Cost and energy implications of leakage in water distribution networks in County Galway

COST AND ENERGY IMPLICATIONS OF LEAKAGE IN WATER DISTRIBUTION NETWORKS IN COUNTY GALWAY

by

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GLOSSARY AND ABBREVIATIONS

ASE - Alliance to Save Energy	HRWC - Halifax Regional Water Commission
AWWA - American Water Works Association	IFC - International Finance Corporation
BEE - Bureau of Energy Efficiency	ILI - Infrastructure Leakage Index
CARL - Current Annual Real Losses (m^3/year)	IWA - International Water Association
CO_{2eq} - Carbon Dioxide Equivalent (kg)	NDP - National Development Plan
C_L - Cost associated to W_L (€)	L_m - Total length of main (m)
C_{LP} - Cost associated to W_{LP} (€)	MU - Million Units
CSF - Community Support Framework	N_c - Total number of connections
CSO - Central Statistics Office	NFGWS - National Federation of Group Water Schemes
C_{AV} - Annual variable costs to abstract, treat and deliver water (€/year)	NRW - Non Revenue Water. It is the difference between the volumes of water delivered into a network and billed authorized consumption.
C_{chem} - Chemicals costs (€)	η_m - motor efficiency
C_V - Variable cost of water production (€/m^3)	η_p - pump efficiency
C_{uv} - UV energy cost (€)	OFWAT - Office of Water Services
DBO - Design Build Operate	OJEC - Official Journal of the European Communities
DEFRA - Department for Environment, Food and Rural Affairs	P_h - Pump hydraulic power (kW)
DOEHLG - Department of Environment, Heritage and Local Government	P_o - Pump overall power (kW)
DMA - District Metered Area	P_{uv} - UV power (kW)
EA - Environment Agency	ρ - Density (kg/m^3)
EC - European Council	q - Flow (m^3/h)
ELL - Economic Level of Leakage	Q_P - Water produced during the year (m^3)
E_L - Energy associated to W_L (kW)	R - Electricity Rate (€/kWh)
E_{LP} - Energy associated to W_{LP} (kW)	SCADA - Supervisory Control And Data Acquisition
E_{pumps} - Pumping electricity cost (€)	SHTEFIE - Social; Health and Hygiene; Technical; Economic; Financial; Institutional; Environmental
ESB - Electricity Supply Board	TSSL - Treatment Systems Services Ltd

E_V - Variable energy per m^3 of water (kW/m^3)	UARL - Unavoidable Annual Real Losses (m^3/year)
E_{AV} - Annual variable Energy used to abstract, treat and deliver water (kW/year)	U_a - Unbilled authorised consumption is water which is accounted for but no revenue is collected. (m^3/year)
FAEC - Fitzpatrick Associates Economic Consultants	UFW - Unaccounted for Water is difference between "net production" (Total input) and "consumption" (the volume of water that can be accounted for by legitimate consumption, whether metered or not).
g - Gravity (9.81 m/s^2)	UK - United Kingdom
GCC - Galway City Council	UV - Ultra Violet
GIS - Geographic Information Systems	WHO - World Health Organisation
GHG - Greenhouse Gas	W_L - Water loss determined by the Water Balance Methods described in Section 3.6 (m^3/year)
GWS - Group Water Scheme	WLS - Weighted Least Square
h - Total Head of the System (m)	W_{LP} - Potential reduction in water loss determined using methods described in Section 3.6.5 (m^3/year)
HDPE - High Density Poly Ethylene	WSP - Water Service Provider
H_p - Pump total hours run	WSNTG - Water Services National Training Group
HSE - Health Service Executive	WSS - Water Supply Scheme
H_{uv} - Hours Run of the UV unit	WTP - Water Treatment Plant

CONVERSION FACTOR

1 Imperial gallon = 4.546 litres

1 pound per square inch (Psi) = 0.0689 bars

1 Horse Power = 0.75 kW

EXCHANGE RATE

€1 = 1.32054 USD (XE, 2010)

ABSTRACT

Leakage in Water Supply Schemes (WSS) is a major problem in Ireland. Cost and energy associated with leakage is becoming more and more apparent as higher levels of treatment are required to ensure that increasingly stringent drinking water quality standards are met.

Many solutions have recently emerged to tackle the growing leakage problem in large WSS around the world but small to medium size WSS as commonly found in Ireland have received little consideration.

The severity of the problem in three WSS in County Galway has been exposed by associating the potential energy and cost savings that can be achieved if leakage was reduced to an acceptable level. Potential measures and a model have been proposed which can be further developed to enhance decision making while preparing leakage management strategies in WSS in County Galway and elsewhere.

Key Words

Unaccounted For Water, Non Revenue Water, Current Annual Real Loss, Infrastructure Leakage Index and CO_{2eq}

CHAPTER 1 EXECUTIVE SUMMARY

1.1 Background

'Unaccounted for Water' (UFW) is a growing concern worldwide as well as in Ireland. UFW includes leakage from water supply system, under reading of water meters, water loss through overflow at service reservoirs, theft, etc. UFW figures vary from as low as 6% to as high as 62% of the net water production (Water and Wastewater Utilities, 1996:11) in countries around the world and in Ireland this figure is estimated by DOEHLG (2010) to vary from 16.8% to 58.6% in different regions of the country. As UFW is alarmingly high in some regions, the Government of Ireland is planning capital investment of around €300 million for the coming three years to reduce water losses in water distribution networks that will allow local authorities to better manage the distribution network and encourage users to reduce water usage and wastage. The proposed measures of the government are summarised below (DOEHLG, 2010).

- Monitor water usage and losses throughout water supply networks, fix leaks and replace defective pipes where repair is no longer an economic option
- Install water meters to 1.1 million homes connected to the public water supply across. Charge households for water services based on usage after installation of meters.

Both measures are expected to have positive impact on reducing water loss and hence lower down the actual UFW. The first measure will help to reduce water loss in distribution networks by providing additional financial support to local authorities allowing them to either fix more leaks or where necessary replace pipes in distribution networks which are no longer economically viable to repair. The second measure would help customers to reduce wastage and improve conservation on their side.

The policy of the government does appear to be heading in the right direction yet the approach to control leakage in water distribution networks varies widely across the country. This depends mostly on the existing knowledge and resources available to local authorities who may still be carrying out repairs in water distribution networks after failures have occurred or have been reported to them. This method of dealing with leakage has been considered as 'reactive maintenance' or the 'ambulance method', Hadzilacos et al. (2000:217).

1.2 Rationale of the Study

UFW throughout Ireland and particularly in County Galway is at an alarmingly high level (Over 50% in many water supply schemes). The figure is very high as compared to the AWWA Leak detection and Accountability Committee (1996) recommendation of 10% as a benchmark for UFW (Sharma, 2008:7). The Government of Ireland are aware of this dramatic situation and are prepared to invest in water network management to reduce UFW to a reasonable level.

The financial support and resources available to WSPs are limited and need to be used wisely to ensure that the maximum benefit is realised. This can only be achieved by implementing leakage control strategies which are based on sufficient knowledge on the level of water losses and the potential cost and energy savings that can be achieved. Cost and energy savings accrued from leakage reduction are thought to be the main driver that can help WSP to take the right leakage control decision in small to medium size WSS.

It is therefore essential to consider the potential energy and costs savings from individual WSS while preparing a leakage management strategy throughout the county. These factors can also help to justify decision and budget made available to reduce leakage in a particular WSS.

1.3 Aim and Objectives

The aim of this study is to determine cost and energy associated with leakage in small to medium size WSS in County Galway. The following WSS were selected for the study.

* Galway City
* Ardrahan
* Caherlistrane/Kilcoona

Objectives of the study are as follows.

- Determine variable energy and costs associated with water abstraction, treatment and distribution.
- Carry out a top down water audit in these WSS to estimate UFW, NRW, ILI, etc.
- Determine the total volume of water loss including leakage and the potential reduction in water loss in the three WSS.
- Estimate the equivalent CO_2 which can potentially be reduced by reducing energy use as a result of water loss reduction.
- Demonstrate the importance of considering factors such as energy and cost savings while implementing a leakage management strategy.

1.4 Methodology

The following summarises the method used during the study.

- Primary data for a period of one year (January to December 2009) was collected from Water Service Providers, operators of WTPs, websites, journals, published and unpublished reports, internet, etc. Different methods including semi structured interview, email and telephone conversation, etc. were used during data collection.

- The following secondary data was determined using the primary data.
  - * Cost and energy required to abstract, treat and distribute water
  - * Leakage level and potential reduction in water loss including leakage
  - * Energy and costs associated with total water loss and the potential reduction if water loss is reduced to an acceptable level.
  - * CO_{2eq} associated with the energy involved was also established.
- The data was analysed, the severity of the problem was discussed and a conclusion including some recommendations based on results obtained are provided.

1.5 Summary of Results

The study met the aim and objectives. The results obtained are notable. A significant volume of real loss was found in the three WSS particularly in Galway City.

In Galway City WSS, the volume of water loss was found to be over 7 million cubic metre in 2009 with potential reduction of about 6 million cubic metre achievable if water loss was to an acceptable level. Two water balance methods were used and both methods this high water loss. The potential water reductions in Galway City represents approximately 3 million kWh of energy and variable cost of over €600,000 (Figures quoted are projected based on the assumption that all Water to Galway City is supplied by Terryland WTP). Nearly 2,000 tons of indirect CO_{2eq} emission to the atmosphere could have been reduced due to reduction in electricity use only. Indirect CO_{2eq} emission due to chemical use was not quantified in the study. Considering that an average dwelling uses approximately 5,000 kWh of electricity and emits approximately 10 tons of CO_{2eq} annually (energy related emission including electricity), Howley and Ó Gallachóir (2005:54&56), the total potential energy saving in Galway City WSS is equivalent to the electricity usage by approximately 600 dwellings and the associated CO_{2eq} is equivalent to the emissions from 200 dwellings.

The total real loss in Ardrahan WSS in 2009 was found to be over 8,000 cubic metre with savings of about 7,000 cubic metre achievable if leakage was to an acceptable level. The potential water loss reduction in Ardrahan represents approximately 5,000 kWh of energy and variable cost of over €700. Over 3 tons of indirect CO_{2eq} emission to the atmosphere could have been reduced due to electricity use only.

The real loss in Caherlistrane/Kilcoona WSS was found to be over 17,000 cubic metre and the leakage level was found to be at an acceptable level. Energy and costs associated with the total real loss was estimated to be over 5,000 kWh and over €1,000 respectively. The total energy due to the real loss represents over 3,000 tons of indirect CO_{2eq} emission to the atmosphere.

The study also found that although Galway City WSS is relatively larger, energy and cost required to abstract, treat and distribute water in that scheme was highest which confirm cost and energy is not only dependent on the volume of water involved in a WSS but also on factors such as quality of raw water, the topography between the water source and its destination, distance from the bulk water supply, and the integrity distribution networks, etc.

Conclusions, recommendations and suggestions on further works are also provided in this report based on the results.

1.6 Outline of the Report

The report consists of six chapters including the Executive Summary.

Chapter 2 consists of literature review and identification of the information gaps.

Chapter 3 provides a detail methodology including description of the methods used to collect data, sources of data used, limitations of data collection, reliability and accuracy of the data collected, etc.

Chapter 4 provides a description of the study areas and provides a summary of all primary data collected.

Chapter 5 provides a summary of secondary data derived using the primary data collected and focuses on detailed analysis followed by constructive discussions.

Chapter 6 provides conclusions of the study and recommendations including suggestions on future works in this field.

The report contains a list of appendices which include Plant Layouts, Maps, detail workings to derive the secondary data and results of the two water balance methods used.

CHAPTER 2 LITERATURE REVIEW AND INFORMATION GAP

2.1 Introduction

It is widely recognised that water is a precious commodity that needs to be managed in an integrated manner. 'We rely on it to drink and keep us clean; we do not always have enough of it; and the water environment is a source of pleasure and a necessary support for the whole of our ecology', (DEFRA, 2002:2). Water has also been described as the new oil or the 'petroleum for the next century' (Cooper, 2008) and it is believed that carbon will be its currency, Caffoor (2010:9). As far as possible we need to make sensible use of water and try to conserve it. Conservation of water does not only help to preserve our natural water resources but also helps us to use less energy, chemicals and hence to the cost associated in treating a large volume of water; a large proportion of which is often lost through leakage in distribution networks and through wasteful use of it.

Water is generally obtained by the natural water cycle and raw water which becomes available either as surface water or ground water needs several energy intensive processes such as collection, treatment and distribution to ensure a safe supply that complies with all legislative requirements. Enough good quality water is important in ensuring health. As our understanding of water and its effect to health is increasing, organisations such as the European Council (EC) and the World Health Organisation (WHO) are continuously revising the drinking water quality standard to higher levels. Against a backdrop of increasing water demand, deteriorating raw water quality and more stringent drinking water standards (OJEC, 1998 and WHO, 2008) it is quite evident that energy and the cost of producing a cubic metre of water is on the rise, (Sturm and Thornton, 2007; Ragot and Maquin, 2006:887).

Earlier works in the field (Morais and Almeida, 2007:442, Ulanicki et al., 2000:105, Burrows et al., 2000:83-95) have acknowledged that water lost from water supply schemes is one of the key problem issues faced by both the developing and developed countries throughout the world. It is also recognised that water loss through leakage represent a significant proportion of the total losses (Morais and Almeida, 2007:458) and this could be either in the distribution side or in the consumer side, (Sturm and Thornton, 2007).

2.2 Water and Energy

The fundamental relationship between water and energy is not widely understood. The water-energy relationship is based on the reality that treating water for human consumption and moving treated water to households is extremely energy intensive. The relative energy importance in each stages starting from abstraction to final delivery of water depends on factors like the topography between the water source and its destination, distance from the bulk water supply, and the integrity of the primary mains (supply pipes) and secondary mains (distribution pipes). It is acknowledged that energy is among the top three cost items to water service providers, often coming second after labour costs, Watergy (2007:2). In India for example, it is found that water works consume more than 12,000 MUs as compared to Public lighting which consumes 5,000 MUs of electricity. Energy audits in India have also found that energy costs account for 40% to 60% of the operating expense of supplying water (IFC et al. 2008:3). In developing countries, energy is thought to be the highest cost associated to water supply, Watergy (2007:2) but data to substantiate this thought was not available. For example, in Ireland energy and costs associated with the water supply sector are still unknown.

2.3 Water and Green House Gases (GHG)

There is no direct GHG emission during water abstraction, treatment and distribution, but there is indirect emission of CO_2 mainly from production of Electricity and Chemicals which are used during these processes, Frijns (2009:5). So the more water that is supplied, the more energy and chemicals are used and the more GHGs are emitted to the atmosphere. As part of the overall carbon reduction targets, it is believed that the water sector also has a role to play. For example, the UK water industry emitted five million tonnes of GHGs in 2007/2008 (EA, n.d).

In Ireland, CO_{2eq} is estimated for sectors such as electricity generation; industry; transport; residential; and commercial and public services, (Howley and Ó Gallachóir, 2005). However, CO_{2eq} emission by the water sector is still unknown.

2.4 Non Revenue Water and Unaccounted For Water

Non Revenue Water (NRW) and Unaccounted For Water (UFW) are two terms widely used to describe water losses in water distribution networks. UFW includes mainly leakage from water supply schemes as well as under reading of water meters, water loss through overflow at service reservoirs, theft, etc.

'Non revenue water' (NRW) is water that has been produced and is "lost" before it reaches the customer. Losses can be real losses (through leaks, sometimes also referred to as physical losses) or apparent losses (for example through theft or metering inaccuracies). High levels of NRW are detrimental to the financial viability of water utilities and to the quality of water itself. NRW is typically measured as the volume of water "lost" as a share of net water produced.

Definition of UFW and NRW and their interrelationship as commonly used is summarised in Table 2.1.

UFW	UFW is the difference between the volume of water delivered into a network and the volume of water that can be accounted for by legitimate consumption UFW = “net production” – “legitimate consumption”
NRW	NRW is the difference between the volumes of water delivered into a network and billed consumption. NRW = “Net production” – “Revenue water” = UFW + water which is accounted for, but no revenue is collected (i.e. unbilled authorized consumption)

Table 2.1 Unaccounted-For-Water vs. Non-Revenue Water

Sources Kayaga (n.d.:2) and Sharma (2008:3-4)

The term UFW is used in many countries including Ireland. As discussed in AWWA (2010a) the term UFW has varying definitions. For example, some definitions allow a certain volume of leakage – deemed "unavoidable" leakage – to be included as "accounted for water”. Similarly, utility personnel have sometimes classified leaks that are known to exist in inaccessible locations (such as pipelines under streams or rivers) as "accounted-for water”.

Although it is not recommended by AWWA, the term UFW has been used in this study as this is a widely used term in Ireland. However, to be consistent, only one definition is used in this study for UFW as provided in Table 2.1. All unavoidable leakages or leakages which are located under streams or rivers are considered as real losses similar to the AWWA water audit method.

2.5 Strategies to reduce water use and wastage by water users

Water loss through leakage from pipeworks in the consumer side is often categorised as water wastage and are generally the responsibility of the user to fix it. As shown by Van der Walt (2009), consumer side leakage could also be considerable and therefore the government needs to come up with policies to encourage water users conserve this precious commodity. Installation of water meters and charging users by volume consumed are generally the most common method.

In Ireland domestic customers supplied by the public WSS are generally not metered and domestic water charges were abandoned since 1997 (Citizen Information, 2010). Domestic customers from Private or Part Private Group Water Schemes are allowed a free allocation of water and have to pay a flat water rate above this free allocation. All non domestic customers are generally charged for water they use at a flat rate. To achieve the Government objective to re-introduce water charges above a free allocation as a measure to reduce water use and wastage, domestic customers supplied by the public WSS would have to be metered.

Policies can also target manufacturers of household appliances which are major water users. Some of these appliances are water closets, bath, washing machines, etc. Improving the design of these appliances can help to reduce water usage while maintaining the same level of service to users, Jones et al. (1987). New policies can be developed or existing policies strengthened to encourage manufacturer to improve design of such household appliances. This can help to reduce water use and enhance water conservation on the consumer side.

2.6 Type of Leakages and Factor affecting them

Leakage is one of the major contributors to water losses from water distribution networks. It occurs in either the water service provider's communication (or distribution) pipeworks or the customer's supply pipe. The point of delivery (usually the customer's roadside stop tap) splits the service pipe into the water service provider's communication pipe and the customer's supply pipe. Distribution leakage is generally considered as that which occurs on the length of pipe between the point of delivery and the first point of use inside the customer's building. Losses in the customer's supply pipe are considered as water delivered and are often regarded separately to distribution losses. Customer's supply pipe losses do actually contribute to high volume of water leakages.

As noted by Skipworth et al. (1999:184-188), there are many factors which affect leakage levels in a distribution network and these factors have been identified in Table 2.2.

Type of Leakage	Factors affecting leakage
Water Service Provider's Side	Network Characteristics Pressure of System Age of System and Type of Mains Length of Mains' Network Climate Type of ground Traffic and Loading Density of Connections
Customer's Side	Supply Pipe Leakage

Table 2.2 Type of leakage and factors affecting them

2.7 Leakage control strategies and methods to minimise energy use

Several leakage reduction methods have recently been researched in an attempt to reduce the growing problem of water loss through leaking pipes on the distribution side. This has led to the emergence of several models and leakage reduction techniques which can be used to detect faults or abnormal system operations; manage leakage; or manage energy use in water supply networks. Some of these methods recently developed are the FINESSE software, fuzzy residual analysis approach, PROMETHEE V method, UtilNets Software, EPANet modelling software, etc.

FINESSE computer-aided water network engineering software can be used to manage the energy use in a large-scale network (Bounds et al., 2006:209-220). By using this software it was possible to achieve a 14% saving in electrical energy in a large scale network while satisfying operating constraints using a set of mixed integer optimal schedules. UtilNets is another software that uses input data such as the year the pipe was installed, its wall thickness, its diameter, the working pressure, surge pressure (if any), corrosion rate of the pipe, etc to perform analysis of pipes by means of several modules and help decision making on pipe rehabilitation or replacement strategies, Hadzilacos et al. (2000:220-227). It also provides optimisation options by providing capital costs for water main rehabilitation; by setting priority of water main rehabilitation, etc. The method can help local authorities in very large cities to develop strategies for water main rehabilitation or replacement. Marunga et al. (2006) described the use of EPANet modelling software to manage pressure in a distribution network which allows leakage reduction to an optimum level without affecting the level of service.

Methods such as the District Metered Area (DMA) which is a network modelling method has also been used in many countries as a means to continuously monitor water flow and detect any abnormal water usage. As described by Burrows et al. (2000:83-95) water companies in the UK use this method to routinely monitor flow and pressure for active leakage management. The method consists of designating District Metered Areas (DMAs) which constitute of 1000-5000 properties and using the geographic information systems (GIS) for routine monitoring of flow and pressure in each DMA. The method was mostly promoted as a measure required by Office of Water Services (OFWAT) to prevent customers suffering from lower level-of service which are categorized as DG1 - 'population at risk of water shortage', DG2 - 'properties at risk of low pressure' and DG3 - 'properties subjected to unplanned supply interruptions of 12 hours or more'.

Morais and Almeida (2007:441-459) have described the PROMETHEE V method which uses a group decision-making model to develop a leakage management strategy. The method takes into account the points of view of four stakeholders, selects feasible options and considers the available budget as a constraint. The strategy uses a combination of options that is considered to efficiently meet technical, socio-economic and environmental criteria to achieve sustainable development. The authors argue that the model has the potential to positively help in the development of leakage management strategy and they think that leakage management strategies can be specific to each water company which will change with time as unit costs of water and active leakage control method changes when new techniques become available. They seem to be quite reasonable in their argument that their method is more transparent as it considers opinions of each member involved in the decision process more than when it is analyzed in a closed way without society participation.

Other proactive approaches have recently emerged to assess the structural condition of pipes. As described in Saegrov et al. (1999:16), these approaches use the electromagnetic inspection technique or ultrasonic tools for the assessment and they provide information on wall thinning that allows decision makers to become aware of pipes which need replacement.

2.8 Leak detection methods

While strategies to manage leakage are important, methods for detecting them are equally important. Development in leak detection methods are essential to minimise the expenses in excavation and other works associated with locating leakage by the trial and error method. The primary tool developed to locate leaks in distribution networks is the acoustic leak detection method, Saegrov et al. (1999:16). This method relies on detecting leaks by the characteristic sounds they make as the water leaves the pipeline. The more sophisticated leak detection tools can locate leaks by automatically correlating the time of arrival of the sounds to two different locations on the pipe. The technique is commonly used for small diameter metallic pipes. While it is known that these systems have a high degree of success in finding leaks in pipes, no studies appear to have been made to indicate the number of false positives and false negatives created during a network wide campaign of leak detection.

Several other leak detection methods in water distribution networks have recently emerged. The Bayesian system identification methodology uses information from flow test data to provide estimates of the most probable leakage events (magnitude and location of leakage) as well as the uncertainties in such estimates, Poulakis et al. (2003: 315–327). Andersen and Powell (2000) have described how the method of weighted least squares (WLS) in conjunction with the Lagrangian approach can be used to detect leaks. Another method more recently developed consists of supervision software which is based on the fuzzy fault isolation method (Ragot and Maquin, 2006:887-902). As detailed by the author, the approach uses the analytical redundancy to detect and isolate faults on sensors.

2.9 Economic level of leakage

The level of losses from water distribution systems is often considered to be unacceptable. However, any water service provider has to work within current operating budgets and seek additional finance if these are not sufficient. Leakage control is expensive, and the aim of water service providers is to achieve an economic balance between the costs of leakage control and the benefits that accrue from it. The concept of an economic level of leakage (ELL) dates back several decades, and there have been many previous attempts to determine a practical definition and methodology. As described in Pearson and Trow (2005:1), ELL is based on the knowledge that each and every activity aimed at reducing leakage follows a law of diminishing returns; the greater the level of resources employed, the lower the additional marginal benefit which results. In the UK due to substantial investments and achievements in the past 15 years, ELL is better understood as compared to other countries such as Ireland where there are no economic incentives to water service providers or resources available to them are limited. These could be the main reasons which limit proactive leakage control measures in Ireland. Assessment of the ELL in Ireland is yet to be carried out.

2.10 Water Audits

Leakage detections and controls are usually referred as the ‘bottom up’ approach used to reduce leakage in water distribution networks. These activities involve investment in specialised models and equipment, but their projected costs can objectively be weighed against the inherent costs of water losses as determined by a top-down water audit method (Mathis et al., 2008:3-4). The water audit (also referred to as water balance) is used to systematically determine where losses occur in a water supply scheme and evaluate such losses. An internal top-down water audit approach is largely a desktop exercise gathering data and information from water consumption and loss reports already compiled by local authorities. Hence the method can be used to produce sufficient data which can help to determine the best leakage management strategy involving bottom-up activities. These are usually longer in nature and can be implemented incrementally over periods of months or years.

Recent works carried out in this field (Morais and Almeida, 2007:443; Farley et al., 2008: Chapter 2; Sturm and Thornton, 2007; Mathis et al., 2008:2) illustrates the application of water audit method to define different kinds of losses that are associated with water delivery. Water auditing measures efficiency, encourages water accountability, quantifies water losses, and standardizes water loss reporting. As stated by MacKenzie and Seago (2005) and quoted by Morais and Almeida (2007:443), ‘a clearly defined water balance is the first essential step in the assessment of volume of Non Revenue Water and the management of water distribution systems.’

Farley et al (2008:9-10) has explained the structure and terminology of the standard international water balance developed by the International Water Association (IWA) and which has been adopted by national associations in many countries across the world. Other methods of carrying out a water audit may be used in some countries. In Ireland for example, a standard water audit based on UFW developed by the Department of Environment, Heritage and Local Government, Frank (2010a), is commonly used.

As indicated by Liemberger (2006) and quoted in Kölbl et al. (n.d:179), the IWA water balance is used in many countries all over the world e.g. Australia, Germany, Canada, New Zealand, South Africa and by the American Water Works Association. Study carried out by Halifax Regional Water Commission (HRWC - Water service provider representing 4 municipalities in Canada) shows that the use of IWA methodology has reduced leakage in the distribution system by 27 million litres/day which represented an annual savings of $500,000 (Yates, 2005:1). Reduction in leakage also helped to reduce the plant output considerably and hence the cost of treating water. This was considered a major achievement by HRWC.

2.10.1 Acceptable Level of UFW

Acceptable level of water loss is a compromise between the cost of reducing water loss and maintenance of distribution system and the cost (of water) saved. The AWWA Leak detection and Accountability Committee (1996) recommended 10% as a benchmark for UFW. Table 2.3 provides the levels for UFW and actions needed.

UFW level	Action
< 10%	Acceptable, monitoring and control
10-25%	Intermediate, could be reduced
> 25%	Matter of concern, reduction needed

Table 2.3 UFW level and action required

Sources Kayaga (n.d.:8) and Sharma (2008:7)

2.10.2 Acceptable level of NRW

The following Index and bands have been set up by international organisations (Sharma, 2010:8 -19) which are used as benchmarks for the IWA water balance method.

- Infrastructure Leakage Index (ILI)
- World Bank Institute Banding System to interpret ILI

2.10.2.1 Infrastructure Leakage Index (ILI)

The Infrastructure Leakage Index (ILI) is an indicator which describes the quality of infrastructure management. It is the ratio of Current Annual Real Losses to Unavoidable Annual Real Losses.

$$ILI = CARL / UARL$$

Where UARL is an Unavoidable Annual Real Losses which can be estimated using equations as provided in Sharma (2010:10-11) and CARL is the Current Annual Real Losses which can be determined using the IWA Water Audit method.

McKenzie and Seago (2005:38-39) reports median and mean ILI results for water distribution systems in some countries are provided in Table 2.4.

No. of WSS	Country/ Countries	Median ILI	Mean ILI
20	England and Wales	2.44	2.58
20	USA and Canada	4.27	4.90
20	Australia	2.33	2.99
27	South Africa	4.97	6.26

Table 2.4 Mean and Median ILI results in Different Countries

Recent study by Winarni (2009:134) concludes that ILI results are ideal indicator for making international comparison and provides an improved basis for technical comparisons of leakage management performance. He also demonstrated that there is no correlation between ILI and NRW as percentage of system input volume is not necessarily an indication for good real losses management.

Due care is needed while interpreting ILI results and NRW as a percentage of system input volume for a particular water distribution network.

2.10.2.2 World Bank Institute Banding System

The World Bank Institute Banding System classifies ILI into Bands A to D and set different limits for developed & developing countries as illustrated in Table 2.5. Each Band has a general description of performance and suggests a range of recommended activities as described in Table 2.6.

