Water Resources Management Plan 2012

Appendices

March 2012

ATKINS

Northern Ireland Water Limited
Final Water Resources Management Plan

Appendices

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Glossary of acronyms

Term	Description
AIC	Average incremental cost
AIR AIR09	Annual information return Annual information return 2009
AISC	Average incremental social cost
ALC	Active leakage control
Aquator	Water resource modelling application
BAG	Benefits assessment guideline
BFI	Base flow index
Capex	Capital expenditure
CCDeW	Climate change and demand for water report
CCNI	Consumer Council for Northern Ireland
CoP	Code(s) of Practice
DAF	Dissolved air filtration
DC	Demand centre
DECC	Department of Energy and Climatic Change
DI	Distribution input
DMA	District Meter Area
DO	Deployable output
DOE	Department of the Environment
DRD	Department for Regional Development
DYAA	Dry year annual average
EA	Environment Agency (England and Wales)
EBSD	Economics of balancing supply and demand
ELL	Economic level of leakage
FDC	Flow duration curve
GAC	Granulated activated carbon
GHG	Greenhouse gases
GIS	Geographical information system
HH	Household
l/h/d	Litres per head per day – unit of per capita consumption
LFE	Low Flows Enterprise software
LGD	Local Government District

Term	Description
LoS	Levels of Service
LRMC	Long-run marginal cost
LTA	Long term average
MILP	Mixed integer linear program
Ml/d	Mega litres per day
MLE	Maximum likelihood estimation
NEP	National Environment Programme (England & Wales)
NIAUR	Northern Ireland Authority for Utility Regulation
NIEA	Northern Ireland Environment Agency
NISRA	Northern Ireland Statistics and Research Agency
Non-HH	Non-household
NPV	Net present value
NYAA	Normal year annual average
Opex	Operational expenditure
OSNI	Ordnance Survey Northern Ireland
PC10	Price Control 2010
PCC	Per capita consumption
PET	Potential evapotranspiration
Planning period	5-year regulatory planning periods, starting in 2013–18
PPP	Public Private Partnership
PR09	Periodic Review 2009 (England and Wales)
Q4	4th quarter of the Financial Year (January to March)
R&D	Research and development
RDS	Regional Development Strategy
ROI	Region of Influence
SBP	Strategic Business Plan
SEA	Strategic Environmental Assessment
SEPA	Scottish Environment Protection Agency
SIC	Standard Industrial Classification
SPL	Supply pipe leakage
TMM	Trunk mains model
UKCIP02	UKCIP 2002 climate projections
UKCP09	UK Climate Programme 2009

Term	Description
UKTAG	UK Technical Advisory Group
UKWIR	UK Water Industry Research Ltd
WAFU	Water available for use
WDMS	Water Demand Management Strategy
WFD	Water Framework Directive
WG	Weather generator
WISKI	Water Information System (database) developed by Kisters AG
WRMP	Water Resources Management Plan
WRP Table	Water Resource Plan Table
WRPG	Water Resources Planning Guideline (England and Wales)
WRS 2002	Water Resources Strategy 2002–2030, published in January 2003
WRZ	Water resource zone
WTW	Water treatment works
WWTW	Wastewater treatment works

Appendix A
Deployable output

A.1 Summary

Atkins was appointed by Northern Ireland Water (NI Water) in March 2009 to prepare the Company's Water Resources Management Plan (WRMP) for the 25 year planning period from 2010–11 to 2034–35. The new WRMP, referred to here as WRMP 2012, replaces the current Water Resource Strategy (WRS) prepared by Ferguson McIlveen[1] (referred to here as WRS 2002) and updated by Scott Wilson in January 2007[2]. The main supply-side component of the WRMP is deployable output (DO). This is calculated using a standard methodology that requires the use of behavioural models of the water resource system. This Appendix describes the construction of water resource system models for the calculation of DO.

None of the models or input data sets used for WRS 2002 was available. New water resource models have therefore been constructed. The models have been developed using the Aquator water resource modelling application. The 2010 supply system has been configured to five Water Resource Zones (WRZs) based on information and data collated from a variety of sources and through collaboration with both NI Water staff and the Atkins Trunk Mains Modelling (TMM) team.

There are few direct measurements of reservoir inflows and flows at river intakes. A bespoke method for determining flow time series for use in the water resource system model was therefore developed for WRMP 2012. The methodology employed utilises gauged flow data provided by the Rivers Agency along with software developed for Northern Ireland Environment Agency by Wallingford Hydrosolutions Ltd.

The overall DO for Northern Ireland was calculated as 773.6 Ml/d until 2015 falling to 759.5 Ml/d after the decommissioning of the Camlough source in the South WRZ. The individual WRZ results as follows:

- North WRZ 106.2 Ml/d (56.2 Ml/d excluding PPP transfers);
- West WRZ 88.2 Ml/d;
- Central WRZ 31.1 Ml/d (12.1 Ml/d excluding PPP transfers);
- East WRZ 329.5 Ml/d (149.5 Ml/d excluding PPP transfers); and
- South WRZ 218.6 Ml/d and 204.5 Ml/d beyond 2015 (71.6 Ml/d excluding PPP transfers).

Overall, it seems that there is little change in the total DO for Northern Ireland with the WRMP 2012 DO value around 3 Ml/d higher than the WRS 2002 DO of 771 Ml/d. On an individual WRZ level, the major differences are due to the repositioning of WRZ boundaries, decommissioning of older sources and inclusion of PC10 schemes.

The models were configured to investigate the potential impacts of changes in flow regime from climate change. The river flow series in the model were perturbed in accordance with the UKWIR UKCP09 Rapid Assessment. Looking across the whole of Northern Ireland, the 50th percentile scenario showed virtually no change from the baseline. Under the 5th percentile perturbations there was a DO reduction of just below 27 Ml/d (3.5%) simulated. Under the 95th perturbations simulated DO was increased by 23 Ml/d (3.0%).

[1] Ferguson McIlveen (2003) Water Resource Strategy 2002-2030
[2] Scott Wilson (2007) WRS Review of Recent Published Data - Revision B

The work described in this Appendix provides a robust basis for the DO values to be used in the supply/demand balance elements of the WRMP. The approach makes best use of available data and techniques. The analysis can be updated as and when improved data and information becomes available, for example using longer (pre 1975) flow time series generated from rainfall-runoff models.

A.2 Background

Atkins has updated all aspects of the NI Water supply demand balance for the new WRMP 2012. The update has followed UK water industry best practice, as used by water companies in England and Wales for the PR09 Business Plan and related submissions, and it conforms to the guidelines issued by DRD[3].

The supply demand balance analysis includes:

- Reassessment of deployable output (DO) from the Company's existing sources;
- Preparation of new demand forecasts;
- Reassessment of target headroom to allow for uncertainty; and
- Outage allowances for existing and future sources.

A detailed options appraisal was undertaken as part of the WRMP process to identify the least cost planning solution for NI Water over the planning period. Atkins has also undertaken a Strategic Environmental Impact Assessment (SEA) for the Draft WRMP.

In addition to the preparation of the WRMP and undertaking a SEA, the scope of Atkins' work includes for the development of a trunk mains model (TMM) for the Northern Ireland network. When complete this will allow a better understanding of the hydraulic capacity of the system and hence the potential for transfers between areas of surplus and areas of deficit both within Water Resource Zones (WRZ) and between WRZs.

The preparation of a WRMP follows a standard approach that represents UK water industry best practice that is set out in guidelines based on a programme of R&D projects funded by UKWIR and the Environment Agency to develop practical methodologies. The methodologies have been reviewed and where necessary updated over time to take account of new techniques and analytical tools, greater computing power, and more data.

The fundamental supply-side building block for the supply demand balance is the estimation of deployable output (DO); other measures of source yield such as "safe yield" or "reliable yield" do not form part of the current WRMP definitions and process. The value of DO represents the output of a source (or group of sources) that can be achieved under specific design conditions. For surface water sources, the calculation of DO is based on behavioural analysis using flow time series that are as long as possible. The DO of a source is a measure of what the source can produce under the hydrological conditions of the worst drought on record. Under more favourable hydrological conditions, a given source may be able to deliver more than the DO, up to limits determined by the capacity of the treatment works and/or abstraction licence conditions.

None of the models or input data sets used for WRS 2002 was available for WRMP 2012. New water resource models have therefore been constructed using the Aquator water resource modelling application. The models have been configured to represent the current

[3] Guidelines for preparing a water resources management plan, September 2010, DRD Water Policy Division

supply system. Model construction has used information and data collated from a variety of sources and through collaboration with both NI Water staff and the Atkins TMM team. In addition to assessing the current supply system, the models have been used to test scenarios related to climate change and were used to assist the optioneering process. At the end of the WRMP it is the intention that the models will be available for NI Water to allow future scenarios to be tested if such a requirement arises.

This Appendix details the reasons for opting to use a water resources model, the decision to use Aquator, the model build process and the model setup and execution of DO and scenario model runs. At each stage of the Appendix recommendations are given for possible future improvements that could be included in later plans; the recommendations are generally linked to further data becoming available for inclusion in the models. This Appendix should always sit alongside the models to provide the basis for a comprehensive audit trail which is a critical element of any long-term modelling exercise.

A.3 Introduction to Aquator

Whilst it is possible to determine the DO of individual sources without the aid of a computer model, such a tool is essential when looking at conjunctive use across a Water Resource Zone[4] (WRZ). There are a number of appropriate software packages that are commercially available but Aquator has been chosen as the most suitable one for WRMP 2012. It has been used for a number of years by various water companies in the UK as a high level strategic water resources planning tool. It provides an intuitive and flexible platform for simulating all elements of a WRZ and, importantly, allows future supply system modifications to be incorporated into the model environment with ease.

The following information is taken from the Oxford Scientific Software website (the developers of Aquator) and the Aquator User Manual. A brief history, a description of the features of the model and an introduction to the DO analyser which has been be used to complete the supply forecast for the WRMP is provided.

- **History**: The first version of Aquator was developed for use by the then Scottish Water Companies now Scottish Water and the Scottish Environment Protection Agency (SEPA). It was delivered to these organisations early in 2001 as part of the Surface Water Yield Project undertaken by Water Resource Associates. Since then Aquator has been adopted by other water companies, environmental organisations and consulting engineers worldwide.
- **Features**: Aquator is a state of the art simulation package that enables one to construct a representation of any water supply system on-screen by dragging and dropping components from the toolbox onto the schematic area. Each component encapsulates a built-in set of operating rules. As Aquator seeks to satisfy the daily demand, these rules are automatically enforced no matter how complex the system. While obeying these rules Aquator implements a multi-pass strategy for supplying water. These passes enable Aquator to calculate leakage, to satisfy minimum flow requirements, and to supply at lowest cost when water is plentiful but otherwise supply according to resource state.
- **DO analyser**: The main function of Aquator in relation to WRMP 2012 is the DO analyser which is used to calculate the DO of each of the WRZs. Aquator has

[4] A Water Resource Zone is the largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall.

analysers for both the English & Welsh and Scottish methods of determining DO. The English & Welsh method, which is applicable to WRMP 2012, involves setting a minimum and maximum overall demand in a resource zone and increasing the demand incrementally until failure is encountered. The DO of the system is defined as the overall demand that is one increment below the demand causing a failure.

A.4 Aquator model build

A.4.1 Introduction

The following sections of the Appendix outline the construction phase of the Aquator models that were developed to simulate water supply in each of the five WRZs in Northern Ireland. The boundaries of the five WRZs used for WRMP 2012 were identified using information from the previous WRS, and through collaboration with the Atkins TMM team. The WRZ boundaries have been presented and discussed at various progress, Project Steering Group and technical meetings with NI Water staff. The agreed boundaries are shown Figure A.1.

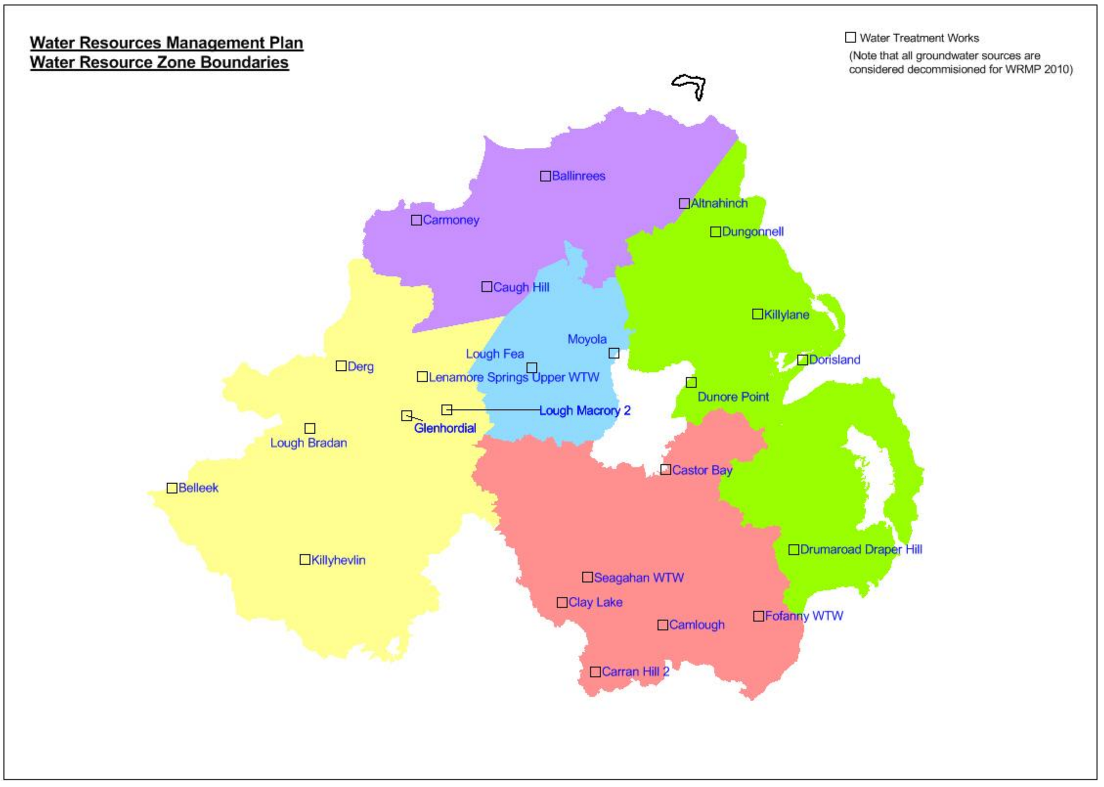

Figure A.1 – WRMP 2012 WRZs: North WRZ in purple shading; West in yellow; Central in blue; East in green; and South in red

As with all computer modelling exercises, the most important success factor is the amount and the quality of data that can be provided to feed into the model build. Therefore, prior to commencing model development, a comprehensive data collation phase was undertaken with data requests to NI Water and the Northern Ireland Rivers Agency.

The data collated were used to feed into the model structure (section A.4.2) and as model input data (section A.4.3) which were used to set the physical constraints in the model, for example reservoir storage capacities, as well as providing boundary conditions, for example the amount of flow entering the WRZ in rivers. The knowledge and expertise of the Atkins TMM team was also employed at various stages of the Aquator model build.

A.4.2 Model structure

A.4.2.1 Introduction

As is the case for all high level strategic tools, deciding on an appropriate level of simplification of the real system on the ground is a critical step in the model build. In this supply forecast this is mainly based on:

- Professional judgement of what is suitable for a DO assessment;
- Review of how DO has been determined in Northern Ireland for previous studies; and
- Ensuring that the work is consistent with the amount and quality of data that have been provided in the data collation phase.

A.4.2.2 Provenance

In the initial stages of the model build four schematics were put together with the Aquator software in a format suitable for DO assessment. These were based on information in the WRS 2002 (text in section A.5.2, Table 4.1 and various maps from WRS 2002). The schematics were grouped according to a previous divisional structure used at that time. Each component was checked against a GIS mapping layer of the water supply network produced by NI Water on 22/12/2008 and provided as background material with the tender for the WRMP.

These schematics (Figures A.3 to A.7) were then issued to a number of key personnel within NI Water who were asked to comment on the schematics in relation to the current situation on the ground, especially in the geographical areas of which they held particular expertise. The original schematics then were updated to take account of this new information. The schematics were also rearranged into the five new WRZs (North, West, Central, East and South) as set out for the WRMP 2012 and reissued to NI Water for final checks.

In the final step of the model structuring process, each schematic was verified with the Atkins TMM team. This was to ensure that the distribution network set out in Aquator was an appropriate representation of the real one. Although Aquator necessarily involves a large degree of simplification of the distribution system, it is still important to ensure that overall movements of water around the WRZ are representative.

All PC10 funded schemes are included in the models and following the recommendations of WRS 2002 all groundwater sources are assumed to be out of service for WRMP 2012. Any assets which have been identified as being ‘out of service’ or abandoned have not been removed from the original schematics. However they have been disabled in the model and are represented with a line through the component name. Assets known to be operated under the PPP have ‘PPP’ inserted into the component name. Aquator demand centre components (yellow circles in the model schematics) are still included based on the 2002 WRS resource zone names as they remain the most appropriate means of apportioning demand across each WRZ.

In addition to the model structures shown in the section below, a further set of models were constructed to give an unconstrained view of the WRZ, where all sources are linked to one central demand centre. In this approach DO results are not limited by pipeline capacity constraints and so provide a useful indication of supply potential in the WRZ. These four model schematics (the Central WRZ is already connected in this respect) are included in section A.8.1 and more explanation of this approach is given in section A.5.1.

A.4.2.3 Schematics

This section provides schematics for each WRZ model, Figure A.2 provides a guide to the component symbols shown in the schematics, (North WRZ in Figure A.3 West WRZ in Figure A.4; Central WRZ in Figure A.5; East WRZ in Figure A.6; and South WRZ in Figure A.7), exported directly from Aquator, and

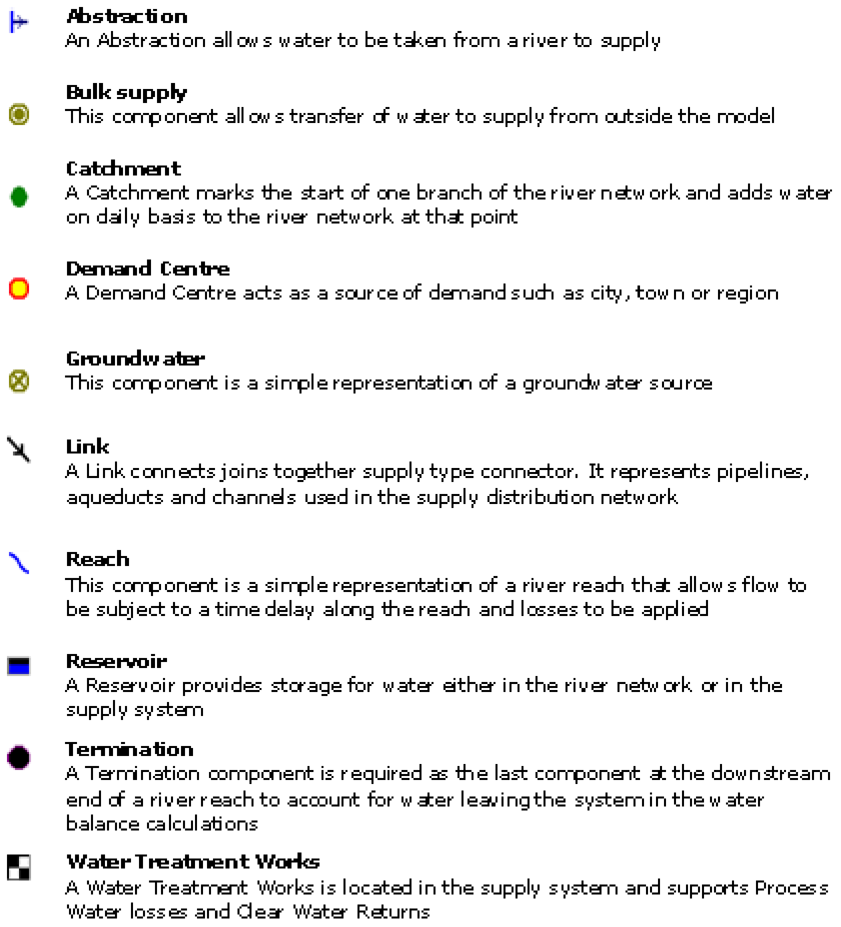

Figure A.2 – Key to Aquator model components symbols

North WRZ Schematic

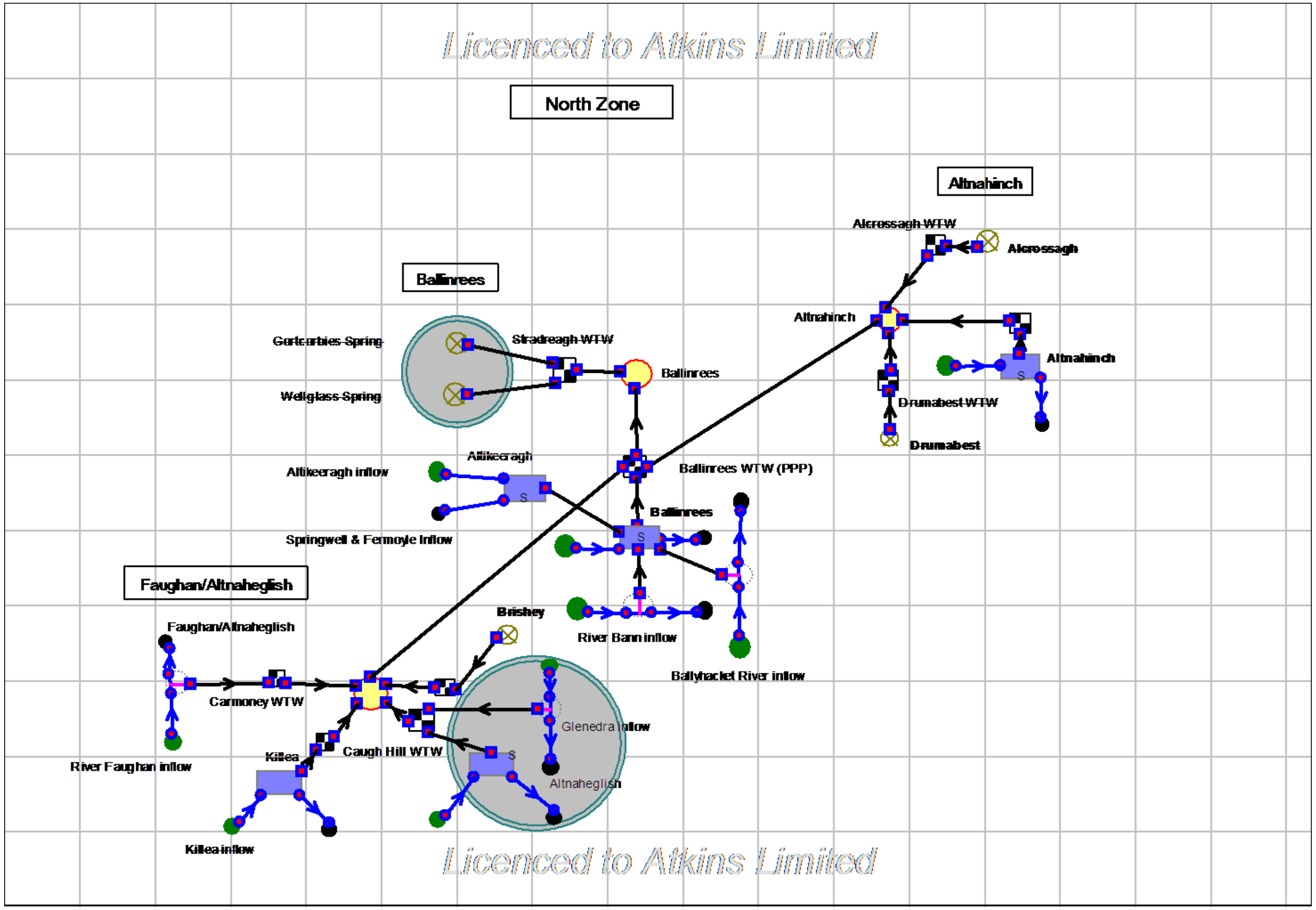

Figure A.3 – North WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

West WRZ Schematic

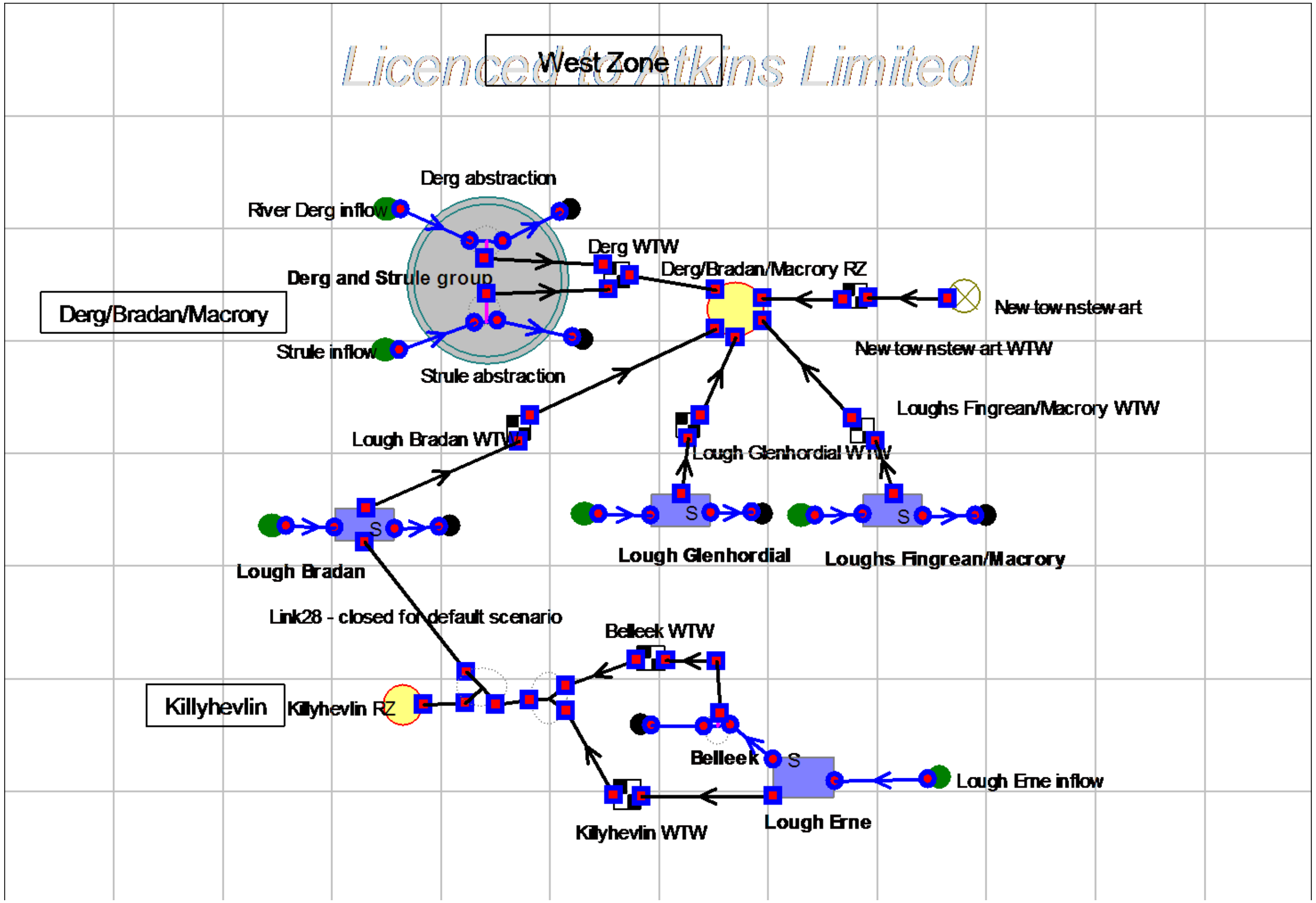

Figure A.4 – West WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

Central WRZ Schematic

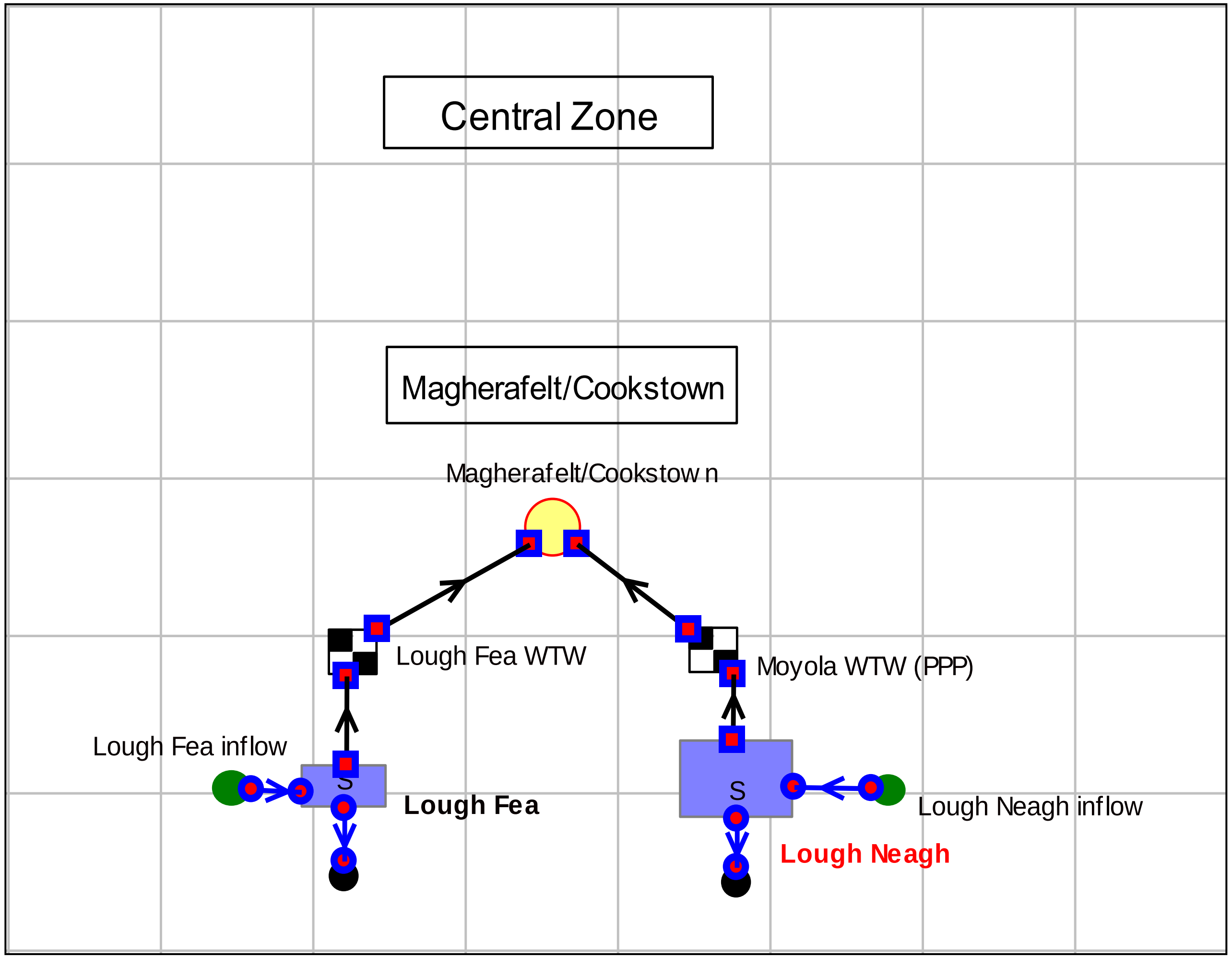

Figure A.5 – Central WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

East WRZ Schematic

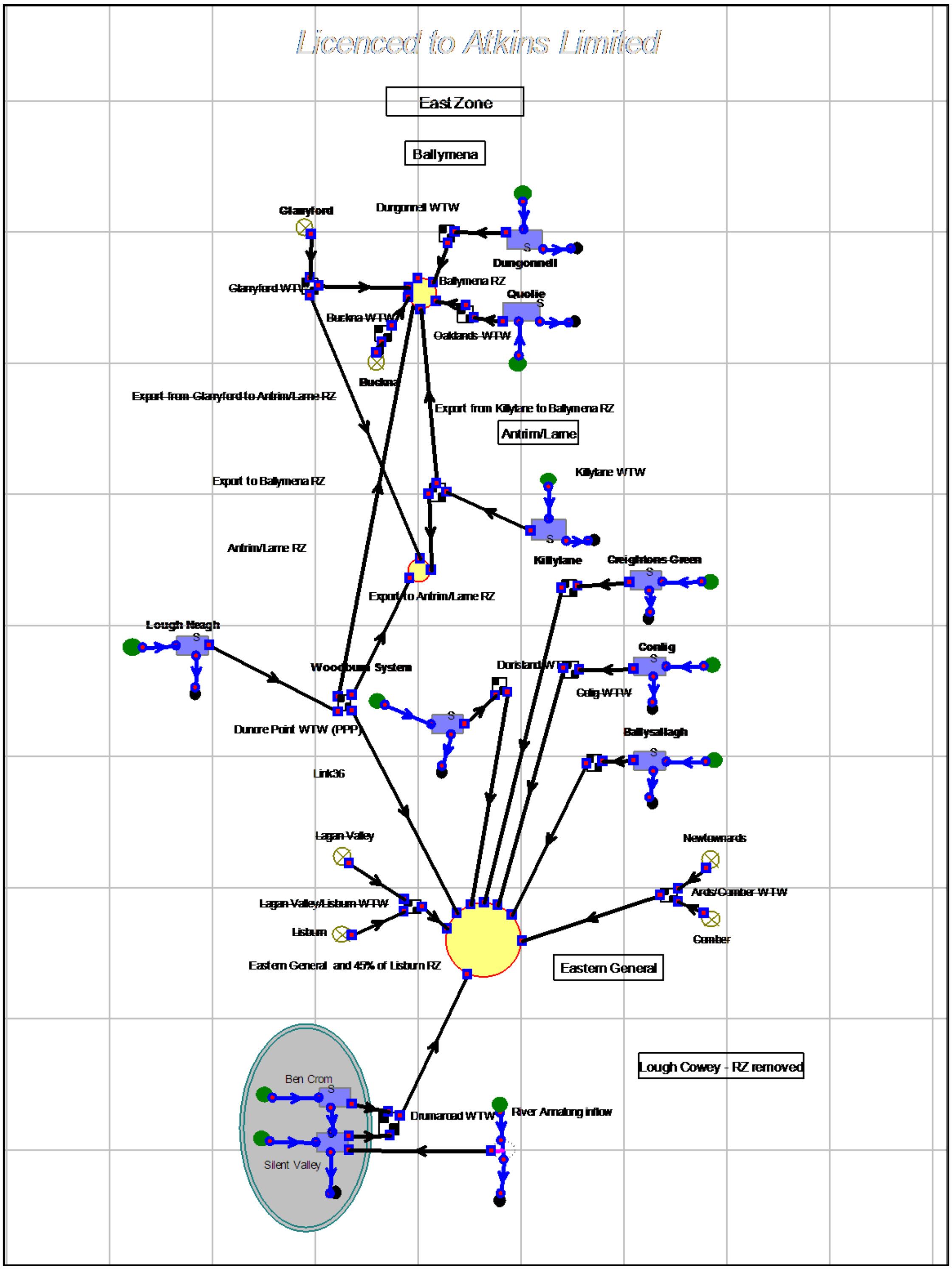

Figure A.6 – East WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

South WRZ Schematic

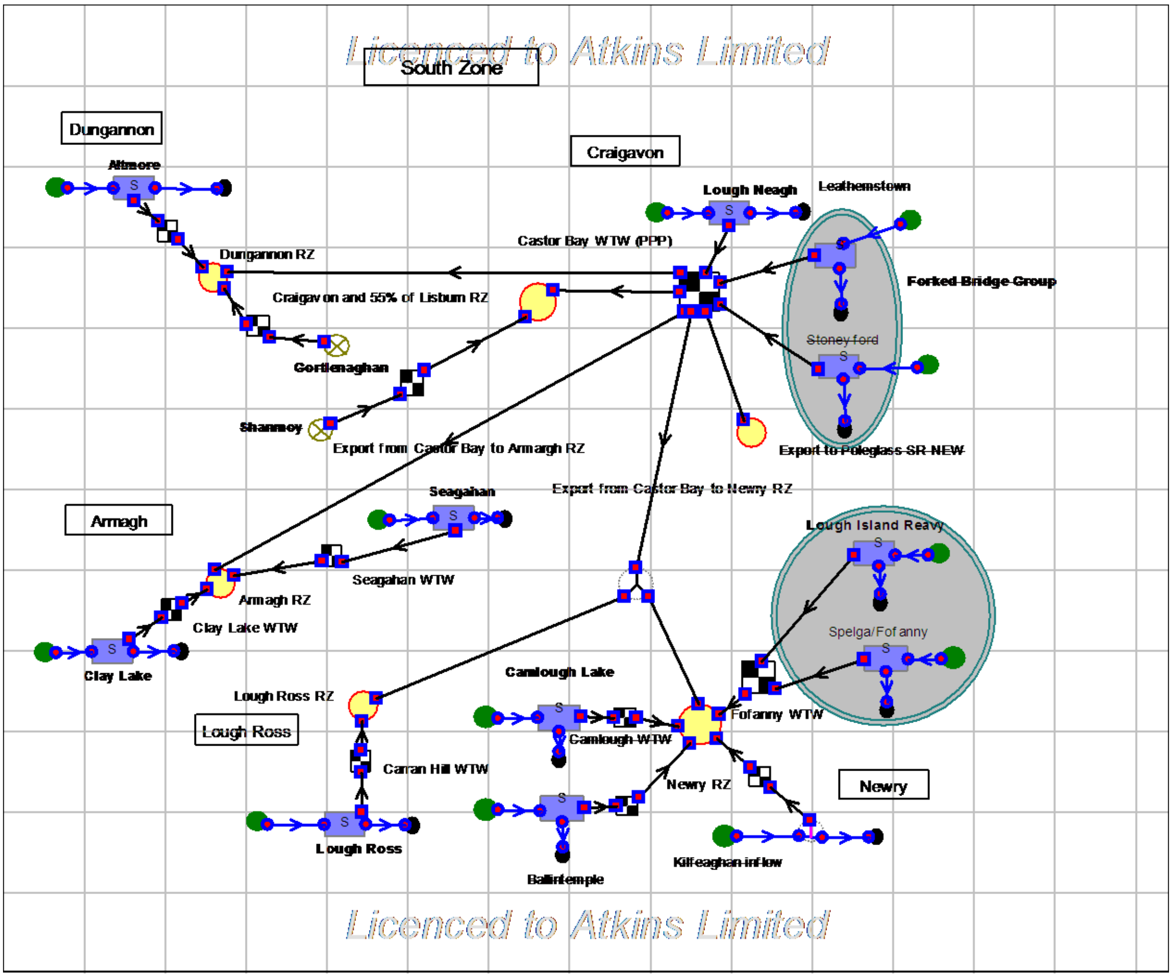

Figure A.7 – South WRZ model schematic

Note that the links (black arrows) do not necessarily represent individual pipelines, rather a general movement of water

A.4.2.4 Recommendations for improvement

There are a number of cross-WRZ transfers currently in operation in Northern Ireland. These transfers are not included in the current model structures as they have been developed for determining DO on an individual WRZ basis. However, it would relatively simple to model these transfers, either by merging separate WRZ models together (straightforward in Aquator) and adding in new links between sources and the relevant demand centres, or by incorporating transfers as an bulk imports into the WRZ with an assumption of some normal level of use. This is beyond the scope of work required for the WRMP.

As noted in the Provenance section above, the distribution network in Aquator is always a simplification of the real network. The level of detail in the current model setup is appropriate for use in WRMP 2012. However, if in future modelling work a more in-depth analysis of any particular area is required then the distribution system can be easily expanded to include more pipes and more complex operational rules. It is important to note that this will still be a limited physical representation of the system and not comparable to the TMM.

Similarly, the river system in the models can be expanded to allow a more comprehensive simulation of hydrology across the WRZ. This can be useful for a variety of purposes, for example examining the environmental impact downstream of river abstractions.

A.4.3 Input data

A.4.3.1 Data collation

Initially a full Aquator data request form was issued to NI Water and this is shown in section A.8.2. However, it became apparent that it would not be possible for NI Water to fulfil all of these requirements within the timescale set out for data collation. Therefore, the list was condensed to a shorter 'critical list' which was viewed as the minimum required for an appropriate DO assessment. It was still not possible for NI Water to provide all of these data, however, it was possible to replace those that were missing (noted in italics below) with data from an alternative source or with data that were derived as part of this investigation.

- Impounding reservoirs
  - Storage capacity;
  - Inflow record – *not available so determined using LFE software* (*Catchment Hydrology*);
  - Observed storage records;
  - Important operational rules – *not available so models optimised manually (section A.5.2);*
  - Storage control curves – *not available so models optimised manually (section A.5.2);*
  - Compensation releases.
- Boreholes
  - Confirmation of whether still in service;
  - Yields.
- Abstraction licences
  - Daily and annual quantities;
  - Minimum and environmental flow conditions.
- Infrastructure (link mains and Water Treatment Works [WTW])
  - Critical capacities constraints (e.g. between the source (impounding reservoir, river, borehole etc.) and the water treatment works); i.e. whether there a critical capacity limitation relating to the intake structure, pumping station or link (pipe, channel etc.) that will constrain the volume of water that is able to reach the works in addition to any licence constraint;
  - Treatment works capacities.
- River and stream flows above each intake (flows into impoundments covered under impounding reservoirs)
  - Mean daily flow time series – obtained from Rivers Agency for all 106 gauges.

The following sections describe the data collated during this period, along with the processing required to produce the input data for each element of the Aquator models used to determine DO.

A.4.3.2 Abstraction licences

Digital copies of all Northern Ireland abstraction licences, associated maps and abstraction licence applications were provided. The information from all the licences (which were issued in 2007) was translated into to a format suitable for Aquator and the current organisation of WRZs as shown in Table A.1. Only daily licences conditions were provided and there are no minimum flow conditions.

WRZ	Source	Daily Licence quantity (Ml/d)	Notes
North	Glenedra River/Altnaheglish	40	Licence covers both intakes (also covers Kerlins Burns but this is not modelled separately in Aquator and is combined with Altnaheglish)
	Altnahinch	14.5	
	Ballinrees/River Bann	50/40	The licence application separates out the component intakes (e.g. Ballyhacket River 25 Ml/d) but the actual licence just quotes 50 Ml/d overall with a maximum of 40 Ml/d of this coming from the River Bann
	River Faughan	55	
West	Belleek	2.5	
	Loughs Fingrean/Macrory	18.5	
	River Derg and River Strule	26.6	A new licence has been issued for 26.6 Ml/d, but its implementation is dependent on an agreed monitoring plan being in place, which is expected to be enacted only when the new Strule pipeline is operational. The previous licence limits abstraction to 15 Ml/d from the River Derg alone but has no environmental flow conditions imposed.
	Lough Bradan	16	
	Lough Erne (Killyhevlin)	44	
	Lough Glenhordial	8	
Central	Lough Fea	17	
	Lough Neagh (Moyola)	20	
East	Woodburn system	50	
	Silent Valley, Ben Crom and Annalong River	115	In the licence document the licensed amount is 155 Ml/d. However, this includes 40 Ml/d which was pumped from Lough Island Reavy (South WRZ) so this has been subtracted from the licence quantity.
	Dungonnell	14.5	
	Lough Neagh (Dunore Point)	189	
	Killylane	16.1	

WRZ	Source	Daily Licence quantity (Ml/d)	Notes
South	Lough Neagh (Castor Bay)	154	The application requests 183 Ml/d. The amount sought for Castor Bay in the 2005 abstraction licence application was 155 Ml/d
	Camlough Lake	5	Camlough is decommissioned in 2015
	Clay Lake	10	The licence application only requests 5 Ml/d
	Lough Island Reavy	22	The licence allows 40 Ml/d to be abstracted from the Lough, but also states that only 22 Ml/d can be pumped to Fofanny the remainder to Drumaroad (Silent Valley – East WRZ). The full 40 Ml/d can be pumped to Drumaroad within the licence but there is no infrastructure to deliver this at present).
	Lough Ross	9.5	
	Seagahan	20	
	Spelga/Fofanny (+ Lough Island Reavy)	52	This is part of combined licence with Lough Island Reavy which also has a separate individual licence of 22 Ml/d

Table A.1 – Abstraction licence conditions

(based on licences re-issued in 2007 and licence application documents)

A.4.3.3 Demand centres

It is important that the Aquator models contain current information on demand across each of the WRZs. Demand values are attached to each demand centre (DC) so that as Aquator scales up demand across the WRZ (during a DO run) it can do so proportionally with respect to the demand centres. In this case, demand corresponds to post MLE (Maximum Likelihood Estimation) average values of distribution input from the 2008–09 Water Balance as reported in the 2009 Annual Information Return (AIR09). Because this was based on a total of 21 WRZs it was necessary to combine some areas to produce values for the 15 demand centres included in the Aquator models. It was also necessary to split the Lisburn area across the East and South WRZs (Eastern General and Craigavon demand centres) as shown in Table A.2.

WRZ	Demand Centre	Demand (Ml/d)	Notes
North	Faughan/ Altnaheglish	45.04	
	Altnahinch	13.69	
	Ballinrees	17.62	
West	Derg/Bradan/ Macrory	37.22	
	Killyhevlin	25.68	
Central	Magherafelt/ Cookstown	26.70	

WRZ	Demand Centre	Demand (Ml/d)	Notes
East	Antrim/Larne	30.34	
	Ballymena	24.32	
	Eastern General	236.96	Includes Belfast, Carrick, Lough Cowey, Ards, Lisburn (45%) and Downpatrick
South	Newry	53.28	Includes Newry and Mournes (originally Mournes had some overlap with Eastern General but currently fully included in the South WRZ)
	Craigavon	94.74	Includes Craigavon, Lisburn (55%) and Craigavon SE
	Lough Ross	6.43	
	Armagh	18.33	
	Dungannon	5.20	
Total		**635.56**	

Table A.2 – Demand values applied to each demand centre in the Aquator models

(based on post MLE values from 2008–09 Water Balance)

A.4.3.4 Links

Links (black arrows) in Aquator are used to join together components of the supply system. They can represent pipelines, aqueducts or channels. As Aquator is a simplification of the real supply system, each link often represents a number of actual pipes on the ground. In the Aquator models developed here many links have no maximum capacity set. This is because the WTWs to which they are connected have maximum capacities which control flow through the distribution system. However, in some cases, particularity where links are transferring water from one area of a WRZ to another and where WTWs have multiple outputs, the application of capacity constraints to links can have a significant effect on model operation and hence DO results. Therefore, considerable effort has been expended in assigning appropriate maximum capacity constraints to certain links.

Again it is important to stress that each of these links does not necessarily represent an individual pipeline – it is more convenient to think of the links as a general movement of water between areas across the supply network. Table A.3 gives a list of all links to which maximum capacities have been applied along with the reasons behind the limit. In addition to links in current operation, all new links which have approved funding under PC10 have also been included. If a link has been investigated but it did not prove possible to attach a reliable capacity the link was left as unrestricted. The reasons for this are noted against the link in Table A.3.

WRZ	Origin component	Destination component	Maximum capacity (Ml/d)	Provenance and reasoning
North	Ballinrees WTW	Ballinrees DC	35	This relates to the capacity of the main supplying Coleraine, Castlerock and Garvagh. In practice it would be difficult for the distribution network to utilise more than 30 Ml/d. There are several trunk mains from the works into the Ballinrees demand centre but the capacity of these are not known at this stage so 35 Ml/d was considered to be an appropriate capacity to use.
	Ballinrees WTW	Faughan/Altnaheglish DC	15	Known physical constraint on Ballinrees to Limavady and Londonderry Transfer[5]
	Ballinrees WTW	Altnahinch DC	10	Set to PPP contracted volume but physical capacity also known to be 10 Ml/d (determined during testing on project handover)
West	No link capacities applied			
Central	No link capacities applied			
East	Killylane WTW	Ballymena DC	3	Established during field tests and modelling carried out by Mouchel Parkman in 2009. The low capacity is due to low pressure problems on the main. There are proposals to upgrade this main but as there is no valid justification at the moment the link is restricted to 3 Ml/d.
	Dunore Point WTW	Ballymena DC	22	Established during field tests and modelling carried out by Mouchel Parkman in 2009
	Dunore Point WTW	Antrim and Larne DC	Unrestricted	The main from Dunore Point to Larne has a known capacity of 11 Ml/d. However, in the Aquator demand centre Larne is combined with Antrim and there are multiple inputs to Antrim making it impossible to assign a reliable overall flow capacity to this link.

[5] Capita Symonds (2008)

WRZ	Origin component	Destination component	Maximum capacity (Ml/d)	Provenance and reasoning
	Dunore Point WTW	Eastern General DC	160	The Dunore Point to Belfast link was completed in 2008 with a design flow capacity of 140 Ml/d. However, further upgrades were applied during construction taking the capacity to 160 Ml/d. This was established during field tests and modelling carried out by Mouchel Parkman in 2009
South	Castor Bay WTW	Dungannon DC	30	Castor Bay to Dungannon strategic transfer project tender document
	Castor Bay WTW	Craigavon and Lisburn DC	Unrestricted	The Castor Bay to Forked Bridge strategic transfer (29 Ml/d) is represented by this link but so are a number of other connections. When combined the overall capacity is above that of Castor Bay WTW and hence not restrictive. However, there is a complicated network of links in this area and it's not possible to assign one single constraint
	Castor Bay WTW	Jerretspass PS	18	Castor Bay to Newry Phase 1 PC10 scheme (capacity determined by Atkins TMM test). Phases 2 and 3 (taking capacity to 38 Ml/d) are very likely to go ahead but will be reviewed at the next price control period so are not included in the baseline model
	Jerretspass PS	Lough Ross DC	5	PC10 and next price control period capacity. There is a design capacity of 9.8 Ml/d for the proposed main from Jerretspass to a new SR at Tullyhappy. This SR will then feed about 5 Ml/d into Newry distribution and then about 5 Ml/d into the Lough Ross area. The information available would indicate that 1 Ml/d can pass to Lough Ross through an existing system but there is uncertainty over the performance of the existing system once the new system is in place, so the capacity of the link is set to 5 Ml/d.

WRZ	Origin component	Destination component	Maximum capacity (Ml/d)	Provenance and reasoning
	Jerretspass PS	Newry DC	18	There is a 450 mm downstream main via gravity and a 12” DI main via the pumps at Jerretspass into the Newry demand centre so Atkins TMM team do not envisage any other restriction than the amount of water that can pass along link 1 from Castor Bay. For the next price control period the capacity of this link is been increased to 33 Ml/d.
	Castor Bay WTW	Armagh DC	10	The Castor Bay to Dungannon strategic transfer project tender document gives a value of 6.7 Ml/d as a current supply amount for this link. However, it is known that there is some surplus in capacity in this area so the maximum has been set to 10 Ml/d
	Lough Island Reavy Reservoir	Fofanny WTW	20	There is an actual infrastructure constraint on the pipe between Lough Island Reavy and Fofanny WTW.

Table A.3 – Supply network link capacities

A.4.3.5 Reservoirs

All significant impounding reservoirs were included in the Aquator models although some were combined together as one component, for example those of the Woodburn system. The most important parameter attached to the reservoir components was storage capacity but there were also a few compensation flow conditions that have been applied at the reservoir outlets. The determination of reservoir inflows is described in Catchment hydrology.

Storage capacity

The Aquator reservoir component storage volume parameter was set based on ‘Maximum Usable Storage’ values provided by NI Water for WRMP 2012 and shown in Table A.4.

Water Resource Zone	Reservoir	Aquator Storage Volume (Ml)
North	Altnaheglish	2,227
	Ballinrees	1,209
	Altnahinch	1,250
	Altikeeragh	185

Water Resource Zone	Reservoir	Aquator Storage Volume (Ml)
West	Loughs Fingrean/Macrory	1,282 (combined)
	Lough Glenhordial	92
	Lough Bradan	950
	Lough Erne	Assumed storage is extremely large relative to demands
Central	Lough Fea	1,696
	Lough Neagh	Assumed storage is extremely large relative to demands
East	Lough Neagh	Assumed storage is extremely large relative to demands
	Lough Island Reavy	9,092
	Woodburn System	8,193
	Silent Valley	12,913
	Ben Crom	7,721
	Killylane	1,327
	Dungonnell	942
South	Spelga/Fofanny	3,932
	Camlough Lake	3,300
	Lough Neagh	Assumed storage is extremely large relative to demands
	Lough Ross	4,678
	Clay Lake	1,468
	Seagahan	2,453

Table A.4 – Reservoir storage capacity

Compensation flow conditions

Compensation flow requirements were provided for three reservoirs in the same NI Water table as the storage capacity values. These were applied to the relevant Aquator models and are shown in Table A.5. The compensation condition at Altnahinch is specifically stated in the abstraction licence but this is not the case for the Dungonnell or Spelga/Fofanny ones.

Water Resource Zone	Reservoir	Compensation flow condition (Ml/d)
North	Altnahinch	3.21
East	Dungonnell	0.454
South	Spelga/Fofanny	2.27

Table A.5 – Reservoir compensation flow conditions

A.4.3.6 Catchment hydrology – hydrological record length

Introduction

The DO modelling for the supply forecast was undertaken over the period of 29/12/1975 to 11/07/2009 as this represented the full period of gauging station flow data available from the Rivers Agency (the method for the generation of input flow sequences is outlined in section A.4.3).

UK water industry best practice requires the use of long time series of river flows to determine DO. The length of observed flow records available in Northern Ireland is relatively short, and a longer record should make it more likely that critical drought conditions are included within the design period, and a more drought resilient analysis should result. To undertake DO analysis using longer flow time series it would be necessary to infer river flow from rainfall records which are likely to go back further than 1975. The best method for this is to construct rainfall-runoff models which would be calibrated against post-1975 river flow records. This would require an extensive programme of hydrological work to obtain and ensure the quality of the basic hydrometric data, and to develop, calibrate and validate appropriate rainfall-runoff models. However, the benefits in terms of a more representative analysis and a greater statistical credibility are also clear. Such a programme of work is beyond the scope of this WRMP.

To consider the context of the 1975-2009 hydrological period against a longer historical record a number of analyses have been undertaken. The basis for all of this work is the Armagh metrological record which stretches back to 1853 in terms of rainfall measurements. This is the longest continuous rainfall record we are aware of for Northern Ireland and it has been used to assess the dry periods which are of interest when determining DO. There are four parts to the investigation:

- Historical drought length and severity
- Rainfall frequency distribution
- Aridity index
- Aquator failures

The first part of the analysis studies the Armagh rainfall record to determine the duration and severity of dry events by making comparisons against long terms averages. The second part looks at rainfall totals as a proxy for resource status. As there are a variety of types and sizes of sources in Northern Ireland different rainfall periods ranging between 3 months and 36 months are analysed. The third part of the investigation involves the calculation of aridity indices[6] to incorporate temperature data and hence give some consideration to historical evaporation. The fourth and final part briefly examines the Aquator DO demand failures to determine where and when hydrological conditions were most constraining.

Historical drought length and severity

The Armagh rainfall record was used to determine the driest periods during 1853-2010 both in terms of severity and duration. Severity was determined by calculating the cumulative departure of the rainfall measurements from the long-term mean; and the duration was determined by counting the number of consecutive months where the rainfall fell below the long-term mean (if necessary extended back into previous years).

Where a dry period appears in the record less often than 1 in 100 years, 1 in 20 years or 1 in 10 years it was noted (although no formal frequency analysis was completed). Consecutive dry years were lumped together into dry periods, rather than listing each year separately. The dry periods were ranked based on duration.

Table A.6 shows the 20 driest periods in the long term record based on a rank of duration with the return period indicated to show severity. As noted above the return period corresponds to a category rather than an absolute return period, so where the type is indicated as 1 in 20 years it means that the actual return period is between 1 in 20 years and 1 in 100 years. Not sure why didn't just calculate actual return period – big gap between 1/20 and 1/100 and also easier to rank actual return periods.

The table shows that on this basis the WRMP hydrological record period of 1975-2009 includes the dry period with the second longest duration (2003-2004) and two periods which are severe enough that they have a return period of less than 1 in 100 years (1995 and 1975-1976). However, it is important to note that the more severe part of the 1976-1976 period is not covered by the WRMP record which begins with the start of the flow records on 29/12/1795.

[6] Environment Agency, 2006, SC040068/SR1, The impact of climate change on severe droughts: Major droughts in England and Wales from 1800 and evidence of impact

Date	Duration ranking	Severity type
1952-56	1	1 in 100 year
2003-04	2	1 in 20 year
1864	3	1 in 20 year
1943-44	3	1 in 20 year
1933-34	5	1 in 100 year
1855-56	5	1 in 100 year
1975-76	7	1 in 100 year
1995	7	1 in 100 year
1887-88	9	1 in 100 year
1991	9	1 in 20 year
1919	9	1 in 20 year
1853-54	12	1 in 20 year
1921	12	1 in 20 year
1893	13	1 in 100 year
1858-60	14	1 in 20 year
1911	14	1 in 20 year
1890-91	14	1 in 100 year
1895	14	1 in 20 year
1885	14	1 in 20 year
1932	14	1 in 20 year

Table A.6 – Top 20 driest periods by duration of rainfall deficits against the long-term Armagh record.

Severity is indicated by return period categories based on rank order.

Rainfall frequency distribution analysis of varying drought periods

Following analysis of the duration and severity of dry periods, further studies were undertaken on the Armagh rainfall record to estimate the historical resource state of Northern Ireland's sources. The length of dry period which can become critical to maintaining supplies will vary from source to source. At one end of the scale abstractions from smaller upland rivers with low base flow contributions might be affected by short dry periods, whereas larger reservoirs such as Lough Neagh might only be affected by longer periods. Therefore, for each calendar year in the record the rainfall measurements were summed for the following periods:

- 3 months of summer (June-August)
- 6 months of summer (April-September)
- 12 months (full year)
- 24 months (full year plus the preceding 12 months)
- 36 months (full year plus the preceding 24 months)

The years were then ranked in order of how little rainfall was received during these periods (Table A.7). In addition to ranking the years, frequency distributions were created for each of the five summing periods using bin sizes set to reflect the range of summed rainfall values encountered for each period. In Figure A.8 each plot shows the driest year from the WRMP hydrological period (according to the ranking in Table A.7) indicated above the corresponding bin to show where the driest conditions sit within the full 1853-2010 distribution.

Looking at Table A.7 it is readily apparent that for the shorter 3 and 6 month summer totals the 1975-2009 WRMP hydrological period is very effective in capturing dry periods. For both summing periods 7 out of the 20 driest years fall within the WRMP hydrological period. The year with the driest summer period in both cases is 1995 and for the 3 month total 1983 is the second driest year.

As the length of rainfall summing period is increased, the WRMP period captures relatively fewer and lower severity dry events. For the annual totals 5 out of 20 years still feature in the WRMP period but the driest year in the WRMP (2001) is only the 10th driest year in the long-term rainfall record. For 24 and 36 months fewer years feature within the top 20 but the driest years in the WRMP hydrological period are relatively well placed at 5th (1976) and 8th (1977) respectively. The frequency distribution plots (Figure A.8) show the driest WRMP year falls to the far left for the summer totals but further to the right for the longer 12, 24 and 36 month totals. However, in all cases the vast majority of 1853-2010 rainfall totals still fall to the right of the driest WRMP years.

Figure A.9 presents scatter plots of flow at Camowen gauging station against rainfall at Armagh for 3 and 6-month summer totals and 12 and 24 month (calendar year) totals. This shows that there is a relationship between the two and that it is reasonable to consider rainfall deficits as a proxy for source water supply deficits. However, it is also apparent that there is significant variation and, as noted above, an extensive programme of hydrological work would be needed to obtain representative hydrometric data of a sufficient coverage and quality before developing rainfall-runoff models.

Rank	Summer 3 month (June-August)		Summer 6 month (April-September)		Annual		24 months (including preceding year)		36 months (including preceding years)	
	Year	Total rainfall (mm)	Year	Total rainfall (mm)	Year	Total rainfall (mm)	Year	Total rainfall (mm)	Year	Total rainfall (mm)
1	1995	80.8	1995	199.9	1953	411.2	1954	950.6	1954	1533.1
2	1983	87.8	1953	227.3	1954	539.4	1953	993.7	1955	1656.7
3	1975	96.9	1952	230.6	1933	558	1955	1245.5	1953	1857.2
4	1991	103.1	1991	239.1	1952	582.5	1856	1262.5	1857	2037.1
5	1885	112.1	1954	249.9	1975	585.9	1976	1334.3	1855	2076.1
6	1870	116.9	1933	257.8	1855	602.6	1888	1352.4	1956	2088.3
7	1954	119.6	1982	268.2	1887	606.5	1933	1375.4	1856	2099.7
8	1976	120.2	1853	271.8	1893	617.2	1860	1419.5	1977	2122.9
9	1869	121.2	1978	276.2	1853	636.3	1975	1429.6	1889	2130.3
10	1953	128.1	1983	282.5	2001	646.8	1859	1433.8	1860	2156
11	2006	134.6	1870	285.5	1885	654.9	1857	1434.5	1860	2156
12	1952	139.2	1876	285.7	1856	659.9	1855	1439.8	1893	2166.5
13	1968	144	1914	287.1	1989	665.5	1893	1442.9	1887	2170.7
14	1999	144.9	1977	291.4	1991	679.7	1934	1445.3	1858	2171
15	1969	148.5	1975	294.7	2003	683.6	1952	1446	1973	2172.5
16	1978	149.1	1911	295.9	1971	694	1972	1446.1	1976	2178
17	1868	149.2	1984	297.5	1859	697.3	1894	1460.1	1859	2208.4
18	1919	150.3	1893	299.4	1911	702.3	1854	1473.5	2005	2222.1
19	1911	150.7	1865	302.8	1983	705.1	1973	1478.5	1991	2228.9
20	1961	153.6	1921	304.4	1955	706.1	2004	1483	1895	2232.5

Table A.7 – Years from the Armagh 1853-2010 rainfall record ranked by total rainfall received over: summer 3 month, summer 6 month, annual, 24 months and 36 months.

