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Water Neutrality: An improved and expanded water resources management definition

Resource Efficiency science programme
Science report: SC080033/SR1

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This report is the result of research commissioned and funded by the Environment Agency's Science Programme.

Published by:
Environment Agency, Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol, BS32 4UD
Tel: 01454 624400 Fax: 01454 624409
www.environment-agency.gov.uk

ISBN: 978-1-84911-114-0

Further copies of this summary are available from our publications catalogue: http://publications.environment-agency.gov.uk or our National Customer Contact Centre: T: 08708 506506
E: enquiries@environment-agency.gov.uk.

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Dissemination Status:
Released to all regions
Publicly available

Keywords:
water, neutrality, supply, demand, resources, consumption, offsetting

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Science Project Number:
SC080033/SR1

Product Code:
SCHO1009BQZR-E-P

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Steve Killeen

Head of Science

Executive summary

Background and need

Water neutrality is an important but relatively new concept for managing the demand for water. The concept of water neutrality is important because of two key factors:

- The Government policy to deliver an accelerated rate of housing growth, with the target of 3 million new homes by 2020. This growth would be delivered via existing plans (e.g. in regional spatial strategies), but also via 'growth areas', 'growth points' and eco-towns.
- Constraints on the current and future availability of water resources (e.g. as a result of climate change) to meet unmanaged future demand for water in certain areas of England and Wales (e.g. South East England).

The studies that have been undertaken to date on water neutrality have used the original definition of water neutrality and have used approaches and analyses that are either project-specific or defined by constraints such as available data or time.

Objectives

This study aims to take a step back from the work undertaken to date to consider the broader issues associated with the concept of water neutrality, in order to provide a clear and cogent understanding of water neutrality, so that it becomes possible for the Environment Agency to apply the concept operationally. In particular, this study aims to provide:

- a definitive assessment of what aspects of water supply and demand should be considered in the assessment of water neutrality and when;
- a hydrological context for water neutrality;
- an understanding of the spatial and temporal dynamics of achieving neutrality;
- a basis for identifying when water neutrality is an appropriate aim.

The first task in this study was to scope the water neutrality concept. A number of questions were posed, based on a review of previous study assumptions and approaches, and via consultation with the project steering group. Available data was used to form a response to the question and therefore define the scope of water neutrality.

Results

It was concluded that water neutrality will normally be focused on the management of public water supplies, and should focus on reducing water consumption in households and other buildings. However, it may sometimes be appropriate to consider other types of water abstraction (e.g. industrial or agricultural) in water neutrality calculations, and 'quick wins' from operational uses of water or leakage may sometimes also be appropriate.

Water neutrality analysis is best undertaken at the water company water resource zone level, using water company data for either the annual average or critical period planning scenarios that are used in water resources planning. The analysis should take account of uncertainty associated with demand management activity. There will need to be long-term monitoring and review of supply and demand data to assess whether water neutrality activity is being effective at reducing demand.

It is clear from the study that water neutrality needs to be considered in the context of the existing water resource management and licensing system, and should not be regarded as a replacement for these existing regulatory tools.

The second task in this study was to define water neutrality targets. It is recognised that the primary aim of the water neutrality concept is to reduce demand for water from households and other buildings in new and existing development. Therefore targets should be focused on achieving this goal. However, it is also recognised that other approaches may be appropriate in certain circumstances, as identified in the scoping task described above, and the definition of targets should also take account of these alternative ways of achieving neutrality.

Achieving a 100% level of water neutrality is an aspiration, and it may not be possible or appropriate to set such a demanding target for all new development. There will be ‘drivers’ and ‘constraints’ that will define what level of neutrality (between 0% and 100%) is appropriate. Drivers are likely to include environmental factors, political or social will, climate change mitigation, and cost-effectiveness. Constraints are likely to include the relative size of the development, consumption rates in the existing development and predicted consumption in the new development.

This report considers a number of methods for quantifying these drivers and constraints so that the appropriate neutrality target for a new development can be defined in percentage terms. The report also sets out a broad classification of the potential for achieving water neutrality based on the relative scale of these drivers and constraints. This approach is considered further in the third part of this study using theoretical data that define the offset potential and environmental drivers that define the most appropriate approach to water neutrality. This approach could provide a screening tool to assess appropriate approaches to water resources management for new development.

Conclusions/recommendations

This study has considered the methods and approaches that should be used in the assessment of water neutrality, based on a pragmatic review of evidence. The conclusions from this part of the study should form the basis of future water neutrality investigations.

This study has introduced the concept of using drivers and constraints to identify appropriate approaches to setting water neutrality standards, and has explored this concept by considering environmental drivers and offsetting constraints. An outline framework for considering how environmental surplus can be compared against the demand arising from new development and the reduction in demand that is possible by retrofitting water efficiency measures into existing properties has been presented.

