all important in assessing a SUDS devices effectiveness

- Catchment size,
- SUDS device type,
- Physical size
- The shape of the SUDS device,
- The downstream flows,
- Maintenance,
- Ecological features
- The reason for the SUDS devices installation

The next chapter will discuss how and why this information should be stored in a SUDS database for Dublin.

Chapter 4

SUDS Database

This chapter will provide a step by step process of how the SUDS database was developed. Initially a description will be provided of other SUDS databases that have been built. Then details of where the source information for this database comes from and how the information for inclusion in the database was determined. A description of the field descriptors used in the database will be presented along with an explanation the software used to display the database. And finally the database itself will be displayed where a number of case studies and the types of SUDS systems used will be reviewed.

4.1 International SUDS Databases

The first step in developing the database was to carry out research in order to ascertain if any other county councils, water companies or regional bodies have already developed a SUDS database. Five other relevant databases were found:

- The “SNIFFER report” by the Scotland and Northern Ireland Forum for Environmental Research. (Sniffer Suds Database July 2002)
- “Wetland Classification System, Criteria for Inclusion and Data Presentation” by Environment Australia (Environment Australia 2009)
- International Stormwater Best Management Practises (BMP) Database from the Urban Water Resources Research Council (UWRRC) of the American Society of Civil Engineers (ASCE) (International BMP stormwater Database 2009)
- Dutch Stormwater database (Boogaard F.C 2008)
- UK SUDS Database (CIRIA Suds Database2009)

4.1.1 The SNIFFER Report

(Sniffer Suds Database July 2002)

In July 2002, SNIFFER (Scotland and Northern Ireland Forum for Environmental Research) published their Final Report on “*SUDS in Scotland – the Scottish SUDS Database*”.

Their data was collected primarily from plans and correspondence contained within SEPA’s (Scottish Environment Protection Agency) planning and working files. The author examined files wherever possible in order to optimise data quality. This approach was adopted in preference to the widespread use of surveys employing questionnaires or interviews, since these techniques could lead to inconsistencies in responses, and to varying quality of output.

The terms ‘SUDS Systems’ and ‘SUDS Sites’ were clearly defined for the purpose of storing and analysing the data.

- A SUDS system is defined as “*a surface water or stormwater drainage installation, which maximises benefits in terms of water quality, water quantity and amenity*” e.g. 1 soakaway, 1 Retention pond.
- A SUDS site is defined as “*a site served by one or more SUDS system*”. e.g. 200 house development served by 200 soakaways and 1 retention pond.

A list of the characteristics or field descriptors stored within the SUDS Database is shown in Figure 19 below. The SNIFFER Report also states that the data was stored and analysed using an MS Excel spreadsheet.

SCOTLAND
Sustainable Urban Drainage Systems and SUDS sites
Location
Land use
National Grid Reference
(SEPA) Team
File/Consent Reference
Client/Developer and Consultant
Addresses and telephone numbers
Local Authority
Status (constructed or otherwise)
Previous land use (greenfield or brownfield)
Date of correspondence
Size of the site
Other comments
Sustainable Urban Drainage Systems and SUDS sites
Location

Figure 74: Characteristic Fields in Scottish Database

4.1.2 Wetland Classification system, Criteria for Inclusion and Data Presentation

(Environment Australia 2009)

A Report entitled “Wetland Classification system, Criteria for Inclusion and Data Presentation” published by Environment Australia was also examined. The system uses the field descriptors shown in Figure 21 to classify nationally important wetlands in Australia. These wetlands include human made wetlands for wastewater treatment.

AUSTRALIA/NZ
Name of Wetland
Reference Number
Location
Area
Elevation
Other Wetlands in same Aggregation
Wetland type
Criteria for Inclusion (reference number 1-6)
Site Description
Physical Features
Hydrological Features
Ecological Features
Significance (reference code for Endangered, Rare etc)
Notable Flora

AUSTRALIA/NZ
Notable Fauna
Social and Cultural Values
Land Tenure
Current Land Use
Disturbances or Threats
Conservation Measures Taken
Management Authority and Jurisdiction
Compiler & Date

Figure 75: Characteristic Fields In Australian Database

4.1.3The International Stormwater BMP Database project

(International BMP stormwater Database 2009)

The International Stormwater BMP Database project (first known as the National BMP Database) began in 1996 through the efforts of a team of experts from the Urban Water Resources Research Council (UWRRC) of the American Society of Civil Engineers (ASCE).

The project's original long-term goal which remains the central focus of the project, is to gather transferable technical design and performance information to improve BMP selection and design, so that local stormwater problems can be cost-effectively addressed. Original project tasks included:

1. Developing a set of recommended monitoring and reporting protocols for BMP monitoring studies.
2. Designing and creation of a national stormwater BMP database.
3. Collecting existing BMP design and performance data, evaluating it to ascertain if it could meet the protocols and, if so, entering the data into the BMP Database.
4. Developing a recommended data evaluation approach.
5. Evaluating the data entered into the database and reporting initial findings.

The database encompasses a broad range of field descriptors including test site location, watershed characteristics, climate data, BMP design and layout characteristics, monitoring instrumentation, and monitoring data for precipitation, flow and water quality.

The International Stormwater BMP Database project (USA)
PART 1. GENERAL TEST SITE INFORMATION
1. General Test Site Information
2. Test Site/Study Documentation Information
3. Monitoring and Sponsoring Agencies
4. Location Information
PART 2. ESTABLISH MONITORED EVENTS
5. Monitoring Events
6. Site Monitoring Costs
PART 3. WATERSHED (TRIBUTARY AREA) INFORMATION
7. General Watershed Information
8. Roads and Parking Lots in Watershed
Streets, Roads and Alleys
Parking Lots in Watershed

The International Stormwater BMP Database project (USA)
Highway Data
9. Land Use
PART 4. GENERAL BMP INFORMATION (required for all sites)
10. General BMP Information
11. BMP Cost Data
PART 5. MONITORING STATIONS
12a. Monitoring Station ID
12b. Monitoring Station Relation
13. Site Monitoring Instrumentation
PART 6. MONITORING RESULTS (PRECIPITATION, FLOW AND WATER QUALITY)
14. Precipitation Data
15. Flow
16. Water Quality Data for Sampling Event
17. TSS Settling Velocity Distribution
PART 7. INDIVIDUAL BMP DESIGN SPREADSHEETS
18. Detention Basin Design Data
19. Retention Pond Design Data
20. Grass Filter Strip and Swale Design Data
21. Media Filter Design Data
22. Porous Pavement Design Data
23. Infiltration Basin Design Data
24. Percolation Trench and Dry Well Design Data
25. Wetland Channel and Swale Design Data
26. Wetland Basin Design Data
27. Manufactured Device
28. Green Roof
29. Low Impact Development (LID)
30. Non-structural BMPs

The International Stormwater BMP Database project (USA)
31. Other

Figure 76: Characteristic Fields in American Database

4.1.4 The Dutch Stormwater Database

(Boogaard F.C 2008)

In the Dutch Stormwater database measurements were taken from stormwater outfalls from numerous SUDS devices throughout Holland, which were then assessed against the Dutch water quality guidance.

“The Dutch Stormwater database consists of over 500 measurements in Holland and more than 200 from nearby countries in Europe” (Boogaard F.C 2008)

This database is mostly concerned with documenting the water from runoff of from the SUDS devices. Details on the field descriptor used could not be located.

4.1.5 The UK SUDs database

(CIRIA SUDS Database)

The UK SUDS database which has been set up on the CIRIA website, has 75 entries and does not appear to have been updated since 2007. The database is a public database which gives the following information regarding each SUDS site.

UK SUDS Database		
Site Location	Street:	Grid reference:
	Town:	Local district:
	Postcode:	County/Unitary Authority:
	Receiving watercourse:	River catchment:

UK SUDS Database		
SITE DETAILS	Status: Date of Start month: End month: construction Start year: End year:	
Site Description	Development type: Size of development: Description of the site and its drainage system: Objectives of the drainage system: Who currently maintains the drainage system and what is done: How the system has been accepted by local residents, and the reasons why it is or is not considered a success: Any other comments: Description of any monitoring of the site:	
Components	Component:	Number: Quantity
CONTACT INFORMATION	Organisation: Town: County: Contact: Tel: Email: Developer Organisation: Town: County: Contact: Tel: Email: Designer Organisation: Town: County: Contact: Tel: Email: Local Authority LA Name: Contact: Environmental regulator Organisation: Contact:	

Figure 77: Characteristic Fields in UK Database

4.2 SUDS database for Dublin

The information for the SUDS database was primary sourced from the planning files of Dublin City Council Drainage Divisions Planning and Development Control Section and was from planning permissions submitted between 2005 and 2009. Over this time an average of 7,000 planning permissions were submitted to Dublin City Council this search was reduced by only looking at planning permissions with drainage reference in drainage divisions filing system. This left between 500 and 1000 planning permission per year to review.

One of the first necessary steps in developing a SUDS database is to define the “**scope of interest**”. This involved setting inclusion or exclusion criteria for SUDS in the database, as including every SUDS would be near impossible. In Scotland for example, surface water drainage was omitted from the analysis wherever systems served fewer than 10 housing units or 10 car parking spaces within commercial, retail, industrial or public developments.

The following were the criteria for inclusion in the Dublin City Council SUDS Database:

1. Developments which include SUDS devices in their storm water drainage, found in the Drainage Divisions electronic Planning files between 2005 and 2009.
2. All new developments in the Dublin City Council area are required to fill out a sewer connection form prior to connection to the drainage network. As part of this process applicants must agree their drainage details with Dublin City Council Drainage Division and Dublin City Council Drainage division ensures that all the planning permission conditions have been complied with. Once this is completed a final approved drawing is agreed. Only those developments which have their final drainage details agreed were included.
3. Developments of a single house and over.

4. SUDS devices constructed by Dublin City Council Drainage Division or constructed in consultation with Dublin City Council drainage division

The SUDS database includes all types of SUDS devices including attenuation tanks. This is due to the large amount of development built in Dublin that have used attenuation tanks as their main form of storm water attenuation

4.2.1 Setting Characteristics or Field Descriptors

The next step involved the development of field descriptors that were relevant to the needs of Dublin City Council Drainage Division. The field descriptors should enable Drainage Division to view planning, maintenance, and pollution issues at any given SUDS site as well as providing the necessary information about the SUDS device for future network modelling. The fields descriptors captured should be in sufficient detail to eliminate the need for additional searching through planning files or a site visit and if possible should be digitised into GIS.

The following field descriptors have been included in the Database:

- Location: (i.e. the street address). The first step for ease of use of the database in the future.
- The Geo Co-ordinates: (i.e. the x-y co-ordinates). This information is essential for carrying out any transfer of the proposed excel database into a GIS package
- The SUS Reference: (.i.e. the drainage network id). This provides the necessary link point into the existing SUS25 drainage record database. This will assist Drainage Division staff in checking problems in the network. Also it will allow for future

drainage network models to allow for the SUDS input into the drainage system at this location.

- Dublin City Council and Developer Contacts for the SUDS Site. This field is necessary for following up and updating the database for SUDS sites that are currently in planning of construction stages. It will help future modifications of the SUDS device to be recorded in the database
- The Size of the Site: (i.e. the catchment area for the SUDS device.) This is necessary in order to help qualify the benefits of a SUDS device. It will also allow anyone who using the database to carry out the storage calculations for the catchment area.
- The Previous Land Use: (i.e. whether an old site is being redeveloped (Brownfield) or is in a new development area (Greenfield)). This will have an effect on network models. For a Greenfield site the SUDS device will only mimic the existing surface water capacity while in a Brownfield site a SUDS device may improve surface water drainage capacity
- The Status of the Development: Whether it's constructed or not, and when it is expected to be completed.
- The Type of SUDS Device: The types of SUDS devices used is important as different devices have different benefits and problems
- The Reason for Installation: SUDS devices are generally installed because of planning conditions, to improve water quality in an area or to increase stormwater storage. It is important to future drainage planning in the local drainage catchment that the reason for a SUDS device's installation is known.
- Ownership: Field descriptors showing ownership and the organisation responsible for maintaining the SUDS device are also essential to the needs of Dublin City Council

Drainage Division. This will assist in the tracing and resolving of any problems caused by the malfunction of a SUDS device.