Cells shaded red correspond to years which fall outside of the WRMP hydrological period (1975-2009)

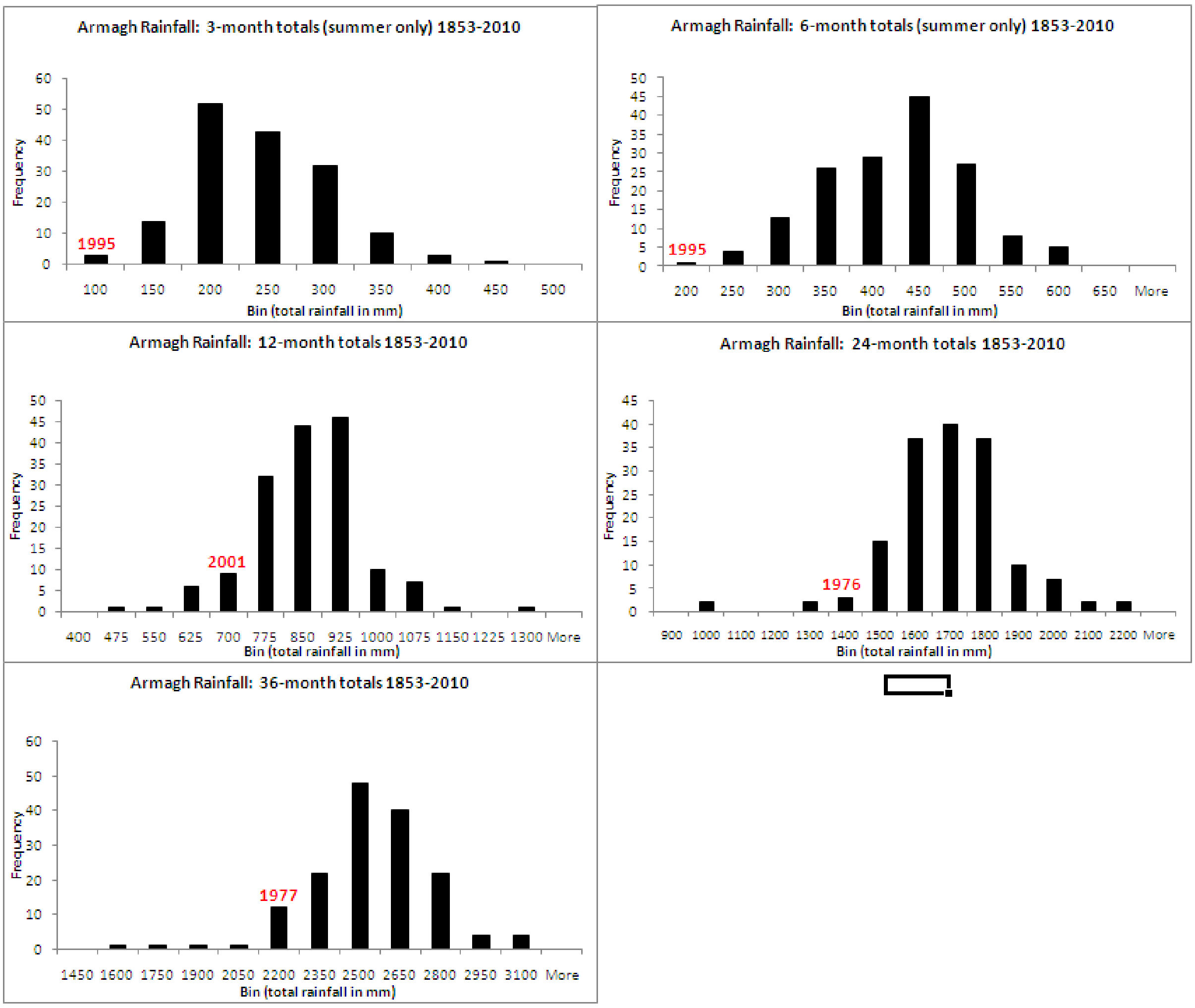

Figure A.8 – Total 1853-2010 rainfall distributions for each of the defined periods: summer 3 month, summer 6 month, annual, 24 months and 36 months.

The placement of red years corresponds to the bin into which the driest years from the WRMP hydrological period (according to the ranking in Table A.6) fall.

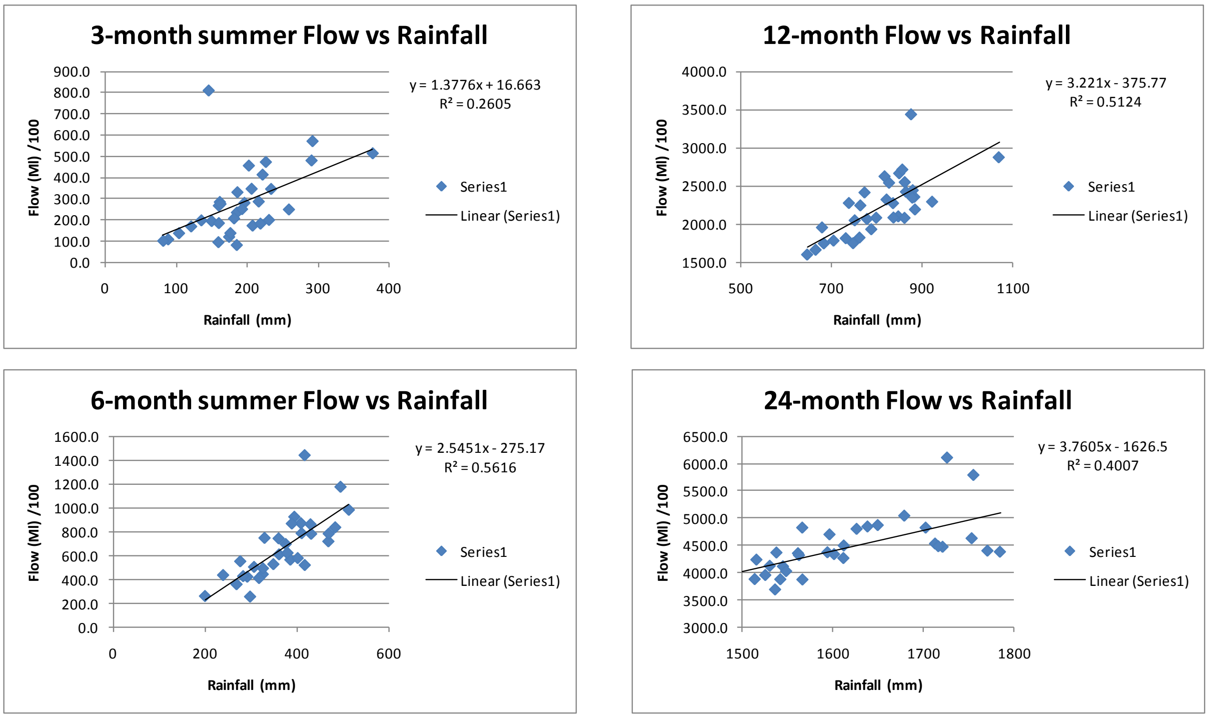

Figure A.9 – Scatter plots of flow at Camowen gauging station and rainfall at Armagh for 3 and 6-month summer totals and 12 and 24 month (calendar year) totals.

The Aridity Index

The above analyses rely solely on rainfall measurements and whilst comparison is made with flow in Figure A.9 aridity indices calculations allow one to incorporate temperature data in order to improve the representation of historical dry periods. Temperature records at Armagh are slightly shorter than the rainfall records available but still reach back to 1865 (1866 for complete years of readings). The Aridity Index methodology has been taken from the Environment Agency's Science Report SC040068/SR1 (Environment Agency, 2006[7]). The homogenised England and Wales rainfall record and Central England Temperature series were substituted with data from the Armagh record. The formula takes the following form:

- Aridity index = – (Rainfall – Average rainfall)/SD rainfall + 0.5(Temp. – Average Temp.)/SDTemp.

Where 'Rainfall' is the April–September total and 'Temp.' is the April–Sept average temperature. The 'Average' is the full record average in both cases.

Figure A.10 shows the results of the analysis. Indices above zero represent drier periods and those below zero represent wetter periods. The WRMP hydrological period has been shaded in yellow and it can be seen that on average this period experiences a greater number of drier summers and the year with the highest index value is 1995.

The results tie well with the 6 month summer rainfall analysis which is not surprising given that the same April to September totals are used. The fact that some account of

[7] Environment Agency, 2006, SC040068/SR1, The impact of climate change on severe droughts: Major droughts in England and Wales from 1800 and evidence of impact

evaporation has been included by incorporating the temperature record adds more confidence to the findings.

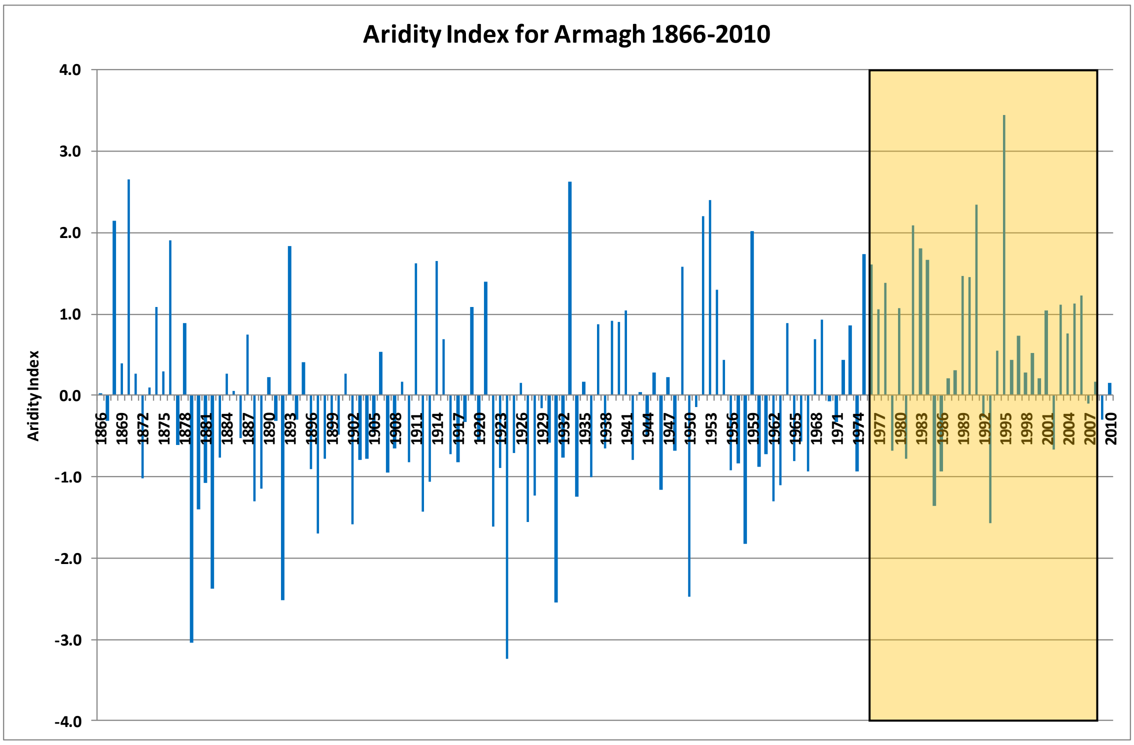

Figure A.10 – Aridity indices for the Armagh record. The yellow shaded area corresponds to the 1976-2009 WRMP hydrological period.

Aquator failures

In the final part of the investigation the hydrological period was re-visited once the Aquator modelling for deployable output (DO) assessment had been completed. The DO assessment is described in later sections of this appendix failures but pertinent information is used here to complete this analysis of the hydrological period covered by the models.

It is very important to note the limitations of this part of the analysis. First of these limitations is that the DO analysis is of course only based on the period 1975-2010. Secondly, little information was provided in relation to the operational rules of the supply system, for example the reservoir control curves. The models were therefore optimised manually and as such behaviour is geared towards achieving a high DO result. As DO should be determined conjunctively within a WRZ a failure at one particular source does not necessarily mean that it was the only source that was hydrologically constrained. There is potential for multiple sources to share their supplies with multiple demand centres and the rate at which these shared sources are deleted is dependent to some extent on the characteristics of all of the contributing sources. The sources which are most likely to be affected by shorter dry periods are likely to be protected as far as possible throughout the whole model run sequence.

Having warned against not considering the conjunctive contributions of sources, the largest sources in Northern Ireland such as Lough Neagh are very large in comparison to the volume of water that is abstracted. Therefore, even during long and dry periods they will continue to provide the maximum abstraction that can be achieved with the assets in place and as such are extremely unlikely to impact on DO. Therefore, failures leading to the definition of DO are more likely to be due to conditions in the rivers and smaller reservoirs in the WRZ. The full details of the DO assessment for each WRZ are given in section A.5.

- In the North WRZ DO is defined by Altnahinch reservoir failing in 1984. Altnahinch is a moderate sized reservoir (1250 Ml) which supplies the Altnahinch area, which in turn also receives supplies from Ballinrees. 1984 is one of the driest 20 years according to the 1853-2010 Armagh rainfall record when 6 month summer rainfall totals are taken into consideration (Ref above). The preceding year 1983 is the second driest years in the 1853-2010 record in terms of the 3 month summer rainfall totals and also sits in the top 20 for the 6 month and 12 month totals.
- In the West WRZ the DO is defined by hydrological constraints at Lough Bradan (950 Ml). Lough Bradan is just one of a number of sources supply water to the Derg/Bradan/Macrory demand centre. However, Aquator optimisation is set to minimise use of water from Lough Bradan throughout the model run suggesting that it really does suffer from a high level of hydrological constraint. Like Altnahinch, the reservoir fails in 1984.
- In the East WRZ Silent Valley and Ben Crom reservoirs become empty in 1978 during the DO assessment. These reservoirs are two of a number of supplies to the Eastern General demand centre. In fact in the model these supplies were equally balanced with the Woodburn System which could easily have been the source which failed with slightly different optimisation rules. In contrast to Altnahinch and Lough Bradan these are all large reservoirs (Silent valley is 12913 Ml, Ben Crom 7721 Ml and Woodburn system 8193 Ml). However, in reality these are actually small sources in comparison to the other source supplying the demand centre which is Lough Neagh. 1978 features in the top 20 years (from 1853-2010) of the 3 and 6 month Armagh rainfall totals and the preceding years 1976 and 1977 fall into both of the summer totals and the 24 and 36 month totals. Strangely, neither of the three years appears in the 12 month rainfall totals.
- The DOs of the Central and Southern WRZs are determined by asset constraints rather than hydrological constraints.

Outcomes

The first part of the analysis, in which rainfall was compared to the long term average, showed that the 1975-2009 WRMP hydrological period included the second longest dry period in the overall 1853-2010 Armagh record (2003-2004) but this only had a severity of between 1 in 20 years and 1 in 100 years. The period contains at least one event severe enough to have a return period of less than 1 in 100 years (1995).

In the second part of the analysis, where rainfall was totalled over 3 months of summer, 6 months of summer, 12 months, 24 months and 36 months, 1995 was confirmed as being a very severe year – the driest in the whole record over 3 and 6 months. However, it didn't feature in the top 20 ranked years for the 12, 24 and 36 month totals. Both 2003 and 2004 (identified at the second longest dry period in the first featured in the first part of the analysis) feature in the top 20 driest years but not prominently – 2003 is only in the top 20 for the 12 month totals (15th) and 2004 only for the 24 month totals (20th).

In the third part of the analysis temperature (and hence to some extent evaporative) influences are introduced by using the Environment Agency's aridity index methodology. The results show that the WRMP hydrological period includes relatively more dry periods than the overall record. It also clearly indicated 1995 as the driest year. As this method sums rainfall on the same 6 month basis as in the second part of the analysis it is perhaps unsurprising that there is good correlation between the two methods.

Thus, the analysis seems to indicate that shorter more severe dry periods (including the 6 month summer period selected by the Environment Agency for their aridity index) are represented very well by the WRMP hydrological period relative to the overall Armagh rainfall record. The longer periods are also represented but they are less prominent and the relative severity in terms of rainfall received is lower than for the shorter periods.

In terms of the sources present in Northern Ireland many are either direct river abstractions or smaller reservoirs and there are no groundwater sources in the WRMP, suggesting that shorter dry periods are likely to be most critical. Therefore, this would indicate a high degree of confidence in using the period 1975-2009 to determine DO.

In examining the sources and years which are critical in terms of determining DO in the Aquator models caution should be exercised due to the conjunctive nature of the assessment as explained above. For the North and West WRZs DO is determined at smaller reservoirs in 1984 which is a recognised period for dry events. However, in the East WRZ the DO is determined by hydrological constraints at the larger reservoirs Silent Valley, Ben Crom and the Woodburn system (though still much smaller than Lough Neagh which also supplies Eastern General). Whilst it might be argued that these larger sources are likely to be less well represented by the 1975-2009 WRMP hydrological period, the failure year of 1978 and the two preceding years feature fairly prominently in the top 20 driest years according to the Armagh rainfall record totals for all summing periods apart from the 12 month one.

Therefore, this analysis has shown that the WRMP 1975-2009 hydrological period is largely appropriate for the purposes of determining DO. Beyond the completion of the WRMP it might be beneficial to extend the hydrological record further back into history to determine the potential impacts of earlier longer duration dry periods on the larger sources. However, it is unlikely that further investigations would lead to a redefinition of DO in most of the WRZs. The WRZ most likely to benefit from additional analysis would be the East WRZ where DO is defined by hydrological constraints at larger sources.

It is critically important if records are extended backwards that a high degree of confidence in the hydrological sequence is maintained. This is especially true for rainfall runoff modelling which relies on long high quality rainfall records with good spatial variability and appropriate river flow records for calibration. Even if it is deemed that sufficient data are available for these purposes then, as explained in the Introduction, a significant amount of effort would need to be expended to generate extended flow records.

A.4.3.7 Catchment hydrology – reservoir inflows & river flows

Introduction

As flow is not recorded at the majority of river intakes or reservoir inflows a bespoke method for determining hydrological model inputs was devised for the WRMP 2012. Aquator requires a time series of daily flow values at each of its catchment components (green circles in the model schematics shown in Figure A.3 to Figure A.7) which are located above each reservoir (blue rectangles) in the model schematics and at the start of each river reach (blue lines in the model schematics). The methodology employed utilises gauged data provided by the Rivers Agency along with software developed for Northern Ireland Environment Agency by Wallingford Hydrosolutions Ltd, and is described in the following sections. For the purpose of WRMP 2012, Lough Neagh and Lough Erne are considered as insensitive to hydrology (abstractions are limited only by infrastructure constraints and licence conditions not hydrology) and hence catchment inflows have not been calculated.

Data

Data available on the Rivers Agency's WISKI database were downloaded, checked by an experienced hydrologist and comments on the quality of the data with respect to this study were made. In addition, the Northern Ireland Environment Agency supplied information on the quality of recorded flows and the reasons why particular gauging stations were included or rejected for use in Low Flows Enterprise software. Reasons for rejection included artificial influences on the flow regime (abstractions or discharges) and insufficient record length. The information provided was used in the hydrological assessment. The available data are summarised in Table A.16.

Software

The Low Flows Enterprise (LFE) software was used to provide Flow Duration Curves (FDCs) at each of the licensed intake locations. Mapping information added to the software included the WISKI gauging stations, licensed intakes (taken from paper copies of NI Water's abstraction licences) and 1:50,000 scale OSNI maps. The software also included flow gauges selected by CEH Wallingford and the intakes from Northern Ireland Water GIS layer. No artificial influences on the flows or impoundments were included.

Approach

The aim of the hydrological analysis was to estimate mean daily flows from 29/12/1975 to 11/07/2009 (as this represented the full period of gauging station data available from Rivers Agency) at each of the licensed intakes shown in Table A.17 in section A.8.3. To do this the following method was developed:

- The LFE software was used to delineate a catchment draining to each of the licensed intakes. The software is able to use either a digital (using an inflow grid from the CEH-Wallingford Digital Terrain Model to identify watersheds) or analogue (defining the area contributing to a catchment by an association of grid squares to the nearest reach of river) boundary. Generally a digital boundary was used unless the software was unable to find a digital climb thread (it should be noted that the analogue catchment outlets were generally located downstream of the licensed intakes). Boundaries were checked using OSNI mapping and amended where necessary. Detailed notes for the delineation of each catchment are given in section A.8.3 (Table A.18).
- For each catchment, similar gauged catchments were selected based on the Region of Influence (ROI) methodology which uses catchment characteristics that can be obtained for any ungauged catchment in the UK. These are called Region of Influence gauging stations; five were selected and ranked based on their distance in 'HOST space' from the licensed intake catchment, with rank 1 being the nearest (or most similar).
- Flow statistics were generated and the catchment boundaries saved. The flow statistics were generated using the ROI gauges and included annual mean flow, annual runoff, Base Flow Index, annual and monthly flow duration statistics for the natural flow regime (FDCs). Where available, geographically local data gauges were used to improve the estimation of these statistics.
- If it was necessary to use an analogue catchment downstream of the intake site, then the FDCs created were adjusted using area weighting.

A bespoke excel tool was created which contained data processing functions for estimating the flow time series for each licensed intake as follows:

- The annual FDC for the licensed intake site, the five ROI gauges and the recorded flow time series were imported into the Excel spreadsheet. For the ROI gauge ranked 1, the flow recorded each day was compared to the FDC for the gauge and the percentage time this flow is exceeded was noted. This was then related to the flow statistics obtained for the intake site from LFE to create a mean daily flow time series at the intake site. In Table A.8, for example, if the flow recorded at GS1 (203029) is 4.17 m^3/s (flow exceeded 5% of the time), the corresponding flow at the intake site is 0.264 m^3/s (flow exceeded 5% of time). If flow data for the particular date is not available then GS2 (203097) was used, then GS3 etc. until a complete time series from 29/12/1976 to 11/07/2009 was produced. In some cases it was necessary to replace ROI gauge 5 with a different gauge if insufficient flow data was available; gauges geographically close to the intake site were used to do this.

This methodology is illustrated graphically in Figure A.11 and with each aspect shown in full detail in section A.8.2.

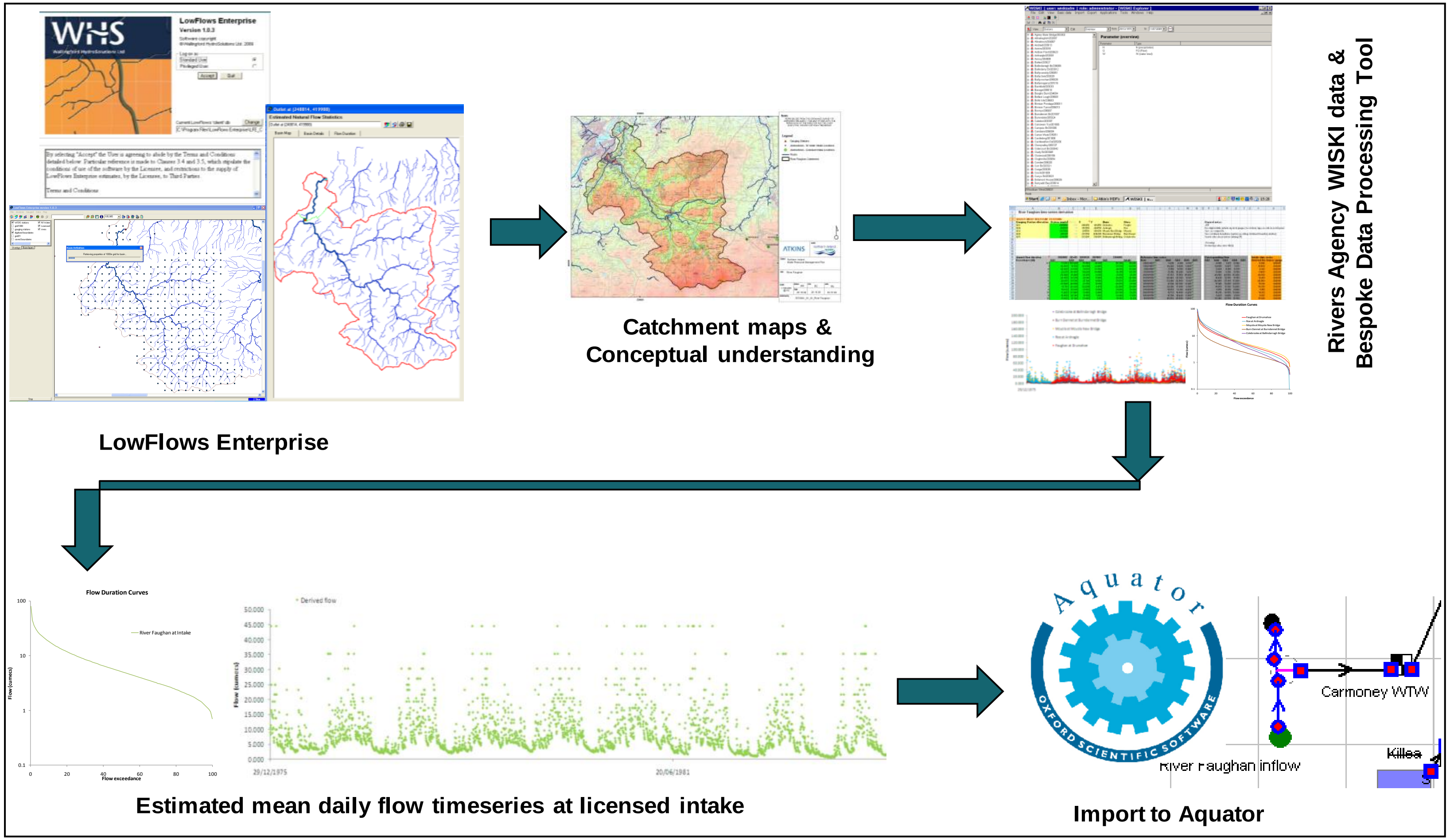

Figure A.11 – Graphical illustration of the methodology for the determination of catchment hydrology

Annual flow duration	ROI gauge 1	ROI gauge 2	ROI gauge 3	ROI gauge 4	ROI gauge 5	Intake
Exceedance (%)	203029	203097	203046	203093	203033	
0.1	23.620	66.120	4.296	177.700	47.330	0.988
1	8.656	39.260	2.286	106.800	23.480	0.505
2	6.514	30.400	1.761	80.420	18.020	0.390
3	5.333	24.600	1.491	70.970	14.740	0.328
4	4.631	21.150	1.342	62.430	12.420	0.290
5	**4.170**	19.170	1.243	57.320	11.070	**0.264**
6	3.888	17.450	1.150	53.340	9.872	0.244
7	3.635	15.700	1.073	50.070	9.112	0.226
8	3.384	14.310	1.000	46.590	8.422	0.210
9	3.207	13.320	0.935	44.030	7.831	0.197
10	3.073	12.530	0.880	41.830	7.309	0.187

Table A.8 – Example of flow duration curve sampling

Checking of the flow time series

As stated above, the gauged data from WISKI was checked and comments on the data were made. The time series were also plotted and examined for erroneous data, for example improbably high or low values (e.g. greater than 1,000 m^3/s or more), were removed.

An additional check was carried out at a gauged site: Martin's Bridge on the River Callan. This gauging station was chosen because it is not including in the LFE software and, according to the Hydrometric Register, the influence of abstractions and discharges is minimal. The methodology was followed as if the site was ungauged, and the flows calculated were compared with the recorded flows. Figure A.12 shows the results of this test for 1981. There is a generally good agreement between the two sets of flows.

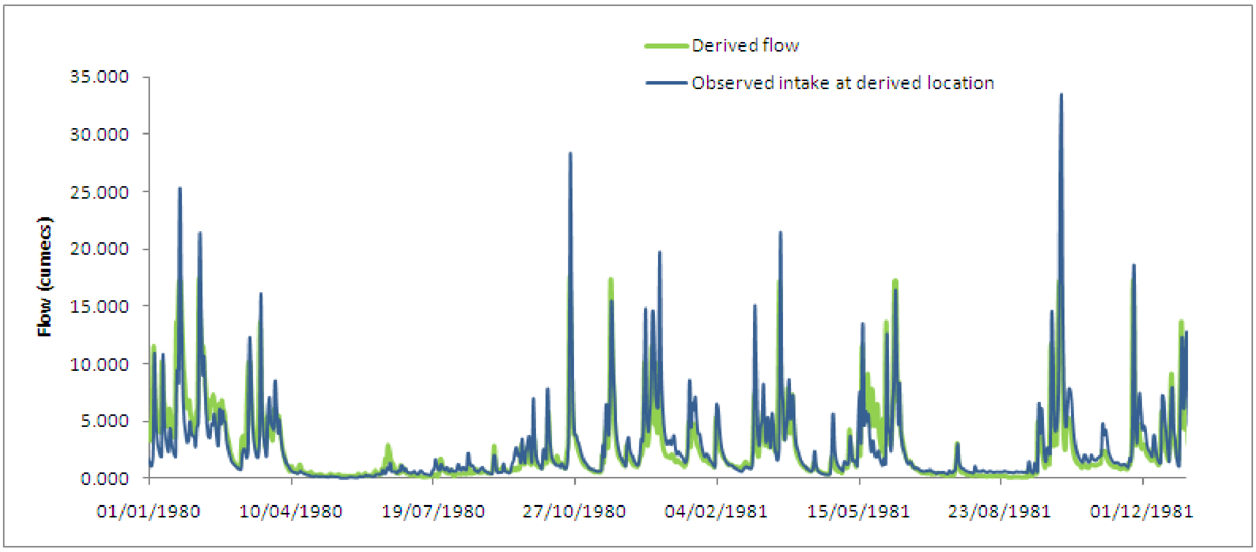

Figure A.12 – Recorded and Derived Flow at the Martin's Bridge gauging station during 1981

Limitations

The checks performed on the incoming data and the flows generated, illustrated that the method reliably produced flow time series for each of the licensed intakes. However, there were a few limitations and these are listed below:

- The length of the overall flow record is relatively short at 33 years (29/12/1976 to 11/07/2009);
- Not all the gauging stations have recorded data for the whole period of record and therefore the time series may be generated from more than one of the ROI gauges. When the record switches from one gauge to another the flows may show a relatively large increase or decrease. The time series were checked and no significant increases or decreases were found;
- The time series created will never be greater than the Q0.1 flow, which is the flow which is exceeded 0.1% of the time; and
- The LFE software contains no abstractions, discharges nor impoundments.

A.4.3.8 Water treatment works

Physical capacity

During the data collation phase a number of sources of information regarding physical capacities of water treatment works (WTW) were provided. These included Water Service Works Overview sheets produced in 2005, NI Water GIS layers and AIR09 pumping station capacities. However, the most important source of information was a table assembled by the NI Water Water Supply Team for the purposes of WRMP 2012. This table provided values for each of NI Water's WTWs for both normal production and delivery capacity. These delivery capacity values were used to populate the Aquator models.

Whilst most data provided related to maximum flow capacity, the Water Service Works Overview sheets also stated a minimum flow capacity for some WTWs. Where possible, these have been incorporated into the Aquator models. For the PPP scheme WTWs a separate table was provided outlining flow capacities at the various delivery points for each WTW. Table A.9 shows all maximum and minimum WTW capacities applied in the models.

WRZ	Water Treatment Works	Minimum flow (Ml/d)	Source	Maximum capacity (Ml/d)	Source
North	Altnahinch	-	-	10.3	WRMP 2012
	Ballinrees	-	-	50.0	PPP capacity table
	Carmoney	-	-	35.0	WRMP 2012
	Caugh Hill	8	Water Service 2005 Works Overview	24.0	WRMP 2012
West	Belleek	-	-	2.0	WRMP 2012
	Killyhevlin	-	-	35.0	WRMP 2012
	Lough Bradan	-	-	12.3	WRMP 2012
	Lough Glenhordial	-	-	6.0	WRMP 2012
	Loughs Fingrean/Macrory	-	-	12.0	WRMP 2012
	Derg			25.0	WRMP 2012
Central	Lough Fea	-	-	12.1	2002 WRS
	Moyola	-	-	19.0	PPP capacity table
East	Dorisland	25	Water Service 2005 Works Overview	46.0	WRMP 2012
	Drumaroad	-	-	116.0	WRMP 2012
	Dungonnell	-	-	11.0	WRMP 2012
	Dunore Point	-	-	180.0	PPP capacity table
	Killylane	-	-	12.0	WRMP 2012
South	Camlough	-	-	5.0	WRMP 2012
	Castor Bay	-	-	147.0	PPP capacity table
	Fofanny	18	Earthtech Project Profile Sheet	44.0	WRMP 2012
	Clay Lake	-	-	5.0	WRMP 2012
	Lough Ross/ Carran Hill	-	-	6.8	WRMP 2012
	Seagahan	-	-	13.0	WRMP 2012

Table A.9 – WTW flow capacity constraints

Production losses

Using 2009 estimated abstraction and measured delivery volume data provided by Dalriada (delivered through NI Water) it was possible to calculate typical losses for the PPP scheme WTWs. Therefore, a loss value of 5% was applied to each of these WTWs during modelling.

Data were also provided which allowed a loss value of 10% to be applied to Drumaroad WTW. All other NI Water WTWs were given a default loss value of 5% based on Atkins' experience of works in England.

Is it is important to note that where the abstraction licence quantity is identical to WTW delivery capacities, for example at Ballinrees WTW, then the delivery capacity will be reduced because it is not possible to abstract additional water to compensate for losses.

A.4.3.9 Recommendations for improvement

The data provided for WRMP 2012 have facilitated a full and appropriate assessment of DO in each of the five WRZs. In any modelling exercise it is always possible to improve the accuracy of any outputs by increasing the volume and quality of input data. In this particular modelling exercise the most significant omission was the supply system operating rules, in particular the control curves for reservoirs. With these incorporated into the models it would be possible to base the DO assessment more on actual representation of operational practices and less on hypothetical model optimisation (section A.5.2) It would also be possible to use the models to explore how the different sources might be operated under non-drought conditions.

A.5 Deployable output

A.5.1 Introduction

For surface water systems, the DO is defined as the constant rate of supply that can be maintained from the water resources system except during periods of restriction. The DO values determined with the Aquator models are taken through to the supply demand balance where they will be converted to Water Available for Use (WAFU) through the application of an outage allowance.

With the exception of the Central WRZ, which only has one demand centre (DC), two separate Aquator models were developed to assess DO for each WRZ. The first model type incorporates multiple demand centres representing distinct supply areas (initially based on the 15 resource zones used for WRS 2002) and a simplified representation of the trunk main distribution system with some maximum capacity constraints included. The second model type has only one central DC to which all sources are connected with links that have no capacity constraints. The results from this second model type are intended to provide an estimate of the unconstrained DO of the WRZ. In this case unconstrained is a hypothetical condition in which there are no internal transfer capacity constraints. Therefore water can be moved freely around the WRZ and all demand anywhere in the WRZ has equal accessibility to all supplies.

The Aquator inbuilt DO analyser was employed to measure the DO of each constrained and unconstrained WRZ model. Aquator has two DO analysers that follow the guidance in the English & Welsh and Scottish methods of determining DO. The English & Welsh method, which is applicable to WRMP 2012, involves setting a minimum and maximum overall demand in a resource zone and increasing the demand incrementally until failure is encountered. The DO of the system is defined as the overall demand that is one increment below the demand causing a failure. All reservoirs are set to 100% storage at the start of the run (29/12/1975). Unplanned outages from events such as pollution, poor raw water quality, and power failure are not included in the DO assessment but are included later in the supply demand balance.

A.5.2 Model optimisation

In the absence of any operational rules such as reservoir control curves it was necessary to exert some additional control on the models to ensure that they would behave sensibly during the determination of DO. The main aims of the optimisation carried were to:

a) Ensure that demand was fulfilled at each of the demand centres in the WRZ on any given day unless there was insufficient water across the WRZ to do so; and

b) Ensure that for conjunctive use the sources most sensitive to low-flow conditions were used least preferentially in order to maintain the highest level of storage and hence the best protection to supplies during dry periods.

In addition to this general optimisation, as mentioned above the models were also optimised so that the non-NI Water WTWs operated under the PPP scheme were used most preferentially. This is because these Dalriada WTWs are contracted to supply their full amounts to NI Water at any time requested and also because they are all connected to large sources with very little chance of failure due to hydrological conditions (with exception to Ballinrees WTW, they are all connected to Lough Neagh which, for the WRMP 2012 supply forecast, is assumed to be extremely large relative to demands). Under the design condition for the supply demand balance, the PPP schemes will be expected to deliver at the contracted volumes.

There are two main types of parameter that have been adjusted during optimisation; the minimum flow parameter (units of Ml/d) and the cost of supply parameter (units of £/Ml). Neither parameter was set on the basis of known costs or known physical constraints at this stage; this was purely done to achieve sensible model behaviours as described above. The minimum flow parameter was adjusted on a number of links and WTWs. When the parameter was set above zero the model aimed to supply water from this link or WTW at this level or higher for as long as there is sufficient demand to support such a movement of water. This is an effective means of moving water from certain sources in a preferential fashion but in some cases it can lead to the model behaving in an unrealistic manner with respect to fulfilling demand across a number of demand centres. For this reason it was used in combination with the cost of supply parameter which was also adjusted on a number of links and WTWs. This parameter allows a cost to be added to supply and hence reduces the preferentiality at which sources are used. Using a number of different costs across a WRZ is a particularly effective optimisation technique.

With manual optimisation the model setup is only generally valid for one set of conditions. For a DO run, the critical period with respect to total demand in the WRZ is determined using the DO analyser. The model is then run in normal time series mode up to the failure date. The total demand is set to the same level as the demand that caused the failure in the DO analyser. If the model does not appear to behave sensibly (for example demand is not satisfied at one demand centre whilst another connected demand centre has surplus supply available) then some of the above parameter changes are made and the DO analyser is repeated to determine the new demand that can be met. This iterative process continues until the model is fully optimised.

There are a number of drawbacks to this method. Firstly, every time that model conditions are changed, for example when looking at conditions anticipated under climate change (section A.6.2) or examining the effects of adding new infrastructure during the optioneering process (section A.6.3), the models must be re-optimised which can be a time consuming process. Secondly, the models are optimised to behave most effectively for just one set of conditions. It is therefore unlikely that real operational rules would be able to achieve the same level of supply under that one set of conditions, resulting in a lower DO.

Finally, the models now contain parameter settings that are no longer based on actual processes occurring in the field. Therefore it is imperative that the audit trail which sits alongside the models clearly states which parameters have been set for model optimisation and which have been set to represent reality.

Despite these issues, this type of optimisation is necessary and appropriate in the absence of real operational rules and a satisfactory automatic optimisation procedure. It should be noted that one such application may become available in a future version of Aquator in which case it will likely be possible to apply this to the NI Water models retrospectively.

The model optimisation that has been applied is shown for the DO runs in Table A.10 and Table A.11 in the 'Model optimisation required' row. The additional optimisation required in the climate change runs is shown in section 0.

A.5.3 Results

The following tables give the results of the DO determination for each WRZ along with the constraints linked to the failure to meet higher demand and the model optimisation that was required (North, West and Central in Table A.10 and South and East in Table A.11). The tables contain the following information:

- Actual demand centre demand – based on 2008–09 average distribution input figures;
- WRMP 2012 WRZ DO – multi demand centre model;
- WRMP 2012 Unconstrained WRZ DO – single demand centre model;
- Demand factor – the ratio of DO to 2008–09 distribution input;
- Model optimisation requirements – measures taken to control model operation where no information had been provided on NI Water operating rules, for example reservoir control curves. The optimisation applied is not intended to replicate NI Water operating manuals, but only to achieve sensible behaviour in the model;
- Failure year – the critical year in which resources are most constrained by hydrology or licence/ asset constraints and hence the period over which DO is defined;
- Critical demand centre – the demand centre at which resources are most constrained and hence where DO is defined;
- Cause of failure – an explanation of the events that determine the condition under which DO is calculated;
- Failure analysis – some additional work to investigate the sensitivity of results to changes in hydrology and also the temporal extent of the failures that determine the DO results; and
- Assets constraints – the relevant WTW and link capacities, along with the corresponding licence conditions.

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WRZ	North			West		Central
Demand Centre (DC)	**Altnahinch**	**Ballinrees**	**Faughan/ Altnaheglish**	**Derg/ Bradan/ Macrory WRZ**	**Killyhevlin WRZ**	**Magherafelt/Cookstown**
Actual Demand (2008–09 post MLE Distribution Input (DI)) (Ml/d)	**13.69**	**17.62**	**45.04**	**37.22**	**25.68**	**26.70**
WRMP 2012 WRZ DO (Ml/d)	106.2			88.2		31.1
Demand factor	1.391			1.402		1.165
Model optimisation required	1. Assign cost of £10/Ml to all WTWs apart from Ballinrees to force preferential use of PPP. 2. Add minimum flow of 35 to Ballinrees WTW to Ballinrees DC link to prevent above costs from causing a failure at Ballinrees DC. 3. Add cost of £5/Ml to link between Caugh Hill WTW and Faughan DC to promote use of Faughan River intake and protect Altnaheglish storage (important to prevent early failure). 4. Add minimum flow of 10 to the link between Ballinrees WTW and Altnahinch DC to prioritise the DC with the more serious hydrology constraints			1. Add a £10/Ml cost to Lough Bradan WTW as this is the most hydrologically challenged source. This source still causes the failure in the DO run so no further optimisation required.		1. Added cost of £10/Ml to Lough Fea WTW to ensure full use of PPP Moyola (not required for DO run anyway but may be useful for CC)
Failure year	1984			1984		1975
Critical demand centre	Altnahinch			Derg/Bradan/Macrory		WRZ
Cause/observations	Altnahinch reservoir empties on 20/09/1984. The model supplies a continuous 10 Ml/d from Ballinrees to the Altnahinch DC. Increasing the capacity of this link would appear to be key to increasing overall WRZ DO but there isn't too much more that can be extracted anyway, based on current asset constraints			Lough Bradan empties on 19/09/1984. This is despite all other sources being used in preference over the full run. At this point Killyhevlin DC is receiving 36 Ml/d out of a possible 37 Ml/d so there's not much scope for inter-zonal transfers in improving overall DO. This is highlighted in the unconstrained run DO.		Asset constraints
WRMP 2012 Unconstrained WRZ DO (Ml/d)	115.6			89.1		31.1
Demand factor	1.514			1.530		1.165
Model optimisation required	1. Minimum flow of 50 Ml/d assigned to Ballinrees WTW to force full supply. 2. Cost of £10/Ml added to Altnahinch WTW to preserve the source with the highest hydrology constraints			1. Add a £10/Ml cost to Lough Bradan WTW as this is the most hydrologically challenged source. This source still causes the failure in the DO run so no further optimisation required.		1. Added cost of £10/Ml to Lough Fea WTW to ensure full use of PPP Moyola (not required for DO run anyway but may be useful for CC)
Failure year	1984			1984		1975
Cause	Altnahinch reservoir empties on 19/09/1984.			Lough Bradan empties on 18/09/1984. This is despite all other sources being used in preference over the full run.		Asset constraints
Failure analysis	1. If not hydrologically constrained would expect a WRZ DO of 113.2 Ml/d based on this ratio between demands on each DC and the maximum that can be supplied to Altnahinch based on infrastructure constraints. 2. If not hydrologically constrained would expect an Unconstrained WRZ DO of 118.1 Ml/d based on the WTW capacities and specified losses (i.e. DO run is just 1.3 Ml/d down at Altnahinch rest at full capacity) 3. Licence is also constraining Ballinrees as 50 Ml/d limit on abstraction is then subject to 5% losses 4. DO failure is just for one day if the run is extended beyond the initial failure. The model can meet higher demands as a WRZ DO with very few failures; achieved a maximum asset delivery of 113.2 Ml/d with 22 failure days all essentially in one block around September 1984. We may want to check flows at that time, but the hydrograph looks OK – just a prolonged dry spell.			1. If not hydrologically constrained would expect a WRZ DO of 90.6 Ml/d based on this ratio between demands on each DC and the maximum that can be supplied to Killyhevlin based on infrastructure constraints. 2. If not hydrologically constrained would expect an Unconstrained WRZ DO of 92.3 Ml/d based on the WTW capacities and specified losses (i.e. 3.2 Ml/d down). 3. DO failure is just for 3 days if the run is extended beyond the initial failure. The model can meet higher demands as a WRZ DO with relatively few failures; but to achieve a maximum asset delivery of 90.6 Ml/d there would be 32 failure days all primarily in August and September in the 1980s.		1. Not hydrologically constrained so WRZ DO matches some of infrastructure delivery capacities. 2. Model runs suggest Lough Fea could be considered in the options if additional supply in Central Zone is needed and Moyola could not be readily extended. A quick check suggests that the hydrology would (just) support full use of the Lough Fea licence (17 Ml/d) if the works capacity was increased.
DC WTW capacities (Ml/d)	10.3 at Altnahinch WTW	50 at Ballinrees WTW (PPP)	35 at Carmoney WTW, 24 at Caugh Hill WTW	25 at Derg WTW, 12.3 at Lough Bradan WTW, 6 at Glenhordial WTW, 12 at Fingrean/Macrory WTW	2 at Belleek WTW, 35 at Killyhevlin WTW	12.1 at Lough Fea WTW, 19 at Moyola WTW (PPP)
DC licence constraints (Ml/d)	14.5 at Altnahinch Reservoir	50 at Ballinrees Reservoir, 40 at River Bann	55 at River Faughan, 40 at Altnaheglish Reservoir and Glenedra (group)	26.6 at Derg/Strule, 16 at Bradan, 8 at Glenhordial, 18.5 at Fingrean/Macrory	2.5 at Belleek, 44 at Lough Erne	17 at Lough Fea, 20 at Lough Neagh
Link capacities (Ml/d)	Ballinrees WTW to Ballinrees DC 35, Ballinrees WTW to Faughan/Altnaheglish DC 15, Ballinrees WTW to Altnahinch DC 10.			None applied	None applied	None applied
Notes	Ballinrees can only deliver 47.5Ml/d because the licence is 50 and then there are 5% loss			A new licence has been issued for 26.6 Ml/d, but this is dependent on an agreed monitoring plan being in place.	Lough Erne is assumed insensitive to hydrology for water resource purposes (see comment to the right)	Lough Neagh is assumed insensitive to hydrology for water resource purposes. Abstraction is a very small proportion of the total storage, so the impact of abstraction on total storage, and hence water levels is small. This means that the deployable output from the Lough Neagh sources is controlled by licensed quantities and not hydrology.

Table A.10 – WRMP 2012 DO results; North, West and Central WRZs

WRZ	East			South				
Demand Centre (DC)	**Antrim/Larne WRZ**	**Ballymena WRZ**	**Eastern General WRZ (with 45% of Lisburn)**	**Newry WRZ**	**Craigavon WRZ (with 55% of Lisburn)**	**Lough Ross WRZ**	**Armagh WRZ**	**Dungannon WRZ**
Actual Demand (2008–09 post MLE Distribution Input (DI)) (Ml/d)	**30.34**	**24.32**	**236.96**	**53.28**	**94.74**	**6.43**	**18.33**	**5.20**
WRMP 2012 WRZ DO (Ml/d)	329.5			218.6 (204.5 after 2015)				
Demand factor	1.130			1.228 (1.149 after 2015)				
Model optimisation required	1. Add 100% control curve-fill (not normal curve) to Silent Valley to encourage maximum filling of the reservoir from the River Annalong intake. 2. Add cost of £10/Ml to Dorisland and Drumaroad WTWs to encourage full use of PPP. This was not applied to Dungonnell and Killylane as it meant that these sources were grossly under-utilised. Therefore, a cost of £1/Ml was applied to these WTWs. 3. Add minimum flow of 9 Ml/d to link between Dungonnell WTW and Ballymena DC to encourage use of own source over PPP water thus sending more PPP water towards E General. 9 found by trial and error as too high a number causes failure at Ballymena (not enough flow from PPP) 4. Add minimum flow of 8 Ml/d to link between Killylane Reservoir and Killylane WTW to encourage use of own source over PPP water thus sending more PPP water towards E General. The 8 is set by trial and error to prevent over-utilisation of Killylane Reservoir. 5. Add minimum flow of 33 Ml/d to link between Dorisland WTW and Eastern General DC to balance use of Dorisland and Drumaroad			1. Assign cost of £10/Ml to all WTWs apart from Castor Bay to force preferential use of PPP. 2. Add minimum flow of 5 Ml/d to link between Clay Lake WTW and Armagh RZ to minimise use of Castor Bay water 3. Add minimum flow of 13 Ml/d to link between Seagahan WTW and Armagh RZ to minimise use of Castor Bay water 4. Add minimum flow of 10 Ml/d to link between LIR and Fofanny WTW to balance use of LIR and Spelga/Fofanny (not that relevant at this demand but may need further optimisation for option runs) 5. Add minimum flow of 16 Ml/d (17 Ml/d after 2015) to link between Jerretspass PS and Newry demand centre to balance use of water from Jerretspass PS between Lough Ross and Newry demand centres.				
Failure year	1978			1975				
Critical demand centre	Eastern General			Newry				
Cause/observations	Silent Valley and Ben Crom reservoirs become empty on 15/11/1978. However, the model is optimised to balance storage between Silent Valley/Ben Crom and the Woodburn system so with slightly different optimisation Woodburn could cause the failure. In relation to other WTWs, they are both utilised as little as possible throughout the run.			Asset constraints at Newry both before and after decommissioning of Camlough in 2015. However, this could easily have been Lough Ross with slightly different optimisation which has the same access to Castor Bay water.				
WRMP 2012 Unconstrained WRZ DO (Ml/d)	329.7			223.7				
Demand factor	1.131			1.257				
Model optimisation required	1. Add costs of £10/Ml to all WTWs apart from PPP to encourage PPP use. Increase to £20/Ml for Drumaroad and Dorisland; the most hydrologically challenged sources. 2. Apply minimum flow of 88 Ml/d (trial and error) to link between Drumaroad WTW and E General DC to balance utilisation between Drumaroad and Dorisland.			1. Add minimum flow to Castor Bay of 127 Ml/d to force use 2. Add 100% control curve to Spelga/Fofanny to balance use with LIR 3. Add cost of £10/Ml to Clay Lake to preserve the most hydrologically challenged source. 4. Add minimum flow of 44 Ml/d to the link between Fofanny WTW and DC to force full use of Fofanny				
Failure year	1978			1991				
Cause	Woodburn Reservoir becomes empty on 13/11/1978. However, the model is optimised to balance storage between Silent Valley/Ben Crom and the Woodburn system so with slightly different optimisation Silent Valley/Ben Crom could cause the failure. In relation to other WTWs, they are both utilised as little as possible throughout the run.			Clay Lake empties on 30/10/1991 despite other sources being used preferentially for the duration of the run.				
Failure analysis	1. If not hydrologically constrained would expect a WRZ DO of 342.3 Ml/d. 2. DO failure is just for 3 days if the run is extended beyond the initial failure, with a demand of 329.8 Ml/d. The model can meet 343 Ml/d as a WRZ DO with 'only' 179 hydrological failures in late summer and autumn of many years. Any attempts to increase the WRZ DO beyond this point are limited by delivery constraints to the Ballymena DC where the DI ratio combined with capacity limits in the model mean that no greater demand can be met (it may be worth looking at sensitivity to DI if hydrological constraints are mitigated).			1. Not hydrologically constrained so WRZ DO matches some of infrastructure delivery capacities. 2. If ignore failures on Lough Ross, it is clear DO is not just constrained by Lough Ross and it is the Newry DC that then constrains further water use. Running at a capacity limit produces many failure days generally in late summer and autumn and in most years. Increasing the link from Castor Bay looks to be the best option.				
DC WTW capacities (Ml/d)	12 at Killylane WTW, 1 80 at Dunore Point WTW (PPP), 46 at Dorisland WTW	11 at Dungonnell WTW, 12 at Killylane WTW, 180 at Dunore Point WTW (PPP)	180 at Dunore Point WTW (PPP), 46 at Dorisland WTW, 140 at Drumaroad WTW	44 at Fofanny WTW, 5 at Camlough WTW (decomm'd in 2015), 147 at Castor Bay WTW (PPP)	147 at Castor Bay WTW (PPP)	6.8 at Carran Hill WTW	5 at Clay Lake WTW, 13 at Seagahan WTW, 147 at Castor Bay WTW	147 at Castor Bay WTW (PPP)
DC licence constraints (Ml/d)	16.1 at Killylane, 50 at Woodburn, 189 at Lough Neagh	14.5 at Dungonnell, 16.1 at Killylane, 189 at Lough Neagh	189 at Lough Neagh, 50 at Woodburn, 115 group licence for Silent Valley, Ben Crom and Annalong River	22 at Lough Island Reavy (paper licence states 22 to Fofanny but 40 to Drumaroad – no link at present, 52 at Spelga/Fofanny and LIR group) , 5 at Camlough Lake (decomm'd in 2015), 154 at L. Neagh	154 at Lough Neagh	9.5 at Lough Ross	10 at Clay Lake, 20 at Seagahan, 154 at Lough Neagh	154 at Lough Neagh
Link capacities (Ml/d)	Killylane WTW to Ballymena WRZ 3, Dunore Point to Ballymena WRZ 22, Dunore Point to Eastern General 160			Castor Bay to Dungannon WRZ 30, Castor Bay to Armagh WRZ 10, Castor Bay to Jerretspass PS 18, Jerretspass PS to Lough Ross DC 5, Jerretspass PS to Newry DC 18. Also added link of 20 between LIR and Fofanny to enforce Stuart Walsh view that LIR can supply 20 this way (licence 22) New link to take water from Castor Bay towards Lough Ross via Jerretspass PS (5 Ml/d) based on TMM				
Notes	Lough Neagh is assumed insensitive to hydrology for water resource purposes (see Table A.10).		Drumaroad losses set to 10% based on information from Stuart Walsh	In 2015 Camlough is decomm'd	Lough Neagh is assumed insensitive to hydrology for water resource purposes (see Table A.10).			Altmore now disabled

Table A.11 – WRMP 2012 DO results; South (before and after decommissioning of Camlough in 2015) and East WRZs

Based on the constrained modelled view of WRZ, i.e. according to the standard approach (not the Scottish method), the overall DO for NI Water is 773.6 Ml/d until 2015 and 759.5 Ml/d after the decommissioning of the Camlough source in the South WRZ. A summary of the DO assessment in each WRZ is given below.

North WRZ

The DO for the North WRZ is 106.2 Ml/d which is equivalent to 1.4 times the 2008–09 post MLE Distribution Input (i.e. the DO is 1.4 times higher than the average demand met in those years). The DO is determined by Altnahinch reservoir emptying in September 1984. If there were no hydrological constraints, i.e. DO was only constrained by assets in place across the WRZ, then the result would be increased to 113.2 Ml/d.

With the unconstrained model, where all sources are connected to one central demand centre, DO is increased to 115.6 Ml/d which again is determined by Altnahinch reservoir emptying in September 1984.

With the current model setup a continuous 10 Ml/d is supplied from Ballinrees to Altnahinch. Increasing the capacity of this link would appear to be the key to increasing overall WRZ DO.

West WRZ

The DO for the West WRZ is 88.2 Ml/d which is equivalent to just over 1.4 times the 2008–09 post MLE Distribution Input. The DO is determined by Lough Bradan emptying in September 1984. If there were no hydrological constraints then the result would be increased to 90.6 Ml/d.

With the unconstrained model, DO is increased to 89.1 Ml/d which again is determined by Lough Bradan emptying in September 1984.

This DO is achieved with all other sources being used in preference over the full run. In terms of inter-WRZ connectivity, the Killyhevlin demand centre is receiving 36 Ml/d out of a possible 37 Ml/d so there's not much scope for moving inter-zonal transfers to Derg/ Bradan/ Macrory demand centre in improving overall DO. This is highlighted in the unconstrained DO run.

In West WRZ, the Strule/Derg PC10 scheme to provide the Derg Water Treatment Works (WTW) with an alternative supply of raw water has required a new abstraction licence. Strict application of the abstraction licence conditions would mean that there could be some very dry, but rare circumstances when no water to feed the WTW would be available. A lack of interconnectivity in the WRZ means that at times of very low flow, when no water can be abstracted from either the River Derg or the River Strule due to licence constraints, there are no alternative sources of supply to make up any short term deficits. The available flow record suggests that low flow conditions that could severely restrict abstraction only arise about 1% of the time, but these events could last for up to 3 weeks.

Discussions between NI Water and NIEA regarding the licence reached an agreement whereby in the event of such water scarce periods arising, the output from the Derg WTW could be maintained by following normal drought planning procedures under Article 4.6 of the WFD. It is therefore appropriate for NI Water to consider mitigating the risks to public water supply within the Derg area during drought periods, although such measures are outside the scope of the Water Resources Management Plan process. Further consideration is included in section 9.4 of the main report.

Central WRZ

The DO for the Central WRZ is 31.1 Ml/d which is equivalent to about 1.2 times the 2008–09 post MLE Distribution Input. At present there are no hydrological constraints and the result for this WRZ with a single demand centre is determined only by asset constraints (not hydrology).

East WRZ

The DO for the East WRZ is 329.5 Ml/d which is equivalent to just over 1.1 times the 2008–09 post MLE Distribution Input. The DO is determined in the Eastern General area by Silent Valley[8] and Ben Crom reservoirs emptying in November 1978. However, the model is optimised to balance storage between Silent Valley/ Ben Crom and the Woodburn system so with slightly different optimisation Woodburn could cause the failure.

With the unconstrained model, where all sources are connected to one central DC, DO is increased very slightly to 329.7 Ml/d which this time is determined by the Woodburn system emptying in November 1978 (again this could easily have been Silent Valley and Ben Crom).

South WRZ

The DO for the South WRZ is 218.6 Ml/d which is equivalent to about 1.3 times the 2008–09 post MLE Distribution Input. In 2015 the Camlough source (5 Ml/d consistent with the previous safe yield assessment) is planned to be decommissioned which leads to a decrease in DO to 204.5 Ml/d. This DO reduction of 14.1 Ml/d is larger than the supply capacity of Camlough which is 5 Ml/d due to the conjunctive nature of the model[9]. The capacity of the link between Castor Bay and Newry is 18 Ml/d and means that additional water from Castor Bay cannot be moved towards the Newry DC to compensate for the loss of the Camlough supply to the Newry demand centre.

Both before and after the loss of Camlough in 2015, DO is determined by asset constraints at Newry. However, the model is optimised to share water from Castor Bay between the Newry and Lough Ross DC's. With slightly different optimisation, Lough Ross could easily cause the failure. Using the unconstrained model, DO is increased slightly to 223.7 Ml/d which is determined by Clay Lake emptying in October 1991. After 2015, with the loss of Camlough, DO in the unconstrained model is 218.9 Ml/d.

A.5.4 Looking back to WRS 2002

Table A.12 shows a comparison of the WRMP 2012 DO results with the WRS 2002 DO assessment. Overall, it seems that there is little change in the total DO for Northern Ireland. The WRMP 2012 unconstrained DO is about 18 Ml/d higher than the WRS 2002 DO of 771 Ml/d; the WRMP 2012 constrained DO is about 3 Ml/d higher than the WRS 2002 DO of 771 Ml/d. From 2015, with the decommissioning of Camlough, overall DO would be reduced to 759.5 Ml/d (unconstrained 784.4 Ml/d); i.e. below the WRS 2002 total.

On an individual WRZ level, the major differences are due to the repositioning of WRZ boundaries, decommissioning of older sources and inclusion of approved sources. There is the opportunity to transfer water between the South and East WRZs but how and indeed whether this should contribute to individual WRZ DO results has still to be established.

[8] Table A.1 shows that while the licensed amount that can be abstracted from Silent Valley is 155 Ml/d, this includes 40 Ml/d to be pumped from Lough Island Reavy (South WRZ) so this has been subtracted from the licence quantity in the East WRZ calculations

[9] Where there is more than one demand centre in a single zone model, the demands are increased proportional to one another in following a standard DO assessment approach. This means that yield changes for single sources can have affects on DO that are greater or less than the direct change in source yield

WRMP 2012 WRZ	Sub-Zone Demand Centre (based on WRS 2002 WRZs)	WRS 2002 DO (Ml/d)		WRMP 2012 WRZ DO (Ml/d)	WRMP 2012 Unconstrained WRZ DO (Ml/d)	Comments
North	Altnahinch	17.0	101.2	106.2	115.6	A number of groundwater sources have been decommissioned since the WRS 2002
	Ballinrees	25.0				
	Faughan/ Altnaheglish	59.2				
West	Derg/ Bradan/ Macrory	32.0	68.9	88.2	89.1	The WRMP 2012 incorporates the planned River Strule abstraction and the assumptions that the Derg WTW can operate at its full capacity but all groundwater sources have been decommissioned
	Killyhevlin	36.9				
Central	Magherafelt/ Cookstown	29.3	29.3	31.1	31.1	
East	Antrim/ Larne	33.9	418.9	329.5	329.7	The boundary between the WRMP 2012 South and East WRZs has divided some of the WRS 2002 WRZs, with Lough Island Reavy and a portion (55%) of Lisburn area demand moving into the South WRZ. The current model setup does not include transfers from Lough Island Reavy to Drumaroad WTW (16 Ml/d safe yield – calculated prior to WRMP 2012, 10 Ml/d normal summer use), or from Castor Bay to the East WRZ (no information provided by NI Water but could be around 20 Ml/d into the Eastern General DC). There are a number of sources that have been decommissioned since the WRS 2002, as well as Forked Bridge WTW.
	Ballymena	26.2				
	Lough Cowey	3.8				
	Eastern General	355.0				

WRMP 2012 WRZ	Sub-Zone Demand Centre (based on WRS 2002 WRZs)	WRS 2002 DO (Ml/d)		WRMP 2012 WRZ DO (Ml/d)	WRMP 2012 Unconstrained WRZ DO (Ml/d)	Comments
South	Newry	53.0	152.4	218.6 (204.5 beyond 2015)	223.7 (218.9 beyond 2015)	The Craigavon demand centre now incorporates 55% of the Lisburn area demand (100% in Eastern General for WRS2002)
	Craigavon	67.6				
	Lough Ross	6.8				
	Armagh	21.0				
	Dungannon	4.0				
Total DO (Ml/d)		**770.7**		**773.6 (759.5 beyond 2015)**	**789.2 (784.4 beyond 2015)**	

Table A.12 – Comparison of WRMP 2012 DO results with the WRS 2002 DO assessment

A.5.5 Recommendations for improvement

In comparison with the assessment completed by many water companies in England the length of record used to determine DO here is relatively short at 1975 to 2009. The longer the record used the more chance that there is of encountering drought conditions and the higher the resilience of the DO determined by analysis is likely to be to future droughts. As recordings of river flow generally started later in Northern Ireland than England, in order to start the analysis before 1975, it would be necessary to infer river flow from rainfall records which are likely to go back further. The best method for this is to construct rainfall-runoff models which would be calibrated against post 1975 river flow records. This would require an extensive programme of hydrological work to collect and quality control the basic hydrometric data, and to develop, calibrate and validate appropriate rainfall-runoff models. Another benefit of using a longer record is that it increases the value of statistical analysis.