Developing Countries	Developed Countries	Band	General description of real loss performance management categories
ILI Range			
< 4	< 2	A	Further loss reduction may be uneconomic unless there are shortages; careful analysis is needed to identify cost effective improvement
4 to <8	2 to <4	B	Potential for marked improvements; consider pressure management, better active leakage control practices, and better network maintenance
8 to <16	4 to <8	C	Poor leakage record; tolerable only if water is plenty and cheap; even then analyze level and nature of leakage and intensify leakage reduction efforts
16 or more	8 or more	D	Very inefficient use of resources; leakage reduction programs imperative & high priority

Table 2.5 WBI Banding System to Interpret ILIs

Source Sharma (2008:14)

WBI Recommendations for BANDS	A	B	C	D
Investigate pressure management options	Yes	Yes	Yes	
Investigate speed and quality of repairs	Yes	Yes	Yes	
Check economic intervention frequency	Yes	Yes		
Introduce/improve active leakage control		Yes	Yes	
Identify options for improved maintenance		Yes	Yes	
Assess Economic Leakage Level	Yes	Yes		
Review burst frequencies		Yes	Yes	
Review asset management policy		Yes	Yes	Yes
Deal with deficiencies in manpower, training and communications			Yes	Yes
5-year plan to achieve next lowest band			Yes	Yes
Fundamental peer review of all activities				Yes

Table 2.6 WBI Recommended Activities

Source Sharma (2008:14)

2.11 Information gap

Leakage in water distribution networks is a common problem worldwide that has attracted recent researches. Many models have emerged that consider the different aspects of leakage such as socio-economic, level of service, environmental impact, etc. and develop strategies for leakage management in large networks where the volume of water leakage is relatively large. The potential savings across large networks justify the development of such models to help improve leakage control strategies.

In small to medium size networks such as those present in County Galway, the potential saving from leakage control may be low and may not substantiate the use of similar models. It is believed that leakage management strategies in similar contexts should be simple but yet comprehensive encompassing aspects such as cost and energy associated with it.

Different methods are used worldwide to estimate leakage, energy and cost in a WSS. These methods are sometimes specific to the country or area being considered. In Ireland for example Water Audits are carried out using the UFW: Integrated Flow Method which to some extent helps to estimate the level of water losses. The IWA Water Balance method which has proven itself in many countries worldwide has not been used. In addition, there has been no study carried out to estimate energy and cost associated to water supply let alone the energy and cost associated to leakage.

Moreover, in Ireland CO_{2eq} is estimated into different categories such as electricity generation; industry; transport; residential; and commercial and public services, (Howley and Ó Gallachóir, 2005). CO_{2eq} estimate for the water sector is yet to be determined.

Information on water losses including leakage and the associated energy and cost is still very basic or unknown in Ireland. It is thought that leakage control strategy is still being based on only partial information available. This study aims to associate energy and cost of leakage in three WSS in County Galway which are small and medium in sizes. The method used in the study can be extended to other WSS in County Galway as well as in Ireland countrywide. The information generated can help to identify WSS where leakage, energy, and costs are at a critical level and help in the implementation of the correct leakage control strategy.

CHAPTER 3 SOURCES OF DATA AND METHODOLOGY

The aim of this study is to determine cost and energy associated with leakage in small to medium size WSS in County Galway. The following WSS were selected for the study.

* Galway City
* Ardrahan
* Caherlistrane/Kilcoona

Objectives of the study are as follows.

- Determine variable energy and costs associated with water abstraction, treatment and distribution.
- Carry out a top down water audit in these WSS to estimate UFW, NRW, ILI, etc.
- Determine the total volume of water loss including leakage and the potential reduction in water loss in the three WSS.
- Estimate the equivalent CO_2 which can potentially be reduced by reducing energy use as a result of water loss reduction.
- Demonstrate the importance of considering factors such as energy and cost savings while implementing a leakage management strategy.

The methods used to achieve the above aim and objectives of the study are provided in this chapter.

3.1 Summary of Research Methodology

Published Journals, manuals, unpublished documents, information available on the Internet were reviewed to understand the recent works carried out in the field. The literature reviewed was mainly prepared by industry professionals and were mainly available from universities, recognised organisations, Governmental bodies, etc. The review helped to identify the information gaps. A summary of literature reviewed and gaps in information are provided in Chapter 2. The study areas which are all in County Galway were selected followed by identification of data required and their sources. The methods used to collect primary data, derivation of secondary data and their analysis are summarised below.

- Primary data for a period of one year (January to December 2009) was collected from Water Service Providers, operators of WTPs, websites, journals, published and unpublished reports, internet, etc. Different methods including semi structured interview, email and telephone conversation, consultation, etc. were used for data collection.

- The following secondary data was determined using the primary data.
  - * Cost and energy required to abstract, treat and distribute water
  - * Leakage level and potential reduction in water loss including leakage
  - * Energy and cost associated to total water loss and their potential reduction if leakage is reduced to an acceptable level.
  - * CO_{2eq} associated to energy involved was also established.
- The data were analysed, the severity of the problems were discussed and a conclusion including some recommendations based on results obtained are provided.

Primary data for a period of one year (January to December 2009) was collected as this period was particularly suitable and most of the data required was available.

3.2 Selection of Study Areas

The aim of the study is to determine the cost and energy associated with leakage in small and medium size WSS in County Galway. Actually, there are a few medium sized WSS in County Galway. One of them is in Galway City and was particularly suited for this study due to its size and location. In addition, members from Galway City Council were particularly interested in the project and agreed to allow access to the City WSS including the treatment plant.

There are quite a few small WSS in County Galway which required more careful selection. The following factors were taken into consideration:

- Location of the networks
- Size and distribution of population
- Size of the networks
- Availability of the required data

After due consideration and having discussed with staff from the National Federation of Group Water Schemes the following two small schemes were identified and considered in the study:

- Ardrahan GWS
- Caherlistrane Kilcoona GWS

3.3 Data Collection

The first data collection step involved collection of information about the WSS to understand the main processes involved in each scheme. This entailed site visits to get familiar with the water treatment plants and understand the water distribution networks. At this stage the data required for the study and their sources were identified.

Different methods such as interviews, meetings, site visits, consultations of published and unpublished reports, publications, etc. were used to collect the required data. More details on data required and their sources, methods used to collect the required data and constraints during data collection are provided in the following Sections.

3.3.1 Sources of Data

The main sources of quantitative data required for the study were identified at an early stage of the study and these are listed in Table 3.1.

3.3.2 Methods Used to Collect Data

Several methods were used during the study to collect quantitative data identified. These methods are listed below.

- Physical Survey - this method of data collection was used to collect primary data such as equipment capacity, efficiency, etc of the equipment used in the water treatment plants at the three WSS.
- Interview - a semi structured interview was used to carry out interview with key personnel identified in Section 3.2.1 to collect quantitative data such as system input volume (Water production at respective water treatment plants), consumption data, water distribution network data, population served etc. A questionnaire was used to ensure that all the required data was collected.
- Websites - quantitative data such as population served, details of previous works carried out in each scheme, etc were collected by visiting the following websites
    - Central Statistics Office in Ireland
    - Galway City Council
    - Environmental Protection Agency in Ireland, etc
- Investigations - This involved finding information from water supply and consumption reports/documents available from individual water providers, consultants, research organisations, etc. to collect data on population and density, details on the WSS, energy consumption by each dwelling in Ireland, etc.
- Consultation involving telephone conversations and e-mail correspondence with individual water providers, non - domestic meter operator, etc. as appropriate.

Details / data	Source	Contacts
Equipment details within the water supply schemes	Operators of Treatment Plants and Pumping Stations	• Eoin Hughes, Environmental Engineer, TSSL • Joe McGuire, Executive Engineer, Terryland Water Treatment Plant and related Pumping stations.
Volume of water abstracted, treated and distributed to the networks	Treatment plant measuring instruments and SCADA. Members of the Group Water Schemes	• Eoin Hughes, Environmental Engineer, TSSL • Joe McGuire, Executive Engineer, Terryland Water Treatment Plant and related Pumping stations.
Energy used during abstraction, treatment, and distribution to the networks	Treatment plants and pumping stations	• Eoin Hughes, Environmental Engineer, TSSL • Joe McGuire, Executive Engineer, Terryland Water Treatment Plant and related Pumping stations.
Chemical used during water treatment and disinfection	Treatment plants and pumping stations	• Eoin Hughes, Environmental Engineer, TSSL • Joe McGuire, Executive Engineer, Terryland Water Treatment Plant and related Pumping stations.
Volume of water supplied to non domestic users, domestic users, institutional, firefighting, etc.	GCC, Members of the GWS and Veolia Ireland (DBO contractor for Non Domestic Metering in City Galway)	• Frank Clancy, Senior Engineer, GCC. • Damien Crean, Project Manager, Veolia Ireland • Michael Moran, Kilcoona/Caherlistrane GWS • Michael Kelly, Ardrahan GWS
Population Served by the WSS	Statistical offices, GCC, members of GWS	• Information available from Websites • Frank Clancy, Senior Engineer, GCC. • Michael Moran, Kilcoona/Caherlistrane GWS • Michael Kelly, Ardrahan GWS
Details of water distribution network	GCC, members of GWS	• Information available from Websites • Frank Clancy, Senior Engineer, GCC. • Michael Moran, Kilcoona/Caherlistrane GWS • Michael Kelly, Ardrahan GWS • Other published and unpublished reports

Table 3.1 Sources of Data

- Examination of existing data on the relevant operational Programmes and from wider sources such as case studies of a number of completed investments in Ireland; international comparative information; and published and unpublished documents.

3.3.3 Limitation of Data Collection

In this study, the data collected, derived and analysed was essentially limited to existing data available. As a result primary data and secondary data including analyses are based on partial or piecemeal information obtained from different sources. Data and information collected during the survey were primarily limited to the following.

- The variables, records, and items that water service providers (WSPs) normally keep, as they were not asked to generate new data for this study.
- Some data was considered sensitive to the general public and WSPs were reluctant to release such data or information.
- Due to unavailability of data for year 2010 and the risk of not obtaining the required data during the schedule data collection period of the study, it was thought more reasonable to collect data for the full calendar year 2009.
- Quality and reliability of overall information is poor particularly in regard to such critical issues as volume consumed, record of plant and equipment in use (e.g. run hours and maintenance records), precise and full details on the distribution networks, number of connections in the networks, etc. This led to several assumptions during the study mainly based on current information available from informants and other sources such as the Central Statistics Office. For example, the level of domestic water consumption in Galway City is based on simple assumptions derived from population levels and estimated per capita consumption. Moreover, in the private schemes although customers are metered, the meter was read only on an annual basis and the exact dates for meter readings were not properly recorded. This made it difficult to estimate an exact volume of water consumed based on certain assumptions.
- It was also a great challenge to estimate unbilled unmetered consumption for fire fighting and other water uses in public locations such as washing streets or watering public gardens in Galway City are not recorded and a figure for this consumption has been assumed.
- Another problem faced was the estimation of the average network pressure. Depending on the structure of the distribution system (homogenous topography or hilly), there is a lack of pressure data. The average network pressure is one of the most influencing parameters for calculating the Infrastructure Leakage Index (ILI) and the average pressure for each WSS was assumed.
- Estimating apparent losses was also quite challenging. For example, customer metering inaccuracies were only estimated based on research carried out elsewhere due to the lack of this information in Ireland.

- The average length of service connections is needed for the calculation of the Infrastructure Leakage Index. In the absence of appropriate figure, only estimated average values for each scheme were used.
- Generally WSPs apply inconsistent definitions to UFW. Since the study includes the determination of UFW, this is another source of error. For the purposes of this study, UFW has been defined as the difference between the volume of water delivered into a network and the volume of water that can be accounted for by legitimate consumption. UFW is also dependent on factors such as water reuse, metering effectiveness, as well as losses attributed to line flushing, fire fighting, and other public activities. All these data are mostly estimates as they are not metered or recorded and hence has an influence in the final result of the study.

3.4 Data Analysis

The data analysis phase of the study involved assessing and weighing all quantitative data that are collected from the different data sources including those derived from the data collected. However, prior to any comparative assessment, the data were divided into two categories (Primary and Secondary Data) as detailed in the following sections.

3.4.1 Primary Data

These data are mainly data required to derive the secondary data. They consist of all data identified in Sections 3.3 and 3.4. As most of the primary data cannot be compared, they have been tabulated separately for each WSS in Chapter 4.

3.4.2 Secondary Data

Secondary data are mainly data derived from primary data. Secondary data are required for comparison and the final conclusion of the study. These data consist of:

- Total energy used to abstract, treat and distribute the total volume of water required in each WSS in a year
- Energy required to abstract, treat and distribute a cubic meter of water in each WSS
- Total cost associated with abstraction, treatment and distribution of the total volume of water required in each WSS in a year
- Cost per cubic meter of water in each WSS
- Volume of NRW / UFW in each scheme
- Percentage of NRW / UFW in each scheme
- Total cost associated with NRW / UFW in each WSS

- Total energy associated with NRW / UFW in each WSS
- Potential energy and cost saving that can be achieved if leakage is reduced to an acceptable level.

Secondary data are derived using the methods described in Sections 3.5 and 3.6. These data were used for comparison, discussion and the final conclusion of the study.

3.4.3 Plan to ensure reasonable level of accuracy

As outlined in Section 3.2.3, several constraints were experienced especially during primary data collection. Due to these constraints, several data had to be estimated and their quality was considered not particularly accurate. To ensure a reasonable level of accuracy and to minimise bias, the reliability and accuracy of data collected was a very important factor which has an influence in the secondary data and hence in the final result of the study. Although all efforts were taken to select reliable data sources, it was difficult in many instances to obtain accurate data. As a matter of fact, all primary data was provided with an accuracy level based on its reliability as set in Table 3.2. This level was based on the experience of the author and informants.

Category	Reliability	Accuracy
A	very reliable	< 5 %
B	reliable	5 – 25 %
C	unreliable	25 – 100 %
D	very unreliable	>100 %

Table 3.2 Categories of Data

Source Kölbl et al, n.d.:180.

Moreover, the secondary data derived varied in range. The yearly water consumption figures, energy use and cost varied from figures as high as tens of millions while the unit rate of energy use and cost was as low as thousandths. To minimise computational errors, four decimal places are used for smaller figures especially those related to unit rates while two decimal places are used for the larger figures in the study.

3.5 Chemicals, Energy and Associated Costs

There are several design and operational factors that affect the cost of water production as summarised below.

* Plant capacity
* Qualified manpower

* Energy cost
* quality of Raw water
* Plant life and amortization

Annual operating costs are those costs related to electricity, labour, insurance, chemicals, amortization, maintenance and spares. The study concentrates on energy used and variable cost of water production. Given that the size of the WSS are not subject to changes during the study (i.e. infrastructure such as water treatment plants and pipeworks), the variable costs components are mainly influenced by the following.

* Energy used
* Chemicals used

Other operating costs such as labour costs, costs for insurance cover and amortisation costs do not usually vary with the volume of water production and are considered as fixed costs. As indicated by El-Dessouky et al. (n.d) and quoted by Atikol and Aybar (2005:255), the maintenance cost can be based on a percentage of the capital cost on a yearly basis and have been assumed to be fix for this study.

3.5.1 Energy Use and Associated Cost

In a water treatment plant, energy is mainly used during water abstraction, treatment, distribution, office use and lighting. The main energy consuming items in the three WSS are summarised in Table 3.3.

Energy intensity values in the study are typically expressed in kilowatt hours because electricity is the only energy type used in the three WSS similar to other WSS in Ireland.

In all the schemes, most of the energy intensive processes are carried at the WTPs except for further pumping or pressure boosting in the distribution networks. The electricity meters at the WTPS records most of the energy use in the schemes.

In Galway City WSS, the Terryland WTP supplies a major proportion of water required. It was considered most appropriate to estimate the energy used by individual equipment at the WTP rather than using the electricity meter readings as part of electricity is used for other purposes such as for an office used by full time staff and yard lighting. Energy used for lighting and office use are actually considered fix and do not vary with water production.

As for Ardrahan and Caherlistrane/ Kilcoona WSS the WTPs are small with no office on site. Due to small size of these two sites, yard lighting is minimal and is assumed to be negligible. In these two WSS electricity recorded by the meters are assumed to be mainly used for abstraction, treatment and distribution of water.

The following sections describe the methods used to estimate the energy use, chemicals use and their associated costs at Terryland WTP. The main energy users at Terryland WTP are the pumps and ultra violet disinfection units. There are several small equipment which have been grouped under other process equipment.

WSS	Abstraction	Treatment	Distribution	Office and yard lighting
Galway City	Low lift pumps	Dosing equipment, compressor, wash water pumps	High lift pumps at Terryland WTP and pumps at Coolagh and Clifton Hill distribution lines	A fully operational Office at Terryland WTP with yard lighting
Ardrahan	Borehole pumps	Dosing equipment, compressor, wash water pumps	Pumps at the treatment plant and one booster set to feed customers at higher level	No office within the WSS and lighting is minimal due to size of the site
Caherlistrane / Kilcoona	Borehole Pumps	Dosing equipment, compressor, wash water pumps	Pumps at the treatment plant and one booster set to feed customers at higher level	No office within the WSS and lighting is minimal due to size of the site

Table 3.3 Main energy using components

3.5.1.1 Pump Power

The hydraulic power to drive a pump depends on the mass flow rate, the liquid density and the total head (Static lift from one height to another + Pipe Friction Loss). The hydraulic pump power, P_h was calculated using the total head loss component of the system as follows

$$P_h = \frac{q\rho g h}{3.6 \times 10^6} \qquad (1)$$

Where P_h = Pump hydraulic power (kW)

q = flow (m^3/h)

ρ = density of fluid (kg/m^3), assumed 1000 kg/m^3

g = gravity (9.81 m/s^2)

h = Total Head of the System (m)

Overall Pump Power

The overall power to drive the motor and pump depends on the overall efficiency of the motor and pump and was calculated using

$$P_o = \frac{P_h}{\eta_m \times \eta_p} \qquad (2)$$

Where P_o = Pump overall power (kW)

η_m = motor efficiency

η_p = pump efficiency

The total pump power is then the sum of all the pumps. Total cost of electricity for pumping, E_{pumps} (€) was estimated using:

$$E_{pumps} (€) = P_o \times R \times H_p \qquad (3)$$

Where H_p = Pump total hours run

R = Electricity Rate in €/kWh

Data Required

The following data are required to estimate electricity use by pumps and their associated costs.

- Pump rating
- Pump efficiency
- Motor Efficiency
- Friction head loss of the system
- Static lift from one height to another
- Flow
- Pump run hours
- Electricity rate applicable

3.5.1.2 Ultra Violet (UV) Disinfection

The UV unit is another major energy user at Terryland WTP. The power used was estimated based on manufacturer's data and on actual power consumed by the unit. UV energy cost in €, C_{uv} was determined using:-

$$C_{uv} = P_{uv} \times R \times H_{uv} \qquad (4)$$

Where P_{uv} = UV power in kW (manufacturer's data or actual power consumed)

H_{uv} = Total Hours Run of the UV unit

R = Electricity Rate in €/kWh

Data Required

Data required to estimate UV energy and associated costs are listed below.

- Power consumption of the UV unit
- Hours run of the UV unit
- Electricity rate applicable

3.5.1.3 Other process equipment

Other than the pumps and UV units, there are other process equipment used at Terryland WTP. These are small chemical dosing equipment, compressor, blower, etc. The energy used by these equipment were estimated based on their rated power and their hours run.

Data required

- Rated power of the equipment
- Hours run of the equipment

3.5.2 Chemical Use and Associated Costs

Treatment of raw water to make it potable requires the use of some or all of the following chemicals.

- Aluminium Sulphate
- Poly Aluminium Chloride
- Polyelectrolyte
- Fluorosilicic Acid
- Sodium Chloride Salt
- Sodium Hypochlorite
- Sodium Hydroxide
- Sulphuric Acid, etc.

These chemicals are used in treatment processes such as flocculation, disinfection, clarification, etc and are generally purchased from chemical suppliers. Sodium hypochlorite is produced locally on site at Terryland WTP. Salt is the raw material used for the production of this chemical which is purchased from salt suppliers.

Chemicals costs (C_{chem}) at the water treatment plants represent a significant proportion of the variable cost. The estimated cost is the product of the amount (Volume / Weight) of the chemicals used and their respective cost.

Data Required

Data required to estimate chemical costs at Terryland WTP are listed below.

- Amount (Volume or Weight) of chemicals used in each plant
- Unit cost of the chemicals

3.6 Water Balance

Leakage forms a major proportion of water loss which includes leakage from reservoirs, pipe, meters, etc. in a water supply scheme. Water loss is estimated using a top down water balance method such as the IWA method or the UFW Integrated Flow methods as explained in the following sections. The Author is of opinion that using both water audits methods would be a basis to compare the water audit results and also to ensure their consistency.

3.6.1 IWA Water Balance

Figure 3.1 illustrates the standard international water balance structure and terminology that has been adopted by national associations in many countries across the world.

<table>
<tr><td rowspan="9">System Input Volume</td><td rowspan="4">Authorised Consumption</td><td rowspan="2">Billed Authorised Consumption</td><td>Billed Metered Consumption</td><td rowspan="2">Revenue Water</td></tr>
<tr><td>Billed Unmetered Consumption</td></tr>
<tr><td rowspan="2">Unbilled Authorised Consumption</td><td>Unbilled Metered Consumption</td><td rowspan="7">Non-revenue Water</td></tr>
<tr><td>Unbilled Unmetered Consumption</td></tr>
<tr><td rowspan="5">Water Losses</td><td rowspan="2">Apparent Losses</td><td>Unauthorised Consumption</td></tr>
<tr><td>Customer Metering Inaccuracies</td></tr>
<tr><td rowspan="3">Real Losses</td><td>Leakage on Transmission and/or Distribution Mains</td></tr>
<tr><td>Leakage and Overflows at Utility’s Storage Tanks</td></tr>
<tr><td>Leakage on Service Connections up to Point of Customer Metering</td></tr>
</table>

Figure 3.1 IWA water balance

(Source Kölbl et al., n.d:179)

Farley et al. (2008:11) provides abbreviated definitions of the principal IWA water balance components which are given below.

- System Input Volume is the annual volume input to that part of the water supply system.

- Authorised Consumption is the annual volume of metered and non-metered water taken by registered customers, the water supplier, and others who are implicitly or explicitly authorised to do so (e.g. water used in government offices or fire hydrants). It includes exported water and the leaks and overflows after the point of customer metering.
- Non-Revenue Water (NRW) is the difference between System Input Volume and Billed Authorised Consumption. NRW consists of Unbilled Authorised Consumption (usually a minor component of the water balance) and Water Losses.
- Water Losses is the difference between System Input Volume and Authorised Consumption. It consists of Commercial Losses and Physical Losses
- Commercial Losses, sometimes referred to as 'apparent losses', consist of Unauthorised Consumption and all types of metering inaccuracies
- Physical Losses, sometimes referred to as 'real losses', are the annual volumes lost through all types of leaks, bursts and overflows on mains, service reservoirs and service connections, up to the point of customer metering.

Data Required

As detailed in Farley et al. (2008:12), the following information are required to conduct a water balance based on the IWA method.

- System input volume
- Billed consumption
- Unbilled consumption
- Unauthorised consumption
- Customer metering inaccuracies and data handling errors
- Network data
- Length of transmission mains, distribution mains and service connections
- Number of registered connections
- Estimated number of illegal connections
- Average pressure
- Historic burst data
- Level of supply service (24-hour, intermittent, etc)

3.6.2 UFW Water Balance

The method used in Ireland has been developed by the Department of Environment, Heritage and Local Government which is generally used by water service providers to carry a water balance on a yearly basis. It is a standard programme in Microsoft Excel called UFW: Integrated Flow Method.

Copy of the principal components of the UFW: Integrated Flow Method is illustrated in Figure 3.2. Definition of the terms used was not available.

UNACCOUNTED FOR WATER : INTEGRATED FLOW METHOD							
Scheme Name:				DMA Name:			
DMA Flow Details							
Period Covered by Water Audit					Flow m^3/day		
				Total Inflow[1]	A		
				Exports to Neighbouring WSA or DMAs[2]	B		
				Distribution Inflow	C	0.0	
Water Delivered							
Permanent Domestic Demand:							
Number of Properties[3]			Occupancy Rate[4]				
Population Supplied	0	persons @	-	litres/capita/day		0.0	
Per Capita Consumption (PCC) litres/capita/day:							
PCC from Individual Study[5]			or PCC from NWS[6]				
Seasonal Domestic:							
Number of Properties[7]			Occupancy Rate[8]				
Population Supplied	0	persons @	-	litres/capita/ day		0.0	
Non-Domestic Metered Demand[9]:			properties				10
Non-Domestic Un-metered[11]:		properties @	700	liters/prop/day		0.0	
Group Water Scheme Bulk Meter demand[12]:							
GWSS Name	Demand						
Name GWSS 1		m^3/day					
		m^3/day					
Name GWSS n		m^3/day					
				Total GWSS Demand		0.0	
Demand from Major Consumers[13]:							
Consumer Name	Demand						
Name consumer 1		m^3/day					
		m^3/day					
Name consumer n		m^3/day					

UNACCOUNTED FOR WATER : INTEGRATED FLOW METHOD							
				Total Major Consumer Demand		**0.0**	
Operational Use (Allow 1% of Distribution Inflow):						**0.0**	
Total Accounted for Water					**D**	**0.0**	
Unaccounted For Water, U.F.W		**UFW= E = C - D**		**m^3/day**	**E**	**0**	
				l/sec		**0**	
						-	
Total length of mains in DMA[14] =			kilometers (**L**)				
Total No. Of Connections [15] =			**(P)**				
U.F.W as :					**ALSO AS:**		
% of daily DMA demand=		(E/C)x100			**#DIV/0!**	**of net inflow**	
Rate per Connection per Day=		(Ex1000)/P			**#DIV/0!**	**litres/ conn/day**	
Rate per km main per hour=		E / (Lx24)			**#DIV/0!**	**m^3/km/hr**	
Water Services Authority Name:				**Completed By**			
				Checked By			

Figure 3.2 Components of UFW Water Balance as used in Ireland

(Source: Frank, 2010a)

Data Required

The following information are required to carry out a water balance using the UFW: Integrated Flow Method.

- Total Inflow
- Exports to Neighbouring WSA or DMAs
- Number of Properties
- Occupancy Rate
- Population Supplied
- Per capita consumption in litres/capita/day
- Non-Domestic Metered Demand
- Non-Domestic Un-metered
- Group Water Scheme Bulk Meter demand
- Demand from Major Consumers
- Total length of mains in DMA
- Total No. of connections

3.6.3 Availability of data and assumptions

Data required by the two Water Audit methods were collected as detailed in Section 3.2. The following sections provide a brief description of the data and assumptions made while collecting the data.

3.6.3.1 System Input Volume or Total Inflow

The water distribution networks in the three schemes are supplied by water treatment plants as listed in Table 3.4.

WSS	Water Treatment Plants
Galway City	Terryland and Luimnagh WTPs
Ardrahan	Ardrahan WTP
Caherlistrane/ Kilcoona	Caherlistrane / Kilcoona WTP

Table 3.4 WTPs supplying water to the WSS

Except in Galway City, water is mainly supplied to customers in the schemes by their own water treatment plant. Water is not imported nor exported. In Galway City, the Terryland WTP supply a major proportion of water required. As a temporary measure water was imported from Luimnagh WTP which is under the Responsibility of Galway County Council. Cost and energy associated to water imported from the Luimnagh WTP were not considered as they are outside the scope of this study.

Water produced by the water treatment plants was considered synonymous to system input volume or Total Inflow in the three schemes. This was considered acceptable as the water use inside the treatment plants (e.g., for backwashing filters) is not recorded by the flowmeters used to measure the treated water pumped into the distribution networks and hence does not form part of the figures for water production, Wyatt (2010:4).

Flowmeters are available at the water treatment plants in the three schemes to record volume of water being pumped into the distribution networks and therefore the system input volume was readily available.

3.6.3.2 Water Consumed

Collection of Water Consumption data required more careful attention. This data depends on existing infrastructure such as existing customer meters and the level of records being kept by the WSPs.

Water consumed by domestic and non domestic customers can actually be derived with reasonable accuracy from billing records and supply meters at household connections wherever available. As there are many unmetered customers especially domestic customers in Galway City, it was difficult to estimate the water consumed. Estimation was made based on demographic data and using estimated per capita consumption. As per Frank (2010b) there is an increase in water consumption during the 3 summer months of the year (approximately 90 days) as there are people coming for holidays. The volume of water consumed in the year needs to cater for this period as well and a 20% increase to the estimated per capita consumption was actually used to cater for this increase in Galway City. Total domestic consumption for Galway City was determined using the following equation.

$$\text{Water Consumption} = (C \times P \times 365) + (C \times P \times 0.2 \times 90) \quad (5)$$

Where, P = No. of people living in the city

C = average water consumption, in m^3/person/day

Water consumption data such as volume of water used for fire fighting and other public activities are non revenue water. These are not metered and are therefore estimated values based on WSPs' knowledge.