- The Physical Features: an essential element to record in the database is the feature of the SUDS system (inlets, retention feature, outlet...) and its geographic location and dimension. This is vital for the Planning Control Section in guarding against the removal of any SUDS in future planning permissions. The database should also record the geographical shape of the feature and the capacity of the SUDS device.
- The Outflow Limit Flow: This is the limit set on the flow rate out of the site. Sites are limited under GDSDS criteria 2 to an outflow of Greenfield flow ($QBARR_{rural}$) or 2 l/s/ha
- The Water Quality/ Ecological Features: The Water Framework Directive requires all inland and coastal water to reach “*good status*” by 2015 and it is important that the water quality information field be included in the database. This is particularly important for SUDS devices installed by Dublin City Council to improve water quality.

Figure 77 details those field descriptors used in the DCC SUDS database

<i>DCC SUDS Database Field Descriptors</i>
Sustainable Urban Drainage Systems and SUDS sites
Location
Land use
National Grid Reference
SUS Reference
DCC Contact
File/Consent Reference
Client/Developer and Consultant
Addresses and telephone numbers
Status (constructed or otherwise)
Previous land use (Greenfield or Brownfield)
Ownership
Maintained by
Size of the Catchment
Type of Device
Reason for Installation
Physical Features, (Shape, size, etc)
Hydrological Features (Capacity, hydro brake flow limit, Etc)
Ecological Features (Plant life)

DCC SUDS Database Field Descriptors
Water Quality
Other comments

Figure 78: Characteristics or field descriptors

4.2.2 Software

The drainage Manhole database is stored on a DOS based SUS25 system. This system does not allow for the numerous character fields that a SUDS database requires. The software used to display the SUDS database is called Mapdrain which does allow additional information to be displayed alongside the drainage data. Through discussion with Dublin City Council Drainage IT it was determined that the optimum method of displaying the data, once it has been collected would be an excel database. The SUDS excel database is then Geo- reference and converted into .tab format. This format is compatible with the Mapdrain system and the database is displayed alongside the drainage data as shown in Figures 25 and 26

The Regional GIS Office, which is part funded by Dublin City Council, is currently working on a new system for mapping drainage infrastructure in the Greater Dublin Region and this method of data collection and geographical representation is compatible with this new drainage records system.

4.2.3 DCC SUDS Database

The a sample from the database is shown in a tabular format in Figure 78. The whole database containing 95 Sites throughout the Dublin Region is shown in tabular format in Appendix A. Figure 79 shows the extent of the database across the DCC administrative area with all 95 site represented as a blue star. Figure 80 shows a zoom in on one individual site,

in this case SUDS site 61. Site 61 is the Shelling Hotel on the Howth Road. In the top right of the screen the information available with a click of the “i” button on this site is shown. The total catchment area is 7665m². The SUDS on site 61 are an attenuation tank (198 m³), permeable paving (188 m²) and a swale (90 m²).

Database Reference	Location	Land use	National Grid Reference X	National Grid Reference Y	SUS Reference	DCC Contact	File/Consent Reference	Client/Developer and Consultant	Addresses and telephone numbers	Status (constructed or otherwise)	Previous land use (Greenfield or Brownfield)	Owners hip	Maintained by	contributing area (both permeable and impermeable) m2	Type Device
1	Beaumont Co-location	Hospital	318236.438	239272.328	so18382904	Maria Treacy 222-xxxx	K:\Development\Planning Files\2008\1083-08 Beaumont Co Location Hospital, Beaumont, Dublin 9,	Niamh Cronin, Senior Engineer, Michael Punch & Partners, Consulting Engineers,	T: 01 2352980 F: 01 2352985 M: 087 6529775 E: ncronin@map.ie	Planning	Brownfield	Private	Private hospital	15000	Attenuation tarpervaporation
2	BRL	mixed use development	314283.326	239936.2		Fiona Craven	K:\Development\Planning Files\BRL	Ballymun regeneration limited		under construction	Brownfield	Public (once it's taken in charge)		1500000	Detention porpervaporation Gre roc
3	Pelletstown	Mixed use development	312193.438	237547.719	SO12372305	Fiona Craven	K:\Development\Planning Files\2008\3306-08 Block K of Pelletstown, Ashstown, Dublin 11	DBFL Consulting Engineers		under construction	Greenfield	Public (once it's taken in charge)		400000	Detention porpervaporation swall
4	Lansdowne stadium	Stadium	318172.354	233039.129		Fiona Craven	K:\Development\Planning Files\2006\5692-06 7 Lansdowne	Aviva Stadium		Planning	Brown field	Private	private	50000	Attenuation tarpervaporation
5	St Pats Drumecondra	College	316153.832	237080.552	SO16372002	Maria Treacy 222-xxxx	K:\Development\Planning Files\2008\4245-08 St Patricks College, Drumecondra\	Michael Punch & Partners		Planning	Brown field	Private	private	38415	Green Ro Perme pavior Attenuation ta



Database Reference: 61

Location: Shering hotel howth

Land use: Redevelopment and extension of hotel

National Grid Reference X: 322,405,469

National Grid Reference Y: 238,177,453

SUS Reference: SO2284207

DCC Contact: Maria Treacy 222-xxxx

File Consent Reference: K1/Development Control/Planning Files

Client Developer and Consultant: DBFL Consulting Engineers

Addresses and telephone number: 4004000

Status: constructed or otherw: constructed

Previous land use: Greenfield : brownfield

Ownership: Private

Maintained by: Private

contributing area both perme: 7665

Type of Device: Permeable paving, swale and attanual

Reason for installation: Planning Requirement

Physical Features Shape: st: Permeable paving 185m2, Attanual

Outflow Flow limit: Hydrobrake 3.3l/s

Ecological Features Plant: If:

Water Quality:

Other comments:



Chapter 5

Discussion

5.1 Analysis of Database

As shown in the chapter 4 the database consists of 95 SUDS sites drawn from final approved drawings in the electronic planning records from 2005 to 2009. In the database there is a large range in the sizes of catchment area for each SUDS sites. Figure 82 below shows the number of SUDS sites divided up based on catchment size. The categories are as follows:

- 0 to 300 m³ - these are generally one off houses
- 300 to 1000 m³ - these sites are small housing developments or city centre redevelopments
- 1000-5000 m³ -these are generally large city centre developments
- 5000 m³ and upwards -these are generally large suburban developments

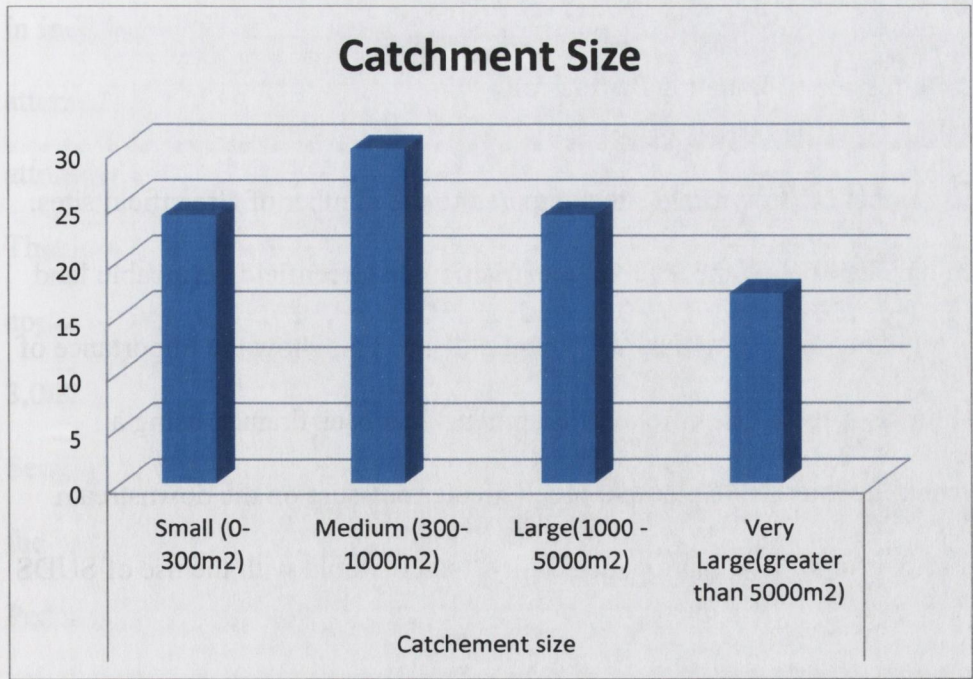


Figure 82: Catchment size for SUDS devices

Figure 83 shows the number of SUDS sites from the years 2005 – 2009, the lower number in 2005 are due to changes in the planning records systems and the introduction of the electronic storing of final approved drawing system for drainage connections. Prior to mid 2005 the final approved drawing was not stored digitally. Due to time constraints paper records have not been reviewed.

Due to the downturn in the economy there was drop in number of planning permissions for the years 2008 and 2009 and the lag in receiving connection drawings from developers.



Figure 83: Year of Submission of Planning Permission

Figure 84 shows the number of Brownfield site compared to the number of Greenfield sites. As can be seen from the chart below the level of construction on Greenfield permeable land in the last 5 years is higher compared to that of Brownfield site. This show the importance of use of SUDS in Dublin, as if these Greenfield developments had been drained using a traditional piped system, it would have placed a much greater pressure on the downstream drainage network in terms of water quantity and quality, than it would with the use of SUDS

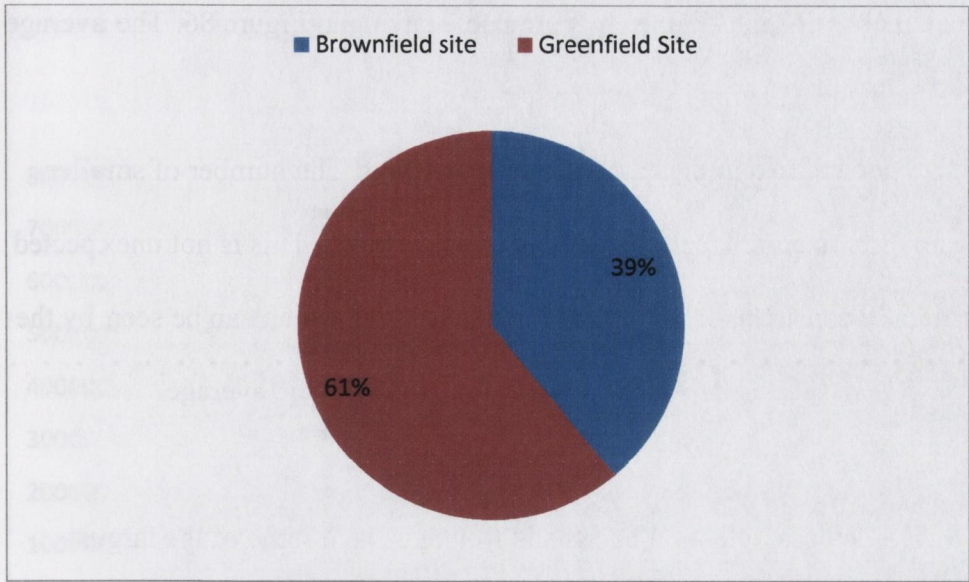


Figure 84: Greenfield/Brownfield Site

Figure 85 shows the different type of SUDS devices in use in the city, Figure 86 shows the areas drained to the different SUDS devices and Figure 87 shows the average area contributing to each device. As Figure 85 shows the most common SUDS system in use in the city is the attenuation tank. The majority of attenuation tanks in use in Dublin are located in medium sized sites that are primarily located within the city centre. The developers' use of attenuation tanks in these city centre locations is higher as the sites are smaller and attenuation tanks have a smaller land take than other SUDS devices.