However, the work described here provides a robust basis for the DO values to be used in the supply demand balance elements of the WRMP. Analyses on the available flow data and a long rainfall record (back to 1853) at Armagh have shown that the 1975-2009 hydrological period used in this WRMP is appropriate for the purposes of determining DO. Beyond the completion of this WRMP it might be beneficial to extend the hydrological record further back to determine the potential impacts of earlier longer duration dry periods on the larger sources. However, it is unlikely that further investigations would lead to a redefinition of DO in most of the WRZs. The WRZ most likely to benefit from additional analysis would be the East WRZ as the Aquator failures analysis shows that Silent Valley and Ben Crom could be susceptible to longer drought periods than most of the sources (which are more vulnerable to short but severe drought events) while the largest sources are not significantly utilised in comparison with the natural hydrology Even if it is deemed that sufficient data are available for these purposes then, a significant amount of effort would need to be expended to generate extended flow records and that is beyond the scope of this WRMP.

At the outset of the WRMP 2012 programme there was an expectation that NIEA would have been able to advise NI Water on the scope and timetable of its programme of work to review existing abstraction licences and hence the possible location and magnitude of Sustainability Reductions. However, at the time of writing the Draft WRMP, that process is still ongoing. Therefore the Aquator model includes current licence conditions only; there are no constraints built into the model to prevent abstractions from removing all flow up to the licence limit. Once any proposals for changes to existing licence conditions are provided by NIEA any changes can be incorporated into the Aquator models and any affect on DO assessed. Similarly, the river system in the models could be expanded to allow a more comprehensive simulation of hydrology across each WRZ thus allowing the potential impact on flows downstream of river abstractions to be examined. Sustainability Reductions could lead to changes in DO with consequential impacts on the supply demand balance and hence the WRMP.

A.6 Scenarios

A.6.1 Introduction

Once the baseline DO had been determined the focus of modelling shifted towards looking at future scenarios which need to be investigated for WRMP 2012. These include the anticipated effects of climate change and the investigation of new supply options during the optioneering process.

A.6.2 Climate change

A.6.2.1 Introduction

The models were configured to investigate the potential impacts of anticipated changes that could be brought about in Northern Ireland due to climate change. The river flow series in the model were perturbed in accordance with the UKWIR UKCP09 Rapid Assessment. As explained in section A.5.2, the models required some further optimisation and this is outlined, along with full detail model outputs in Table A.19.

A.6.2.2 Methodology

The update of previous flow meteorological and flow factors for UKCP09 – referred to as the 'UKWIR UKCP09 Rapid Assessment' – provides a revised set of monthly and seasonal flow factors based on the updated projections. The factors are produced for 183 catchments in the UK, and for the 2020s.

The more complex approach within the UKWIR methodology would require rainfall-runoff models to convert perturbed precipitation and PET time series into associated flow perturbations. Without these models for Northern Ireland, it is necessary to use the more simple method, perturbing river flow series instead. UKWIR flow factors[10] are provided for five catchments in Northern Ireland:

- Six Mile Water at Antrim;
- Claudy at Glenone Bridge;
- Burn Dennet at Burndennet;
- Camowen at Camowen Terrace; and
- Fairywater at Dudgeon Bridge[11].

As these catchments do not cover all of the required area of Northern Ireland, it was necessary to examine key meteorological, geographical and hydrological characteristics of the catchments draining to these gauging stations, with each of the supply catchments; thus enabling the flow factors to be transferred (i.e. applied) to other catchments. This is a way of estimating the flow factors in the absence of hydrological models and without detailed examination of the UKCP09 projections (in a similar manner to the UKWIR Rapid Assessment).

The data comparison uses the following four factors:

- Region of Influence (ROI) stations (top 5);
- Hydrometric Area (location);
- Rainfall; and
- Base Flow Index (BFI).

The ROI data was derived from the LFE software, which provides a variety of information on each catchment, from which a gauged catchment can be selected for use as a proxy. This software is the same as has been used already to generate daily time series for Aquator catchment inflows. Each catchment of interest was scored, based on the four factors, in its similarity to the catchments for which flow factors were available. The outcome of this and the factors applied are presented in section 0, but an example for Six Mile Water is included as Figure A.13. The

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[10] Von Christierson, B., Wade, S. and Rance, J. 2009. Assessment of the significance to water resource management plans of the UK Climate Projections 2009, UKWIR, London.

[11] Fairywater was not included in the assessment as it is mislabelled as 'Scotland' in the UKWIR Rapid Assessment spreadsheets and was thus overlooked. This fifth catchment could be included in any subsequent assessment.

perturbations to the baseline flow series for each supply catchment provide a quantified estimate of the impact of climate change on river flows for the 2020s timeslice.

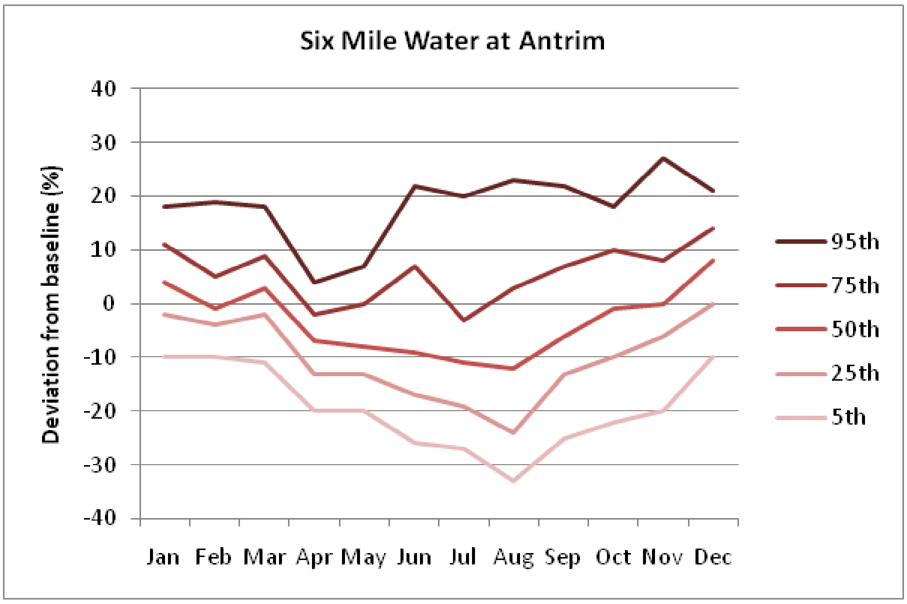


Figure A.13 – Flow factors for Six-Mile Water at Antrim

A.6.2.3 Results

The absolute changes to DO are shown in Table A.13 for the three climate changes scenarios investigated with the Aquator models (5th, 50th and 95th percentile) and Table A.14 gives the results in percentage terms. Looking across the whole of Northern Ireland, the 50th percentile scenario showed virtually no change from the baseline. Under the 5th percentile perturbations there was a DO reduction of just below 27 Ml/d (3.5%) simulated. Under the 95th perturbations simulated DO was increased by 23 Ml/d (3.0%).

In percentage terms the biggest individual WRZ reduction in DO seen under the 50th percentile projections was a 0.9% decrease in DO simulated in the North WRZ. For the 5th percentile projection there was a 5.8% reduction in the North zone, and at the 95th percentile, the largest increase in DO simulated was a 5% increase in the East WRZ.

WRZ	Deployable output (DO) Result (Ml/d)	Climate Change Scenario DO Results (Ml/d)			Notes
		5th Percentile	50th Percentile	95th Percentile	
North	106.2	100.0	105.2	111.3	Altnahinch reservoir is always critical with supplies running out at the same time in each scenario.
West	88.2	86.8	88.0	89.5	Lough Bradan is always critical with supplies running out at the same time in each scenario.
Central	31.1	31.1	31.1	31.1	Hydrological conditions do not become limiting under

WRZ	Deployable output (DO) Result (Ml/d)	Climate Change Scenario DO Results (Ml/d)			Notes
		5th Percentile	50th Percentile	95th Percentile	
					any of the climate change scenarios.
East	329.5	314.4	328.1	346.1	DO responds to changing hydrological conditions across the WRZ under the climate change scenarios.
South	218.6 (204.5 after 2015)	215.1 (200.4 after 2015)	218.6 (204.5 after 2015)	218.6 (204.5 after 2015)	The DO for this WRZ is determined by the isolated Lough Ross demand centre. If this is removed from the analysis, the remaining DO under all scenarios but one is 189.2 Ml/d. This value is determined by asset constraints but for the 5th percentile climate change scenario the additional hydrological constraints are such that they Spelga/Fofanny reservoirs to empty in 1977 and DO is further reduced to 185.1 Ml/d.
NI Total	**773.6 (759.5 after 2015)**	**747.4 (732.7 after 2015)**	**771.0 (756.9 after 2015)**	**796.6 (782.5 after 2015)**	

Table A.13 – Climate change run results showing revised DO values under the 5th, 50th and 95th percentile climate change scenarios

WRZ	Climate Change Scenario DO Results (Ml/d)			Range (%)
	5th Percentile	50th Percentile	95th Percentile	
North	94.2%	99.1%	104.8%	10.6%
West	98.4%	99.8%	101.5%	3.1%
Central	100.0%	100.0%	100.0%	0.0%
East	95.4%	99.6%	105.0%	9.6%
South	98.4% (98.0% after 2015)	100.0% (before and after 2015)	100.0% (before and after 2015)	1.6% (2.0% after 2015)
Total	**96.6% (96.5% after 2015)**	**99.7% (before and after 2015)**	**103.0% (before and after 2015)**	**6.4% (6.6% after 2015)**

Table A.14 – Climate change impact on baseline DO

A.6.3 Optioneering

These Aquator models form a strong basis for the high level strategic testing of new options for supply in the optioneering process (see section 8 of the main report).

A.7 Conclusions

A number of Aquator models have been built to represent the five WRZs of Northern Ireland. The structure of each model was initially based on the WRS 2002 and updated using the expertise of key NI Water personnel and the Atkins TMM team. An extended data collation period was undertaken to assemble model input data. There were difficulties in collating the full data set required for Aquator but enough data were either collected or derived for an appropriate assessment of DO using Aquator's inbuilt English & Welsh method DO analyser.

The overall DO output for Northern Ireland was determined as 773.6 Ml/d until 2015 and 759.5 Ml/d after the decommissioning of the Camlough source in the South WRZ. The individual WRZ results are as follows:

- North WRZ – 106.2 Ml/d (116.8 Ml/d if transfers are unconstrained within the WRZ);
- West WRZ – 88.2 Ml/d (89.1 Ml/d if unconstrained);
- Central WRZ – 31.1 Ml/d (no different if unconstrained);
- East WRZ – 329.5 Ml/d (334.2 Ml/d if unconstrained); and
- South WRZ – 218.6 Ml/d and 204.5 Ml/d beyond 2015 (224 and 219 Ml/d if unconstrained).

The results from the unconstrained models (all sources linked to one central DC) suggest that there is most scope for increasing DO by increasing connectivity of the distribution system in the North WRZ.

Comparison of the results from this analysis with WRS 2002 shows that there is little change in the total DO for Northern Ireland. The WRMP 2012 unconstrained DO is about 25 Ml/d higher than the WRS 2002 DO of 771 Ml/d; the WRMP 2012 constrained DO is about 3 Ml/d higher than the WRS 2002 DO of 771 Ml/d. On an individual WRZ level, the major differences are due to the repositioning of WRZ boundaries, decommissioning of older sources and inclusion of approved sources.

The models have also been used to determine the potential impacts of anticipated changes to river flows patterns due to climate change. On a Northern Ireland wide basis the largest simulated changes only showed a 3.5% change to the baseline DO values. At individual WRZ level this was only increase to a maximum impact of just under 6%. However, it is important to state that there could be a much greater effect on DO if minimum flow conditions were applied to river abstractions as part of any review of abstraction licences by NIEA.

The work described in this Appendix provides a robust basis for the DO values to be used in the supply/demand balance elements of the WRMP. The approach makes best use of available data and techniques. The analysis can be updated as and when improved data and information becomes available, for example using longer (pre 1975) flow time series. In any modelling exercise it is always possible to improve the accuracy of any outputs by increasing the volume and quality of input data. In this particular modelling exercise the most significant omission was the supply system operating rules, in particular the control curves for reservoirs which were not available for use in WRMP 2012. With such information incorporated into the models it would be possible to base the DO assessment on actual representation of operational practices and less on hypothetical model optimisation (section A.5.2). It would also then be possible to use the models to explore different operating procedures under average and wet (rather than drought) hydrological conditions.

A.8 Additional information

A.8.1 Unconstrained model schematics

The following schematics represent the unconstrained version of each WRZ (North WRZ in Figure A.14; West WRZ in Figure A.15; East WRZ in Figure A.16; and South WRZ in Figure A.17), where all sources are connected to a single demand centre (explained in section A.5.1). There is no schematic for the Central WRZ which is already structured in this way.

North Zone

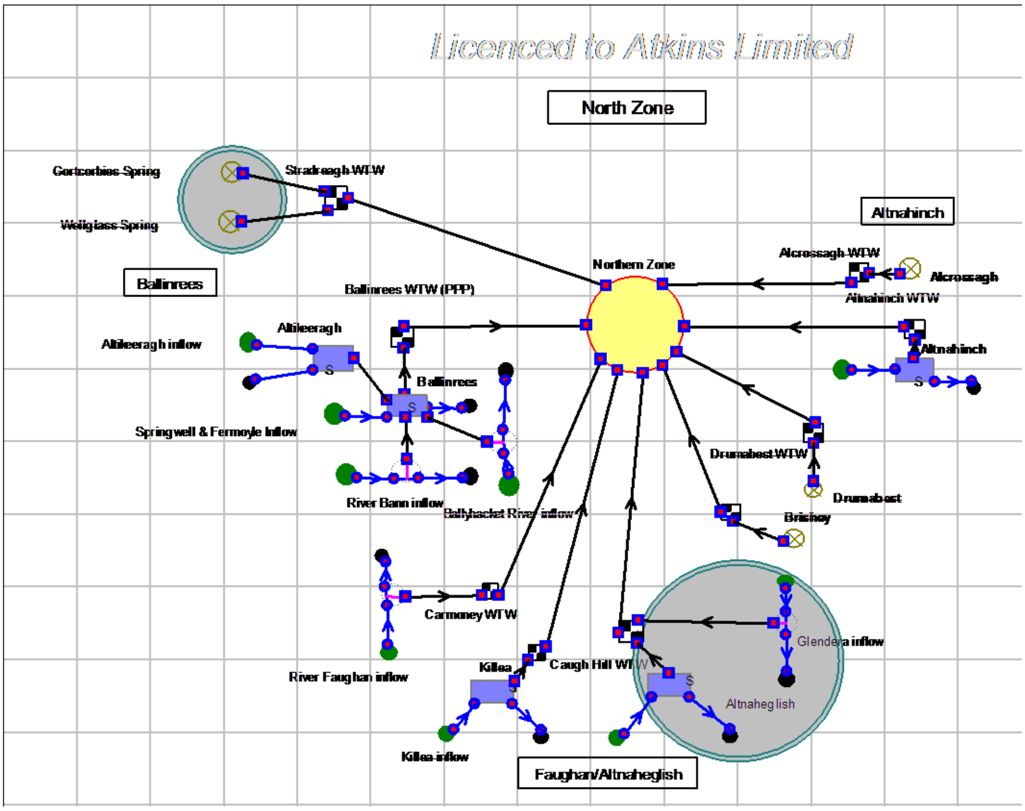


Figure A.14 – North WRZ unconstrained model schematic

West Zone

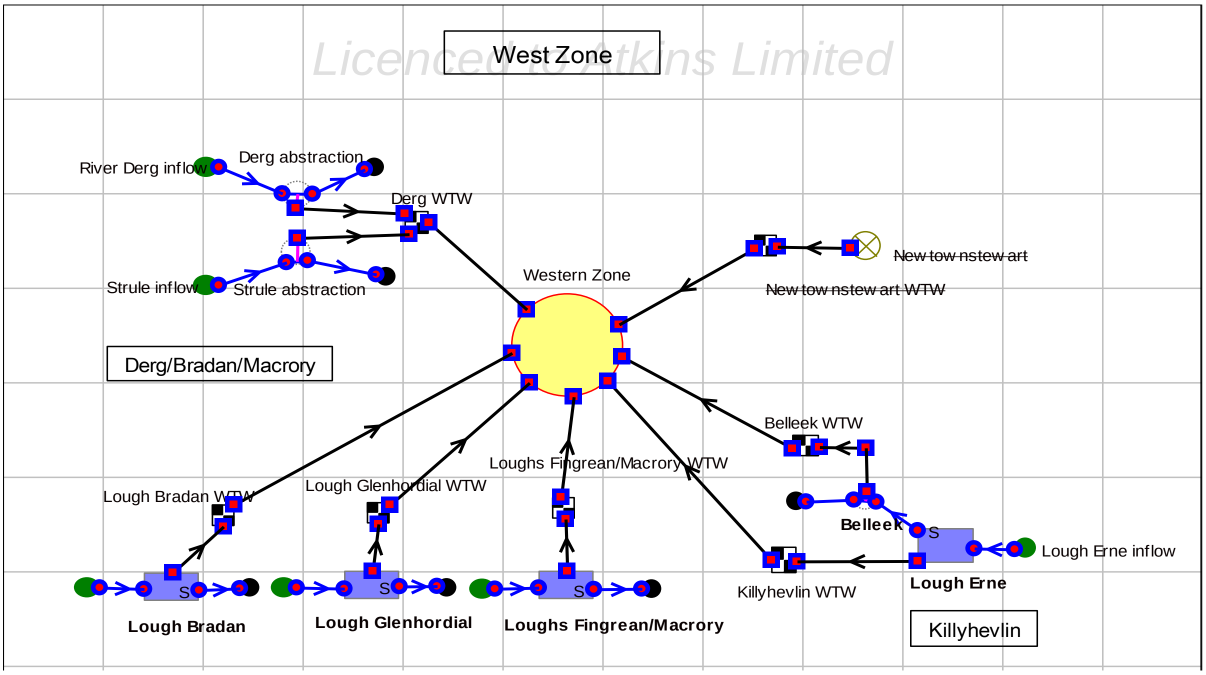


Figure A.15 – West WRZ unconstrained model schematic

East Zone

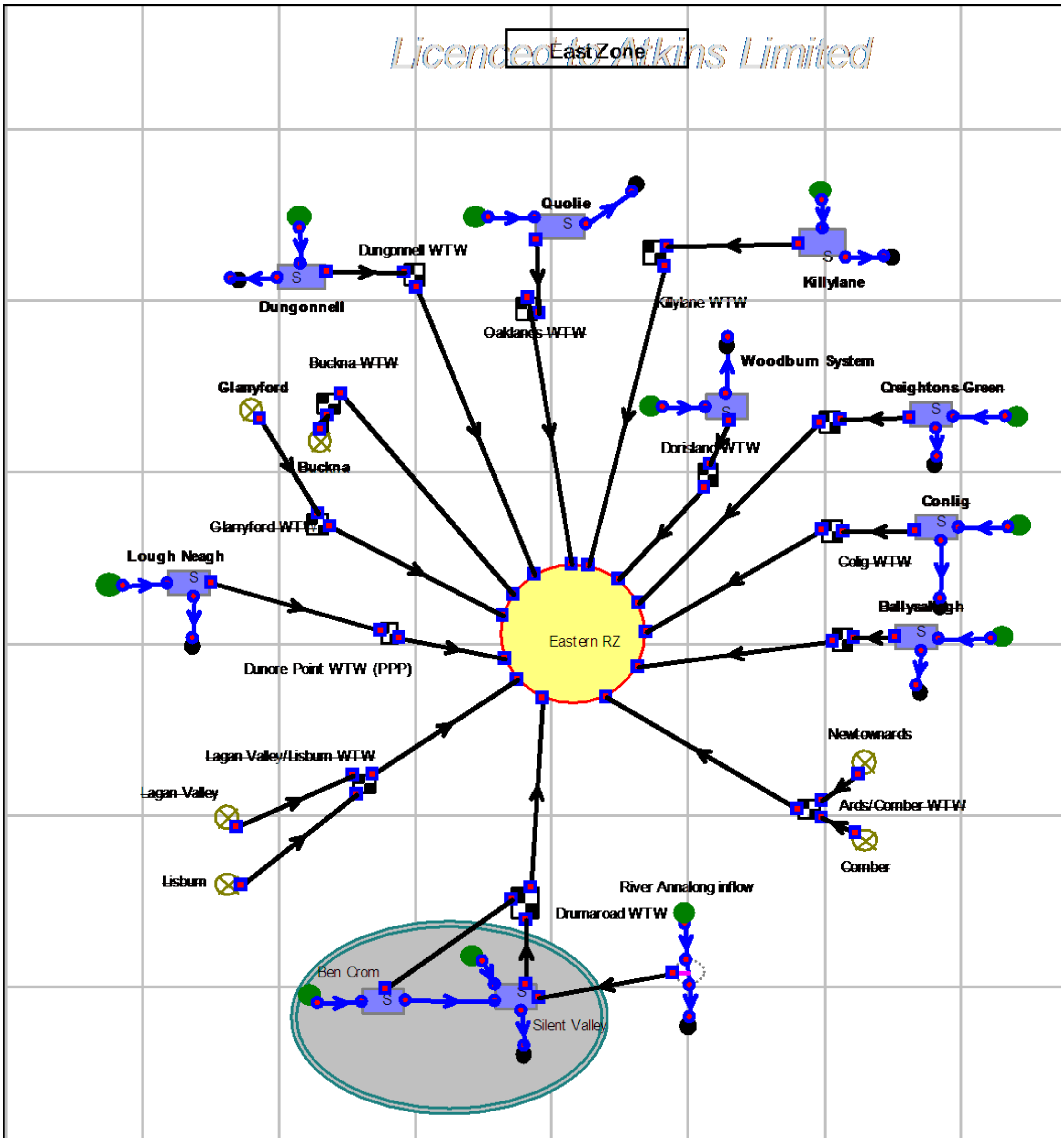


Figure A.16 – East WRZ unconstrained model schematic

South Zone

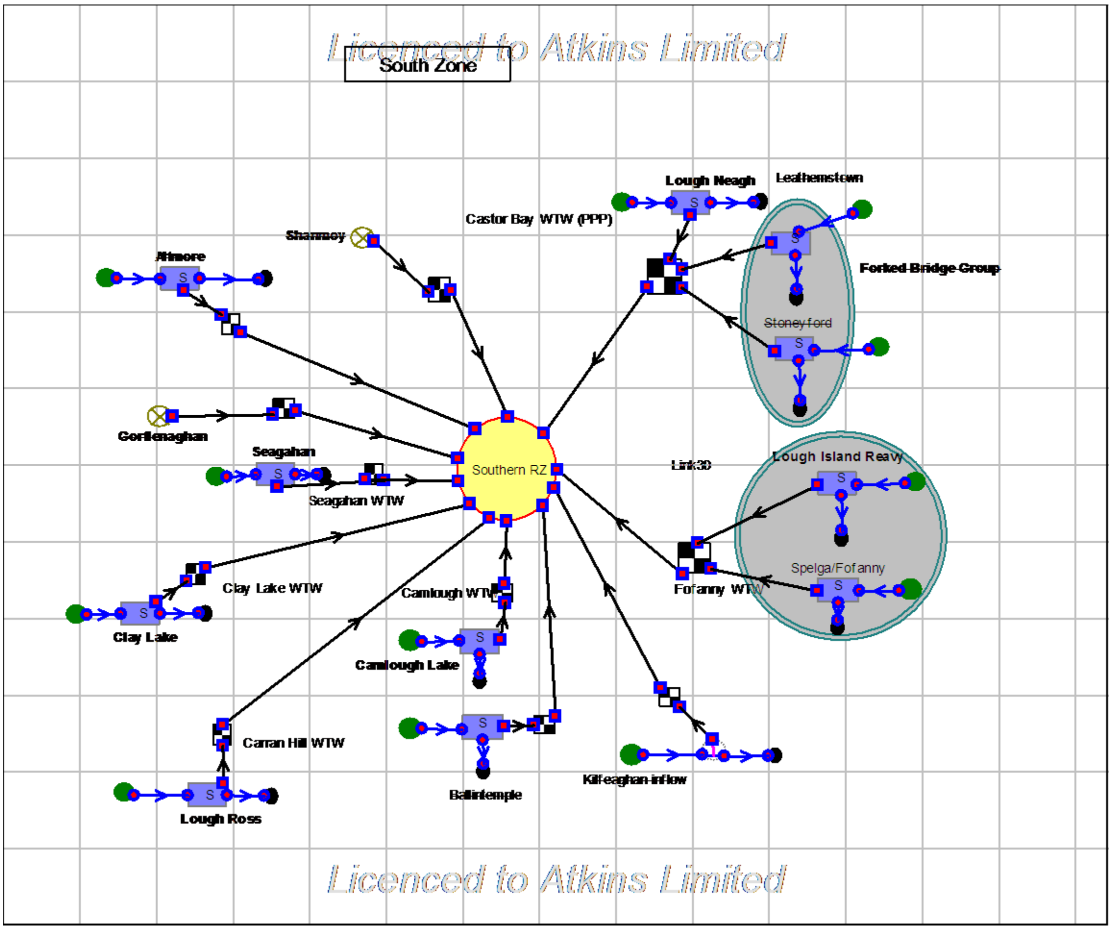


Figure A.17 – South WRZ unconstrained model schematic

A.8.2 Data request list

A.8.2.1 Expected data requirements for the Aquator modelling

Note that 'time-series' can refer to a single value, time series (daily, weekly, monthly or annual), or a fixed profile (daily, weekly, monthly or annual) to be used each year
Blenders (mixes water in supply to meet minimum quality standards)

Parameter	**Format/Data type**	**Likelihood of requirement**
Operational?	Yes/no	
Sources	Component name or ID	
Blend method (fraction or determinand based)	Drop-down selection	Not likely required – only if significant blending operations exist
Fraction	Percentage distribution	
Determinand levels	Values	

Bulk supplies

Parameter	**Format/Data type**	**Likelihood of requirement**
Operational?	Yes/no	
Amount	Time-series	Definitely required
Must use entire amount?	Yes/no	

Catchment

Parameter	**Format/Data type**	**Likelihood of requirement**
Flow	Time-series	Definitely required but may come from outside NI Water

Discharge

Parameter	Format/Data type	Likelihood of requirement
Flow	Time-series	Not likely required

Gauging stations

Parameter	Format/Data type	Likelihood of requirement
Operational?	Yes/no	
Flow constraint	Time-series	Not likely required
Flow	Time-series	

Groundwater abstractions

Parameter	Format/Data type	Likelihood of requirement
Operational?	Yes/no	
Efficiency	Percentage	
Daily maximum abstraction	Time-series	Definitely required
Monthly maximum abstraction	Time-series	
Minimum flow	Time-series	

Groundwater abstraction licences

Parameter	Format/Data type	Likelihood of requirement
Individual or group?	Drop-down selection	Definitely required
Type of licence	Drop-down selection	
Enforced?	Yes/no	
Amount	Time-series	
Start month	Drop-down selection	

Links (supply system pipes, aqueducts etc.)

Parameter	Format/Data type	Likelihood of requirement
Operational?	Yes/no	Definitely required – some help may be available from Atkins Network Modelling Team
Bi-directional?	Yes/no	
Maximum flow – forward	Time-series	
Maximum flow – reverse	Time-series	
Minimum flow – forward	Time-series	
Minimum flow – reverse	Time-series	
Licence constraints?	Constraint component name or ID	

Pumping stations

Parameter	Format/Data type	Likelihood of requirement
Operational?	Yes/no	Not likely required
Minimum flow	Time-series	
Maximum flow	Time-series	
Monthly maximum flow	Time-series	

Reservoirs

Parameter	Format/Data type	Likelihood of requirement
Operational?	Yes/no	Definitely required
Compensation	Time-series	Definitely required
Additional outflow	Time-series	Not likely required
Hydropower	Time-series	Not likely required
Irrigation	Time-series	Not likely required
Flood drawdown	Time-series	Not likely required
Level Area Storage	Array of single values	Required if available
Abs. emergency level	Single value	Required if available
Rel. emergency level	Percentage	Required if available
Abs. dead water level	Single value	Required if available
Rel. dead water level	Percentage	Required if available
Control curves (time series or profile of storage)	Time-series	Definitely required
Rainfall	Time-series	Required if available
Evaporation	Time-series	Required if available
Observed levels or storage	Time series (daily, weekly, monthly or annual) to be used each year	Definitely required

Reservoir licences

Parameter	Format/Data type	Likelihood of requirement
Individual or group?	Drop-down selection	
Type of licence	Drop-down selection	
Enforced?	Yes/no	Definitely required
Amount	Time-series	
Start month	Drop-down selection	

River reach

Parameter	Format/Data type	Likelihood of requirement
Abstraction	Time-series	Not likely required
Discharge	Time-series	

Surface water abstractions

Parameter	Format/Data type	Likelihood of requirement
Operational?	Yes/no	Definitely required
Flow constraint	Time-series	
Daily maximum abstraction	Single value, time series (daily) or fixed profile (daily) to be used each year	
Monthly maximum abstraction	Single value, time series (monthly) or fixed profile (monthly) to be used each year	

Surface water abstraction licences

Parameter	Format/Data type	Likelihood of requirement
Individual or group?	Drop-down selection	Definitely required
Type of licence	Drop-down selection	
Enforced?	Yes/no	
Amount	Time-series	
Start month	Drop-down selection	

Water treatment works

Parameter	Format/Data type	Data availability/source/contact details
Operational?	Yes/no	Definitely required
Minimum flow	Time-series	Required if available
Daily maximum flow	Single value, time series (daily) or fixed profile (daily) to be used each year	Definitely required
Monthly maximum flow	Single value, time series (monthly) or fixed profile (monthly) to be used each year	Definitely required
Losses	Percentage	Required if available

Table A.15 – Data request list

A.8.3 Hydrological analysis

A.8.3.1 **WISKI gauging stations and quality checks**

Station number	Gauge Name	River	Atkins' Quality Check	Start Date	End Date	No. of gaps in record
203017	Dynes Bridge	Upper Bann	Record ok	28/12/1978	05/07/1994	1082
203039	Tullynewy Bridge	Clogh	Record ok	19/12/1983	08/07/2009	91
203043	Shanmoy	Oona Water	Record ok	11/11/1986	11/07/2009	12
205033	Woodburn East	Woodburn	Record ok	07/06/2000	11/07/2009	0
203024	Gambles Bridge	Cusher	Record ok	29/12/1975	11/07/2009	8
205029	Feeny	Lagen	Record ok	30/09/2004	31/12/2008	0
203947	Flat Vee Weir	Four Mile Burn	Record ok	06/10/1977	12/08/1986	479
204001	Seneirl	Bush	Record ok	29/12/1975	02/07/2009	81
203024	Gambles Bridge	Cusher	Record ok	29/12/1975	11/07/2009	8
203019	Glenone Bridge	Claudy	Record ok	29/12/1975	11/07/2009	1443
205015	Grandmere Park	Cotton	Poor Data Set in 1980–1990 where flows need adjusting	01/03/1987	11/07/2009	163
206002	Jerretts Pass (River)	Jerretts Pass	Record ok	02/01/1980	11/07/2009	47
203096	Kilraghts	Breckagh Burn	Record ok	26/03/1996	31/12/2008	0
203063	Leap Bridge	Glenavy	Record ok	23/05/2001	11/07/2009	91
203619	Lough Neagh Inflow	Lough Neagh	Record ok	30/08/1995	02/01/2001	8
203010	Maydown Bridge	Blackwater	Record ok	29/12/1975	11/07/2009	1
203097	Moyallan	Upper Bann	Poor Data Set in 2000 and 2002 where flows need adjusting	19/08/1990	16/08/2008	15
205004	Newforge	Lagan	Record ok	28/12/1977	11/07/2009	0
205110	Park Centre	Clowney	Record ok	23/09/1988	03/01/2001	209
236053	Ratoran	Pubble	Record ok	27/06/1994	31/12/2007	0
205102	Townsend Street	Farset	Record ok	30/12/1987	08/04/2002	743
203041	Tullybryan	Ballygawley Water	Record ok	05/11/1980	11/07/2009	278
236052	Rawbridge	Corlough	Record ok	28/06/1994	11/07/2009	11
235052	Rockstown	County River	Record ok	27/11/2002	30/06/2009	0
203050	UUC	Ballysallyblag h	Record ok	02/06/1993	08/07/2009	0
205309	Lusky Mill	Blackwater (Down)	Record ok	31/12/1975	07/01/1982	1
203090	Recorder F	Braid	Record ok	29/12/1975	18/03/2007	8788
205031	Woodburn West	Woodburn	Record ok	19/05/2000	11/07/2009	8

Station number	Gauge Name	River	Atkins' Quality Check	Start Date	End Date	No. of gaps in record
205005	Ravernet	Ravernet	Poor Data Set in 1999 where flows need adjusting	27/12/1979	06/07/2009	224
203046	Rathmore Bridge	Rathmore Burn	Record ok	31/12/1983	31/12/2008	0
203052	Pollands Bridge	Upper Bann Tributary	Record ok	31/12/1999	02/07/2009	1219
205105	Orangefield	Knock	Record ok	30/09/1983	02/06/2009	114
206015	Ohares, Castlewellan	Burren	Poor Data Set in 1999 where flows need adjusting	17/10/1994	31/12/2007	20
202005	Muff Glen	Muff	Record ok	15/02/1995	11/07/2009	0
205108	Rosepark	Knock	Record ok	03/07/2003	30/06/2009	62
203020	Moyola New Bridge	Moyola	Record ok	29/12/1975	11/07/2009	796
203040	Movanagher	Lower Bann	Record ok	25/06/1980	27/06/2009	2921
205023	Meaghlough Road	Carryduff	Record ok	29/12/1988	29/06/2009	3316
204007	Altnahinch	Bush	Record ok	21/09/2000	02/06/2009	15
202007	Altnaheglish	Roe	Record ok	27/09/2001	31/03/2009	0
205032	Woodburn Central	Woodburn	Record ok	19/05/2000	04/07/2009	2
203028	White Hill	Agivey	Record ok	15/03/1976	11/07/2009	280
205012	Watsons Bridge	Annahilt	Record ok	31/12/1980	26/09/1984	0
236058	Tilery Bridge	Arney	Record ok	01/02/1999	11/07/2009	183
203045	Springmount	Engine Burn	Poor Data Set	31/12/1981	29/12/1987	1388
203093	Shane's Viaduct	Main	Record ok	30/12/1983	11/07/2009	0
203038	Rocky Mountain	Rocky	Record ok	25/12/1985	02/07/2009	332
201304	Stonebridge	Strule	Record ok	22/12/1986	16/10/1997	0
203023	The Moor Bridge	Torrent	Record ok	01/01/1980	11/07/2009	1025
22565	#N/A	#N/A	#N/A	11/08/2004	05/08/2008	0
236009	Thompsons Bridge	Swanlinbar	Record ok	24/02/1987	07/03/1995	1
203025	Martin's Bridge	Callan	Record ok	29/12/1975	11/07/2009	7
203620	Lough Neagh Outflow	Lough Neagh	Record ok	25/06/1980	11/07/2009	2921
206009	Tipperary Wood	Shimna	Record ok	17/10/1994	11/07/2009	0
203012	Ballinderry Bridge	Ballinderry	Record ok	30/08/1995	11/07/2009	5
203018	Antrim	Six Mile Water	Record ok	29/12/1975	11/07/2009	0
203027	Ballee	Braid	Record ok	01/01/1980	11/07/2009	0
236005	Ballindarragh Bridge	Colebrooke	Record ok	30/12/1986	11/07/2009	0
202001	Ardnagle	Roe	Record ok	29/12/1975	11/07/2009	0
203013	Andraid	Main	Record ok	21/12/1982	31/12/1990	1105

Station number	Gauge Name	River	Atkins' Quality Check	Start Date	End Date	No. of gaps in record
236051	Ballycassidy	Ballinamallard	Record ok	16/04/1991	11/07/2009	1
201015	Ballymagory	Glenmorgan	Record ok	29/08/1995	11/07/2009	0
203029	Ballyclare	Six Mile Water	Record ok	03/01/1980	01/01/2000	1493
205036	Dromore Street	Ballynahinch	Record ok	17/10/2001	02/07/2009	12
203033	Bannfield	Upper Bann	Record ok	29/12/1975	11/07/2009	24
205010	Banoge	Lagan	Record ok	27/12/1983	25/07/1994	0
204004	Glendurn	Beaghs Burn	Poor Data Set in 1996 and 1998 where flows need adjusting	19/11/1995	11/07/2009	1226
206007	Bonnys	Tullybranigan	Record ok	19/10/1994	11/07/2009	0
201007	Burndennet Bridge	Burn Dennet	Record ok	29/12/1975	11/07/2009	15
205024	Burrendale	Burren	Record ok	01/03/1989	25/06/1994	0
201005	Camowen Terrace	Camowen	Poor Data Set in 1976 where flows need adjusting	29/12/1975	01/07/2009	1
201006	Campsie Bridge	Drumragh	Record ok	29/12/1975	11/07/2009	27
206004	Carnbane	Bessbrook	Record ok	13/12/1983	03/07/2009	285
205109	Loop Bridge	Loop	Record ok	29/12/1986	30/06/2009	3904
203044	Looblands	Ballinaloob	Record ok	10/09/1981	07/01/1988	0
236056	Larkhill	Garvary River	Poor Data Set in 1976 where flows need adjusting	16/08/1995	11/07/2009	138
205011	Kilmore	Annacloy	Record ok	22/11/1979	11/07/2009	12
236006	Killhevlin	Erne	Record ok	24/09/1984	11/07/2009	100
203091	Kernoghan	Devenagh Burn	Record ok	29/12/1976	05/11/1981	927
206005	Hockey Club	Newry	Record ok	13/06/1994	18/06/2009	819
205022	Gransha Road	Ward Park Stream	Record ok	31/12/2003	04/12/2008	104
202006	Gortenny	Castle	Poor Data Set in 1999 where flows need adjusting	27/02/1995	27/05/1999	142
203026	Glenavy	Glenavy	Record ok	02/01/1980	02/01/2001	8
203098	Galgorm (formerly Gallahers)	Main	Record ok	26/09/1984	11/07/2009	1075
203055	Flume 4	Fourmileburn	Record ok	31/12/1976	30/12/1979	0
203053	Flume 3	Fourmileburn	Record ok	18/12/1979	31/12/1985	0
203054	Flume 2	Fourmileburn	Record ok	17/01/1979	31/12/1985	3
203051	Flume 1	Fourmileburn	Record ok	18/12/1979	31/12/1985	0
205111	Fire Authority	Blackstaff	Record ok	01/11/2001	15/05/2007	626
202004	Eglinton	Muff	Record ok	19/12/1994	11/07/2009	6
205101	Easons	Blackstaff	Record ok	11/10/1983	04/04/2001	156

Station number	Gauge Name	River	Atkins' Quality Check	Start Date	End Date	No. of gaps in record
203092	Dunminning – Lower	Main	Poor Data Set in 1984, 1999 and 2000 where flows need adjusting	24/08/1983	11/07/2009	59
201002	Dudgeon Bridge	Fairy Water	Poor Data Set in 2000 where flows need adjusting	29/12/1975	11/07/2009	782
201010	Drumnabuoy House	Mourne	Record ok	17/06/1982	31/12/2008	0
236007	Drumrainy Bridge	Sillees	Record ok	22/09/1981	11/07/2009	14
205008	Drummiller	Lagan	Record ok	27/12/1977	11/07/2009	82
203911	Dromona (Kennaways)	Main	Record ok	29/12/1975	18/11/1980	0
201008	Castlederg	Derg	Record ok	29/12/1975	11/07/2009	0
203042	Cidercourt Bridge	Crumlin	Poor Data Set in 1999 and 2001 where flows need adjusting	29/12/1982	11/07/2009	3
202002	Drumahoe	Faughn	Poor Data Set in 1999 where flows need adjusting	27/08/1976	11/07/2009	31
203049	Clady Bridge	Clady	Record ok	19/12/1983	11/07/2009	5
203011	Dromona	Main	Record ok	08/09/1980	11/07/2009	1154
205020	Comber	Enler	Record ok	29/12/1983	11/07/2009	8
203022	Derrymeen Bridge	Blackwater (Armagh)	Record ok	04/01/1983	06/07/2009	4993
205025	Delamont Bridge	Delamont	Record ok	27/09/1989	02/07/2009	3150
203021	Currys Bridge	Kells Water	Poor Data Set in 2000–2002 where flows need adjusting	29/12/1975	11/07/2009	77
203035	Craigs	Aghill Burn	Record ok	21/12/1982	15/09/1992	2
201009	Crosh	Owenkillew	Poor Data Set in 2001 where flows need adjusting	14/02/1980	11/07/2009	24

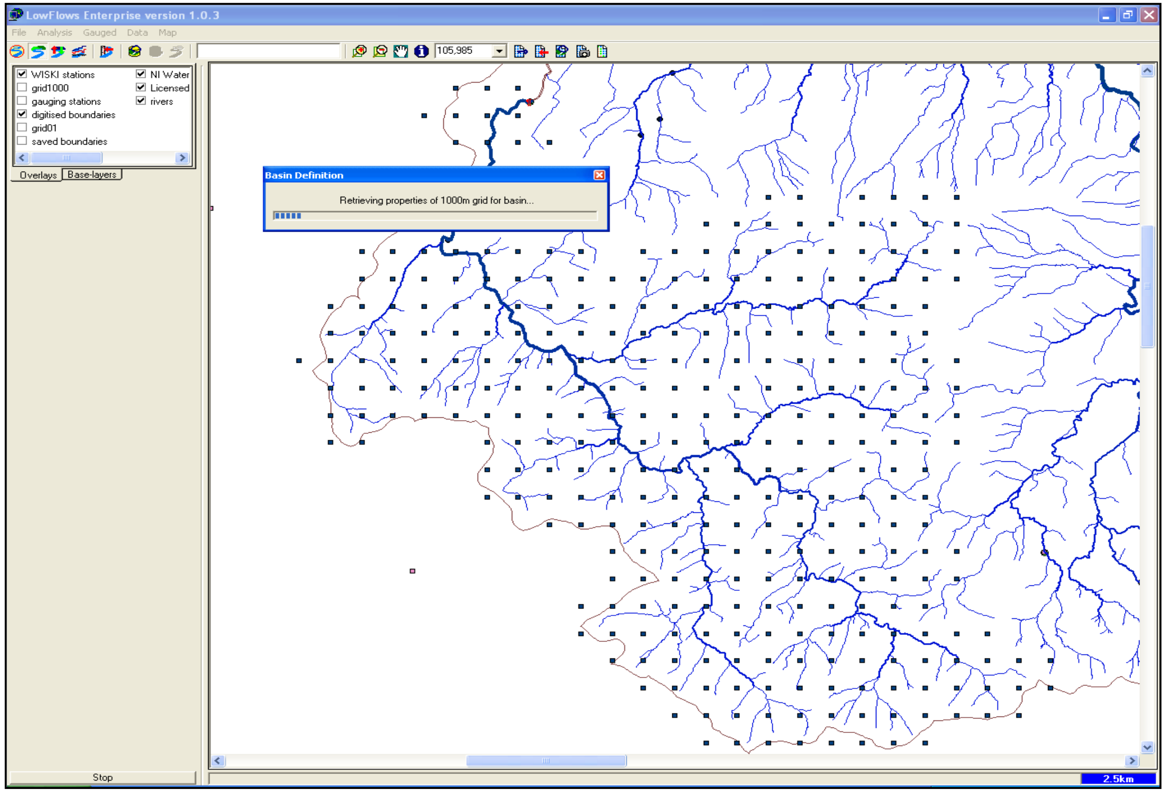
Table A.16 – WISKI gauging stations and record checks

A.8.3.2 Licensed abstraction intakes

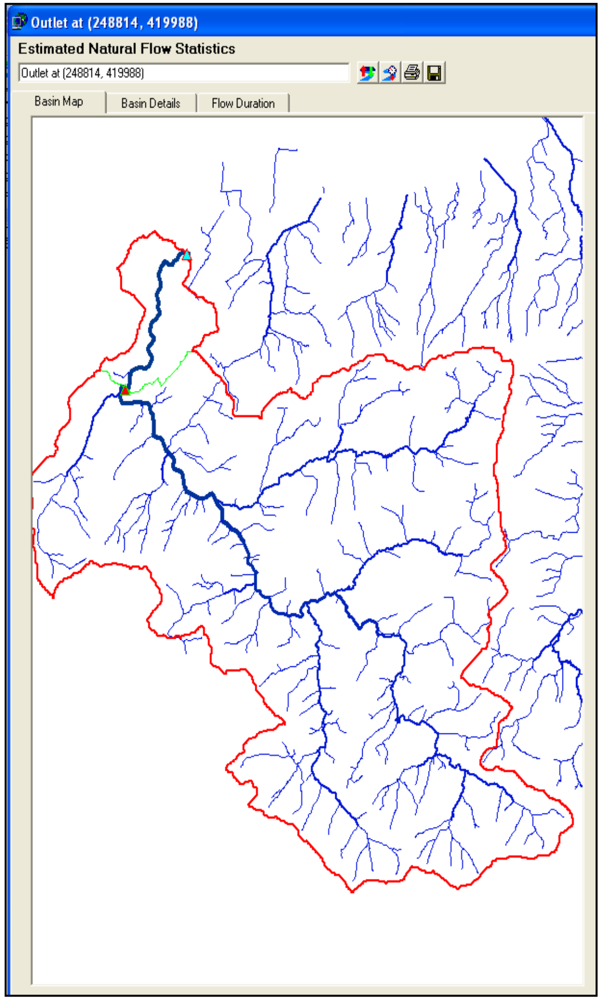
Local Name	Easting	Nothing	Source	Licence Name
Altmore Reservoir	267313	367499	Reservoir	Altmore
Cappagh Reservoir	269122	366943	Reservoir	Altmore
Altnahinch Impounding	312100	423500	Reservoir	Altnahinch
Springwell No 1	277148	428037	River	Ballinrees
Springwell No 2	277094	427899	River	Ballinrees
Springwell No 3	277074	427627	River	Ballinrees
Fermoyle	277286	428992	River	Ballinrees
Altikeeragh No 1	275478	430096	River	Ballinrees
Altikeeragh No 2	274474	430914	River	Ballinrees
Altikeeragh No 3	273925	431142	River	Ballinrees
Ballyhacket	274423	432692	River	Ballinrees
River Bann	286201	430098	River	Ballinrees
Lough Erne Belleek	194530	358640	Lough	Belleek
Camlough	302920	325854	Lake	Camlough
River Faughan	248880	420000	River	Carmoney
Lough Ross	288000	315700	Reservoir	Carron Hill Lough Ross
Glenedra River	268410	402380	River	Caugh Hill
Kerlins Burn	265310	403490	River	Caugh Hill
Altnaheglish	269650	403490	River	Caugh Hill
Clay Lake	283852	332806	Reservoir	Clay Lake
Gentle Owen Lake	283608	330035	Lake	Clay Lake
River Derg	232473	386169	River	Derg
Beltoy Water Course	341340	394423	River	Dorisland
Bellyvallagh Course	337720	393820	River	Dorisland
Frenchpark Conduit	339260	389750	River	Dorisland
Lough Mourne	341600	392380	Reservoir	Dorisland
Copeland	342810	391400	Reservoir	Dorisland
North Woodburn	337090	391140	Reservoir	Dorisland
Up South Woodburn	336660	388740	Reservoir	Dorisland
Mid South Woodburn	337280	388890	Reservoir	Dorisland
Low South Woodburn	337770	389120	Reservoir	Dorisland
Dorisland	338600	388100	Reservoir	Dorisland
Annalong	334800	323280	River	Drumaroad
Annalong	334820	323210	River	Drumaroad
Ben Crom	331470	325540	River	Drumaroad
Silent Valley	330840	321840	Reservoir	Drumaroad
Collin Burn	321800	418400	River	Dungonnell
Lough Garve 1	320800	417900	River	Dungonnell
Lough Garve 2	320487	417870	River	Dungonnell
Inver River	321968	419118	River	Dungonnell
Dungonnell IR	319268	417140	Reservoir	Dungonnell
Spelga	326600	327300	Reservoir	Fofanny
Fofanny	328603	329122	Reservoir	Fofanny
Slievemeel	329425	329300	Watercourse	Fofanny
Glenhordial Burn	248250	375650	River	Glenhordial
Crosh	249550	376350	River	Glenhordial
Camowen	247360	371220	River	Glenhordial
Glenhordial	248090	375250	Reservoir	Glenhordial
Lough Erne Killyhevlin	224710	342250	Lough	Killyhevlin
Donaghy's	330858	399497	Reservoir	Killylane
Crosswater 2	330187	401155	Reservoir	Killylane
Crosswater 3	329390	401308	Reservoir	Killylane
Curraghmacall Stream	226050	374160	Stream	Lough Bradan

Local Name	Easting	Nothing	Source	Licence Name
2				
Curraghmacall Stream 1	225900	374440	Stream	Lough Bradan
Scraghey Burn	224280	372560	River	Lough Bradan
Lough Bradan	225950	371440	Reservoir	Lough Bradan
Lough Lee	225800	376240	Reservoir	Lough Bradan
Whitewater	278400	389600	Reservoir	Lough Fea
Sruhannaclogh	277900	389400	River	Lough Fea
Sruhanpollakeeran	276900	389100	River	Lough Fea
Lough Fea	276400	386500	Reservoir	Lough Fea
Muddoch	328470	332680	River	Lough Island Reavy
Moneyscalp	331480	334020	River	Lough Island Reavy
Lough Island Reavy	329230	333830	Reservoir	Lough Island Reavy
Bauck Hill	259350	378250	River	Lough Macrory
Loughanadarragh	256760	377770	Lough	Lough Macrory
Loughnepeast	256540	377480	Lough	Lough Macrory
Lough Carn	257460	378890	Lough	Lough Macrory
Stradowan No 1	253450	379750	River	Lough Macrory
Stradowan No 2	253450	379850	River	Lough Macrory
Glencolpy	253450	381050	River	Lough Macrory
Cornagillagh Bridge	254050	380650	River	Lough Macrory
Lenagh Bridge	254050	381850	River	Lough Macrory
Lough Fingrean	257220	377720	Reservoir	Lough Macrory
Lough Macrory	257550	376450	Reservoir	Lough Macrory
Seaghan Dam	326600	327300	Reservoir	Seaghan
Leathenstown Reservoir	321440	372444	Reservoir	Forked Bridge
Andersons	321949	370457	River	Forked Bridge
Stoneyford River Pumping Station	322005	370487	River	Forked Bridge
Stoneyford Reservoir	321475	369899	Reservoir	Forked Bridge
Dornans Intake	321056	372361	River	Forked Bridge

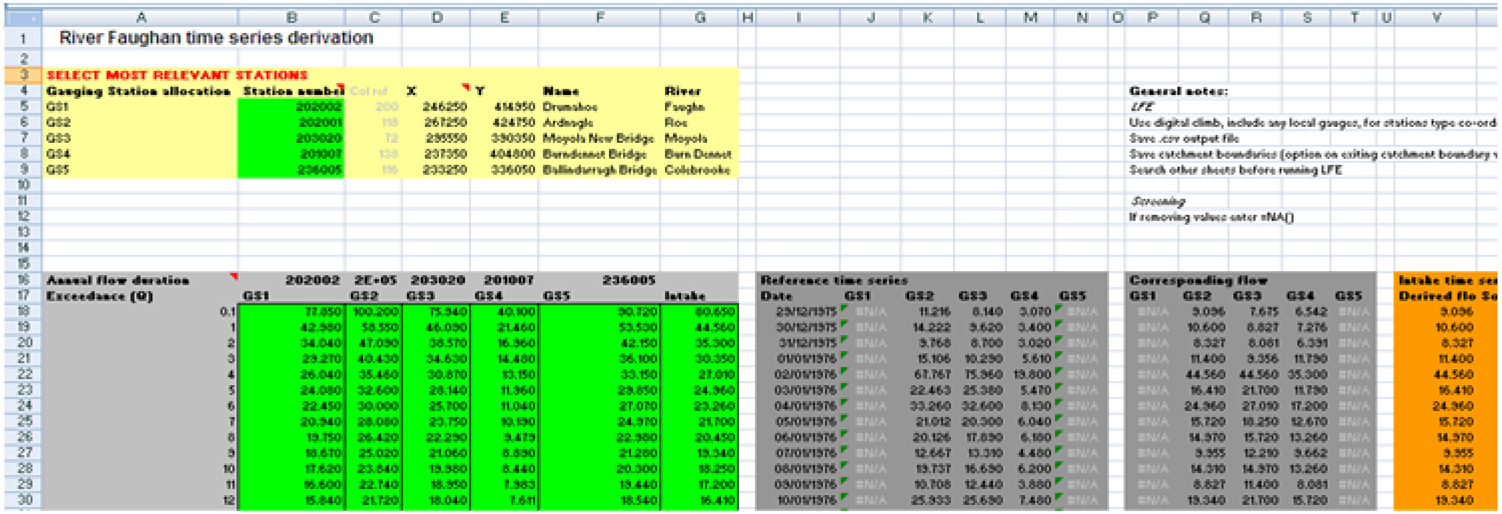
Table A.17 – Licensed abstraction intakes



a) An example of delineation using LFE software



b) LFE software showing catchment boundary with a local gauging station just upstream



River Faughan time series derivation

SELECT MOST RELEVANT STATIONS

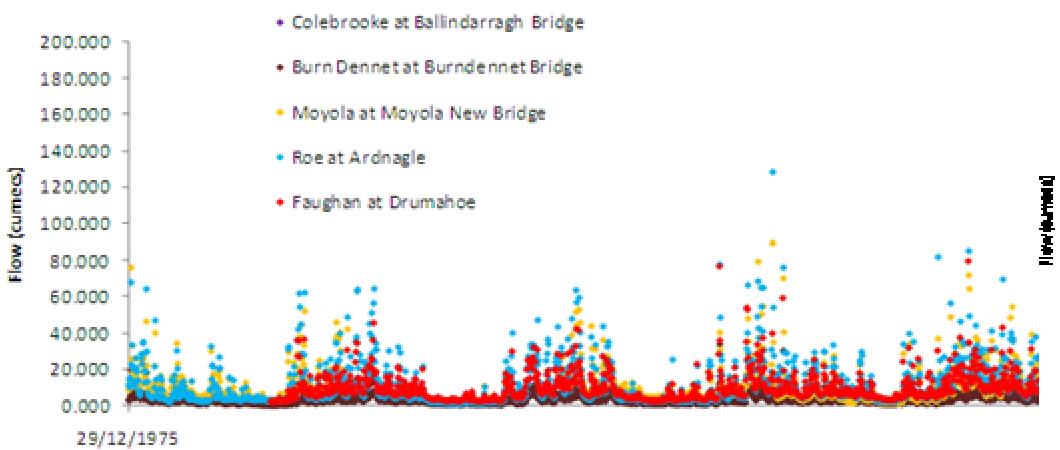
Gauging Station allocation	Station number	Col ref	X	Y	Name	River
GS1	202002	200	246250	414350	Drumahoe	Faughan
GS2	202001	118	267250	424750	Ardnagle	Roe
GS3	203020	72	295550	390350	Moyola New Bridge	Moyola
GS4	201007	138	237350	404800	Burndennet Bridge	Burn Dennet
GS5	236005	116	233250	336050	Ballindarragh Bridge	Colebrooke

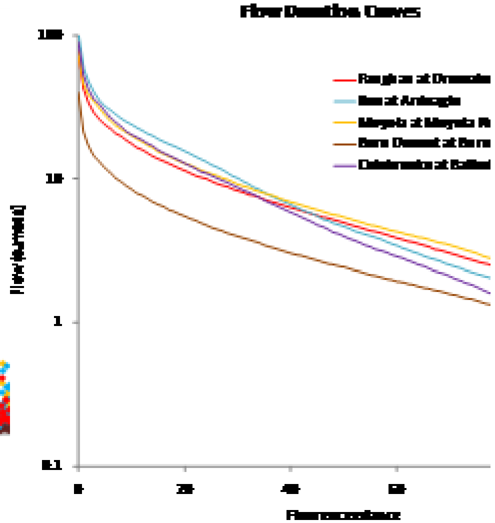
General notes:
LFE
Use digital climb, include any local gauges, for stations type co-ord
Save .csv output file
Save catchment boundaries (option on exiting catchment boundary v
Search other sheets before running LFE

Screening
If removing values enter =NA()

Annual flow duration Exceedance (Q)	202002 GS1	2E+05 GS2	203020 GS3	201007 GS4	236005 GS5	Intake
0.1	77.850	100.200	75.340	40.100	90.720	80.650
1	42.980	58.550	46.090	21.460	53.530	44.560
2	34.040	47.090	38.570	16.360	42.150	35.300
3	29.270	40.430	34.630	14.480	36.100	30.350
4	26.040	35.460	30.870	13.150	33.150	27.010
5	24.080	32.600	28.140	11.960	29.850	24.960
6	22.450	30.000	25.700	11.040	27.070	23.260
7	20.940	28.080	23.750	10.190	24.970	21.700
8	19.750	26.420	22.290	9.479	22.980	20.450
9	18.670	25.020	21.060	8.890	21.280	19.340
10	17.620	23.840	19.980	8.440	20.300	18.250
11	16.600	22.740	18.950	7.983	19.440	17.200
12	15.840	21.720	18.040	7.611	18.540	16.410

Reference time series Date	GS1	GS2	GS3	GS4	GS5	Corresponding flow GS1	GS2	GS3	GS4	GS5	Intake time series Derived flo So
29/12/1975	#N/A	11.216	8.140	3.070	#N/A	#N/A	9.096	7.675	6.542	#N/A	9.096
30/12/1975	#N/A	14.222	9.620	3.400	#N/A	#N/A	10.600	8.827	7.276	#N/A	10.600
31/12/1975	#N/A	9.768	8.700	3.020	#N/A	#N/A	8.327	8.081	6.391	#N/A	8.327
01/01/1976	#N/A	15.106	10.290	5.610	#N/A	#N/A	11.400	9.356	11.790	#N/A	11.400
02/01/1976	#N/A	67.767	75.960	19.800	#N/A	#N/A	44.560	44.560	35.300	#N/A	44.560
03/01/1976	#N/A	22.463	25.380	5.470	#N/A	#N/A	16.410	21.700	11.790	#N/A	16.410
04/01/1976	#N/A	33.260	32.600	8.130	#N/A	#N/A	24.960	27.010	17.200	#N/A	24.960
05/01/1976	#N/A	21.012	20.300	6.040	#N/A	#N/A	15.720	18.250	12.670	#N/A	15.720
06/01/1976	#N/A	20.126	17.890	6.180	#N/A	#N/A	14.970	15.720	13.260	#N/A	14.970
07/01/1976	#N/A	12.667	13.310	4.480	#N/A	#N/A	9.355	12.210	9.662	#N/A	9.355
08/01/1976	#N/A	19.737	16.690	6.200	#N/A	#N/A	14.310	14.970	13.260	#N/A	14.310
09/01/1976	#N/A	10.708	12.440	3.880	#N/A	#N/A	8.827	11.400	8.081	#N/A	8.827
10/01/1976	#N/A	25.933	25.690	7.480	#N/A	#N/A	19.340	21.700	15.720	#N/A	19.340





c) Bespoke excel spreadsheet containing data from ROI gauged catchments used to estimate flow time series

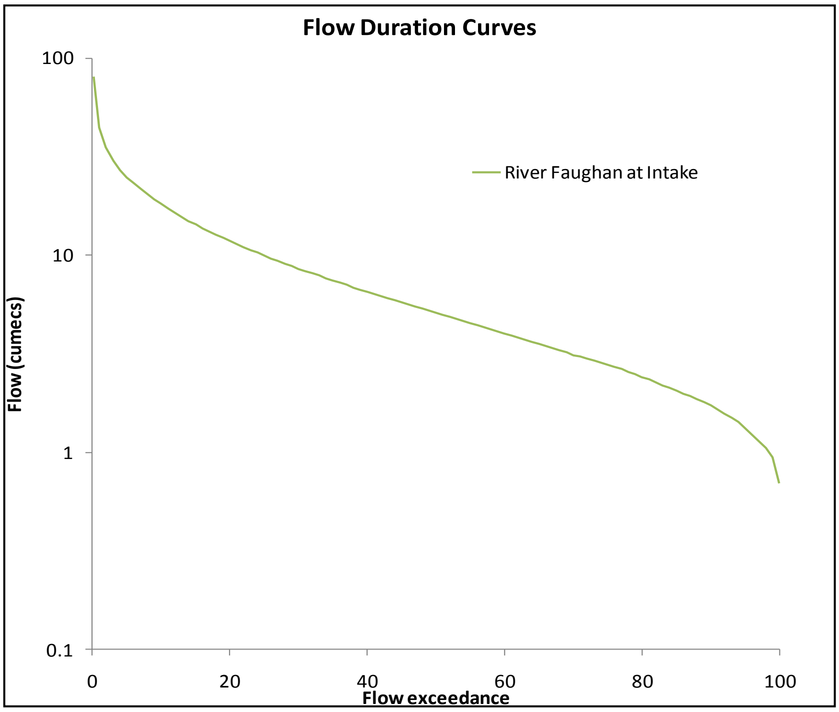
Figure A.18 – Catchment delineation maps and estimate flow time series

North WRZ	Notes
River Faughan	There is a WISKI station nearby (Altnaheglish, River Roe, 270800, 402650) but this does not appear in LFE or the Hydrometric Register. It is also a fairly short record of low flow values. Therefore, it was not included in the derivation of any of these flow series.
Altnaheglish and Kerlins Burn	There is a WISKI station nearby (Altnaheglish, River Roe, 270800, 402650) but this does not appear in LFE or the Hydrometric Register. It is also a fairly short record of low flow values. Therefore, it was not included in the derivation of any of these flow series.
Glenedra River	There is a WISKI station nearby (Altnaheglish, River Roe, 270800, 402650) but this does not appear in LFE or the Hydrometric Register. It is also a fairly short record of low flow values. Therefore, it was not included in the derivation of any of these flow series.
Ballyhacket	In area 202 although rest of intakes for same licence are in area 203.
River Bann	Comprises most of area 203 including Lough Neagh, but LFE does not yet represent impoundments
Altikeeragh No.1, Altikeeragh No.2, Altikeeragh No.3	Could not generate correct boundary in LFE, so seems too large and overlapping with Altikeeragh2
Springwell No.1, Springwell No.2, Springwell No.3 and Fermoyle	Some issues with defining small catchments. Also Springwell 2 and 3 using gauges still needing screening
Altnahinch Impounding	Catchment definition runs too far downstream below the intake but may not be too great an error. Have used the local GS at Altnahinch but this was not one of the LFE GS so should check why it was omitted
West WRZ	**Notes**
River Derg	Digital used. Derg gauge used as local gauge.
Curraghmacall Stream 1&2, Scraghey Burn, Lough Bradan, Lough Lee	Curraghmacall Stream 2 digital area 3.26 km^2, analogue 1.66 km^2, both saved, digital used. Curraghmacall Stream 1 digital used. Scraghey Burn used digital. Lough Bradan digital 3.22 km^2, analogue 5.15 km^2, used digital but weighted by are as catchment area into reservoir approx 1.4 km^2. Lough Lee digital 0.82 km^2 (just downstream of lake), analogue 1.88 km^2, digital used. For Lough Lee needed to replace ROI gauges 4 and 5 to get a complete time series, so 204001 replaced 201010 at 4th and 201002 replaced 203028 at 5th.
Glenhordial Burn, Crosh, Camowen, Glenhordial	Crosh analogue area almost twice as big as digital, used digital. Nearest WISKI station upstream at Camowen. Camowen nearest WISKI stations Camowen Terrace (201005) and Campsie Bridge (201006). Glenhordial: digital area 6.23 km^2, analogue 0.34 km^2, used digital, cannot see WISKI station nearby.
Bauck Hill, Loughanadarragh, Loughnepeast, Lough Carn, Stradowan No1&2, Glencolpy, Cornagillah Bridge, Lenagh Bridge, Lough Fingrean, Lough Macrory	Bauck Hill digital used, but additional station 201008 added as ROI gauge 5 to obtain complete time series. No WISKI station nearby. Loughnepeast, Lough Fingrean and Lough Macrory are all included in the Lough Macrory catchment, digital at Lough Macrory used for these. Lough Carn saved as digital and analogue, used digital for calculations (the digital one selected is further downstream than Licence site) but adjusted FDC by 0.84/1.4 (0.84 is approx area at the Licence site). Stradowan 1 and 2 upstream of Cornagillah so just used Cornagillah digital for all 3. Glencolpy digital area 2.17 km^2, analogue 3.03 km^2, used digital as point seemed closer to the intake grid reference. Lenagh Bridge message that could not find climb thread in digital, used analogue instead, but adjusted analogue by 0.6/0.96 (area weighting, approx area at License point is 0.6 km^2).