3.6.3.3 Apparent Losses

Apparent losses (commonly referred to commercial losses) are losses that relate to water that is consumed but are not paid for. According to Mutikanga et al. (2010), most research carried out in the last decade particularly in the United Kingdom focused mainly on leakage. There is no set procedures and guidelines for assessment of apparent losses. In the absence of adequate data and proper methodology, most developed countries use default values for computation of apparent losses. Apparent losses result in appreciable revenue loss for water utilities and distort the integrity of consumption data required.

In Ireland domestic and non domestic customers in the Group Water Schemes are all metered. Domestic customers supplied by the public water schemes such as in the Galway City are at present generally not metered while most non domestic customers are metered.

To cater for apparent losses in the WSS being considered the figures shown in Table 3.5 were used. These figures are provided in Seago et al. (2004) and quoted in Sharma (2008:11).

3.6.4 Comparison of NRW and UFW

The results based on the two methods are compared to verify their integrity. This was achieved by using the following relationship as provided in Sharma (2008:4).

$$NRW = UFW + U_a$$

$$UFW = NRW - U_a \quad (6)$$

Where, U_a = Unbilled authorised consumption (Water which is accounted for but no revenue is collected)

3.6.5 Potential reduction in Water Loss

It is very difficult to achieve zero leakage in a distribution network. Leakage can actually be reduced to an economic level below which no further benefits can be achieved. This minimum acceptable leakage level needs to be established. As a guideline, the acceptable level of UFW is set to be less than 10%, Sharma (2008:7) and this level has been assumed to determine the potential reduction of UFW in the three WSS.

Moreover, real loss in the WSS needs to be based on the ILI band which can be achieved. Based on Sharma (2008:14), for developed countries like Ireland, ILI Band A is the targeted Band to achieve below which further leakage reduction may be uneconomical. For developed countries ILI is set below 2 for the Band A.

Illegal Connections		**Meter Age and Accuracy**			**Data transfer**	
		Meter Condition	**Good Quality Water**	**Poor Quality Water**		
Very high	10%	Poor >10 years	8%	10%	Poor	8%
high	8%					
Average	6%	Average 5-10 years	4%	8%	Average	5%
Low	4%	Good < 5 years	2%	4%	Good	2%
Very Low	2%					

Table 3.5 Percentage apparent losses

Adapted from Sharma (2008:11)

As shown in Sharma (2008:12), ILI is actually given as:

$$ILI = CARL / UARL \qquad (7)$$

UARL is determined using data such as the length of the network, number of connections, average pressure of the main, etc as detailed in Sharma (2008: 10-11) which is fix assuming there are no changes in the distribution network. To achieve the targeted ILI of below 2, CARL is the only component which can be reduced. Using the relationship, the UARL value and targeted ILI of below 2, the potential reduction in CARL was determined.

3.7 Energy and Cost Associated to Leakage

Variable energy used to produce a cubic meter of water (E_V) in kW/m^3 was determined using

$$E_V = E_{AV} / Q_P \qquad (8)$$

Where E_{AV} = Annual variable Energy used for water abstraction, treatment and distribution in kW/year

Q_P = Water produced during the year in m^3

The variable cost of water production (C_V) in €/m^3 was determined using the following relationship:

$$C_V = C_{AV} / Q_P \qquad (9)$$

Where C_{AV} is the Annual variable costs for water abstraction, treatment and distribution in €/year. C_{AV} includes chemicals and energy costs but exclude other short-run water production costs which are assumed to be negligible and other costs such as amortisation costs, maintenance costs etc which are assumed to be fix as mentioned in Section 3.5.

Energy and costs associated with water loss and potential reduction in water loss were determined using the following relationships.

$$E_L = W_L \text{ x } E_v \qquad (10)$$

$$E_{Lp} = W_{Lp} \text{ x } E_v \qquad (11)$$

$$C_L = W_L \text{ x } C_v \qquad (12)$$

$$C_{Lp} = W_{Lp} \text{ x } C_v \qquad (13)$$

Where W_L is water loss determined using the Water Balance Methods

W_{LP} is the potential reduction in water loss determined as per methods described in Section 3.6.5

E_L is the energy associated to W_L

E_{Lp} is the energy associated to W_{LP}

C_L is the cost associated to W_L

C_{Lp} is the cost associated to W_{LP}

3.8 CO_2 Associated to Leakage

Generally, there is no direct GHG emission during water abstraction, treatment and distribution, Frijns (2009:5). Although there is no direct emission of GHGs during abstraction, treatment and distribution, there is indirect emission of CO_2 mainly from production of Electricity and Chemicals which are used during these processes.

Based on Howley and Gallachóir (2005:2), 651g of CO_2 is associated with every 'kWh of electricity consumed in aggregate'. This conversion factor is used to estimate the indirect CO_{2eq} emission due to energy use in the three schemes.

Moreover, chemicals used can be converted to kg of CO_2. Chemical use and their equivalent CO_2 emission can be used to estimate the indirect CO_{2eq} emission. Conversion of kg CO_{2eq}

per kg of chemicals were not available for the chemicals used during treatment of water in the three WSS. CO_{2eq} conversion for some chemicals were found in Frijns (2009:17) but was not sufficient to estimate the CO_{2eq} for water supply in the three schemes and was therefore not considered in this study.

CHAPTER 4 THE STUDY AREA AND PRIMARY DATA

This chapter provides an overview of the Island of Ireland, County Galway and the selected WSS. A summary of the data collected including their reliability are provided.

4.1 Island of Ireland

The island of Ireland covers 84,431 square kilometres (32,599 square miles), Walsh (2009) which includes the Republic of Ireland (70,283 sq km/27,136 sq mi) and Northern Ireland (14,148 sq km/5,463 sq mi), Walsh (2009). The total population of the Republic of Ireland (henceforth referred to Ireland) is 4,015,700 million (Worldatlas, 2006) which represents a population density of approximately 57 people/sq km which is low as compared to other European countries such as the UK, Germany or the Netherlands (population densities are approximately 247, 231 and 395 respectively, Worldatlas, 2006). Due to the low population density, houses more particularly in rural areas are widely spread. The most densely populated area of the country is Dublin City with a population density of 2950 people per sq km (Citymayors, 2007). Population density in the counties varies considerably from as low as 18.2 in County Leitrim to 135 people per sq km in County Louth, (Wikipedia, 2010).

4.2 Water Supply in Ireland

In Ireland water services are mainly provided by the Government, private and part-private water schemes. The county councils and city councils assure services on behalf of the Government. The private and part-private schemes are Group Water Schemes that have emerged due to lack of piped drinking water in rural areas, (WSNTG, n.d.:9). Figure 4.1 provides an overview of water supply services in Ireland.

4.2.1 Private and Part Private Group Water Schemes

Private and Part Private Group Water Schemes (GWS) are communities in rural areas that set up voluntarily in co-operative structures to privately manage water distribution systems. GWS vary in size from a minimum of two houses sharing a water connection to the same source to over a thousand houses in some cases (DOEHLG, 2007:9). It is now estimated that over 5,500 GWS in Ireland serves up to 300,000 households and there are 729 GWS each serving more than 50 persons (DOEHLG, 2007:9).

Many of these GWS are connected to the public water mains but they have control over their pipe distribution network. Such GWS are called Part Private Group Water Scheme. Other GWS have an independent source of raw water. The raw water is treated before it is distributed to water users. These GWS are called Private Group Water Schemes.

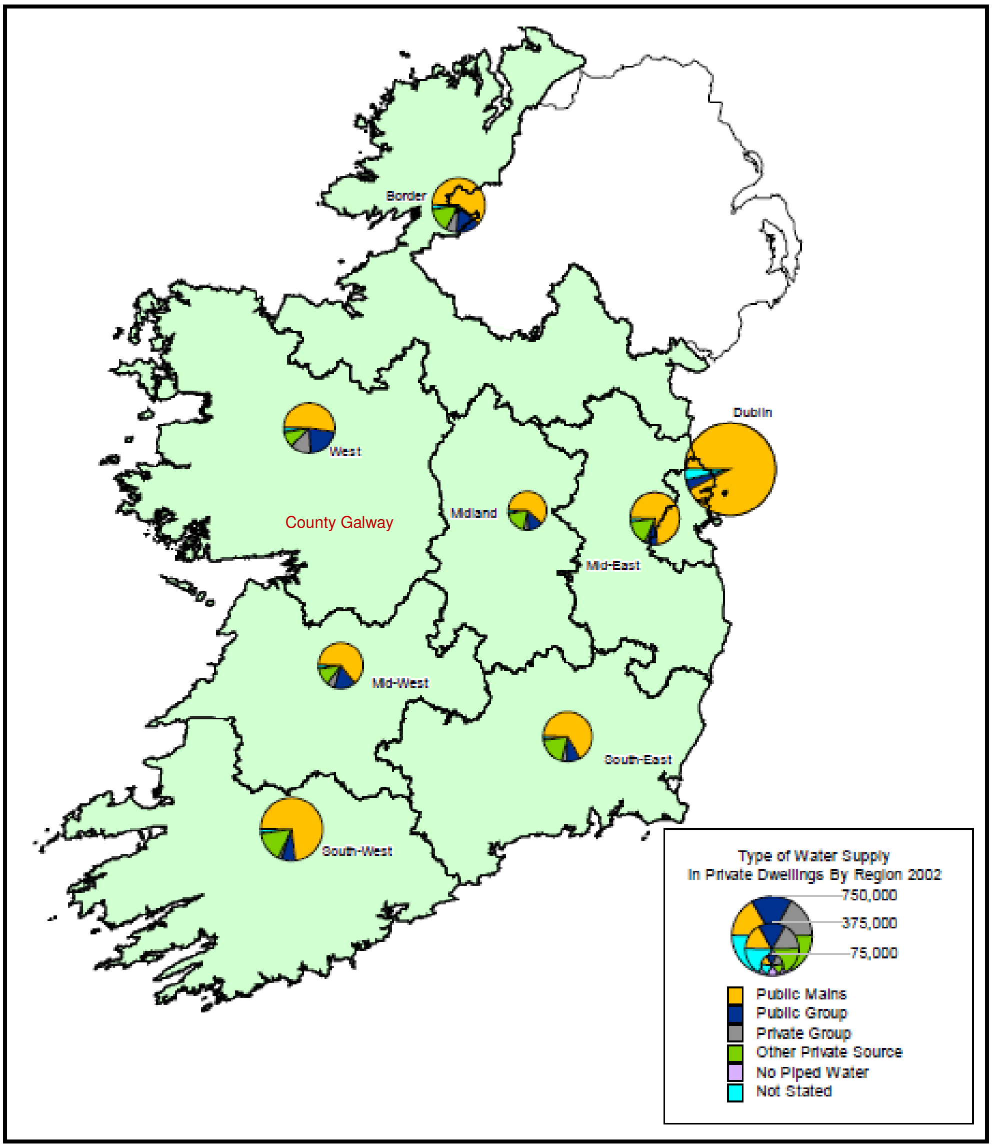

Figure 4.1 Water Supply in Private Dwellings 2002 (May not be required)

Source FAEC, 2005: 18

A county breakdown of the 729 GWS is provided in Appendix 1 and in county Galway alone you would note that there are 177 serving 20,987 domestic users.

All customers in Private and Part Private GWS are metered. Domestic customers are generally allowed a minimum free allocation of water which varies from one scheme to another. Non domestic customers do not benefit from free allocation of water. Water are charged based on volume consumed and all water consumed excluding the free allocation are charged annually on a flat rate basis.

4.2.2 Public Water Schemes

Public water supply is generally under the responsibility of local authorities in Ireland. Funding for maintaining and improving the water supply infrastructure (pipes, filtration and disinfection systems) comes from the Department of Environment, Heritage and Local Government.

Presently there is no water charge to domestic customers but there are charges levied on water supplied to commercial premises (referred to as Non - Domestic Customers) only. The Government of Ireland has recently signified their intention of introducing water metering for domestic users and water charges will be based on volume consumed above a free allocation (DOEHLG, 2010).

4.3 County Galway

Galway is the second largest county in Ireland covering 6,150 square kilometres (HSE, 2010). County Galway is bordered to the east by the river Shannon. The river Corrib runs through the county. The population density in County Galway including Galway City is 37.7 people per sq km compared to 60.3 persons per square km for the whole of Ireland (HSE 2010). Excluding the City the County has a population density of 26 people per sq km and Galway City on its own has a population density of 1431 people per sq km (HSE 2010). Figure 4.2 shows the variation of the population density in county Galway. Population density in the City and in surrounding towns is higher as compared to the rural areas.

4.4 Overview of present WSS situation in County Galway

In Ireland, county Galway has the highest number of WSS serving over 50 people which are either privately, part privately or publicly managed. There are 177 small GWS serving over 50 people in the County Galway. In addition there are 45 public water supply schemes which are managed by Galway County Council (44 Schemes) and Galway City Council (1 Scheme). The water supply scheme in Galway city serves a population of 71,983 (GOI, 2006:21). Galway County Council operates the remaining 44 public water supply schemes (GCC, n.d.).

Due to low population density in Ireland, water supply networks are generally characterised by low connection density per km of main (for example in Caherlistrane / Kilcoona, Ardrahan, and Galway City the number of connections density per km of main are 6, 20 and 75 respectively). This is particularly notable in rural areas where water supply to scattered houses is ensured by the private or part private GWS.

4.5 Study Areas

Sections 4.6, 4.7 and 4.8 describe the processes involved and provide a summary of primary data collected in the selected WSS which are listed below.

- Galway City WSS
- Ardrahan GWS
- Caherlistrane Kilcoona GWS

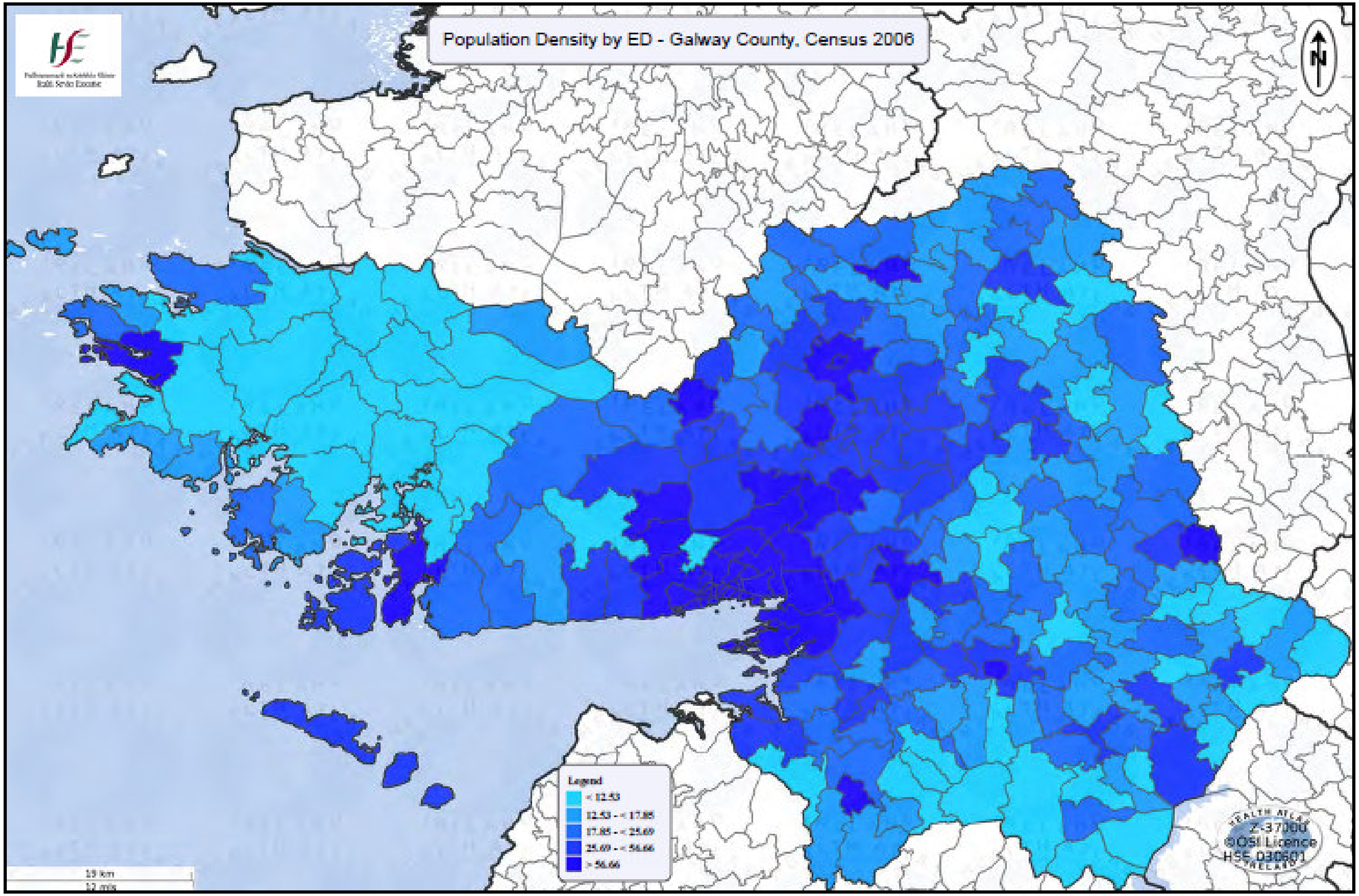

Figure 4.2 Population Densities in Galway by Electoral Division

Source HSE, 2010 (Note ED: Electoral Division)

4.6 Galway City WSS

Water in Galway city is mainly provided by the Terryland Water Treatment Plant whose capacity has recently been upgraded from existing capacity of 33,000m^3/day to 55,000 m^3/day, Frank (2010a). A smaller proportion of water is imported from the Luimnagh WTP. For this study only water supplied by the Terryland WTP has been considered as it supplies most of the water to the city. Figure 4.3 provides a brief outline of the main components of the WSS. A Map showing the different zones in Galway City and detailed layout of the City WSS are enclosed in Appendix B and C respectively.

4.6.1 Raw Water Source

The raw water source for the WTP is the Terryland River, which is fed by the River Corrib. Raw water flows into an intake chamber through coarse screens. Further screening using 5mm band screens are provided before the water is pumped by six raw water pumps. Three pumps feed each stream 1 and 2 at Terryland WTP.

4.6.2 Terryland Water Treatment Plant

In both streams, water flows from the raw water tanks through the treatment processes by gravity. The treatment process at the plant consists of coagulation, flocculation, clarification, filtration, followed by Ultra Violet disinfection, chlorine disinfection and fluoridation.

4.6.3 Water Supply Network

Treated water is pumped to reservoirs at Coolagh and Clifton Hill via the high lift treated water pump station. The water is distributed throughout the city and environs by a network of 426 km of water main.

4.6.4 Water Conservation in the Network

A number of water conservation initiatives, including mains rehabilitation works, were carried out in the City between the mid 1990's and 2002. Galway City Council collates data required with respect to a water conservation programme. A Geographical Information System (GIS) for Water Services in the City was established and includes asset data and comprehensive maps of the network. An updated database is being prepared to include new developments that have taken place in the city in recent years.

Some District Metering Areas (DMA's) have been established in the city, but the city council is in process of improving on the current system. The existing bulk meters are predominantly turbine type meters but also include electromagnetic and insertion type meters. The Supervisory Control and Data Acquisition (SCADA) system in use is 'In Touch'. Flow and level data from each of the service reservoirs in the system relay information back to the central system located in the Terryland WTP. The system enables technical staff at headquarters and

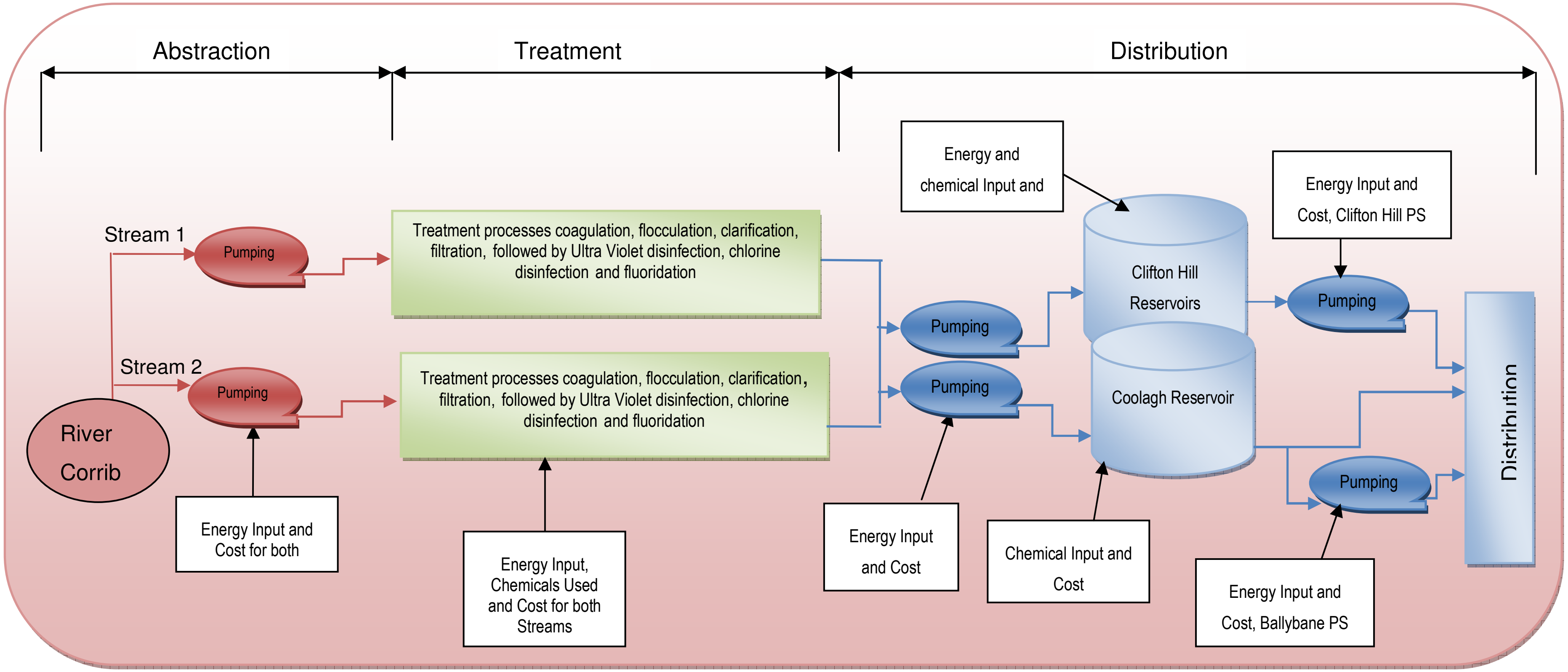

Figure 4.3 Layout of WSS in City Galway

supervisory staff to monitor daily flows in the city water supply. There is also a telemetry system in place that receives flow information from strategic flow meters in the city network.

4.6.5 Non Domestic Water Metering

In line with the Water Services Pricing Policy of the Department of the Environment and Local Government all non-domestic consumers of water are charged by Local Authorities for water services. There are 2,488 (2009 figure based on Crean, 2010) registered non-domestic metered connections in the city. Number of non domestic customers which are not registered is unknown.

Veolia Water is an appointed Private Service Provider for the Galway City Non Domestic Water Metering Project which commenced in 2004. They undertook initial survey, design and installation of all non domestic meters and are currently carrying out the following tasks

- Meter Reading
- Maintenance
- Billing
- Revenue Collection

4.6.6 Primary Data

Table 4.1 provide the primary data collected for the Galway WSS from the different sources such as the Galway City Council, statistical office, etc. Sources of each data are indicated.

Description	Data / Information	Level of Accuracy and reliability of data collected
System input volume for 2009, m^3	Volume from Terryland WTP + Volume imported from Luimnagh WTP - Water exported to adjacent WSS = 12,237,115.00+ 4,968,601 - 1,576,099 (McGuire, 2010a & 2010b) = 15,629,617 m^3	A
No. of Domestic Customers	29,493 (Frank, 2010b)	A
No. of Non Domestic Customers (Metered only)	2,488 (Crean, 2010)[1]	A
Non Domestic Water Consumption in 2009, m^3	2,537,620 (Crean, 2010)[2] + 600*365[3] = 2,756,620	A

1 Number represents the total number of non domestic customers present in the excel sheet provided by Crean (2010). For more details refer to Appendix D.

Description	Data / Information	Level of Accuracy and reliability of data collected
Domestic Water Consumption in 2009, m^3	(75,000*180[4]*365)/1000 + (75,000*0.2*180*90)[5]/1000 = 5,170,500.00	B
Billed consumption in 2009, m^3	2,537,620 + 600*365 = 2,756,620	A
Unbilled authorised consumption in 2009, m^3	5,170,500.00 (Domestic water consumption in 2009)	B
Unauthorised consumption in 2009, m^3	312,592.34 (Assumed 2% of system input volume as illegal connections are expected to be very low)	B
Customer metering inaccuracies in 2009, m^3	50,752.40 (Meters are 5 years old. Accuracy of meters is expected to be good as the quality of water pumped is good. Therefore 2% of metered non domestic flow is assumed)	A
Systematic Data Handling Inaccuracies in 2009, m^3	50,752.40 (Data from meters are read by meter readers and updated by Veolia Water in their data base. Data transfer is expected to be good and hence 2% of the metered non domestic flow is assumed)	B
Length of transmission mains, distribution mains and service connections, km	426 (Frank, 2010b)	B
Number of registered connections	29,493 (Frank, 2010b) + 2,488 (Crean, 2010) = 31,981	B
Estimated number of illegal connections	N/A	B
Average pressure	45 m	B
Historic burst data	Not Recorded	C

[2] This number represents the projected volume of water consumed by the Non Domestic Customers in 2009 based on the readings provided by Crean (2010). Further details are provided in Appendix D.

[3] Approximate unmetered bill non domestic consumption is 600 m^3/day (Frank, 2010b)

[4] Water usage of 180 l/c/d is assumed based on Frank (2010b)

[5] This part represents 20% extra consumption for three months in the summer as described in Section 3.6.3.2

Description	Data / Information	Level of Accuracy and reliability of data collected
Level of supply service (24-hour, intermittent, etc)	24 hour	A
Total electricity cost and units used at Terryland WTP in 2009	5,337,855 kWh (Detail of ESB units are provided in Appendix E)	B
Total electricity cost and units used at Clifton Hill PS in 2009	€10,000.00 a month (Average figure) €120,000 for the year	B
Total electricity cost and units used at Clifton Hill PS in 2009	€2,500.00 a month (Average figure) €30,000 for the year	B
Total ESB Cost in 2009 (€)	€570,245.31 (Refer to Appendix E for details) + 120,000 + 30,000 = €720,245.31	B
Chemical Cost in 2009 (€)	575,119.74 (See Appendix F, Section 4 for more details)	A
Total Inflow for 2009	12,237,115.00 + 4,968,601[6] (McGuire, 2010c) = 17,205,716 m^3	A
Exports to Neighbouring WSA or DMAs	1,576,099 m^3	A
Number of Properties	29,493 Domestic	B
Population Supplied	75,000 (projected figure for year 2009, Frank, 2010c)	B
Occupancy Rate	2.7[7] (CSO, 2006)	A
Per capita consumption in litres/person/day (l/p/d)	180 (Frank, 2010b)	B
Non-Domestic Metered Demand	2,537,620 (Crean, 2010)	A
Non-Domestic Un-metered Demand, m^3	600*365 = 219,000 (Frank, 2010b)	B
Group Water Scheme Bulk Meter demand	N/A	N/A

[6] This is water imported from nearby WSS

[7] This figure is the average number of persons per private household

Description	Data / Information	Level of Accuracy and reliability of data collected
Demand from Major Consumers	Included in the Non Domestic Demands	N/A
Total length of mains in DMA	426 km (Frank, 2010b)	B
Total No. Of Connections	31,981	B
Seasonal variability on demand	20% increase in summer (Assumed)	B

Table 4.1 Galway City WSS Data Collected

4.7 Ardrahan GWS

A schematic layout showing Ardrahan water supply system including abstraction, treatment, and distribution is illustrated in figure 4.4.

4.7.1 Source of Raw Water

Raw is abstracted from three boreholes. One of the boreholes is located approximately 1 km north from the treatment plant while a more recent one is located about 5m from the Treatment Building.

4.7.2 Summary of Treatment Process

Pressure Filtration is the main process plant used to treat water at Ardrahan WTP. The pressure filtration unit consists of a sealed vessel containing Anthracite and Silica Sand Layers.

Raw water is evenly distributed over the filter media by the inlet manifold system. Filtered water is then collected and discharged by a water collection system located at the base of the vessel. The filter media is periodically washed with treated water. The backwash water is discharged to a soak pit.

Chlorination is used as the disinfection and is carried out by the addition of Sodium Hypochlorite. Target residual chlorine after 30 minutes contact time is 0.5 mg/l of free Chlorine. UV disinfection is also provided to ensure protection against chlorine-resistant biological contaminants commonly found in the drinking water source.