This is reflected in Figure 86 in the area drained by attenuations tanks, which at approximately 186,000 m² is shown as the third lowest and an average contribution area of 3,060 m² which is the second lowest. Dublin City Council Drainage Planning and Control Section are currently trying to move away from the use of attenuation tanks by encouraging the use of permeable paving, green roofs and rainwater harvesting for city centre sites. Permeable paving is the second most commonly used SUDS device in the database and is generally used in private car parking areas in Dublin as Dublin City Council Road and Paving Department do not take in charge permeable paving because of perceived maintenance issues. Permeable paving is commonly used in very large, large and medium sized developments as

shown by the large area, 604, 677 m², drained by permeable paving in Figure 86. The average contribution area to a permeable paving is 20,850 m².

The third largest SUDS device used in the database are soakaways. The number of smaller sites in the database appears to correlate to the number of soakaways.. This is not unexpected as soakaways are generally considered most useful for smaller sites which can be seen by the relative small area, 16,023 m², drained to soakaway in Figure 86 with the average contribution area being just 696 m²

The least common SUDS devices, retention ponds and wetlands have some of the largest contribution areas, with the average wetland contribution area of 50 ha and the average retention pond contribution area of 25.5 ha. This is reflective of their use on very large catchment wide schemes

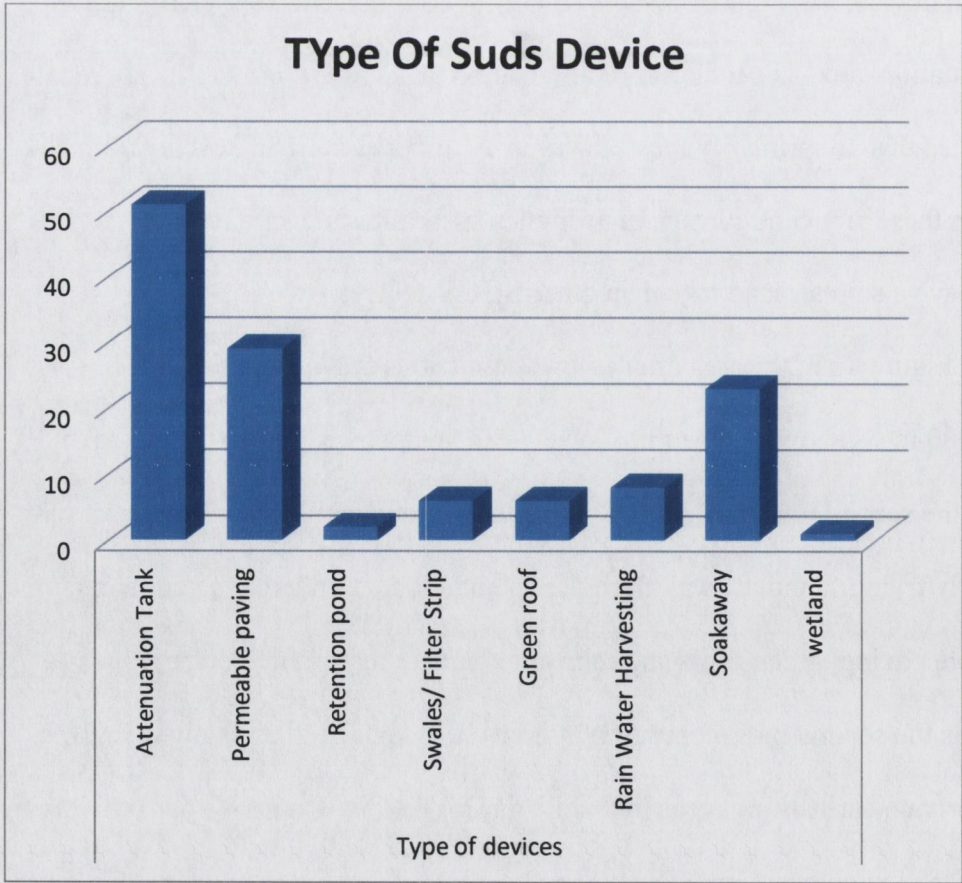


Figure 85: Type of SUDS devices in use in Dublin

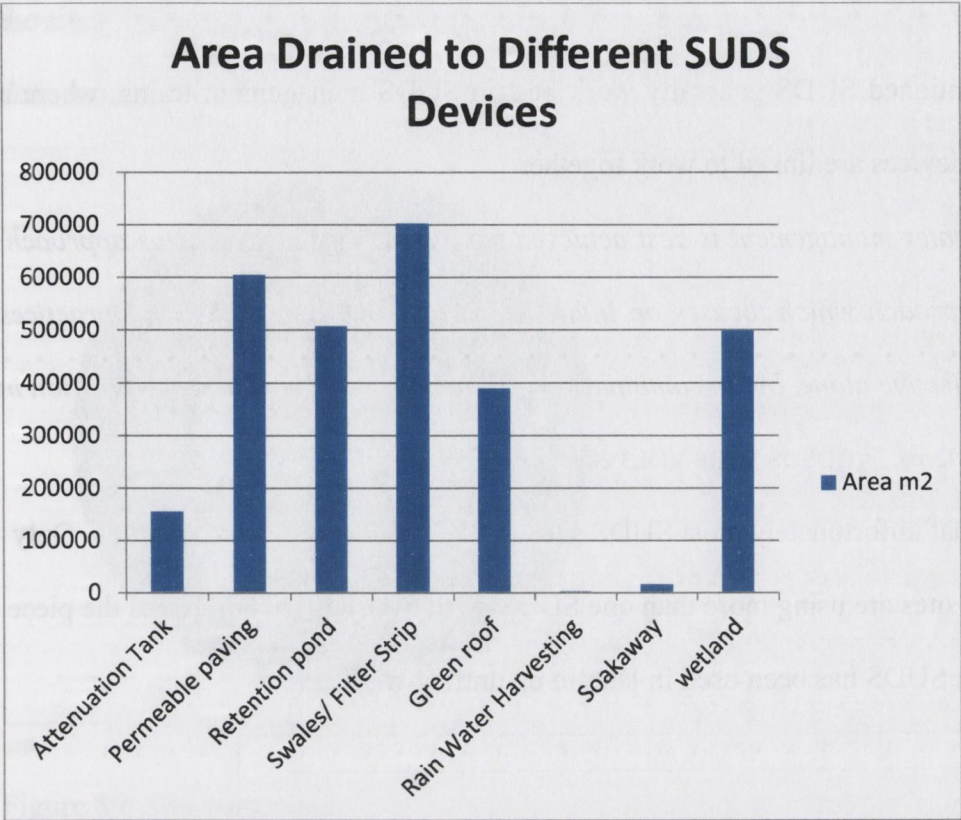


Figure 86: Area drained by SUDS devices in use in Dublin

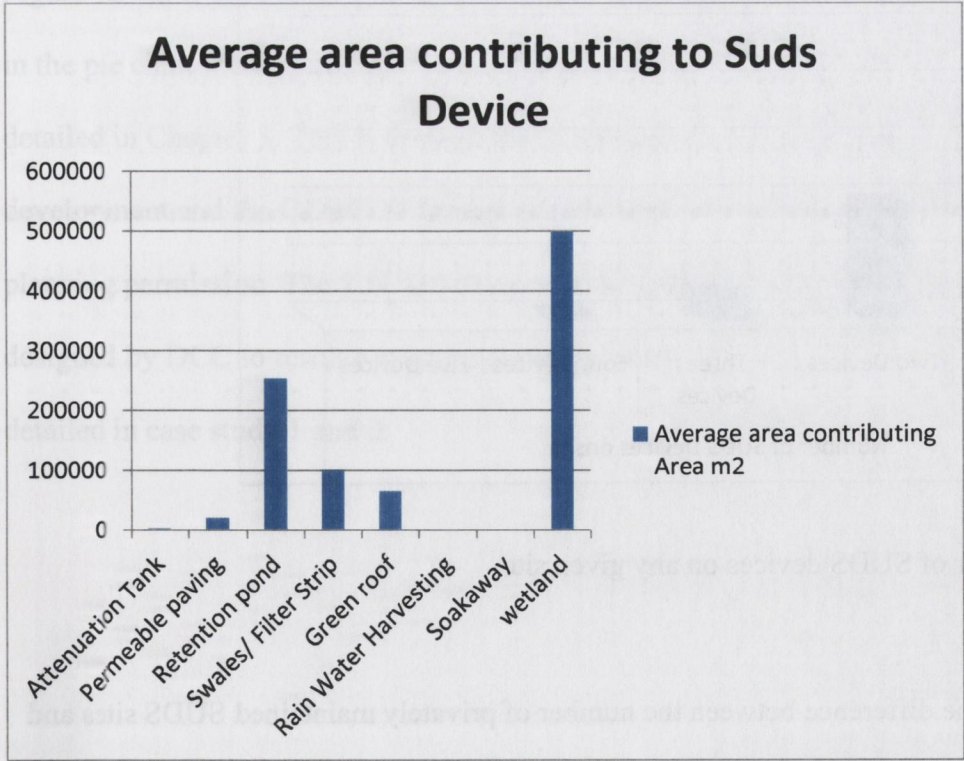


Figure 87: Area drained by SUDS devices in use in Dublin

As previously mentioned SUDS generally work best in SUDS management trains, where a number of SUDS devices are linked to work together.

“Effective stormwater management is best achieved from a management systems approach, rather than an approach which focuses on individual practices. Some individual practices may not be very effective alone, but in combination with others, may provide a key function in highly effective systems.” (GSDSDS SUDS VOL3 2005)

Figure 88 shows that unfortunately most SUDS sites in the database are working alone. Only a small number of sites are using more than one SUDS device onsite. This indicates the piece meal way in which SUDS has been used in Dublin up until now.

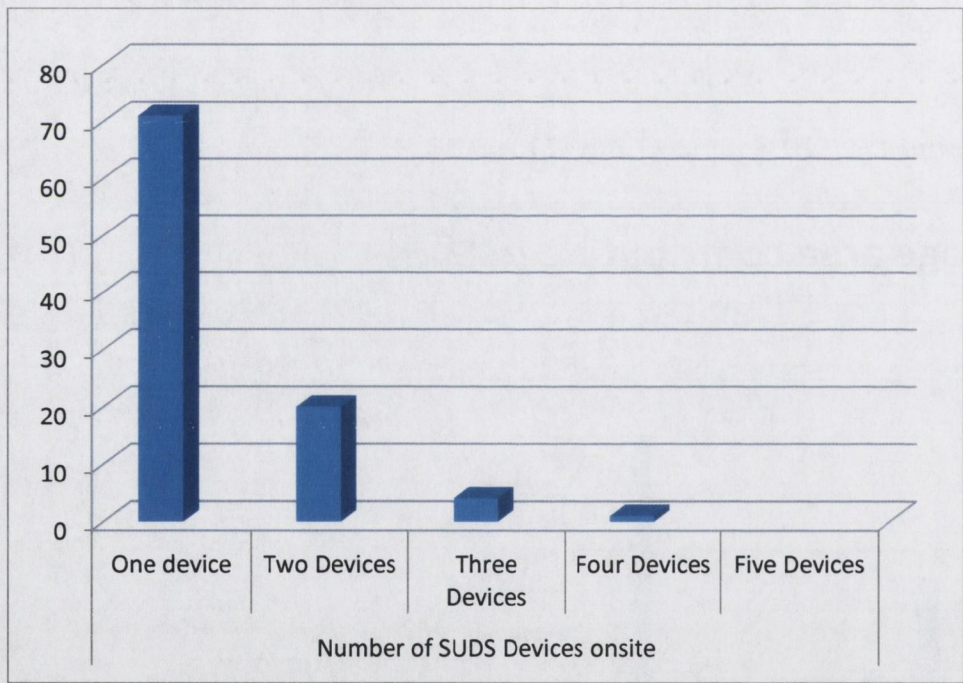


Figure 88: Number of SUDS devices on any given site

Figure 89 shows the difference between the number of privately maintained SUDS sites and the number of publicly maintained SUDS site. As can be seen from the graph the majority of

the sites are in private ownership. Because of this Dublin City Council Drainage Divisions does not know if these SUDS devices are properly maintained