East WRZ	Notes
Collin Burn, Lough Garve 1, Lough Garve 2, Inver, Dungonnell	Collin Burn 206001 ranked 5th ROI gauge, but no data available therefore used 203021. Lough Garve 1&2 couldn't select digital for either, used analogue which is downstream and weighted FDC by area, both included 206001 ranked 4th ROI gauge (for which no data is available), moved 203028 from 5th to 4th and added 203021 as 5th ROI GS. Inver used digital. Dungonnell digital not representative, used analogue which is only a little way downstream.
Donaghy's, Crosswater1, Crosswater2	Donaghy's digital seems fine. Crosswater2 and Crosswater3 digital boundaries cross a drainage path, but boundaries don't overlap so overall flow probably OK. Analogue site is further downstream of licence sites so used digital.
Lough Neagh	Assumed extremely large relative to demands.
Bellyvallagh, Frenchpark, Lough Mourne, Beltoy Copeland, North Woodburn, South Woodburn, Dorisland	Bellyvallagh used digital, but not enough data to produce time series so replaced 203019 with 203018 as 5th ROI GS. North Woodburn used digital. South Woodburn all on same river reach so only one inflow, analogue used and weighted by area, not enough data to produce time series so used 203018 instead of 203019 as 5th ROI GS. Lough Mourne and Beltoy upstream of Copeland, Copeland flows only required. Dorisland analogue used but weighted by area (0.16/0.983)
Silent Valley	Just downstream of Ben Crom, but separate inflow required for Aquator. This was obtained by subtracting Ben Crom from the Silent Valley flows. Digital used.
Ben Crom	Digital used.
Annalong	Nearly in the same location so just one inflow created. Digital used.
Central WRZ	**Notes**
Lough Fea, Whitewater, Shruhannaclogh, Shruhapollakeeran	Whitewater digital 5.29 km^2, analogue 7.12 km^2, used digital (looks like the analogue point is quite a lot further downstream). Sruhanpollakeeran: digital 0.43 km^2, analogue is further downstream 1.87 km^2, digital boundary upstream not same as analogue but if you were to draw the boundary manually looks like it would be the same size roughly as the digital. Lough Fea climb thread could not be found in digital, analogue used, catchment area drawn manually 4.1 km^2, FDC adjusted by area weighting (4.1/7.34). For Sruhapollakeeran and Shruhannaclogh the 5 ROI gauges did not provide a complete time series, therefore gauge 201007 added in as the 5th GS for both.
Lough Neagh	Assumed extremely large relative to demands.
South WRZ	**Notes**
Altmore Reservoir, Cappagh Reservoir	Altmore is upstream of Cappagh on the same river, therefore Cappagh used for both. Digital used and boundary looks OK.
Clay Lake, Gentle Owen Lake	Clay Lake analogue area = 7.9 km^2, not possible to select digital, but analogue is downstream of licence point so adjusted FDC by area weighting (5.9/7.9). Gentle Owen Lake is in a different catchment (and hydrometric region) so water must be transferred from Gentle Owen Lake to Clay Lake. Not possible to select digital boundary so used analogue and adjusted FDC by area weighting (0.56/2.25), manual area draining to Gentle Owen Lake is approx 0.56 km^2.
Lough Neagh	Assumed extremely large relative to demands.
Lough Ross	Analogue didn't include all the area draining to the lake so used digital. Selected point just downstream of the lake so captured all inflows. 206001 first ROI gauge, however no data available, 203025 added in at 5 to provide complete time series.

Seagahan Dam	All fine.
Camlough Lake	Digital boundary looks odd and crosses a drainage path. Used analogue and adjusted using area weighting. Approx manual area at licence point is 2.3 km^2 and analogue area is 3.02 km^2, so adjusted by 2.3/3.02. 206001 is ROI gauge 1 but no data available, therefore 203033 added in at 5 to provide complete time series. NB only selected catchment at the upstream inflow to the lake since this is the licence location shown on the map; if the abstraction is for the whole lake then the catchment area will be larger.
Spelga, Fofanny and Slievemeel	Spelga, local gauge found but not used because generated negative value for mean flow. At Fofanny there seems to be a bypass channel round the reservoir. Just took the location at the dam. Slievemeel used digital (both analogue and digital saved).
Muddoch, Moneyscalp and Lough Island	The catchments are difficult to define, however an analogue catchment downstream of the reservoir was chosen and used for all the licence points.
Leathenstown Reservoir and Dornan's Intake	Dornan's Intake downstream of Leathenstown reservoir. Dornan's flows only used.

Table A.18 – Catchment delineation notes and comments



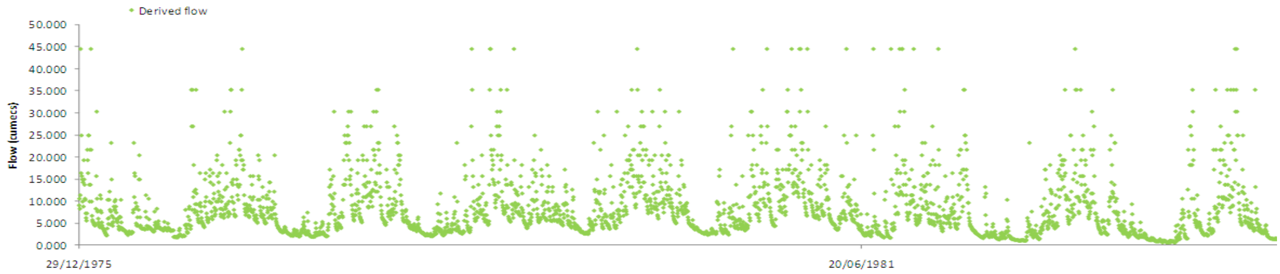


Figure A.19 – Example of flow duration curves and times series generated at each licensed intake

A.8.4 Climate change

Climate change Flow factors

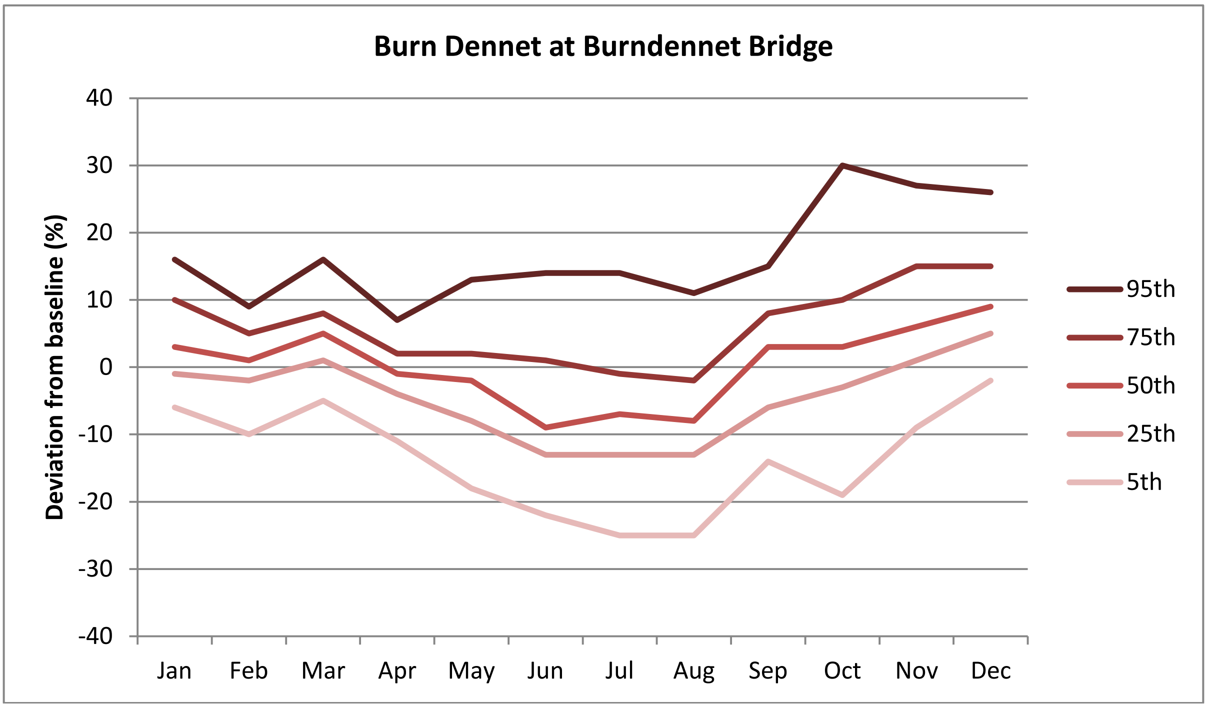


Figure A.20 – Flow factors for Burn Dennet at Burndennet Bridge

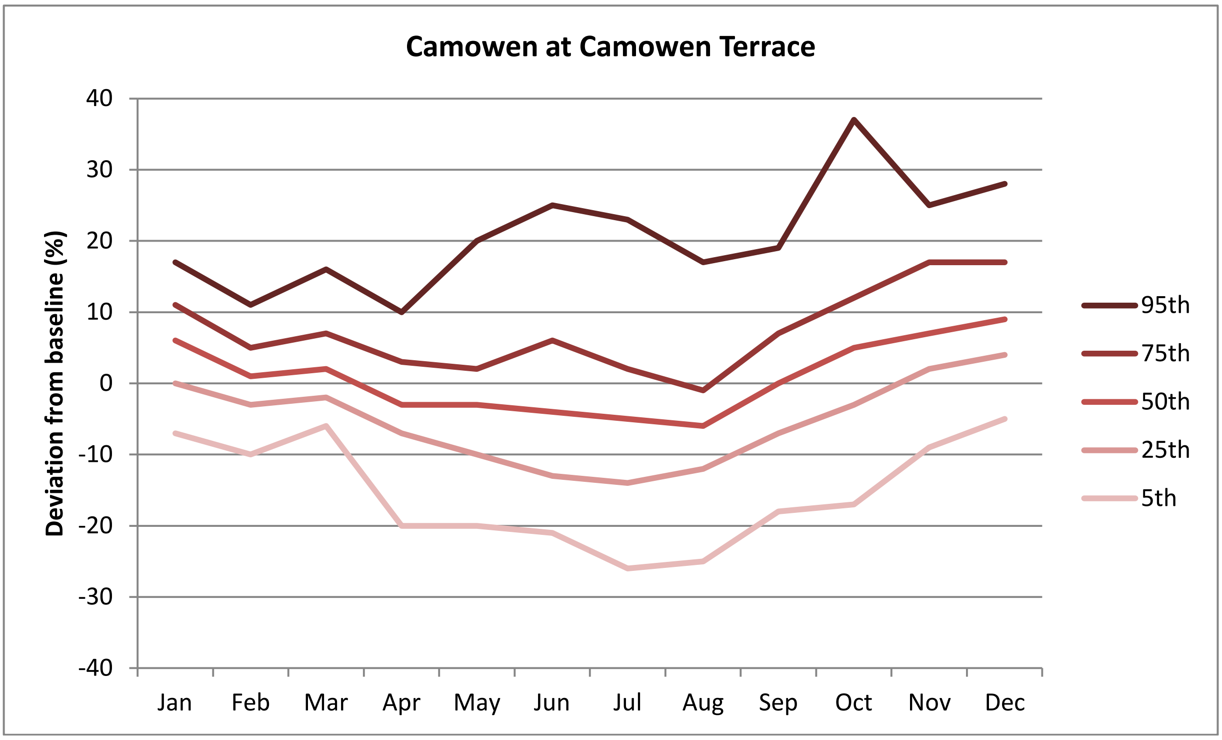


Figure A.21 – Flow factors for Camowen at Camowen Terrace

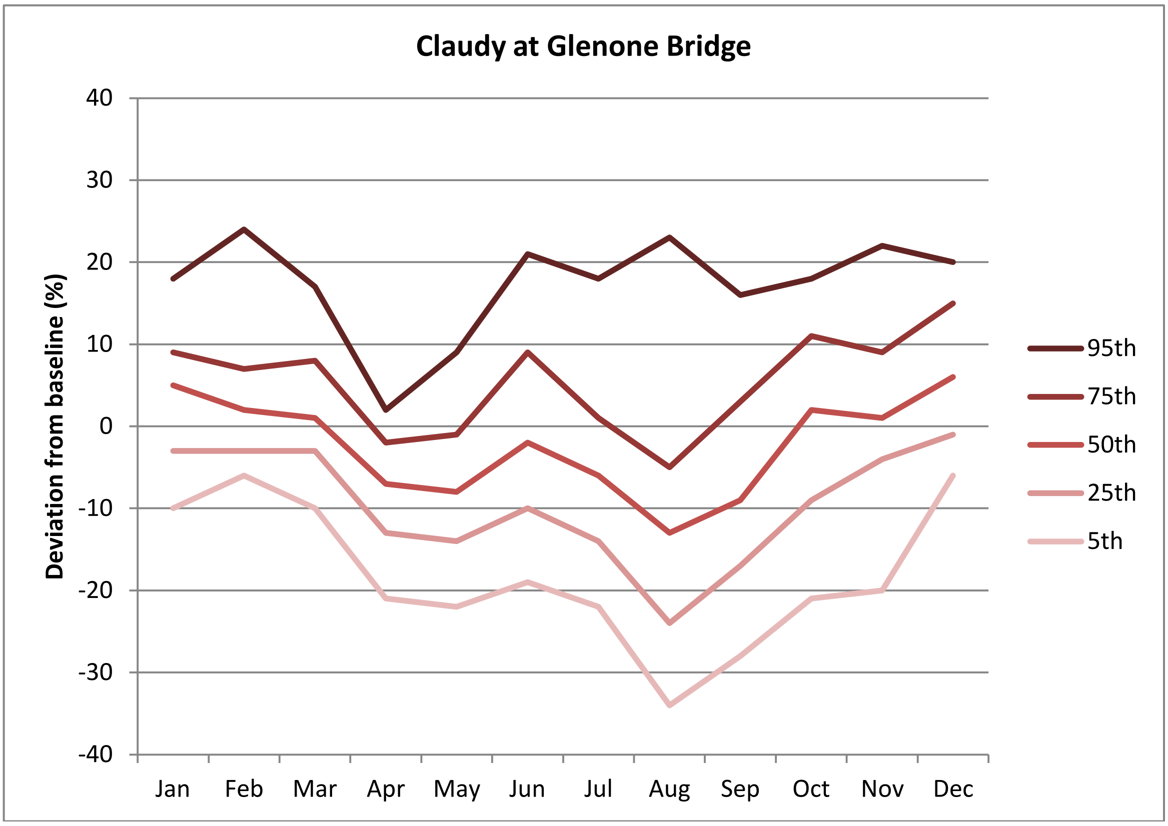


Figure A.22 – Flow factors for Claudy at Glenone Bridge

Simulation details and results

			5th Percentile Climate Change Runs						50th Percentile Climate Change Runs						95th Percentile Climate Change Runs					
WRZ	**Demand Centre**	**Demand (2008–2009 post MLE DI) (Ml/d)**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause/ observations**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause/ observations**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause/ observations**
North	Altnahinch Ballinrees Faughan/Altnaheglish	13.69 17.62 45.04	100	1.310	None required as the model is already set up to conserve Altnahinch supplies whenever possible	1984	Altnahinch	Same failure date and conditions as non-CC run	105.2	1.378	None required as the model is already set up to conserve Altnahinch supplies whenever possible	1984	Altnahinch	Same failure date and conditions as non-CC run	111.3	1.458	None required as the model is already set up to conserve Altnahinch supplies whenever possible	1984	Altnahinch	Same failure date and conditions as non-CC run
West	Derg/Bradan /Macrory RZ Killyhevlin RZ (DC1)	37.22 25.68	86.8	1.380	None required as the model is already set up to conserve Lough Bradan supplies whenever possible	1984	Derg/Bradan /Macrory	Same failure date and conditions as non-CC run	88.2	1.399	None required as the model is already set up to conserve Lough Bradan supplies whenever possible	1984	Derg/Bradan/ Macrory	Same failure date and conditions as non-CC run	89.5	1.423	None required as the model is already set up to conserve Lough Bradan supplies whenever possible	1984	Derg/Bradan/Macrory	Same failure date and conditions as non-CC run
Central	Magherafelt/ Cookstown (DC5)	26.70	31.1	1.165	None	1975	Hydrological conditions still not limiting		31.1	1.165	None	1975	Hydrological conditions still not limiting		31.1	1.165	None	1975	Hydrological conditions still not limiting	
East	Antrim/Larne RZ (DC8) Ballymena RZ (DC7) Eastern General RZ (DC2)	30.34 24.32 236.96	314.4	1.0781	Changed the balance of minimum flows to reflect the changes in hydrology (all found by trial and error) 1) Dungonnell WTW to Ballymena DC – reduced to 7 Ml/d 2) Killylane Reservoir to Killylane WTW – retained at 8 Ml/d 3) Dorisland WTW to Eastern General DC – reduced to 30 Ml/d	1978	Eastern General	Silent Valley and Ben Crom reservoirs become empty on 23/11/1978. However, the model is optimised to balance storage between Silent Valley/Ben Crom and the Woodburn system so with slightly different optimisation Woodburn could cause the failure. Dungonnell can supply more water at this time but increasing its utilisation means that it fails later in the record and ultimately reduces DO	328.1	1.125	Changed the balance of minimum flows to reflect the changes in hydrology (all found by trial and error) 1) Dungonnell WTW to Ballymena DC – reduced to 7 Ml/d 2) Killylane Reservoir to Killylane WTW – reduced to 7 Ml/d 3) Dorisland WTW to Eastern General DC – increased to 34 Ml/d	1978	Eastern General	Silent Valley and Ben Crom reservoirs become empty on 15/11/1978. However, the model is optimised to balance storage between Silent Valley/Ben Crom and the Woodburn system so with slightly different optimisation Woodburn could cause the failure.	346.1	1.187	Changed the balance of minimum flows to reflect the changes in hydrology (all found by trial and error) 1) Dungonnell and Killylane minimum flow controls retained from non-CC model – no further water can be moved away from the Ballymena and Antrim/Larne DCs 2) Dorisland WTW to Eastern General minimum flow removed to protect the over-utilised Woodburn system 3) Add minimum flow of 105 Ml/d (currently max supply just less than 105 Ml/d) to link between Drumaroad WTW and Eastern General to minimise use of Woodburn	2005	Eastern General	The Woodburn System becomes empty on 17/10/2005 despite optimisation to maximise preferential use of other sources

			5th Percentile Climate Change Runs						50th Percentile Climate Change Runs						95th Percentile Climate Change Runs					
WRZ	**Demand Centre**	**Demand (2008–2009 post MLE DI) (Ml/d)**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause/ observations**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause/ observations**	**RZ DO (Ml/d)**	**Demand factor**	**Additional model optimisation**	**Failure year**	**Demand Centre**	**Cause/ observations**
South	Newry RZ (DC5)	53.28	215.1 (200.4 after 2015)	1.209 (1.126 after 2015)	1) Increase minimum flow between FIR and Fofanny WTW to 20 Ml/d to maximise use of LIR against the heavily utilised Spelga/Fofanny. Further optimisation was limited by the maximum capacity of 20 Ml/d on this link. 2) Increase minimum flow on link between Jerretspass PS and Newry demand centre to 16.5 (17.5 after 2015) to re-balance supply with Lough Ross	1977 (1975 after 2015)	Newry (Lough Ross after 2015)	218.6 (204.5 after 2015)	1.228 (1.149 after 2015)	1) Increase minimum flow between FIR and Fofanny WTW to 20 Ml/d to maximise use of LIR against the heavily utilised Spelga/Fofanny. Further optimisation was limited by the maximum capacity of 20 Ml/d on this link.	1975	Newry	Not hydrologically constrained in baseline so increasing water in catchment has not effect. Failure could easily be in Lough Ross demand centre with slightly different optimisation	218.6 (204.5 after 2015)	218.6 (204.5 after 2015)	1.228 (1.149 after 2015)	1) Increase minimum flow between FIR and Fofanny WTW to 20 Ml/d to maximise use of LIR against the heavily utilised Spelga/Fofanny. Further optimisation was limited by the maximum capacity of 20 Ml/d on this link.	1975	Newry	Not hydrologically constrained in baseline so increasing water in catchment has not effect. Failure could easily be in Lough Ross demand centre with slightly different optimisation
	Craigavon RZ (DC4)	94.74																		
	Lough Ross RZ (DC3)	6.43																		
	Armagh RZ (DC2)	18.33																		
	Dungannon RZ (DC1)	5.20																		

Table A.19 – Climate change run results (5th, 50th and 95th percentile) and model optimisation

Appendix B – Outage

B.1 Introduction

The Water Resource Planning Guideline (WRPG) (written by the Environment Agency for England and Wales and followed by UK water companies for their recent WRMPs) recommends that companies follow the principles set out in the operating methodology section of the report Outage allowances for water resources planning (UKWIR 1995) to determine their outage allowance. However, the WRPG also notes that the degree to which a company explores outage will vary according to need and circumstance. The Guideline thus notes that the minimum approach is for a company to justify outage allowances in relation to the likelihood of events occurring, given the magnitude, duration and timing of actual outage circumstances, as supported by recorded data.

In the glossary of the WRPG, outage is defined as:

> *A temporary loss of deployable output. (Note that an outage is temporary in the sense that it is retrievable, and therefore deployable output can be recovered. The period of time for recovery is subject to audit and agreement. If an outage lasts longer than 3 months, analysis of the cause of the problem would be required in order to satisfy the regulating authority of the legitimacy of the outage).*

The UKWIR (1995) methodology notes that outages may occur from either planned or unplanned events.

Unplanned outages are caused by an unforeseen or unavoidable events affecting any part of the source works and occurring with sufficient regularity that the probability of occurrence and severity of effect may be predicted from previous events or perceived risk. The methodology provides a definitive list of events that could be considered as unplanned outages:

- Pollution of sources;
- Turbidity;
- Nitrates;
- Algae;
- Power failures; and
- System failures.

Planned outages arise from maintenance, inspection, refurbishment, and repair of source works. These outage events would not generally be considered where the loss of deployable output (DO) resulting from such regular maintenance issues was already taken into account in the calculation of DO for the source works in question. The company would not generally undertake major planned maintenance during periods or prolonged dry weather when reservoir storage has been drawn down and rivers are experiencing low flows.

B.2 Outage assessment

B.2.1 Data gathering

In the previous Water Resource Strategy (WRS 2002), the assessment of outage was based on discussions with each of the four Water Service Divisions in existence at the time, but no historic outage data was available. A nominal outage allowance of 3% of distribution input was assumed. It is understood that this was an allowance for unplanned outage only. No comment was made regarding planned outages, and no data have been made available to calculate this since the Draft WRMP. Recommendations for the improvement of the routine collection of outage data are included in B.3.1.

Unplanned outage would normally be assessed using both observed outage from historical data and expected outage based upon interviews. Ideally there would be sufficient historical data to allow calculated outage values to be simply checked by operations staff to ensure that they were still consistent with the present state and expected future state of the source works.

For the Draft WRMP a meeting was held with key NI Water staff to try to develop an understanding of outage, identify sources most at risk from specific outage events, and where possible to quantify these risks in terms of frequency, magnitude and duration of event. In an effort to provide a robust update to the estimation of outage for this WRMP, Atkins developed a pro forma to capture outage events. The staff interviewed were:

- Charles Gallagher – Head of Water Supply; and
- Gordon Nicholl – Business Unit Manager for Water Supply.

During this meeting each source works was assessed in terms of risk of unplanned and planned outage events. The results are included in Table B.2 in section B.4. This summary represents relative risk at each source works. The key points to note from the meeting were:

- Production capacity estimates are based on the “20 hours rule” – i.e. if the works is shut for 4 hours, it can be run at a higher rate for 20 hours to catch up any lost capacity. As a result, <u>planned outages are assumed to be zero</u>;
- The supply system is, out of necessity, run with minimal outage as there is insufficient security in the system. So any outage event must be dealt with immediately. Therefore, even if data/information of historic outage events is available, the level of <u>overall unplanned outage would be expected to be low</u>;
- All sources have back-up power generators, so there are no “power failure” outage events;
- It was not possible to derive more detailed quantification of outage events than the relative risk assessment included in Table B.2 in section B.4. Therefore, <u>no estimates of frequency, duration or magnitude of outage events were made</u>; and
- Water treatment works production capacity (July 2009) figures are based on estimates of safe yield (WRS 2002), plus allowances for safety factors. The safety factors make some allowance for uncertainty, outage, etc. However the NI Water staff noted that it was not possible to disaggregate and separate out each component making up the general safety factor.

This means that there is little historical outage data available to support an assessment of outage. The only data available was from Upwards Reports, which detail issues at WTWs. These were available from July 2008 to November 2009. They were assessed as the primary means to gather information on historical outage events.

The Upwards Reports data has been collated and entered into the outage pro forma for each source works. The results suggest that over a period of approximately 17 months, there was a total of nearly 17 days of outage events at the source works, as summarised in Table B.1 below.

Source works	Total outage duration days (Jul 2008 – Nov 2009)	Approximate outage (days/year)
Carmoney	2.8	2.0
Moyola	8.0	5.6
Clay Lake	0.2	0.1
Dunore	0.5	0.4
Derg	0.5	0.4
Castor Bay	0.5	0.4
Camlough	1.2	0.8
Killyhevlin	0.1	0.1
Altnahinch	1.2	0.8
Lough Macrory	1.1	0.8
Dorisland	0.2	0.1
Foffany	0.2	0.1
Seagahan	0.2	0.1
Total days outage	16.7	11.8

Table B.1 – Summary of Upwards Report unplanned outage events, Jul 2008 to Nov 2009

However whilst the Upwards Report data provides an indication of outage events experienced over approximately 17 months, they provide no indication of the magnitude of the impact.

B.2.2 Planned outages

No data was available regarding planned maintenance, inspection, refurbishment, and repair of source works. However, planned outages were discussed at the outage meeting with NI Water staff. They stated that the production capacity estimates are based on the “20 hours rule” – i.e. if the works is shut for 4 hours, it can be run at a higher rate for 20 hours to catch up any lost capacity. Thus, planned outages are already considered in the WTW capacity estimates. If an allowance for planned outages were to be included this would result in double counting. Therefore planned outage is assumed to be zero.

B.2.3 Unplanned outages

Due to the lack of suitable historic data, and the difficulties of operations staff in quantifying potential outage risks through interviews, the assessment again has to be based on expert judgement. However, recommendations for improved data collection for the future assessment of outage events have been made.

PPP source works are assumed to act effectively like bulk imports, as these are contracted amounts of water. Therefore, no allowance has been made for potential outages at these source works.

B.3 Conclusions

An attempt to collect relevant outage data was made through interviews with key operational staff aided by a pro forms developed to capture information and judgements in a robust and auditable manner. Potential data capturing historical outage events was also investigated, of which the only relevant available source were the Upwards Reports, but these were only available since July 2008, and did not capture information on magnitudes of impact.

Due to the lack of suitable historic data, and the difficulties of operations staff in quantifying potential outage risks through interviews, the assessment has again been based on expert judgement. However, approaches for improved data collection for future assessment of outage events have been considered.

The operations staff interviewed stated that the supply system is run with minimal outage because there is insufficient security in the system. So any outage event must out of necessity be dealt with immediately. Therefore, they felt that overall unplanned outage would be expected to be low – in the region of 1–2%. Planned outages are already allowed for within WTW capacity estimates, so no additional allowance for these has been made.

The outage allowance used for this Draft WRMP has therefore been based on expert judgement and has been set as 2% of deployable output. Benchmark comparisons with other parts of the UK suggest that this is relatively low but it is felt to be a reasonable estimate for the ranges of sources available to NI Water and the characteristics of the distribution system. The total deployable output of NI Water sources (i.e. excluding PPP schemes) is approximately 378 Ml/d (section A.1). Thus the assumed 2% allowance for outage equates to approximately 7.54 Ml/d.

B.3.1 Recommendations

In order to increase confidence in the estimates of outage for future planning purposes, and given the difficulties operational staff had in trying to quantify potential outage events, consideration should be given to the development of a data collection system.

Currently, the outage allowance is relatively low, although the value is felt to represent the conditions experienced in Northern Ireland – i.e. operations staff must currently ensure that outages are minimised and any events resolved in a short period of time, as there is insufficient security and resilience within the supply system. However, as steps are taken to improve the resilience of the system, the issue of outage may become more critical to the planning process. Therefore it will be necessary to base future outage allowances on reliable data sets.

Improved data collection will also facilitate a move towards a probabilistic determination of outage, so that an allowance may be chosen at which the company understands the risk that it may be exceeded in any given year. For instance, if the outage value is taken from the 95^{th} percentile of cumulative probability, then there would be a 5% chance that the level of outage that actually occurs would be greater than this value.

Data capture systems

A data capture system could follow the template currently used in the Upwards Reports (an example of which is below), but perhaps with a section to estimate the magnitude of the impact in Ml/d terms, as well as the duration. For ease with outage assessment, events could also be classified under one of the definitive categories of unplanned outages.

Standard Upwards Report

Event type/classification:	*Carmoney Water Treatment Works*	**Report N°.:** *1*
Event category:	*2*	
Basis for categorisation;	*Received a telephone call form NIEA to inform plant staff that there was white foam covering over the full width of the River Faughan intake at Cloghole road. This is a possible detergent used for the oil spill clean up from last week on the river. Oil pollution in River Faughan last week resulted in plant shutdown of Faughan PS and Carmoney WTW for 36 hours. May give rise to local public or media interest.*	
Name of Reporter:	*Shaun Kelly*	
Date and time of Event:	*15/11/009*	*14.00*
Report Date and time:	*15/11/09*	*16.30*
Functional Area:	*Water Supply & Networks*	
Site Name/Location:	*Carmoney WTW, Londonderry*	
Asset Name:	*Faughan PS & Carmoney WTW*	

Event Details:

- *Plant operational staff were informed of white foam in the river by at approx. 14.00 hrs and as a precaution shut down the pumping station and treatment works immediately.*
- *NIEA staff to check river for source of pollution including site where oil pollution occurred last week.*
- *Water Supply on site to establish extent of pollution. Carried out manual checks for Ammonia, phosphates & taste & odour tests through out the treatment plant & nothing was detected*
- *White foam is clearly visible in the river below the Weir gates where the water is turbulent.*
- *Water Supply staff currently investigating whether any pollution has got into the works but no visible signs of foam anywhere in the works.*
- *A boom has been installed at the works intake to deflect river flow away from the works.*
- *Monitoring of the river intake ongoing.*
- *Current storage level at Carmoney sufficient for24-30 hour's min. Rezoning not required at this time*
- *NIEA have contacted ENVA who were used to clean up the oil spill last week to check if any detergent was used in the clean up. ENVA were adamant that no detergent was used by them.*
- *Scientific staff will be on site shortly to conduct checks in the Raw Water and through out the works.*
- *Plant will remain shutdown while further analysis of the river and plant takes place.*

Population Affected including potential:	*No customers are affected at present.* *WTW currently produces about 25 ML/day to about 100,000 population.*

Action Taken:

- *Supply and scientific staff on site to ascertain extent of problem*
- *Approximately 24 -30 hours storage in the system.*
- *Telemetry & Networks have been informed of the problems*

Estimated time of restoration:	*As a precaution Treatment works has been shut down. Hopefully plant will be started up at 08:00hrs tomorrow with the guidance of scientific section*
Information passed to the following:	*A Law, B McKee, C Gallagher, M Wright, M Mailey, G McKeague, G Murphy, D Devaney*
Line to take:	• *NI Water is monitoring the situation and will take all necessary action to protect and maintain supplies to customers.* • *Final water quality is not affected.*

Figure B.1 – Example of current Upwards Report

An alternative, although similar system, could make use of the pro forma already developed as part of this assessment. For any legitimate outage event, the pro forma could be completed and issued to a designated member of staff responsible for data collection, and then entered into a data base to allow easy access to the data in future assessments.

Sourceworks:		**Date of Review:**	26/11/2009				
Source type:	**Water Treatment Works**	**NIW Staff:**					
		Atkins Staff:					
UNPLANNED OUTAGE							
Event Group	**Outage Event**	**Data available (identify source)**	**Estimated return period (years)**	**Duration (days)**	**Outage (days/year)**	**Proportion (%) of treatment affected**	**Comments**
Pollution of Source	Contamination risk						
	Accidental spills						
	Pollution of nearby river						
	Algae						
	Cryptosporidium/Giardia						
	Nitrates / agriculture (e.g. pesticides)						
	Turbidity - operational / air						
	Turbidity - rain induced						
Power failure	Loss of Supply - rural & no generator						
	Loss of Supply - urban						
System failure	Flooding - fluvial						
	Flooding - drainage						
	Flooding - pipe burst						
	Control Failure (e.g. telemetry)						
	Disinfection problems (incl UV failure)						
	Ortho-Phosphate control problems						
	Pump failure (including multiple failures)						
	Age related (general M&E/ICA)						
	New process (microfiltration etc)						
	Complex process (iron removal etc)						
	Burst main (raw water transfer to WTW)						
	Catastrophic failure (e.g. fire)						
	Operator Error						
	Other works failures						
		Total days outage experienced		0.0			
PLANNED OUTAGE							
Event Group	**Outage Event**	**Data available (name source)**	**Estimated return period (years)**	**Duration (days)**	**Outage (days/year)**	**Proportion (%) of treatment affected**	**Comments**
Planned	Inspections						
	Maintenance						
	Repair						
	Refurbishment						

Figure B.2 – Example of outage pro forma

Another approach could be to conduct regular analysis of water into supply data from each source works. This could be done, for example, on a monthly basis. Occurrences of significant decreases of water into supply could be followed up with the operations manager to understand the reason for the variation, and determine if it is due to a legitimate outage event or not. If so, the approximate magnitude could be determined from the data. At the time of inquiry with the operations manager, the approximate duration of the outage event could also be assessed. Note that not all reductions in output would be due to outage events, and it may also be possible to maintain supply through increased output from alternative sources or storage (and then catch up to replace “lost” storage from covering the outage event).

B.4 Outage records

B.4.1 Unplanned outage risks

Add a tick (✓) to the top-left section of box to indicate if the type of outage has been experienced historically. Add a tick in the bottom-right (using spaces to align) to indicate if data might be available. An example is here:	✓ / ✓

Production Source	Head WTWs	Unplanned Outage						
		Source pollution	Turbidity	Nitrates	Algae	Power failures	System failures	Comments
Altnahinch Impounding Reservoir	Altnahinch	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	medium risk system failure
Lough Erne	Belleek	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Camlough Lough	Camlough	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
River Faughan	Carmoney	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	High risk system failure surrently, but upgrade now underway
Lough Ross	Carran Hill	× / ×	× / ×	× / ×	✓ / ×	× / ×	✓ / ×	Low risk system failure
Altnaheglish Impounding Reservoir	Caugh Hill	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Glenedera River	Caugh Hill	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure. Low risk source pollution
Clay Lake Impounding Reservoir	Clay Lake	× / ×	× / ×	× / ×	✓ / ×	× / ×	✓ / ×	medium risk system failure (due to membrane plant)
River Derg	Derg (Tievenny)	✓ / ×	× / ×	× / ×	× / ×	× / ×	× / ×	
Woodburn Combined Impounding Reservoirs	Dorisland	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure

Production Source	Head WTWs	Unplanned Outage						
		Source pollution	Turbidity	Nitrates	Algae	Power failures	System failures	Comments
Silent Valley/Ben Crom Impounding Reservoirs River Annalong	Drumaroad	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Dungonnell Impounding Reservoir	Dungonnell	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Fofanny/Spelga Impounding Reservoirs	Fofanny	× / ×	× / ×	× / ×	× / ×	× / ×	× / ×	
Lough island Reavy	Fofanny	× / ×	× / ×	× / ×	× / ×	× / ×	× / ×	
Glenhordial Impounding Reservoir	Glenhordial	× / ×	✓ / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure. Low risk turbidity
Lough Erne	Killyhevlin	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	medium risk system failure (due to process issues)
Killylane Impounding Reservoir	Killylane	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	medium risk system failure. Low risk source pollution
Lough Bradan Impounding Reservoir	Lough Bradan	× / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	High risk system failure surrently, but scheme is in capital programme
Lough Fea Impounding Reservoir	Lough Fea	✓ / ×	× / ×	× / ×	× / ×	× / ×	✓ / ×	Low risk system failure
Lough Macrory/Lough Fingrean Impounding Reservoirs	Lough Macrory	× / ×	× / ×	× / ×	× / ×	× / ×	× / ×	
Seagahan Impounding Reservoir	Seagahan	× / ×	× / ×	× / ×	✓ / ×	× / ×	× / ×	No system failure risk subject to successful comissioning. Low risk of algae
Ballinrees & Altikeeragh Impounding Reservoirs Rivers Bann and Ballyhacket	Ballinrees							PPP
Lough Neagh	Castor Bay							PPP
Lough Neagh	Dunore Point							PPP
Stoneyford and Leathemstown Impounding Reservoirs	Forked Bridge							PPP
Lough Neagh	Moyola							PPP

Table B.2 – Summary of unplanned outage risks at each source works

Appendix C – Demand forecast

C.1 Planning scenarios

The WRP Guideline (WRPG) requires water companies to consider their supply demand balances under different planning scenarios. For each planning scenario a baseline forecast is produced, and where there are supply demand balance deficits identified, a final planning forecast must also be produced to demonstrate the options required to overcome the deficit.

The primary planning scenario is the dry year annual average scenario, which is defined by a period of low rainfall and unconstrained demand. This forms the basis of the Water Resources Management Plan (WRMP), because the overall objective of the WRMP is to ensure that even under drought conditions, when supplies may be stressed, the level of demands associated with hot dry conditions can be met in full. All water companies are expected to derive this dry year scenario in their WRMP.

The dry year demand forecast is developed from normal year annual average data – i.e. base year data that has been normalised to represent demands under average climatic conditions. Some companies might also need to derive critical period scenarios, where their supply demand balance is sensitive to these because there are sustained periods when demands are significantly higher than average; this is a peak demand condition. Supply-side characteristics may also influence whether or not critical period analysis is required.

Generally, dry year and peak factors are derived from historic information on consumption and water into supply. Climatic data can be used to help identify historic dry years or hot dry summers, so that the demands that were experienced in those periods can be identified and used in the assessment of dry year/critical period peaking factors.

Although there is daily DI data available for the base year (2008-09), it should be noted that there is less confidence in the historic DI data, which is anyway only available back to 2006–07. Annual Information Return (AIR) data, providing annual average inputs is available back to 2002–03. Overall, the lack of historic data significantly constrains the approach to assessing dry year and peak period demands.

This section sets out a discussion on the planning scenarios that have been considered for the WRMP analysis.

C.1.1 Planning scenarios analysis

Distribution input data

Daily distribution input (DI) data was available for the base year and two years prior to it (i.e. 2006–07, 2007–08, and 2008–09). This was analysed and presented in the Draft WRMP to investigate the critical demand periods, and magnitude of peaks compared to the annual average for each given year. This is shown in Figure C.1 to Figure C.3. Each figure shows daily DI (in Ml/d), the rolling 7 and 30 day averages, and the annual average for each given year for the whole of Northern Ireland.

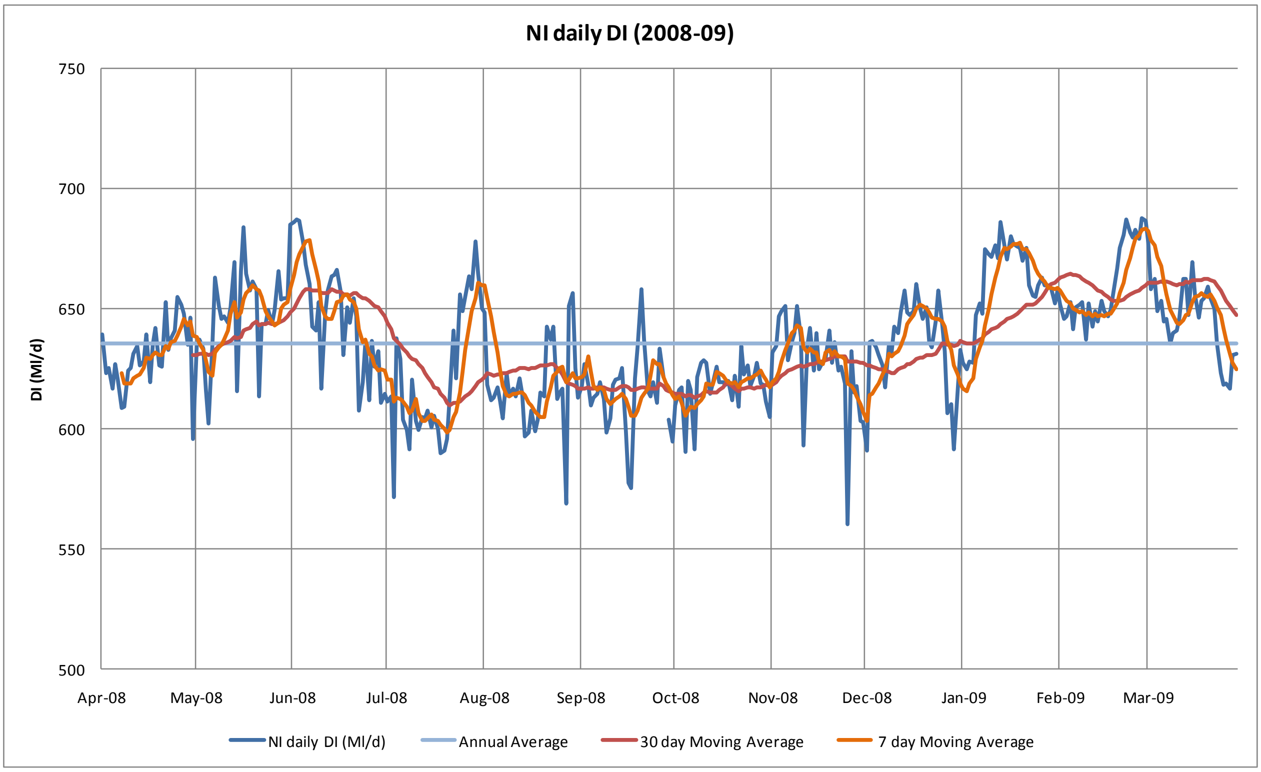


Figure C.1 – DI analysis for Northern Ireland in 2008–09

The summer months, June to August, in 2008–09 barely show any peak in demand, except for a small one towards the end of July. In fact, most daily DI in July and August actually lies below the annual average for the year. This is unusual, as demand would normally be expected to occur during the summer months due to additional water use in hotter/dryer conditions. The peak week (684 Ml/d) actually occurs in February/March 2009, although this is probably driven by leakage events rather than actual customer demand. The next highest peak week (679 Ml/d) occurs in early June 2008.

The annual average for the year was 635 Ml/d, so the peak week to annual average factor is 1.07.

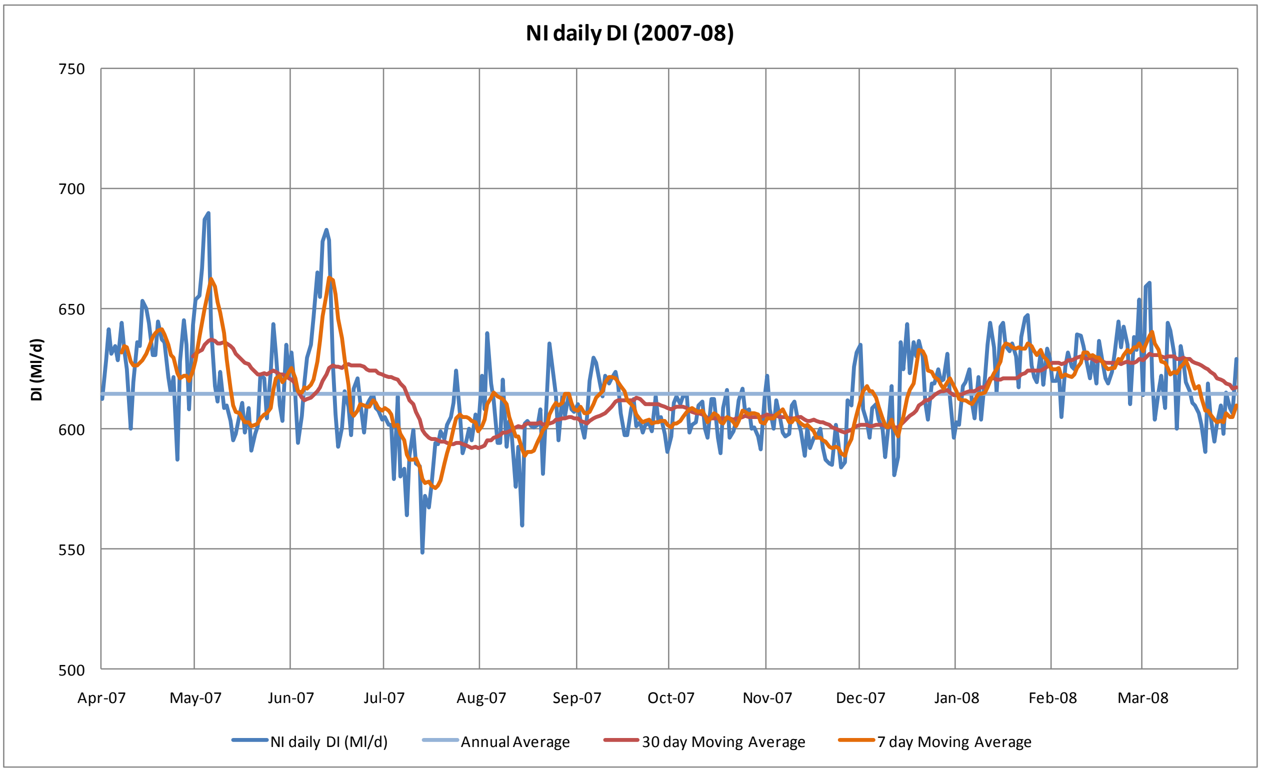


Figure C.2 – DI analysis for Northern Ireland in 2007–08

The DI plot for 2007–08 is similar to 2008–09, although it is more pronounced in that there is no peak observed in July and August whatsoever, and demands in this period generally lie below the annual average for the year. The peak week occurs in mid-June, where a value of 663 Ml/d occurs, and in early May (also 663 Ml/d). The pattern is similar to 2008–09, in that DI is relatively high over the winter period (January to March), probably as a result of leakage events.

The annual average for the year was 614 Ml/d, so the peak week to annual average factor is 1.08.

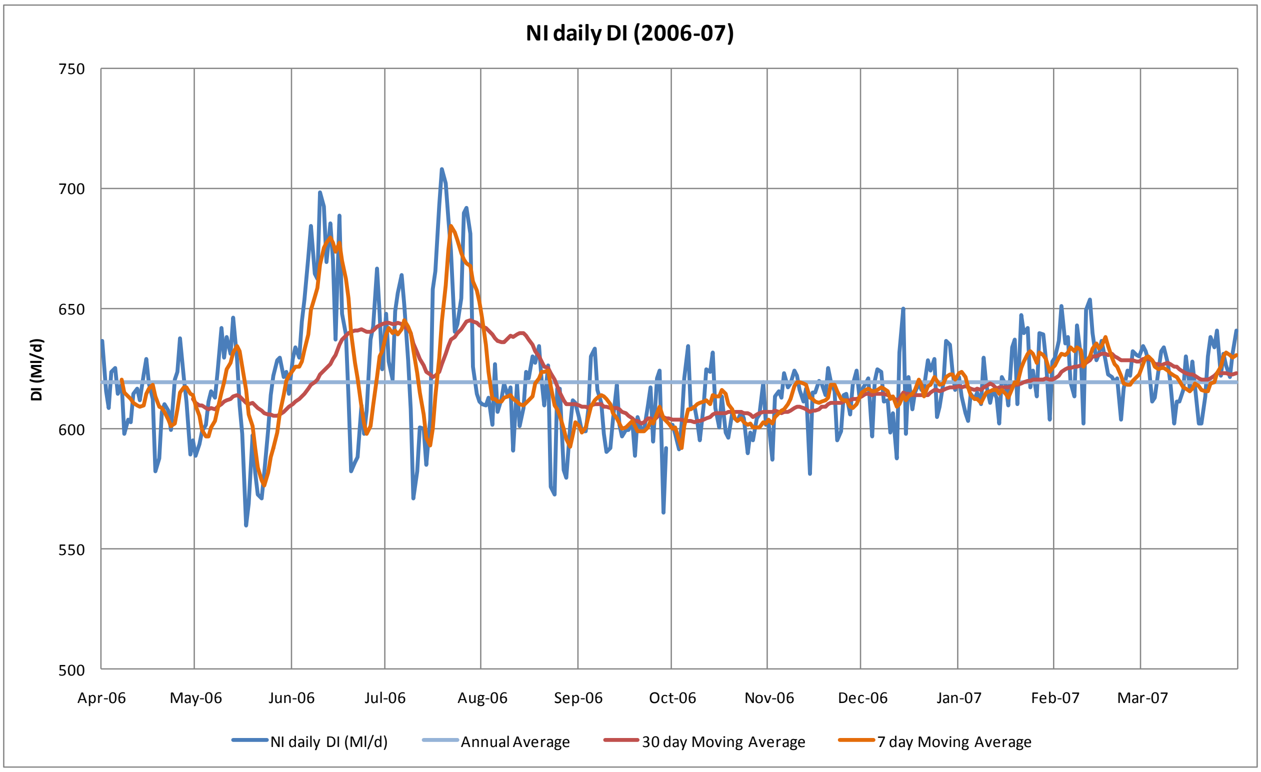


Figure C.3 – DI analysis for Northern Ireland in 2006–07

The DI plot for 2006–07 demonstrates a profile that is generally more like what would be expected for typical demand through the year. The peak week occurs in the latter half of July 2006, with a value of 684 Ml/d. There is also a significant peak in early to mid-June (680 Ml/d).

The annual average for the year was 619 Ml/d, so the peak week to annual average factor is 1.10.

The key DI data for Northern Ireland in the period 2006–07 to 2008–09 are summarised in Table C.1.

Year	Annual average DI (Ml/d)	Ave Day Peak Week DI (Summer only) (Ml/d)	Peak factor
2006–07	619.3	684.2	1.10
2007–08	614.4	662.9	1.08
2008–09	635.3	678.8	1.07

Table C.1 – Summary of Northern Ireland DI for 2006–07 to 2008–09

Figure C.4 shows the rolling weekly and monthly average DI for NI for all three years, from April 2006 to March 2009. Whilst the maximum average day peak week value seen in NI over 2006 to 2009 was 684 Ml/d in the middle of July 2006, other notable peak weeks were:

- Mid-June 2006 – 680 Ml/d;
- Early June 2008 – 679 Ml/d;
- January 2009 – 677 Ml/d (although probably driven by leakage); and
- End-February 2009 – 684 Ml/d (also probably driven by leakage).

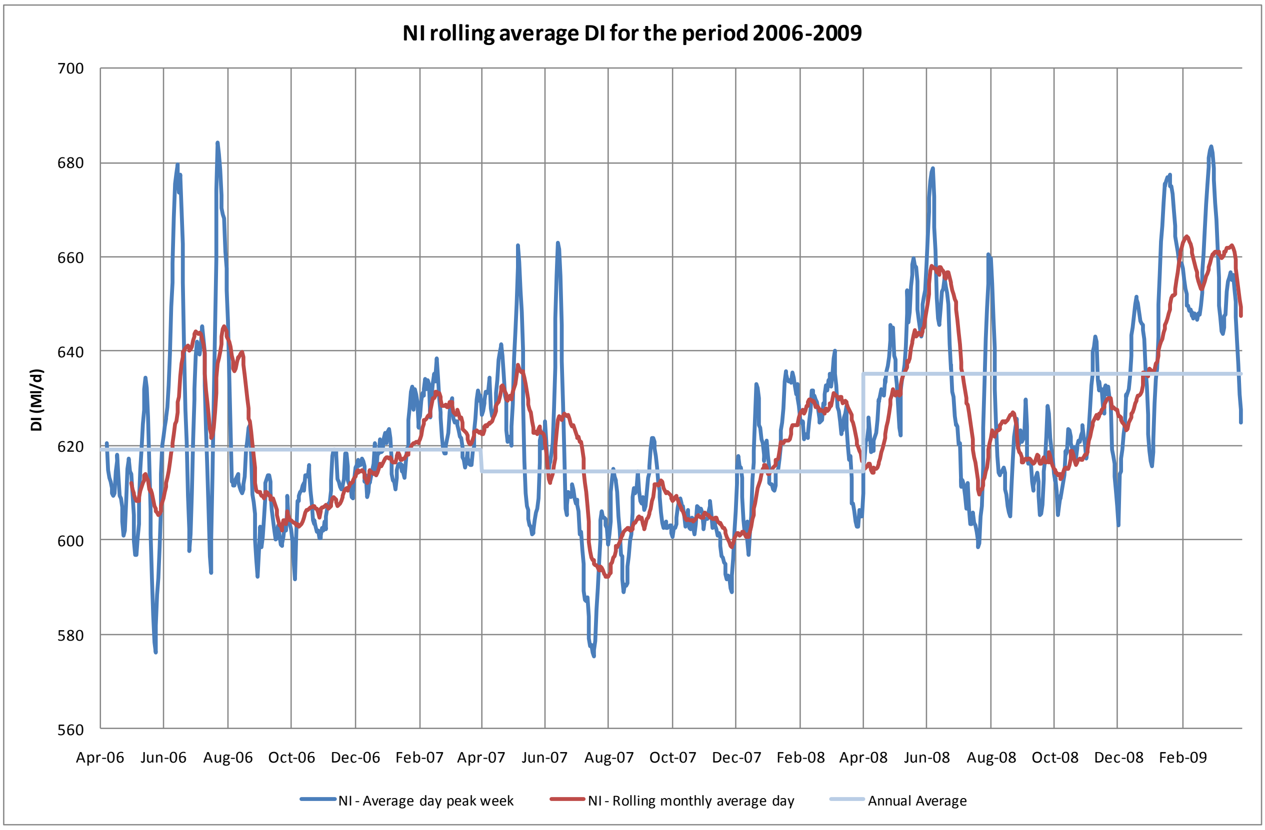


Figure C.4 – Rolling average DI (weekly and monthly) for NI, 2006 to 2009

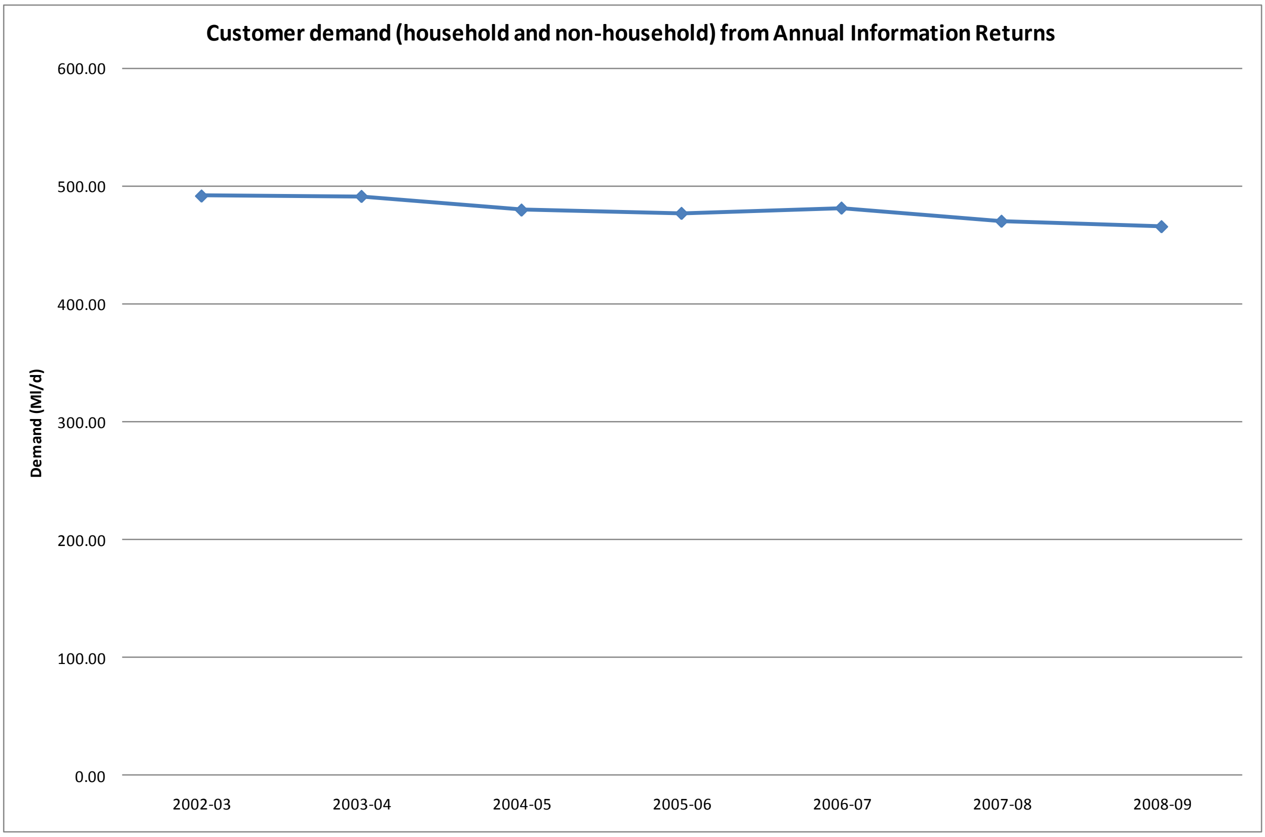


Figure C.5 – AIR data for total measured consumption (2002–03 to 2008–09)

Figure C.5 implies that total customer demand (households and non-households) from the Annual Information Returns are reasonably consistent from year to year; although there is a slight downward trend through time.

The DI was also normalised for each WRZ, by dividing the daily DI by the annual average DI for that year. This allows comparison between the different WRZs over the period 2006 to 2009.