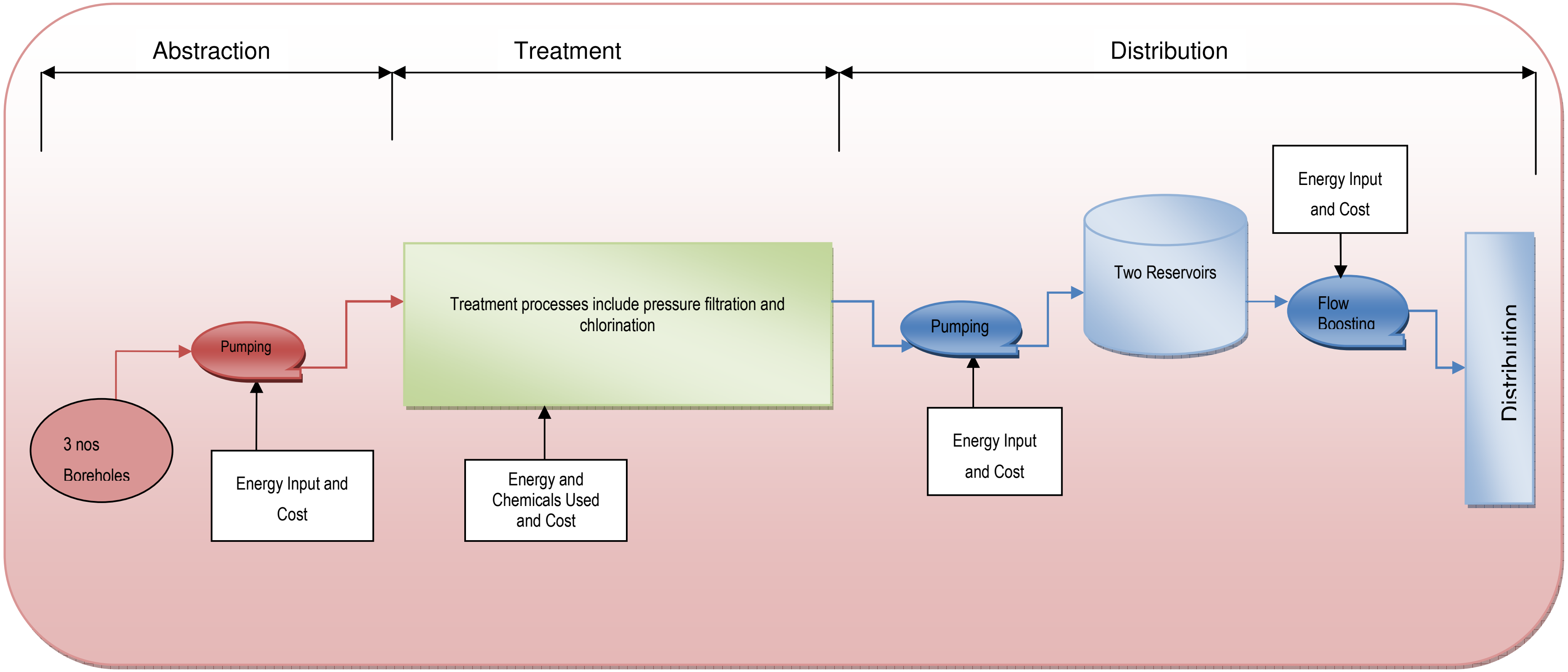

Figure 4.4 Layout of WSS in Ardrahan

4.7.3 Distribution Network

Water is pumped from the treatment plant to two storage reservoirs on Furzypark Hill (Combined Capacity of 72,000 imperial gallons or approximately 327 cubic metres). A booster pumping station close to the reservoirs is used to boost water to both domestic and non domestic consumers in the Furzypark and Rathbane areas in Ardrahan. The average pressure of the network is 40 psi (approximately 2.75 bar), (Kelly, 2010). The distribution network consists of approximately 11.2 km pipework which includes the pressure main from the treatment plant to the two reservoirs.

4.7.4 Primary Data

Table 4.2 summarises the primary data collected. Unless other indicated, the data were obtained from Kelly (2010) and Bonaventure (2010).

Description	Data / Information	Level of Accuracy and reliability of data collected
System input volume for 2009, m^3	65,793	A
No. of Domestic Customers	197	A
No. of Non Domestic Customers	25	A
Non Domestic Water Consumption in 2009, m^3	16,036	A
Domestic Water Consumption in 2009, m^3	34,872	A
Billed consumption in 2009, m^3	50,908 (16,036 + 34,872) less unbilled consumption as detailed below, i.e. 50,908 - 9,085.6 = 41,822.4 m^3	A
Unbilled authorised consumption in 2009, m^3	9,085.6 (10,000 gallons/year or 45.46 m^3/year free allocation to domestic customers. This represents approximately 197 x 45.46 = 8,955.6 m^3. In addition fire fighting and line scouring used approximately 130 m^3).	A
Unauthorised consumption in 2009, m^3	None (This is assumed to be none as the network is small and all customers have to apply for a water connection before obtaining the planning permission)	A

Description	Data / Information		Level of Accuracy and reliability of data collected
Customer metering inaccuracies and data handling errors in 2009, m^3	6,579.3 (60% of meters are 20 years old and the number of customers are small. 8% of the total system input for meter inaccuracies and 2% for data handling errors are assumed.)		A
Length of transmission mains, distribution mains and service connections, km	Length and diameter of main from WTP to reservoirs = 3.2 km, 180 mm dia. HDPE pipe. Total length of pipe in the network from reservoir to customer meters is 8 km and is split as follows. 4 km 220 mm HDPE Pipe (Installed in 2004) 2km 4" Class B Pipe (installed in 1981/1982) 2km 63mm Class B Pipe (installed in 1981/1982)		B
Number of registered connections	197+25 = 222		A
Estimated number of illegal connections	None		A
Average pressure	40 PSI (2.756 bar) after reservoir.		B
Historic burst data	Three meters burst in 2009 due to frost. No major leakage reported or detected.		A
Level of supply service (24-hour, intermittent, etc)	24 hour		A
ESB Units for abstraction, treatment and distribution in 2009 (kWh)	35,762.00 (Hughes, 2010)		A
Total ESB Cost (€) for abstraction, treatment and distribution in 2009	4,741.00 (Hughes, 2010)		A
Date of ESB meter reading (day rates applicable only) for booster station	17/12/08	16/10/09	A
ESB meter reading at start of 2009 (state date) for booster station	16,051	25,062	A

Description	Data / Information	Level of Accuracy and reliability of data collected
ESB Units for 2009 projected based on the above (kWh)	10,819	A
Total ESB Cost (€) for this period	€1,685.00	A
Chemical Cost in 2009 (€)	65,793.00 (See Appendix G, Section 2 for more details)	A
Total Inflow for 2009	65,793 m^3 (Same as system input)	A
Exports to Neighbouring WSA or DMAs, m^3	N/A	A
Number of Properties	197	A
Population Supplied	600	B
Occupancy Rate	600 / 197 = 3.05	B
Per capita consumption in litres/person/day (l/p/d)	185	B
Non-Domestic Metered Demand, m^3/day	43.93	A
Non-Domestic Un-metered Demand, m^3/day	N/A	A
Group Water Scheme Bulk Meter demand, m^3/day	180.25 (average for 2009)	A
Demand from Major Consumers	None	N/A
Total length of mains in DMA, km	11.2	B
Total No. of Connections	197+25	A
Seasonal variability on demand	20% increase in hot summer weather	B

Table 4.2 Ardrahan GWS Data Collected

4.8 Caherlistrane / Kilcoona GWS

Layout of Caherlistrane / Kilcoona water supply system including water abstraction, treatment and distribution is illustrated in Figure 4.5.

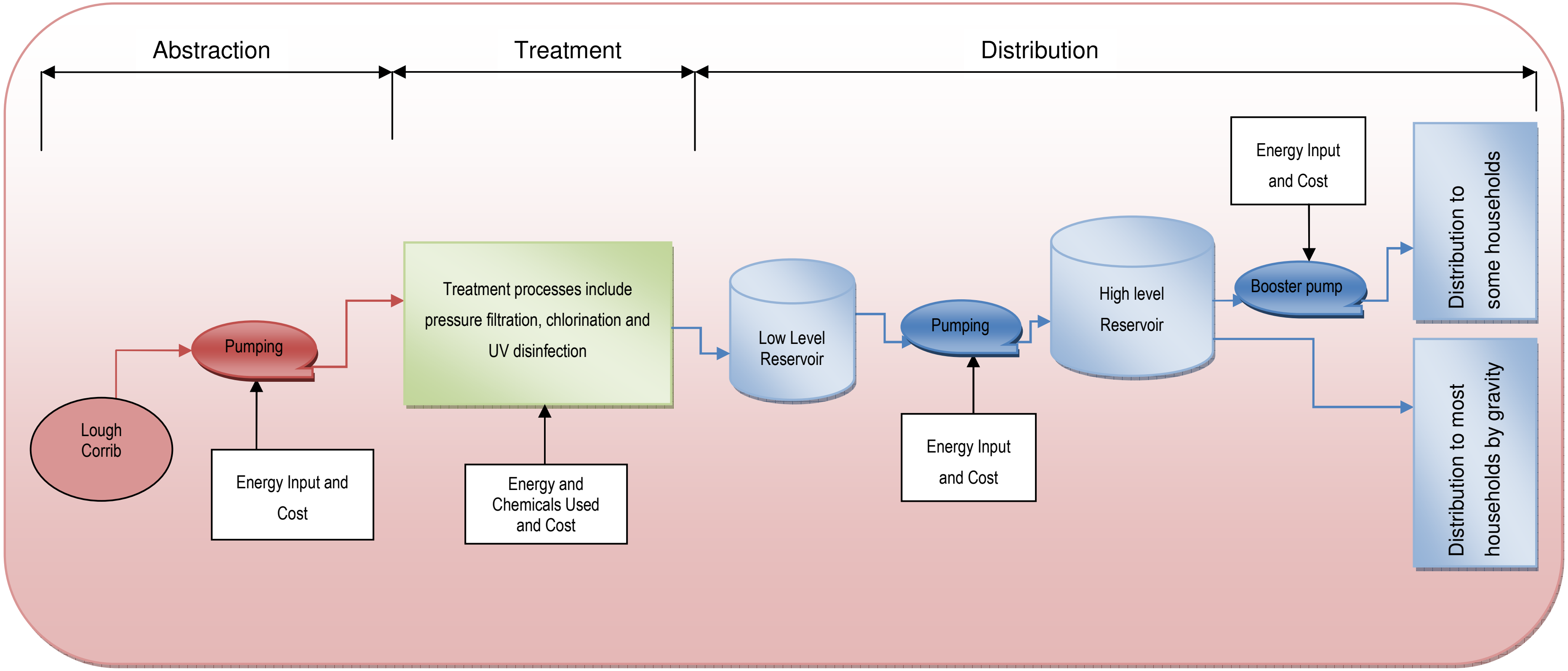

Figure 4.5 Layout of WSS in Caherlistrane / Kilcoona

4.8.1 Source of Raw Water

Water is abstracted from Lough Corrib and is collected in an inlet sump located approximately 1km from the intake. Water is then pumped from the sup to the treatment plant located 7 km upstream.

4.8.2 Summary of Treatment Process

Pressure Filtration is the main process plant used to treat water at Ardrahan WTP. The pressure filtration unit consists of a sealed vessel containing Anthracite and Silica Sand Layers. Chlorination is used as the disinfection and is carried out by the addition of Sodium Hypochlorite. Target residual chlorine after 30 minutes contact time is 0.5mg/l of free Chlorine. UV disinfection is also provided to ensure protection against chlorine-resistant biological contaminants commonly found in the drinking water source.

4.8.3 Distribution Network

Treated water flow from the WTP to a low level reservoir and is then pumped to a high level reservoir. Water from the high level reservoir gravitates to all regions in Caherlistrane and Kilcoona except for one area which is located at a relative higher level. A booster station is used to ensure that households in this area receive a good supply of water.

4.8.4 Primary Data

Table 4.3 summarises the primary data collected for Caherlistrane/Kilcoona GWS. Except where otherwise indicated, data provided in the table below are based on Moran (2010a).

<table>
<tr><th>Description of Data</th><th>Caherlistrane / Kilcoona GWS</th><th>Level of Accuracy and reliability of data collected</th></tr>
<tr><td>System input volume for 2009, m^3</td><td>426,721 m^3</td><td>A</td></tr>
<tr><td>No. of Domestic Customers</td><td>1,050</td><td>B</td></tr>
<tr><td>No. of Non Domestic Customers</td><td>100</td><td>B</td></tr>
<tr><td>Non Domestic Water Consumption in 2009, m^3</td><td rowspan="2">391,740 m^3 (Total Non Domestic and Domestic Water consumed)</td><td rowspan="2">B</td></tr>
<tr><td>Domestic Water Consumption in 2009, m^3</td></tr>
<tr><td>Billed consumption in 2009, m^3</td><td>302,490 m^3</td><td>B</td></tr>
</table>

Description of Data	Caherlistrane / Kilcoona GWS	Level of Accuracy and reliability of data collected
Unbilled authorised consumption in 2009, m^3	89,250 m^3 (free allocation of 100 m^3/year per domestic customer and average 85 m^3 per year free allocation is assumed as some domestic customers uses less than 100 m^3/year)	B
Unauthorised consumption in 2009, m^3	None (This is assumed to be none as the network is small and all customers have to apply for a water connection before obtaining the planning permission)	A
Customer metering inaccuracies and data handling errors in 2009, m^3	17,068.84 (3 years old on average. Inaccuracy is assumed to 2% of the System Input Volume. Data handling error is assumed to be 2% of the systems input)	B
Length of transmission mains, distribution mains and service connections	170 km installed in 1978/79 - out of which 33 km replaced in 1998 and 20 km replaced in 2005. 10 km new pipe laid in 2005. Out of the 170 km, 7 km of pipeworks is used to convey the abstracted water to the treatment plant.	B
Number of registered connections	1,150	B
Estimated number of illegal connections	None	A
Average pressure	3 bar (40 PSI average - max 60 Psi and min 22 Psi)	B
Historic burst data	None recorded	B
Level of supply service (24-hour, intermittent, etc)	24 hour	A
Exports to Neighbouring WSA or DMAs	N/A	N/A
Number of Properties	1050 + 100	B
Population Supplied	4000 people	B
Occupancy Rate	4000 people / 1050 = 3.81	B
Per capita consumption in litres/person/day (l/p/d)	185	B
ESB Units for abstraction, treatment and distribution in 2009 (kWh)	119,245, (Hughes, 2010)	A

Description of Data	Caherlistrane / Kilcoona GWS	Level of Accuracy and reliability of data collected
Total ESB Cost (€) for abstraction, treatment and distribution in 2009	27,479, (Hughes, 2010)	A
ESB Units for booster station in 2009	Day units = 1,256 kWh average bimonthly, Moran (2010b) Night Units = 579 kWh average bimonthly, Moran (2010b) Average bimonthly total = 1,835 kWh Total yearly = 11,010 kWh	B
Total ESB Cost (€) for booster station in 2009	Bimonthly Average €317, Moran (2010b) Total Yearly = €1,902	B
Chemical Cost in 2009 (€)	426,721.00 (See Appendix G, Section 2 for more details)	A
Non-Domestic Metered Demand	Total volume including domestic demand available	B
Non-Domestic Un-metered	None	A
Group Water Scheme Bulk Meter demand in 2009, m^3	426,721	A
Demand from Major Consumers	None	A
Total length of mains in DMA, km	180	B
Total No. Of Connections	1,150	B
Seasonal variability on demand	20% increase in hot summer weather	B

Table 4.3 Caherlistrane / Kilcoona Network Data Collected

CHAPTER 5 SECONDARY DATA, ANALYSIS AND DISCUSSION

Chapter 5 provides a summary of the secondary data determined using the method detailed in Chapter 3 and primary data summarised in Chapter 4. Workings to determine secondary data are provided in Appendices F and G.

The secondary data are used to analyse the total energy loss and cost associated to the annual water leakage from the three WSS. Potential reduction in leakage from each scheme based on an acceptable level of leakage is used to determine the potential energy and costs savings that can accrue if water loss is reduced to this level.

All the data are represented graphically and a detailed analysis including discussions and observations are provided.

5.1 Energy and Costs Involved

Tables 5.1 and 5.2 provide a summary of total variable energy and cost associated to water abstraction, treatment and distribution in Galway City, Ardrahan and Caherlistrane/ Kilcoona WSS in 2009. The variable energy and cost per m^3 of water production for the three schemes are summarised in Table 5.3.

WSS	Total Annual Variable Energy Use (kWh)	Average energy use per m^3 of water (kWh/m^3)
Galway City	6,166,196.33	0.5039
Ardrahan	46,581.00	0.7080
Caherlistrane/ Kilcoona	130,255.00	0.3052

Table 5.1 Total and Average Energy Use in 2009

WSS	Total Annual Variable Cost of Energy Use (€)	Total Variable Cost of Chemical Use (€)	Total Variable Cost (€)
Galway City	673,633.57	575,119.74	1,248,753.31
Ardrahan	6,425.65	574.32	6,999.97
Caherlistrane/ Kilcoona	29,380.68	4,127.76	33508.44

Table 5.2 Total Variable Cost Involved in the Three Schemes in 2009

WSS	Variable Cost of Energy per m^3 of water produced (€)	Variable Cost of Chemical per m^3 of water produced (€)	Variable Cost (Energy and Chemical) per m^3 of water produced (€)
Galway City	0.0548	0.0469	0.1017
Ardrahan	0.0977	0.0087	0.1064
Caherlistrane/ Kilcoona	0.0688	0.0097	0.0785

Table 5.3 Total Variable Cost per m^3 of water in the Three Schemes in 2009

Energy and cost data provided in Tables 5.1, 5.2 and 5.3 have been presented in charts, Figures 5.1, 5.2 and 5.3 respectively. Two different scales have been used in Figure 5.1 and 5.2 to enable the total and average value per m^3 of water or larger values for Galway City and lower values for the two smaller WSS to be presented in a single chart.

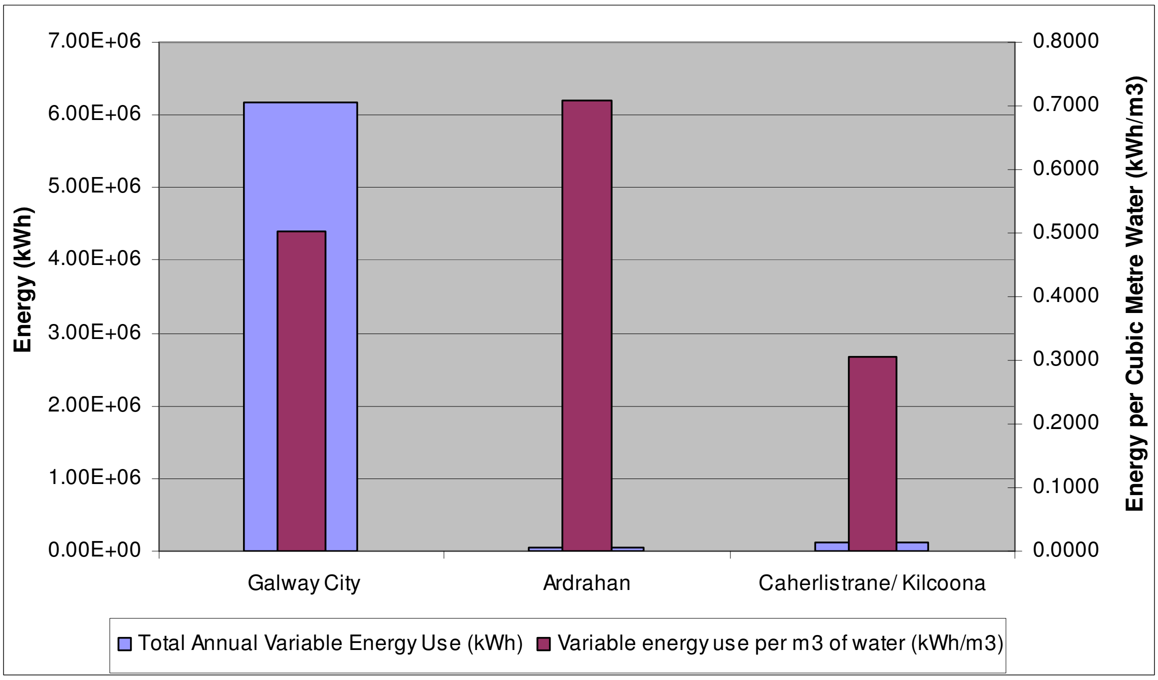

Figure 5.1 Total and Average Energy Use in 2009

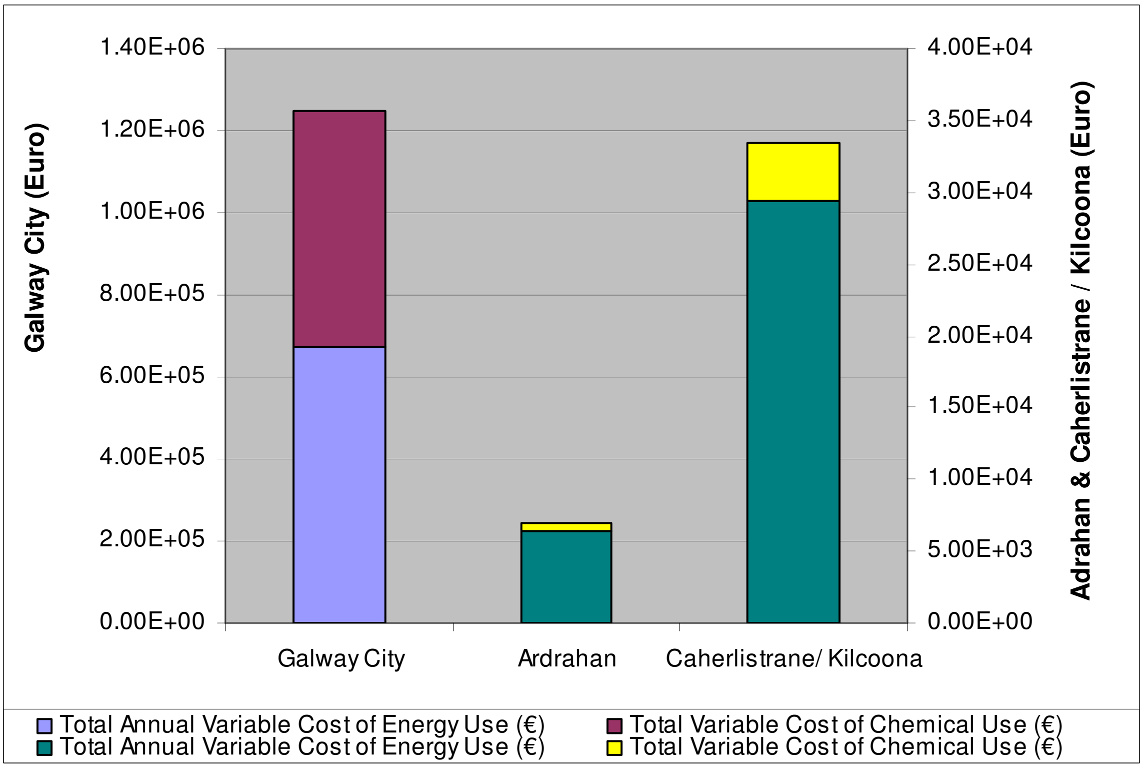

Figure 5.2 Breakdown of Variable Cost

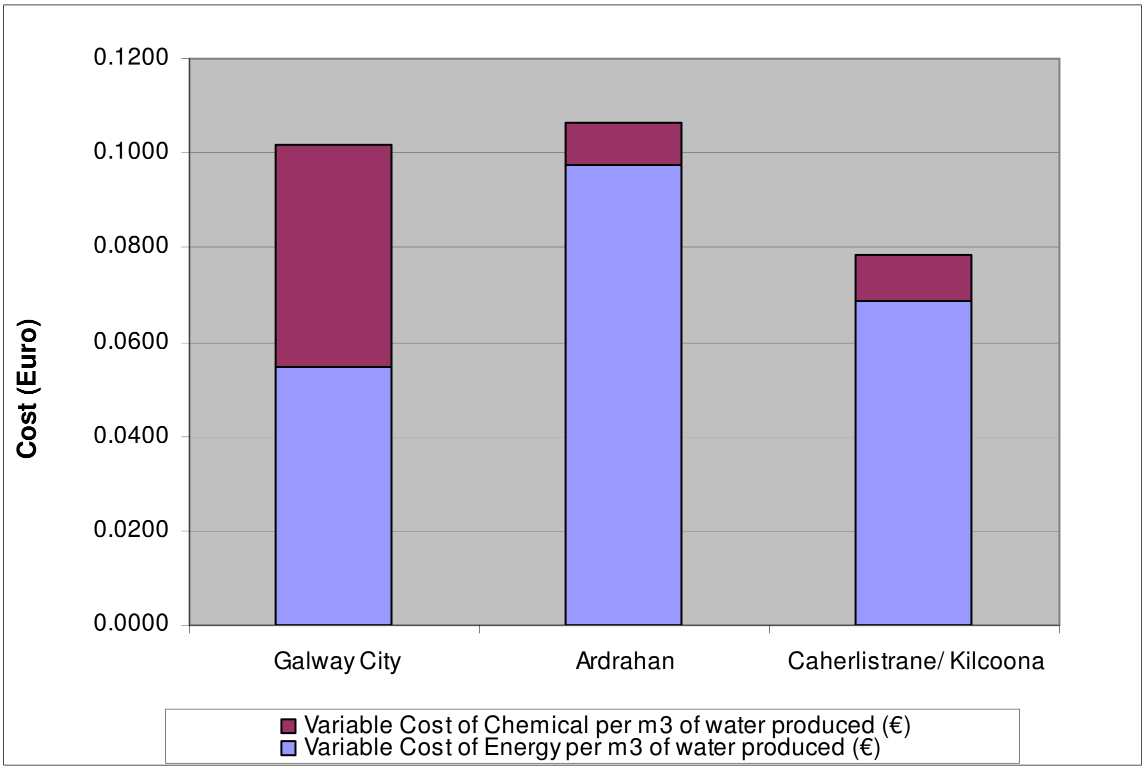

Figure 5.3 Breakdown of Average Cost per m^3 of Water

5.1.1 Observations and Discussions

- As expected, the total annual variable energy is much higher in Galway City WSS as the volume of water abstracted, treated and distributed is relatively higher than the two other WSS. Interestingly it is noted that although the volume of water is higher, the energy use per m^3 of water abstracted, treated and distributed is not the lowest in the City. Energy use per m^3 of water in Ardrahan WSS is highest while it is the lowest in Caherlistrane/ Kilcoona WSS.

- Figure 5.2 shows the total annual variable cost for 2009 in the three schemes and its breakdown in terms of chemical and energy cost. In Galway City, energy cost is only slightly higher than chemical cost while in the other two schemes, the cost of energy is much higher than chemical cost in 2009. Again the total cost in Galway City WSS is higher as the water involved is relatively higher.

- Variable cost per m^3 of water abstracted, treated and distributed as shown in Figure 5.3 is highest in Ardrahan WSS and lowest in Caherlistrane/ Kilcoona WSS. It is also noted that the cost per m^3 of water in Galway City is not the lowest although the volume of water involved is highest.

5.2 Results of Water Audits

Non Revenue Water (NRW) and Unaccounted For Water (UFW) were determined by carrying out water audits. Both water audit methods, i.e. the IWA Water Balance and the UFW: Integrated Flow methods were used. The AWWA Water Loss Control Committee (WLCC) Free Water Audit Software v4.1 (AWWA, 2010b) and the UFW: Integrated Flow Method were used.

5.2.1 Results Based on IWA Water Balance Method

The standard software developed by the AWWA Water Loss Control Committee (WLCC) Free Water Audit Software v4.1 (AWWA, 2010b) are used to determine the non revenue water. Detail results of the water audit are provided in Appendix H and a summary of results are provided in Table 5.4. The band associated to ILI for each scheme has also been indicated.

WSS	NRW (m^3/year)	NRW as a percentage of System Input	Real Loss = CARL (m^3/year)	UARL (m^3/year)	ILI (CARL/ UARL)	WBI Band
Galway City	12,872,997.00	82.40	7,288,401.00	677,500.00	10.76	D
Ardrahan	23,971.00	36.40	8,076.00	Not Valid	Not Valid	N/A
Caherlistrane / Kilcoona	123,931.00	29.00	17,413.00	46,190.00	0.38	A

Table 5.4 Water Balance Result based on the IWA Method

Figure 5.4 and 5.5 displays NRW, CARL (or real losses), and NRW as a percentage of total system input for 2009 as per data available in Table 5.3.