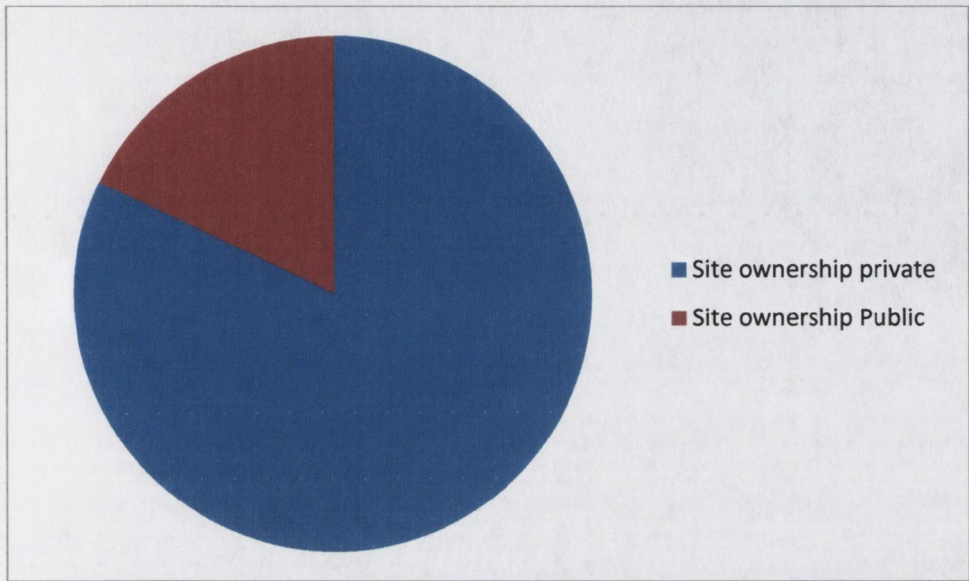


Figure 89: Site ownership

Figure 90 show the design criteria use for the SUDS devices in the database. As can be seen in the pie chart the majority have been design to comply with GDRCOP, which have been detailed in Chapter 3. This is because the SUDS device has been installed as part of a new development and the GDRCOP Design criteria were as included as a condition of the planning permission. The 2 SUDS devices in the Other category are both retro fit systems designed by DCC to resolve existing drainage issues. The designs of these two devices are detailed in case study 1 and 2.

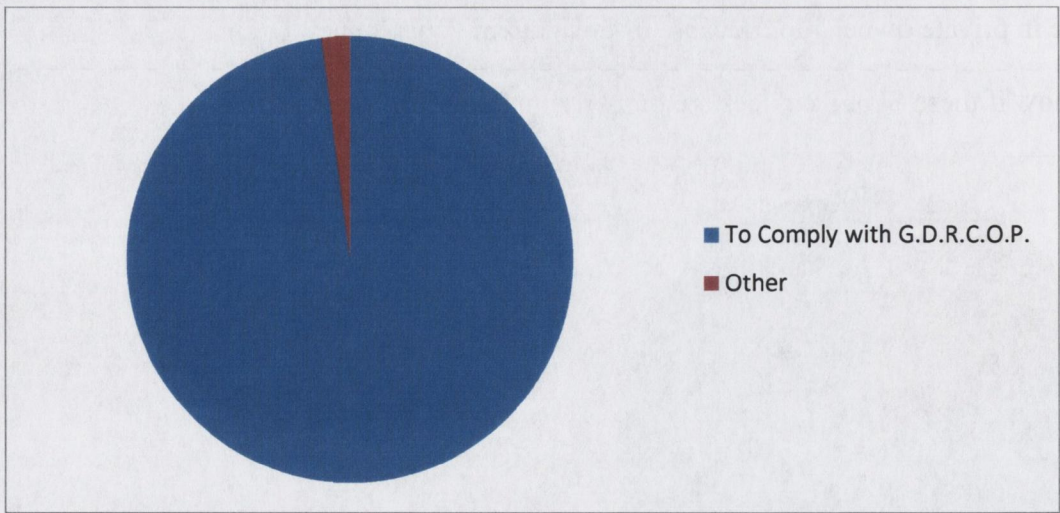


Figure 90: Design Criteria

5.2 Benefits of database

Why is a SUDS Database needed? Since the introduction of stormwater management to Ireland there have been a large numbers of SUDS devices installed and the exact location and performance level of these SUDS devices is generally unknown. At present, no digital database exists with the details of SUDS devices and features in the Dublin City Council Administrative area

“SuDS implementation in the Dublin region is in its infancy, and the Policy therefore recommends that databases be kept of SUDS installations, and their performance, in order that knowledge can be built up and shared between the stakeholder” (GDSDS SUDS Vol 2 2005)

Some of the main benefits of developing a SUDS database are

1. Assist in the forward planning and prevention of any accidental removal of SUDS devices by developer or contractors in the future.

2. Essential in the future modelling of the Dublin City Council's drainage network to include SUDS devices. *"All SUDS systems need recording, both those in private ownership as well as those in the public domain. This is because any change in any part of the system will have an influence on the performance of the drainage system downstream"* (R. Kelleher 2008)
3. Ownership of a SUDS device: responsibility for the maintenance of a SUDS device is critical, as poorly maintained devices may not benefit the drainage network hydraulically or improve water quality. They may in fact even be causing some local drainage issues.
4. *The Water Framework Directive (2000/60/EC)* requires all inland and coastal water to reach "good status" by 2015. Dublin City Council is now required to provide details of all outfalls to rivers to the EPA. A number of these outfalls may be affected and changed by the use of SUDS devices. This is particularly relevant when Dublin City Council install a SUDS device for the purpose of improving water quality.
5. The recording of SUDS information in a centralised database will aid in future research into the benefits of using SUDS in Dublin and the design of SUDS devices. Indeed in investigating the design criteria in Chapter 3 of this thesis use it was discovered that the approached in sizing SUDS devices a approach is generally conservative due the lack of research into the long term impact of various SUDS devise

A series of meetings have been conducted in order to define the benefits Dublin City Council Drainage Division in the development of a SUDS database. The following parties were involved in these meetings: Strategic Planning and Project Management Divisions Record Section, the Pollution, Maintenance and Planning Control Sections of Drainage Division,

Don MacEntee (Dublin City Council Senior Engineer responsible for IrishSUDS.com website), Patrick Daily (Resident Engineer responsible for Regional GIS for drainage and Water) and Richard Kelleher Hrwallingford (consultant on Dublin City Council Irish SuDS website). Through these meetings the following issues were identified

- Drainage Division has no database of SUDS currently in use in Dublin City Council's jurisdiction.
- Interrogating planning applications would be highly impractical due to the large volume in our possession, and the volume that continues to be received on a daily basis.
- In general practise, Dublin City Council Drainage Planning and Control Section does not receive As-Constructed Drawings from Contractors. For the review of SUDS systems currently installed these would have been beneficial.
- No individual with Dublin City Council Drainage Division reviews what SUDS have been installed in new developments
- Dublin City Council currently has no record if SUDS devices already installed by developers are being maintained properly
- The *Water Framework Directive (2000/60/EC)* requires all inland and coastal water to reach "good status" by 2015. Dublin City Council is required to provide details of all outfalls to rivers to the EPA. A number of these outfalls may be affected and changed by the use of SUDS devices. This is particularly relevant when Dublin City Council has installed a SUDS device for the purpose of improving water quality.
- SUDS measures may be included in Dublin City Council's future surface water separation schemes and will need to be recorded.
- Development of a greater understanding of the use of SUDS in Dublin now and in the future. The database shows that most SUDS sites in Dublin are installed by

developers because of planning permission requirements and the SUDS concept in generally is seen as a planning obstacle to be overcome rather a tool to optimise the local drainage system. This database promotes a greater understanding both in DCC and outside of the council of why SUDS is essential to future drainage needs.

5.3 Recommendations for the Maintenance and updating of the SUDS Database

5.3.1 Collection of SUDS Data from new developments

Should the SUDS Database fulfil all of Dublin City Council Drainage Division's requirements it is proposed to update the database to record all SUDS in any **new developments fulfilling the criteria in the "scope of interest"** as laid out in the chapter 4.

For this to be carried out, changes in Dublin City Council's planning procedure will need to be implemented. It is proposed that before expanding the database that a procedure is put in place (involving Dublin City Council Drainage Planning and Control Section and Dublin City Council Strategic Planning and Project Management Divisions) to facilitate the recording of SUDS systems in future development.

These procedures would likely include

- Amending planning application conditions to include a new standard condition for the construction, inspection and recording of details of SUDS devices.
- Amending the planning application procedure to give developers an incentive to provide **"as constructed" drawings** to Drainage Division. These could then be examined for SUDS. The most obvious incentive would be withholding a bond until such drawings are received.

- Requirements for Drainage Inspectors to check the required **SUDS systems detailed in new planning applications** have been implemented. This could be implemented when reviewing new drainage infrastructure during the construction of a development.
- Development of a system to **Quality Check the SUDS data** from any development prior to it being entered into the database. This would be similar to the quality check performed prior to other drainage infrastructure being entered into the drainage database.

As part of this proposal a SUDS card (Figure 91) similar to Manhole cards (Figure 92) has been developed. The SUDS card is designed to aid the recording of SUDS details ensuring that entry into the SUDS database is more streamlined. These SUDS cards would be filled out by the developer in conjunction with Dublin City Council Planning and Control Section and can then be used as part of the quality control check process.

Manhole Survey Report									
		East		North		Temporary Manhole No			
Nat Grid Ref						Manhole No			
Location									
Surface Type		e.g. Side Road, Main Road, Field, Path, Driveway etc							
Status		Function		Manhole Type		Date of Survey			
Square or Rectangle		Double Triang		Oval		Single Triang		Circular	
								Clover	
Hinged		Lockable		Cover Duty		Cover Level			
PIPE DETAILS - Incoming Pipes									
Internal Inspection					Location				
Cover 1 (dia)					Shaft 1 (dia)				
Opening					mm				
Shaft depth from C.L.					Chamber 1 (dia)				
mm					Ladder				
Brick		Pre-cast Concrete		In Situ Concrete		Segments Unlined		Segments Lined	
Reducing Sabs		Taper		Arch		Side Entry		No of Landings	
Condition					Depth of Silt				
Evidence of					mm				
Rough Calculations					Depth of Surcharge				
					m				

Figure 91: DCC Drainage Records Manhole Card

Suds Card					
Location	Name				
	Address				
	Database reference				
	X Co-ordinate				
	Y Co-ordinate				
	Outfall Manhole Reference				
Site Details	Land use				
	Greenfield /Brownfield				
	Ownership: Public /private				
	Reason For Suds				
	Catchment Size				
Contacts	DCC Contact	Name			
		Phone Number			
		Email			
	Site Contact	Name			
		Phone Number			
		Email			
Suds Details	Type of Suds	Device 1	Device	Capacity	
		Device2			
		Device3			
		Device4			
		Device 5			
		Site Outflow Limit			
		Ecological Features			
		Water Quality Restrictions			
	Comments				

Figure 92: Proposed SUDS Record Card

5.3.2 SUDS Database - maintenance

As with any database without continuous maintenance and updating the SUDS Database would prove to be ineffective. Currently this SUDS database only includes the SUDS data from the “final approved drawings” from the electronic planning files between 2005 and 2009. As the SUDS database does not include paper planning files it is certain that are SUDS devices in existence in Dublin City Council’s area that have not been included in the current database. It is envisaged that the collection of the additional SUDS data for this database will be carried out hand in hand with the updates of information for the rest of the drainage network. With that in mind, it is recommended that the maintenance and updating of the database be incorporated into the maintenance of overall Drainage Manhole Database which is maintained by Dublin City Council Strategic Planning and Project Management Division, Drainage Records Section.

As can be seen in Figure 89 most of the SUDS devices in the database are privately maintained. Therefore it is important to the overall working of the drainage system that these devices are regularly checked. It is recommended that an inspection process of the recorded SUDS devices may also have to be initiated by Dublin City Council Drainage Division to ensure that the devices are still working as intended. Maintenance of the SUDS database would assist the Drainage Division in this inspection process.