In order to see patterns more clearly, a rolling monthly average of the daily normalised DI was developed for each WRZ, to allow comparison in terms of demand profile, and timing and magnitude of peaks. This is shown in Figure C.6. The plot shows that, over the period from April 2006 to March 2009, there is little difference between WRZs in the general demand profile. There is also no clear trend of one WRZ showing significantly higher normalised DI response to peaks than other WRZs, nor in the timing of peak demands.

The figure demonstrates that a summer peak was observed in all WRZs in July/August 2006, although this was no greater than 10% over the annual average DI. It also clearly demonstrates the lack of a summer peak in 2007 and 2008, with the exception of the North WRZ in May–June 2008. The largest average day peak month observed compared to the annual average DI occurs in March 2009, in the East WRZ – a maximum peak value of 1.15 – but this was probably driven by winter leakage events rather than customer demand.

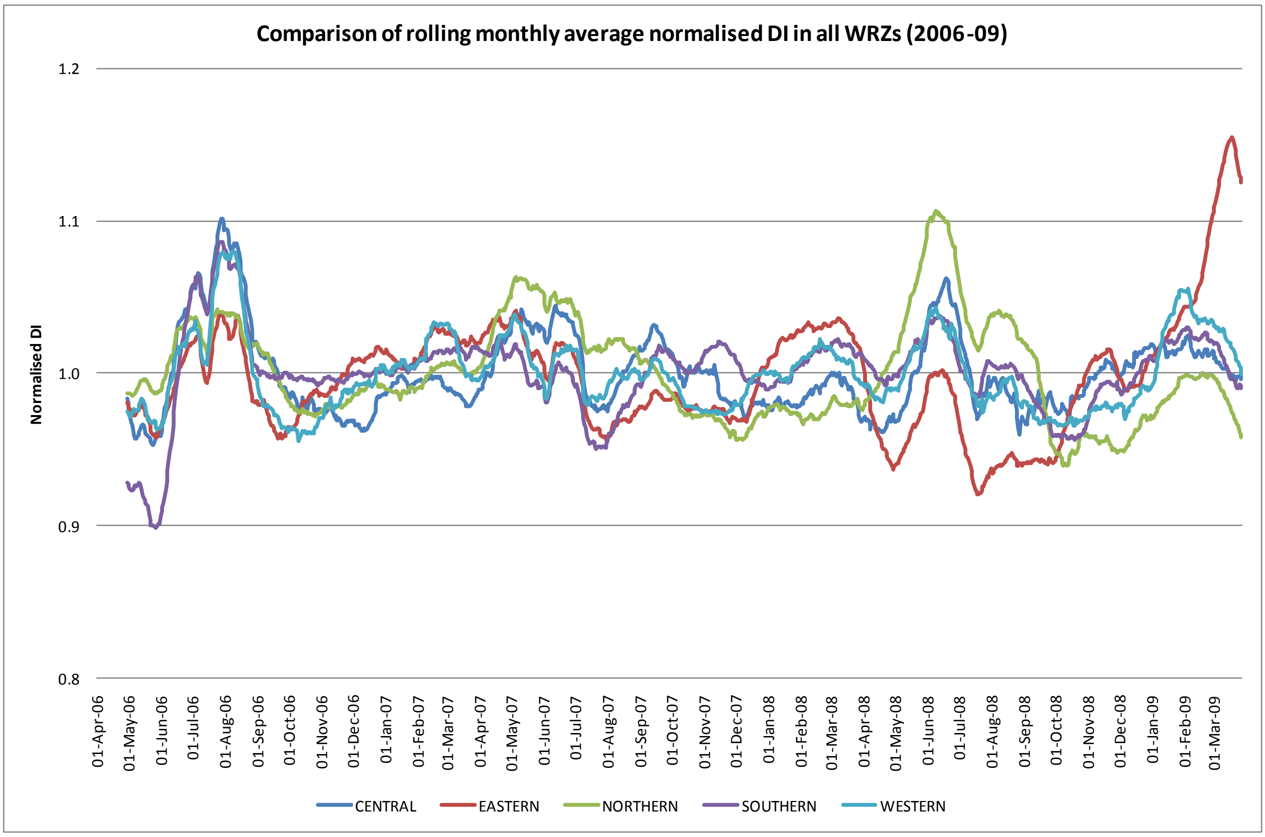


Figure C.6 – Comparison of rolling monthly average day normalised DI in each WRZ (2006–09)

The rolling weekly average values, presented in Figure C.7, suggest maximum peak week factors occurred in July 2006, as follows:

- Central WRZ – factor of 1.17;

- East WRZ – factor of 1.11;
- North WRZ – factor of 1.11;
- South WRZ – factor of 1.15; and
- West WRZ – factor of 1.18.

The exception is the North WRZ, where the maximum peak week factor actually occurred in May/June 2008, with a factor of 1.14. Note also that the highest peak week factor in the East WRZ was 1.18, but this occurred in early March 2008 (following high factors through February), so was probably due to leakage events.

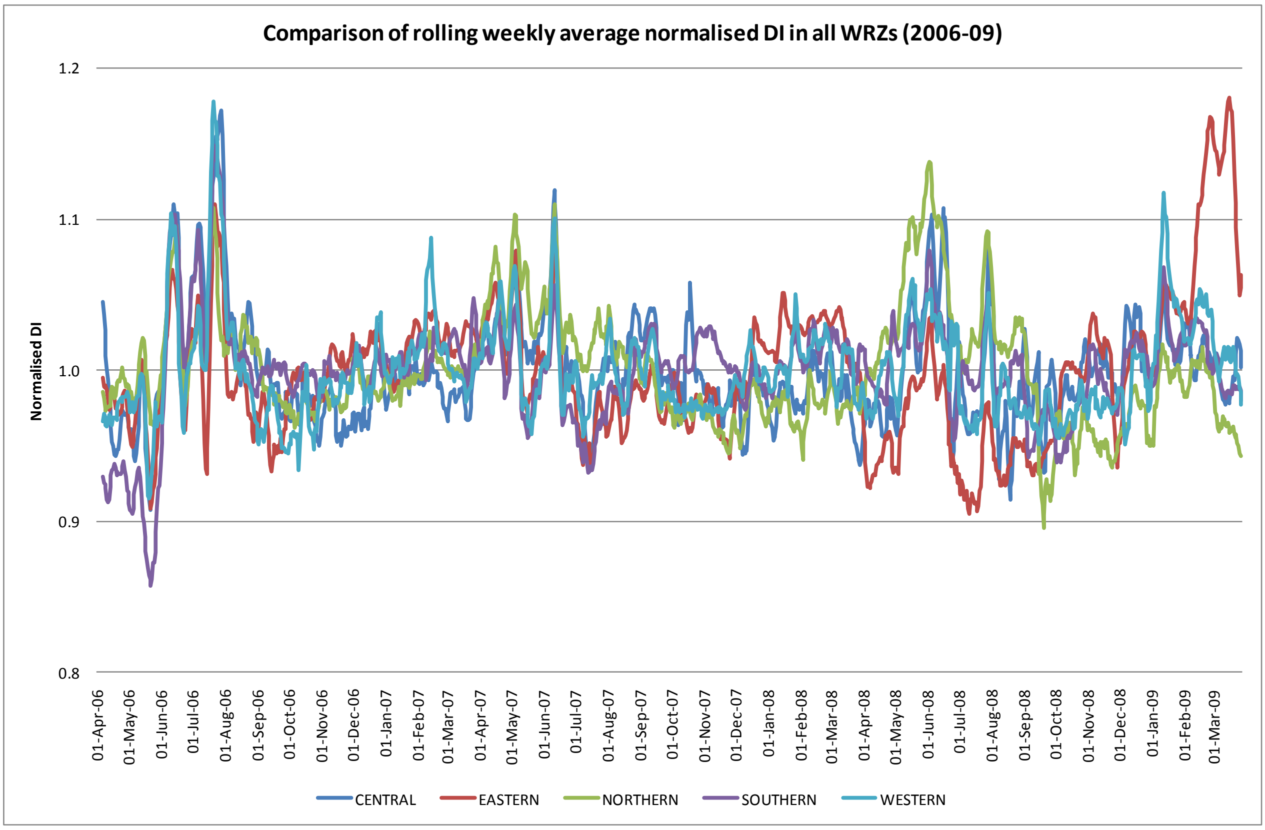


Figure C.7 – Comparison of rolling weekly average day normalised DI in each WRZ (2006–09)

Climate data

Rainfall and temperature can have a strong influence on customer demand, particularly domestic. During the summer months rainfall reduces customer demands from outside activities. Conversely, drought conditions accompanied by sustained periods of high temperature can lead to rapid increases in demand.

Data from the Met Office website for the Armagh weather station was used to conduct climate analysis of the last 20 years, in comparison to Long Term Averages (1961–1990 and 1971–2000).

Figure C.8 shows average temperature and total rainfall over the extended "summer" months of April to September, a period over which climate is generally considered to influence customer demand. Figure C.9 shows the average temperature and total rainfall over the year (note that this is the financial year, to correspond with AIR data).

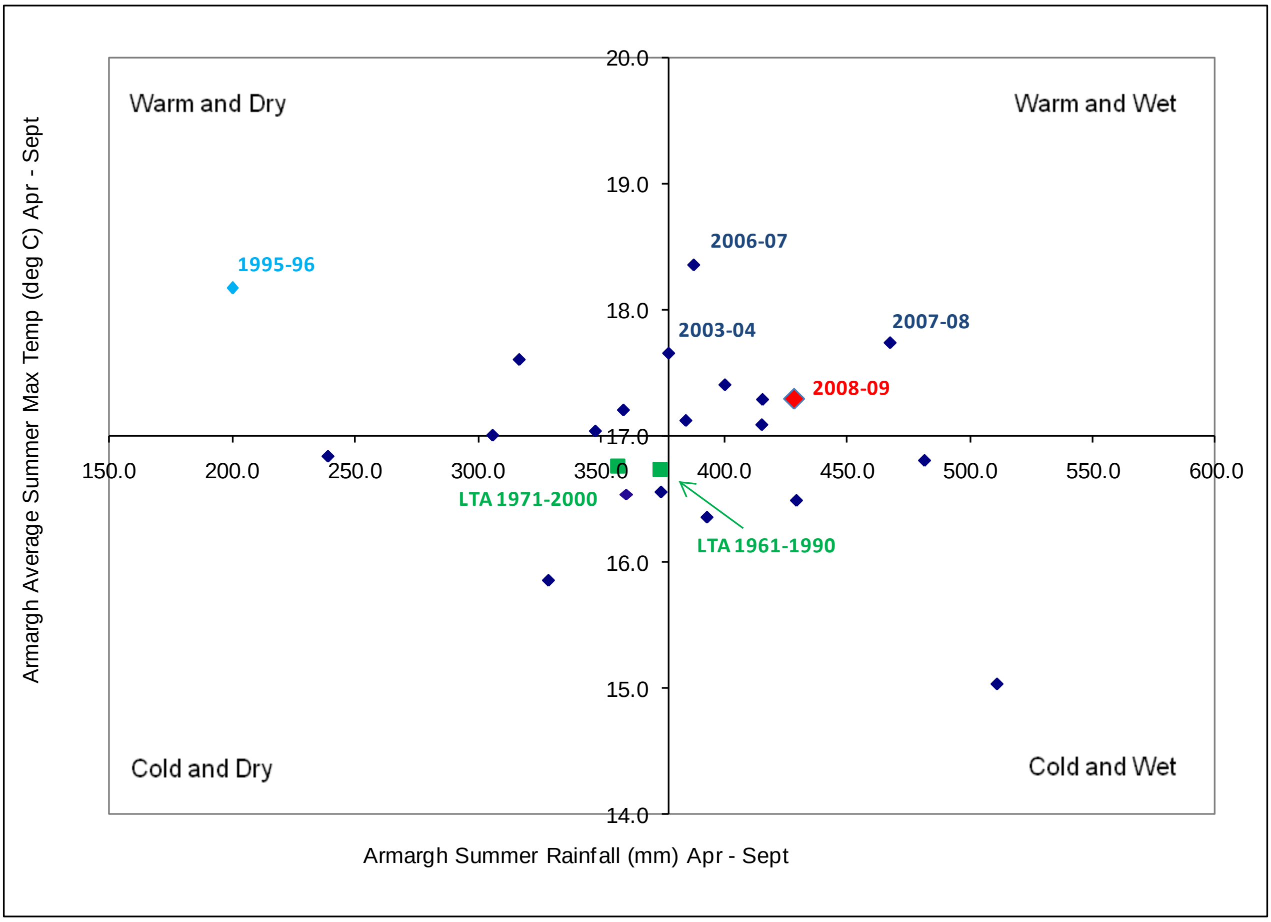


Figure C.8 – Average temperature and total rainfall in summer months (Apr–Sep), 1988–89 to 2008–09

The summer of 1995 was clearly very dry, and also warmer than most other years. To define a dry year, it would thus be useful to have demand data for this year. However, no such detailed data is available.

The summer of 2006 was warm on average, although fairly typical in terms of rainfall. However, given that data is only readily available for the last three years, it may be reasonable to use this as an example of a dry summer, and so potentially a time when one might expect to see peak periods of demand. This is clear when looking at average day peak week normalised DI in each WRZ (Figure C.7). The 2007 summer was very wet, and so despite being reasonably warm, peak demand would not generally be expected to be very large due to less need for outdoor watering by customers.

The “long summer” of 2008 was unexceptional in terms of the average temperature experienced, but was slightly wetter than usual.

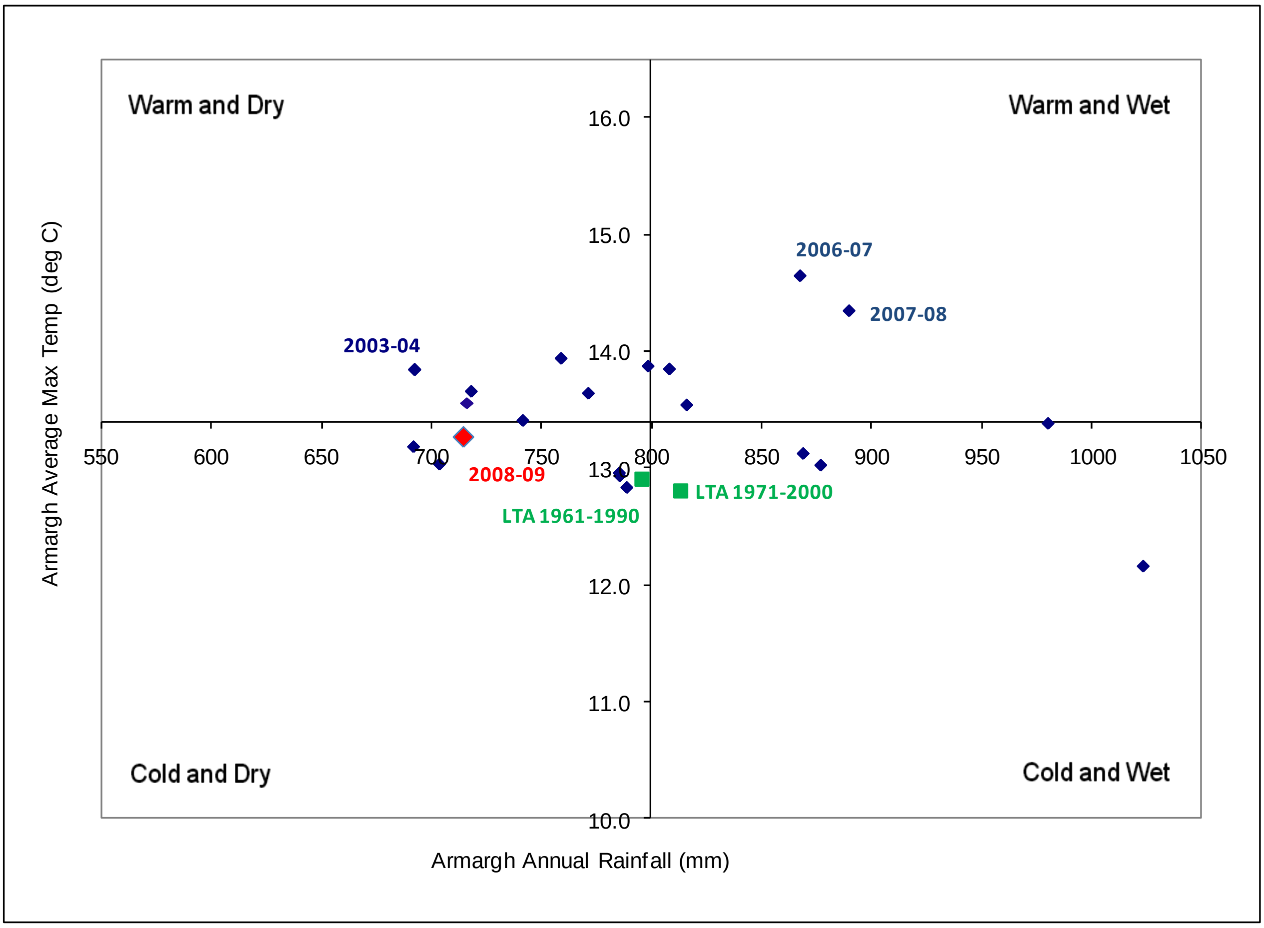


Figure C.9 – Annual average temperature and total rainfall over the year, 1988–89 to 2008–09

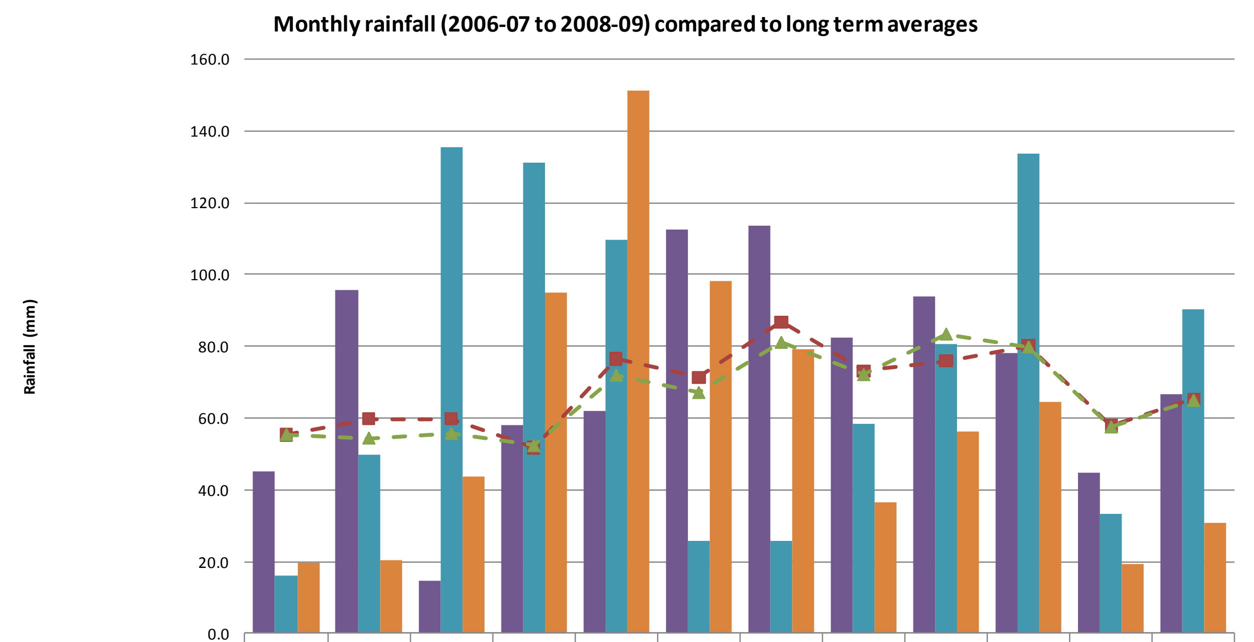
The scatter plot presented in Figure C.9 suggests that the total rainfall over the year 2008–09 was lower than usual, though the average temperature was fairly typical. This compares to both 2006–07 and 2007–08 which were both warm and wet years. Both had relatively low annual average DI values, suggesting that the wet weather on average over the year resulted in reduced DI.

It is also interesting to note that most of the last 20 years have been warmer than the LTAs.

The three years for which DI data are available (2006–07, 2007–08, and 2008–09) were plotted against the long term average (LTA) for both monthly rainfall and monthly average maximum temperature, as shown in Figure C.10 and Figure C.11 respectively.

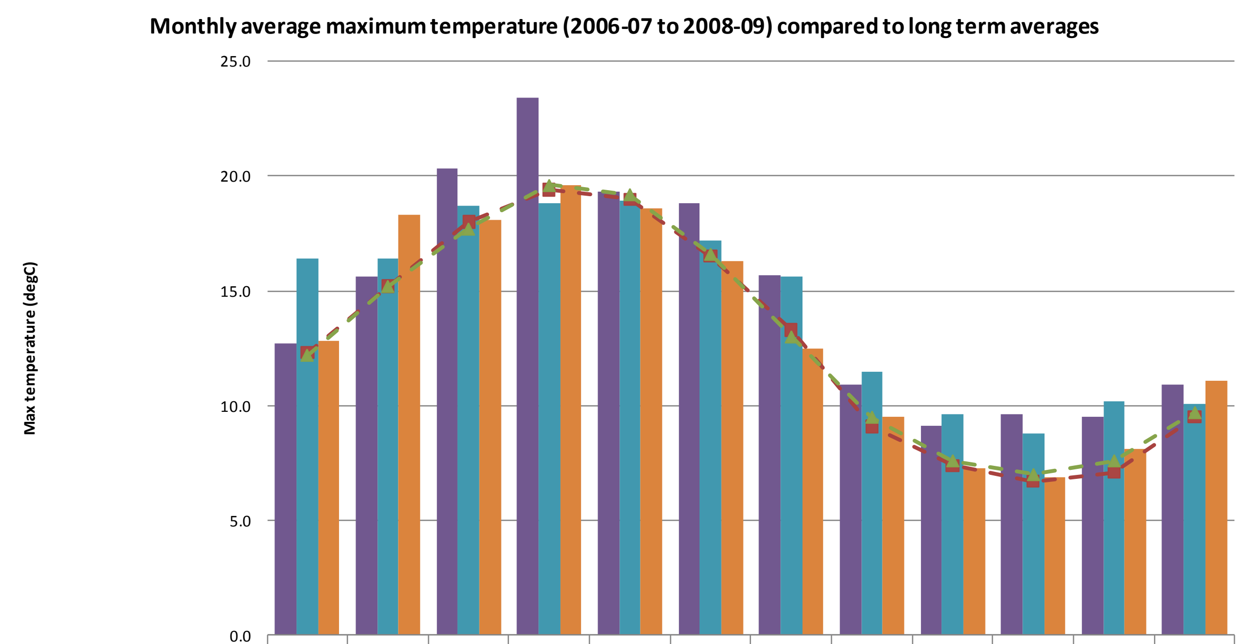
Figure C.10 demonstrates the very wet summer (June–August) experienced in 2007–08, and in 2008–09 (in July and August). What is also apparent is that rainfall in spring 2008 and winter 2008–09 was lower than the LTA.

Figure C.11 demonstrates that temperature in all three years largely followed the LTA monthly profiles, particularly 2008–09 which matches the LTA lines very closely. 2006–07 and, to a lesser extent, 2007–08 were generally slightly warmer than the monthly LTA profile.



	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
2006-07 Rainfall	45.2	95.7	14.6	57.9	62.1	112.4	113.7	82.4	93.8	78.2	44.7	66.8
2007-08 Rainfall	16.1	49.8	135.3	131.0	109.8	25.8	25.8	58.5	80.6	133.5	33.4	90.2
2008-09 Rainfall	19.8	20.4	43.8	94.9	151.2	98.2	79.0	36.6	56.2	64.4	19.2	30.9
LTA 1961-1990 Rainfall	55.3	59.8	59.7	51.7	76.5	71.3	86.8	73.2	75.9	80.2	57.8	65.2
LTA 1971-2000 Rainfall	55.4	54.4	55.7	52.3	71.9	67.1	81.1	72.1	83.4	79.8	57.5	64.9

Figure C.10 – Monthly rainfall compared to long term averages



	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
2006-07 Ave Max Temp	12.7	15.6	20.3	23.4	19.3	18.8	15.7	10.9	9.1	9.6	9.5	10.9
2007-08 Ave Max Temp	16.4	16.4	18.7	18.8	18.9	17.2	15.6	11.5	9.6	8.8	10.2	10.1
2008-09 Ave Max Temp	12.8	18.3	18.1	19.6	18.6	16.3	12.5	9.5	7.3	6.9	8.1	11.1
LTA 1961-1990 Max Temp	12.3	15.2	18.0	19.4	19.0	16.5	13.3	9.1	7.4	6.7	7.1	9.5
LTA 1971-2000 Max Temp	12.2	15.2	17.7	19.6	19.2	16.6	13.0	9.5	7.6	7.0	7.6	9.7

Figure C.11 – Monthly average maximum temperature compared to long term averages

C.1.2 Conclusions: planning scenarios for WRMP

Normal year

The base year 2008–09 appears to have had a summer in which there was little peak demand for water. However, daily DI data is only available for the last 3 years, so it is difficult to conclude definitively whether the demand profile seen in 2008–09 was unusual.

From the Annual Information Returns, total households and non-households demand data (i.e. excluding leakage) shows that customer demand has been relatively consistent since 2002–03, although with a slightly decreasing trend.

The analysis of climate data does not imply that 2008–09 was particularly out of the ordinary – although it had a wet July and August, it also had relatively dry spring and winter. In terms of average monthly temperature, 2008–09 was very similar to the monthly LTAs.

Overall, the analysis above suggests that the base year (2008–09) can be considered relatively “normal”. Therefore, it is assumed that no normalisation of the base year demand is required.

Critical period and dry year annual average

The WRPG suggests that a critical period forecast should be derived where the critical period “is likely to be significant and is driving the need to implement water management options”. Examples of where this may be necessary include WRZs “supplied only by groundwater or run of river abstractions and limited storage, or where resource zone supply demand balances are judged to be particularly sensitive to peak demands”.

Generally, the supplies available to NI Water include a reasonable amount of storage. The supplies are in fact dominated by abstractions from Lough Neagh. Here, abstraction is a very small proportion of the total storage, so the impact of abstraction on total storage, and hence water levels is small. This means that the deployable output from the Lough Neagh sources is controlled by licensed quantities and not hydrology. . On the demand-side, it is clear from the DI analysis for the three years up to and including the planning base year that there is no strong peak customer demand driver in NI (this refers to demand in the sense of customer demand, rather than leakage components of demand driven by exceptional winter freeze-thaw events).

There is insufficient evidence to suggest that peak week or critical period demands are the main driver for investment to maintain the supply demand balance. Therefore, it does not appear appropriate to consider the critical period scenario; so only dry year annual average demands have been derived for the WRMP. However, a number of consultation responses to the Draft WRMP made reference to the freeze-thaw events over winter in both 2009-10 and 2010-11. Further analysis and comments on this are made below in section C.2.

The derivation of dry year factors is described in section C.3.

C.2 Winter peak periods: Freeze-thaw events

A number of responses received during the consultation process on the Draft WRMP made reference to the freeze-thaw events that occurred in the winters of both 2009-10 and 2010-11. These extreme weather events caused operational issues for the company, but are considered to fall outside the usual WRMP process. Extreme events such the loss of supply from a major treatment works (for example the summer 2007 floods leading to the loss of Mythe WTW) and winter freeze-thaw events are addressed through the operational resilience of water treatment and distribution infrastructure rather than water resource infrastructure. For completeness, this section has been added to provide a description and brief analysis of those freeze-thaw events.

The recent NIAUR report (Mar 2011) *Utility Regulator's report of the investigation into the Freeze/Thaw incident 2010/11* states that: "Temperatures in December 2010 in Northern Ireland were the coldest for 100 years. Indeed, the two most recent winters have been exceptionally cold".

Figure C.12 presents monthly average minimum temperatures for the years 2006-07 to 2010-11 compared to LTAs. This demonstrates the very cold conditions experienced in winter 2010-11 (particularly December 2010), and winter 2009-10 (particularly January and February 2010) compared to other recent years and to the long term averages for 1961-1990 and 1971-2000.

However, one critical factor in the effects observed in winter 2010-11 event was reportedly the speed of the thaw, as the NIAUR report (Mar 2011) recognises: "*The low temperatures were unprecedented, the most severe in the past 100 years. But what was even more unexpected was the very rapid thaw, which started on 26 December*".

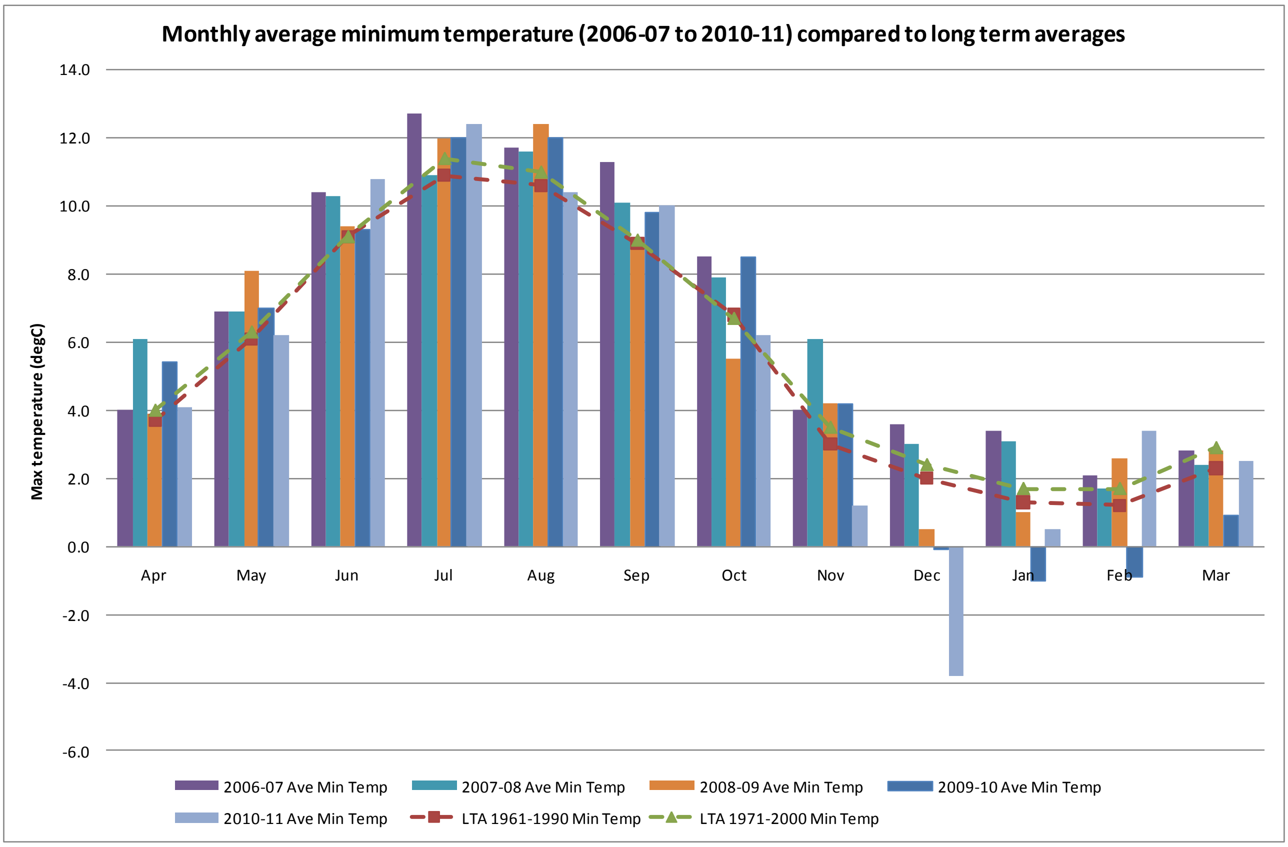


Figure C.12 – Comparison of monthly average minimum temperatures 2006-07 to 2010-11 and LTAs

Figure C.12 shows the extreme nature of the recent 2009-10 and 2010-11 winter events in terms of maximum recorded temperature. Figure C.13 shows that the average day peak week (ADPW) distribution input during winter 2009-10 and 2010-11 far exceeds the maximum in the preceding three years – 684 Ml/d in the middle of July 2006. In the winter of 2009-10, the maximum ADPW was 785 Ml/d, while in 2010-11 it reached 847 Ml/d. Peaking factors, calculated as the ADPW divided by the annual average, are 1.25 and 1.35 respectively – far higher than that 1.10 peaking factor experienced due to summer demand in July 2006.

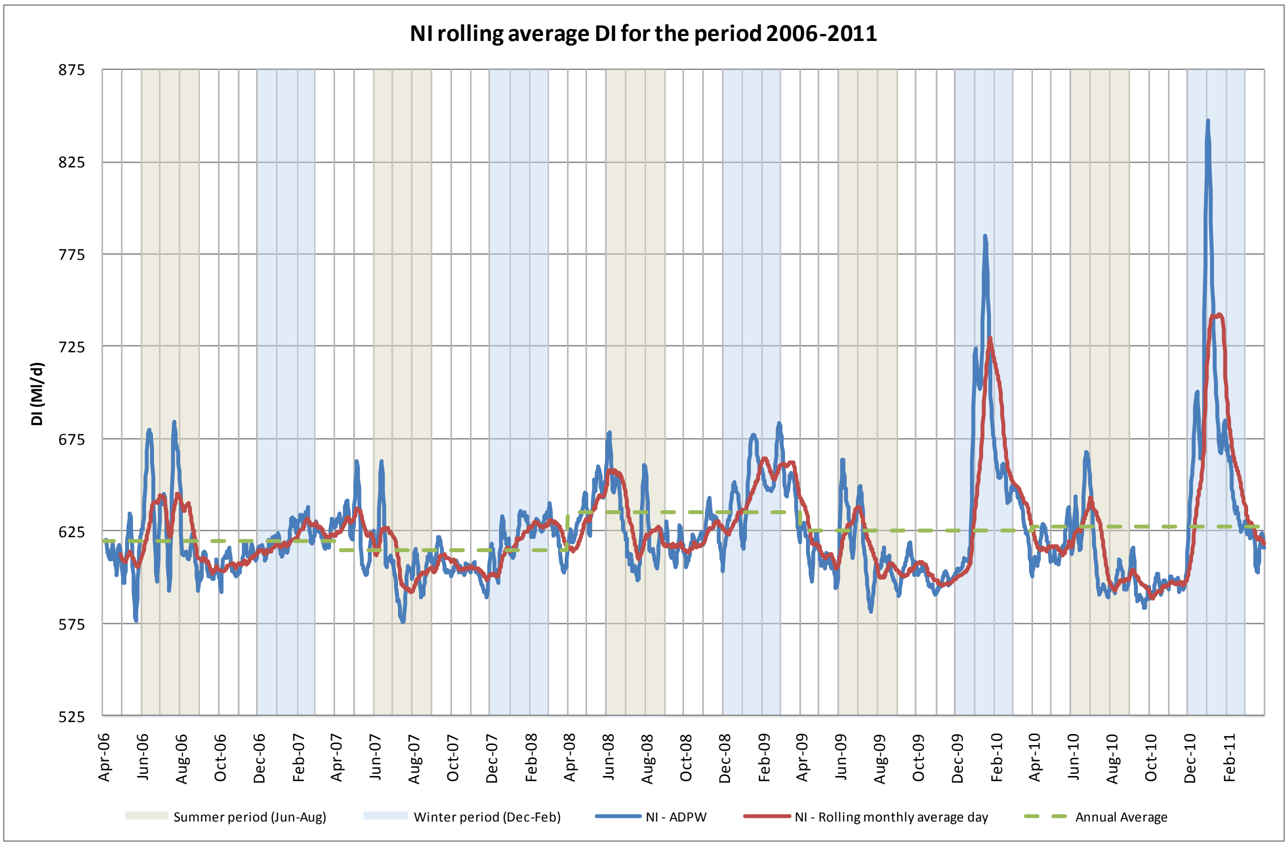


Figure C.13 – Rolling average DI in NI for the period 2006-07 to 2010-11

Figure C.14 shows the maximum ADPW in each winter month, again over the period 2006-07 to 2010-11. This again demonstrates the extreme nature of the winter demands experienced in 2009-10 and 2010-11 compared to the three preceding years.

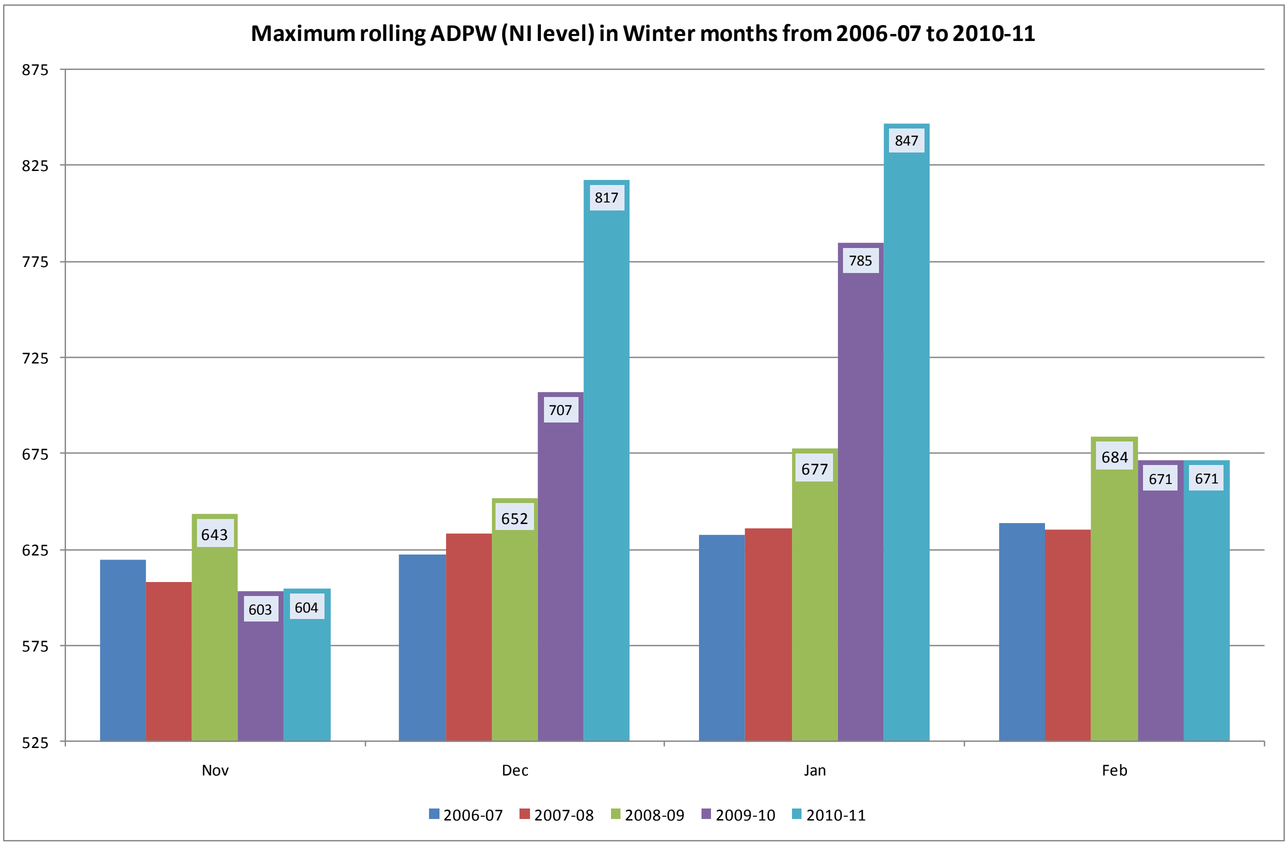


Figure C.14 – Maximum ADPW DI in NI in winter months for the period 2006-07 to 2010-11

The above analysis covers Northern Ireland as a whole. Figure C.14 demonstrates, for the winter 2010-11 event, that the ADPW occurred at the same time and with a similar impact across all five WRZs. The observed DI figures for 2010-11 have been analysed to assess whether there were any spatial differences in the occurrence of peak demands. Figure C.15 shows normalised plots of DI for each WRZ and illustrates similar behaviour across all the WRZs.

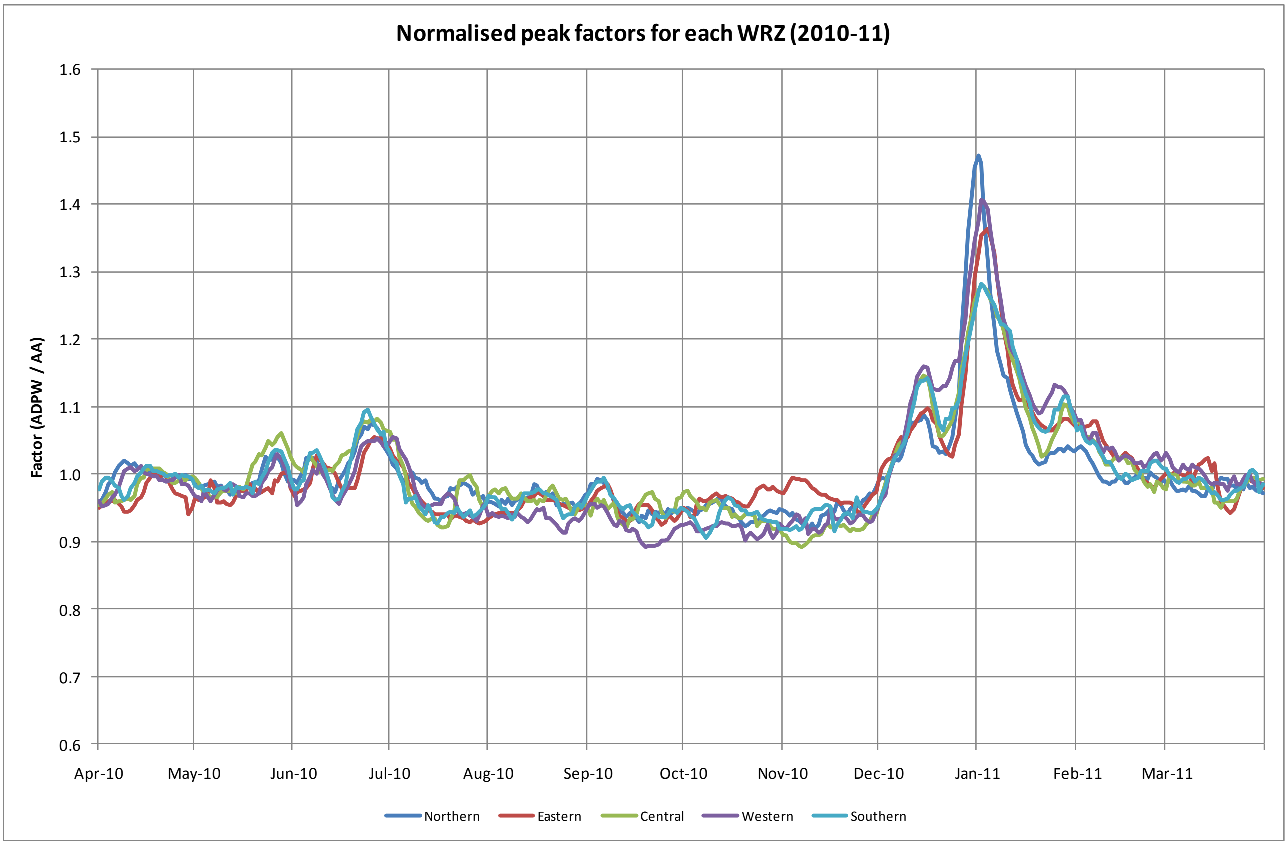


Figure C.15 – Normalised ADPW peak factors for each WRZ in 2010-11

C.2.1 Conclusions: winter peak periods

Recent operational experience, both in Northern Ireland (for example the winter "freeze-thaw" conditions in 2009-10 and 2010-11) and in England (for example the 2007 summer floods) show that despite long-term strategies for balancing supplies and demands at the scale of a water resource zone (WRZ), extreme events can nevertheless cause local operational difficulties which may lead to short-term interruptions to supplies. Such extreme events are considered to fall outside the locus of a WRMP, which looks at the conditions likely to be experienced under dry drought conditions.

The above analysis clearly demonstrates that the recent winter peak periods were quite exceptional. Nevertheless, NIAUR concluded in their *Utility Regulator's report of the investigation into the Freeze/Thaw incident 2010/11* report (Mar 2011) that "*NI Water's mains performed as well as could be expected under the harsh conditions by comparison with other water mains in the rest of the UK. Therefore, there is no need for an immediate change in mains infrastructure investment levels*".

The NIAUR report (Mar 2011) also recognised that: "*80% of the additional water demand caused by the freeze thaw leaked from domestic and business water pipes. The remainder was lost from NI Water's network.*"

Clearly, infrastructure schemes that contribute an appropriate operational and management response to short-term supply difficulties can also contribute to maintaining the supply demand balance in the longer term. Such infrastructure may also provide alternative operational responses that allow environmentally sensitive sources to be rested during drought.

For the Final WRMP, a critical winter period scenario has not been investigated or run through the investment model. This is because the WRMP process is focused on ensuring that there are sufficient supplies available over the long term planning horizon to meet demands likely to be experienced in dry year conditions, because it is not considered appropriate to plan and justify investment on short-term operational grounds in response to extreme events, especially when 80% of increased demand is on the customer side.

It is worth noting that a UK Water Industry Research (UKWIR) project which aims to investigate the effect of weather on leakage and bursts (research project WM08 was commissioned during 2011-12; the project is due to be completed in autumn 2012. It is anticipated that the project will recognise that climatic events such as recent harsh winters as well as hot weather and prolonged wet or dry spells can affect leakage and bursts, and that this could become more common place due to climate change impacts. The objective of the work is therefore expected to be to forecast the effects of weather factors (such as temperature, rainfall and soil moisture deficit) on leakage or bursts.

C.3 Dry year analysis

The WRPG requires that water companies should consider their supply demand balances under different planning scenarios. For each planning scenario a baseline forecast is produced, and where there are supply demand balance deficits identified, a final planning forecast must also be produced to demonstrate the options required to overcome the deficit.

The primary planning scenario is the dry year annual average scenario (DYAA), which is defined by a period of low rainfall and unconstrained demand. This forms the basis of the WRMP, because the overall objective of the WRMP is to ensure that even under drought conditions, when supplies may be stressed, the level of demands associated with hot dry conditions can be met in full (without restrictions). All water companies are expected to derive this dry year scenario in their WRMP.

The dry year forecast is developed from normal year annual average data – i.e. base year data that has been normalised to represent average climatic conditions. Some companies might also need to derive critical period scenarios (for example periods of peak demands associated with extended periods of hot, dry weather), where their supply demand balance is sensitive to these periods. For NI Water, the annual average, rather than critical period, scenario is considered to be most important.

Generally, dry year factors are derived from historic information on consumption and distribution input (DI). Climate data can be used to help identify historic dry years or hot dry summers, so that the demands that were experienced in those periods can be identified and used as the basis to calculate dry year/critical period peaking factors.

This section follows on from the analysis set out in section C.1. It sets out the analysis to derive dry year factors for each water resource zone (WRZ).

The type of analysis that is possible depends to a large extent on the quality, spatial coverage and period of time for which DI and if possible more detailed consumption data are available. The analysis will need to be reviewed and updated when necessary in future, particularly following periods of sustained hot dry weather.

C.3.1 Climate data

Rainfall and temperature can have a strong influence on customer demand, and in particular domestic consumption. During the summer months, periods of wet weather mean that there is little inclination for domestic customers to use water outside the home, so customer demands may be similar to winter levels. In contrast, drought conditions accompanied by sustained periods of high temperature can increase customer consumption through discretionary use such as gardening and other outside leisure activities.

Data from the Met Office website for the Armagh weather station was used to undertake climate analysis using data from the last 20 years. Note that for the analysis annual totals were based on the 12 month period from April to March because this is the period for which AIR returns are compiled. The totals for these years were compared with the Long Term Averages (1961–1990 and 1971–2000). A number of dry years were identified using rainfall data, as presented in Table C.2.

Year	Annual rainfall (mm)	Summer rainfall (Apr–Sep)	Winter rainfall (Oct–Mar)	Rank by annual rainfall	Rank by summer rainfall
1988–89	741.3	374.6	366.7	7	9
1989–90	771.1	316.9	454.2	9	4
1990–91	785.2	306.1	479.1	10	3
1991–92	691.5	239.1	452.4	1	2
1992–93	788.6	429.7	358.9	12	18
1993–94	1023.7	511.3	512.4	21	21
1994–95	785.4	328.8	456.6	11	5
1995–96	717.8	199.9	517.9	6	1
1996–97	703.3	360.2	343.1	3	8
1997–98	798.3	384.7	413.6	13	11
1998–99	868.9	393.3	475.6	17	13
1999–00	815.9	415.6	400.3	15	15
2000–01	876.9	415.9	461.0	18	16
2001–02	758.7	347.9	410.8	8	6
2002–03	980.4	481.8	498.6	20	20
2003–04	692.4	377.7	314.7	2	10
2004–05	808	400.6	407.4	14	14
2005–06	715.9	359.3	356.6	5	7
2006–07	867.5	387.9	479.6	16	12
2007–08	889.8	467.8	422.0	19	19
2008–09	714.6	428.3	286.3	4	17
LTA 1961–90	813.3	374.3	439.1	*n/a*	*n/a*
LTA 1971–00	795.4	356.8	438.8	*n/a*	*n/a*

Table C.2 – Climate analysis for Armagh weather data over the last 20 years

From this analysis of rainfall over the last 20 years, the year with highest combined ranking (annual and summer rainfall) is 1991–92, but no DI data was available for this year. For those years for which annual average DI data may be available (i.e. from 1994 onwards) the following years were identified as dry years:

- 1995–96 (lowest period of summer rainfall in the 20 year period);
- 1996–97;
- 2003–04; and
- 2005–06.

The rainfall and average temperature for each month of the identified dry years were plotted against the long term averages for 1961–1990 and 1971–2000. In this analysis, 2006–07 was also considered because, although it was not particularly dry, it had the highest annual average temperature and highest average summer temperature for the 20 year period. The comparisons are presented in Figure C.16 and Figure C.17. Note that 2008–09 was also included for comparison, because this is the base year for the demand forecast.

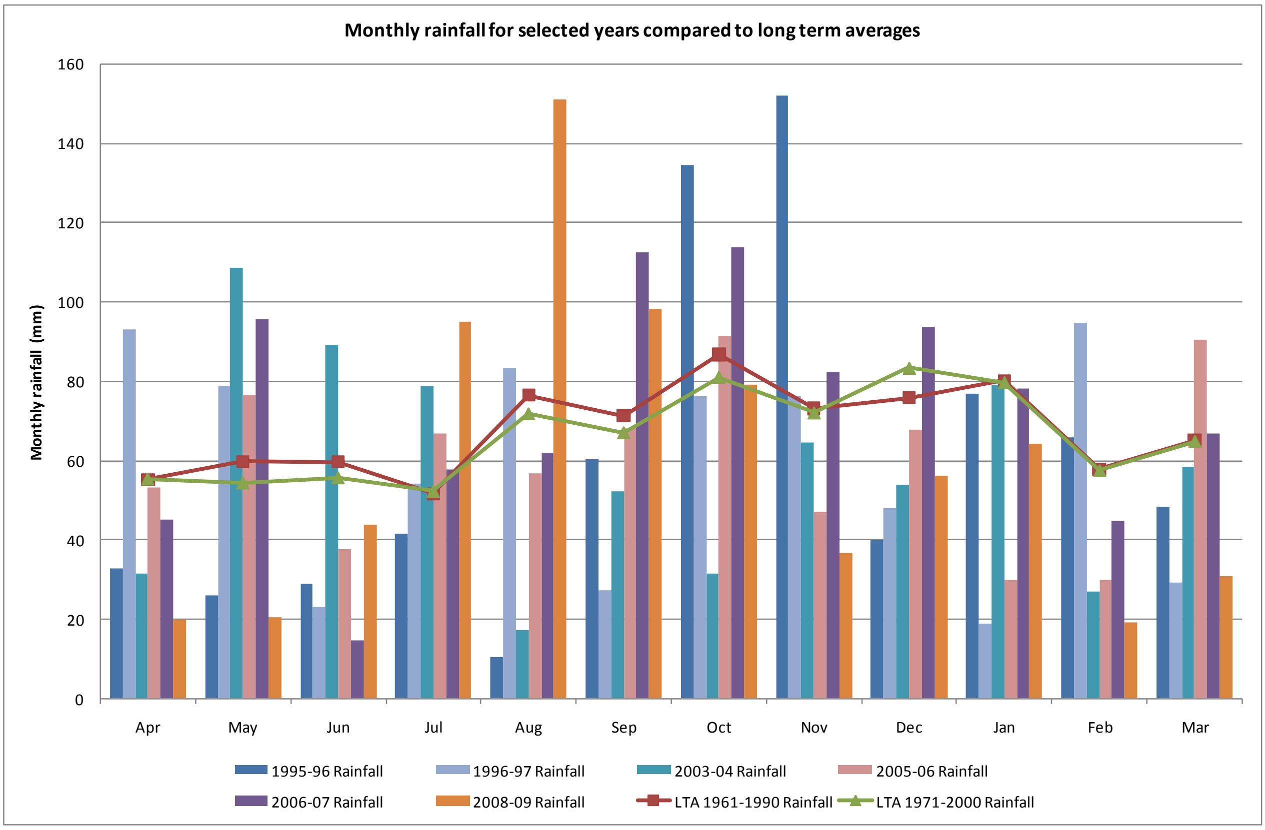


Figure C.16 – Monthly rainfall in selected dry years compared to long term averages

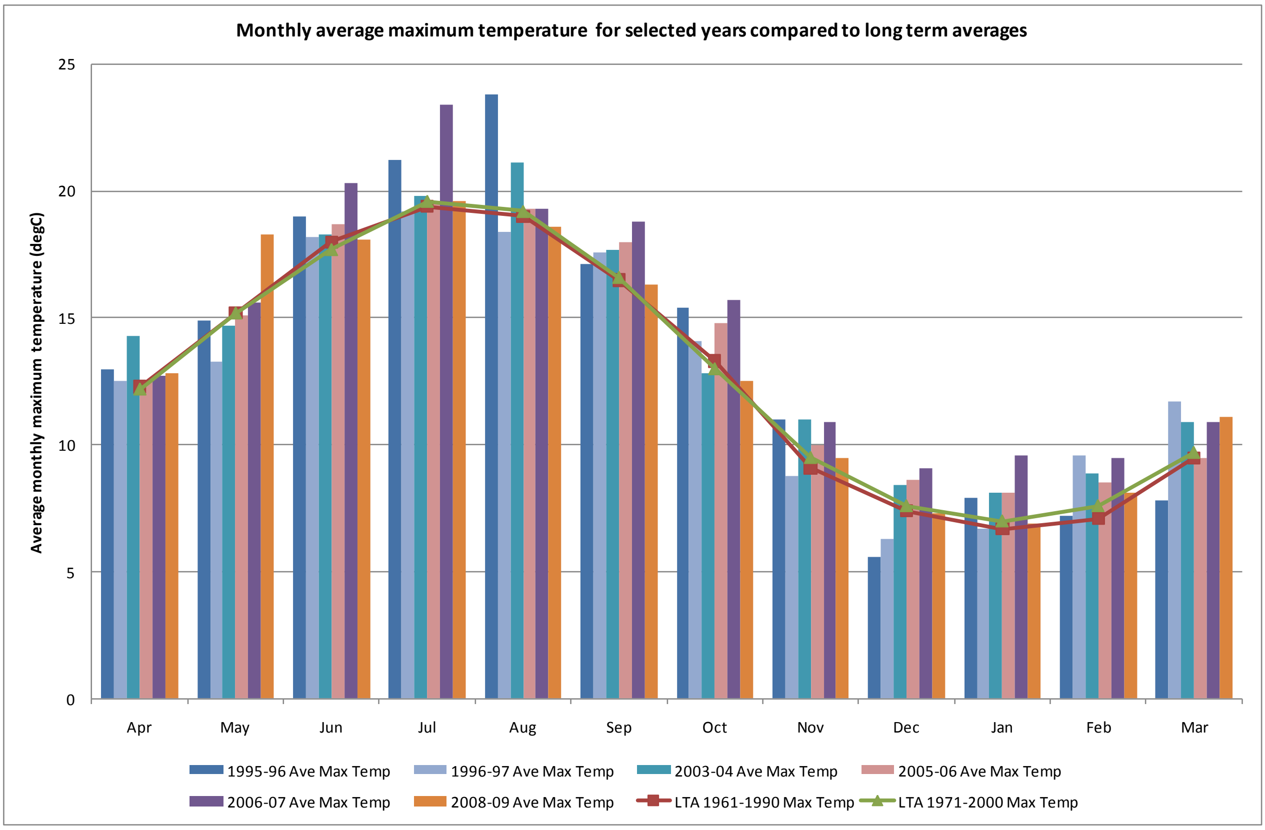


Figure C.17 – Average monthly maximum temperature in selected dry years compared to long term averages

These figures suggest that the spring/summer of 1995 were particularly dry and warm, although early 1996 was less unusual. 1996–97 does not appear particularly exceptional in climatic terms, although the winter was very dry (however winter rainfall tends to have less impact on demand than summer rainfall).

August 2003 to March 2004 were drier months than average (particularly August), although the earlier part of the summer (May–July) was wetter than average. The average temperature was comparable to the LTAs.

2005–06 was relatively dry throughout the year. It was close to the LTA in most months in terms of average temperature.

The June of 2006 was very dry, but other than that the rainfall was reasonably average (or above average from September to December). From June 2006 for the rest of the financial year, temperatures were significantly higher than average.

There was a very wet summer in 2008–09 (in July and August), although rainfall in April to June 2008 and winter 2008–09 was lower than the LTA. The temperature largely followed the LTA monthly profiles.

C.3.2 Demand restrictions

It is understood that there have not been any restrictions on demand imposed in recent years. Even in 1995, a year in which restrictions were imposed in much of England and Wales, it is believed that, although a publicity campaign was adopted to encourage customers to conserve water, there were no restrictions imposed.

As such, NI Water does not have a level of service in terms of frequency of imposing hosepipe bans or other measures to suppress demands.

A recent survey of NI Water customers, *Tapping into consumer views on water* (Mar 2009) found that in terms of water services, water supply restrictions such as hosepipe bans were given the lowest priority by customers. This was “for two reasons – most struggled to remember the last restriction and restrictions should not be in place when high levels of leakage exist”.

C.3.3 Derivation of dry year factors

The analysis presented in the section C.1, suggested that the base year (2008–09) could be considered to be relatively “normal”. Therefore, it was assumed that no normalisation of the base year demand was necessary. Thus dry year factors were applied to the 2008–09 components of demand.

From the analysis conducted in section C.1, it was determined that critical period demand is not the main driver for investment to maintain the supply demand balance, therefore, only dry year annual average factors have been derived.

C.3.3.1 **Analysis of DI data, 1992–1999**

Appendix C of the previous Water Resource Strategy for 2002–2030 (WRS 2002) presented annual average historic data for the period 1992–1999. This showed the DI from each source works in each WRZ in each calendar year, although it should be noted that the 1992 and 1993 data sets were incomplete. However, no information was given to show how much of the total DI was consumption and how much was leakage.

The customer base is likely to have changed from the 1990s to the present. For instance, the population has grown across NI over that time period. It would therefore be sensible to consider rebasing the historic DI so that it is representative of the current base year customer characteristics. This is the approach developed for the recent UKWIR guidance *Peak water demand forecasting methodology* (2006).

However, rebasing total DI on the basis of population growth is unlikely to provide a representative rebased historic DI time series, as it is not possible to disaggregate the non-household demand and leakage components of the total DI figures. Therefore, it was not considered appropriate to rebase the total DI in this instance.

Leakage levels are likely to have changed over the time period under consideration. It is expected that leakage may have reduced over the 1990s to present. However, there is no leakage data for this period which can be reliably used to separate out the leakage component of total DI.

For the years for which there is a complete set of data (1994–1999), analysis of the historic observed DI time series suggests that the years with the highest total DI were in 1996 and 1999. Figure C.18 shows the observed data for this period.

The results of this analysis do not correlate particularly well with the climate data. The obvious dry year in the 1990s was in 1995–96 due to the very dry and warm “long” summer from April to September 1995. Yet the observed DI data do not reflect this.