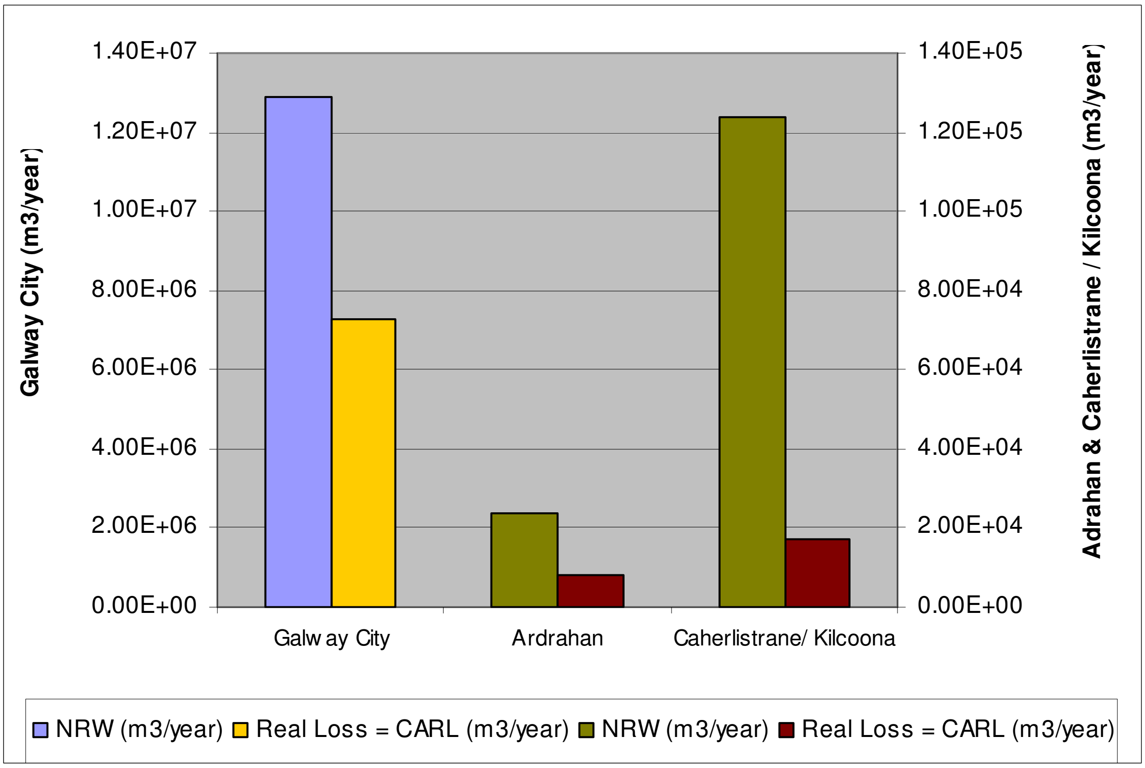

Figure 5.4 NRW and Real Losses in 2009

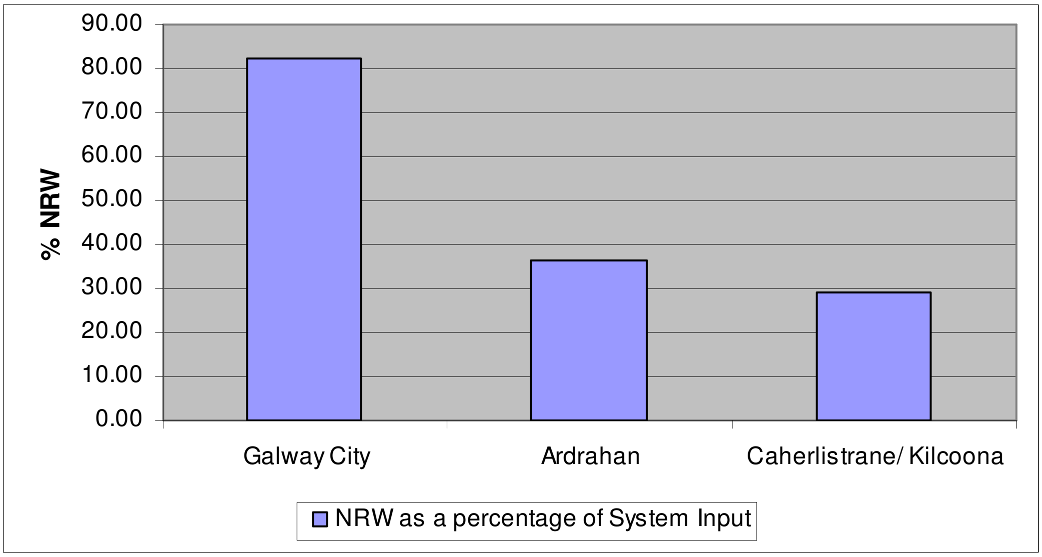

Figure 5.5 NRW as a Percentage of System Inputs

5.2.1.1 Observations and Discussions

- As expected NRW is significantly high in Galway City as compared to the two smaller WSS. Figure 5.5 shows that NRW as a percentage of system input is also significantly high in Galway City (higher than 80%) as compared to Ardrahan and Caherlistrane/ Kilcoona WSS (36.4 and 29.0 respectively).

- ILI for Galway City WSS is above 10 while it is below 2 in Caherlistrane/ Kilcoona WSS. ILI for Ardrahan WSS cannot be determined as UARL is actually not valid for small water distribution systems such as Ardrahan where (L_m x 20) + N_c < 3000. L_m is actually the total length of main and N_c is the total number of connections, AWWA (2010b). L_m and N_c are 11.2 km and 222 connections respectively for Ardrahan WSS which makes (L_m x 20) + N_c = 446 which lower than 3000. This is a shortcoming of using this method for WSS of similar size to Ardrahan.

5.2.2 Results based on UFW Integrated Flow Water Balance Method

The standard excel spreadsheet was used to determine the UFW in the three schemes. Detailed results are provided in Appendix I and a summary of the results are provided in Table 5.5. Figure 5.6 displays the total UFW while table 5.7 illustrates UFW as a percentage of the total inflow in the three schemes.

WSS	UFW, m^3/year	UFW as a percentage of total Inflow	UFW as rate per connection, m^3/conn/year	UFW as rate per km main per hour, m^3/km/hr
Galway City	7,546,201.00	48.30	235.96	2.02
Ardrahan	13,506.00	20.50	60.84	0.14
Caherlistrane/ Kilcoona	30,714.00	7.20	26.71	0.02

Table 5.5 Water Balance Result based on the UFW: Integrated Flow Method

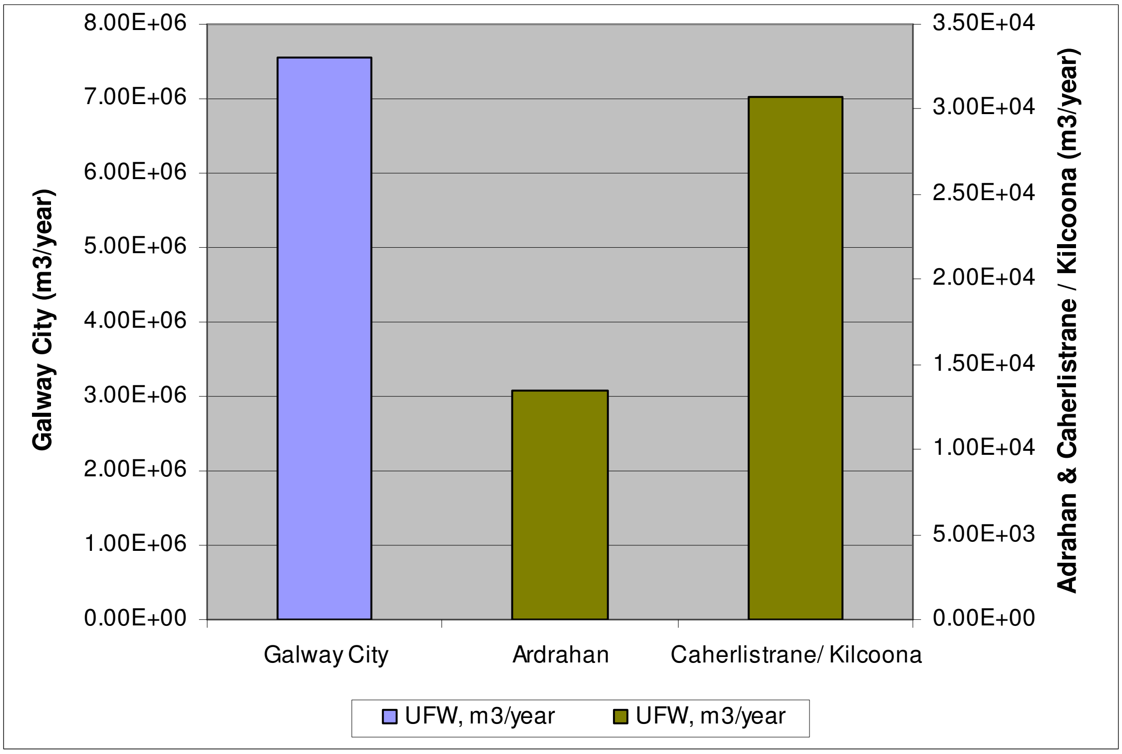

Figure 5.6 UFW in 2009

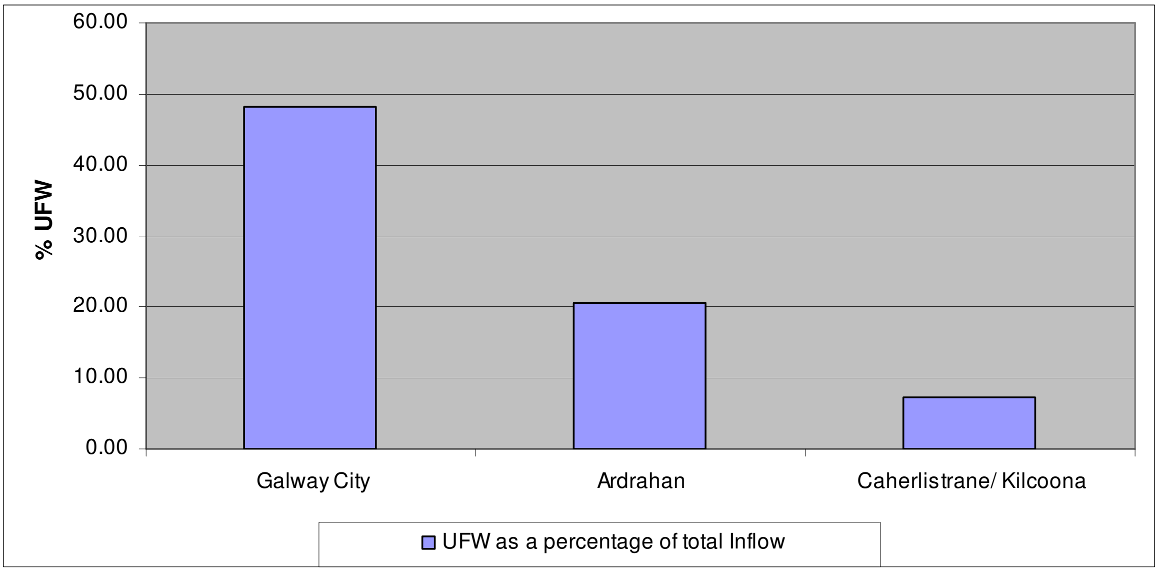

Figure 5.7 UFW as a Percentage of Total Inflow

5.2.2.1 Observations and Discussions

Figure 5.6 and 5.7 confirm that the water loss from Galway City WSS is relatively high as compared to Ardrahan and Caherlistrane/ Kilcoona WSS. Figure 5.7 shows that UFW as a percentage of total inflow in Caherlistrane/ Kilcoona is below 10%. UFW is about 20% in Ardrahan WSS while in Galway City UFW as a percentage of total input is slightly below 50%.

5.2.3 Comparison of Water Balance Results

UFW was determined using equation 6 as provided in Section 3.5.4. UFW obtained using this equation is compared with UFW obtained using the UFW: Integrated Flow Water Balance Method. U_a, NRW and UFW as well as the value of 'NRW-U_a' for the three schemes are provided in Table 5.6 and are presented in Figure 5.8.

WSS	U_a (m^3/year)	NRW, (m^3/year)	UFW, (m^3/year)	NRW - U_a (m^3/year)
Galway City	5,170,500.00	12,872,997.00	7,542,826.00	7,702,497.00
Ardrahan	9,085.60	23,970.00	13,506.00	14,884.40
Caherlistrane/ Kilcoona	89,250.00	123,930.00	30,714.00	34,680.00

Table 5.6 Comparison of NRW and UFW

5.2.3.1 Observations and Discussions

Some discrepancies are noted between UFW determined by the UFW: Integrated Flow Method and that using the relationship (UFW = NRW - U_a). This is thought to be mainly due to the fact that the UFW: Integrated Flow Method assumes a fixed percentage (1%) of the total Inflow for operational use while a percentage for all losses are assumed based on previous experience and data available from international researches carried out in this field with the IWA Water Audit Method.

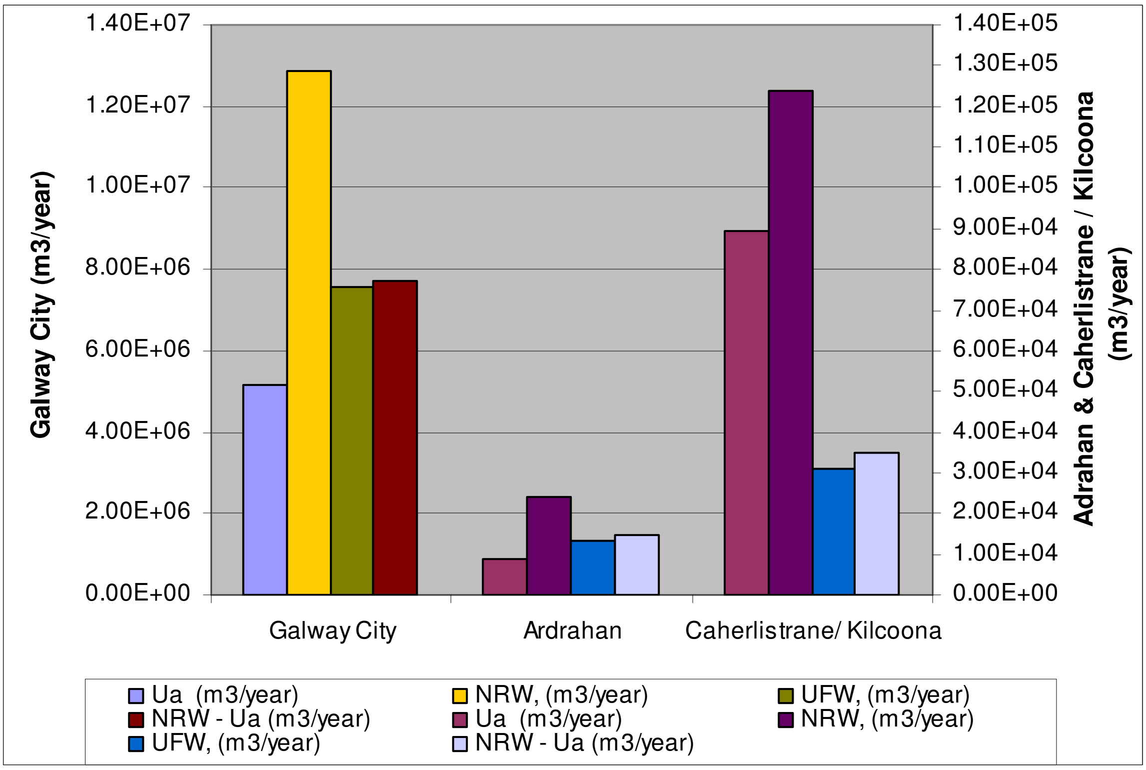

Figure 5.8 Comparisons of UFW and (NRW-U_a)

5.2.4 Potential reduction in CARL and UFW

The potential reductions in both UFW and CARL have been determined as described in Section 3.6.5.

Table 5.7 provides the potential reduction in UFW in the three schemes. The potential reduction in UARL in the two schemes (Galway City and Caherlistrane/ Kilcoona) with the targeted ILI value of 2 is provided in Table 5.8. ILI for Ardrahan WSS has been omitted from Table 5.8 as the UARL for this scheme is not valid.

WSS	Actual level of UFW (%)	Targeted level of UFW (%)	Potential Reduction of UFW (%)	Potential Reduction in UFW (m^3/year)
Galway City	48.30	10	38.30	5,981,164.30
Ardrahan	20.50	10	10.50	6,917.71
Caherlistrane/ Kilcoona	7.20	Current level below 10 already	Nil	Nil

Table 5.7 Potential reduction in UFW

WSS	Actual ILI	Targeted ILI	UARL (m^3/year)	Targeted CARL (m^3/year)	Potential Reduction in CARL (m^3/year)
Galway City	10.76	2	677,500.00	1,355,000.00	5,933,401.00 (7,288,401.00 - 1,355,000.0)
Caherlistrane/ Kilcoona	0.38	Current level below 2	46,190.00	Nil	Nil

Table 5.8 Potential reduction in CARL

5.2.4.1 Observations and Discussions

The potential reduction in UFW and CARL for Galway city is remarkably close (5,981,164.30 as compared to 5,933,401.00). The 1% operational use of water as assumed in the UFW: Integrated Flow Method does seem to be a good estimate in this particular case.

The potential reduction in NRW or UFW for Galway City WSS is relatively high. In Caherlistrane further reduction in leakage is not economical as confirmed by the low percentage UFW (below 10%) and ILI (below 2). In Ardrahan WSS, there is some scope to reduce the current UFW level to below 10%.

5.3 Discount Factor

The energy use for water import into Galway City WSS is not considered in the study and the energy and cost associated to part of the leakage associated to water import cannot be quantified. To associate energy and cost to the fraction of water that leaks from Terryland WTP, parameters such as water losses, UFW, etc. have been discounted proportionately by a discount factor as given below.

$$\text{Discount Factor} = \frac{\text{(Water Produced at Terryland WTP - Water Exported)}}{\text{Total System Input}}$$

$$= (12{,}237{,}115.00 - 1{,}576{,}099.00)/\ 15{,}629{,}617.00$$

$$= 0.6822$$

5.4 Energy Loss due to Leakage and Associated CO_{2eq}

Energy loss in a water distribution network is the product of variable energy used per m^3 of water abstracted, treated and distributed; and the total water leakage in the WSS. Water leakage (or the Current Annual Real Losses, CARL) determined by the IWA Water Balance method or the UFW: Integrated Flow Method and the energy use per m^3 of water can be used to estimate the energy loss due to leakage in year 2009. Table 5.9 illustrates the total energy loss and the potential energy savings that can accrue if leakage level in the WSS is reduced to an acceptable level. It is to be noted that the energy Loss for Galway City is associate to water supplied from Terryland WTP only. The calculation does not include water that is imported and exported from Terryland WTP. This is achieved by using the discount factor of 0.6822 as determined in Section 5.3. For Ardrahan WSS, the UFW value is used rather than CARL which allows quantifying the potential reduction of UFW for this scheme.

WSS	Variable energy use per m^3 of water (kWh/m^3)	CARL / UFW (m^3/year)	Total Energy Loss (kWh)	Potential Reduction in CARL / UFW (m^3/year)	Potential Reduction in Energy Loss (kWh)
Galway City	0.5039	4,972,147.16	2,505,464.95	4,047,766.16	2,039,669.29
Ardrahan	0.7080	13,506.00	9,562.25	6,917.71	4,897.74
Caherlistrane/ Kilcoona	0.3052	17,413.00	5,314.45	Nil	Nil

Table 5.9 Energy Loss due to Leakage and Potential Reduction in 2009

Table 5.10 shows CO_{2eq} associated to energy loss and potential reduction in energy loss in 2009 for the three schemes. Based on Howley and Gallachóir (2005:2), 651g of CO_2 is associated with every 'kWh of electricity consumed in aggregate' to estimate CO_{2eq} for the three schemes.

WSS	CO_{2eq} associated to total energy loss (Kg)	CO_{2eq} associated to Potential reduction in energy loss (Kg)
Galway City	1,631,057.68	1,327,824.71
Ardrahan	4,503.43	3,188.43
Caherlistrane/ Kilcoona	3,459.71	Nil

Table 5.10 CO_{2eq} Associated to Energy Loss and Potential Reduction in 2009

Figure 5.9 shows the total energy loss and potential reduction in energy if leakage level is reduced to an acceptable level for Galway City, Ardrahan, Caherlistrane/ Kilcoona WSS in year 2009.

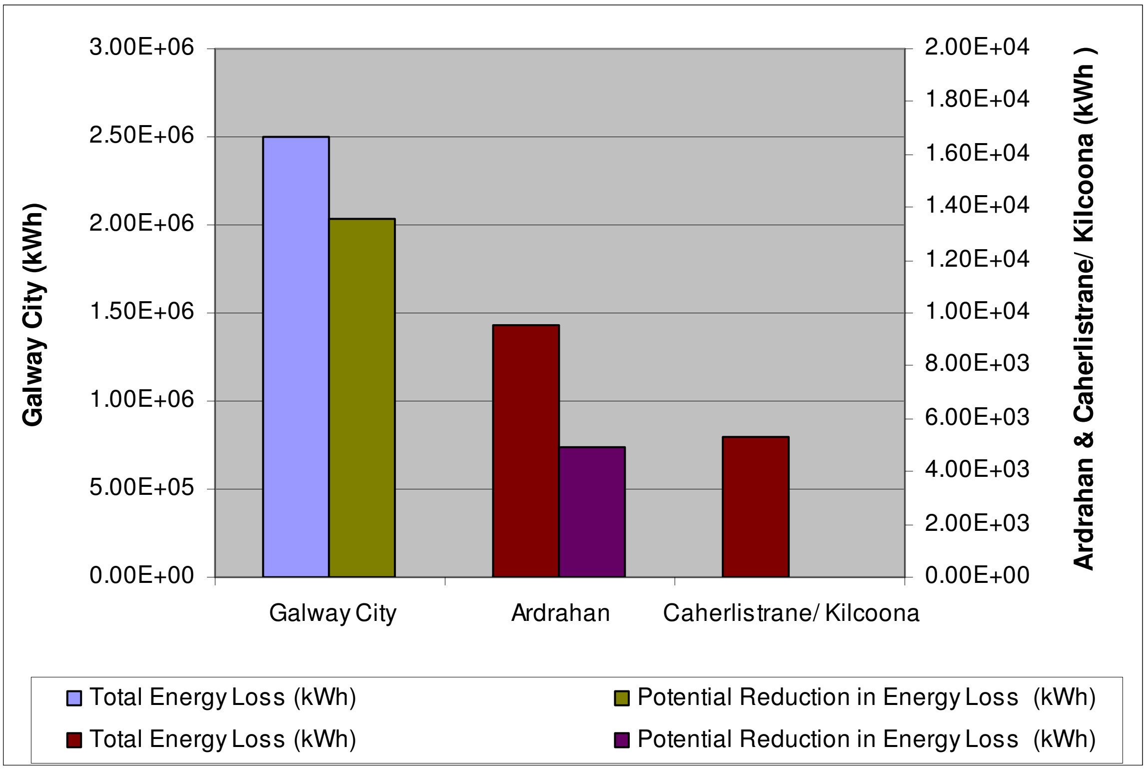

Figure 5.9 Table 5.9 Energy Loss due to Leakage and its Potential Reduction in 2009

Figure 5.10 shows CO_{2eq} associated to total energy loss and potential reduction in energy if leakage level is reduced to an acceptable level for Galway City, Ardrahan, Caherlistrane/ Kilcoona WSS in year 2009.

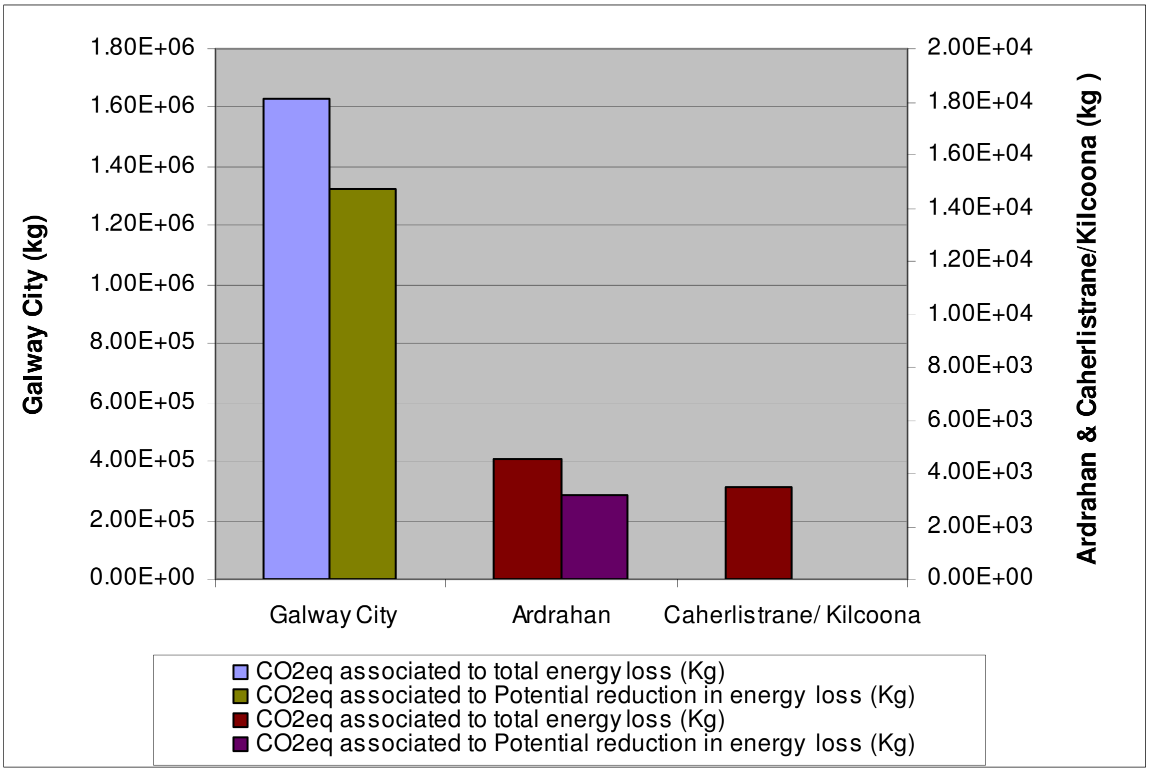

Figure 5.10 CO_{2eq} Associated to Energy Loss and Potential Reduction in 2009

5.4.1 Observations and Discussions

The energy associated with total water loss in Galway City in 2009 is slightly over 2.5 million kWh with potential savings of over 2.0 million kWh if water loss was reduced to an acceptable level. The projected savings in energy if water loss is at an acceptable level is approximately 3 million kWh assuming all water is supplied by Terryland WTP in 2009. CO_{2eq} associated with energy loss and potential reduction in energy loss for Galway City are nearly 1,600 tons and 1,300 tons respectively. CO_{2eq} associated with projected savings in energy assuming all water is supplied by Terryland WTP in 2009 is over 2,000 tons. Considering that an average dwelling uses approximately 5,000 kWh of electricity and emits approximately 10 tons of CO_{2eq} annually (energy related emission including electricity), Howley and Ó Gallachóir (2005:54&56), the total potential energy saving in Galway City WSS is equivalent to the electricity usage by approximately 600 dwellings and the associated CO_{2eq} is equivalent to the emissions from 200 dwellings.

The total real loss in Ardrahan WSS in 2009 was found to be over 8,000 cubic metre with potential water loss reduction of about 7,000 cubic metre achievable if leakage was to an acceptable level. The potential water loss reduction in Ardrahan represents approximately 5,000 kWh of energy and over 3 tons of CO_{2eq}.

The real loss in Caherlistrane/Kilcoona WSS was found to be over 17,000 cubic metre and the leakage level was found to be at an acceptable level. Energy associated with the total real loss was estimated to be over 5,000 kWh which represents over 3.4 tons of CO_{2eq}.

While there is no further reduction of energy loss possible due to reduction in real loss in Caherlistrane/ Kilcoona WSS, the potential reduction in energy loss by reducing leakage to an acceptable level in Galway City and Ardrahan WSS is not negligible.

5.5 Cost Associated to Leakage

The cost associated to leakage is essentially the variable cost of water abstraction, treatment and distribution. Cost associated to leakage is the product of variable cost of water abstraction, treatment and distribution per m^3; and the estimated volume of water leakage. The total cost associated to leakage and the potential cost reductions in the three schemes if the leakage level is reduced to an acceptable level are provided in Table 5.11. It is to be noted that the Energy Loss for Galway City is associated to water supply from Terryland WTP only. Water that is imported or exported has been omitted from the calculation by using a discount factor of 0.6822 as determined in Section 5.3. Again for Ardrahan WSS, the UFW value is used rather than CARL which allows quantifying the potential reduction of UFW for this scheme.

Figure 5.11 shows the total cost associated to leakage and the potential cost reduction in the three schemes if the CARL/UFW level is reduced to an acceptable level.