5.4 Future of SUDS in Dublin

With the downturn in the economy the pressure for ongoing development in Ireland has eased. This downturn is an opportunity for County and City Councils to catch up in relation to environmental planning. This will allow the Planning division to focus on large scale

development plans rather than one off helter-skelter development which has been a feature of the last ten years. The future in urban planning is most likely to have catchment plans like BRL or Pelletstown. This in turn will allow SUDS planning to follow a catchment wide SUDS Management Train rather than one off SUDS devices on individual sites fitting into these catchment wide plans.

The Dublin Institute of Technology development at the Grangegorman site is a good example of this new approach to planning. The developers are required to submit a catchment wide Storm Water Management Plan, while Dublin City Council Drainage Division has also carried out some small scale drainage modelling to check the capacity of the network and any likely upgrades needed.

In addition Dublin City Council is currently carrying out a number of large scale surveys of the drainage network, focusing on the effect of CSO in Dublin in response to the EPA discharge licence which was issued to Dublin City Council earlier this year. These surveys will result in a drainage network and water quality model which will be used for the development of solutions to existing environmental and capacity issues identified in the GDSDS throughout the city. SUDS systems are likely to have some part to play in the solutions to the hydraulic capacity and environmental issues found. SUDS systems are already being seen by Dublin City Council Drainage Division as a cost effective way to solve some of the drainage issues impacting on some of the Dublin City Council areas. The case studies on Glendhu Park and Tolka Valley wetland have shown that SUDS systems can be integrated into the landscape, improving the amenity value of the area while ensuring that the systems has the capacity to prevent flooding within the area. Another trial wetland has been proposed to resolve an existing CSO issue in Chapelizod and a second swale development is being proposed in Cabra to resolve a local capacity issue

5.5 SUDS and Groundwater

While SUDS have shown themselves as a cost-effective method for improving drainage in an area, the impact of infiltration type SUDS requires further investigation. As can be seen in Figure 93, North Dublin lies on a regionally important aquifer, with most of the rest of Dublin on a locally important aquifer. Infiltration type SUDS devices are designed to allow some of the polluted runoff to soak away into the ground, most other SUDS devices such as swales, detention ponds and wetlands while not directly using infiltration also do allow some infiltration into the ground. Over time the portion of polluted runoff which infiltrates into the ground increases, which may have a detrimental effect on the water quality of the groundwater in the aquifers in the Dublin region. While the suitability of all SUDS devices are assessed with by DCCDPS with a view to their impact on ground water it is difficult to carry out this assessment fully due to the lack of research in this area in an Irish context, indeed the runoff calculations in the GDSDS are based on rural catchments in the UK. Therefore it is recommended that further research is conducted which investigates infiltration type SUDS.

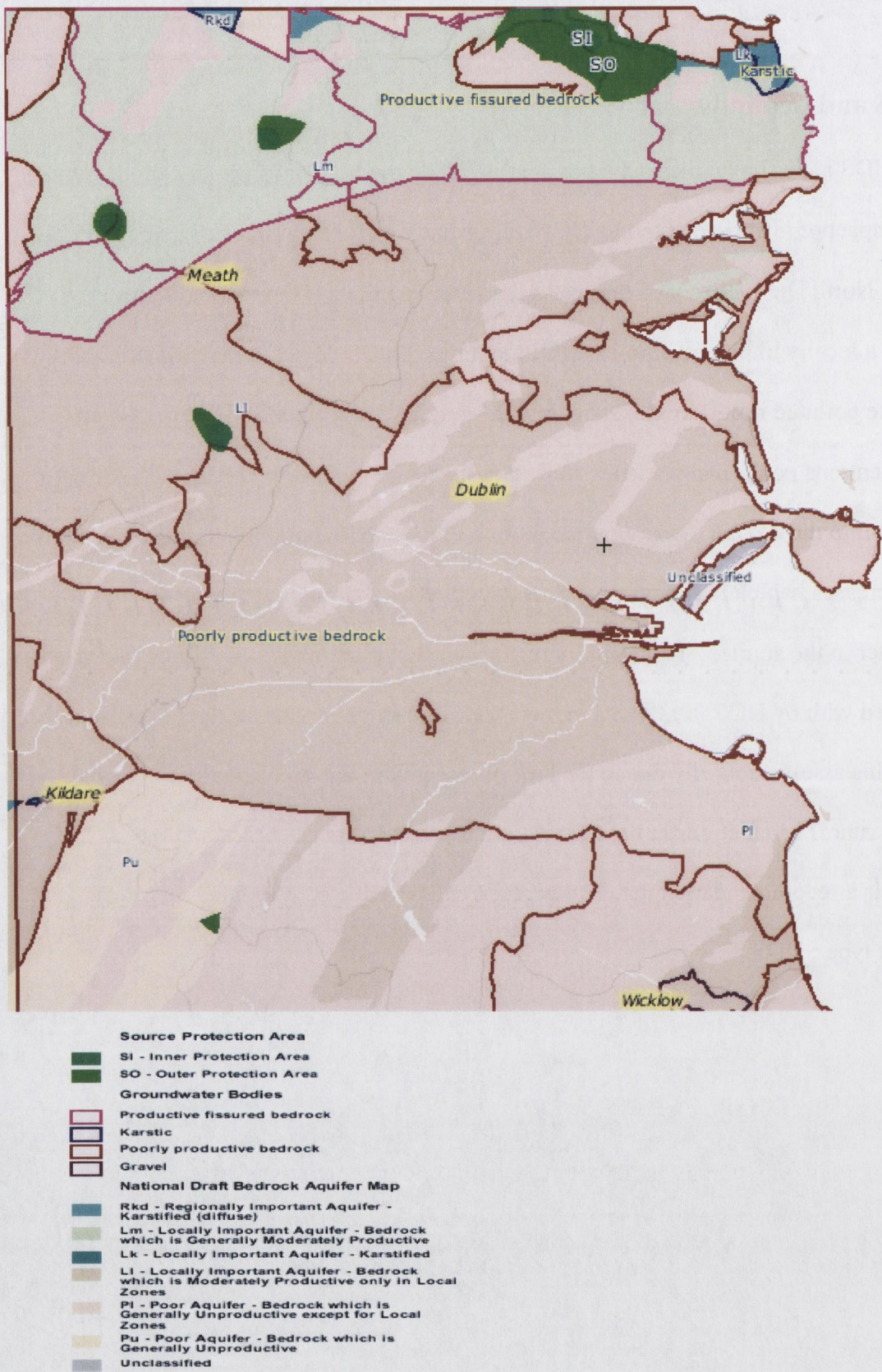


Figure 93: DCC Drainage Records Manhole Card (Geological Survey of Ireland 2010)

Chapter 6

Conclusion

It was the objective of this thesis to collate and record the occurrences of Sustainable Urban Drainage Systems (SUDS) in the Dublin area and to understand their design and functioning.

The environment has become a major issue in recent years and in particular the effect that increases in urbanisation has had on it. This thesis assessed the influence of environmental legislation such the Water Framework Directive and the Urban Wastewater Treatment Directive and programmes such as the Eastern River Basin Study and the Environmental Protection Agency Discharge Licences and how these regulatory instruments have become a major driver in the use of SUDS in Dublin.

A key concept of SUDS is the maintenance of natural hydrological conditions as against concentrating drainage discharges at specific points/outfalls. A review of how urban drainage grew from basic stormwater management into the more complex systems underlying SUDS has been presented. The motivation behind the increasing use of SUDS is partly regulatory and partly the need to reduce environmental impact. The differences between traditional drainage systems and SUDS systems has been assessed in the context of the benefits of SUDS in general and of typical SUDS devices.

The development of Dublin's drainage system over time ranged from the culverting of rivers through the transport waste, to the building of the Ringsend tertiary treatment works was reviewed, with respect to how Dublin's drainage system currently works. It is clear that what is perceived as a SUDS system is much wider now than was probably intended by the original proponents.

The impact of the Greater Dublin Stormwater Drainage System (GDSDS) project and its associated reports has strongly influenced stormwater management in Dublin particularly under the philosophy of SUDS. New developments must design and utilize SUDS sites and must meet specific criteria designed to limit pollution and flooding both off and onsite as well as provide a means of protecting river morphology. An explanation of the basis for each criterion and how each criterion is applied has been presented.

Four case studies were assessed to show how different SUDS devices have been employed for different reasons and to indicate how each system fulfils their design criteria. These case studies were selected to give as wide a range of different types of SUDS sites and also to reflect the different reasons for their installation. They also highlight the issues and difficulties in applying the relevant design criteria in a practical setting such as the area restrictions of a SUDS retro fit to an existing urban catchment, the problem of using downstream solutions to resolve water quality issues, the design of SUDS for new developments in the city centre and the creation of catchment wide stormwater systems.

The review of other international SUDS databases was undertaken and using the information gathered from these and the four case studies, a scope of interest and the appropriate field descriptors for a Dublin SUDS database was developed.

A database of known SUDS sites has been compiled as a way of presenting the current 'state of the play' in SUDS in Dublin. A desk study of all the planning permissions submitted to Dublin City Council (DCC) Drainage division between the years 2005 to 2009 was carried out. This study identified 95 different SUDS sites throughout the city which fitted the scope of interest. A SUDS database for the DCC area was then constructed using the 95 sites identified and the relevant field descriptors and this was mapped onto the DCC GIS system.

Patterns within the SUDS database were examined, such as the large number of sites which use one-off SUDS devices, the types of site ownership and the large amount of attenuation tanks/ponds built as part of SUDS for development sites. The database also shows that to date most SUDS sites in Dublin are installed by developers under planning permission requirements and the SUDS concept generally is seen as a planning obstacle to be overcome rather a tool to optimise the local drainage system and improve the environment.

The benefits of having a SUDS database both operationally for DCC and in promoting the better understanding and design of SUDS in the future was set out. A recommendation for a system to record future SUDS devices in use in the Dublin City Council administration area and the maintenance of the database is made. Finally an evaluation of the impacts arising from the future use of SUDS in Dublin was made with detailed recommendations for future research.

As drainage and environmental legislation continue to set ever more strict criteria for the health of the water environment in the future there is no doubt that the use of SUDS in Dublin will become more common place in the drainage network. As an asset in the management of the drainage network, pollution and development, SUDS devices in Dublin can be better deployed in the future, than they have been to date.

As mentioned throughout this thesis SUDS are not a comprehensive solution to pollution control but if they are carefully designed and managed SUDS will yield acceptable hydraulic and environmental improvements. SUDS devices work best in tandem with other SUDS devices and depending on local conditions the correct SUDS device can vary from site to site. This thesis shows that the development of a database for Dublin City Council is an important part of the increasing implementation of SUDS.

The information gathered in the SUDS database will help Dublin City Council in more accurately identifying current drainage problems. It can support the management of the drainage network and can be used to help better targeting of SUDS devices to a drainage problem, be it a development site and/or an environmental issue like combined sewer overflows or a hydraulic capacity issue in the drainage network.

It is anticipated that the SUDS database will help promote a greater understanding both in DCC and outside the council of why SUDS is essential to meeting future drainage needs.

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[http://www.tobermore.co.uk/\(S\(dz3zip24zfko1g55ibwep545\)\)/siteFiles/resources/car%20park%20booklet%20roi.pdf](http://www.tobermore.co.uk/(S(dz3zip24zfko1g55ibwep545))/siteFiles/resources/car%20park%20booklet%20roi.pdf)

September 2010

53. M. Uhl and L.Schiedt

Green Roof Storm Water Retention –Monitoring Results

21 Muenster University of Applied Sciences, Department of Civil Engineering,

Laboratory of Water Ressources Management, Corrensstr. 25, 48149 Muenster, FRG.