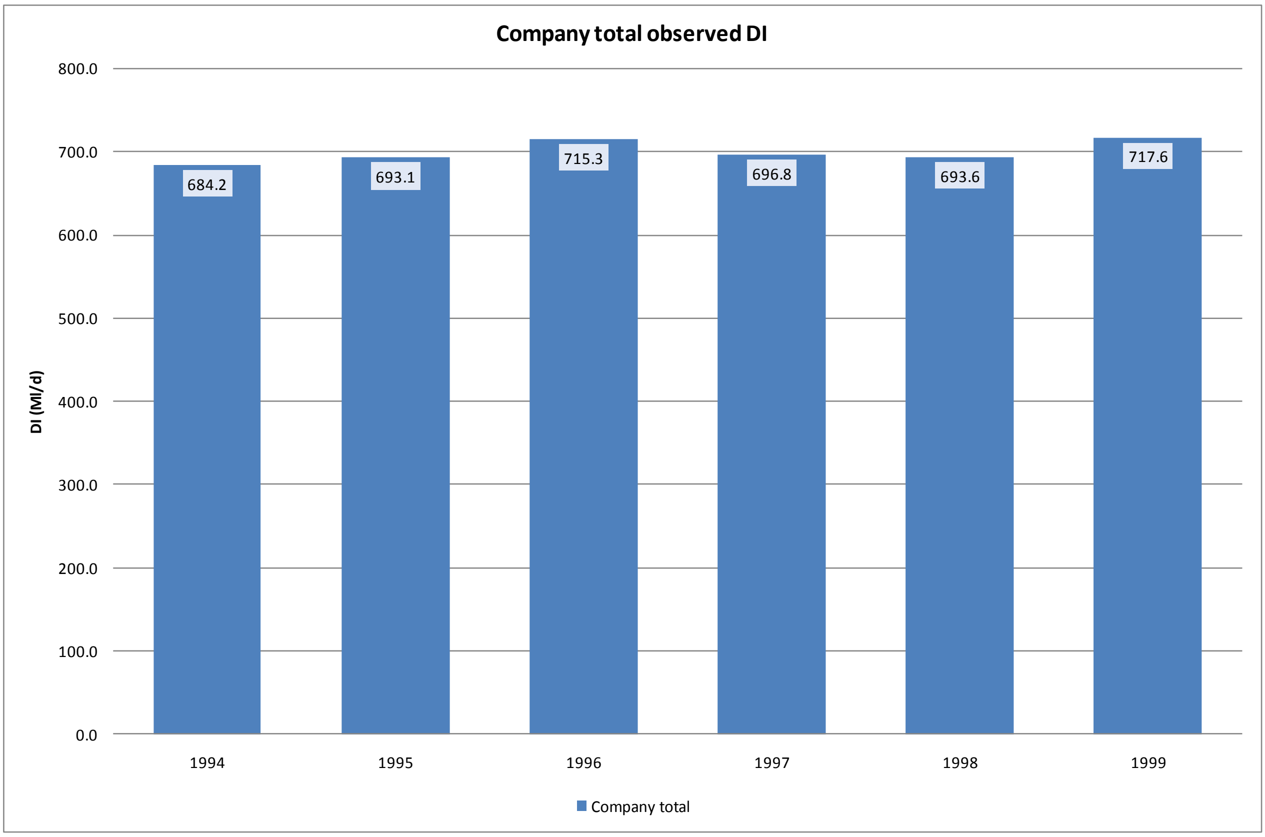


Figure C.18 – Observed distribution input 1994–1999 (from WRS 2002)

It is difficult to draw accurate comparisons with this data and other more recent historic Annual Information Returns data, because the AIR data is based on financial years, while the historic DI data from the 1990s was based on calendar years.

Also, as noted earlier, the customer base and other factors affecting DI, such as leakage levels, are likely to have changed since the 1990s. Nevertheless, it may be instructive to consider these as giving a guide to the maximum DI likely to be experienced. From the 1990s DI data (from WRS 2002), the maximum observed DI was 718 Ml/d in 1999, and 715 Ml/d in 1996, while the 90th percentile value of the 1994–1999 data set gives a value of 716 Ml/d. Therefore an upper bound dry base year value of approximately 715 Ml/d would seem reasonable.

C.3.3.2 Analysis of historic AIR data, 2002–2008

The most recent data available for assessing dry year demands is from the Annual Information Returns, for which complete data was available from 2002–03 to the base year of analysis (2008-09). The annual average distribution input for this period is presented in Figure C.19.

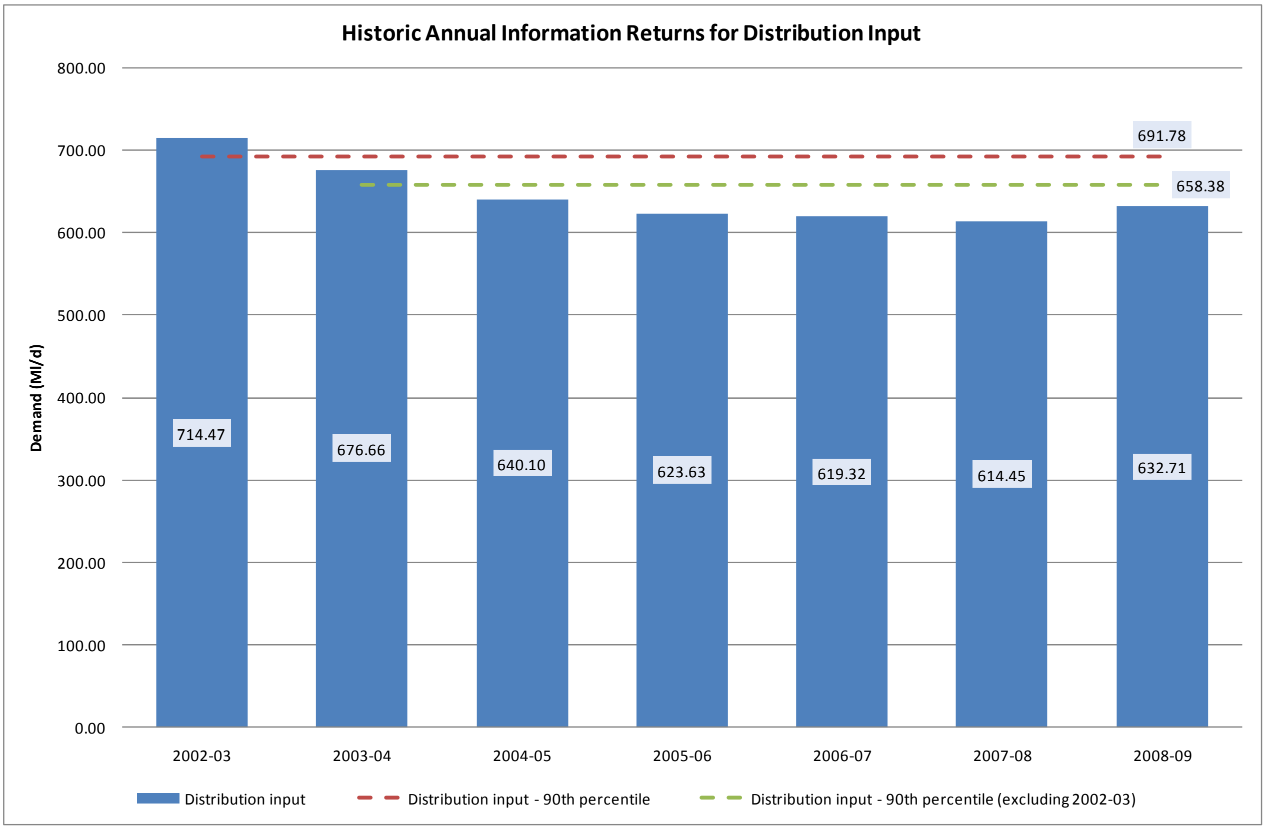


Figure C.19 – Annual average DI for NI Water (from historic AIR data)

One obvious comparison between this data and that for 1994–99 is that total DI has clearly reduced over time. The annual average demands observed since 2004–05 have all been 640 Ml/d or less.

It is not clear why 2002–03 has such a high peak compared to other recent years. From the climate analysis, 2003–04 may have been expected to have been affected by the dry (and warm) period from August 2003 to March 2004, so have a correspondingly higher demand than 2002–03 (although generally there is not much discretionary demand from September through March). The DI in 2003–04 is clearly quite high compared to later years; however, given the higher value in 2002–03, this could be part of a trend of high DI decreasing through time to present, perhaps due to decreasing non-household demand and leakage over these years.

Note that the demand in 2006–07 (which was a warm year on average) was actually less than that in 2008–09 (which did not have typical monthly average climate characteristics normally expected to drive demand up). This suggests a relatively weak correlation between the climate analysis and annual average DI.

Also presented in Figure C.19 are the 90th percentile of the 2002–03 to 2008–09 DI data and the 90th percentile of the data with 2002–03 excluded as an outlier (not representative of recent trends in DI). These have been derived to give an idea of what a reasonably high value is within the data set, although the usefulness/validity of this based on only 6 or 7 points is arguable.

The issue with trying to use DI to derive a dry year factor is that not all components of demand are affected in the same way by climate. For instance, domestic customer demand is generally influenced by hot dry weather, as this generally leads to, amongst other things, increased garden watering and other outdoor use, as well more frequent use of showers and clothes washing. However, leakage levels may be affected more by very cold weather resulting in ground frosts, and thus high leakage levels over the winter. Non-households may or may not be influenced by weather, depending on the type of industry. For instance, water demand in agriculture is clearly affected by weather, but the impact is also influenced by the time of the year; whereas climatic conditions may be almost irrelevant for many industrial processes.

Household demand

The historic AIR data contains a breakdown of DI by demand component, so it is possible to look at some of these components on their own. A plot of unmeasured household demand (including supply pipe leakage) is shown in Figure C.20. Note that the accuracy of the distribution of DI into the components of unmeasured consumption and leakage may change from year to year. This may have had a larger effect than any weather related changes in consumption from year to year.

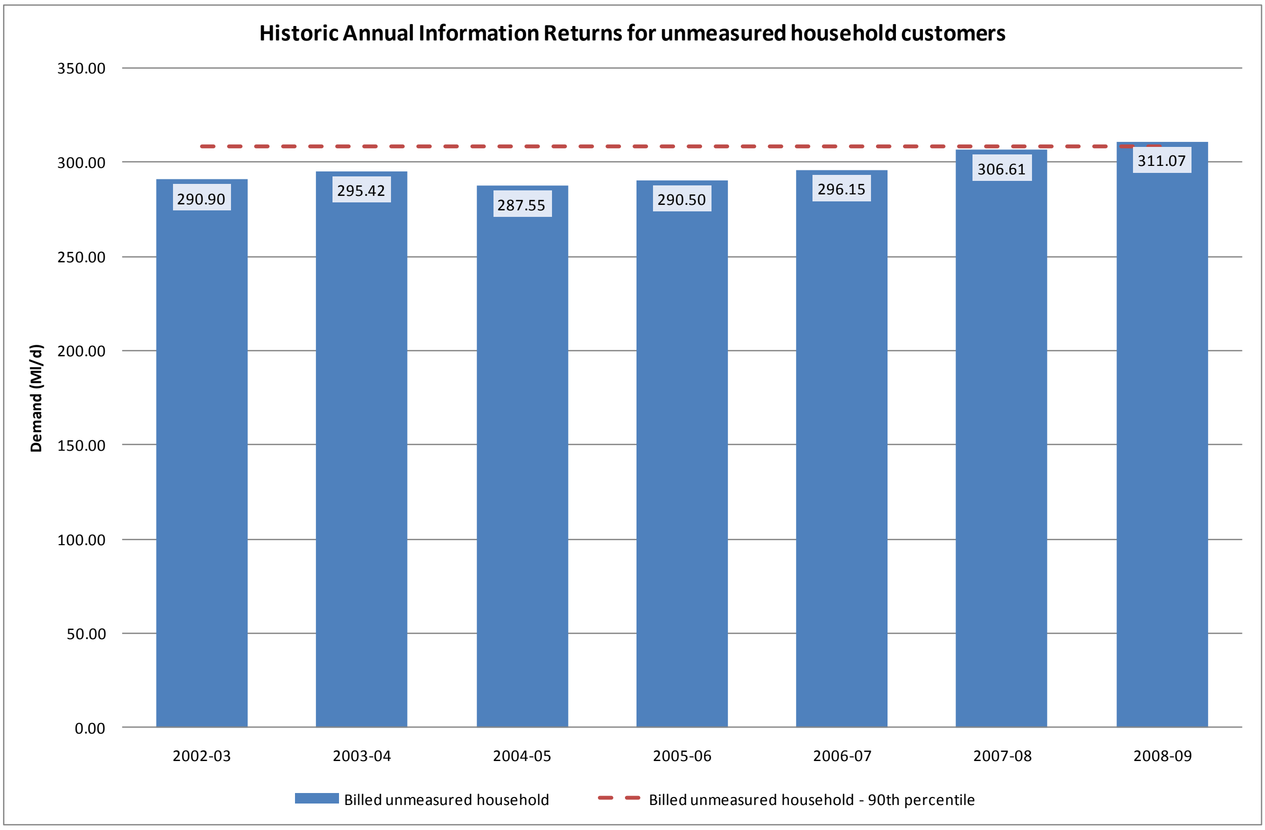


Figure C.20 – Annual average unmeasured household demand for NI Water (from historic AIR data)

The annual average household demand does not appear to correlate strongly with the climate analysis. For instance, 2008–09 had a wet summer yet has the greatest unmeasured household demand over the period from 2002–03 onwards; while a dryer and warmer year like 2003–04 does not have a particularly high demand.

This may be influenced by changes in the customer base over the period of analysis – especially in terms of increasing population. Thus there may be a case for rebasing the unmeasured household demand to account for changes in household population by applying an adjustment to estimate what demand would have been if historic years had the same customer base as in 2008–09. The simplest way of rebasing household demand, where there is no metering, would be on the basis of population, as it can be reasonably assumed that more people equates to greater demand. The rebased unmeasured household demand is presented alongside the actual observed unmeasured household demand in Figure C.21.

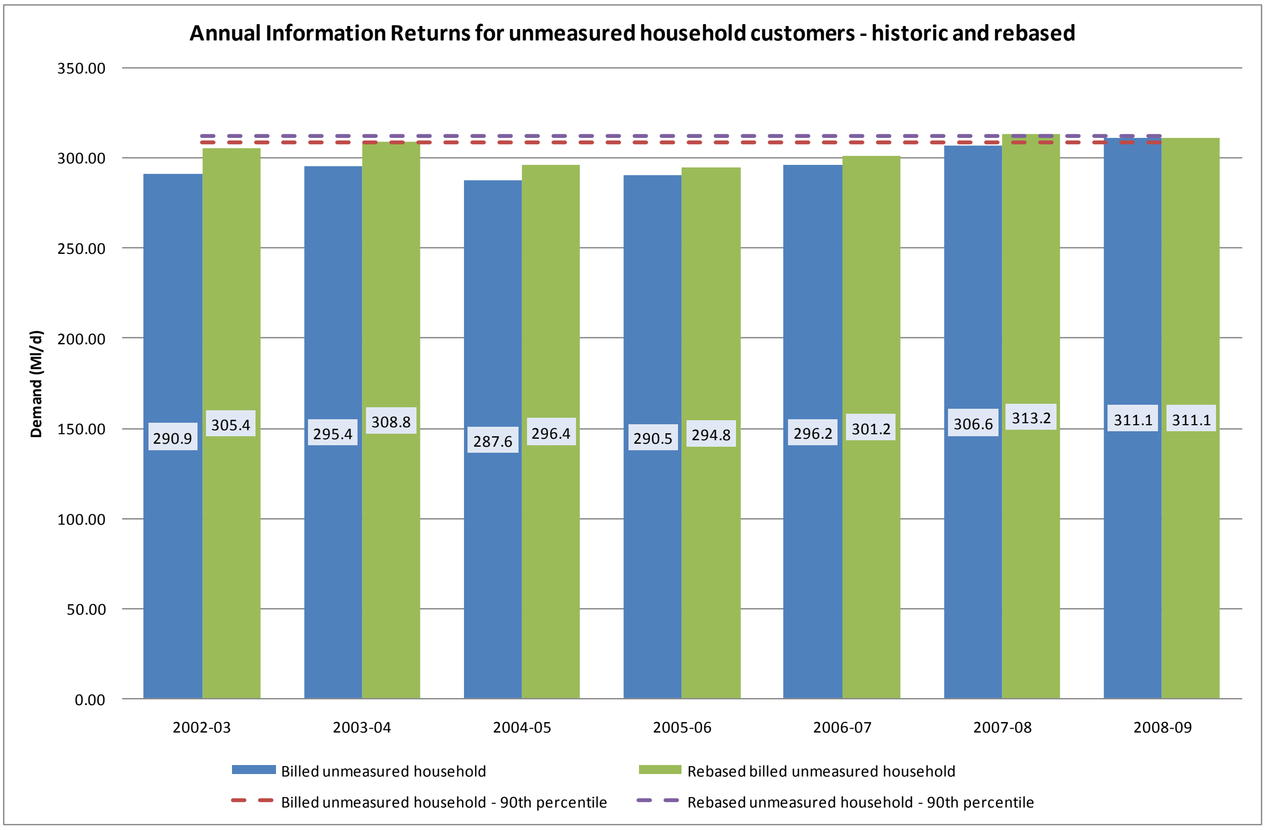


Figure C.21 – Observed and rebased annual average unmeasured household demand (from AIR data)

This has the result of increasing the household demand seen in 2003–04, but the rebased demand in 2007–08 and the demand in 2008–09 is still slightly greater than in 2003-04 – i.e. the “dry year” factor calculated for household demand only using 2003–04 compared to the base year of 2008-09 would be marginally less than 1.

Non-household demand

A similar analysis could be applied to non-household demand. Rebasing could be on the basis of change in non-household properties, although the correlation with demand is probably weaker than for household population, as the range of water use of non-household customers in different sectors is very wide. Nevertheless, the results are shown in Figure C.22. Note that non-households include the “measured household” category from years prior to 2008–09, as these are understood to be farms.

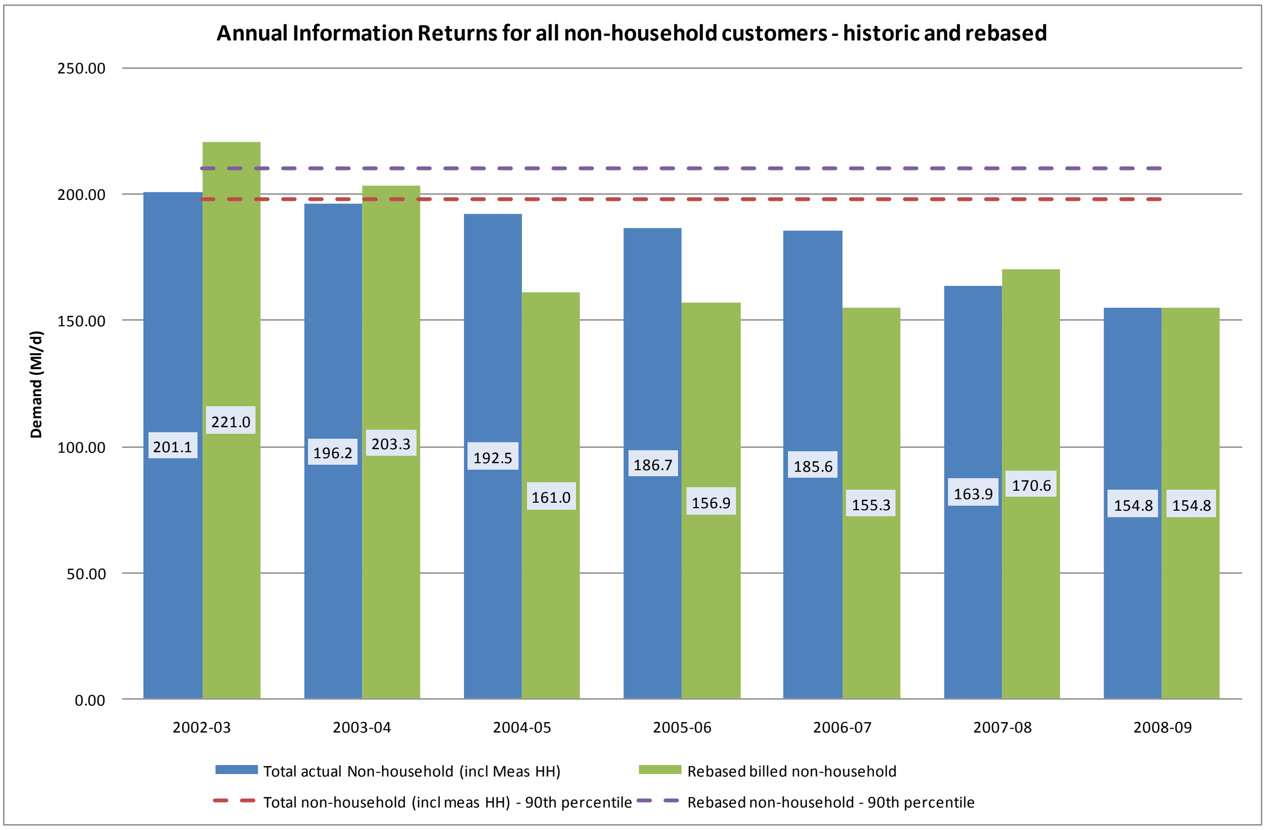


Figure C.22 – Observed and rebased annual average non-household demand (from AIR data)

The results of this analysis suggest a dry year factor (calculated by comparing the 2008–09 demand to that in 2003–04) of around 1.27 (based on observed demands). This seems unlikely, and it may be assumed that the overall trend of reducing non-household demand through time is the critical factor here – i.e. the demands seen are not strongly related to the climatic conditions experienced on average across each year.

C.3.4 Comparative analysis

An alternative approach given the lack of long term DI data on which to base a quantitative analysis could be based on comparison of dry year factors developed by other water companies likely to experience similar conditions and dry year demand drivers to NI Water.

Table C.3 presents a summary of dry year factors for those water companies from England and Scotland, which are likely to experience similar climatic conditions to NI Water. Note that many of these will have a proportion of domestic customers who are metered, with assumed consequent reductions in demand.

Company	Dry Year Factor	Peak	Notes
Scottish Water	Uplift of 3% applied to the total demand. Dry year factor therefore 1.03 on total DI	None	
Northumbrian Water	Based on 1995/96 dry year demand – applied to household PCC only. Impact on measured customers less than unmeasured. Average overall dry year factor appears to be approximately 1.03.	1 in 20 year peak week factor of: 1.43 in 2004; 1.39 in 2017; 1.36 in 2029	Peak factor calculated for Berwick WRZ only – pilot trial using 2006 methodology.
United Utilities	Based on 1995/96 dry year demand. Micro-component based. 4x normal annual average water use for garden watering; small increases assumed in shower use and clothes washing. Dry year factor therefore estimated as: 1.07 in 2006/7; 1.08 in 2014/15; 1.1 in 2024/25; 1.1 in 2034/35.	None	
Yorkshire Water	Based on 1995/96 dry year demand. Micro-component based. 77% of increased demand from household customers (due to garden use and personal washing); remaining from non-households. Dry year factor estimated as 1.07	None	2006/07 was considered a partial dry year with increase in demand of 10 Ml/d

Table C.3 – Summary of dry year factors used by other water companies in their WRMP

C.3.5 Dry year factors from WRS 2002–2030

The estimated dry year factors used in the previous Water Resource Strategy (WRS 2002) were based on the highest ratio of demand in April to September compared with October to March in each year from 1992 to 1999 to identify the dry year for each record. This ratio for the dry year was then divided by the same ratio applied to the base year of 1999–2000. The data set used included 1995. The dry year factors from WRS 2002 are given in Table C.4.

WRS 2003 Resource zone	New Water Resource Zone (WRZ)	Dry year factor
Ballinrees	North	1.108
Altnahinch	North	1.079
Faughan/Altnaheglish	North	1.141
Ballymena	East	1.127
Antrim/Larne	East	1.108

WRS 2003 Resource zone	New Water Resource Zone (WRZ)	Dry year factor
Eastern General	East	1.091
Lough Cowey	East	1.200
Magherafelt/Cookstown	Central	1.107
Dungannon	South	1.186
Craigavon	South	1.117
Newry	South	1.112
Lough Ross	South	1.103
Armagh	South	1.168
Derg/Bradan/Lough Macrory	West	1.103
Killyhevlin	West	1.360

Table C.4 – Summary of dry year factors for 2002–2030 (from WRS 2002, Table 8.3)

It is believed that these factors were then applied to the total demand (i.e. distribution input) to generate the dry year demand for each resource zone.

Note that the level of information that the WRS 2002 analysis was based on was not available for this WRMP, because daily DI was only available for the most recent three years up to and including the base year for planning (2008-09).

C.3.6 Dry year demands

The analysis presented above suggests that:

- Distribution input in Northern Ireland does not correlate particularly well with the demands that might have been expected in the years that have been identified from analysis of weather data as dry years;
- Household demand does not correlate well with climate analysis, and the trend over the period 2002–03 to 2008–09 of increasing household demand may mask any differences in annual average demand due to dry years. Applying a simple rebasing technique cannot replicate demands that might be expected on the basis of climate analysis; and
- Non-household demand shows a very strong downward trend over the period 2002–03 to 2008–09, which significantly masks any potential correlation with climate data.

Given the issues with data availability and validity, the simplest approach would be to derive an overall dry year annual average demand (distribution input) which is at the upper limit of what the company feels could reasonably be met before demand restrictions need to be applied.

Based on a combination of the climate analysis and the DI data, it is proposed to use the 2003–04 DI as the basis for estimating dry year demands. So the total company dry year annual average (DYAA) demand would therefore be 676.66 Ml/d. An upper bound could be based on the DIs experienced in the 1990s, so would be approximately 715 Ml/d, although the customer base and other components of demand (such as leakage) are likely to have changed from the 1990s.

However, this does mean that the dry year demand for the WRMP (based on observed DI in recent years) is significantly less than the dry year demand derived for the previous WRS 2002, which was based on the 1990s demand. These issues are illustrated in Figure C.23. This clearly shows the trend of DI decreasing through time. It also presents some of the components of demand from 2002–03 onwards, in which non-household demand and leakage have a clear decreasing trend, while there is a trend of gentle increase in unmeasured households (due to population increases).

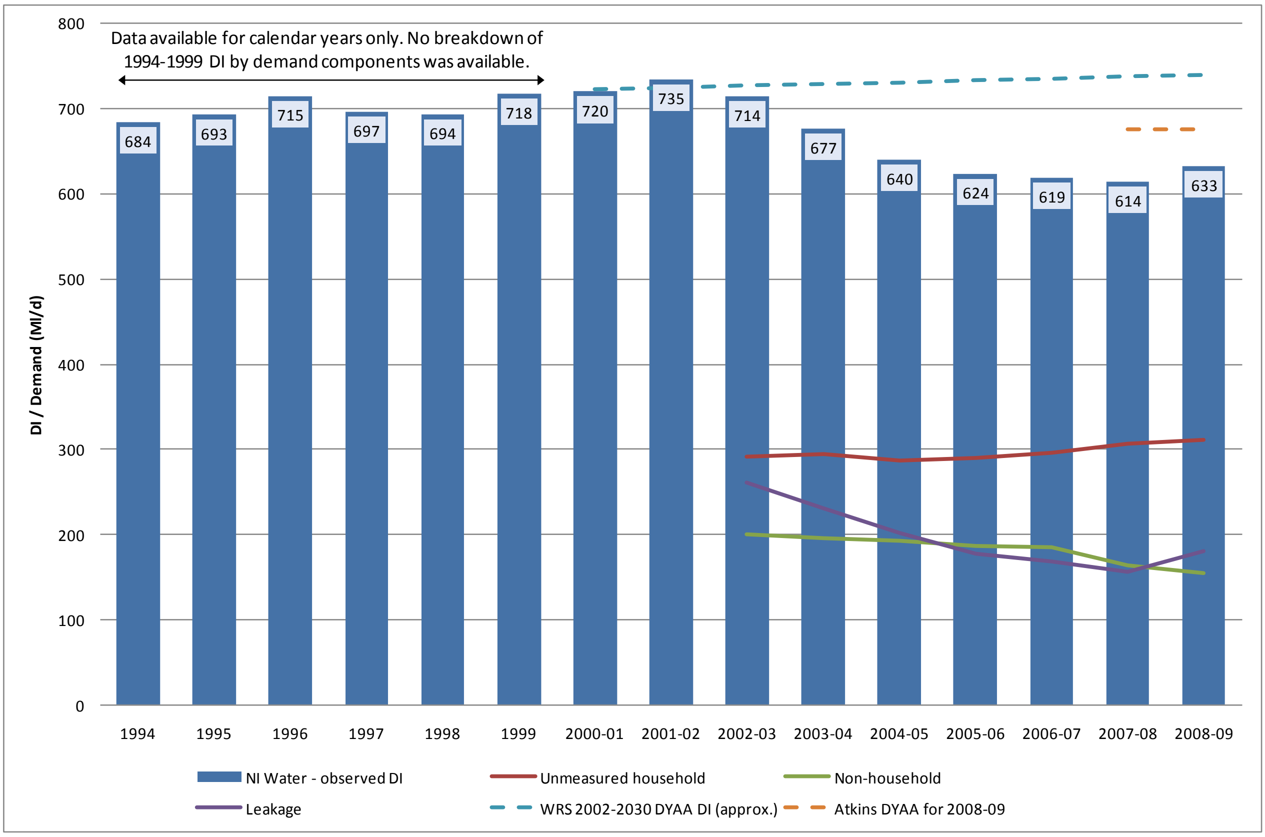


Figure C.23 – Historic DI and recent trend in demand components

No information is available that would allow the 2003–04 (or the 1990s) DI to be disaggregated into the 5 new WRZs required for the WRMP, so the dry year demand must be apportioned between the WRZs. This is done on the basis of the percentage contribution of DI from each WRZ to the overall company DI in the base year 2008–09. The results are presented in Table C.5.

The household and non-household components of demand could then be adjusted so that the calculated overall DYAA demand for each WRZ is reached in the base year (2008–09). All other components of demand are assumed to be unaffected by dry year conditions.

The calculated factors are presented in Table C.5 for the 2003–04 based dry year demand. Note that it has been assumed that non-household is influenced to a lesser extent by dry years, and hence an assumed dry year factor of 1.05 has been applied to all non-households. This is based on general experience which suggests that on the whole dry years have either no effect or little effect on non-household demand. The dry year household factors are calculated so that the total DI reaches the target DYAA value considered appropriate to NI Water, once the non-household factor has been applied.

Also presented are the typical WRZ-level dry year demands that would be expected if the 1990s "upper bound" demand were used for the dry year, and a comparison with the WRS 2002–2030 assumed demands.

Component	East	North	Central	West	South	Company
Base year "normal year" demand:						
2008–09 DI	313.32	76.38	26.47	62.24	154.30	632.71
% of company DI in 2008–09	49.5%	12.1%	4.2%	9.8%	24.4%	100.0%
DYAA estimates using 2003–04 demand:						
Estimated 2003–04 dry year annual average DI	**335.09**	**81.69**	**28.30**	**66.57**	**165.01**	**676.66**
Uplift factor for total DI (using 2003–04 DYAA)	1.07	1.07	1.07	1.07	1.07	1.07
Calculated household dry year factor	1.12	1.12	1.15	1.16	1.15	n/a
Assumed non-household dry year factor	1.05	1.05	1.05	1.05	1.05	n/a
DYAA estimates using 1990's "upper bound" demand:						
Estimated 1990's dry year annual average DI	**354.07**	**86.32**	**29.91**	**70.34**	**174.36**	**715.00**
Uplift factor for total DI (using 1990's DYAA)	1.13	1.13	1.13	1.13	1.13	1.13
Comparison with WRS 2002 (2002–2030):						
Total demand (DI) in 1999–2000 base year	-	-	-	-	-	***721***
Factors applied to total DI (range seen in old RZs which make up the new WRZs)	*1.091–1.200*	*1.079–1.141*	*1.107*	*1.103–1.360*	*1.103–1.186*	*n/a*

Table C.5 – Summary of dry year demand and dry year factors for each WRZ

C.4 Population and properties

The WRPG suggest that companies should produce, for both population and properties:

- Policy-based forecasts – which incorporate planned development initiatives; and
- Trend-based forecasts – which assume recent trends will continue and do not take account of future policy changes.

The rationale behind this is to help assess the uncertainty associated with the forecasts. However, the WRPG recommends that "final property and population projections should be policy-based", because this ensures that the WRMP is as consistent as possible with regional strategies.

The base year (2008–09) breakdown of population and properties should be based on the Annual Information Returns 2009 (AIR09).

C.4.1 Base year

The AIR data has been used to conduct some recent trend analysis for NI Water's customer base. Note that prior to the AIR09 submissions, the category of measured household customers actually represented farms. Hence, the analysis assumes that only the unmeasured households category in the AIR data truly represents household customers. The other components, measured and unmeasured non-households and measured households, are all assumed to represent non-households.

C.4.2 Base year population

Figure C.24 presents the total customer population estimates from historic AIR Table 7 data to the base year (2008-09). This shows an increase from 2000–01 to 2008–09 of approximately 73,000 people. The total base year population is assumed to be 1,775,110.

Figure C.25 presents the population of domestic customers (assumed to be the unmeasured household population only), over the period 2002–03 to 2008–09. In the base year the domestic population 1,672,510, while the non-household customer base comprised a population of 6,670 unmeasured non-household customers and a population of 95,930 measured non-household customers.

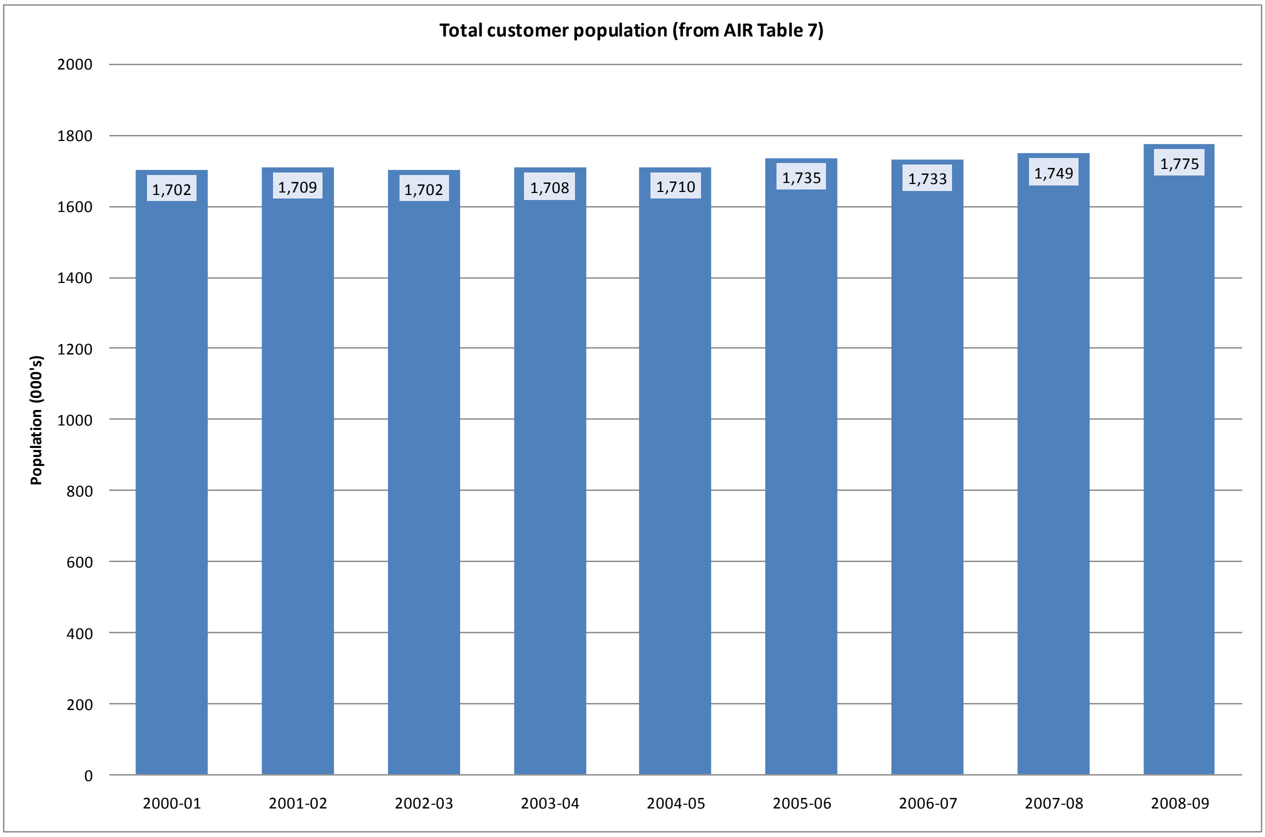


Figure C.24 – Total customer population of NI Water (from AIR table 7)

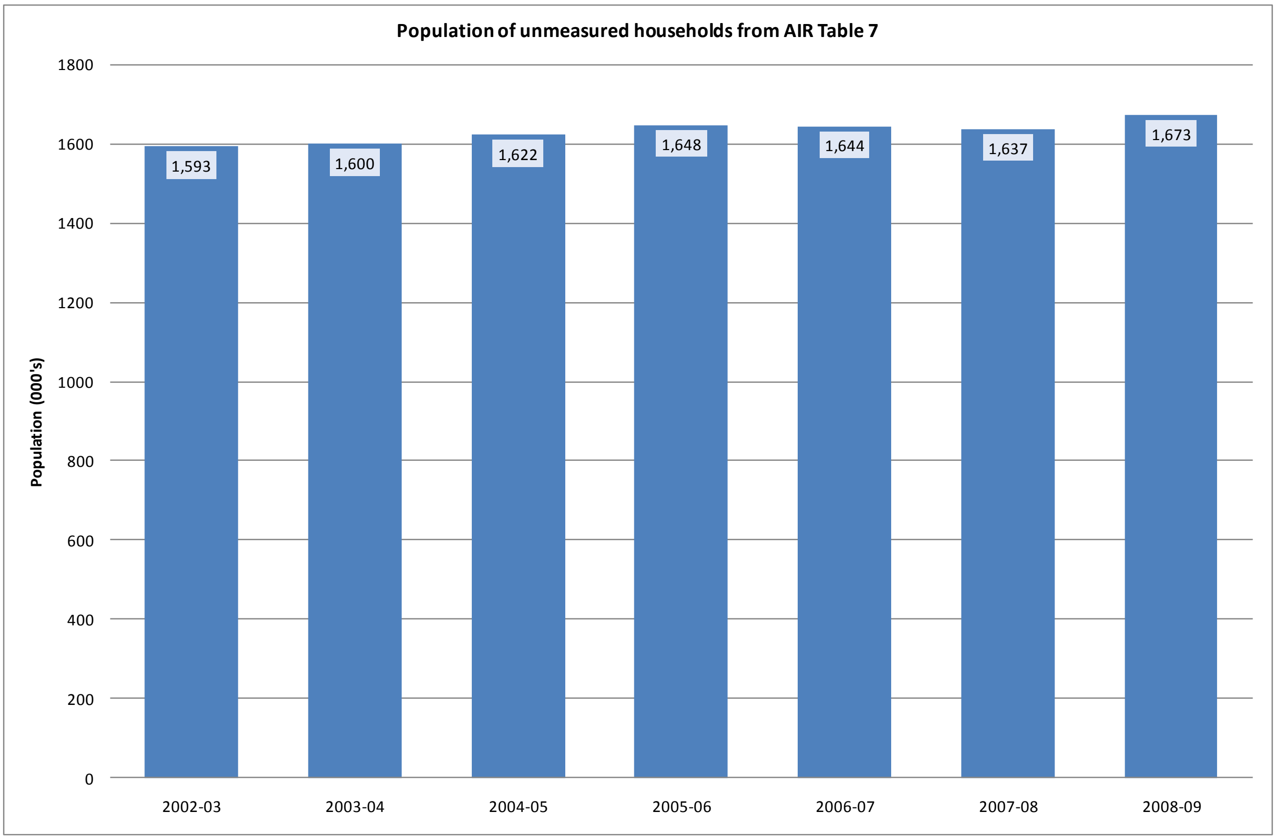


Figure C.25 – Total population of domestic customers in NI Water (from AIR table 7)

In line with the WRPG, it is assumed that void properties have no residential population.

The NI Water data has been apportioned by WRZ. Data was available from AIR09 providing information broken down into 21 resource areas. The percentage contribution of each WRZ to overall population and property breakdown was used to apportion the NI Water Table 7 data into the 21 resource areas. These areas have then been rationalised into 5 new WRZs for this WRMP. A summary of this data is presented in Table C.6.

Population component	NI Water	North WRZ	East WRZ	South WRZ	West WRZ	Central WRZ
Measured household	0	0	0	0	0	0
Unmeasured household	1,672,510	230,070	844,520	382,980	149,390	65,550
Measured non-household	95,930	13,200	48,440	21,970	8,570	3,760
Unmeasured non-household	6,670	920	3,370	1,530	600	260
Total population	1,775,110	244,180	896,330	406,470	158,550	69,570

Table C.6 – Summary of base year (2008–09) AIR09 population data

C.4.3 Base year properties

The number of household properties has increased slightly over the period 2002–03 to 2008–09, as shown in Figure C.26, with a total of 646,100 in the base year.

There is a less clear trend over the same period with regard to non-household customers, as presented in Figure C.27. The total number of non-household properties in the base year was 108,940, which comprised 78,420 measured non-household properties and 30,520 unmeasured non-household customers. Hence the meter penetration rate of non-household customers across NI Water in the base year is approximately 72%.

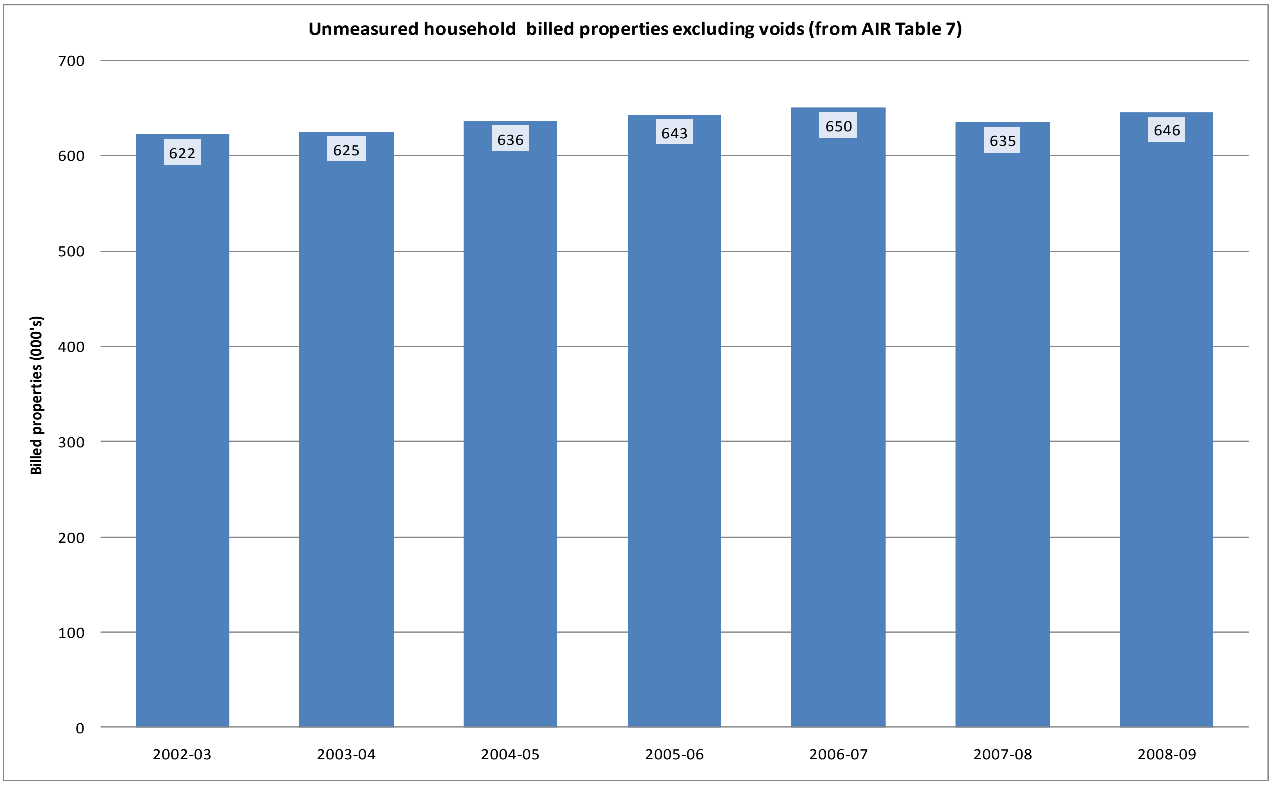


Figure C.26 – Total number of domestic customer properties in NI Water (from AIR table 7)

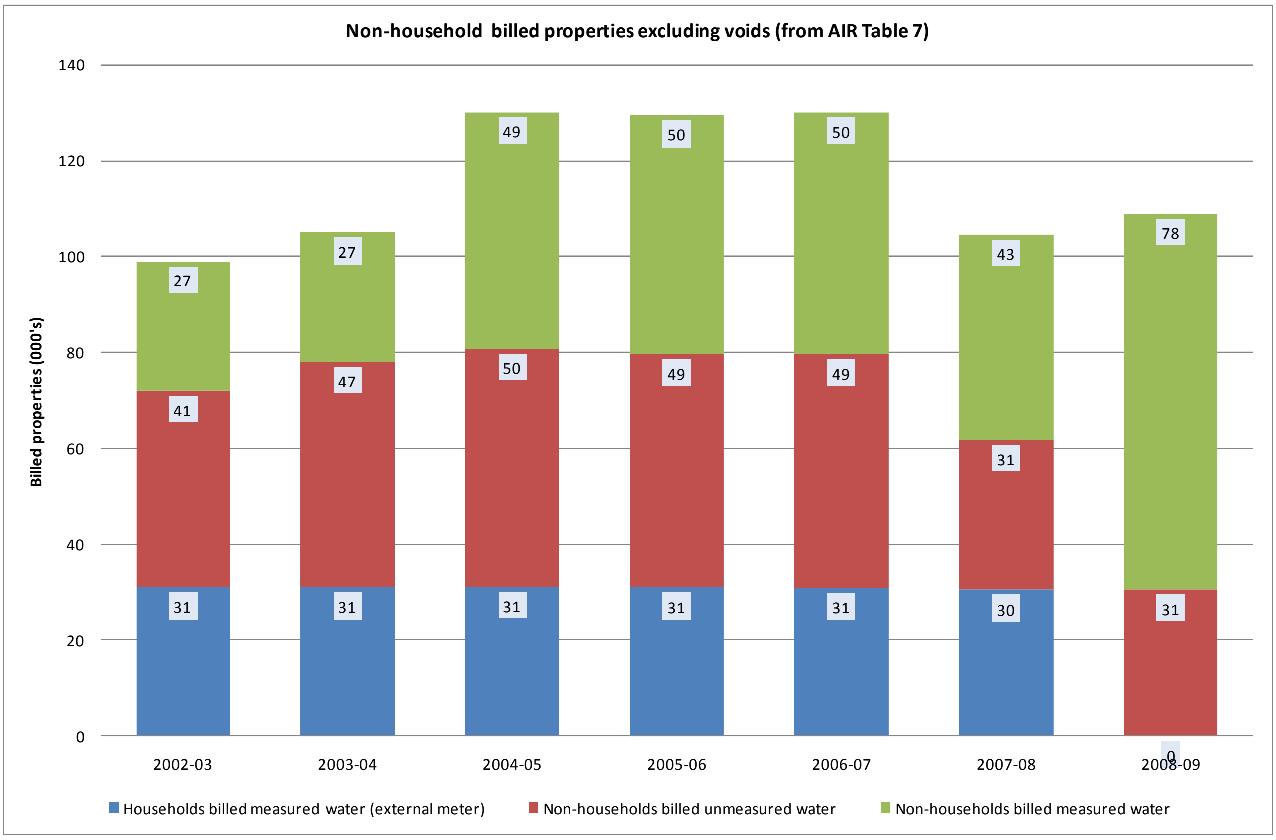


Figure C.27 – Total number of non-household customer properties in NI Water (from AIR table 7)

The NI Water data has been apportioned by WRZ, and the same approach was applied to the base year property data as was used for the population data, as described previously. The split of property data by component for each WRZ is presented in Table C.7 below.

Property component	NI Water	North WRZ	East WRZ	South WRZ	West WRZ	Central WRZ
Measured household	0	0	0	0	0	0
Unmeasured household	646,100	88,880	326,240	147,950	57,710	25,320
Void households	42,530	5,850	21,470	9,740	3,800	1,670
Measured non-household	78,420	10,790	39,600	17,960	7,000	3,070
Unmeasured non-household	30,520	4,200	15,410	6,990	2,730	1,200
Void non-households	7,170	990	3,620	1,640	640	280

Table C.7 – Summary of base year (2008-09) AIR09 property data

Note that total void properties in NI Water were reported in AIR09 as 49,700. For the purposes of the WRMP, these have been split into void households and void non-households according to the ratio of total households to non-households excluding voids. The same approach was used for the WRZ-level derivations.

C.4.4 Data for forecasts

Population and property forecasts are available from the Northern Ireland Statistics and Research Agency (NISRA). The information used at the time of producing the Draft WRMP was downloaded from the NISRA website on 6th Nov 2009. As the base year will remain 2008-09, there has been no update of the population and property forecast. However, this will be reviewed in future WRMPs.

Population data

- 2006-based population projection by Local Government District (LGD) for the period 2006–2021;
- 2006-based population forecast (by age structure) for the whole of Northern Ireland for the period 2006–2056. (Note that the NI total population projection coincides with sum of LGD population projections 2006–2021);
- 2008-based population forecast (by age structure) for the whole of Northern Ireland for the period 2006–2058; and
- Historical population estimates by LGD for the period 1981–2007.

Household data

- Household projections by Local Government District for the period 2006–2021. This includes estimates of average household size by LGD and for Northern Ireland as a whole; and
- Household projections household types for the whole of Northern Ireland for the period 2006–2031. This includes estimates of average household size for Northern Ireland as a whole. (Note that the NI total property projection coincides with sum of LGD property projections 2006–2021).

The projections for which estimates were provided at sub-Northern Ireland level (i.e. LGD level) were 2006-based. The overall 2008-based population projection did not have a LGD level breakdown.

Historic property data does not appear to be available from the NISRA website, so additional analysis using historic trends was not possible for properties.

This information is only available for calendar years, whereas the components of the demand forecast and base year (AIR09) data are all based on financial years. It has been assumed that the calendar year can approximate the financial year – e.g. the population or property projection for the year 2010 could be used to approximate the figure for 2010–11.

In addition to the published NISRA data set, Michael Smyth and Dr Mark Bailey of the School of Economics, University of Ulster, were commissioned by NI Water to conduct an economic outlook for Northern Ireland as part of the PC10 process. This assessment included a section in which NI-level population and property forecasts from NISRA, based on 2006 estimates, were modified to take account of the economic downturn. The University of Ulster adjusted figures were available for the period 2007–2017. After 2017, it has been assumed that the projections will return to the NISRA-based 2006 projection over a five year period.

The Regional Development Strategy (RDS) for Northern Ireland, *Shaping our future*, was published in 2001. An update, *Adjustments to the regional development strategy – 2025*, was published in June 2008. The main change was that the number of additional residential units estimated to be required by 2015 was increased from 160,000 in the original RDS to 208,000 in the adjusted RDS. The adjusted RDS provides a breakdown of these additional units broken down into LGD's. The base year from which additional residential units were estimated was 1998.

1998-based information was not available from the NISRA website, so it was not possible to determine what proportion of "additional residential units" may have already been built and hence included in the 2006-based NISRA figures from which their forecasts are based.

Therefore a policy-based approach is not currently possible. The uncertainties associated with population and household forecasts are included in the headroom analysis (see Appendix D).

The population and property forecasts by Local Government District (LGD) were apportioned into WRZs using an assessment of the percentage of area of each LGD in the 5 WRZs. The percentages assumed are presented in Table C.8.

Local Government District	North WRZ	East WRZ	South WRZ	West WRZ	Central WRZ
Antrim		97.6%	1.8%		0.6%
Ards		100.0%			
Armagh			100.0%		
Ballymena	0.1%	99.6%			0.4%
Ballymoney	89.7%	10.3%			
Banbridge		0.7%	99.3%		
Belfast		96.9%	3.1%		
Carrickfergus		100.0%			
Castlereagh		100.0%			
Coleraine	95.4%				4.6%
Cookstown			0.2%	0.2%	99.6%
Craigavon			100.0%		
Derry	96.3%			3.7%	
Down		87.5%	12.5%		
Dungannon			60.6%	38.9%	0.5%
Fermanagh				100.0%	
Larne		100.0%			
Limavady	97.0%			0.1%	2.9%
Lisburn		53.5%	46.5%		
Magherafelt	7.6%	0.7%		0.1%	91.7%
Moyle	69.5%	30.5%			
Newry & Mourne			100.0%		
Newtownabbey		100.0%			
North Down		100.0%			
Omagh			0.4%	98.0%	1.6%
Strabane	4.9%			93.9%	1.2%

Table C.8 – Summary of base year (2008–09) population data by LGD and WRZ

C.4.5 Analysis for population forecast

A range of data freely available from the NISRA website was analysed for the population forecast, as shown in Figure C.28. This shows both the 2006 and 2008-based projections which run through the planning period. Both projections give similar results, but only the 2006-based projection had a breakdown of the population forecast by Local Government District.

Both the 2006 and 2008-based population projections are supported by the historical trend in population growth in Northern Ireland.

Also shown is the Ulster University adjusted population projection, which takes account of the current economic downturn. Figures were provided for 2007 to 2017. As part of this WRMP, it was assumed that after 2017 the population would return to the original total predicted population over a five year period.

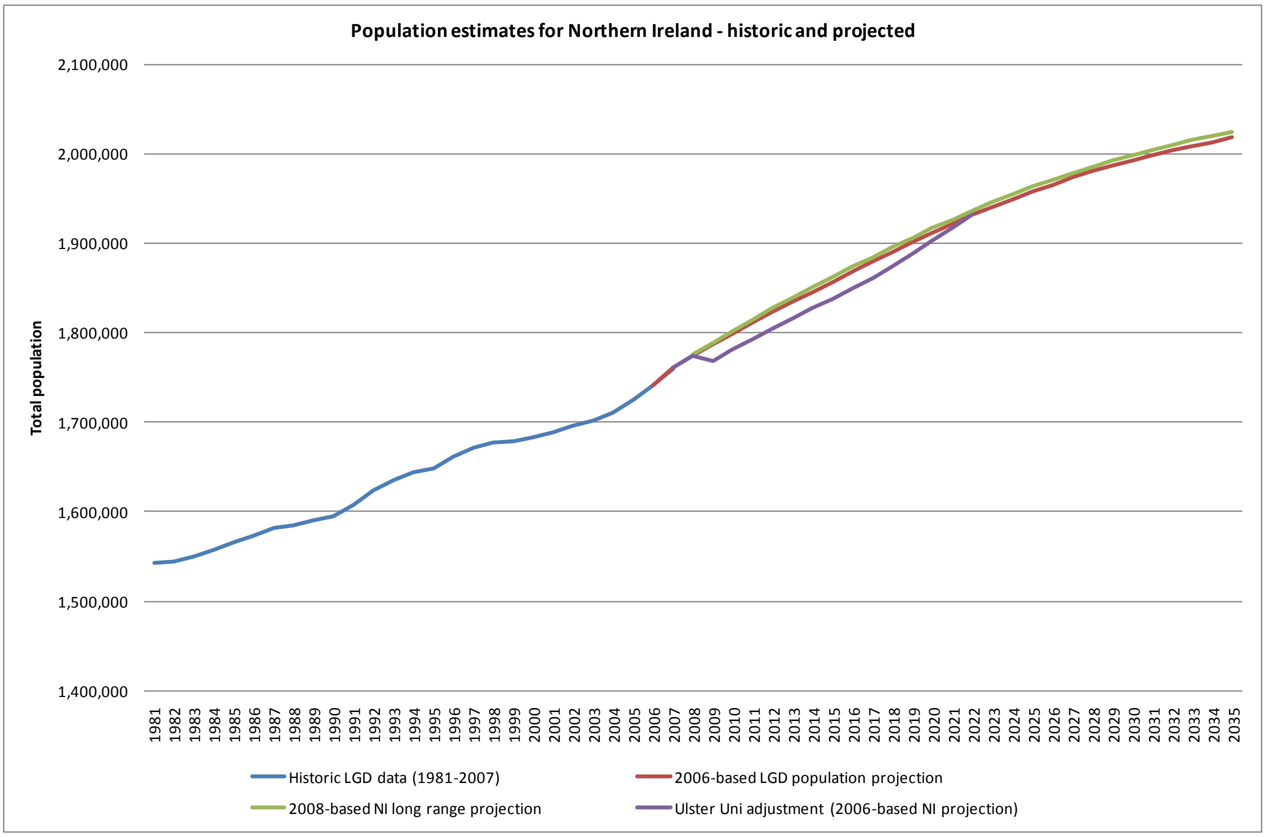


Figure C.28 – Historic and projected population estimates for Northern Ireland (from NISRA)

The base year (2008–09) total population from the NI Water AIR09 submission is 1,775,110, which can be compared with the 2008 year figure from the NISRA (2006-based) population projection of 1,773,620. At the Northern Ireland level, the two numbers are very close. However, for each WRZ the comparative total population figure for 2008–09 from AIR09 and for 2008 from the NISRA projection differed more significantly. These are presented in Table C.9.

WRZ	AIR09 total population, 2008–09	NISRA (2006-based) population projection, 2008
North	244,180	236,680
East	896,330	877,030
South	406,470	402,168
West	158,550	176,250
Central	69,570	81,480
Northern Ireland	1,775,110	1,773,620

Table C.9 – Comparison of AIR09 and NISRA base year WRZ total populations

The overall population forecast was derived for each WRZ, by using the LGD population forecasts from 2006–2021, and the relative area of each LGD in each of the 5 WRZs, combined with the University of Ulster adjusted NI population projection (2007–2017) to account for the potential effects of the economic downturn. From 2022 onwards, the population forecast was available at the NI level only, but the forecast was apportioned on the basis of the percentage contribution of the WRZ population to total NI population in the final year for which detailed information was available (2021).

The annual growth in total population for each WRZ from the NISRA projections has been used in the demand forecast. Note that the Ulster University adjustment actually results in a decrease in population in the East and North WRZs (and for NI Water as a whole) in moving from the base year to the second year of the forecast.

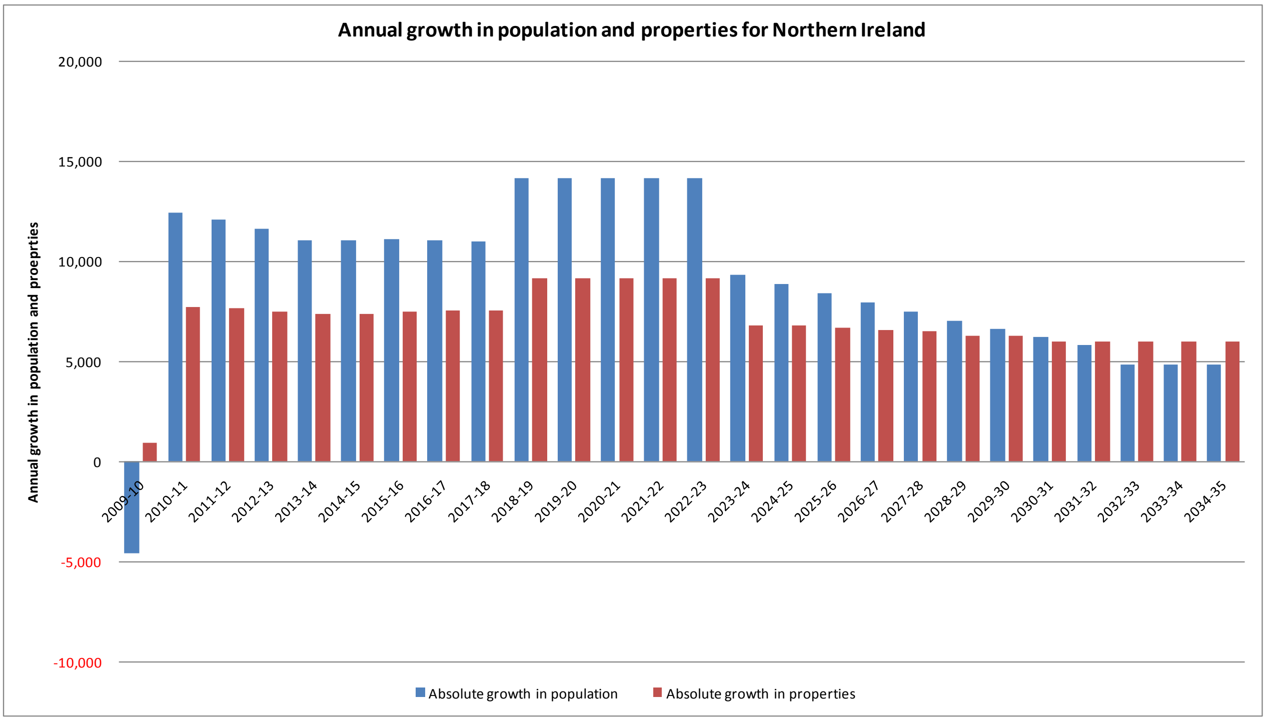


Figure C.29 – Assumed annual growth in forecast population and properties for Northern Ireland in the demand forecast

C.4.6 Breakdown of population forecast

The overall population for each WRZ must be disaggregated into measured/unmeasured households/non-households.

It is assumed that the population of non-households, which is due to people living on farms and in communal establishments (such as hospitals, prisons, educational establishments, etc.), is unlikely to change significantly through time, so the base year non-household population presented in Table C.6 will be kept constant through the planning period to 2034–35.

Therefore, the growth in total population over the planning period is assumed to contribute entirely to the household population.

The Executive has yet to conclude its position on water charging for domestic customers and has deferred domestic water charges until at least 2012. In line with this, there can be no universal domestic metering until a decision is made by the Executive. For the baseline it has therefore been assumed that there will be no metering of domestic customers over the planning period. This means that in the baseline all the growth in total WRZ population has been assigned entirely to the unmeasured household category, and that measured households will be zero throughout the planning period. The potential impact of different domestic metering programmes has however been considered as theoretical options to inform the development of the WRMP.

For the final planning scenario, the demand forecast model must have the flexibility to assess different metering options. Hence, there may be a metered household population. The estimate of this population is based on the assumed numbers of metered properties, multiplied by an assumed occupancy rate. The occupancy rate could differ depending on the metered category. For the purposes of the WRMP, the following occupancy rate assumptions were made:

- Optant metered category – assumed to have a lower occupancy than average, as these customers would tend to be smaller families. However, no information is available on this relevant to NI. Therefore, the average occupancy profile of 1, 2 and 3 person households from the NISRA Northern Ireland level 2006–2031 projection has been used to represent the average occupancy of optant type customers over the planning period;
- New household metered category – like optants, new households tend to have a smaller average occupancy than the existing housing stock. The same occupancy rate profile as for the optant metering category has therefore been used;
- Change of occupier metering category – it has been assumed that the average occupancy profile of this category will be the same as the overall occupancy profile for the all domestic customers in each WRZ; and
- Universal (compulsory) metering category – the same occupancy profile as for change of occupier metering has been assumed.