WSS	Variable Cost of water (€/m^3)	CARL / UFW (m^3/year)	Total Cost Associated to CARL/ UFW (€/year)	Potential Reduction in CARL / UFW (m^3/year)	Potential Reduction in Cost (€/year)
Galway City	0.1017	4,972,147.16	€505,667.37	4,047,766.16	411,657.82
Ardrahan	0.1064	13,506.00	€1,437.04	6,917.71	736.04
Caherlistrane/ Kilcoona	0.0785	17,413.00	€1,366.92	Nil	Nil

Table 5.11 Total Cost Associated to Leakage

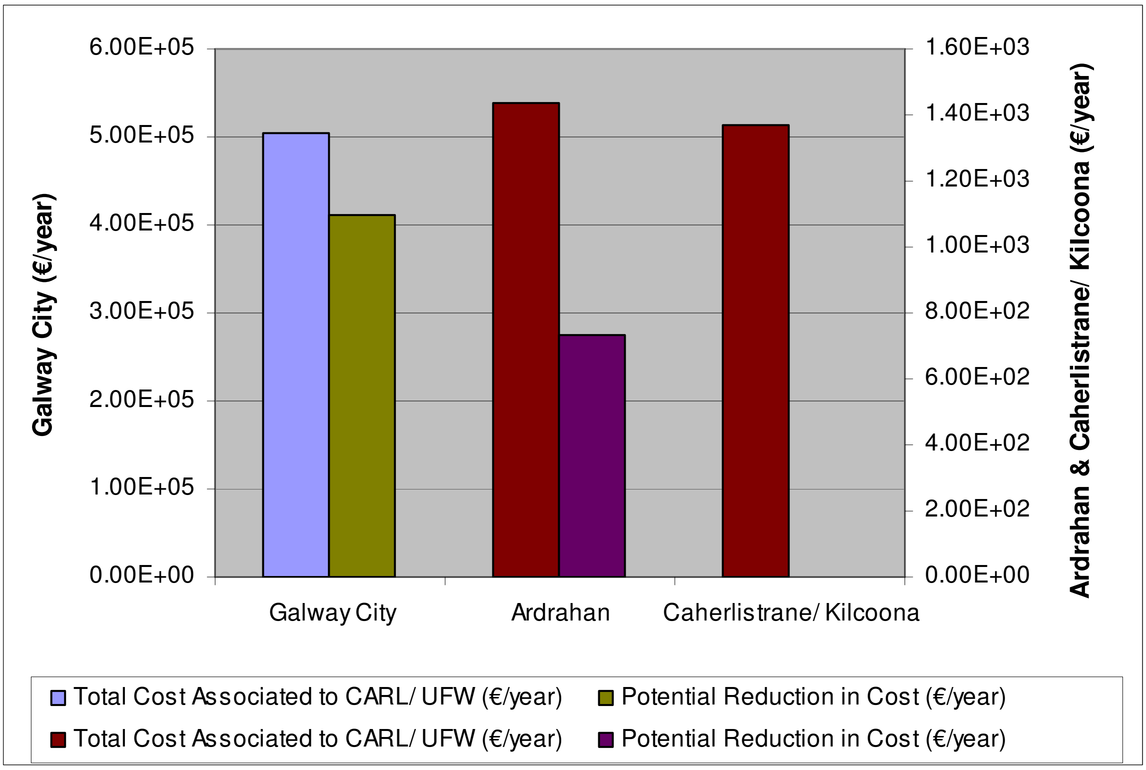

Figure 5.11 Total cost associated to leakage and potential savings for year 2009

5.5.1 Observations and Discussions

It is evident from Table 5.11 and Figure 5.11 that the cost implication to leakage is quite significant and as expected it is much higher in Galway City WSS due to its larger size. Further cost saving cannot be achieved in Caherlistrane/ Kilcoona WSS, but savings in Galway City is high enough to warrant further reflection.

The projected cost and potential reduction in cost if leakage is reduced to an acceptable level in Galway City WSS assuming that the all water is supplied from Terryland WTP are 741,230.39 and 603,426.88 in 2009 respectively using the discount factor of 0.6822.

CHAPTER 6 CONCLUSIONS AND RECOMMENDATIONS

This chapter provide the conclusions of the study based on results and discussions provided in Chapter 5. Recommendations and suggestions for further study are also provided.

6.1 Conclusions

The study has successfully exposed the severity of leakage in the three WSS by associating energy and cost to it. The method used proves to be adequate for this study but there are certain limitations in regards to data availability to WSPs. This led to certain assumptions which had some impact on the final results.

The study met the original aim and objectives which are summarised below.

- Cost and energy associated with leakage in the three WSS (Galway City, Ardrahan, and Caherlistrane/Kilcoona) in County Galway were determined.
- Variable energy and costs associated with water abstraction, treatment and distribution were established in the three WSS.
- Two methods were used to carry out top down water audits in three WSS to estimate UFW, NRW, ILI, etc.
- The total volume of water loss including leakage and the potential reduction in water loss in the three WSS were exposed.
- CO_{2eq} associated to energy that can potentially be reduced through reduction of water loss and leakage was estimated.
- The significance of considering factors such as energy and cost savings while implementing a leakage management strategy has been discussed.

Detailed conclusions are provided in the following sections.

6.1.1 Leakage Level

The leakage level was successfully determined using the two water balance methods. Based on the results obtained, the following are the conclusions on the leakage level in the three WSS.

* In Galway City WSS the volume of water loss or unaccounted for is as high as the volume consumed. The level of leakage is lower in the smaller schemes and this implies that the smaller schemes may have a better system in place to manage leakage. It could also mean that the size of these WSS is more manageable.

* A main difference that exists between Galway City WSS and the other two WSS is metering and water charge which is another reason for higher level of water losses in Galway City. In the City only non domestic customers are metered and charged at a flat rate while in the Group Water Schemes all domestic and non domestic customers are metered. Non domestic customers in these GWS are charged a flat rate for all water used while domestic customers are charged only above a minimum free allocation of water. Metering and charging actually help to quantify volume used by customers and also provide additional incentives to the customers to reduce water usage or wastage. It is believe that similar provision in Galway City may help to reduce level of leakage.

* The two different water audit methods used has proved to be very useful for assessing and comparing leakage in the three WSS in County Galway. The method developed by IWA has recently received lot of attention and has proved to be very successful in many countries around the world but it has some limitations especially when considering small WSS like Ardrahan WSS. For this reason, the UFW: Integrated Flow Method may still be used but more work is required to standardise the method and quantify certain commercial losses.

* Based on the ILI results in Table 5.4 and associated ILI band, it can be concluded that leakage management in Galway City WSS is not adequate and the recommended activities based in Table 2.6, Section 2.10.2.2 are as follows.

  - Review asset management policy
  - Deal with deficiencies in manpower, training and communications
  - 5-year plan to achieve next lowest band
  - Fundamental peer review of all activities

  ILI band associated to Caherlistrane is A which means that the leakage is at an acceptable level and the recommended activities are

  - Investigate pressure management options
  - Investigate speed and quality of repairs
  - Check economic intervention frequency

  ILI result for Ardrahan WSS is not valid due to its size. In similar schemes the UFW: Integrated Flow Method can be an option as concluded in the previous conclusion. The potential reduction in UFW was found to be 6,917.71 m^3/year which shows that there is potential for further reduction of water losses in Ardrahan.

* As there is no domestic water meters in Galway City, the total loss determined by both water balance methods include water losses in the water distribution networks as well as in pipeworks in the customer service line. It is very difficult to establish the volume of water

loss out of the total loss within the public network as compared to water loss / wastage within domestic compounds. This is another reason why universal customer metering is required in the Galway City.

6.1.2 Energy and Associated CO_{2eq}

Variable energy uses in terms of kWh per year and per cubic metre of water in the three WSS and potential energy savings if leakage level is reduced to an acceptable level. Equivalent figures were determined for CO_{2eq} associated to energy loss and potential savings. The following are conclusions based on the results.

* The result confirms that variable energy per cubic metre of water produced and delivered in a WSS is not necessarily low in a larger WSS such as Galway City. Other factors such as the topography between the water source and its destination distance from the bulk water supply, and the integrity of the distribution networks have impact on the energy use per m^3 of water delivered.

* As expected, the total energy associated to water loss and potential reduction in energy use if water loss is reduced to an acceptable level is significant, especially in Galway City. In Ardrahan WSS, it is found that the potential reduction is low. Being a large network on its own, Galway City Council can invest in additional resources both in terms of manpower and equipment to reduce the level of water losses. In Ardrahan WSS, the fact that the potential reduction in energy losses is low, may not justify the use of full time resources to manage leakage. For similar WSS in County Galway, there may be scope to build up a central team responsible for leakage control activities in small WSS in the Rural Areas. This team could be formed with the help of Galway County Council and the National Federation of Group Water Scheme.

* Determination of energy use during water abstraction, treatment and distribution helped to determine the indirect CO_{2eq} associated to the three WSS schemes considered. Similar exercise in the remaining WSS in Ireland may help to quantify the total indirect CO_{2eq} associated to the potable water sector in the country although more works are required to determine the CO_{2eq} associated to chemical use to help quantify the total indirect CO_{2eq} associated to potable water supply in Ireland. The estimate of CO_{2eq} for the water sector is important as it will help to quantify the contribution of this sector to the total GHG emission in Ireland.

* Moreover, the potential CO_{2eq} reduction due to reduction in leakage to an acceptable level shows that the water sector may help to reduce the overall Ireland GHG emission to some extent. It may help Ireland reduce its current level of CO_{2eq} to below the Kyoto target level which is set to slightly above 60 Million tons (Howley and Gallachóir, 2005:25) for the period 2008 – 2012. The Kyoto level was actually breached in 1997 due to increasing level of GHG emission from the different sources.

6.1.3 Cost Associated with Leakage

Leakage has also an impact on the variable cost of water production and delivery as shown by the results in Chapter 5. The potential cost savings if leakage is reduced to an acceptable level for year 2009 was found to be significant especially in Galway City. Based on the results obtained, the following are concluded.

* The unit variable cost of water in Galway City is highest which again confirms that unit cost of water does not depend solely on size of a WSS but also on factors such as raw water quality, topography of the area it serves, etc.

* The potential savings in cost if water loss is reduced to an acceptable level shows that there is scope for leakage reduction in Galway City. As discussed in Section 6.1.2, additional resources is required to tackle the problem of leakage and this can easily be justified by the potential cost which can be saved if leakage is reduced to an acceptable level.

6.2 Recommendations and Future Works

The following are recommendations based on the results of the study. Future works which can be undertaken to help better manage leakage in County Galway or countrywide in Ireland have also been proposed.

6.2.1 Recommendation No. 1

The WSS in Galway City is in a poor state especially in terms of leakage as seen by the above results and conclusions. Based on the ILI band, several actions are required which are mainly related to the leakage control policies of the City Council as listed in the conclusions above. The primary solution to tackle the problem is believed to be metering and billing as this is the fundamental difference between the smaller WSS in the rural areas where leakage level is lower and Galway City WSS. Apart from being a mean to quantify the volume of water consumed by domestic customers, it is believed that this measure will help these customers to use water more cautiously and hence reduce overuse and reduce loss of water in their service pipes. Reduction in water loss would also reduce energy and cost associated to the reduction.

6.2.2 Recommendation No. 2

It is evident from the results that the smaller WSS in County Galway are better managed as the level of water loss is lower than the larger WSS in Galway City. To reduce level of leakage in City Galway, another fundamental step is to set up more manageable Data Management Areas (DMAs). The DMAs can be sized such that they serve 1000 - 5000 connections approximately. Geographic information systems (GIS) can be used for routine monitoring of flow and pressure in each DMA. This may help to routinely quantify the leakage level in each DMA and hence help prioritise leakage control activities. It is also important to include data such as energy and cost associated to leakages in each DMA as the level of energy especially due to pumping in the DMAs may be different because of topography and their distance.

6.2.3 Recommendation No. 3

As per recommendation No. 2, it is important to assess the magnitude of leakage problem to prioritise intervention in WSS which are in a critical state. The Author believes that to assess the magnitude of the problem, we cannot only focus on a single aspect of leakage such as volume of leakage in each WSS or DMA, or simply on cost associated to it. The assessment need to integrate perspective from a wide range of disciplines which are presented using the acronym SHTEFIE and stands for Social; Health and Hygiene; Technical; Economic; Financial; Institutional; Environmental (Reed et al., 2008:1.8). The Author believes that factors such as leakage (UFW/CARL) as a percentage of system input, potential reduction in leakage, the benefit in terms of cost and energy of reducing leakage to an acceptable level encompass all the SHTEFIE disciplines.

A simple model can be built by assigning a score to these four factors by taking into consideration all the disciplines. For a particular factor for example, a weighted score between 0-9 can be assigned, with 0 indicating good status and 9 indicating poor status. Guidelines need to be put in place to help assign scores associated to a range of values for each factor. The scores for a particular scheme may then be added together to determine its current status. This is a very initial thought, but the model can be further developed with more study and research. A simple model has been shown as an example for the three WSS considered in this study to illustrate the Author's initial thought.

The four factors proposed to be considered and the scores attributed to each factor based on results obtained are given in Table 6.2. For this example, the possible scores for each factor used are provided in Table 6.1. You will note for this example the %UFW have been used instead of %CARL.

In this particular scenario, score 36 would mean leakage control measures are required immediately while score of 0 would mean leakage is at an acceptable level but continuous monitoring is required. You will note that Galway City has a high score of 20 which means that leakage control more urgent than the other two schemes where the score is 0 and 2. This example shows a medium WSS and two smaller WSS. The result may be more important if the medium WSS is split into smaller DMAs as recommended earlier where each DMA and small WSS are compared using this model.

Again, the model is based on the Author's preliminary thought for the WSS being considered which can be further researched and studied for implementation in county Galway as well as countrywide in Ireland.

% UFW	Potential Leakage Reduction (CARL/UFW), m^3/year	Energy Associated to potential Leakage Reduction, kWh	Cost associated to Potential Leakage Reduction, €	Score
0 - 9	0 - 599,000	0-299,000	0 - 99,000	0
10 - 19	600,000 -1,199,000	300,000 - 599,000	100,000 - 199,000	1
20 - 29	1,200,000 -1,799,000	600,000 - 899,000	200,000 - 299,000	2
30 - 39	1,800,000 - 2,399,000	900,000 -1,199,000	300,000- 399,000	3
40 - 49	2,400,000 - 2,999,000	1,200,000 -1,499,000	400,000 - 499,000	4
50 - 59	3,000,000 - 3,599,000	1,500,000 -1,799,000	500,000 - 599,000	5
60 - 69	3,600,000 - 4,199,000	1,800,000 - 2,099,000	600,000 - 699,000	6
70 - 79	4,200,000 - 4,799,000	2,100,000 - 2,399,000	700,000 - 799,000	7
80 - 89	4,800,000 - 5,399,000	2,400,000 - 2,699,000	800,000 - 899,000	8
90 - 99	5,400,000 - 6,000,000	2,700,000 - 3,000,000	900,000 - 100,000	9

Table 6.1 Scores Associated to Range of Values for Leakage Factors

Factors	Galway City WSS	Score	Ardrahan WSS	Score	Caherlistrane/ Kilcoona WSS	Score
%UFW	48.30	4	20.50	2	7.20	0
Potential Leakage Reduction (CARL/UFW), m^3/year	4,047,766.16	6	6,917.71	0	Nil	0
Energy Associated to potential Leakage Reduction, kWh	2,039,669.29	6	4,897.74	0	Nil	0
Cost associated to Potential Leakage Reduction, €	411,657.82	4	736.04	0	Nil	0
Total Score		**20**		**2**		**0**

Table 6.2 Scores Associated to Leakage Factors for the Three WSS Studied

6.2.4 Recommendation No. 4

Generally in Ireland the responsibility of the water supply sector is shared among various organisations such as the Group Water Schemes, County Councils, City Councils, National Federation of Group Water Scheme, Department of Environment, Heritage and Local Government, etc. As mentioned in Sansom et al. (2005:117) there are two priority aspects of a utility's work which are neglected in similar situation and these are non revenue water and effective management of asset to achieve adequate and reliable services. This could be one of the main reasons for a high level of water loss in Ireland.

With various departments, organisations involved in the Water Supply Sector in Ireland, inadequate communication, collaboration, etc. could be a major constraint. An important step to proper manage water loss and the water sector in general in Ireland would be the introduction of New Public Management where the Department of Environment, Heritage and Local Government take the enabling role while a single Water Utility with sufficient autonomy is set up to manage the water sector. This necessitates lot of reflection and may require time to undertake but action are required in this direction to see a better managed water sector with an acceptable level of water loss in the future.

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APPENDIX A BREAKDOWN OF GROUP WATER SCHEMES BY COUNTY

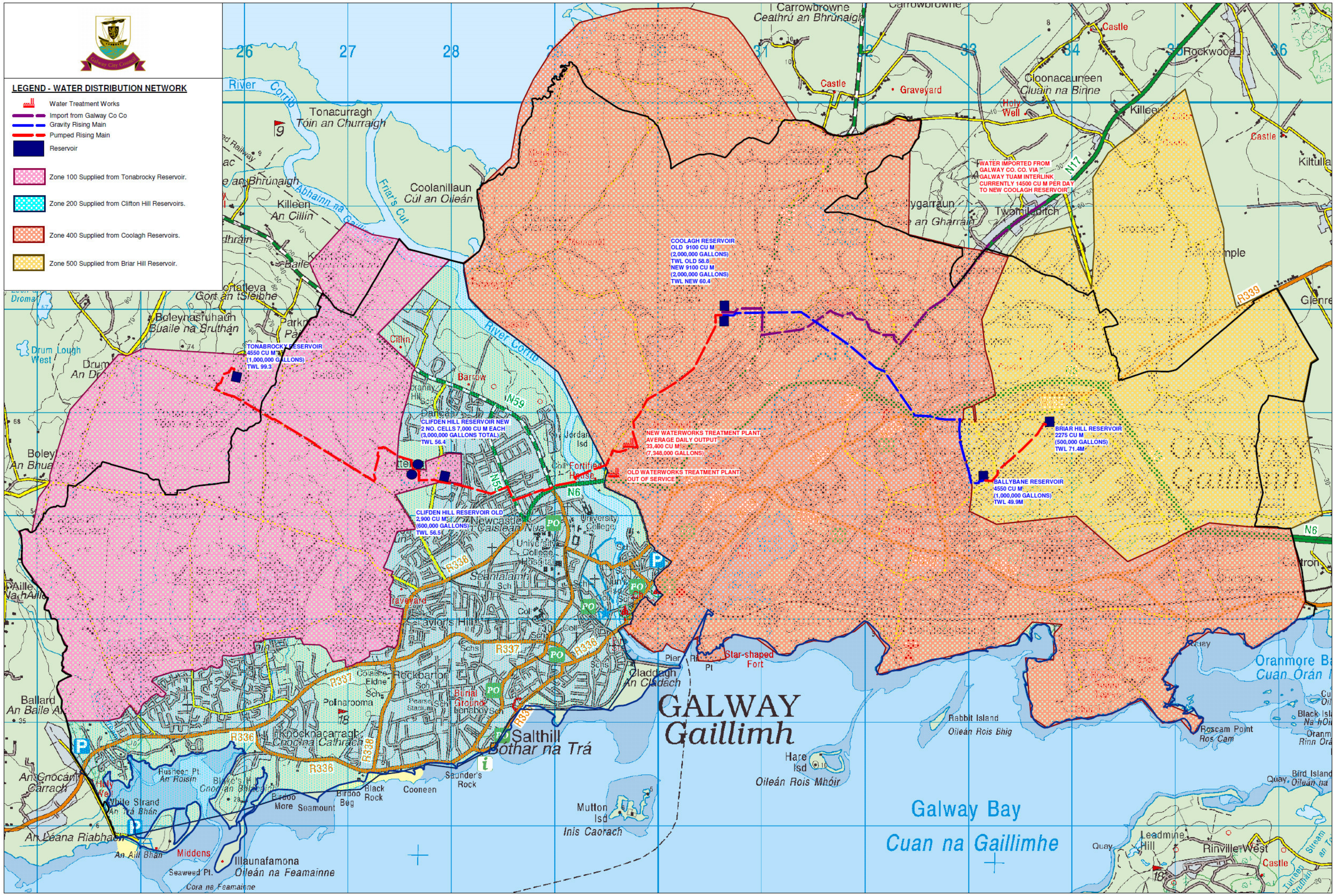
County	Annex 14		Non Annex 14		All Schemes	
	Schemes	Domestic	Schemes	Domestic	Schemes	Domestic
Carlow	9	843	2	11	11	854
Cavan	25	7,759	3	1,401	28	9,160
Clare	9	1,139	4	2,377	13	3,516
Cork	0	0	33	1,237	33	1,237
Donegal	26	2,238	10	488	36	2,726
Galway	139	17,852	38	3,135	177	20,987
Kerry	0	0	12	707	12	707
Kildare	3	523	1	84	4	607
Kilkenny	0	0	25	3,385	25	3,385
Laois	10	1,659	6	187	16	1,846
Leitrim	18	1,943	9	545	27	2,488
Limerick	43	3,456	14	1,563	57	5,019
Longford	0	0	6	332	6	332
Louth	9	890	0	0	9	890
Mayo	79	10,890	32	3,145	111	14,035
Meath	4	451	1	233	5	684
Monaghan	13	7,500	0	0	13	7,500
North Tipperary	0	0	41	1,995	41	1,995
Offaly	14	3,012	5	893	19	3,905
Roscommon	29	2,308	5	360	34	2,668
Sligo	13	2,319	3	118	16	2,437
South Tipperary	2	124	1	90	3	214
Waterford	0	0	4	94	4	94
Westmeath	2	246	0	0	2	246
Wexford	6	518	4	849	10	1,367
Wicklow	0	0	17	671	17	671
Total	**453**	**65,670**	**276**	**23,900**	**729**	**89,570**

Source DOHELG (2007:14)

Note: Explanation of terms in above table

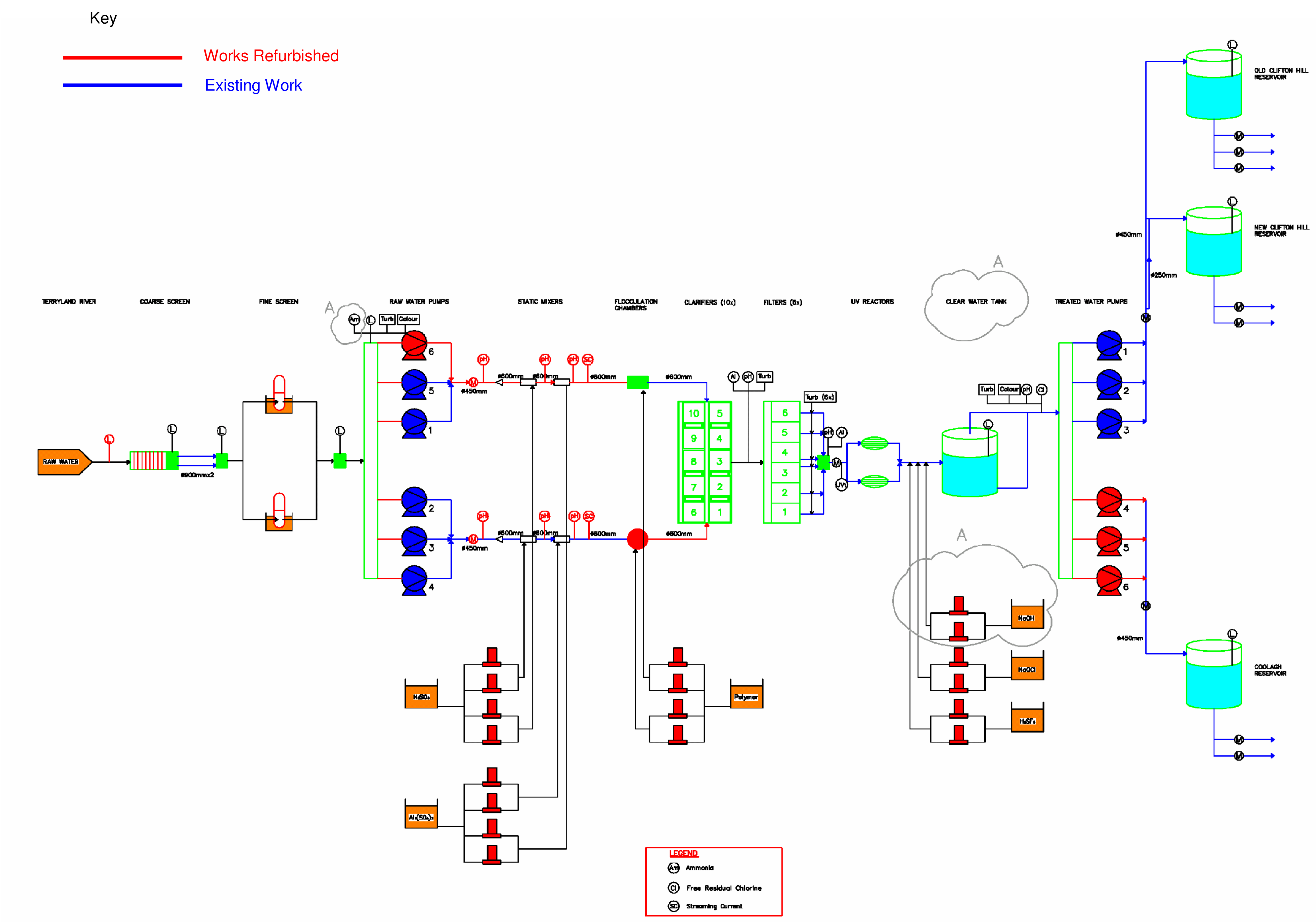
- Schemes – No. of Group Water Schemes
- Domestic – No. of domestic connections i.e. households
- Annex 14 Schemes – Group Schemes serving > 50 persons cited in 2002 ECJ ruling
- Non-Annex 14 Schemes - Schemes serving > 50 persons not cited in 2002 ECJ ruling but subsequently identified by local authorities as requiring compliance

APPENDIX B GALWAY CITY MAP SHOWING DIFFERENT ZONES



Source McGuire (2010c)

APPENDIX C PROCESS FLOW DIAGRAM FOR TERRYLAND WTP



Source McGuire (2010c)

APPENDIX D METERED NON DOMESTIC WATER CONSUMPTION IN GALWAY CITY WSS

Meter reading records for 2009 was received from Crean (2010). The records consisted of readings taken for all non domestic customers in year 2007 - 2010 (as at March) in an excel sheet. Each customers had a reference number assigned to them. There was over 39,000 readings in total. The readings basically consisted of previous and current meter readings and their dates. This was a significant volume of data and the total volume of water consumed by non domestic customers in the city during the year 2009 had to be estimated.

To achieve this, the meter readings were filtered out such that all current meter readings were in year 2009. This reduced the numder readings to slightly above 9,000. There was some previous readings which was taken in late 2008.

The readings were then sorted by customer numbers and it was observed that for each customers there were at least one reading available and at most seven readings. To determine the average volume of water consumed by each customer, the first reading available were subtracted from the last reading which was taken in 2009 and the total was divide by the difference in the number of days in between the two readings. This average was then multiplied by 365 days to project the total volume each customer used. Table D.1 show an example for customer with reference number 10000001. You will that for this customer four different readings were taken with the last reading in 2009 being on 28/09/2009 and the first being on 19/11/2008. The total volume consumed in this period is 58 m^3 (246-188) and the number of days in this period is 313. Then the average daily consumption for 2009 is 0.19 m^3 (188/313) and the projected yearly consumption is then estimated to be 67.64 m^3 (minor difference in computation can be noticed due to rounding errors. Actually 0.19*365 = 69.35 and the figure shown in Table D.1 is 67.64. All calculations were carried out using equations on an excel spreadsheet which actually takes a significantly higher number of decimal places as compared to two or three decimal places shown in Table D.1.

Customers with a reference number was counted and for the period considered, 2488 customers were recorded with total projected volume cosumed in 2009 by all metered non domestic customers being 2,537,620.40 m^3. The average daily consumption is then found to be 6,952.38 m^3 (2,537,620.40 / 365).

Cust. ref.	Cur. Read	Cur. Read Date	Prev. Read.	Prev. Read. Date	Volume m^3/Day	Av. Vol. Consume m^3/Day	Average based on (No. of Days)	Est. Vol. for 2009 m^3
10000001	246	28/09/2009	221	28/05/2009	0.203			
10000001	221	28/05/2009	212	06/04/2009	0.173			
10000001	212	06/04/2009	203	05/02/2009	0.150			
10000001	203	05/02/2009	188	19/11/2008	0.192	0.19	313.00	67.64

Table D.1 Projected volume of Water consumed by a Non Domestic Customer in 2009 in Galway City

APPENDIX E ELECTRICITY USE AND COST AT TERRYLAND WTP

Electricity was provided at Terryland WTP by ESB Network. ESB issues a monthly bill based on the units of electricity used at the plant. ESB bills for five months (January - April and August) were not available. Data for months for which a bill was not available has been proportionately calculated based on water production and average unit rates of electricity for the other months during the year. Table E.1 summarises the data extracted from ESB Bills available and those estimated.