This study has necessarily been constrained by time and budget. As a result, some of the ideas presented in this report need further development. In particular the concepts developed for defining drivers and constraints could be tested more fully using actual data for a particular development. Other suggestions for further work are included in Section 5.

Acknowledgements

This report was prepared by Entec with contributions from the authors identified in the inside of the cover sheet. The project was managed by Dr John Phillips at the Environment Agency.

The authors would like to thank the members of the project steering group for committing their time to attend project meetings and making a valuable contribution to the outcome of this study. The steering group consisted of Rob Soley from Entec UK Ltd and the following Environment Agency staff:

Gordon Davies
Julie Foley
Richard Howell
Dave Johnson
Michael Lord
Marion Martin

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1 Introduction

1.1 Background

Water neutrality is an important, but relatively new concept for managing water resources in the context of new development. There is an established definition of water neutrality that states that '…total demand for water should be the same after new development is built, as it was before. That is, the new demand for water should be offset in the existing community by making existing homes and buildings in the area more water efficient' (Therival *et al*., undated).

This definition formed the basis for all of the studies into water neutrality that have been completed to date, notably the Environment Agency study into the feasibility of achieving water neutrality in the Thames Gateway Growth Area (Environment Agency 2007). The Thames Gateway is one of the key components of the Government's plans to increase the rate of housing supply in order to improve affordability. To address this issue, the Government's 2007 Housing Green Paper (Communities and Local Government, 2007) set out the policy to deliver 3 million new homes by 2020, at a rate of 240,000 new homes per year. These figures include the planned growth already set out in pre-existing regional spatial strategies (RSSs) and growth areas such as Thames Gateway and Milton Keynes–South Midlands (identified in the Sustainable Communities Plan). The Housing Green Paper indicated that the additional growth (i.e. about 400,000 further new houses) would be planned for in the most recent round of RSS for existing and new growth points and eco-towns.

- This accelerated rate of housing growth, together with limitations on existing supplies and the threat of climate change, have led to a need for the Environment Agency to explore the concept of water neutrality further. Specifically, the Environment Agency wishes to consider the concept of water neutrality within a broader hydrological framework, and then identify how the concept can be used to support or supplement existing water resource management strategies. To this end, the Environment Agency has commissioned Entec to undertake this project.[1]

1.2 Purpose of this report

This study aims to:

'Develop a broader understanding of water neutrality, especially with respect to the spatial/temporal dynamics of achieving neutrality so that it becomes a useful concept for the Environment Agency to apply operationally.'

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[1] The project included two work packages. Work Package 1 focused on developing an improved definition of water neutrality, while Work Package 2 is focused on scoping the monitoring activities that should be implemented to assess the impact of eco-towns on the water environment.

Further, this study should consider:

- What are the key environmental risks (and benefits) of moving towards water neutrality? For instance, what are the potential environmental impacts of point source discharge returns to the hydrological system?
- What is the most meaningful spatial scale to achieve water neutrality over, i.e. community, subcatchment, water resource zone, region? For instance, how do you calculate the water resource baseline – making reference to Environment Agency Catchment Abstraction Management Strategies (CAMS)?
- Does the environment or specific ecological parameters require water neutrality over all timescales and what is the environmental justification for seeking to achieve water neutrality over a particular time step and spatial scale?
- In what circumstances is water neutrality (or variation of) an appropriate aim (i.e. develop a criteria for water neutrality based on water availability)?

The study will be from a hydrological and water neutrality delivery perspective, focusing on the environmental risks and benefits and potential delivery issues that may have greater relevance at different spatial scales or in different geographical contexts.

1.3 Tasks and report structure

The study is being undertaken in three tasks. These are summarised in Table 1.1, which also indicates the report sections in which the findings are presented.

Table 1.1 Water Neutrality Work Package tasks.

Task	Title	Summary and report section
Task 1	Scoping water neutrality	Scope the range of issues that should be included in a holistic definition of water neutrality, i.e. moving beyond a simple consideration of water consumption. See Section 2
Task 2	Defining water neutrality options	Develop a set of water neutrality definitions, from the simple pragmatic consideration of water consumption to more complex and aspirational definitions that take into account spatial and temporal issues. See Section 3
Task 3	Water neutrality criteria	Establish criteria for the selection of locations where water neutrality could be a realistic goal and identify the most achievable water neutrality option from Task 2. See Section 4

Conclusions and recommendations are drawn together in Section 5, with references listed in Section 6.

1.4 Project steering group and review meetings

Project deliverables have been drafted by Entec staff and reviewed/revised in discussion with the Environment Agency's steering group, which has included representation from across Water Resources, Sustainability and Science functions, as summarised in Table 1.2.

Table 1.2 Water neutrality work package personnel and responsibilities.