The results of these assumptions on occupancy rate are shown in Figure C.30.

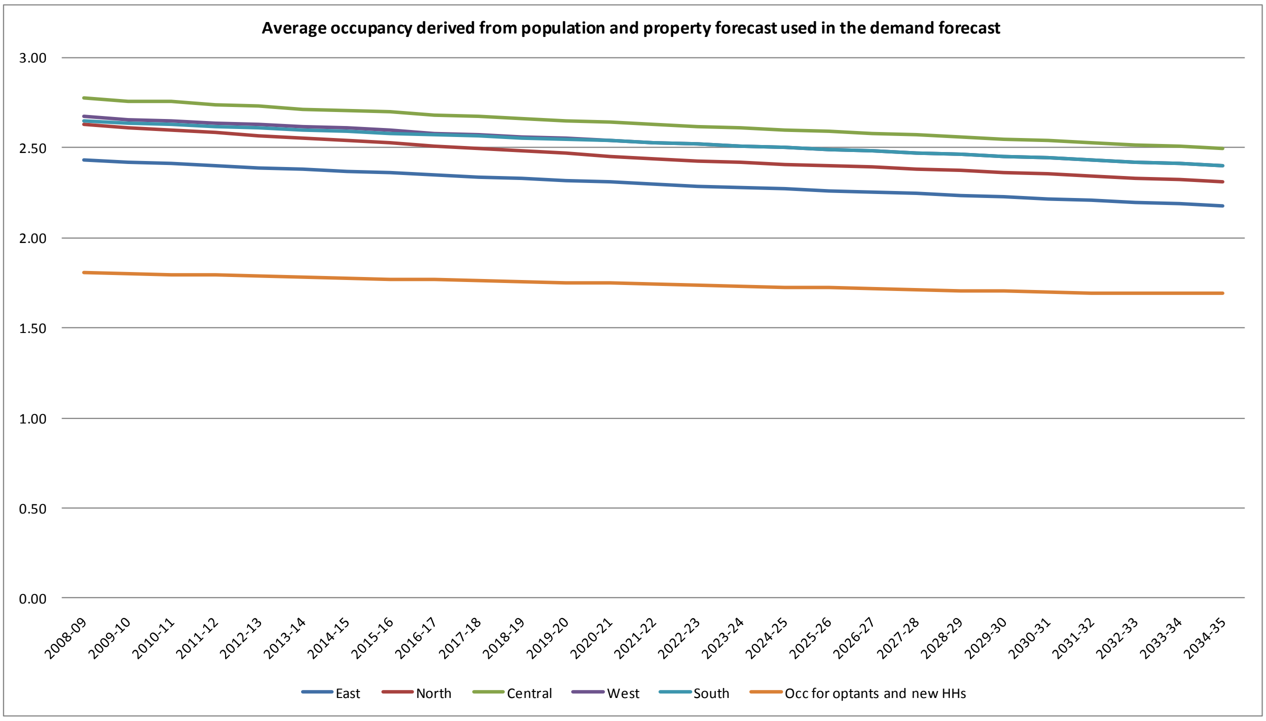


Figure C.30 – Assumed overall average occupancy rate profile for each WRZ and for optant and new household customers

The population of unmeasured household customers is calculated as a residual of the total population minus the populations of non-households and measured households.

C.4.7 Analysis for property forecast

NISRA property data was also examined for the property forecast, as presented in Figure C.31. On the whole, less data and information was available for the property projections. 2006-based property projections were available down to Local Government District, for the period 2006–2021, while an overall Northern Ireland level forecast was available until 2031.

Like the population forecast, there was also an Ulster University adjusted property projection, to take account of the current economic downturn. Figures were provided for 2007 to 2017. As part of this WRMP, it was assumed that after 2017 the population would return to the original rate predicted over a five year period.

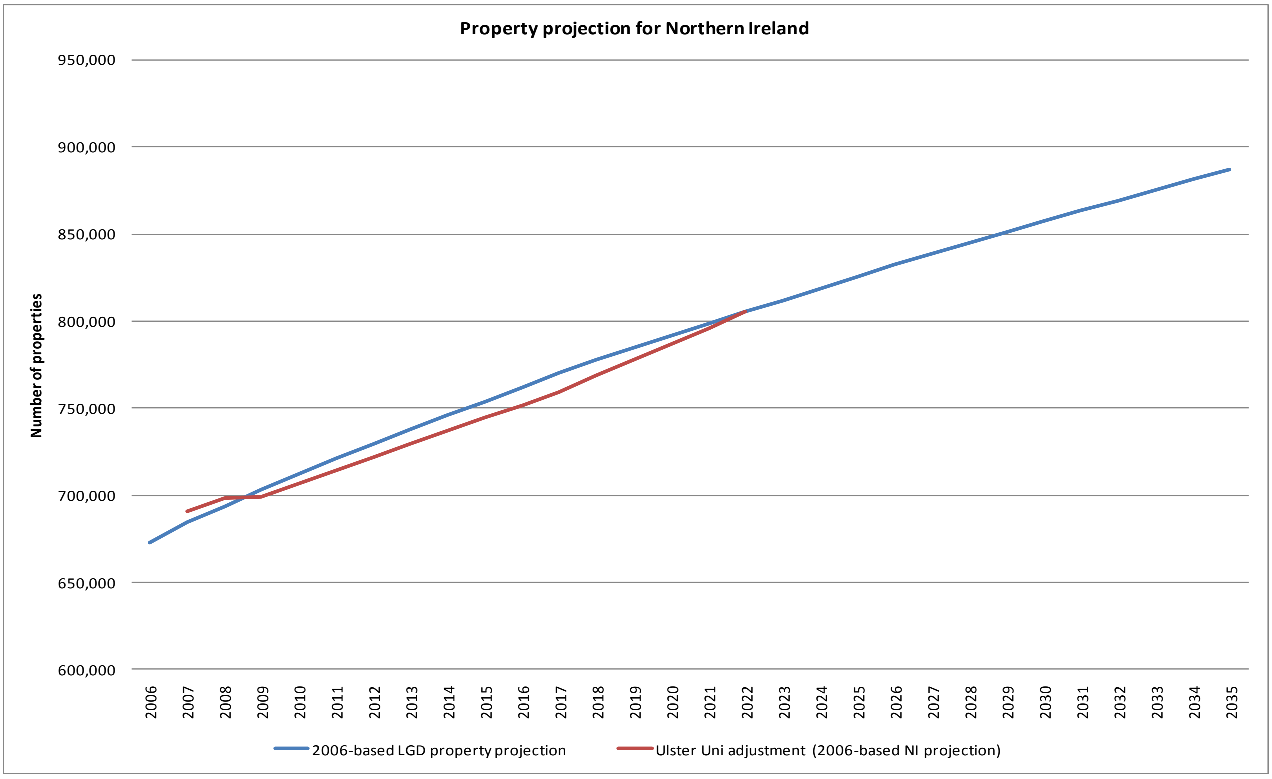


Figure C.31 – Property projection estimates for Northern Ireland (from NISRA)

The overall property forecast was derived for each WRZ, by using the LGD projections from 2006–2021, and the relative area of each LGD in each of the 5 WRZs, combined with the University of Ulster adjusted NI property projection (2007–2017) to account for the potential effects of the current economic downturn. From 2022 onwards, the property forecast was available at the NI level only, but the forecast was apportioned on the basis of the percentage contribution of WRZ properties to total NI properties in the final year for which detailed information was available (2021). This forecast was only available until 2031. After this point, it was assumed that annual growth from 2030 to 2031 would continue until the end of the planning period.

The annual growth in total domestic properties for each WRZ from the NISRA projections has been used in the demand forecast. Note that the Ulster University adjustment actually results in a decrease in properties in the East WRZ in moving from the base year to the second year of the forecast.

Occupancy rates

As part of the NISRA data set, a forecast of occupancy for Northern Ireland was also available, as shown in Figure C.32. This suggests that the average occupancy in Northern Ireland is expected to fall from a level of 2.55 in 2006 to an estimated 2.26 by 2031.

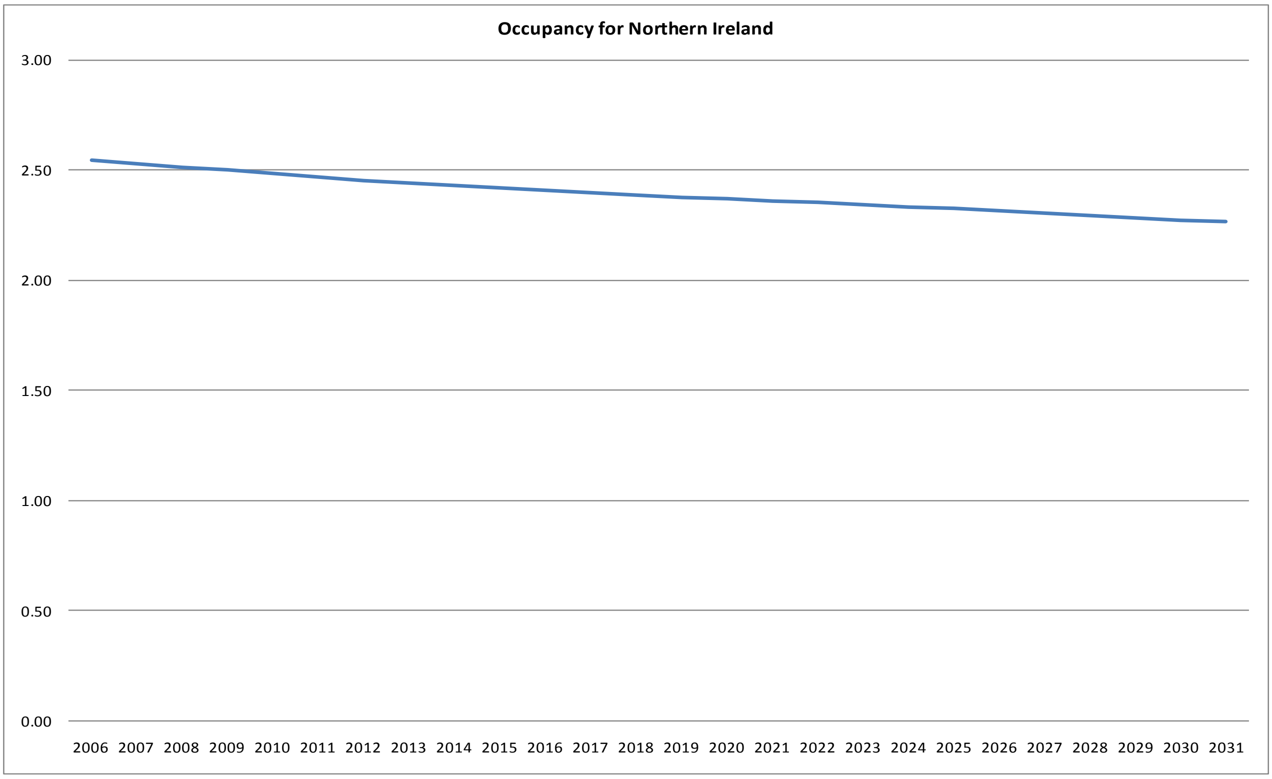


Figure C.32 – Occupancy projection estimates for Northern Ireland (from NISRA)

C.4.8 Breakdown of property forecast

The overall number of properties for each WRZ must be disaggregated into measured and unmeasured households.

It is assumed that non-household properties included in the forecast will be due to people living on farms, and that the total number of farms is unlikely to change significantly through time, so the growth in properties forecast by NISRA for each WRZ will be solely attributable to households.

As noted in section C.4.6, the Executive has yet to conclude its position on water charging for domestic customers. It has therefore been assumed that the growth in total WRZ properties should be entirely assigned to the unmeasured household category which means that measured households will remain as zero through the planning period.

Nevertheless for the final planning scenario, the demand forecast model must have the flexibility to assess different metering options. Current government policy is to defer a decision on the applicability of metering until at least the next price control period, in accordance with instructions from the Minister for Regional Development. Hence for the purposes of this WRMP, the metering of domestic properties has been considered as a theoretical option only. The assumptions regarding different scenarios for metering domestic properties are discussed in section 8 Options Appraisal of the main WRMP.

The unmeasured household properties would be derived by subtracting any customers switching to metering in any given year from the previous year unmeasured household properties total, plus any growth in domestic properties excluding any proportion of this who would become metered under the new household metering category.

C.4.9 Baseline population and property forecasts

Using the assumptions outlined in the previous sections, the following forecasts of population and properties, broken down into metered and unmetered households and non-households were derived, as shown in Figure C.33 and Figure C.34 respectively.

These assume AIR09 population and property values for each customer category in the base year (2008–09). The forecast is derived using NISRA 2006-based forecast and incorporates the Ulster University adjustments where available. However, because of discrepancies between the 2008 NISRA figure and the 2008–09 AIR09 data and because of the uncertainties associated with apportioning data into the 5 WRZs for the WRMP, the annual growth in the combined NISRA/Ulster University adjustment forecasts has been used rather than the absolute numbers.

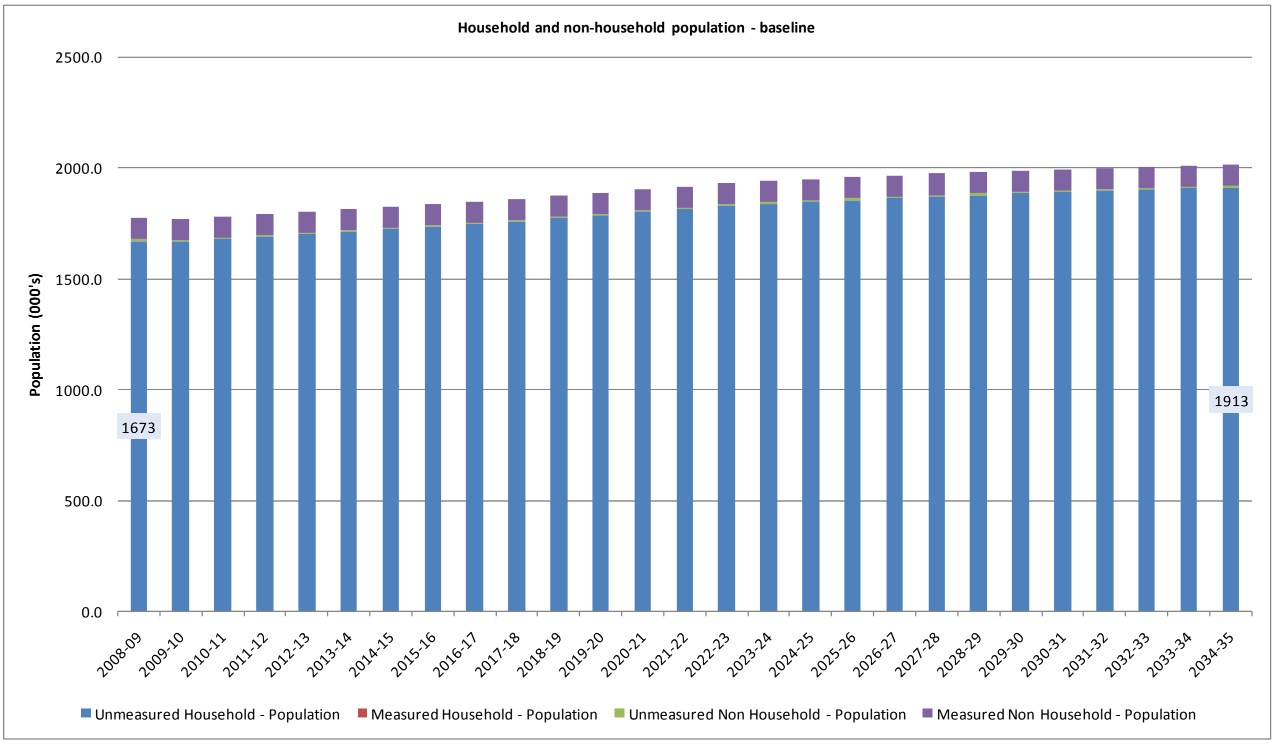


Figure C.33 – NI Water population forecast by customer category

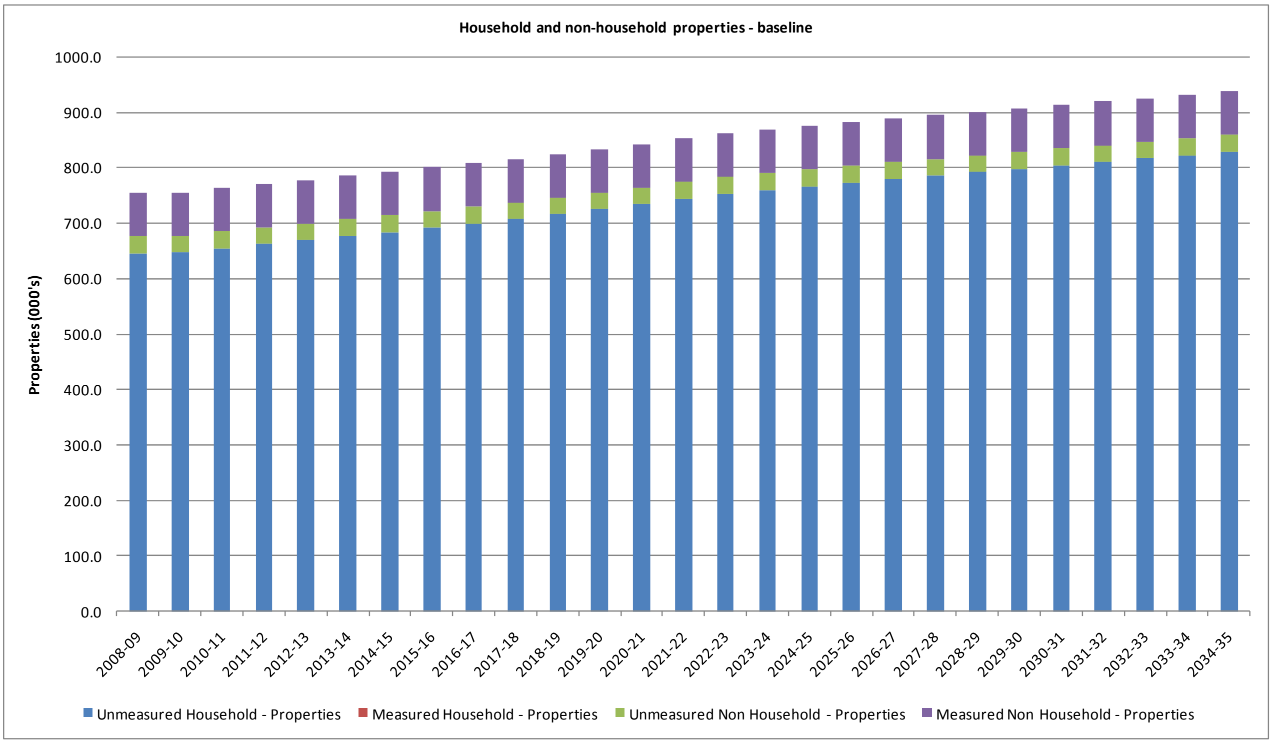


Figure C.34 – NI Water property forecast by customer category

C.5 Household demand

The purpose of this section of the Appendix is to present the key issues and assumptions associated with the household demand forecast. The household demand component accounts for a significant proportion of the base year water balance, as shown in Figure C.35.

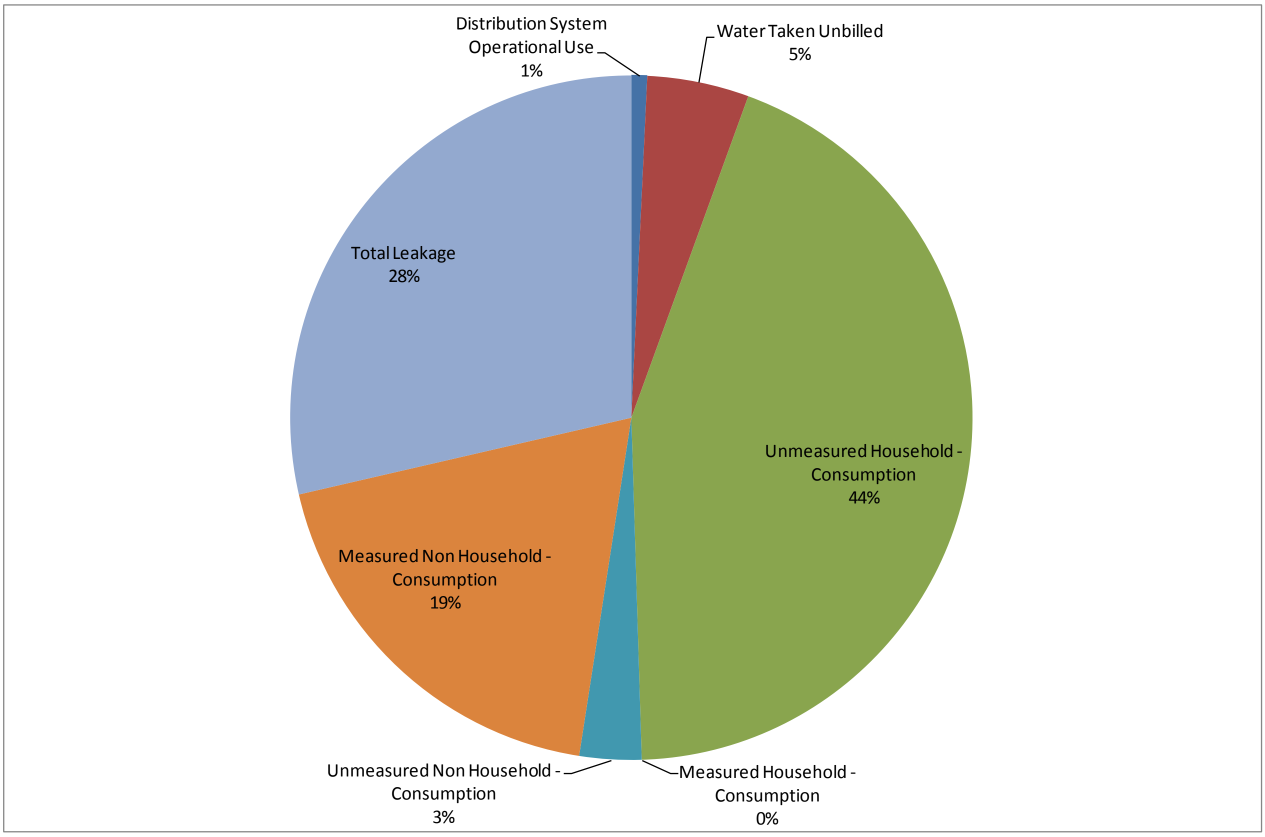


Figure C.35 – Base year (2008–09) water balance components

There is currently no charging of domestic customers, and plans to do so have been deferred until at least the next price control period, in accordance with instructions from the Minister for Regional Development.

C.5.1 Base year household demand

Unmeasured domestic consumption figures reported in the Annual Information Return 2009 (AIR09) were derived using a small area consumption monitor of 115 small areas to derive per capita consumption (PCC). A review of the sites within the consumption monitor was conducted by NI Water/Crowder Consulting in 2008–09 with the result that data quality is considered by NI Water to have improved through the year. Further rationalisation of the consumption monitor was planned for 2009–10.

All small areas reportedly contain only unmeasured household properties – there are no measured household or non-household properties. Of the 115 areas available, 101 were actually used in the assessment of PCC for 2008–09, the other 14 areas being excluded for various quality reasons. Around half of the areas have fewer than 30 properties, so are sensitive to small changes in usage and population.[12]

A major survey of customers within the consumption monitor was completed in spring 2008, providing a count of property types and any vacant properties within each area. 85% of the households in the small areas completed surveys providing information on occupancy, use of appliances at night and awareness of water saving devices.[12]

Data from AIR09 was used to derive the base year household demand. The AIR09 data has been reconciled using the maximum likelihood estimation (MLE) method so that the sum of estimated components is equal to the distribution input.

This data was disaggregated to derive WRZ-level estimates. The disaggregation made use of MLE-adjusted demand estimates for 21 resource areas, all of which were assigned to one of the five WRZs used for the WRMP. This allowed the post-MLE unmeasured household demand for the company to be apportioned between the five WRZs.

The base year MLE-adjusted unmeasured household demand was used to derive a calculated base year PCC in each WRZ. However, there was some discrepancy in the overall NI Water base year PCC estimates:

- The calculated value from the consumption monitor suggests a PCC of 141.5 l/h/d (although this value does not allow for any MLE adjustment); and
- The value for PCC from AIR09 used in the demand forecast for the WRMP is 166.2 l/h/d.

There were also reasonably large differences between the calculated estimates of PCC in each WRZ (Table C.10). This can be explained on the basis of estimation of the split of AIR09 population data into each WRZ, which may be refined in future. It could also be partly a function of potential differences in the socio-economic characteristics of customers in different areas. For example, the proportion of each property type (and associated garden size) is likely to vary between urban and rural areas, with urban areas being likely to have more apartments and rural areas more detached houses with larger gardens; affluence of the customer base may vary in different parts of Northern Ireland; the population demographic and therefore water using behaviours may vary; and local climate characteristics may also induce differences in consumption.

WRZ	Normal year annual average PCC in base year, 2008–09 (l/h/d)
North	148.1
East	166.9
Central	157.9
West	149.6
South	183.4
Company	166.2

Table C.10 – Estimates of base year PCC in each WRZ derived from values in AIR09

[12] Crowder Consulting, June 2009, *Per capita consumption report*

C.5.2 Forecast household demand

The baseline forecast shows how demands in dry years are expected to change through time. For WRZs where a supply demand balance (SDB) deficit is predicted during the planning period a final planning forecast is also required. This should give consideration to the introduction of demand management schemes to reduce demand as part of a twin track approach to meeting SDB deficits.

Trend analysis

Figure C.36 shows the trend in unmeasured household demand (including supply pipe leakage) in recent years, based on AIR submissions.

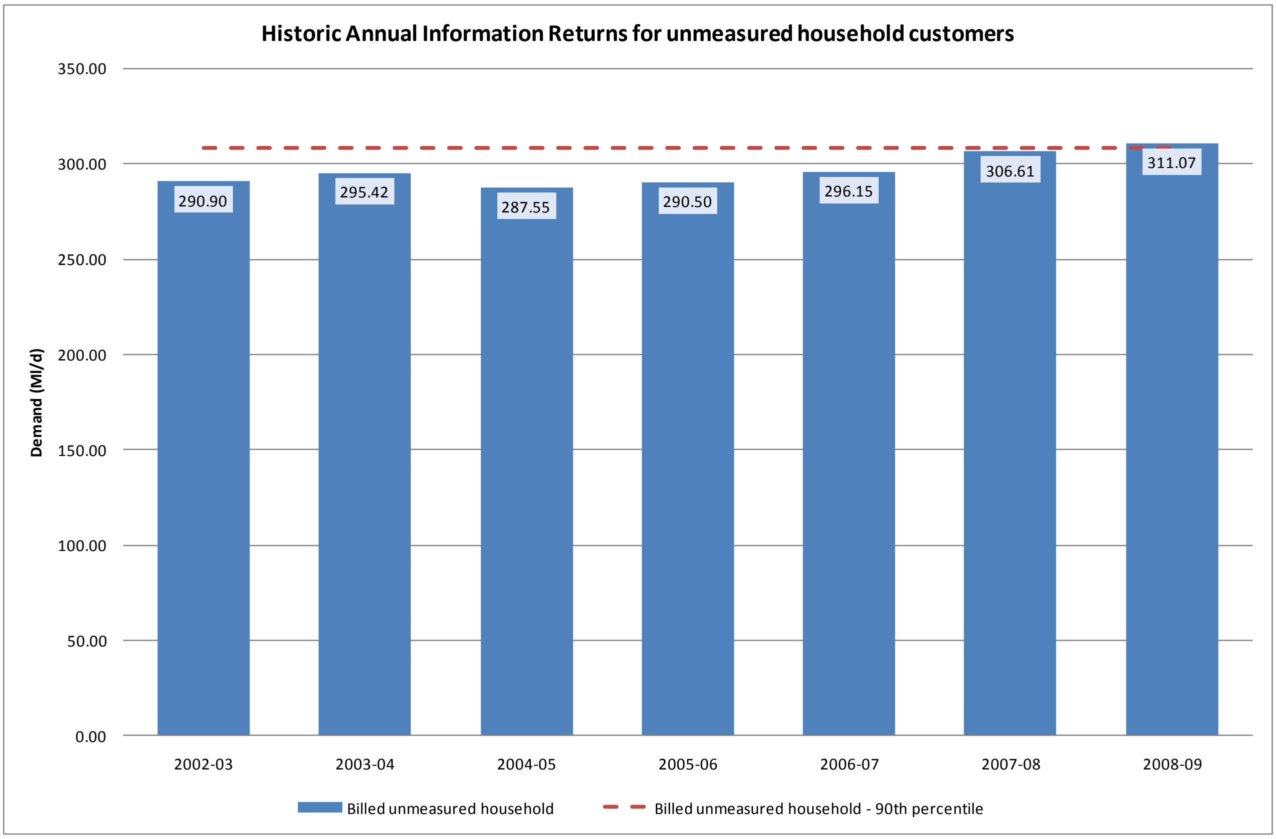


Figure C.36 – Unmeasured household demand from AIR submissions

It should be noted that there is a general lack of confidence in the historic data available, and there may also have been a change in methodology in the estimation of PCC and demand in recent years compared to earlier estimates. The accuracy of the proportioning of distribution input into the components of unmeasured consumption and leakage may change from year to year. Changes in the customer base over the period of analysis, especially in terms of increasing population, will affect the trend of household demand over time. Climatic effects will also normally influence the household demand seen in any given year, although section C.2 presented analysis which suggests that the annual average household demand does not appear to correlate strongly with year to year variations in the weather conditions that would affect customer demands.

C.5.3 Micro-component analysis and forecast

There is a strong focus in the WRPG towards micro-component analysis and then forecasting of PCC. Micro-component analysis can be a useful means of building up an impact assessment profile of likely or known regulatory, behavioural and technological changes that influence household water consumption. For example, trends have been identified in the past suggesting a move towards increased frequency of personal washing, reflecting rapid growth in shower ownership but declining use of baths. Micro-component analysis allows such trends to be incorporated into a demand forecast in a readily quantifiable way. This helps to develop a plausible range of estimates of how per capita consumption may change through time, as an alternative to historical trend analysis.

The potential components of household demand comprise the following eight categories of micro-components:

- Toilet flushing;
- Bath use;
- Shower use;
- Clothes washing;
- Dish washing;
- Garden use;
- Car washing; and
- Miscellaneous use.

The approach to calculating total consumption for each micro-component involves the equation outlined below (often referred to as OFV analysis):

Micro-component consumption (litres per head per day, l/h/d) = *Ownership (% of population) x Frequency of use (per head per day) x Volume per use (litres)*

For some micro-components, frequency of use data is estimated on a per household basis. This is most appropriate for household appliances such as dishwashers and washing machines, where there is not usually more than one per household. In these cases, frequency of use per person is calculated by dividing the frequency of use per household by the relevant occupancy rate.

Volume per use for some micro-components can be calculated using the following variables:

Volume per use (litres) = Duration of use (unit time) × Flow rate (litres per unit time)

A value for each of the three key variables (ownership, frequency of use and volume per use) was derived for each micro-component. These were multiplied together for each micro-component, and the total consumption of individual micro-components summed to give an overall estimate of PCC.

The assumptions underlying the derivation of these values are listed in Table C.11.

Component	Ownership assumptions	Frequency of use assumptions	Volume per use assumptions
Toilet flushing	WRc (2005) confirmed the logical assumption that all customers have a toilet.	Ofwat (2008) states that companies in England and Wales should assume **5 flushes per person per day**.	**8.8l/flush** assumed for base year, as average of estimates from WRc (2005), MTP and EA (2003). Proposed Water Supply (Water Fittings) Regulations (Northern Ireland) 2009 will require newly installed cistern volumes to be no more than 6l. Toilet replacement rate of 15 years estimated in Regulations, thus all toilets expected to consume **6l/flush** by end of planning period.
Bath use	Average of the following sources: twelve water companies' Draft WRMPs (except Veolia Water East) in Waterwise (2009), MTP (2008a, cited in Waterwise, 2009) and WRc (2005). Base year ownership estimated at 92%, moving to 91% by 2020 (MTP (2008a, cited in Waterwise, 2009). Decline assumed to continue at same rate until end of planning period, reaching 90% in 2034/35.	Average of the following sources: twelve water companies' Draft WRMPs in Waterwise (2009), MTP (2008a, cited in Waterwise, 2009) and WRc (2005). Base year value of 42%. Some of the sources describe frequency of use per household per day. These values have been varied according to NI Water occupancy rate hence frequency of use increases to 43% by end of planning period.	Average of the following sources: twelve water companies' Draft WRMPs in Waterwise (2009), MTP (2008a, cited in Waterwise, 2009) and WRc (2005). Base year value of 79.02l/use, assumed constant throughout planning period as no evidence was found to suggest otherwise.
Shower use	Split into electric, mixer and power showers. Estimates are averages from twelve water companies' Draft WRMPs in Waterwise (2009) and MTP (2008a, cited in Waterwise, 2009), and for power showers, sources also included CCW (2007). Base year ownership 34% for mixer and electric showers, and 21% for power showers. No change across planning period for electric and mixer showers as no evidence was found to suggest otherwise. Power shower ownership assumed to double due to increasing affordability of power showers and customers' desire for an improved personal washing experience (in line with EA (2001) Beta scenario).	Split into electric, mixer and power showers. Estimates are averages from twelve water companies' Draft WRMPs in Waterwise (2009). 0.8 showers/day assumed for all showers in base year. Some of the sources describe frequency of use per household per day. These values have been varied according to NI Water occupancy rate hence frequency of use increases for each shower by a total of 0.1 showers/day by end of planning period.	Split into electric, mixer and power showers. Estimates are averages from twelve water companies' Draft WRMPs in Waterwise (2009). Some companies reported variations in duration of shower and flow rates. Total consumption per use was taken forward into micro-components analysis. 39.7l/shower was therefore assumed for electric and mixer showers, and 77.7l/shower was assumed for power showers. This was not assumed to change by end of planning period as no evidence was found to suggest otherwise.

Component	Ownership assumptions	Frequency of use assumptions	Volume per use assumptions
Clothes washing	Average of Defra Sustainable Products paper and WRc (2005) resulted in ownership of 86%. From this value. The average ownership of washer driers was subtracted, as customers are considered unlikely to have both. Washer drier ownership assumed from average of Waterwise (2008) and Defra Sustainable Products paper to be 15% of all customers.	Average of Herrington (1996) and WRc (2005) assumptions led to estimate of 0.3 uses/day. These figures were described in the sources as frequency of use per household per day. They have therefore been varied according to NI Water occupancy rate. Frequency of use increases to 0.31 uses/day by end of planning period. Same assumptions used for washer driers.	Waterwise 'Water Consumption of Components of Domestic Demand' assumption of 80l/use used in base year, reflecting predominance of machines manufactured before 2000. Replacement rate of once every 12 years (Waterwise, 2008) led to development of assumption that machines manufactured after 2000 will be widespread by end of planning period, with Waterwise assumption of 50l/use being used.
Dish washing	Defra Sustainable Products paper states that full size dishwashers comprise the majority of sales in the UK. Average of MTP and WRc (2005) figures suggest ownership of 33% in base year. EA (2001) Beta scenario forecasts an increase of 2% per annum, which has been assumed in micro-components analysis, such that ownership is 54% by end of planning period. Dishwashing by hand assumed to be all customers not having a dishwasher in base year, remaining constant over planning period at this value as many customers will still wash by hand as well as having a dishwasher.	WRc (2005) and EU Energy Label suggest 0.26 uses/day as a reasonable assumption. The EU Energy Label value related to number of uses per household per year, so this has been altered for NI Water occupancy rate (hence the slight variation over the planning period), and also converted to a value per day. Dishwashing by hand once a day per household was assumed to be a logical assumption, adjusted for the NI Water occupancy rate throughout the planning period.	Base year volume per use of 20.1l/use taken as average of WRc (2005), Waterwise (2008) and Waterwise 'Water Consumption of Components of Domestic Demand'. This is assumed to decrease to 14l/use as dishwashers manufactured after 2000 become more prevalent (Waterwise 'Water Consumption of Components of Domestic Demand'), then remaining constant to end of planning period. The average of volume per use of dishwashing by hand using a bowl with the tap off and using a plugged sink (Waterwise 'Water Consumption of Components of Domestic Demand') was taken throughout the planning period. This was 12l/use.
Garden use	Sprinklers assumed owned by 40% of customer base, aligned with the percentage of households in NI Water company area that are detached (Crowder Consulting, 2008). Assumed to increase to 50% by end of planning period, in line with the proportional increase assumed by EA (2001) in Beta scenario. Hosepipes assumed owned by 52% of customer base, aligned with the percentage of households in NI Water company area that are semi-detached or terraced (Crowder Consulting, 2008). Assumed to increase at rate of 0.5% per annum, as assumed in Northumbrian Water's Draft WRMP (cited in Waterwise, 2009). Results in hosepipe ownership of 65% by end of planning period.	Assumed sprinklers and hosepipes are each used once per household every other day during the three month or 90 day summer period (June–August inclusive). This equates to 0.05 uses/person/day in the base year, adjusted for the remainder of the planning period by NI Water occupancy rate.	Assumed a reasonable length of time for each use of a sprinkler or a hosepipe would be 10 minutes. At average flow rates derived from WRc (2005) and Waterwise 'Water Consumption of Components of Domestic Demand', this equates to 167l/use for sprinklers and 90l/use for hosepipes. Assumed the same values throughout planning period as no evidence was found to suggest otherwise.

Component	Ownership assumptions	Frequency of use assumptions	Volume per use assumptions
Car washing	Northumbrian Water assumes in its Draft WRMP that home car washing with a bucket and sponge is carried out by 7% of the population, whilst home car washing with a hosepipe is carried out by 51% of the population.	Northumbrian Water assumes in its Draft WRMP that the average customer washes their car 26 times per year, with either a bucket and sponge or a hosepipe. This equates to 0.07uses/person/day.	Average of Waterwise 'Water Consumption of Components of Domestic Demand' and Northumbrian Water Draft WRMP implies volume per use of 49l/use for bucket and sponge car washing, and 200l/use for hosepipe car washing.

Table C.11 – Assumptions of ownership, frequency and volume per use for micro-components

Information sources

- Consumer Council for Water, led by MVA Consulting in association with WRc (2007) Face-to-face interviews with 2,006 participants
- Crowder Consulting for Northern Ireland Water (June 2009) Per Capita Consumption Report, Version 0.2
- Defra, Sustainable products – Improving the energy efficiency of energy-using products: Domestic Wet Products, a consultation implementing the 2007 Energy White Paper
- Environment Agency (2001) A scenario approach to water demand forecasting
- Environment Agency (2003) The economics of water efficient products in the household
- Essex and Suffolk Water (2008) Draft Water Resources Management Plan
- European Union, EU Energy Label
- Herrington (1996) and Downing et al. (2003) Climate change and the demand for water
- Market Transformation Programme (MTP) http://efficient-products.defra.gov.uk/cms/market-transformation-programme/
- Northumbrian Water (2008) Draft Water Resources Management Plan
- Ofwat (October 2008) Water efficiency targets 2010–11 to 2014–15
- Portsmouth Water (2008) Draft Water Resources Management Plan
- Proposed Water Supply (Water Fittings) Regulations (Northern Ireland) 2009
- Severn Trent Water (2008) Draft Water Resources Management Plan
- South Staffordshire Water (2008) Draft Water Resources Management Plan
- South West Water (2008) Draft Water Resources Management Plan
- Southern Water (2008) Draft Water Resources Management Plan
- Sutton and East Surrey Water (2008) Draft Water Resources Management Plan
- Thames Water (2008) Draft Water Resources Management Plan
- Veolia Water Central (2008) Draft Water Resources Management Plan
- Veolia Water East (2008) Draft Water Resources Management Plan
- Veolia Water Southeast (2008) Draft Water Resources Management Plan
- Waterwise (April 2009) The Water and Energy Implications of Bathing and Showering Behaviours and Technologies

- Waterwise, Database containing over 260 washing machine models available on the UK market in 2007, representative of over 25 brands
- Waterwise, prepared for Defra (2008) Water and energy consumptions of dishwashers and washing machines: An analysis of efficiencies to determine the possible need and options for a water efficiency label for wet white goods
- Waterwise, Water Consumption of Components of Domestic Demand
- WRc (2005) Increasing the value of domestic water use data for demand management

Northern Ireland context

Domestic properties in Northern Ireland are not metered. The micro-component analysis undertaken for this WRMP has therefore been based on assumed characteristics and likely behaviours of occupants of unmeasured households.

Climatic factors

The following assumptions have been considered when designing the micro-component analysis such that it is relevant to the general climatic conditions experienced in Northern Ireland:

- The climate is not considered conducive to high swimming pool ownership. As such, any water use related to the filling of swimming pools has been incorporated in the 'Miscellaneous use' category;
- It is logical that the external use of water, in particular for garden watering, will vary with climate: specifically temperature and rainfall. The assessment of external use in this micro-component analysis for Northern Ireland has been based partially on the assumptions made by water companies operating in areas of England with similar climatic conditions, e.g. the North West; and
- The potential impacts of climate change have not been explicitly incorporated into this micro-component analysis. Although it could be argued that certain behavioural and regulatory changes might be partially attributable to underlying messages relating to climate change, the direct impacts of climate change in terms of, e.g. warmer temperatures resulting in a requirement for increased garden watering, have not been incorporated. The potential impacts of climate change on demand have been incorporated separately and explicitly in the demand forecast as an addition to overall PCC.

Occupancy rate

As described above, for those micro-components where frequency of use data is estimated on a per household basis, the occupancy rate derived for the Northern Ireland Water company area has been used to calculate frequency of use per person. The variation in occupancy rate over the planning period has also been taken into account in the quantitative assessment of consumption of these micro-components.

Property type

The water consumption of some micro-components is often related to property type, in particular the amount of water used in garden watering since property type is often a useful proxy for estimating garden size and therefore the amount of watering required. As such, it is useful to have an appreciation of the housing stock within the company's area. Data of this nature has been aligned with that presented in Northern Ireland Water's *Per Capita Consumption report*, which are based on Northern Ireland Statistics and Research Agency (NISRA) figures. The values shown in Table C.12 have been assumed.

Household type	Percentage of total NI Water households
Apartment	8%
Terraced	29%
Semi-detached	23%
Detached	40%

Table C.12 – Household type in the Northern Ireland Water supply area

Temporal variation

Demand for water can be forecast for different planning scenarios: normal year or dry year, and annual average or critical period. Micro-component consumption has been analysed for the WRMP based on assumptions relating to a normal year annual average scenario.

Base year

There is currently no information available regarding micro-component demand for domestic customers in the base year. The information sources used to derive the base year micro-component values are referenced in Table C.11, along with the assumptions made.

The micro-component analysis was assumed to apply equally to all water resource zones across Northern Ireland. Although, the base year PCC estimate for each WRZ, derived from AIR09 data, shows a range of values.

Planning period (2008–09 to 2034–35)

The Environment Agency in England and Wales published 'A scenario approach to water demand forecasting' in 2001[13] which underpinned its national strategy and eight regional supporting strategies to 2026. Whilst there have been other, more recent, publications carried out by a number of bodies, the EA report remains a source of useful material relating to how to forecast micro-component demand over time.

The EA report brings together information from eight water companies in the eight different EA regions as a baseline from which to assess potential impacts on consumption of changes in social values, science and technology and systems of governance. Figure C.37 illustrates the proportional breakdown of consumption by different micro-components for an average person assumed in the report.

[13] Environment Agency (August 2001) *A scenario approach to water demand forecasting*, National Water Demand Management Centre, Environment Agency

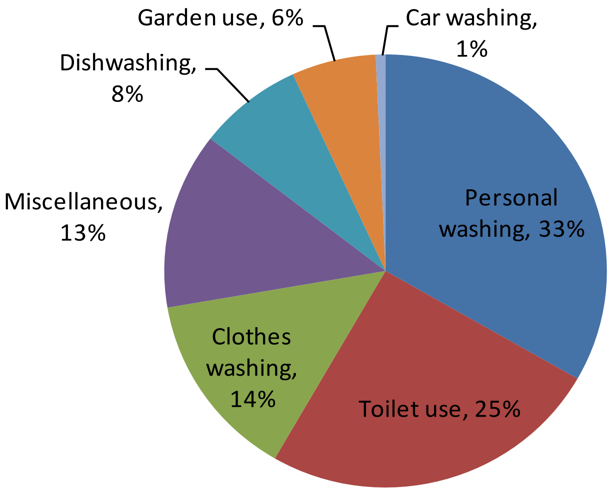


Figure C.37 – Breakdown of PCC into micro-components (EA, 2001)

The EA scenario approach draws on the former Department of Trade and Industry's Foresight 'Environmental Futures' framework. Four scenarios were developed through identification and classification of the drivers of demand. To provide context, the drivers relating to household demand are summarised in Table C.13.

Driver classification	Driver
Water policy	Metering Water Regulations
Technology	White goods Miscellaneous
Behaviour	Type and pattern of personal washing Garden watering
Economics	Personal affluence Market forces The value of water

Table C.13 – Key drivers of household demand

Based on the above classifications, possible future outcomes were developed into the scenarios summarised below.

- Scenario Alpha
  - Growth in personal affluence is stifled;
  - Limited availability and uptake of new water efficient technologies; and
  - Replacement of white goods declines.
- Scenario Beta
  - High economic growth;
  - Technological innovation leads to increasingly water efficient white goods; and
  - Discretionary uses of water increases.

- Scenario Gamma
  - Tighter regulation and promotion of new technology reduces water use of fixtures and fittings;
  - Increase in personal affluence; and
  - Positive consumer attitude to the environment reflected in purchases of more efficient appliances.
- Scenario Delta
  - Marked shift in consumer attitudes and water using behaviour;
  - Widespread uptake of demand management measures; and
  - Decline in discretionary use of water.

The above scenarios were evaluated in light of the current economic and political situation and in the context of Northern Ireland. It was decided that the Beta scenario was the most representative of likely future activity in Northern Ireland. A full description of the scenario is provided here, followed by the reasoning behind its selection:

"With high economic growth, technological innovation leads to improvements in the water efficiency of white goods and average washing machine use reduces to 50 litres by 2025. Discretionary uses of water increases, with more pressure washers, power showers and swimming pools."

Although economic growth in the short term (i.e. the next 2–3 years) is likely to stay fairly constant due to the recession, there are other drivers for technical innovation, such as the carbon agenda and increasingly stringent requirements for and promotion of water efficient behaviour, for example the Government's UK-wide ACT ON CO_2 campaign[14]

Economic recovery is likely in the medium to long term, with market forces starting to again drive technological innovation. HM Treasury compiles independent forecasts of the UK economy, the latest of which predicts an increase in the UK's gross domestic product (GDP) from −4.5% in 2009 to +2.7% in 2013[15]. Sir David Varney's recent 'Review of the Competitiveness of Northern Ireland'[16] makes recommendations which, if implemented, will improve the economic standing of the region in the medium to long term. This is taken to act as evidence in support of long term economic improvement and consequential affluence of the businesses and the population.

Unmeasured households such as those in Northern Ireland Water's company area, lack the financial incentive to minimise consumption that accompanies water metering. As such, increased power shower and pressure washer purchases will not be discouraged from a financial perspective, apart from where consumers make the link between energy and water savings. The increase in personal washing observed by Herrington from 1976–1990 is assumed to continue. Furthermore, as power showers become more popular, it is likely that competition amongst suppliers could push the price down, so even if personal affluence does not increase significantly, it may not impact upon the sale of power showers as much as might be expected.

For the reasons stated above, the EA's Beta scenario was considered to be the most applicable to the Northern Ireland context throughout the planning period to 2034–35, with the relevant micro-component assumptions being reflected in the quantitative analyses.

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[14] http://actonco2.direct.gov.uk/actonco2/home.html.
[15] HM Treasury (November 2009) Forecast for the UK economy: a comparison of independent forecasts; contains forecasts to 2013 http://www.hm-treasury.gov.uk/d/200911forcomp.pdf.
[16] Sir David Varney (April 2008) Review of the Competitiveness of Northern Ireland, Office of Public Sector Information

Micro-component forecast

The micro-component analysis has been used to derive estimates for change in PCC throughout the planning period. The rate of change in total micro-component consumption, as calculated using the micro-component model, excluding 'miscellaneous use', has been used as the basis for the forecast of PCC over time within the demand forecast. The total change in PCC from the micro-components analysis was calculated as an absolute value and a percentage.

A breakdown of PCC into constituent micro-components is presented in Figure C.38 and in Table C.14 (both excluding miscellaneous use), also demonstrating the variation in micro-component consumption over the planning period from the base year 2008–09 to 2034–35.

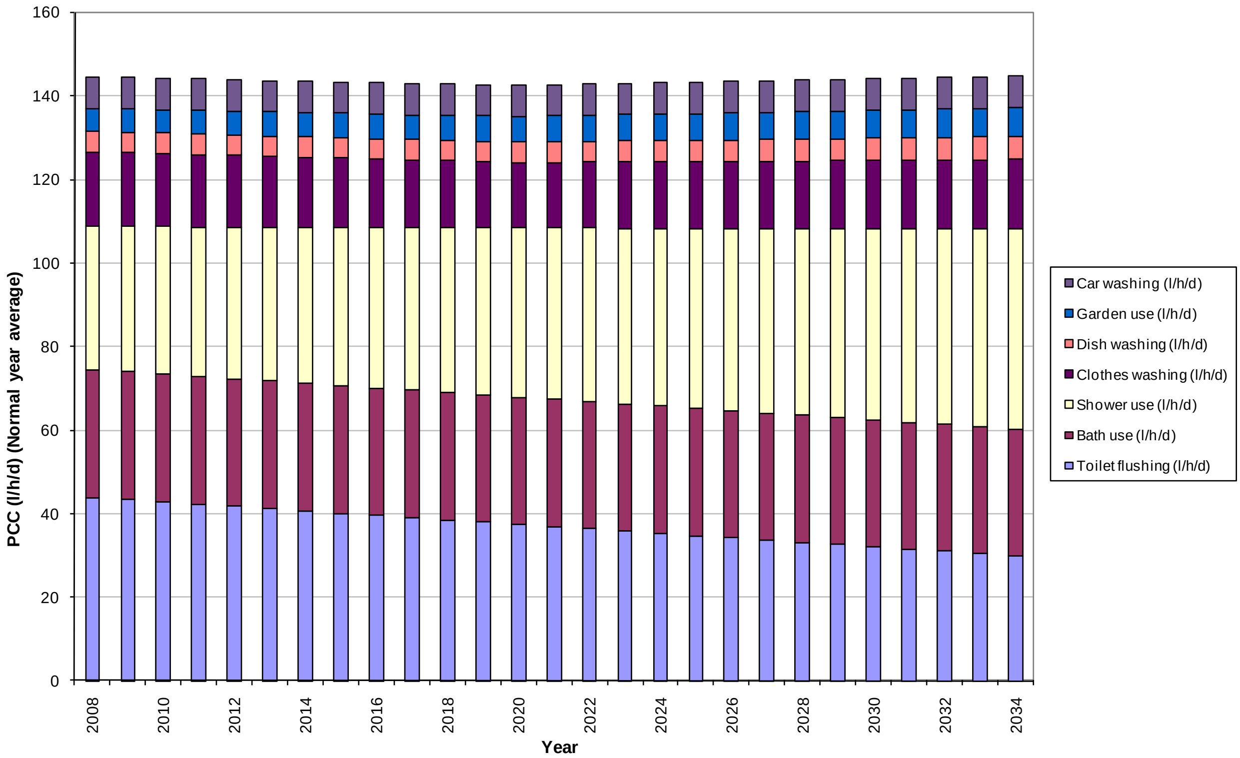


Figure C.38 – Variation in micro-component PCC in "normal years" over the planning period

Micro-component	2008–09 Consumption (l/h/d)	2034–35 Consumption (l/h/d)
Toilet flushing	44.00	30.00
Bath use	30.63	30.37
Shower use	34.25	47.95
Clothes washing	17.94	16.61
Dish washing	4.88	5.61
Garden use	5.51	6.88
Car washing	7.51	7.51
Sub-Total	**144.71**	**144.93**

Table C.14 – Summary of base year and end of planning period normal year PCC for quantifiable micro-components

Figure C.38 shows that total PCC calculated from micro-components is relatively constant, although there are variations in the individual components. The aggregate increase in normal year consumption for those micro-components for which reasonably robust estimates can be derived is just 0.2 l/h/d over the whole of planning period. This corresponds to a 0.15% increase in consumption over the planning period, or approximately 0.006% growth per annum. This minimal percentage increase in PCC suggests that a flat profile of PCC should be assumed in the demand forecast (i.e. PCC should effectively remain constant through the planning period). The miscellaneous use micro-component has been excluded, and the micro-component analysis does not allow for climate change or additional water efficiency promotion activity over what is currently conducted.

The observed trend in consumption over the planning period can be attributed to variations in a number of micro-components. In many cases, it is just one element which drives the change in a micro-component's consumption, i.e. either ownership, frequency of use or volume per use. Changes in levels of ownership generally illustrate responses to market or economic drivers; variations in frequency of use largely demonstrate behavioural differences and changes in attitudes to water efficiency; and changes in volume per use could be argued as being a combination of behavioural changes and technological advances.

Over the whole planning period a fairly significant decline of 14 l/h/d in the use of water in toilet flushing is observed. This is countered almost exactly by the assumed increase of 13.7 l/h/d in use of water in showers. More minor changes in consumption over time are observed in other micro-components, as follows:

- −0.3 l/h/d change in bath consumption;
- −1.3 l/h/d reduction in clothes washing consumption, with increases in washing machine ownership largely being counteracted by improvements in the water efficiency of the appliances;
- 0.7 l/h/d increase in dish washing consumption, with the impact of increases in ownership again being largely counteracted by expected improvements in appliance efficiency; and
- 1.4 l/h/d increase in garden water use.

C.5.4 Dry year forecast

Dry year annual average baseline

The forecast was derived from AIR09 household demand, calculated PCC values, and the PCC forecast as outlined above. It has been assumed that this forecast represents a "normal year" condition; so it must be scaled up to derive a household demand in "dry year" conditions.

The analysis of dry years was described in section C.3. In summary, the approach used was to derive an overall dry year demand (distribution input) which is at the upper limit of what the company feel could reasonably be met before demand restrictions need to be considered. The household and non-household components of demand were then adjusted so that the calculated overall DYAA demand for each WRZ is reached in the base year (2008–09). All other components of demand were assumed to be unaffected by dry years.

Dry year factors were thus derived to be applied to household PCC for each WRZ. The derived dry year PCC values for the base year (2008–09) are presented in Table C.15. The values represent unmeasured household customers only, as there are no metered household customers in the baseline.

WRZ	Dry year annual average PCC in base year, 2008–09 (l/h/d)
North	166.3
East	187.6
Central	181.1
West	173.1
South	210.5

Table C.15 – Base year PCC in each WRZ for DYAA

As described previously, the micro-component analysis suggested little change in overall PCC over the planning horizon – only 0.006% growth per annum on average. For this reason a flat PCC profile was applied in the demand forecast. Such a profile is logical, given that no metering of household customers has been allowed in the baseline case (see section C.4.6) and thus there is no direct financial incentive through water bills for customers to conserve water. Note that ongoing NI Water activity to promote water efficiency is effectively incorporated in the base year estimates of household demand and PCC, and is thus implicitly included in the baseline forecast – the assumption is that a similar level of water efficiency promotion is expected to continue throughout the planning period.

The estimated impacts of climate change on demand are also included in the baseline dry year annual average demand forecast. These have been derived from the *Climate change and demand for water (CCDeW)* work for England and Wales (Defra 2003). The North West region of England has been used as a proxy for NI, as discussed further in section C.7. Adjustment factors were derived to be applied to the household PCC forecast (it also includes factors to be applied to non-household demand).

C.6 Non-household demand

A base year and forecast for non-household demand is required in each water resource zone (WRZ). Non-household demand can generally be split into broad industrial categories, based on Standard Industrial Classification (SIC) codes or similar, where relevant data is available. Section 4.5 of the DRD guidelines states:

"Non-household demand should be split into broad industrial categories, as far as this is feasible."

The WRPG suggests that a detailed set of forecast assumptions be developed that consider how socio-economic growth, emergence of more efficient technology and the impact of regulation will influence non-household demand in future years.

One approach to forecasting non-domestic demand could be to develop econometric forecasts for different industrial sectors. This approach can be relatively simple, but depends on whether there is a base year breakdown of non-domestic demands by SIC (or similar) available. Such an assessment was conducted, with a focus on the short term, as part of the PC10 process by the University of Ulster (28th May 2009).

Another approach could involve the analysis of historic data to assess recent trends in demand, and thus determine reasonable assumptions for forecasting demand.

Section 4.5 of the DRD guidelines states:

"Where possible, the WRMP should describe the assumptions that underpin its forecast assessments and describe how factors such as socio-economic growth, advances in technology and regulatory changes will influence the pattern of water use in each non-household category in future years."

The WRPG also recommends that companies provide a description of the assumptions that underpin the base year including the uptake of water efficiency measures in each category and the assumed savings that are included in the baseline water efficiency policy. In reality, any existing NI Water activity promoting water efficiency amongst non-household customers will already be incorporated in the base year (AIR09) demand data. Separating and quantifying the exact saving in demand from this activity requires estimation and is subject to high levels of uncertainty. Further, the forecast will also incorporate inherent water efficiency savings actually seen in the non-household demand component of the base year. So for the baseline forecast, which assumes that water efficiency activity will remain the same as in the current year, no additional assumptions of water efficiency savings are required. However, under the final planning scenario, water efficiency options are considered for both households and non-households.

C.6.1 Base year non-household demand

Base year data from the Annual Information Return 2009 (AIR09) was reconciled using the maximum likelihood estimation (MLE) method so that the sum of all estimated demand components is equal to the distribution input. The base year AIR09 data can therefore be used to derive the non-household demand experienced across the company for both measured and unmeasured customers. This data must then be disaggregated to derive WRZ-level estimates.

The preferred approach to disaggregating non-household demand by WRZ would generally be to obtain the measured non-domestic consumption data directly from NI Water's billing database, disaggregated into WRZs on the basis of spatial information recorded in the database. However, there are some limitations to this approach. Even though a reasonably large proportion of non-domestic customers are believed to be metered, there is also a significant unmetered component of non-household demand. Additionally, at the time of undertaking the analysis to develop the demand forecast for the Draft WRMP, only around 80% of metered non-domestic customers had a spatial reference in the billing database. Therefore, the remaining 20% of metered non-domestic customers cannot be assigned directly to a WRZ so would need to be apportioned in some way, probably on a pro rata basis. Unmeasured non-household consumption at the company level from the AIR09 water balance would also be disaggregated to WRZ level using pro rata assumptions, such as on the basis of the number or demand of measured non-household customers in each WRZ.

However, this level of database information was not available for the derivation of demand used in the Draft WRMP. Instead, the disaggregation made use of MLE-adjusted demand estimates for 21 resource areas (reported for the AIR09 submission), all of which were assigned to one of the five WRZs used in this WRMP. This allowed the post-MLE non-household demand for the company to be apportioned between the five WRZs.

It should also be possible to report the non-domestic customer demands by industrial sector from the customer database, using classifications based broadly on the Standard Industrial Classification (SIC) codes. The main purpose for doing this would be to try to derive more accurate and robust non-domestic demand forecasts for specific sectors. However, an updated breakdown by SIC code was not available, so this type of approach has not been adopted.

C.6.2 Baseline non-household demand forecast

As part of the PC10 submission, the University of Ulster were commissioned to produce a paper providing an economic outlook, overview and discussion of growth rates for revenue. Section 3 of this considered non-domestic demand.

The report provided a breakdown of NI Water non-household demand according to broad (2 digit) SIC codes (based on an average of October 2008 and February 2009 annualised figures) in simple percentage terms. This has been reproduced in Table C.16 below.

Sector	Percentage of demand
Agriculture and forestry	32.50%
Hospitals, schools and public sector offices	22.09%
Non-metal manufacturing and processing	12.02%
Food and drink manufacturing	8.55%
Pubs, restaurants, cafes, hotels and B&Bs	7.03%
Shops	5.17%
Energy generation	3.00%
Electronics industry	1.53%
Art, entertainment, leisure	1.24%
Chemical industry	0.95%
Other (no sector with >1% of total consumption is included in this category)	5.92%

Table C.16 – Summary of non-household water consumption by sector (University of Ulster 2009)

The report notes that, based on historical trends of new business start-ups in recessions, growth in non-household customer numbers of 2.0–2.5% per year on 2008 levels by 2012 is possible. Thereafter the authors estimate growth for non-domestic customers from 2013–2017 of 2.0–2.5% based on VAT and PAYE enterprises in NI in the period 2003–2008. However, there is no discussion of any reduction in non-household customers from bankruptcies etc. in the same period.

The report provides an economic outlook (over the short term) for each of the main sectors of the NI economy. The headline conclusions are summarised below:

- Agriculture – water consumption expected to be fairly constant (baring weather-related effects);
- Hospital, schools and public sector offices – unlikely to see any significant effects on water consumption outside of a push towards more efficient use of water (as part of cost saving activity);
- Non-metal manufacturing and processing – water consumption likely to decline in the short term before picking up in 2011–12, but generally manufacturing has been less badly effected in NI than in the rest of the UK;
- Food and drink manufacturing – sector may actually grow from 2008–09 onwards;

- Pubs, restaurant, cafes, hotels and B&Bs – recovery in this sector likely to be slower than in other parts of NI economy;
- Shops – the food sector component may benefit from the recession as customers switch to consumption at home, before then returning to normal levels;
- Energy generation – Unlikely to see any significant effects on water consumption outside of a push towards more efficient use of water (as part of cost saving);
- Electronics industry – same comment as for non-metal manufacturing;
- Art, entrainment and leisure – Recovery likely to be slower than in other parts of NI economy; and
- Chemical industry – same comment as for non-metal manufacturing.