Moreover, in 2009 there have been some changes in the electricity rates with the introduction of new rates (day and night rates) at the end of the year. To be consistent with the start of the year rates and charges, the following average rates are used to calculate energy cost by the different equipment at Terryland WTP.

Average monthly other charges for May to Jul 09 = €1,518

Average monthly other charges for Sept to Dec 09 = €11,393

To keep the monthly charges to a fix component of the ESB bill in 2009, an average fix monthly charge of €1,518 is assumed which gives

The total variable cost of energy = €552,033

Then average energy cost for each unit of energy consumed = 552,033/5,337,855

= €0.1034

An additional cost of €1,518 is therefore assumed to form part of the fix electricity supply cost other than the energy used for office and yard lighting.

Month in 2009	Day Units, kWh	Weekday Peak, kWh	Day Units (Weekend) kWh	Night Units, kWh	Total ESB Units, kWh	Total Volume of Water Pumped m^3	Total ESB Cost incl. all charges (€) Excl. VAT	Day Units Rates € cents	Weekday Peak Rates € cents	Day Units Rates € cents	Night Units Rates € cents	Remarks
Jan	283,064			174,509	457,573	1,048,993	53,674.47	13.95			7.26	Cost and kWh estimate based on average
Feb	249,339			153,717	403,057	924,014	47,460.41	13.95			7.26	
Mar	274,059			168,957	443,016	1,015,621	52,015.19	13.95			7.26	
Apr	260,884			160,834	421,718	966,795	49,587.52	13.95			7.26	
May	261,625			157,872	419,497	976,557	49,539.92	13.95			7.26	
June	258,396			162,817	421,213	965,936	49,339.65	13.95			7.26	
July	267,193			164,627	431,820	990,670	50,723.75	13.95			7.26	
Aug	257,209			158,569	415,778	953,178	48,910.47	13.95			7.26	Cost and kWh estimate based on average
Sept	200,265		73,433	165,447	439,145	974,409	33,150.44	7.08		6.37	4.06	
Oct	183,316		86,459	168,910	438,685	973,023	48,746.81	7.08		6.37	4.06	
Nov	170,351	26,195	89,922	177,907	464,375	1,063,381	39,147.92	7.55	12.6	6.37	4.06	
Dec	178,426	27,435	156,572	219,545	581,978	1,384,538	47,948.76	7.55	12.6	6.37	4.06	
				Total	**5,337,855**	**12,237,115**	**570,245.31**					

Table E.1 ESB units and cost (actual and estimated values)

APPENDIX F ENERGY AND CHEMICAL USE IN GALWAY CITY WSS

F.1 Energy usage

In Galway WSS, energy is mainly used at the Terryland WTP, Coolagh PS and Clifton Hill PS. While there are a few small booster stations in part of the city network, the proportion of energy used at these stations were considered very small as compared to energy used by the main plants and are therefore not considered in this study.

Energy at the Terryland Water Treatment Plant is used for the following activities

- Water Treatment
- Office Use
- Street and Yard Lighting

At Terryland WTP there is a full time office and the site is relatively large. A significant proportion of energy on site is used for office works, street and yard lighting. These uses are considered fixed energy consumption and are not related to water production. To have a better estimate of the energy used for water abstraction, treatment and supply, the energy used by the high energy consuming equipment were considered. Energy uses by the equipment vary with varying water production level and to determine energy use in Galway City WSS the following were considered.

- Low lift pumps used for water abstraction
- UV units for water treatment
- Ancillary equipment used for water treatment
- High lift pumps to supply water to Coolagh Reservoirs
- High lift pumps to supply water to Clifton Hill Reservoirs
- Coolagh PS
- Clifton Hill PS

F.1.1 Water Abstraction

There are 6 nos. KSB Etanorm-R 200-330 pumps in total supplying the two process streams at Terryland WTP. 3 pumps are connected to each stream and 2 pumps run all the time to supply water to each stream. The rated power of the pumps is 45 kW. Based on data collected from the site the duty head for a single pump running at a time is 16 m. The net positive suction head varies from 4 to 5.5 m. Diameter of the discharge pipework is 300 mm NB and suction pipework is 400 mm NB. The 6 pumps are connected to two separate rising mains each of diameter 300 mm NB. Each rising main is supplied by two pumps running concurrently.

The duty point at which the pumps are operating was determined using the manufacturer's pump curve and the system curve. The curves are shown in Figure F.1 and the duty point when two pumps runs together is:

Head = 29 m

Flow = 698 m^3/h

The duty point for each pump when both pumps are running concurrently are:

Head = 29 m

Flow = 349 m^3/h

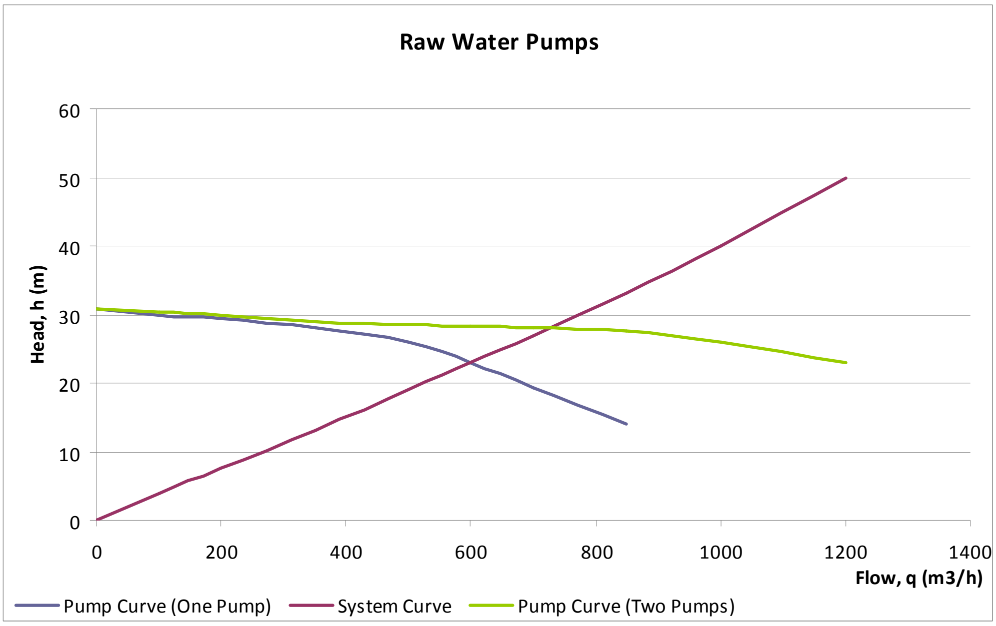


Figure F.1 Duty point for Raw Water Pumps

Total power consumed when 4 pumps are supplying the two 300 mm NB rising mains was determined as follows.

Two pump combine flow per stream, q =	698.00	m^3/h
Head when two pump supplying the stream, h =	27.50	m
Density of water, ρ =	1000.00	kg/m^3
Specific Gravity, g =	9.81	m^2/s

Pump efficiency at duty point, η_p =	86.00	%	(From manufacturer's Pump Curve)
Motor efficiency at duty point, η_m =	92.50	%	(Assumed)
Total volume of treated water pumped during the year =	12,237,115.00	m^3	(Data from Terryland WTP)
Total volume of raw water pumped during the year =	12,848,970.75	m^3	(Assuming 5% water usage for backwashing and other Water Treatment activities)
Hydraulic Power used per hour of pump operation, P_h =	$(q\rho hg) / 3.6 \times 10^6$		
=	52.31	kW/h	
Overall Pump Power used per hour of pump operation, P_o =	$P_h / (\eta_p \times \eta_m)$		
=	65.75	kW/h	
Energy per m^3 =	0.09420	kW/h	
Energy required to pump water for the year =	1,210,395.66	kWh	(Total include for four pumps running continuously)

F.1.2 Energy used by the UV units

Data provided on this section was collected during site visit at Terryland WTP on 11 August 2010. There are two numbers UV units make Trojan UVSWIFT reactor type 8L24 used to disinfect water at Terryland WTP. The rated power of each unit is 80 kW but power consumption varies with usage. Power consumption for each unit when running is 33 kW and one of the two units runs all the time. Operation of the two UV units alternates on a weekly basis to ensure the runhours of the UV units are kept the same.

Lamps in UV reactors were replaced on the 19 February 2010. Since then until the 11 of August 2010 (173 days) the total number of hours run by reactor 1 and 2 were 1964 and 1807 (3771 hours combined run hours).

The average daily run hours =	21.8 hrs	(3771/173)
Average daily energy consumption by the UV unit =	719.4 kWh	(21.8*33)
Total units consumed in 2009 =	262,581 kWh	(719.4 * 365)

F.1.3 Energy use by other process equipment for water treatment

Table F.1 provides a list of other process equipment used at Terryland WTP in addition to the pumps and UV units which use a fair proportion of energy. Motor Horse Powers shown in table F.1 were available from the Terryland WTP - Plant description manual (GCC, n.d). The hours run for each equipment are approximate average daily runhours based on experience of personnel working at the WTP.

Process Equipment	Horse Power (H.P.) each unit	Total H.P	App. hours run per day	Estimated Energy Used in 2009 (kWh)[8]
Wash water pumps (1 duty and 1 standby)	50	50	6	82,125.00
Air blowers (1 duty and 1 standby)	25	25	1/4	1,710.94
Air compressors (1 duty and 1 standby)	16	16	1/4	1,095.00
Alum Dosing pumps (2 duty and 2 standby)	0.33	0.66	24	4,336.20
Poly Dosing Pumps (1 duty and 1 standby)	0.33	0.33	24	2,168.10
Fluorine dosing pumps (1 duty and 1 standby)	0.24	0.24	24	1,576.80
Water sample pumps (4 duty)	0.5	2	10	5,475.00
Sulphuric Acid Dosing Pumps (2 duty and 2 standby)	0.33	0.66	24	4,336.20
Sodium Hydroxide Dosing Pumps (1 duty and 1 standby)	0.33	0.33	24	2,168.10
			Total	**104,991.34**

Table F.1 Energy Usage by other process equipment at Terryland WTP

F.1.4 Coolagh High Lift pumps

There are six treated water pumps used to pump water to Coolagh and Clifton Hill Reservoirs. Three pumps Make KSB Model Omega 200-520A deliver water to the Coolagh Reservoirs. One of the pumps runs all the time to pump water to the Coolagh reservoir as the demand was much lower. The low demand from this part of Galway city was mainly due to water import from Luimnagh WTP to meet part of the demand at Coolagh Reservoir.

The manufacturers pump curves were used in combination with the system curve to determine the duty point at which the pumps operate. The system curve was determined based on data

[8] Conversion factor of 0.75 is used to convert Hp to kW

of the rising main available. From the curves shown in Figure F.2, the duty point when one pump and two pumps run together is

Single pump running,

Head = 99 m

Flow = 810 m^3/h

Two pumps running,

Head = 105 m

Flow = 875 m^3/h

The duty point for each pump when two pumps operate concurrently is

Head = 105 m

Flow = 437.5 m^3/h

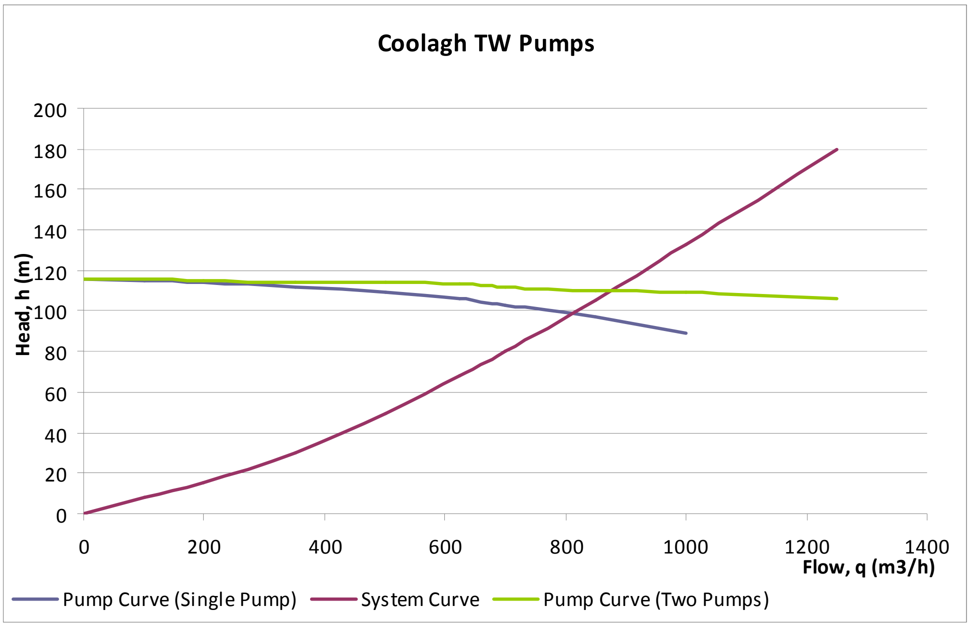


Figure F.2 Duty point for Coolagh TW Pumps

To meet the total demand of 3,057,602.00 m^3 for Coolagh Reservoir, only one pump runs at a time and the total power consumed to meet this yearly demand was determined as follows.

One pump combine flow to Coolagh, q =	810.00	m^3/h
Head when one pump supplying Coolagh, h =	99.00	m
Density of water, ρ =	1000.00	kg/m^3

Specific Gravity, g = 9.81 m^2/s

Pump efficiency at duty point, η_p = 84.00 % (From manufacturer's Pump Curve)

Motor efficiency, η_m = 92.50 % (Assumed)

Total volume of treated water pumped during the year = 3,057,602.00 m^3 (Data from Terryland WTP)

P_h = $(q\rho hg) / 3.6 \times 10^6$

= 218.52 kW/h

Overall Pump Power, P_o = $P_h / (\eta_p x \eta_m)$

= 281.23 kW/h

Energy per m^3 = 0.35 kW/h

Energy required to pump water for the year = 1,061,601.78 kW/h

F.1.5 Clifton Hill High Lift pumps

Three pumps Make KSB Model Etanorm 200-50 deliver water to the Clifton Hill Reservoirs. Two pumps run all the time to pump water to these reservoirs due to a higher demand and there is no water import to meet this demand.

These pumps date back to 1974 and very little information was available at the Terryland WTP on the pumps as well on the KSB website. As the curve for this model of pump was not found, pump curve for another model of KSB pump whose hydraulics closely match to existing pumps, was used. The curves for pump model Etanorm R 200-500 were used in combination with the system curve to determine the duty point at which the pumps operate. The system curve was determined based on data of the rising main available. From the curves shown in Figure F.3, the duty point when two pumps run together is

Two pumps running,

Head = 72 m

Combined flow = 720 m^3/h

Flow per pumps = 360 m^3/h

The duty point for each pump when both pumps are running concurrently is

Head = 58 m

Flow = 625 m^3/h

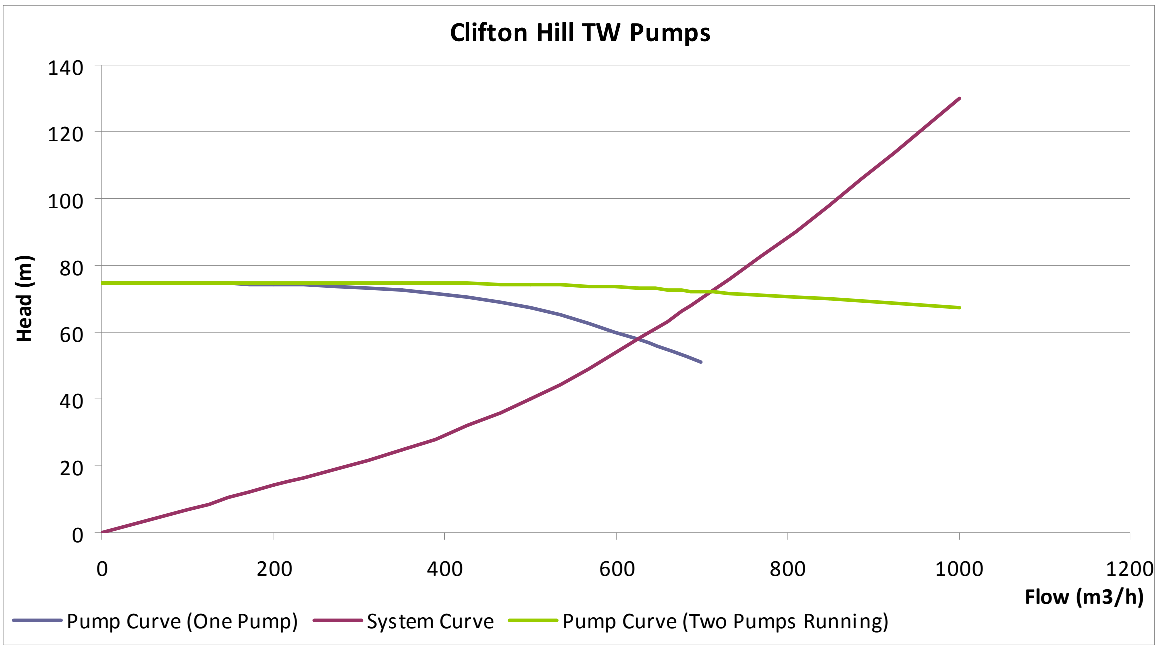


Figure F.3 Duty point for Clifton Hill TW Pumps

Two pumps combine flow to Clifton Hill, q =	720.00	m^3/h
Head when two pumps supply Clifton Hill, h =	72.00	m
Density of water, ρ =	1000.00	kg/m^3
Specific Gravity, g =	9.81	m^2/s
Pump efficiency at duty point, η_p =	82.00	% (From manufacturer's Pump Curve)
Motor efficiency, η_m =	92.50	% (Assumed)
Volume of treated water pumped in 2009=	9,179,513.00	m^3 (Data from Terryland WTP)
P_h =	$(q\rho hg) / 3.6 \times 10^6$	
	141.26	kW/h
Overall Pump Power, P_o =	$P_h / (\eta_p x \eta_m)$	
	188.54	kW/h
Energy per m^3 =	0.26	kW/h
Energy required to pump water for the year =	2,403,764.37	kW/h

F.1.6 Energy Use at Pumping Stations in the Distribution Network

There are two pumping stations which are used to pump water in Galway City. The largest Pumping Station is located at Clifton Hill Reservoir. Water from the Coolagh Reservoirs mostly gravitates to zones it serves except at Briarhill. A pumping station located at Ballybane is used to ensure continuous supply to Briarhill region. Based on (McGuire, 2010c), the monthly average electricity use and cost associated at the two pumping stations are detailed below. As there is no office at the two pumping stations, electricity is mainly used for pumping.

Average ESB bill for Clifton Hill PS	=	€10,000 per month
Energy used at Clifton Hill PS	=	73,569 kWh per month
Energy used at Clifton Hill PS in 2009	=	882,828 kWh
Average ESB bill for Ballybane PS	=	€2,500 per month
Energy used at Ballybane PS	=	18,392 kWh per month
Energy used at Ballybane PS in 2009	=	220,707 kWh

F.1.7 Breakdown of Energy Usage at Terryland WTP

Energy used by the different equipment at Terryland WTP is provided below.

Total energy Used to pump raw water during year 2009 =	1,210,395.66	kWh	
Total energy used to pump treated water at Coolagh & Clifton Hill during year 2009 =	3,465,366.15	kWh	(1,061,601.78+2,403,764.37)
Total energy use by the two UV units =	262,581.00	kWh	
Energy use by other process equipment during year 2009 =	104,991.34	kWh	
Total energy used at Clifton Hill and Ballybane PS =	1,103,535.00	kWh	(882,828+220,707)
Energy use associated to office use and lighting =	294,520.85	kWh	(5,337,855.00 - 5,043,334.15)

The energy use and energy cost in 2009 by each section of Galway WSS is shown as a percentage of the total energy use and cost in WSS in Table F.2.

Section of Galway City WSS	Equipment in use	Energy use (kWh)	Proportion of energy use (%)	Cost associated to energy use (€)[9]	Percentage Cost (%)
Abstraction	Raw Water Pumps	1,210,395.66	18.79	125,154.84	17.38
Treatment	UV units and other process equipment	262,581.00 + 104,991.34 = 367,572.34	5.71	38,006.98	5.28
Distribution	Treated Water Pumps and pumps at Clifton Hill and Coolagh PS	3,465,366.15 + 1,103,535.00 = 4,568,901.15	70.93	358,318.86 + 150,000.00[10] = 508,318.86	70.59
Office use and lighting at Terryland WTP	Office equipment and yard lighting	5,337,855.00 - 5,043,334.15 = 294,520.85	4.57	30,453.46 + (1,518x12)[11] = 48,669.46	6.76
	Total	**6,441,390.00**	**100**	**720,150.14[12]**	**100**

Table F.2 Energy Use and associated cost by different sections in Galway City WSS

Table F.3 summarises the variable energy used per m^3 of water treated in each section of the WSS for Galway City and their associated cost. The variable cost is based on the volume of water produced at Terryland WTP only.

Section of Galway City WSS	Energy used (kWh/m^3)	Cost of Energy to treat one cubic metre of water (€/m^3)
Abstraction	0.09891	0.0102
Treatment	0.03004	0.0031
Distribution	0.3734	0.0415
Total	**0.5041**	**0.0548**

Table F.3 Variable energy and cost by different sections in Galway City WSS

[9] Single rate of electricity unit is used (€0.1034, see Section 4.6) for energy cost at Terryland WTP

[10] Total ESB cost for Coolagh and Clifton Hill PS as per Section 4.6.

[11] As per Section 4.6 a monthly fix charge of €1,518 has been assumed.

[12] Minor deviation from the total ESB costs in Table 4.1 (see Section 4.6) due to rounding errors.

F.2 Chemical Use in Galway City WSS

Chemicals are used at various stages in Galway City WSS. Most of the chemicals dosing are done at the Terryland WTP. Only sodium hypochlorite is dosed at the Coolagh and Ballybane PS to maintain the required level of chlorine residual in the distribution system. Table F.4 list the chemicals used and their estimated usage in 2009 based on water production. These figures are projected based on estimated chemicals usage for water production of 33,000 m^3/day. The average daily production at Terryland WTP in 2009 was 33,526 m^3/day. The unit costs of chemicals shown in the table are actual cost of chemicals as purchased by Galway City Council.

Chemical	Estimate for 33,000 m^3/day production	Estimated chemical usage in 2009 based on current production	Unit Cost (€)	Total Cost in 2009 (€)	Cost per m^3 of water produced
Aluminium sulphate	1,600 Tons	1,625.50 Tons	100 / Ton	162,550.30	0.0133
Polyelectrolyte	2,000 kg	2,031.88 kg	4.5 / kg	9,143.45	0.0007
Fluoride	71,050 Litres	7,2182.49 litres	0.33 / litre	23,820.22	0.0019
Salt	150 Tons	152.39 Tons	163 / Ton	24,839.72	0.0020
Sodium Hypochlorite	20,000 Litres	20,318.79 litres	0.48 / litre	9,753.02	0.0008
Sodium Hydroxide	750 Tons	761.95 Tons	250 / Ton	190,488.64	0.0156
Sulphuric Acid	15 Tons/Week	792.43 Tons	195 / Ton	154,524.38	0.0126
			Total	**575,119.74**	**0.0469**

Table F.4 Chemical Cost Applicable in City Galway WSS

In view of a large volume of water production per year, the cost of reagent at Terryland is minimal and has therefore not been considered in the above calculation.

APPENDIX G ENERY AND CHEMICAL USE IN ARDRAHAN AND CAHERLISTRANE/KILCOONA WSS

G.1 Energy Cost

The energy costs at the WTPs in Ardrahan and Caherlistrane/ Kilcoona GWS are mainly used for abstraction, treatment and distribution. As energy use for activities other than abstraction, treatment and distribution are negligible; the kWh units from the electricity meter readings are assumed to reflect the total energy use by the different water treatment activities. In these two schemes the responsibility for water abstraction, treatment and pumping into the distribution networks are undertaken by an Operation and Maintenance Contractor, Treatment Systems Services Ltd (TSSL). Under the contract TSSL is responsible to pay all cost associated to energy, chemicals, labour, etc. The contractor is then eligible to payment based on a contractually agreed rate.

In both schemes additional pumping is required to boost the flow in some sections of the network to maintain a satisfactory level of pressure to all customers. The booster stations are under the responsibility of the management of the GWS who incur the operation and maintenance cost including the energy cost.

Table G.1 summarises the electricity use and associated cost during water abstraction, treatment and distribution including pressure boosting in the distribution network in the two GWS.

Electricity Use in 2009	Ardrahan		Caherlistrane / Kilcoona	
	Units (kWh)	Cost (€)	Units (kWh)	Cost (€)
Abstraction, Treatment and Distribution, (Hughes (2010)	35,762.00	4,741.00	119,245.00	27,479.00
Use in booster station in distribution network	10,819.00	1,685.00	11,010.00	1,902.00
Total Use	**46,581.00**	**6,426.00**	**130,255.00**	**29,380.00**
Total water production (m3)	65,793		426,721	
Per m^3 of water produced	**0.7080**	**0.0977**	**0.3052**	**0.0688**

Table G.1 Energy Cost at Ardrahan and Caherlistrane / Kilcoona GWS

G.2 Chemical Cost

There are a few different chemicals and reagents used during treatment and disinfection of water at the WTPs in Ardrahan and Caherlistrane / Kilcoona GWS. Tables G.2 and G.3 list all chemicals and reagents used as well as their associated costs during 2009. Except where otherwise stated data provided in Tables G.2 and G.3 were obtained from Hughes (2010).

Chemical Used	Cost of Chemical	Ardrahan		Caherlistrane / Kilcoona	
		Monthly Quantity	Monthly Cost (€)	Monthly Quantity	Monthly Cost (€)
Sodium Hypochlorite	€489.45 + €60.00[13] per 1000 litre	30 litre	16.48	500 litre	274.73
		Total Cost	**16.48**		**274.73**

Table G.2 Chemical use and cost at Ardrahan and Caherlistrane/ Kilcoona WTP

Reagent Used	Cost of reagent	Ardrahan		Caherlistrane / Kilcoona	
		Monthly Quantity	Monthly Cost (€)	Monthly Quantity	Monthly Cost (€)
Ammonia Reagent Set	74.4 per box set	0	0	0.2	14.88
Ph 10 Red Buffer	€40.40 per pkt of 100	1 No.	0.404	1 No.	0.404
ph 4 Blue Buffer	€40.40 per pkt of 100	1 No.	0.404	1 No.	0.404
Chlorine DPE Pillows	€145.35 per pkt of 1000	15 Nos.	2.18	15 Nos.	2.18
Colour Acidified Water	€32.50 per 10 litre	5 litres	16.25	8 litres	26.00
Colour Standard 50 Hazen	€60.00 per 5 litre	1 litre	12.00	2 litre	24.00
De-ionised water	€31.00 per 25 litre	0	0	1 litre	1.24
Turbidity Standard 4000NTU	€142.00 per 500 ml	0.5 ml	0.142	0.5 ml	0.142
		Total Cost	**31.38**		**69.25**

Table G.3 Reagent use and cost at Ardrahan and Caherlistrane/ Kilcoona WTP

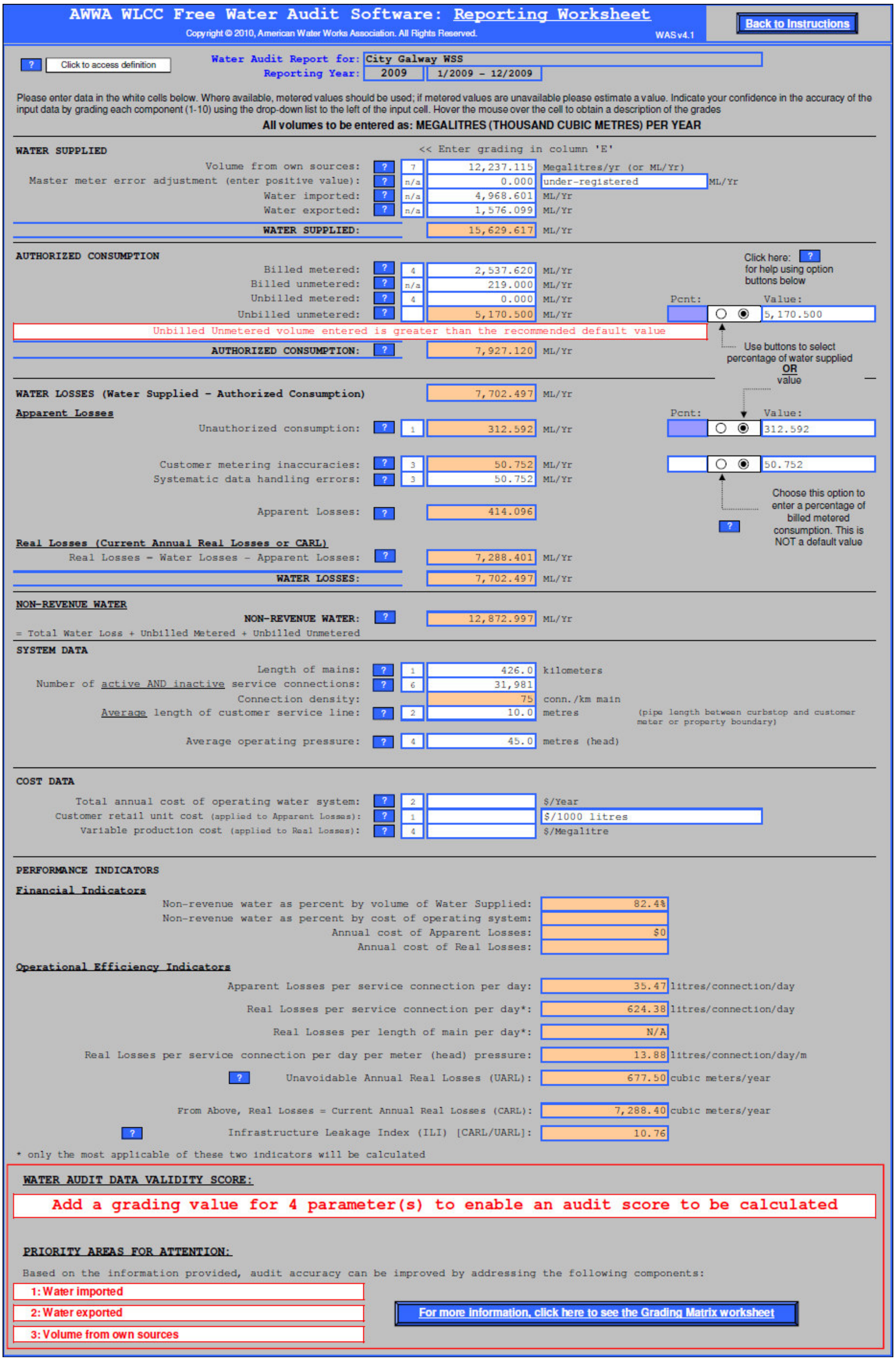
[13] Pumping cost associated to delivery of 1000 litre of chemical

Table G.4 summarises the cost of chemicals and reagents used in 2009 based data available from Tables G.2 and G.3. The table also provide the cost of reagent and chemicals per cubic metre of water produced in both schemes for the year 2009.