Organisation and name	Job title	Project role
Environment Agency steering group		
John Phillips	Principal Scientist, (Hydrology) Hydrosystems	Project Manager
Richard Howell	Policy Manager, Climate Change and Sustainable Development	Project Executive
Michael Lord	Environmental Developments Officer	Project steering group
Julie Foley	Head of Sustainable Communities	Project steering group
Gordon Davies	Water Resources Policy Advisor 1	Project steering group
Marion Martin	Senior Environmental Planning Officer	Project steering group
Dave Johnson	Science Manager	Project steering group
Entec UK Contractors		
Rob Soley	Technical Director	Project Director
Rob Lawson	Associate Director	Project Manager
Anne Kemlo	Senior Consultant	Hydrologist

A project start-up meeting was held on 4 November 2008 to discuss and confirm the scope of work for this project. Draft outputs were reviewed at a steering group meeting on 12 January 2009 and final amendments to the draft were agreed at a further meeting on 26 February 2009.

1.5 Economics and sustainability links

The Environment Agency has commissioned Artesia Consulting to undertake a parallel project to the Water Neutrality Work Package, with the objective of carrying out '…an in-depth exploration and analysis of the delivery options for water neutrality.'

There are clear and important links between the projects being undertaken by Entec and Artesia, particularly with regard to determining criteria for identifying locations where neutrality could be a realistic goal, and the most appropriate approach to neutrality in a particular location.

2 Scoping the water neutrality concept

2.1 Introduction

The objective of this task is to scope the range of issues that should be included in a more holistic definition of water neutrality – broadened beyond the simple consideration of water consumption, based on the evaluation of supply and demand balances, as used in the Thames Gateway feasibility study. In particular, the extent to which water neutrality can be defined in hydrological and ecological terms will be assessed for more general water resource management in relation to new developments.

Section 2.2 sets out the rationale for broadening the water neutrality concept beyond demand management and introduces the questions intended to explore its definition, as discussed in Sections 2.3, 2.4 and 2.5. This discussion has been reorganised and expanded in the light of steering group comments on the initial draft, and a summary of the recommended way forward is provided in Section 2.6, which we have carried forward into the subsequent description of a hierarchy of water neutrality goals (Section 3).

2.2 Questions to broaden and refine the water neutrality concept

The scope of this study was discussed in broad terms at the project start-up meeting on 4 November 2008. This discussion identified the broad issues which need to be considered if the scope of the water neutrality concept is to be expanded beyond the demand-based definition which the Environment Agency currently use, i.e. that:

> …*total demand for water should be the same after new development is built, as it was before. That is the new demand for water should be offset in the existing community by making existing homes and buildings in the area more water efficient*.

This definition was used in the Thames Gateway feasibility study, with the following, more detailed assumptions:

- Neutrality was assessed on the basis of the standard water industry dry year annual average planning scenario.
- Neutrality only considered the 'water delivered' component of public water supplies. This includes water delivered to metered and unmeasured households and non-households. That meant that other types of abstraction were not considered and that water abstracted by water companies for other reasons, including leakage and operational use, were excluded from the analysis of neutrality.

- Rainwater collected at the household or development scale and/or greywater recycled from domestic baths, showers and hand-basins could be used for non-potable purposes to minimise the demand for new potable water supplies (and therefore the potential need for new public water supply abstractions). However, no other additional water could be introduced to new developments.
- The objective of the analysis was to ensure that demand for water was the same after Thames Gateway was completed as it was before. The analysis demonstrated that it was not possible to maintain neutrality through the duration of the development, given the assumed build-out rates for new households, the assumed constraints on building new homes to high Code levels and the maximum retrofitting rates that could be achieved. No consideration was given to how neutrality could or should be maintained beyond the end of the development phase.
- Neutrality should be achieved at the development level – i.e. within the boundary of the Thames Gateway. The nature of the Thames Gateway development is such that there are sufficient existing households available for retrofit to enable this to happen.
- Neutrality only considered offsetting new demand. There was some consideration of uncertainty in the study, but no quantitative assessment of 'margin of error' or headroom. This meant that scenarios in the Thames Gateway study that delivered neutrality in theory could fall some way short of this target in reality if the numerous assumptions used in the study were proven to be over-optimistic.

It is clear that these assumptions (which had to be established to enable the scope of work for this study to be defined correctly), beg further questions and more measured investigations. This is the purpose of this study. In particular this study needs to:

- develop guidance on the use of appropriate supply–demand balance data;
- assess if water neutrality can or should be defined using broader environmental factors (beyond the analysis of supply–demand balance);
- establish how water neutrality should fit into the existing approaches to water resource management;
- consider if different types of new development could achieve water neutrality in different ways and identify the factors that influence this, including the nature of the development and water supply system, the balance between surface and groundwater resources, the relevance of seasonal abstractions and storage, the location of wastewater returns and the sensitivity of the water environment.