2 Ingenieurgesellschaft fuer Stadthydrologie mbH, Stiftstr. 12, 30159 Hannover, FRG

September 2008

54. UK Environment Agency

www.environment-agency.gov.uk/business/sectors/36998.aspx

January 2010

January 2010

55. US EPA

Storm Water Technology Fact Sheet

October 2009

56. US EPA SUDS guidance

http://water.epa.gov/scitech/wastetech/guide/stormwater/upload/2006_10_31_guide_stormwater_usw_a.pdf

September 2010

57. US Government Science

<http://ga.water.usgs.gov/edu/urbanrun.html>

March 2010

58. B. van Duin, C. Brown, A. Chu, J. Marsalek and C. Valeo

Characterization of Long-Term Solids Removal and Clogging Processes in Two Types of Permeable Pavement under Cold Climate Conditions

Department of Civil Engineering, Schulich School of Engineering, University of Calgary, 2500 University Drive NW, Calgary, Alberta, T2N 1N4, Canada 2 Westhoff Engineering Resources, Inc., Suite 601, 1040 – 7th Avenue SW Calgary, Alberta, T2P 3G9, Canada 3 Urban Water Management Project, National Water Research Institute, Environment Canada, 867 Lakeshore Road, Burlington, Ontario, L7R 4A6, Canada
September 2008

59. Jan Voelz

THE CHARACTERISTICS & BENEFITS OF GREEN ROOFS IN URBAN ENVIRONMENTS

UC Davis Extension Sustainability and the Built Environment Jeff Loux
October 2006

60. K. Vopicka

Sediment Assessment of Stormwater Retention Ponds within the Urban Environment of Calgary, Canada

1 Strategic Planning and Policy, City of Calgary, P.O. Box 2100, Stn. M, LOC #433, T2P 2M5, Calgary, AB, Canada
September 2008

61. Water Framework Directive Ireland

<http://www.wfdireland.ie/wfd-more.html>
January 2010

62. Webcomsystems

<http://www.webcomsystems.co.uk/help/pcconc.htm>

March 2010

63. World Health Organisation

WHO Fact sheet N°107

January 2010

June 2010

APPENDIX A:

SUDS Database In Tabular Format

Databas e Referen ce	Locatio n	Land use	Nationa l Grid Referen ce X	Nationa l Grid Referen ce Y	SUS Referen ce	DCC Contact	File/Co nsent Referen ce	Client/ Develo per and Consult ant	Addres ses and telepho ne number s	Status (constr ucted or otherwi se)	Previo us land use (Green field or Brownf ield)	Owners hip	Maintai ned by	contrib uting area (both permea ble and impermea ble) m2	Type of Device	Reason for Installat ion	Physica l Feature (Shape, size, etc)	Outflo w Flow limit	Ecologi cal Feature s (Plant life)	Water Quality	Other comme nts
1	Beaum ount Co- location	Hospita l	318236. 438	239272. 328	sol1838 2904	Maria Trecy 222- XXXX	K:\Dev elopme nt Control \Planni ng Files\20 08\108 3-08 Beaum ont Co Locatio n Hospita l, Beaum ount, Dublin 9,	Niamh Cronin, Senior Engine er, Mich ael Punch & Partner s, Consult ing Engine ers, E: ncro min@m pp.ie	T. 01 235298 01 F. 01 235298 51 M. 087 652977 51 E: ncro min@m pp.ie	Plannin g	Brownf ield	Private	Private hospital	15000	Attenua tion tank, permea ble paving	Plannin g conditi ons	20 no permea ble paved car spaces. 25m3 tank	hydrobr ake with 21s flow	n/a		Case Study 3
2	BRL	mixed use develop ment	314283.3 26	239936.2		Fiona Craven	K:\Dev elopme nt Control \Planni ng Files\B RL	Ballym un regener ation limited		under constru ction	Brownf ield	Public	Public (once it's taken in charge)	150000	Detenti on pond, permea ble paving, swales, Green roofs	Plannin g conditi ons	Retenti on ponds 32,000 m3	15.8	Green Roof on recreati on centre		Case Study 4
3	Pelletst own	Mixed use develop ment	312193. 438	237547. 719	SO123 72305	Fiona Craven	K:\Dev elopme nt Control \Planni ng Files\20 08\330 6-08 Block	DBFL Consult ing Engine ers		under constru ction	Greenfi eld	Public (once it's taken in charge)	Public (once it's taken in charge)	400000	Detenti on pond, permea ble paving, swales,	Plannin g conditi ons	retentio n pond: 1 0000m 3. 70m long swale Over 100 permea	4.9			

[illegible]

7	St Vincent hospice Fairview	Hospital	316937.045	236640	SO17360505	Maria Treacy 222-xxxx	Files\2008\448 Fairview CNU	Michaels & Partners	Planning	Greenfield	public	public	13482	Permeable paving	Permeable paving: 1600mm	Hydrobrake 2l/s			
8	Victoria Lane	3 houses	314417.477	231566.982	SO15300101	Mary-Liz	Files\2007\114 5-07	Michaels O'Reilly	Constructed	Greenfield	Private	Private	225	Permeable paving And Hydro Brake	Driveway	Hydrobrake 2l/s			
9	Eastmoirland Lane	Private Development 20m*6m	317042.818	232895.384	SO17320901	Mary-Liz	Files\2007\115 2-07 20 upper Baggot street	Paul Kelly Michae l Punch & Partners	Constructed	Greenfield	Private	Private	120	Green Roof, Permeable paving.	0.022ha permeable paving +green roof	Hydrobrake 2l/s	Green roof		
10	39A Violet Hill Drive	Single house	314202.938	237562.172	SO14372502	Maria Treacy 222-xxxx	Files\2007\124 2-07 39A Violet Hill	Thomas O'Neill, NCE Civil and Structural consultant Engineer	Planning	Greenfield	Private	Private	320	Filter drains	three 300mm dia x 10m long storage pipes	Hydrobrake 2l/s			

11	274 North Circular Road	Apartments	314662	235597	SO143 55705	Fiona Craven	Drive, Dublin 11	Oconnor Sutton Cronin	8682100	Constructed	Greenfield	Private	Private	14325	Attenuation tank	Planning Requirement	attenuation tank 71m*2.5m*0.625m	Hydrobrake 2l/s				
12	Ballsbridge Avenue	4 houses	318000.031	232560.484	SO173 29509	Mary Liz Walsh		Casey O'Rourke and Associates	6611100	Constructed	Brownfield	Private	Private	225	Filter Drain + rain water harvesting	Planning Requirement	4*15m*100mm filter drains and 4x3m3 rain water harvesting tanks	Hydrobrake 2l/s				
13	288 Bannow Road, Cabra	5 apartment blocks	319970.971	240522.313	SO133 64905	Maria Treacy xxx		Kieron Broderick, Ian Magahy Associates	6746418	Constructed	Brownfield	Private	Private	6205	Attenuation tank.	Planning Requirement	Attenuation tank: 0.85dp x 18m long x 4.35 wide	Hydrobrake 2l/s				

14	40 to 42 Hill Street Dublin	apartment blocks	315940.696	235190.823	SO15359103	Gavin McHugh	K:\Development\Planning\Files\2007\219-07-40 to 42 Hill Street Dublin	Jonathan Lennon Downes Associates Cashel Business Centre Ph: 014901611, 0876683380	Constructed	Brownfield	Private	Private	600	Attenuation tank.	Planning Requirement	Attenuation tank: 20 m3	Hydrob rake 2l/s				
15	old shell garage site. Coolock village. Coolock, Dublin 5	three storey mixed use development comprising residential and commercial use	319742.906	238931.219	SO19387803	Fiona Craven	K:\Development\Planning\Files\2007\227-07-07 old shell garage site. Coolock village. Coolock, Dublin 5	Francis Doherty, Doherty Finegan Kelly 0862447207, 8301852	Constructed	Brownfield	Private	Private	1850	Attenuation tank.	Planning Requirement	Attenuation tank: 12,000mX2,750mX, 600m	Hydrob rake 2l/s				
16	113 Phibsboroigh Road Royal Canal Bank Dublin 7	4 storey over basement mixed development with 3, 1 bedroom and 4, 2 bedroom	318225.156	236384.844	SO15360204	Fiona Craven	K:\Development\Planning\Files\2007\235-0-07 113 Phibsboroigh Road Royal Canal Bank Dublin 7	Liam Keogh, Downes Associates Ph: 014901611, 0864176266	Constructed	Brownfield	Private	Private	240	Attenuation tank.	Planning Requirement	Attenuation tank: 10 m3	Hydrob rake 2l/s				

17	27	Temple Road Darryl	single house	316194.007	230277.14	SO16300001	Mary-Liz Walshe	K:\Development\Planning\Files\2007\2410-0727 Temple Road Darryl	2964697	Constructed	Greenfield	Private	Private	Soakaway	Planning Requirement	Soakaway: 2.4. X1.5X1m	Hydrobrake 2l/s					
18		Fairview park sports ground	Sport ground	317712.727	236300.181	SO18361101	Maria Treacy 222-xxxx	Fairview Park Sports Centre	Mark Gill, Fearon O'Neill Rooney		Constructed	Greenfield	public	DCC parks	online storage		Hydrobrake 2l/s					
19		Elm Mount Avenue Beaumont, Dublin 9	a new two storey house	317900.531	238186.453	SO17388103	Maria Treacy 222-xxxx	Files\2007\2567-0786 Elm Mount Avenue	Malone ymilar construction engineer ing	4930211	Constructed	Greenfield	Private	Private	permeable paving	Planning Requirement	permeable paving :30m2	Hydrobrake 2l/s				

23	Beneav Lodge, Beneav in Rd	Nursing home extension	314208	238971.297	SO14391002	Maria Treacy 222-xxxx	7-07 40A Maryville Road, Raheny	G.I. Martin architects	2890946161	Constructed	Greenfield	Private	Private	4400	Attenuation tank.	Planning Requirement	Attenuation tank: 75 m3	Hydrob rake 2l/s				
24	233 raheny road	new two-storey four (4) bedroom detached house,	321786.844	239287.609	SO21397205	Fiona Craven	5	KJWD	818637	Constructed	Greenfield	Private	Private	225	Attenuation tank.	Planning Requirement	Attenuation tank: 2.7 5x2x0.4 5	Hydrob rake 2l/s				
25	22-24 sheriff st upper	7 storey office building	317512.219	234783.828	SO17345701	Fiona Craven	22-24 Sheriff Street	O'Connor Sutton Cronin	868210	Constructed	Brownfield	Private	Private	630	Attenuation tank.	Planning Requirement	Attenuation tank: 37 m3	pumped flow 3l/s				

26	31-36 Ormond quays upper	5 storey mixed development	315169.188	234207.125	SO153 41123	Fiona Craven	K:\Development\Control\Planning\Files\2007\36 Ormond Quay Upper	DBFL Consulting Engineers	Tel: +35314 004000	Constructed	Brownfield	Private	Private	1175	Attenuation tank.	Planning Requirement	Attenuation tank: 54.3m3	Hydrob rake 3.4l/s				
27	Coolock lane	two storey twelve classroom plus ancillary accommodation on school building	317751.25	239862.438	SO174 07002	Fiona Craven	K:\Development\Control\Planning\Files\2007\3870-07 Gaelscoil Cholmcille off Coolock Lane Adjacent To The Astro Park Football Club And Castletimon Road Coolock	Fahy Fitzpatrick	466056	Constructed	Greenfield	public	School	1575	Soakaway	Planning Requirement	soakaway: 10x12.5x0.8 m	Hydrob rake 2l/s				

28	5	Harcour rt st	new seven storey hotel buildin g	316514. 375	233818. 153	SO153 37204	Mary- Liz Walshe	K:\Dev elopme nt Control \Planni ng Files\20 07\399 2-07 St Stephen s Green Hotel Extensi on	O'Conn or Sutton Cronin	868210 0	Constru cted	Brownf ield	Private	Private	2500	Permea ble paving on roof and rain water harvesti ng tank	Plannin g Require ment	Permea ble paving :175m2 Rain water harvesti ng tank 1.5 m3	Hydrob rake 2l/s				
29	95a	graciefie ld rd	new house	319978. 063	238414. 156	SO193 89303	Maria Treacy 222- xxxx	K:\Dev elopme nt Control \Planni ng Files\20 07\445 3-07 96 graciefie ld road artane Dublin 5	Declan Kearns &associ ates	045 520642	Constru cted	Greenfi eld	Private	Private	160	attenuat ion tank & rain water harvesti ng tank	Plannin g Require ment	attenuat ion tank:1 m3 rain water harvesti ng tank:1 m3	Hydrob rake 2l/s				
30	3	St brendan s AV Cooloc k D15	New House	319598. 906	238504. 125	SO193 85405	Maria Treacy 222- xxxx	K:\Dev elopme nt Control \Planni ng	Malone y Millar constru ction enginee ring	493021 1	Constru cted	Greenfi eld	Private	Private	407	Rain water harvesti ng and attenuat ion tank	Plannin g Require ment	Rain water harvesti ng tank:3.8 m3	Overflo w to soakaw ay Capacit y N/A				