Description	**Chemical & Reagent Cost (€)**	
	Ardrahan	**Caherlistrane / Kilcoona**
Monthly Chemical Cost (€)	16.48	274.73
Monthly reagent Cost (€)	31.38	69.25
Monthly Reagent & Chemical Cost (€)	47.86	343.98
Reagent & Chemical Cost in 2009 (€)	**574.32**	**4,127.76**
Total production in 2009 (m^3)	65,793.00	426,721.00
Reagent & Chemical Cost (€/m^3)	**0.0087**	**0.0097**

Table G.4 Cost of Chemicals and Reagents at Ardrahan and Caherlistrane/ Kilcoona WTP in 2009

APPENDIX H WATER AUDIT RESULTS USING THE AWWA WATER AUDIT SOFTWARE



AWWA WLCC Free Water Audit Software: Reporting Worksheet

Back to Instructions

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? Click to access definition

Water Audit Report for: City Galway WSS

Reporting Year: 2009 1/2009 - 12/2009

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicate your confidence in the accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a description of the grades

All volumes to be entered as: MEGALITRES (THOUSAND CUBIC METRES) PER YEAR

WATER SUPPLIED << Enter grading in column 'E'

	Grade	Value	Units
Volume from own sources:	7	12,237.115	Megalitres/yr (or ML/Yr)
Master meter error adjustment (enter positive value):	n/a	0.000	under-registered ML/Yr
Water imported:	n/a	4,968.601	ML/Yr
Water exported:	n/a	1,576.099	ML/Yr
WATER SUPPLIED:		15,629.617	ML/Yr

AUTHORIZED CONSUMPTION

Click here: ? for help using option buttons below

	Grade	Value	Units
Billed metered:	4	2,537.620	ML/Yr
Billed unmetered:	n/a	219.000	ML/Yr
Unbilled metered:	4	0.000	ML/Yr
Unbilled unmetered:		5,170.500	ML/Yr
AUTHORIZED CONSUMPTION:		7,927.120	ML/Yr

Pcnt: Value: 5,170.500

Unbilled Unmetered volume entered is greater than the recommended default value

Use buttons to select percentage of water supplied OR value

WATER LOSSES (Water Supplied - Authorized Consumption) 7,702.497 ML/Yr

Apparent Losses

	Grade	Value	Units
Unauthorized consumption:	1	312.592	ML/Yr
Customer metering inaccuracies:	3	50.752	ML/Yr
Systematic data handling errors:	3	50.752	ML/Yr
Apparent Losses:		414.096	

Pcnt: Value: 312.592

50.752

Choose this option to enter a percentage of billed metered consumption. This is NOT a default value

Real Losses (Current Annual Real Losses or CARL)

	Value	Units
Real Losses = Water Losses - Apparent Losses:	7,288.401	ML/Yr
WATER LOSSES:	7,702.497	ML/Yr

NON-REVENUE WATER

NON-REVENUE WATER: 12,872.997 ML/Yr

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

	Grade	Value	Units
Length of mains:	1	426.0	kilometers
Number of active AND inactive service connections:	6	31,981	
Connection density:		75	conn./km main
Average length of customer service line:	2	10.0	metres (pipe length between curbstop and customer meter or property boundary)
Average operating pressure:	4	45.0	metres (head)

COST DATA

	Grade	Value	Units
Total annual cost of operating water system:	2		$/Year
Customer retail unit cost (applied to Apparent Losses):	1		$/1000 litres
Variable production cost (applied to Real Losses):	4		$/Megalitre

PERFORMANCE INDICATORS

Financial Indicators

	Value
Non-revenue water as percent by volume of Water Supplied:	82.4%
Non-revenue water as percent by cost of operating system:	
Annual cost of Apparent Losses:	$0
Annual cost of Real Losses:	

Operational Efficiency Indicators

	Value	Units
Apparent Losses per service connection per day:	35.47	litres/connection/day
Real Losses per service connection per day*:	624.38	litres/connection/day
Real Losses per length of main per day*:	N/A	
Real Losses per service connection per day per meter (head) pressure:	13.88	litres/connection/day/m
Unavoidable Annual Real Losses (UARL):	677.50	cubic meters/year
From Above, Real Losses = Current Annual Real Losses (CARL):	7,288.40	cubic meters/year
Infrastructure Leakage Index (ILI) [CARL/UARL]:	10.76	

* only the most applicable of these two indicators will be calculated

WATER AUDIT DATA VALIDITY SCORE:

Add a grading value for 4 parameter(s) to enable an audit score to be calculated

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components:

1: Water imported

2: Water exported

3: Volume from own sources

For more information, click here to see the Grading Matrix worksheet

Figure H.1 AWWA Software Reporting Worksheet for Galway City WSS

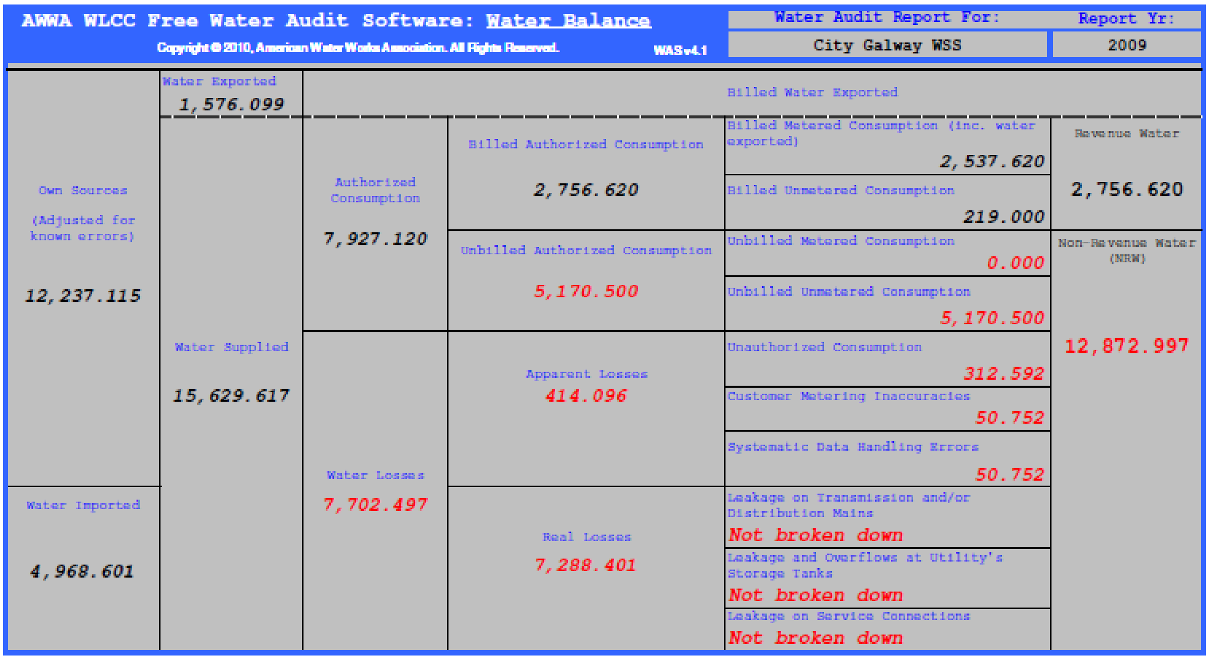

Figure H.2 AWWA Software Water Balance result for Galway City WSS

AWWA WLCC Free Water Audit Software: Reporting Worksheet

Back to Instructions

 WAS v4.1

? Click to access definition

Water Audit Report for: Ardrahan GWS
Reporting Year: 2009 | 1/2009 - 12/2009

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicate your confidence in the accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a description of the grades

All volumes to be entered as: MEGALITRES (THOUSAND CUBIC METRES) PER YEAR

WATER SUPPLIED << Enter grading in column 'E'

Item	Grade	Value	Units
Volume from own sources:	7	65.793	Megalitres/yr (or ML/Yr)
Master meter error adjustment (enter positive value):	n/a	0.000	under-registered ML/Yr
Water imported:	n/a	0.000	ML/Yr
Water exported:	n/a	0.000	ML/Yr
WATER SUPPLIED:		65.793	ML/Yr

AUTHORIZED CONSUMPTION

Click here: ? for help using option buttons below

Item	Grade	Value	Units
Billed metered:	4	41.822	ML/Yr
Billed unmetered:	n/a	0.000	ML/Yr
Unbilled metered:	4	9.086	ML/Yr
Unbilled unmetered:		0.130	ML/Yr
AUTHORIZED CONSUMPTION:		51.038	ML/Yr

Pcnt: Value: 0.130

Use buttons to select percentage of water supplied OR value

WATER LOSSES (Water Supplied - Authorized Consumption) 14.755 ML/Yr

Apparent Losses

Item	Grade	Value	Units
Unauthorized consumption:		0.100	ML/Yr
Customer metering inaccuracies:	3	5.263	ML/Yr
Systematic data handling errors:	3	1.316	ML/Yr
Apparent Losses:		6.679	

Pcnt: Value: 0.100

Value: 5.263

Choose this option to enter a percentage of billed metered consumption. This is NOT a default value

Real Losses (Current Annual Real Losses or CARL)

Item	Value	Units
Real Losses = Water Losses - Apparent Losses:	8.076	ML/Yr
WATER LOSSES:	14.755	ML/Yr

NON-REVENUE WATER

NON-REVENUE WATER: 23.971 ML/Yr

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

Item	Grade	Value	Units
Length of mains:	1	11.2	kilometers
Number of active AND inactive service connections:	6	222	
Connection density:		20	conn./km main
Average length of customer service line:	2	10.0	metres (pipe length between curbstop and customer meter or property boundary)
Average operating pressure:	4	27.6	metres (head)

COST DATA

Item	Grade	Value	Units
Total annual cost of operating water system:	2		$/Year
Customer retail unit cost (applied to Apparent Losses):	1		$/1000 litres
Variable production cost (applied to Real Losses):	4		$/Megalitre

PERFORMANCE INDICATORS

Financial Indicators

Indicator	Value
Non-revenue water as percent by volume of Water Supplied:	36.4%
Non-revenue water as percent by cost of operating system:	
Annual cost of Apparent Losses:	$0
Annual cost of Real Losses:	

Operational Efficiency Indicators

Indicator	Value	Units
Apparent Losses per service connection per day:	82.43	litres/connection/day
Real Losses per service connection per day*:	N/A	litres/connection/day
Real Losses per length of main per day*:	1,975.46	litres/km/day
Real Losses per service connection per day per meter (head) pressure:		litres/connection/day/m
Unavoidable Annual Real Losses (UARL):	Not valid	

*** UARL cannot be calculated as either average pressure, number of connections or length of mains is too small: SEE UARL DEFINITION ***

Indicator	Value
From Above, Real Losses = Current Annual Real Losses (CARL):	8.08
Infrastructure Leakage Index (ILI) [CARL/UARL]:	

* only the most applicable of these two indicators will be calculated

WATER AUDIT DATA VALIDITY SCORE:

Add a grading value for 2 parameter(s) to enable an audit score to be calculated

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components:

1: Volume from own sources
2: Customer retail unit cost (applied to Apparent Losses)
3: Billed metered

For more information, click here to see the Grading Matrix worksheet

Figure H.3 AWWA Software Reporting Worksheet for Ardrahan WSS

AWWA WLCC Free Water Audit Software: Water Balance				Water Audit Report For: Ardrahan GWS	Report Yr: 2009
Copyright © 2010, American Water Works Association. All Rights Reserved. WAS v4.1					
Own Sources (Adjusted for known errors) 65.793	Water Exported 0.000			Billed Water Exported	
	Water Supplied 65.793	Authorized Consumption 51.038	Billed Authorized Consumption 41.822	Billed Metered Consumption (inc. water exported) 41.822	Revenue Water 41.822
				Billed Unmetered Consumption 0.000	
			Unbilled Authorized Consumption 9.216	Unbilled Metered Consumption 9.086	Non-Revenue Water (NRW) 23.971
				Unbilled Unmetered Consumption 0.130	
		Water Losses 14.755	Apparent Losses 6.679	Unauthorized Consumption 0.100	
				Customer Metering Inaccuracies 5.263	
				Systematic Data Handling Errors 1.316	
Water Imported 0.000			Real Losses 8.076	Leakage on Transmission and/or Distribution Mains Not broken down	
				Leakage and Overflows at Utility's Storage Tanks Not broken down	
				Leakage on Service Connections Not broken down	

Figure H.4 AWWA Software Water Balance result for Ardrahan WSS

AWWA WLCC Free Water Audit Software: Reporting Worksheet

 WAS v4.1

Back to Instructions

? Click to access definition

Water Audit Report for: Caherlistrane / Kilcoona
Reporting Year: 2009 1/2009 - 12/2009

Please enter data in the white cells below. Where available, metered values should be used; if metered values are unavailable please estimate a value. Indicate your confidence in the accuracy of the input data by grading each component (1-10) using the drop-down list to the left of the input cell. Hover the mouse over the cell to obtain a description of the grades

All volumes to be entered as: MEGALITRES (THOUSAND CUBIC METRES) PER YEAR

WATER SUPPLIED << Enter grading in column 'E'

	Grade	Value	Units
Volume from own sources:	7	426.721	Megalitres/yr (or ML/Yr)
Master meter error adjustment (enter positive value):	n/a	0.000	under-registered ML/Yr
Water imported:	n/a	0.000	ML/Yr
Water exported:	n/a	0.000	ML/Yr
WATER SUPPLIED:		426.721	ML/Yr

AUTHORIZED CONSUMPTION

Click here: ? for help using option buttons below

	Grade	Value	Units
Billed metered:	4	302.790	ML/Yr
Billed unmetered:	n/a	0.000	ML/Yr
Unbilled metered:	4	89.250	ML/Yr
Unbilled unmetered:		0.100	ML/Yr
AUTHORIZED CONSUMPTION:		392.140	ML/Yr

Pcnt: Value: 0.100

Use buttons to select percentage of water supplied OR value

WATER LOSSES (Water Supplied - Authorized Consumption) 34.581 ML/Yr

Apparent Losses

	Grade	Value	Units
Unauthorized consumption:		0.100	ML/Yr
Customer metering inaccuracies:	3	8.534	ML/Yr
Systematic data handling errors:	3	8.534	ML/Yr
Apparent Losses:		17.168	

Pcnt: Value: 0.100

Value: 8.534

Choose this option to enter a percentage of billed metered consumption. This is NOT a default value

Real Losses (Current Annual Real Losses or CARL)

	Value	Units
Real Losses = Water Losses - Apparent Losses:	17.413	ML/Yr
WATER LOSSES:	34.581	ML/Yr

NON-REVENUE WATER

NON-REVENUE WATER: 123.931 ML/Yr

= Total Water Loss + Unbilled Metered + Unbilled Unmetered

SYSTEM DATA

	Grade	Value	Units
Length of mains:	1	180.0	kilometers
Number of active AND inactive service connections:	4	1,150	
Connection density:		6	conn./km main
Average length of customer service line:	2	15.0	metres (pipe length between curbstop and customer meter or property boundary)
Average operating pressure:	1	27.6	metres (head)

COST DATA

	Grade	Value	Units
Total annual cost of operating water system:	2		$/Year
Customer retail unit cost (applied to Apparent Losses):	1		$/1000 litres
Variable production cost (applied to Real Losses):	4		$/Megalitre

PERFORMANCE INDICATORS

Financial Indicators

	Value	Units
Non-revenue water as percent by volume of Water Supplied:	29.0%	
Non-revenue water as percent by cost of operating system:		
Annual cost of Apparent Losses:	$0	
Annual cost of Real Losses:		

Operational Efficiency Indicators

	Value	Units
Apparent Losses per service connection per day:	40.90	litres/connection/day
Real Losses per service connection per day*:	N/A	litres/connection/day
Real Losses per length of main per day*:	265.04	litres/km/day
Real Losses per service connection per day per meter (head) pressure:		litres/connection/day/m
Unavoidable Annual Real Losses (UARL):	46.19	cubic meters/year
From Above, Real Losses = Current Annual Real Losses (CARL):	17.41	cubic meters/year
Infrastructure Leakage Index (ILI) [CARL/UARL]:	0.38	

* only the most applicable of these two indicators will be calculated

WATER AUDIT DATA VALIDITY SCORE:

Add a grading value for 2 parameter(s) to enable an audit score to be calculated

PRIORITY AREAS FOR ATTENTION:

Based on the information provided, audit accuracy can be improved by addressing the following components:

1: Volume from own sources
2: Customer retail unit cost (applied to Apparent Losses)
3: Billed metered

For more information, click here to see the Grading Matrix worksheet

Figure H.5 AWWA Software Reporting Worksheet for Caherlistrane / Kilcoona WSS

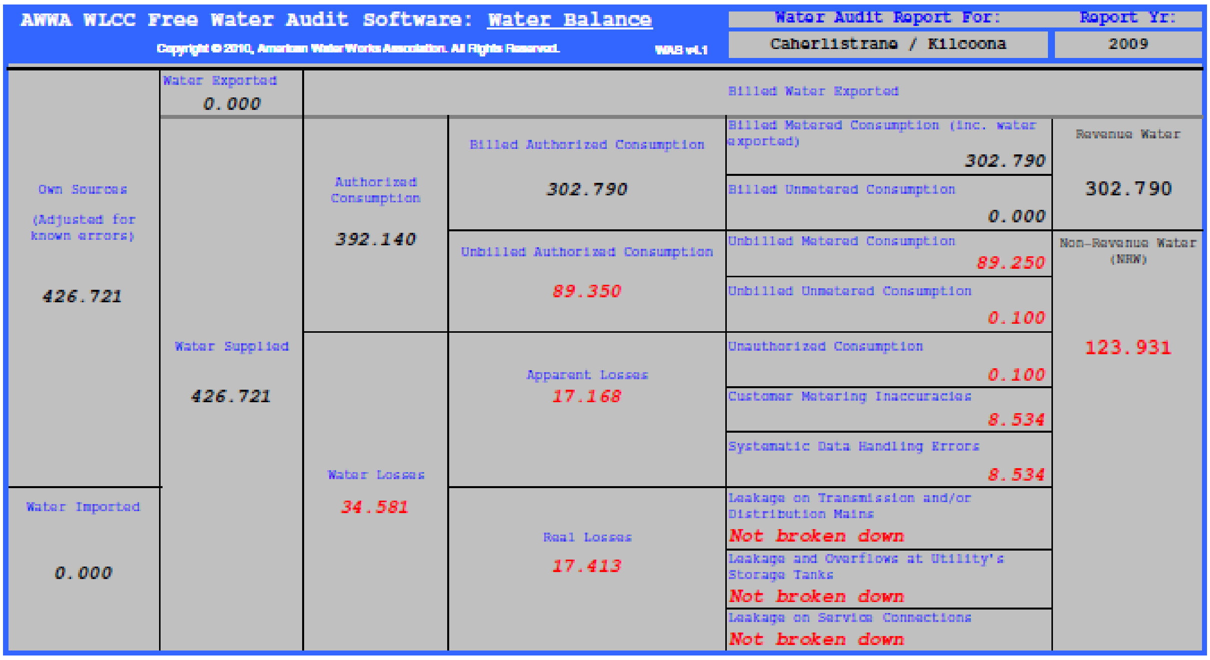

Figure H.6 AWWA Software Water Balance result for Caherlistrane / Kilcoona WSS

APPENDIX I WATER AUDIT RESULTS BASED ON UFW INTEGRATED FLOW METHOD

UNACCOUNTED FOR WATER : INTEGRATED FLOW METHOD					
Scheme Name:	Galway City WSS	DMA Name:	Galway City		
DMA Flow Details					
Period Covered by Water Audit	Year 2009				Flow m^3/year
			Total Inflow[1]	A	17,205,716.0
			Exports to Neighbouring WSA or DMAs[2]	B	1,576,099.0
			Distribution Inflow	C	15,629,617.0
Water Delivered					
Permanent Domestic Demand:					
Number of Properties[3]	29493	Occupancy Rate[4]	2.7		
Population Supplied		persons @	litres/capita/year		5,170,500.0
Per Capita Consumption (PCC) litres/capita/day:					
PCC from Individual Study[5]		or PCC from NWS[6]			
Seasonal Domestic:					
Number of Properties[7]		Occupancy Rate[8]			
Population Supplied		persons @	litres/capita/3 months in summer		
Non-Domestic Metered Demand[9]:	2488	properties			2,537,620.0 [10]
Non-Domestic Un-metered[11]:		properties @	litres/prop/day		0.0
Group Water Scheme Bulk Meter demand[12]:					
GWSS Name	Demand				
Name GWSS 1		m^3/day			
		m^3/day			
Name GWSS n		m^3/day			
			Total GWSS Demand		0.0
Demand from Major Consumers[13]:					
Consumer Name	Demand				
Unmetered Non Domestic Custome	600	m^3/day			
		m^3/day			
		m^3/day			
			Total Major Consumer Demand		219,000.0
Operational Use (Allow 1% of Distribution Inflow):					156,296.2
Total Accounted for Water				D	8,083,416.2
Unaccounted For Water, U.F.W		UFW= E = C - D	m^3/year	E	7,546,201
			l/sec		1,786,279
Total length of mains in DMA[14] =	426	kilometres (L)			
Total No. Of Connections[15] =	31,981	(P)		ALSO AS:	
U.F.W as :					
% of daily DMA demand =	(E/C)x100			48.3	of net inflow
Rate per Connection per Day =	E x 1000 / P			235958.9	litres/conn/year
Rate per km main per hour =	E / L x 24 x 365			2.02	m^3/km/hr
Water Services Authority Name:	Galway City Council	Completed By / Checked By		K. Ramlagan	

Figure I.1 UFW: Integrated Flow Water Balance result for Galway City WSS

UNACCOUNTED FOR WATER : INTEGRATED FLOW METHOD

Scheme Name: Ardrahan GWS DMA Name: Ardrahan

DMA Flow Details

Period Covered by Water Audit 01/01/2009 - 31/12/2009

		Flow m^3/day
Total Inflow[1]	A	65,793.0
Exports to Neighbouring WSA or DMAs[2]	B	0.0
Distribution Inflow	C	65,793.0

Water Delivered

Permanent Domestic Demand:

Number of Properties[3]	197	Occupancy Rate[4]	3	
Population Supplied	591	persons @ 165.0	litres/capita/day	35,593.0
Per Capita Consumption (PCC) litres/capita/day:				
PCC from Individual Study[5]		or PCC from NWS[6]	165	

Seasonal Domestic:

Number of Properties[7]	0	Occupancy Rate[8]	0	
Population Supplied	0	persons @ 165.0	litres/capita/day	0.0

Non-Domestic Metered Demand[9]:	25 properties		16,036.0 [10]
Non-Domestic Un-metered[11]:	0	properties @ 700 litres/prop/day	0.0

Group Water Scheme Bulk Meter demand[12]:

GWSS Name	Demand	
N/A		m^3/day
		m^3/day
N/A		m^3/day

Total GWSS Demand 0.0

Demand from Major Consumers[13]:

Consumer Name	Demand	
N/A	0	m^3/day
		m^3/day
		m^3/day

Total Major Consumer Demand 0.0

Operational Use (Allow 1% of Distribution Inflow): 657.9

Total Accounted for Water D 52,286.9

Unaccounted For Water, U.F.W	UFW= E = (C - D)	m^3/year	E	13,506
		l/sec		1,166,927

Total length of mains in DMA[14] = 11 kilometres (L)

Total No. Of Connections[15] = 222 (P)

U.F.W as : **ALSO AS:**

% of daily DMA demand =	(E/C)x100	20.5	of net inflow
Rate per Connection per year =	$\frac{E \times 1000}{P}$	60838.3	litres/conn/year
Rate per km main per hour =	$\frac{E}{L \times 24 \times 365}$	0.14	m^3/km/hr

Water Services Authority Name:	Ardrahan GWS	Completed By	K. Ramlagan
		Checked By	

Figure I.2 UFW: Integrated Flow Water Balance result for Ardrahan WSS

UNACCOUNTED FOR WATER : INTEGRATED FLOW METHOD

Scheme Name:	Caherlistrane/ Kilcoona GWS	DMA Name:	Caherlistrane/ Kilcoona		
DMA Flow Details					
Period Covered by Water Audit	01/01/2009 - 31/12/2009				Flow m^3/day
		Total Inflow[1]		A	426,721.0
		Exports to Neighbouring WSA or DMAs[2]		B	0.0
		Distribution Inflow		C	426,721.0
Water Delivered					
Permanent Domestic Demand:					
Number of Properties[3]	1050	Occupancy Rate[4]			
Population Supplied		persons @ 165.0	litres/capita/day		302,490.0
Per Capita Consumption (PCC) litres/capita/day:					
PCC from Individual Study[5]		or PCC from NWS[6]	165		
Seasonal Domestic:					
Number of Properties[7]	0	Occupancy Rate[8]	0		
Population Supplied	0	persons @ 165.0	litres/capita/day		0.0
Non-Domestic Metered Demand[9]:	100	properties			89,250.0 [10]
Non-Domestic Un-metered[11]:	0	properties @ 700	litres/prop/day		0.0
Group Water Scheme Bulk Meter demand[12]:					
GWSS Name	Demand				
N/A		m^3/day			
		m^3/day			
N/A		m^3/day			
		Total GWSS Demand			0.0
Demand from Major Consumers[13]:					
Consumer Name	Demand				
N/A	0	m^3/day			
		m^3/day			
		m^3/day			
		Total Major Consumer Demand			0.0
Operational Use (Allow 1% of Distribution Inflow):					4,267.2
Total Accounted for Water				D	396,007.2
Unaccounted For Water, U.F.W		UFW= E = (C - D)/365	m^3/year	E	30,714
			l/sec		2,653,671
Total length of mains in DMA[14] =	170	kilometres (L)			
Total No. Of Connections[15] =	1,150	(P)			
U.F.W as :				ALSO AS:	
% of daily DMA demand =	(E/C)x100			7.2	of net inflow
Rate per Connection per year =	E x 1000 / P			26707.6	litres/conn/year
Rate per km main per hour =	E / (L x 24 x 365)			0.02	m^3/km/hr
Water Services Authority Name:	Caherlistrane / Kilcoona	Completed By		K. Ramlagan	
		Checked By			

Figure I.3 UFW: Integrated Flow Water Balance result for Caherlistrane/Kilcoona WSS