The University of Ulster report sets out a forecast for the period 2009–2013. The report predicts that consumption is most likely to return to base year levels around 2013. This forecast (for the most likely scenario) is reproduced in Table C.17.

2009	2010	2011	2012	2013
95.9%	96.6%	98.5%	99.9%	100.9%

Table C.17 – Short term forecast of non-household water consumption (University of Ulster 2009)

Note: 2008 = 100%

The report also provides a longer term forecast, which the authors feel is likely to be 0.5–1.0% growth per annum, which can be compared to Scottish Water's estimate of annual growth in consumption of 0.3%.

An alternative method to assess potential non-household demand is based on trend analysis of historic data, such as from AIR for the period 2002–03 to 2008–09. The trend for non-households (which includes the "measured household" category, which is assumed to be farms) is shown in Figure C.39.

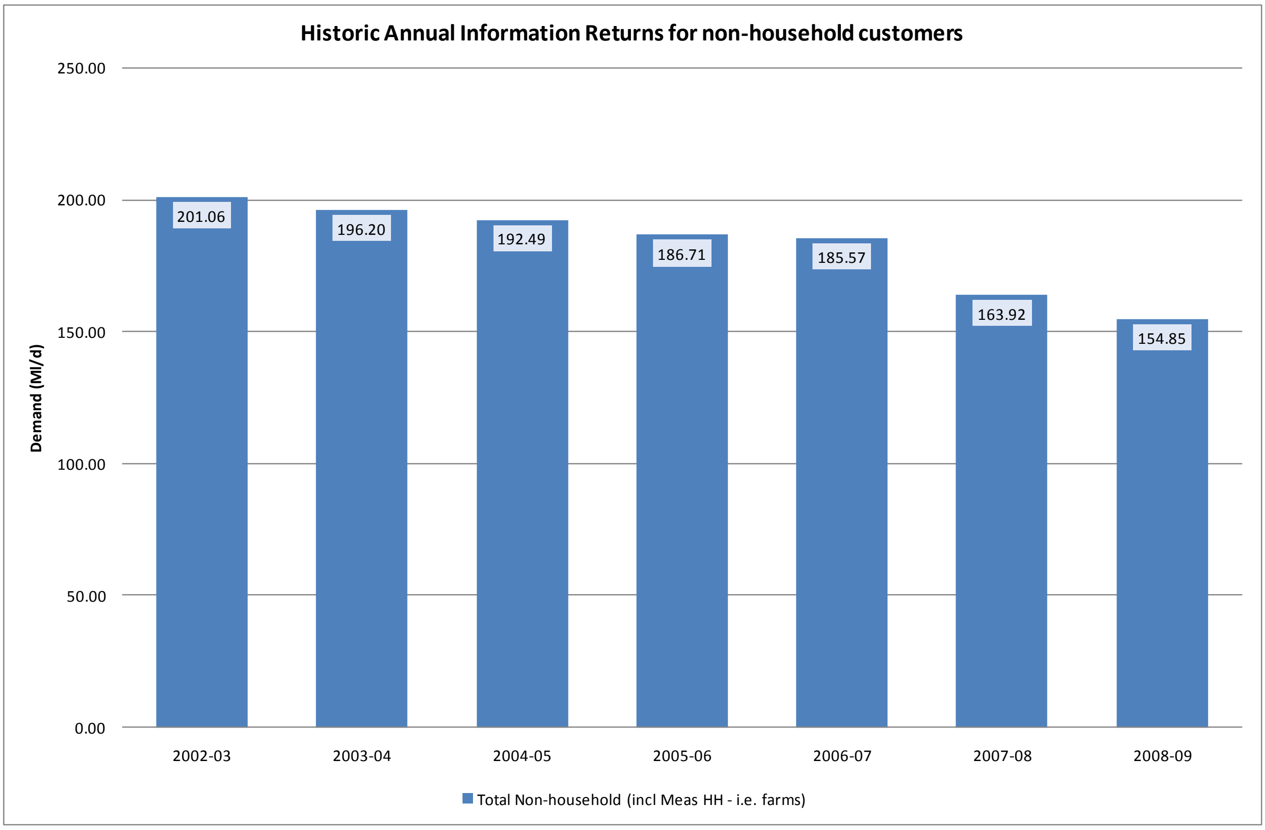


Figure C.39 – Non-household demand from Annual Information Returns, 2002–03 to 2008–09

The University of Ulster report provides an economic summary, which states that there were almost 25 years of continuous growth and rising employment before the Northern Ireland economy fell into recession during the second half of 2008. Yet in terms of water consumption the trend analysis conflicts with the economic review, as it shows a decline in non-household water consumption over the period 2002–03 to 2008–09. Overall this suggests that the relationship between economic activity on the whole and water consumption by non-household customers may be weak.

Given this disparity in correlation, and the trend in non-household demand over recent years shown by data reported in the AIR, the long term forecast of water consumption growth of up to 1% per annum (University of Ulster, 2009) seems high and potentially unrealistic.

Therefore, the lower bound of the University of Ulster forecast of annual growth in water consumption (0.5%) has been being applied in the demand forecast from 2014 onwards. The growth rate from 2009–10 to 2013–14 is based on the University of Ulster forecast of the impact of the recession, suggesting a contraction of 4.1% in 2009-10 (a drop compared to the base year), followed by growth in subsequent years so that by 2013 non-household demand is approximately back to the base year 2008–09 level.

C.6.3 Dry year

The demand forecasts developed for non-household customers in a “normal year” must be uplifted by a “dry year” factor to derive non-household demands for the dry year annual average (DYAA) scenario, where climatic impacts are expected to impact on non-household demand.

As discussed in section C.3, there is little direct evidence of weather related impacts on non-household demand. However, it is generally assumed that some sectors will be affected by climatic factors, for instance agriculture. As a result, a small allowance has been made for increased demand in a dry year, by applying a dry year factor of 1.05 on non-household demand in each WRZ, based on expert judgement.

C.7 Climate change impact on demand

The *Climate Change and Demand for Water (CCDeW)* report was published in February 2003 to provide guidance on planning for future changes in demand caused by climate change. A set of factors describing the impact of climate and socio-economic change were produced for household and non-household demand.

In terms of climate change, the study analysed temperature (monthly maximum, minimum and mean), precipitation, radiation, potential evapotranspiration (PET), relative humidity and wind speed. The mean changes in the climate variables for the 2020s (2011–2040) and the 2050s (2041–2070) were used. These relate to changes from the average of the climate model simulated baseline period, 1961–1990.

The study area was limited to England and Wales, with the 125 water resource zones condensed into 52 zones for the purpose of assigning climate change scenario values. These were then further condensed into eight regions: Anglian, Midlands, North East, North West, South West, Southern, Thames and Wales.

Limitations of CCDeW

CCDeW was based on data and techniques available at the time. However, there are a number of limitations:

- It only covers England and Wales;
- There is no PET data in the UKCIP02 5 km database which therefore required further modelling to derive the data;
- All figures are for unconstrained demand; actual water use will be limited by availability and price and the resulting responses will themselves alter demand elsewhere;
- The impact of climate change on demand refers to average demand and not peak demand – i.e. changes in the frequency and magnitude of extreme events are not included; and
- The main results pertain to the regional level, rather than the water resource zone level.

C.7.1 Method

An immediate limitation of CCDeW is that it does not include Northern Ireland (NI). With no alternative guidance available for the country, it was necessary to develop a methodology to adjust the CCDeW outputs in order to apply them to NI.

The approach adopted was to identify the most closely related CCDeW region to the NI, through an assessment of meteorology, demand and projected climate change impact. If a sufficiently similar region was found, then the CCDeW factors for this region would be applied directly to NI.

The meteorology was assessed using UK Met Office regional climate averages from 1914 to 2008 inclusive[17]. Each region of the UK was assessed for its correlation with NI for mean precipitation and mean temperature. The region of the North West England & North West Wales had the closest correlation with NI for both precipitation (0.770) and temperature (0.959). Figure C.40 shows how average monthly rainfall compares for the regions of England, Wales and NI (Scotland is not included as there are no CCDeW factors for Scotland).

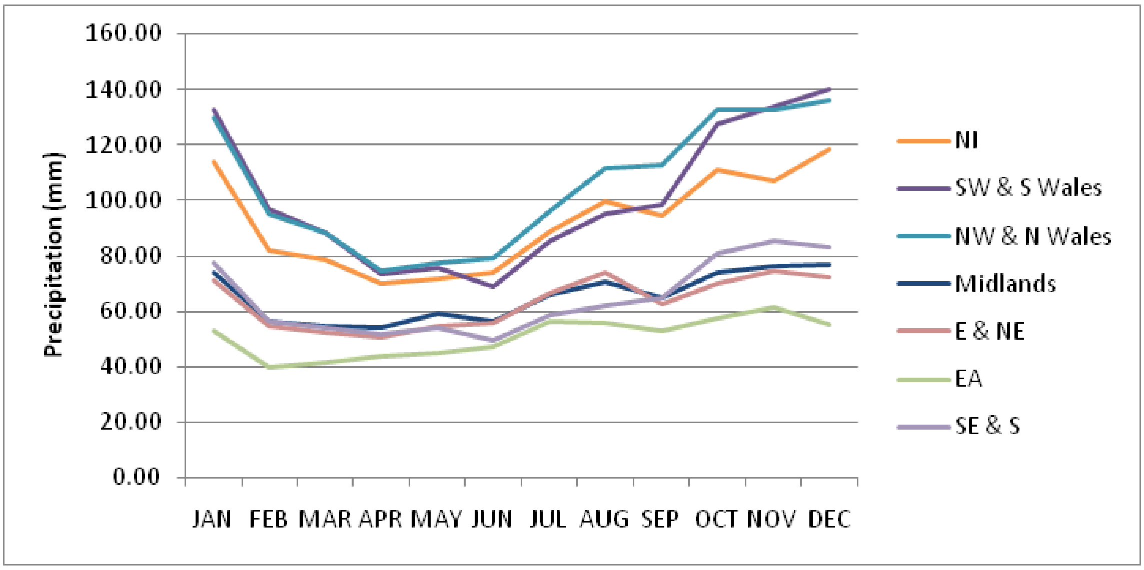


Figure C.40 – Regional mean monthly precipitation

Demand was assessed through a comparison of recent reported figures for per capita consumption (PCC) for water companies in the relevant areas of the UK. At this stage, areas in eastern UK were discounted from further assessment, as they did not have sufficiently similar meteorology to NI. With a relatively limited amount of data, only limited conclusions could be made from this assessment. Regions of Wales (Welsh Water) and Northern England (Northumbria and Yorkshire) were found to have the most closely correlated PCC figures.

Finally, regional climate change projections were compared to ensure consistency with future changes in precipitation and temperature. The North West of England (NW) was found to have a similar set of projections to NI. For the 2020s, for example, mean precipitation changes at the 50th and 10th percentile are projected to be −5% and −19% for the NW, compared to −3% and −15% (under High emissions)[18]. Equivalent projections for mean summer temperatures show increases of 1.5 and 2.5 for the NW, compared to 1.2 and 2.1 for NI (ibid).

It was therefore decided that the NW would provide an adequate proxy for NI with regard to future changes in demand. The CCDeW factors are presented for this region below. However, it should be noted that because climate change projections for the NW show bigger changes in temperature and precipitation, it should be used with caution as an accurate proxy for NI as the demand effects may be greater in the NW.

[17] Met Office Regional Climate Values: http://www.metoffice.gov.uk/climate/uk/datasets/index.html
[18] UKCP09 UK-wide key findings: http://ukclimateprojections.defra.gov.uk/content/view/982/527/

C.7.2 CCDeW Factors

The following are the various factors relevant to the NW Region defined above. Where the UKCIP02 climate scenarios are referred to, they are Low (L), Medium-High (MH) and High (H). Alpha (α), beta (β), gamma (γ) and delta (δ) refer to socio-economic scenarios created as plausible and consistent descriptions of possible futures, namely: Provincial Enterprise, World Markets, Global Sustainability and Local Stewardship respectively.

Domestic demand

The table below presents a regional estimate of climate change impact on domestic demand, as percentage change relative to the same socio-economic scenario with no climate change (CCDeW, p.47):

Low (2020s)		Medium-High (2020s)		Medium-High (2050s)	
α and β	γ and δ	α and β	γ and δ	α and β	γ and δ
1.31	1.04	1.43	1.08	2.97	2.11

Impacts of climate change on domestic PCC (as percentages), with range and standard deviation based on results for different WRZs, for Medium-High emissions scenario (CCDeW, p.171) are presented below:

Scenario	2020s				2050s			
	Min	Mean	Max	SD	Min	Mean	Max	SD
α and β	1.15	1.43	1.67	0.47	2.39	2.97	3.40	0.34
γ and δ	0.26	1.08	2.12	0.47	0.21	2.11	3.28	0.85

By way of comparison with other regions covered by CCDeW, the table below shows the corresponding factors for the Alpha & Beta scenario (which will be used for this analysis).

Scenario	2020s			2050s		
	Min	Mean	Max	Min	Mean	Max
North West	**1.15**	**1.43**	**1.67**	**2.39**	**2.97**	**3.40**
Anglian	1.25	1.83	2.43	2.54	3.04	3.35
Midlands	1.25	1.83	2.43	2.42	3.68	4.95
North East	1.27	1.48	1.61	2.54	3.04	3.35
Southern	0.94	1.45	2.19	1.74	2.92	5.03
South West	0.96	1.39	1.70	1.81	2.81	3.48
Thames	1.00	1.37	1.88	2.01	2.67	3.59
Wales	1.08	1.45	1.97	2.05	2.79	3.90

Table C.18 – Domestic demand factors for the Alpha & Beta scenarios for different regions

Industrial and commercial demand

Estimates of climate change impacts on industrial and commercial demand, as percentage change relative to the same socio-economic scenario with no climate change (CCDeW, p.90) are presented in Table C.19. For comparison, figures for all CCDeW regions are also given.

Region	2020s L	2020s MH				2050s MH
	γ	α	β	γ	δ	β
North West	**1.9**	**1.7**	**1.8**	**2.1**	**1.8**	**3.8**
Anglian	2.4	2.6	2.6	2.7	2.5	5.7
Midlands	1.8	1.7	1.8	2.0	1.7	3.9
North East	1.9	1.7	1.8	2.1	1.8	3.6
Southern	2.5	2.4	2.7	2.8	2.4	5.7
South West	2.9	2.7	3.0	3.1	2.7	6.1
Thames	2.6	2.5	2.5	2.9	2.6	5.4
Wales	2.3	2.3	2.4	2.6	2.3	5.2

Table C.19 – Industrial/commercial demand factors for different regions

C.7.3 Approach

Factors

CCDeW climate change impact factors are unconventional in that they are applied to a reference scenario in the future rather than a baseline value in the present day. Therefore, demand in each year of the forecast must first be calculated without climate change and then the percentage increase for that year for the appropriate climate change scenario should be applied.

For a scenario that is most similar to conventional development, the Beta socio-economic scenario, entitled ‘World Markets’, can be used (in some cases this is combined with the Alpha Scenario, ‘Provincial Enterprise’). There is little difference between the climate change scenarios for the 2020s, and so the medium-high emissions scenario is recommended because most information is provided on this within CCDeW. For domestic demand, this gives a 1.43% mean increase which should be applied to the demand line; for headroom, it is recommended that the WRZ-level minimum (1.15%) and maximum (1.67%) are used with a normal distribution. Where the 2050s factors are used, the minimum, maximum and mean increases are 2.39%, 2.97% and 3.40% respectively.

For non-domestic demand, there are no WRZ-level figures provided in CCDeW and so it is difficult to derive a measure of uncertainty. However, it is recommended that a lower band of zero is used, with an upper band of approximately 2.7%; this reflects the spread of uncertainty in sectors (from 0.0% to 5.2% – see Table 4.9 on p.89 of CCDeW) whilst recognising the potential for over-estimating the climate change impact (see discussion below). The equivalent upper and lower bands for the 2050s are zero and 5.7% respectively (reflecting an uncertainty across sectors from 0.0% to 11.1%).

Interpolation

The WRPG recommends that the CCDeW factors for the 2020s should be scaled back to the base year to give an annual percentage increase. With a base year of 2008-09, this gives an annual mean increment of 0.089% for domestic demand (i.e. the 1.43% mean increase ÷ 16 years, as there are 16 years between the base year and 2025, the mid-point of the 2020s). This could then be scaled back and forward from 2025, and applied cumulatively.

However, this is not the only possible approach that could be used for scaling demand factors, as it is not clear from CCDeW which year should be used to scale back the change factor to, to get an annual increment. If the 1961–90 period is used as the base period (after which it is commonly assumed that climate change would have an impact on the baseline), then 1975 – as the mid-point in this 30-year period – would be appropriate. By not scaling from 1975, there is a risk of over-estimating the impact of climate change after 2025 as the annual increments are likely to be too large. Also, there is an assumption that the base year, and therefore the forecast based on this, is unaffected by climate change; if the base year already includes an element of climate change, the future impact of climate change will then be overestimated.

By scaling back to 1975, this would result in a linearly-average increment of 0.029% for domestic demand accumulating from 1975 to 2025 (i.e. starting at 0 and increasing in annual 0.029% increments to 1.43% in 2025). This compares with an annual increment of 0.089% for the WRPG approach. Figure C.41 shows an indicative graph that provides a comparison of the WRP approach (green line) with an approach that scales back to 1975 (blue line).

One way of avoiding any over-estimation after 2025 is to use the factors for the 2050s and scale back to 2025. In theory, this should give a step-change, as the annual impact should be greater for the 2050s than the 2020s. Two further options are therefore also shown in Figure C.41, showing the path of the annual increments when the 2050s factors are used after 2025 for the WRP guidance (pink line) and when scaling back to 1975 (orange line). Although the 2050s is not within the water resource planning period, showing the impact at 2055 emphasises the difference between the four methods.

The four outcomes are summarised individually below:

- Green method: WRP guidance – 2008/09 baseline, scaling back from 2025 and forward to 2055;
- Blue method: using 1975 as baseline, scaling back from 2025 and forward to 2055;
- Pink method: As green line, but then scaling back from 2055 to 2025; there is a decrease in the rate of climate change (impact) at 2025;
- Orange method: As blue line, and then from 2055 to 2025, the profile shows an increase in the rate of climate change (impact) after 2025.

In each of the following tables then the year 2024-25 is in bold font.

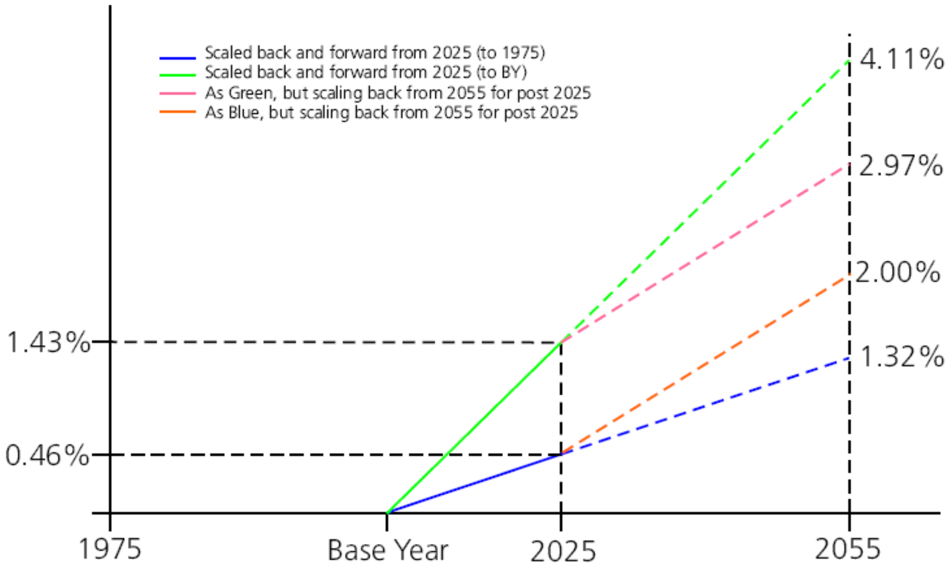


Figure C.41 – Indicative graph of four methods of CCDeW scaling

From the results presented here, we would make the recommendation that the Orange method is used. It provides a profile of annual climate change factors for demand that most accurately portray the likely profile of climate change over the first half of the 21st century and avoids potential issues of double-counting.

Note that if the mean impact on demand is applied to the demand line and headroom is required, then only the differences between the maximum and the mean, and the mean and the minimum, should be used to inform the upper and lower boundaries of headroom respectively.

Note also that these are the factors that should be applied to the in-year demand.

C.7.4 Results – recommended profile

Year Number	Year	% Demand Increase		
		Min	Mean	Max
0	2008–09	0.0000	0.0000	0.0000
1	2009–10	0.0230	0.0286	0.0334
2	2010–11	0.0460	0.0572	0.0668
3	2011–12	0.0690	0.0858	0.1002
4	2012–13	0.0920	0.1144	0.1336
5	2013–14	0.1150	0.1430	0.1670
6	2014–15	0.1380	0.1716	0.2004
7	2015–16	0.1610	0.2002	0.2338
8	2016–17	0.1840	0.2288	0.2672
9	2017–18	0.2070	0.2574	0.3006
10	2018–19	0.2300	0.2860	0.3340
11	2019–20	0.2530	0.3146	0.3674
12	2020–21	0.2760	0.3432	0.4008
13	2021–22	0.2990	0.3718	0.4342
14	2022–23	0.3220	0.4004	0.4676
15	2023–24	0.3450	0.4290	0.5010
16	**2024–25**	**0.3680**	**0.4576**	**0.5344**
17	2025–26	0.4093	0.5089	0.5921
18	2026–27	0.4507	0.5603	0.6497
19	2027–28	0.4920	0.6116	0.7074
20	2028–29	0.5333	0.6629	0.7651
21	2029–30	0.5747	0.7143	0.8227
22	2030–31	0.6160	0.7656	0.8804
23	2031–32	0.6573	0.8169	0.9381
24	2032–33	0.6987	0.8683	0.9957
25	2033–34	0.7400	0.9196	1.0534

Table C.20 – Domestic demand scaled factors (Med-High; Alpha & Beta)

Year Number	Year	% Demand Increase		
		Min	Mean	Max
0	2008–09	0.0000	0.0000	0.0000
1	2009–10	0.0000	0.0360	0.0540
2	2010–11	0.0000	0.0720	0.1080
3	2011–12	0.0000	0.1080	0.1620
4	2012–13	0.0000	0.1440	0.2160
5	2013–14	0.0000	0.1800	0.2700
6	2014–15	0.0000	0.2160	0.3240
7	2015–16	0.0000	0.2520	0.3780
8	2016–17	0.0000	0.2880	0.4320
9	2017–18	0.0000	0.3240	0.4860
10	2018–19	0.0000	0.3600	0.5400
11	2019–20	0.0000	0.3960	0.5940
12	2020–21	0.0000	0.4320	0.6480
13	2021–22	0.0000	0.4680	0.7020
14	2022–23	0.0000	0.5040	0.7560
15	2023–24	0.0000	0.5400	0.8100
16	**2024–25**	**0.0000**	**0.5760**	**0.8640**
17	2025–26	0.0000	0.6427	0.9640
18	2026–27	0.0000	0.7093	1.0640
19	2027–28	0.0000	0.7760	1.1640
20	2028–29	0.0000	0.8427	1.2640
21	2029–30	0.0000	0.9093	1.3640
22	2030–31	0.0000	0.9760	1.4640
23	2031–32	0.0000	1.0427	1.5640
24	2032–33	0.0000	1.1093	1.6640
25	2033–34	0.0000	1.1760	1.7640

Table C.21 – Industrial & commercial demand scaled factors (Med-High; Beta)

Appendix D – Headroom

D.1 Risk modelling

The following provides discussion of the approach and assumptions used in deriving headroom uncertainties for Monte Carlo headroom modelling (based on UKWIR 2003 methodology). The headroom analysis is broadly split in to two categories, supply and demand, each containing several “components”. Uncertainties are identified and modelled under each of these components and combined together to form an overall picture of headroom uncertainty.

To establish suitable values for headroom the elements contributing to the supply demand balance have been scrutinised for potential sources of uncertainty. These risks have been quantified into probability distributions and modelled using Monte Carlo analysis. The output of this analysis provides a probability distribution of uncertainty. A particular percentile of this risk is then chosen to represent a level of service and this value is used as target headroom.

Headroom is analysed at different years in the planning period so that future changes in uncertainty can be modelled.

Years in headroom model						
2008	2012	2017	2022	2027	2032	2034

Additionally some components of headroom may be subject to correlation. Correlation coefficients are used when it is considered that certain input distributions cannot be modelled as independent variables. For example it is reasonable to expect a positive correlation between the effects of climate change on supply and on demand.

D.2 Supply components of uncertainty

D.2.1 Supply side headroom assumptions

The supply-side headroom components are assessed at individual source level (except climate change (S8)). However this methodology conflicts with the conjunctive use assessment of deployable output (DO) at water resource zone (WRZ) level. Individual source contributions to WRZ DO have been estimated as a first order approximation by apportioning this DO between the relative source capacities.

Several supply-side headroom components are modelled with normal distributions described as a percentage range around a mean values. For the purposes of this assessment these percentages have been applied such that 99.7% of the distribution lies within these bounds. When specifying the normal distribution the percentage value is equal to three times the standard deviation. Specifically the normal distribution’s standard deviation is specified as one third of the percentage described. For example an unbiased normal distribution of ±10% will be specified with a mean of 0.0% and a standard deviation of 3.33%.

D.2.2 S1 – vulnerable surface water licences

A single surface water licence has been identified as vulnerable. The Derg/Strule licence was found to be susceptible to particular low flow conditions during the hydrological modelling. A triangular distribution has been created using best estimate and maximum impact analysis as detailed in the guidance. Table D.1 shows how the triangular distribution has been formed from modelling of the licence impact.

	Magnitude of Restriction [Ml/d]	Duration of Restriction	Frequency of Restriction	Values for triangular distribution [Ml/d]
Minimum	0.0	-	-	0.00
Best Estimate	11.6	4 days	6 in 25 years	0.03
Maximum	26.6	29 days	1 in 25 years	0.08

Table D.1 – S1 – Derg/Strule triangular distribution calculations

D.2.3 S2 – vulnerable groundwater licences

There are currently no active ground water licences.

D.2.4 S3 – time-limited licences

At the time of writing there has been no judgement from NIEA on a timetable for sustainability reductions. Therefore no headroom uncertainty has been included for time-limited licences.

D.2.5 S4 – bulk imports

In the Draft WRMP no uncertainty was included under this category. Imports from the PPP sources controlled by Dalriada have been assessed for their uncertainty under other headroom categories as though they were NI Water controlled sources. The UKWIR guidance makes allowance for bulk import uncertainty separately as the receiving company is not likely to have sufficient information to properly assess headroom for those sources outside of its control. However due to the intimate relationship between NI Water and Dalriada sources it is possible to properly assess headroom for those sources controlled by Dalriada.

D.2.6 S5 – gradual pollution

The effect of gradual pollution on source output can be significant, particularly for groundwater sources where serious contamination may lead to abandonment of the source. It is important to distinguish between the risk of temporary losses of output resulting from pollution, which must be included in outage, and the risk of permanent losses, which is a Headroom issue. Surface water sources, which are vulnerable to outages resulting from pollution, are much less susceptible to permanent losses allowed for under headroom uncertainty. Pollution events are therefore not considered to contribute to overall headroom uncertainty of NI Water's sources.

D.2.7 S6 – accuracy of supply side data

Meter uncertainty

All sources are at risk of meter uncertainty, and therefore each have an unbiased ±2% normal distribution applied following the UKWIR guidance.

Infrastructure uncertainty

Many NI Water sources are constrained by their infrastructure. It was deemed that these sources should be subject to additional uncertainty modelled using an unbiased ±5% normal distribution.

This uncertainty is consistent with the confidence grade (B2) given for distribution input in the AIR09 tables.

Hydrological uncertainty

Several NI Water sources are hydrologically constrained; their DO values are subject to the inherent uncertainty involved in modelling the various hydrological processes (e.g. monitoring accuracy, numerical modelling uncertainty). Professional judgement assessed this uncertainty at around ±10%, and this value has been applied for those relevant sources as a normal distribution.

D.2.8 S8 – climate change impacts

Climate change impacts were assessed using the UKWIR report 'Assessment of the significance to water resource management plans of the UKCP09 Scenarios'. The results allowed for reassessment of WRZ DO to form a range of impacts. These ranges were translated into triangular distributions for each WRZ as shown in Table D.2. These values were used at the end of the planning period and interpolated from zero uncertainty at the start for years in between.

WRZ	Minimum	Most Likely	Maximum
North	−5.20	0.00	6.10
West	−1.20	0.00	1.50
Central	0.00	0.00	0.00
East	−13.70	0.00	18.00
South	−4.10	0.00	0.00

Table D.2 – WRZ CC Impacts at the end of the planning period

In contrast to the other supply-side components the uncertainty around climate change is calculated at the water resource zone level using the conjunctive use DO. It is reasonable to assume that the impacts of climate change will be uniform through a particular WRZ.

S8 is the only supply-side components to be included in the correlation matrix. There is a significant positive correlation (+0.8) between neighbouring years. This suggests that the impacts of climate change are likely to be consistently under or over estimated. Additionally S8 is correlated with D3, because if climate change impacts occur it is likely to affect both supply and demand at the same time. The correlation will be positive and should be categorised as "high tendency towards a positive correlation", which would equate to an assumed correlation coefficient of +0.6.

D.3 Demand components of uncertainty

D.3.1 Demand side headroom assumptions

The demand-side headroom elements are all derived using the DYAA baseline demand forecast.

No demand-side components were identified as being mutually exclusive or dependent. Some correlations were identified, both between components/sub-components and through time within a particular component/sub-component. Correlations and assumed coefficients are described in each section below.

It is possible that D1 and D2 sub-component e) "dry year demand in base year" may be correlated, because if the uncertainty in the accuracy of data means that the distribution input is higher (or lower) than reported, then the derived dry year demand may also be higher (or lower) than expected. Thus the correlation would be positive, and has been assumed to have a coefficient of +0.5 (tendency towards a positive correlation).

D.3.2 D1 – accuracy of sub-component data

This component is used to address the risk that the consumption data on which demand forecasts are based maybe of poor quality, leading to errors in demand prediction. Errors in individual components are likely to be distributed between other components of demand.

However, errors on distribution input are of key importance. Meter accuracy may range from ±2% for well installed magflow meters to ±5% for older venturi or dall tube meters (UKWIR 2003).

The details of distribution meters in NI Water is not known, however, there have been issues with the accuracy of estimates of distribution inputs in the past – for instance under-recording of DI was identified and addressed in 2008–09. Given the efforts of the leakage team to rationalise meters and validate data, the base year (2008–09) DI data is considered relatively robust.

Therefore, an error in the middle of the two extremes quoted in the UKWIR 2003 methodology would seem appropriate. Thus this component will use a normal distribution with a mean of 0 (as the UKWIR guidance suggests that there is usually no evidence that the errors are biased positively or negatively), and a standard deviation of ±3 % of total DI. This error bound is assumed to decrease through the planning period (linearly) to ±2% by the end (2034–35). It is assumed that the probability distribution in each time step will be positively correlated through time, with a correlation coefficient of +0.8 (significant positive correlation).

D.3.3 D2 – demand forecast variation

This component is used to assess the risk that actual demand will depart from the dry year demand forecast.

A triangular probability distribution is recommended:

- Maximum decrease in demand (in Ml/d) = the difference between the base case and the minimum demand forecasts at the end of the planning period;
- Best estimate change in demand = 0 Ml/d; and
- Maximum increase in demand = the difference between the base case and the maximum demand forecasts at the end of the planning period.

A number of uncertainties in the demand forecast were investigated, each of which is assumed to be independent of the others. The key uncertainties in the demand forecast are as follows:

a) Population uncertainty through forecast – to account for uncertainty associated with the population forecast: assume ±10% by the end of the planning period increasing linearly from minimal uncertainty of ±0.5% in 2009–10; and assume that the probability distribution in each time step will be positively correlated through time, with a correlation coefficient of +0.5 (tendency toward positive correlation). It is likely that this sub-component will be positively correlated with non-household growth (D2(c)), as an increasing population is likely to support increasing economic activity, and vice versa; hence a correlation coefficient of +0.5 (or a tendency towards positive growth) has been assumed;

b) PCC uncertainty through forecast – to account for uncertainty with how customer behaviour and changes to technology/regulations may affect domestic consumption: assume ±10% by the end of the planning period increasing linearly from 0% in the base year; and assume that the probability distribution in each time step will be positively correlated through time, with a correlation coefficient of +0.5 (tendency toward positive correlation). (Note that uncertainty in base year DI, which includes PCC, would be addressed under component D1, hence the base year uncertainty should be 0% to avoid double counting);

c) Non-household demand growth uncertainty through forecast – to account for uncertainty in assumed non-household customer consumption growth rates due to economic conditions and potential changes to technology/regulations: assume ±10% (on the assumed growth rates) by the end of the planning period, increasing linearly from 0% in the base year; and assume that the probability distribution in each time step will be positively correlated through time, with a correlation coefficient of +0.5 (tendency toward positive correlation). It is likely that this sub-component will be positively correlated with population growth (D2(a)), as an increasing population is likely to support increasing economic activity, and vice versa; hence a correlation coefficient of +0.5 (or a tendency towards positive growth) has been assumed;

d) Balance of dry year contributing factors between households and non-households. The baseline assumed a dry year factor of 1.05 applied to non-household demand, and the household factor was then calculated to reach the derived dry year demand for each WRZ. The uncertainty in the balance between these factors could assume non-household dry year factors of 1.0 for the minimum and 1.10 for the maximum. The recalculation of household demand factors to reach expected dry year demand levels in the base year must then be undertaken. Also assume that the probability distribution in each time step will be positively correlated through time, with a correlation coefficient of +0.8 (significant positive correlation); and

e) Dry year demand in base year – the base year (2008–09) dry year demand was estimated at 676.7 Ml/d on the basis of Annual Information Returns from 2002–03 to 2008–09. However, there was a reasonable degree of uncertainty over this value. Using data provided from the WRS 2002 for the 1990s, an upper bound could be 715 Ml/d, which equates to a maximum of +38.3 Ml/d. It is unlikely that the lower bound would be a reflection of the maximum value (i.e. −38.3 Ml/d) given that the maximum used to derive the base year demand was observed recently (in 2003–04) and that the dry year is focused on an extreme event. However, there is some uncertainty over the accuracy of the historic data, and recent trends from Annual Information Returns suggest a general downward trend in DI in recent years. Thus a nominal lower bound of −10 Ml/d has been used. It has also been assumed that the probability distribution in each time step will be positively correlated through time, with a correlation coefficient of +0.8 (significant positive correlation).

The demand forecast model was run to generate a triangular distribution for each of the above uncertainties under D2 (except the final one), based on the DYAA baseline demand forecast.

D.3.4 D3 – uncertainty of impact of climate change on demand

The impact of climate change on demand has been based on factors set out *in Climate change and demand for water (CCDeW)*. Using these factors, minimum, mean and maximum percentage demand increases were derived for both households and non-households (see section C.7). The mean percentage demand increase was used as the baseline estimate of climate change impact. The minimum and maximum have been applied to the headroom analysis as part of a triangular distribution.

It has been assumed that the probability distribution in each time step will be positively correlated through time, with a correlation coefficient of +0.8 (significant positive correlation).

D3 should be correlated with S8, because when climate change occurs it is likely to affect both supply and demand at the same time. The correlation will be positive and should be categorised as “high tendency towards a positive correlation”, which would equate to an assumed correlation coefficient of +0.6.

D.3.5 D4 – uncertainty of demand management measures

The headroom analysis is based on the DYAA baseline demand forecast. For NI Water, the baseline does not involve explicit demand management measures – there is no metering, and no explicit water efficiency activity (over and above the statutory awareness raising and activity which is incorporated into base year demand figures). Therefore, there is little uncertainty associated with this component of headroom.

However, NI Water has proposed leakage targets for the period 2008–09 to 2012–13 (after which leakage is assumed to remain constant through to the end of the planning period in the baseline case).

In any year there is a chance that the Company may not meet its leakage target. This could be due to cold winters/events which cause burst pipes. Similarly, there is a chance that the Company may exceed its target in any year due to favourable weather conditions, although it seems unlikely that they would exceed the target by a significant magnitude. An example of how cold winter events can affect the likelihood of meeting the leakage target in any given year was seen recently in the cold snap in early January 2010 and the resulting “freeze-thaw” conditions. Distribution Input was seen to rise to exceptionally high levels. This was believed to be due to increased bursts, but also customers running taps permanently to avoid their supply pipes and plumbing freezing. To account for this uncertainty a triangular distribution around the target leakage level has been applied. Because it is highly unlikely that the company would go significantly under its target, the minimum has been assumed to be −0.5% of target leakage (equivalent to 0.8 Ml/d on a target of 166 Ml/d). The maximum could be high, as demonstrated by recent winter freeze thaw events, and for the purposes of this headroom assessment has been assumed to be +20% of target leakage (equivalent to 33.2 Ml/d on a target of 166 Ml/d).

D.3.6 Summary of demand assumptions

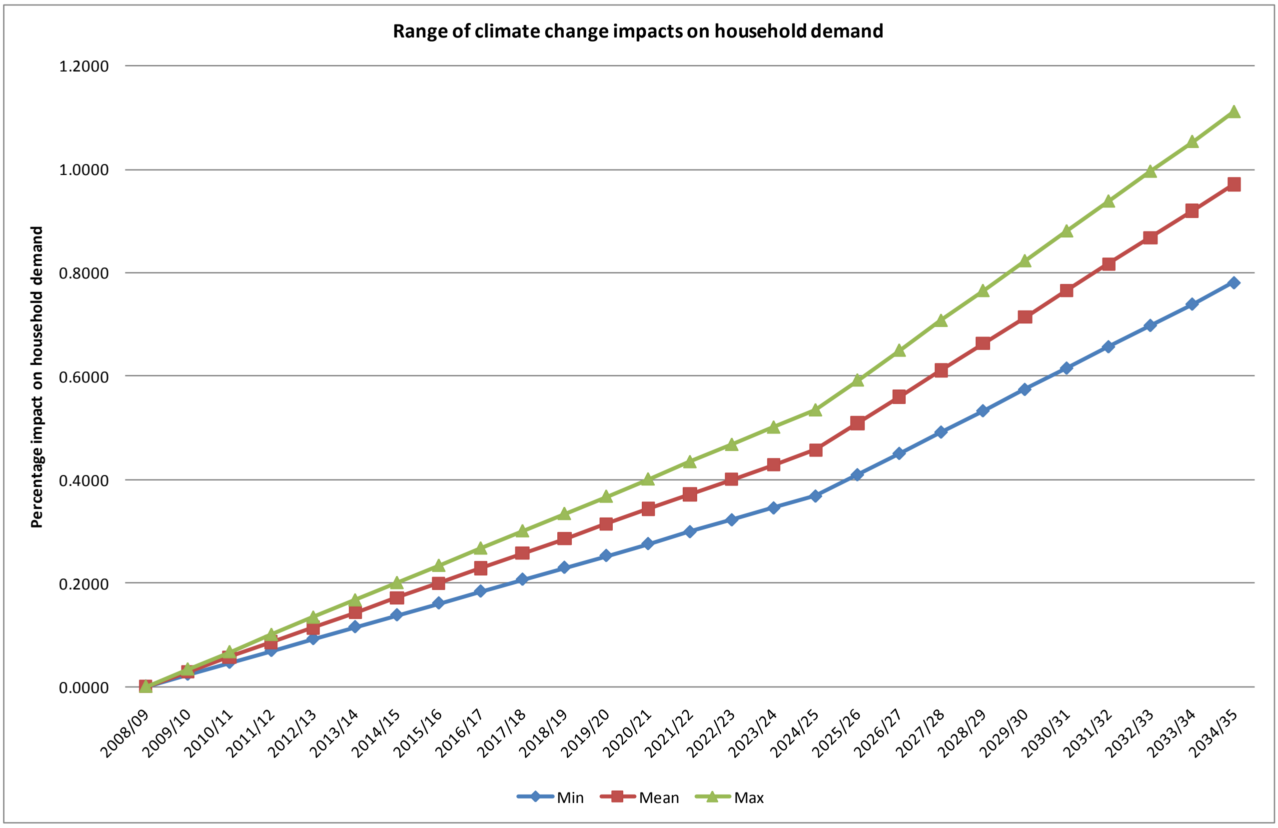
A summary of the demand related headroom assumptions (D1 and D2) is given in Table D.3.

D1 Component	East	North	Central	West	South
Distribution input					
Distribution	Normal (mean=0)	Normal (mean=0)	Normal (mean=0)	Normal (mean=0)	Normal (mean=0)
Variation in base year	±3%	±3%	±3%	±3%	±3%
Variation at end of planning period	±2%	±2%	±2%	±2%	±2%
Correlation through time	+0.8	+0.8	+0.8	+0.8	+0.8

D2 Component	East	North	Central	West	South
Population					
Distribution	Triangular	Triangular	Triangular	Triangular	Triangular
Variation in base year	±0.5%	±0.5%	±0.5%	±0.5%	±0.5%
Variation at end of planning period	±10%	±10%	±10%	±10%	±10%
Correlation through time	+0.5	+0.5	+0.5	+0.5	+0.5
PCC					
Distribution	Triangular	Triangular	Triangular	Triangular	Triangular
Variation in base year	0%	0%	0%	0%	0%
Variation at end of planning period	±10%	±10%	±10%	±10%	±10%
Correlation through time	+0.5	+0.5	+0.5	+0.5	+0.5
Non-household demand					
Distribution	Triangular	Triangular	Triangular	Triangular	Triangular
Variation in base year	0%	0%	0%	0%	0%
Variation at end of planning period	±10%	±10%	±10%	±10%	±10%
Correlation through time	+0.5	+0.5	+0.5	+0.5	+0.5
Balance of dry year factors					
Distribution	Triangular	Triangular	Triangular	Triangular	Triangular
Best guess (baseline)					
Non-HH dry year factor	1.05	1.05	1.05	1.05	1.05
HH dry year factor	1.12	1.12	1.15	1.16	1.15
Maximum					
Non-HH dry year factor	1.00	1.00	1.00	1.00	1.00
HH dry year factor	1.14	1.16	1.18	1.19	1.17
Minimum					
Non-HH dry year factor	1.10	1.10	1.10	1.10	1.10
HH dry year factor	1.10	1.09	1.12	1.12	1.12
Correlation through time	+0.8	+0.8	+0.8	+0.8	+0.8
Dry year demand – *variation constant through planning period (no need to run demand model)*					
Distribution	Triangular	Triangular	Triangular	Triangular	Triangular
Best guess (baseline), Ml/d	0.0	0.0	0.0	0.0	0.0
Minimum, Ml/d	−1.2	−4.6	−0.4	−1.0	−2.8
Maximum, Ml/d	4.6	17.7	1.6	3.8	10.7
Correlation through time	+0.8	+0.8	+0.8	+0.8	+0.8

Table D.3 – Summary of the demand related headroom assumptions (D1 and D2)

The assumptions for the D3 component are illustrated in Figure D.1.



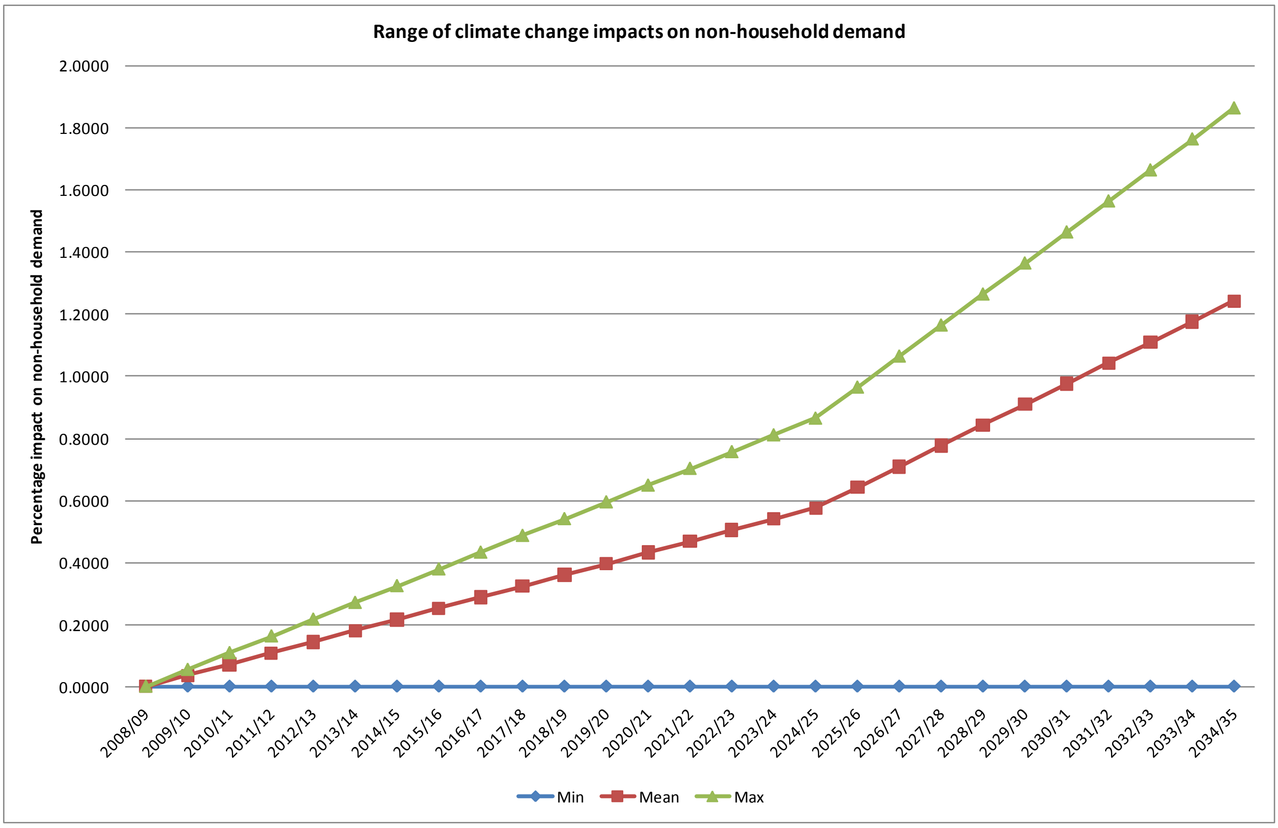


Figure D.1 – Range of climate change impacts on demand (D3)

A summary of the demand related headroom assumption for leakage target uncertainty (D4) is given in Table D.4.

D4 Component	East	North	Central	West	South
Leakage target uncertainty					
Distribution	Triangular	Triangular	Triangular	Triangular	Triangular
Variation in base year	−0.5% +20%	−0.5% +20%	−0.5% +20%	−0.5% +20%	−0.5% +20%
Variation at end of planning period	−0.5% +20%	−0.5% +20%	−0.5% +20%	−0.5% +20%	−0.5% +20%
Correlation through time	0.0	0.0	0.0	0.0	0.0

Table D.4 – Summary of the demand related headroom assumptions (D4)

D.4 Target headroom

Details of overall target headroom are given in the main report. A breakdown of headroom component contributions is provided here in Figure D.2. This analysis shows which areas of uncertainty are most critical to target headroom. In all WRZs the two demand components D2 and D4 are the main contributors. D2 tends to increase throughout the planning whereas D4 tends to reduce. Uncertainty due to climate change (S8) increases rapidly through the planning period in the East, South and, most notably, the North zones. This is the only significant regional variation in uncertainty with other components being either small contributors or generally consistent in relative impact across WRZs.

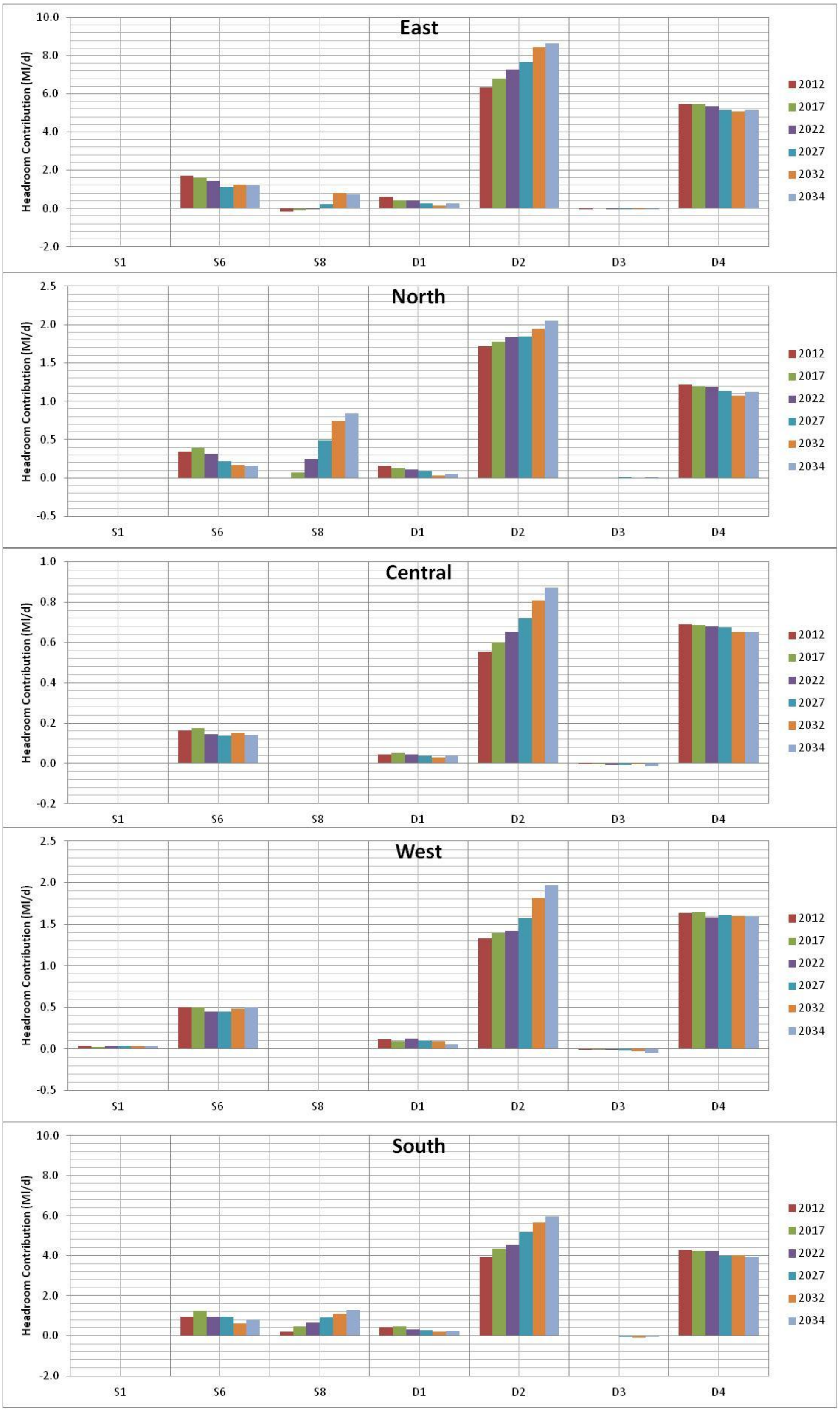


Figure D.2 – Headroom contributions from each component for each WRZ

Appendix E – Investment model

E.1 The investment modelling process

The water resource planning process identifies future deficits combining supply, demand and uncertainty forecasts in to a supply demand balance (SDB). A deficit is identified when supply is not sufficient to meet demand plus target headroom. At this point new water resources or demand management schemes would need to be introduced to ensure levels of service are maintained. An investment model is used at this point to determine the least cost investment strategy to satisfy all of the deficits in all of the WRZs.

The investment model requires information about feasible future options. These options may include new water resources, increases in leakage control or water efficiency measures. Metering scenarios may also be run to establish a least cost metering policy. For each feasible option, capital and operating costs, peak and average yields and earliest commencement dates are required. The investment model uses this information to create and solve a mixed integer linear programme (MILP) that minimises the net present investment value required to satisfy all of the deficit constraints.

Each water resource zone (WRZ) is included in the investment model and contains its own baseline supply demand balance. Individual options are assigned to a particular WRZ and any associated yield contributes to satisfying any deficits. Additionally inter-zonal transfers can be defined to allow water to be exported from one zone and imported in to another. These transfers can either represent existing pipelines or be potential new ones, but in each case the model will attempt to utilise them to minimise the overall cost across the whole supply system. Other constraints can be added to options; for example two or more options can be made mutually exclusive or an option could be dependent on another being selected earlier in the planning period.

Demand management options may also be included and are split between either water efficiency measures or active leakage control (ALC). Each of these is treated separately due to their different impacts on demand and cost structure. Active leakage control options are created by taking discrete steps on the ALC cost curves. These steps are an approximation that only allows leakage to be reduced by a fixed value but it allows the model to be kept linear and is therefore easier to solve. Water efficiency options are modelled using optional decay factors that simulate a drop off in the effectiveness of the measure over time. The rate of decay can be varied depending on the nature of the measure being modelled.

The results from the investment model show what schemes should be selected and in what year they should be scheduled to come online. This information is used to inform the overall plan in a more robust manner than simple AI(S)C (Average Incremental Cost, Average Incremental Social Cost) ranking would allow.

E.2 Modelling assumptions

E.2.1 Discount rates

The investment model allows an annual discount rate to be applied through the planning to represent the time-value of money. The WRPG recommends a discount rate of 4.5%. No specific guidance on discount rates was provided by the DRD. For the Draft WRMP a discount rate of 3.5% was used, which is in accordance with Ofwat guidance[19] that in turn refers to the Social Time Preference Rate in HMT Green Book[20].

E.2.2 Cost of carbon

The investment model can incorporate separate carbon costs or benefits. These costs have an inflation rate assigned to them over the planning period to represent the relative change in the cost of carbon. For the Draft WRMP this value was set at 2% following guidance from DEFRA[21]. It should be noted that carbon costs are also discounted in the same manner as the other costs in the model. For the Final WRMP the 2010 Defra guidance has been used[22].

E.2.3 Current cost of water

Values for the current cost of supplying water are entered into the model to allow additional savings below target headroom to be made from either leakage control or water efficiency measures. These values represent the potential for scaling back existing sources by implementing new demand management measures. If these measures are simply reducing a supply demand balance deficit above target headroom the savings are not accounted through the current cost of water but are implicit in changing the investment model's decisions on other water resource options.

E.2.4 Option definitions

Various options can be defined in the investment model for potential inclusion in the strategy. These are grouped into three categories: water resource, leakage control and water efficiency. Each category is modelled in a different manner to represent the unique manner in which the options impact the supply demand balance.

All types of option are given a year that defines their earliest availability in the planning period and are assigned a WRZ to which they contribute DO.

Water resource options

Water resource option entries usually represent a single capital scheme that provides a fixed maximum increase in DO. Costs may be allocated to CAPEX and/or (fixed and variable) OPEX. A construction period defines the number of years before DO is provided over which any CAPEX costs must be allocated. Other constraints can be added to ensure the mutual exclusivity or dependence of different schemes.

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[19] Ofwat (2007), *Further Ofwat Guidance on the Use of Cost Benefit Analysis for PR09*
[20] HM Treasury, *The Green Book - Appraisal and Evaluation in Central Government*, (Archived 10/09/2008)
[21] DEFRA (2007), *The Social Cost Of Carbon And The Shadow Price Of Carbon: What They Are, And How To Use Them In Economic Appraisal In The UK*
[22] DEFRA (2010), *Updated short term traded carbon values for UK policy appraisal*

Transfer schemes are modelled in the same manner as water resource schemes. However their DO value represents the capacity of the transfer as DO is moved from one WRZ to another. The same costs categories can apply to transfer schemes and thus allow the model to select new inter-zonal transfers if appropriate.

Active leakage control options

Leakage control options can also be defined in the investment model. These options are usually derived from an active leakage control cost curve in which cost increases as leakage is reduced. In order to facilitate the linear nature of the investment model and account for realistic target setting this curve is approximated using incremental linear steps. For example each step could represent a reduction in leakage in a particular zone by 0.25 Ml/d and would therefore require 4 steps to model a maximum reduction of 1 Ml/d. Each step is likely to have an increased cost over the previous step depending on the position along the ALC curve. Constraints ensure that the steps must be selected in the correct order. Other constraints have been added to the NI Water investment model to ensure that total leakage across all WRZs in any given year cannot be reduced by more than 3 Ml/d. This constraint is considered to represent a realistic maximum rate for the identification and fixing of leaks each year in the future. The investment model is free to chose which WRZs should be should be targeted with leakage reductions, if any.

The ALC costs used for the Draft and Final WRPM were provided by NI Water's leakage team from work undertaken by Crowder Consultants and now include the social and environmental costs associated with leakage reductions.

Water efficiency options

Water efficiency options are unique in their definition due to their time dependent demand savings. The option definitions have been modelled on the savings decay rates found in the Waterwise Evidence Base. Here the efficacy of individual water efficiency measures decays exponentially with time. This decay is represented in the model and requires a decay rate to be specified for each potential measure. Due to this decay it is feasible that a single option could be re-introduced in the future once its initial impact has faded away. Therefore, unlike the other options, water efficiency measures may be selected multiple times during the planning period. Scheme costs are created from the bottom up using uptake rates, water savings, and prices for supply and installation based on the baseline populations in each WRZ.

Appendix F – Consultation

F.1 The consultation process

The Water and Sewerage Services (Northern Ireland) Order 2006 (the Order) sets out the procedural requirements for the process which the undertaker must follow in developing its plans. The DRD guidelines set out how the Department expects the undertaker to follow the directions contained in Articles 70-72 of the Order.

In following the guidelines NI Water published the following documentation on the Draft WRMP on its website for public consultation with a 16 week consultation period ending on 24th February 2011:

- The main consultation document, being the Main Report;
- The technical Appendices; and
- The Non Technical Summary that gave an overview of the Draft WRMP.

An Environmental Report that described the outcomes from a Strategic Environmental Assessment (SEA) of the Draft WRMP was published for public consultation at the same time as the Draft WRMP. The way in which the consultation has influenced this Final WRMP is covered in Table 6.1 of the SEA Statement.

F.2 Responses on the consultation received

On 3rd March 2011 DRD wrote to NI Water with the following responses it had received on the Draft WRMP and SEA:

- Varyflush ltd;
- Water Management Unit, NIEA;
- Natural Heritage Division, NIEA;
- Ulster Angling Federation;
- SEA Team, NIEA;
- Loughs Agency;
- Department of Communications, Energy & Natural Resources (RoI) endorsing Inland Fisheries Ireland;
- Fresh Water Task Force;
- Consumer Council NI; and
- Environmental Protection Agency (RoI).

In its letter, the Department also asked NI Water to review all responses and advise the Department on the need to respond to the issues raised on the Draft WRMP. The information provided would then be used to inform the Department whether to issue any directions under Article 71(7) of the Water and Sewerage Services (NI) Order 2006 in relation to the final Water Resource Management Plan.

Separate responses were also received from DRD and from NIAUR.

F.3 Action taken as a result of consultation responses received

In its letter to DRD dated 13th April 2011, NI Water set out how it intended to address the issues raised. The issues fell into one of three categories:

1. Issues to be addressed prior to publishing the final WRMP;
2. Issues to be deferred until the next water resource planning round; and
3. Substantive policy and regulatory issues for debate and agreement outside the scope of the water resource planning process.

The policy and regulatory issues cannot be addressed in the timeframe of this WRMP, but they properly fit in with the on-going dialogue between NI Water, Government and the regulators.

We firmly believe that the Draft WRMP set out a robust framework for future water resources planning; it builds on the existing configuration of infrastructure and past investment decisions and is fit for the current regulatory framework. There is modest investment in the early years of the planning horizon. The major risks and opportunities in the WRMP arise from potential changes in the implementation of environmental legislation and the consequential impacts on abstraction licensing, and changes to policy of charging for domestic water services. Until there is further certainty on the scale and timescale within which these issues will be addressed, we believe that it is appropriate for the final WRMP to address points of clarity, presentation and detail behind the analyses, rather than any major change in assumptions. As required by Section 70(6) of the Water and Sewerage Services (Northern Ireland) Order 2006 NI Water will subject the plan to an annual review, and will expect to revisit the plan every five years or earlier if there should be a material change of circumstance, such as a change to water charging policy or proposals to implement sustainability reductions.

The Draft WRMP recognises the substantial risk to abstraction licences that could arise from the implementation of Sustainability Reductions to meet the requirements of the Water Framework Directive (WFD). In line with UK best practice for water resource planning, NI Water expects the environmental regulator to advise licence holders of the location and magnitude of Sustainability Reductions so that these can be taken into account in long-term water resource planning and appraisal of options to mitigate any consequential losses in deployable output. This will require close liaison between NI Water, the Department and both the Environmental and Utility regulators. It is worth noting that in England & Wales this process has been addressed through the National Environment Programme (NEP) agreed between Ofwat and the Environment Agency, in which the work is undertaken by the water utility affected and funded through price limits. The process generally takes two business planning cycles between identification of a potential issue and identification of a preferred option(s) for implementation.

DRD wrote to NI Water on 18th May 2011 to advise that it was content with NI Water to proceed with the Final WRMP.

The main changes to the WRMP made since the Draft WRMP are:

- Review and update of deployable output (DO) calculations, taking account of more detailed information made available through the Trunk Mains Model (TMM) programme;
- Revised leakage targets, leakage reductions and associated costs;
- Revised draft policy on customer supply-pipe repairs;
- Updated headroom calculations taking account of new baseline demand forecast with revised leakage targets and headroom uncertainty of PPP schemes;

- Current status of PC10 and PC13 strategic transfer schemes;
- Review and update of the costs of options; and
- Inclusion of DECC prices for carbon in the investment model.

Final Water Resources Management Plan 2012 Appendices

NI Water – Asset Management

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