31	33& 34 Kenilworth Square west	4 house develop ment	314832. 4	231073. 2	SO143 18001	Mary- Liz Walshe	Harm and McCart ney Projects LTD	849980 0	Constru cted	Greenfi eld	Private	Private	Permea ble Paving &Atten uation Tank	Permea ble Paving: 102m2 & attenuat ion Tank-8. 8m3	Hydrob rake 2l/s				Attenua tion tank .7m3
32	Hollies St Hospita l	Hospita l revel opment	316904. 632	233551. 362	SO163 39604	Mary- Liz Walshe	Arup Consult ing Engine ers		Constru cted	Brownfi eld	public	public	Attenua tion pipe	Plannin g Require ment 9m3	Hydrob rake 2l/s				
33	48a Willow s park	2 houses	314536. 826	239483. 072		Maria Treacy 222- xxxx	MG Archite ctural Service s	806397 7	Constru cted	Greenfi eld	Private	Private	2 soakaw ays	Plannin g Require ment A	soakaw ays:N/ A				

34	North Brunswick street hostel	314926.797	234885.075	SO14349802	Maria Treacy 222-xxxx	John J lauder	8336200	Constructed	Brownfield	Private	Private	955	attenuation drain	Planning Requirement	attenuation drain 3.75m3				
35	Smithfield, Riverview house	315086.309	234338.621	SO14347309	Fiona Craven	Buro Hapold consultants	8716900	Constructed	Brownfield	Private	Private	3600	permeable paving + attenuation tank below. Green roof	Planning Requirement	Permeable paving 100m2 + attenuation tank 34m3 + green roofs 85m2 + 118m2 + 120m3	Hydrob rake .5l/s			
36	11-13 Brookwood terrace	320314.906	238250.359	SO20382204	Maria Treacy 222-xxxx	DBFL Consulting Engineers	051309500	Constructed	Greenfield	Private	Private	1107	Soakaway	Planning Requirement	soakaway:18.8m3	Hydrob rake 2l/s			

37	68	Kincora court	Single house	320661.656	235922.609	SO20356906	Maria Treacy 222-xxxx	George Morris architect	4925900	Constructed	Greenfield	Private	Private	108	Soakaway	Planning Requirement	Soakaway: 38.4 m4	Hydrob rake 2l/s				
38	62	Ballygal Rd east	4 houses	314709.656	238165.266	SO14386103	Maria Treacy 222-xxxx	Keith Carney	879837432	Constructed	Greenfield	Private	Private	600	3 Soakaways	Planning Requirement	3 Soakways: 7m3 each	Hydrob rake 2l/s				
39	51-50	O'Connell st	mixed use development	315781.175	234897.341	SO15348905	Maria Treacy 222-xxxx	Tj O'Connor & Ass	2952321	under construction	Brownfield	Private	Private	2400	Permeable paving and online attenuation	Planning Requirement	Permeable paving 710 m2 , online attenuation 25m3	Hydrob rake 2l/s				

43	18 Kilbride Killester	319309. 445	237394. 13	SO193 73301	Maria Treacy 222- xxxx	Files\20 08\414 2-08 18 Kilbride Road, Killester, Dublin 5	Eileen Cantwell M.R.I. A.I. Architects	Tel.: 01 832286 2	Constructed	Greenfield	private	private	120	permeable paving	Planning Requirement	permeable paving: 20m2	Hydrobrake 2l/s		
44	rear 18 Ardee rd	315573. 094	231967. 5	sol531 5901	mary- liz	Files\20 08\490 0-08 18 Ardee Road	Philip Brunkard &associates	459302 7	constructed	Greenfield	private	private	104	Attenuation tank	Planning Requirement	Attenuation tank:0.5 66m3	Hydrobrake 2l/s		
45	36 grave rd	315107. 531	222359. 092	SO153 21301	mary- liz	Files\20 06\108 3-06 36 Grove Road	Maloney Millar construction engineering	490302 11	constructed	Greenfield	private	private	650	Attenuation tank	Planning Requirement	Attenuation tank:10 31m3	Hydrobrake 2l/s		
46	Deanstown Green	312102. 5	238436. 3	SO123 80403	Peter Iverson	Files\20 06\192 2-06 Deanstown	Dublin City Council Housing Dept		constructed	Brownfield	public	public	2520	Permeable Paving	Planning Requirement	Permeable paving: 255m2	Hydrobrake 2l/s		

47	Sion Hill Rd	3 storey apartment block	317182.031	237549.641	SO17371509	Maria Treacy 222-xxxx	K:\Development\Planning\Files\2006\1938-06 Apts at Sion Hill Road	Ian Magahy & Associates	6746418	constructed	Brownfield	Private	Private	1023	Attenuation pipe	Planning Requirement	Attenuation pipe 10.3m3	Hydrob rake 2l/s					
48	111 Howth rd	4 house Development	318832.125	236644.703	SO18368602	Fiona Craven	K:\Development\Planning\Files\2006\2443-06 111 Howth Road Lawrence Grove Dublin 3	Ian Magahy & Associates	6746418	constructed	Greenfield	Private	Private	1650	Attenuation tank	Planning Requirement	Attenuation Tank: 18m3	Hydrob rake 2l/s					
49	18 upper Drumcondra rd	New office building	316254.5	236849	SO16362801	Fiona Craven	K:\Development\Planning\Files\2006\2491-06 18 Upper Drumcondra Road	JB Behan & Associates	2947030	constructed	Brownfield	Private	Private	110	green roof	Planning Requirement	Green roof 25m2	Hydrob rake 2l/s					

50	43 lucky lane	Single house	313789. 25	235182. 063	SO133 57108	Maria Treacy 222- xxxx	K:\Dev elopme nt Control \Planni ng Files\20 06\264 4-06 43 Lucky lane. Stonyb atter	OBA consulti ng Engine ering	860214 737	constru cted	Greenfi eld	Private	Private	125	permea ble paving	Plannin g Require ment	permea ble paving 18m2	Hydrob rake 2l/s				
51	84 Briarfe ld rd. killbarr ack Dublin 5	2 houses	322317. 2	238845. 9	SO223 82801	Fiona Craven	K:\Dev elopme nt Control \Planni ng Files\20 06\275 3-06 84 Briarfe ld Road Kilbarr ack Dublin 5 Niall Brunsw ick	EBM Buildin g Consult ants	658005	constru cted	Greenfi eld	Private	Private	735	attenuat ion tank	Plannin g Require ment	attenuat ion tank 10m3	Hydrob rake 2l/s				
52	Mellow s rd. fingals Dublin 11	Garda Station	312702	239027. 953	SO123 97004	Fiona Craven	K:\Dev elopme nt Control \Planni ng Files\20 06\291 7-06 OPW Mellow s Road Fingals Dublin 11	OPW		constru cted	Greenfi eld	public	public	3325	attenuat ion tank	Plannin g Require ment	attenuat ion tank 100m3	Hydrob rake 2l/s				

53	Grange park drive	single house	322028.563	239034.813	SO22390002	Fiona Craven	K:\Development\Planning\Files\2006\3464-0614Grange Park Drive, Raheny, Dublin 5	Martin Brennan Architects	868076431	constructed	Greenfield	Private	Private	196	Soakaway	Planning Requirement	soakaway: 2.4m3	Hydrob rake 2l/s				
54	2a Donaghmede Drive	single house	322631.594	239688.813	SO22396601	Fiona Craven	K:\Development\Planning\Files\2006\3995-062aDonaghmede Drive, Raheny, Dublin 13	Monahan & associates	8462535	constructed	Greenfield	Private	Private	224	Soakaway	Planning Requirement	soakaway: 2.4m4	Hydrob rake 2l/s				
55	55 Rosegle n Rd	2 houses	322442.592	238710.139	SO22384604	Maria Treacy 222-xxxx	K:\Development\Planning\Files\2006\4287-0655a & 55b Rosegle n Road	Lohan & Donnelly	8787770	constructed	Greenfield	Private	Private	430	Permeable Paving	Planning Requirement	Permeable paving: 91.7m2	Hydrob rake 2l/s				

56	Collin Av Ext	Single house	315726. 384	238903. 593	SO153 87801	Fiona Craven	K:\Dev elopme nt Control \Planni ng Files\20 06\436 3-06 Rear 651 Collins Avenue Extensi on	PH McCart hy Consult ants	291480	constru cted	Greenfi eld	Private	Private	288	Permea ble Paving	Plannin g Require ment	Permea ble paving: 40m2	Hydrob rake 2l/s				
57	45 oak rd Donnyc armey d9	Single house	318379. 676	237544. 501	SO183 73505	Maria Treacy 222- xxxx	K:\Dev elopme nt Control \Planni ng Files\20 06\462 0-06 45 Oak Road Donnyc armey Dublin 9	Barrot Mahon ey	677320 0	constru cted	Greenfi eld	Private	Private	210	Permea ble Paving	Plannin g Require ment	Permea ble paving: 38m2	Hydrob rake 2l/s				
58	6 kincora Av.	Single house	319286. 188	236301	SO193 62202	Fiona Craven	K:\Dev elopme nt Control \Planni ng Files\20 06\474 9-06 adj 6 Kincora Avenue	Eileen Cantwe ll M.R.I. A.I Archite cts	832286 2	constru cted	Greenfi eld	Private	Private	420	soakaw ay	Plannin g Require ment	soakaw ay: N/A	Hydrob rake 2l/s				
59	48 Fleet St	Comme rcial/Re sidentia l develop ment	313885. 022	234207. 849	SO153 48204	Mary- Liz	K:\Dev elopme nt Control \Planni ng	Casey O'Rour ke and Associa tes	661110 0	constru cted	Brownf ield	Private	Private	350	attenuat ion tank	Plannin g Require ment	attenuat ion tank: 6m3	Hydrob rake 2l/s				

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63	23 Barry rd finglas	apartme nt block	312344. 563	239534. 422	SO123 93502	Maria Treacy 222- xxxx	K:\Dev elopme nt Control Planni ng Files\20 06\528 1-06 23 Barry Road. Finglas, Dublin 11	Edmon d J Desmo & associat es	890018 6	constru cted	Brownf ield	Private	Private	441	Permea ble Paving an soakaw ay	Plannin g Require ment	permea ble paving 30m2. soakaw ay 12m2	Hydrob rake 2l/s				
64	Fr Scully house, Gardine r st	Housin g block	316024. 789	235240. 243	SO153 59202	Maria Treacy 222- xxxx	K:\Dev elopme nt Control Planni ng Files\20 06\549 5-06 Fr. Scully House	Michae l Punch & Partner s/ DCC housing	235298 0	constru cted	Brownf ield	public	public	2240	attenuat ion tank	Plannin g Require ment	attenuat ion tank:12 0m3	Hydrob rake 2l/s				
65	Sean Treacy House, Buckin gham St	Housin g block	316540. 747	235361. 726	SO163 56310	Maria Treacy 222- xxxx	K:\Dev elopme nt Control Planni ng Files\20 06\549 6-06 Sean Treacy House, Buckin gham Street	Moylan 's Consult ing Engine ers/ DCC Housin g	664890 0	constru cted	Brownf ield	public	public	3584	attenuat ion tank	Plannin g Require ment	attenuat ion tank:75 m3	Hydrob rake 2l/s				
66	128 lower kimma ge rd, d6	2 houses	314186. 271	231281. 166	SO143 11201	Mary- Liz	K:\Dev elopme nt Control Planni ng Files\20 06\557	Gleeso n consulti ng Engine ers		constru cted	Greenfi eld	Private	Private	528	attenuat ion tank	Plannin g Require ment	attenuat ion tank:4.3 m3	Hydrob rake 2l/s				

[illegible]

69	beech hill drive	9 new houses	317840.313	230946.047	SO173 08902	Mary-Liz	K:\Development\Planning\Files\2006\5765-06 Beech Hill Drive\Donnybrook	hayes higgins partners hip	661232	constructed	Greenfield	Private	Private	1716	Soakaway	Planning Requirement	9 Soakways 2m3 each	Hydrob rake 2l/s		
70	Asling hotel parkgate street	Hotel redevelopment	313854.939	234428.309	SO133 48403	Maria Treacy 222-xxxx	K:\Development\Planning\Files\2006\5772-06 Aishling Hotel, Parkgate Street	behane consulting engineers	185700	constructed	Brownfield	Private	Private	3420	attenuation tank	Planning Requirement	attenuation tank: 34m3	Hydrob rake 2l/s		
71	11 Cleggan Rd	2 houses	309012.7	233833.8	SO093 30803	Mary-Liz	K:\Development\Planning\Files\2006\5957-06 11 Cleggan Road	Burroughs Consulting	2985420	constructed	Greenfield	Private	Private	495	permeable paving	Planning Requirement	permeable paving: 35m2	Hydrob rake 2l/s		
72	32 Edenmore ave Raheny	8 apartments	320694.844	239023.984	SO203 97005	Fiona Craven	K:\Development\Planning\Files\2006\6462-06 32-34A	Lohan & Donnelly	8787770	constructed	Greenfield	Private	Private	561	attenuation tank	Planning Requirement	attenuation tank: 7.56m3	Hydrob rake 2l/s		

[illegible]

76	Martins Row Chapelzod	20 apartments	309835.188	235050	SO09358002	Maria Treacy 222-xxxx	O'Connor Sutton Cronin Brian Cronin	868200	constructed	Greenfield	Private	Private	780	Attenuation pipe	Planning Requirement	Attenuation pipe : 45m3	Hydrob rake 2l/s
77	Ivy Cottage s. Howth Junction in court	12 Apartments	322621.449	239374.996	SO22396302	Fiona Craven	Malone y Millar construction engineer ring	493021	constructed	Greenfield	Private	Private	1512	Attenuation Tank	Planning Requirement	Attenuation Tank: 18m3	Hydrob rake 2l/s
78	17 Foxes lane	2 Houses	322743.969	238161.891	SO22387107	Maria Treacy 222-xxxx	Moylan's Consulting Engineers	684890	constructed	Greenfield	Private	Private	483m2	Soakaway	Planning Requirement	soakaway: 1.57 m2	Hydrob rake 2l/s

79	Merton drive	6 houses	316724	231591.5	SO163 17502	Mary-Liz	05\546 3-05 17 a & b Foxes Lane. Raheny, D5	K:\Development\Planning\Files\2005\6150-05 Merton Drive	constructed	Greenfield	Private	Private	2400	Permeable paving and attenuation tank	Planning Requirement	Permeable paving attenuation tank: 62m2	Hydrob rake 2l/s			
80	Newbrook av	1 house	322419.813	239824.578	SO223 94814	Maria Treacy 222-xxxx	05\546 3-05 17 a & b Foxes Lane. Raheny, D5	K:\Development\Planning\Files\2005\6234-05 1 Newbrook Ave, Donaghmede, Dublin 13	constructed	Greenfield	Private	Private	306	Soakaway	Planning Requirement	Soakaway: 1.5m2	Hydrob rake 2l/s			
81	Beaumont oncology building	new oncology building	318411.779	239290.559	SO183 90002	Maria Treacy 222-xxxx	05\546 3-05 17 a & b Foxes Lane. Raheny, D5	K:\Development\Planning\Files\2009\2489-09 Beaumont Hospital Oncology	construction not started	Brownfield	public	public	10000	permeable paving	Planning Requirement	permeable paving 3104m2	Hydrob rake 2l/s			

82	15a tolka cottages glasnevin	Single house	314218.503	237921.108	SO14372905	Maria Treacy 222-xxxx	Buildin g Phase 1	JFOC Architects	4530277	construction not started	Greenfield	Private	Private	780	Soakaway	Planning Requirement	Soakaway: 0.5m3	Hydrobrake 2l/s				
83	Capuchin Friary, Belmont Park, Raheny	Redevelopment and extension	321654.085	238739.536	SO21386702	Maria Treacy 222-xxxx	Buildin g Phase 5	Roughan O'Donnovan	2940800	construction not started	Brownfield	Private	Private	7000	Permeable paving and attenuation tank	Planning Requirement	Permeable paving : 200m2 Attenuation tank 94m3	Hydrobrake 2l/s				

84	25 Monast erboice Rd	Single house	313054. 969	231798. 578	SO133 10704	Maria Treacy 222- xxxx	K:\Dev elopme nt Control \Planni ng Files\20 09\587 9-09 25 Monast erboice Road, Crumli n	Liffey Archite cts	808915 4	constru ction not started	Greenfi eld	Private	Private	384	Permea ble paving and attenuat ion tank	Plannin g Require ment	Permea ble paving :38m2. Attenua tion tank 1.5m3	Hydrob rake 2l/s				
85	82a Spiddal Rd	Single house	308655. 719	233520. 656	SO083 36503	Mary- Liz	K:\Dev elopme nt Control \Planni ng Files\20 05\454 9-05 82A Spiddal Road	NMSW & Associa tes Ltd.	087219 .6707	constru cted	Greenfi eld	Private	Private	174	Soakaw ay	Plannin g Require ment	soakaw ay : 10m3	Hydrob rake 2l/s				
86	6 Burling ton rd	Mixed use Develo pment	316934. 992	232700. 225	SO163 29702	Mary- Liz	K:\Dev elopme nt Control \Planni ng Files\20 06\240 1-06 Burling ton Road Dublin 8	O'Conn or Sutton Cronin	868200 0	constru cted	Brownf ield	Private	Private	7400	attenuat ion tank	Plannin g Require ment	attenuat ion tank:20 0m3	Hydrob rake 2l/s				
87	Sandfor d Pk School Ranela gh	School	316659. 937	231672. 277	SO163 16701	Mary- Liz	K:\Dev elopme nt Control \Planni ng Files\20 06\299	DBFL Consult ing Engine ers	400400 0	constru cted	Greenfi eld	Private	Private	7728	Filter Drain and soakaw ay	Plannin g Require ment	Filter drain 26.8m3 Soakaw ay: 24m3	Hydrob rake 2l/s				

92	4-5 protestant row	5 storey apartment block	315630.282	233263	SO153 36208	Mary-Liz	07/2316-07 White Heather Industrial Estate	McKea Pierse	2897260	constructed	Brownfield	Private	Private	378	permeable paving	Planning Requirement	permeable paving: 90m2	Hydrob rake 2l/s			
93	Tolka Valley wetland	N/A	313081.069	237710.281	SO133 70503	John Collins	N/a	DCC Parks, DCC Drainage Division		constructed	Greenfield	public	public	50000	Wetland	Pollution Prevention	Wetland 1000m3	n/a	See case study 2	See case study 2	Case study 2
94	Glendhu Park	N/A	311698.236	237361.672	SO113 78401	Gerry O'Connell	N/a			under construction	Greenfield	public	public	187000	2 No. Swale	Flood prevention	2 No Swales 2482m3	n/a		Case Study 1	
95	York st	sixty-six social housing units	315688.6	233470.1	SO153 37402			DCC Housing		constructed	Brownfield	public	public	2130	Green roof and rainwater harvester tanks	Planning Requirement	Green roof 1200m2 and rainwater harvester tanks 14*3.6	Hydrob rake 2l/s			Case study 3

APPENDIX B:

Met Eireann Rainfall Frequency Tables

Return Period Rainfall Depths for sliding Durations
Easting: 315000 Northing: 234000
Average Annual Rainfall(1961-1990) for Dublin City Centre: 676mm

Average Recurrence Interval		Return Period															
		Years															
DURATION	6months	1year	2	3	4	5	10	20	30	50	75	100	150	200	250	500	
5 mins	2.4	3.5	4.1	5.0	5.6	6.1	7.7	9.5	10.7	12.4	13.9	15.1	16.9	18.4	19.6	N/A	
10 mins	3.4	4.9	5.7	7.0	7.8	8.5	10.7	13.2	14.8	17.2	19.4	21.0	23.6	25.6	27.3	N/A	
15 mins	4.0	5.8	6.7	8.2	9.2	10.0	12.5	15.5	17.5	20.3	22.8	24.7	27.8	30.1	32.1	N/A	
30 mins	5.3	7.5	8.7	10.6	11.8	12.7	15.9	19.5	21.9	25.2	28.2	30.6	34.2	37.0	39.3	N/A	
1 hours	7.0	9.8	11.3	13.6	15.1	16.3	20.2	24.5	27.4	31.4	35.0	37.8	42.1	45.4	48.1	N/A	
2 hours	9.3	12.8	14.7	17.5	19.4	20.8	25.5	30.8	34.3	39.1	43.4	46.7	51.8	55.7	58.9	N/A	
3 hours	10.9	15.0	17.1	20.3	22.4	24.0	29.3	35.3	39.1	44.5	49.2	52.9	58.5	62.8	66.3	N/A	
4 hours	12.2	16.7	19.1	22.5	24.8	26.6	32.4	38.8	42.9	48.7	53.8	57.8	63.8	68.4	72.2	N/A	
6 hours	14.4	19.5	22.2	26.1	28.7	30.7	37.2	44.3	49.0	55.4	61.1	65.4	72.0	77.1	81.2	N/A	
9 hours	17.0	22.8	25.8	30.3	33.2	35.5	42.7	50.7	55.9	63.0	69.3	74.0	81.3	86.9	91.5	N/A	
12 hours	19.0	25.4	28.8	33.6	36.8	39.3	47.1	55.8	61.3	69.0	75.7	80.8	88.6	94.6	99.5	N/A	
18 hours	22.4	29.7	33.5	39.0	42.6	45.4	54.2	63.8	70.0	78.5	85.9	91.5	100.1	106.6	112.0	N/A	
24 hours	25.2	33.2	37.3	43.3	47.2	50.2	59.8	70.2	76.8	86.0	93.9	100.0	109.1	116.1	121.8	141.4	
2 days	30.8	39.8	44.4	51.0	55.3	58.6	68.9	79.9	87.0	96.6	104.9	111.1	120.6	127.8	133.6	153.5	
3 days	35.4	45.2	50.2	57.3	61.9	65.4	76.3	88.0	95.4	105.5	114.1	120.6	130.4	137.8	143.8	164.3	
4 days	39.4	49.9	55.2	62.7	67.6	71.3	82.8	95.1	102.8	113.3	122.2	129.0	139.1	146.7	152.9	173.9	
6 days	46.3	58.1	63.9	72.2	77.6	81.6	94.1	107.3	115.6	126.8	136.4	143.5	154.2	162.3	168.8	190.8	
8 days	52.5	65.3	71.6	80.5	86.3	90.6	104.0	118.0	126.8	138.6	148.7	156.2	167.5	175.9	182.7	205.6	
10 days	58.1	71.8	78.6	88.1	94.2	98.8	112.9	127.7	136.9	149.3	159.8	167.7	179.4	188.2	195.2	219.0	
12 days	63.3	77.9	85.0	95.1	101.5	106.3	121.1	136.6	146.3	159.2	170.1	178.2	190.4	199.5	206.8	231.3	
16 days	73.0	89.1	96.9	107.9	114.9	120.1	136.2	152.9	163.3	177.1	188.8	197.5	210.4	220.0	227.8	253.7	
20 days	81.9	99.4	107.8	119.6	127.2	132.8	149.9	167.7	178.7	193.4	205.7	214.9	228.5	238.6	246.8	274.0	
25 days	92.3	111.3	120.5	133.3	141.3	147.4	165.8	184.8	196.5	212.1	225.2	234.9	249.3	260.0	268.6	297.1	

NOTES:
N/A Data not available
These values are derived from a Depth Duration Frequency (DDF) Model
For frequencies less than two years Average Recurrence Intervals(ARI) are used
For details refer to:
'Fitzgerald D. L. (2007) Estimates Technical Met Eireann Dublin'
Available for download at www.met.ie/climate/dataproducts/Estimation-of-Point-Rainfall-Frequencies_TN61.pdf