A series of questions are discussed in the following sections to draw out this discussion further:

- Expanding the concept beyond demand management (Section 2.3):
  - Should abstractions for all purposes be considered?
  - How should changes to the location and rate of water returned to surface and groundwater bodies be accounted for in terms of overall environmental impacts (including wastewater flows, pumped refill and artificial recharge schemes)?
  - What are the environmental implications of rainwater harvesting and greywater re-use?

- Should changes in mains leakage be part of the neutrality equation, and how should the uncertainties associated with the predicted supply–demand balance be factored in?
- Should the concept be extended to include water quality, as well as water resources impacts?

• What is the appropriate spatial context for defining water neutrality? (Section 2.4):

- Is the appropriate spatial scale defined by the nature of the development and the availability of existing households for offsetting?
- Could spatial context depend on the nature of the water resources (e.g. predominance of surface or groundwater) or the nature of the water supply system (i.e. complex conjunctive use or simple standalone)?
- Should the appropriate scale reflect the level of environmental stress or sensitivity, so that neutrality is focused on a smaller area where environmental stress or sensitivity is greatest?
- How should neutrality account for potential impacts on downstream critical reaches even if they are a significant distance from the proposed development?

• Defining the temporal context for water neutrality (Section 2.5):

- Over what period should it be assessed – long-term, annual, daily?
- How long could it take to achieve?
- Can water neutrality be expected to be applied 'forever'?

2.3 Expanding the concept beyond demand management

2.3.1 Should water neutrality consider all abstractions?

Licensed abstractions in England and Wales total 53.3 million Ml/year.[2] A breakdown by abstraction purpose shows that 44% of this (23.5 million Ml/year) is for energy production, while 19% (9.9 million Ml/year) is licensed for public water supply. Water used for energy production has a low consumptive factor, and the majority of water abstracted is returned close to the source. For large power plants the Environment Agency adopts a 0.003 consumptive factor for water abstracted for cooling purposes, so 99.7% of water abstracted is returned close to the abstraction point. In addition, the majority of water used for energy production (for cooling in power stations) is

[2] These figures are taken from the Environment Agency Water Resources GIS (SAP) Tool, v 2.1 June 2008.

abstracted downstream of the tidal limit so would not be included in the equation for water neutrality.[3]

In comparison spray irrigation licences are categorised as high loss with a consumptive factor of 1.0. Annual licensed volumes for spray irrigation total 412,000 Ml/year, which represents 0.8% of total licensed annual abstraction, or 1.4% excluding power production. This is clearly a small volume compared to public water supply. However, the temporal and spatial distribution of spray irrigation licences means that in some river catchments (at some CAMS Assessment Points) spray irrigation will be a significant proportion of total abstractions, and this proportion will increase in the summer, when soil moisture deficit is at its greatest.

Other purposes with large total abstractions are for industrial use, and other water supply purposes. This latter category includes use by water companies other than for distribution input, for example in effluent dilution, hydraulic testing and other operational activities.

Water abstracted for public water supply is typically returned to the water resource system at wastewater treatment works remote from the abstraction point – hence the consumptive factor of 1.0; these returns are accounted for as consented discharges, unlike many other small abstractions (where the discharge consent volume is very inaccurate). Careful consideration will be given to how water neutrality accounts for public water supply abstractions.

Summary

The issue of neutrality is considered particularly relevant to public water supply abstractions because:

- Abstraction for public water supply is the largest component of total abstraction other than for energy production (which is returned close to source and generally beyond the tidal limit).
- These abstractions are typically returned to the environment in either different catchments or different water company water resource zones, i.e. remote from their source.

Abstraction for industrial use is also significant and will vary as a proportion from location to location, so may need to be considered in some cases of new development. Spray irrigation is a small component of abstraction nationally but will be significant at a local scale when considering some new developments.

Water neutrality should focus on public water supply abstraction in particular, but also give due regard to abstraction for industrial use and for spray irrigation if these are significant in specific development locations or at specific times of the year.

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[3] Note that some smaller abstractions for energy production (e.g. hydroelectric power) occur upstream of the tidal limit and can cause locally deprived river reaches.

2.3.2 Should water neutrality consider wastewater flows?

The Environment Agency definition of water neutrality focuses on offsetting demand by making existing buildings more water efficient. This does not allow for the potential offsetting of new demand against indirect re-use of discharges. A broader interpretation of neutrality could mean, to take a simple example, that if wastewater from a new development is treated and returned to the same river catchment and upstream of where it is abstracted, this discharge could offset the new demand in the neutrality equation.

Hence for neutrality:

New demand for water – Discharge for indirect re-use = Offsetting requirement

In this case, there is an increase in abstraction from the environment as a result of increased demand from new development. It is possible that allowing a definition of water neutrality that in fact results in a new abstraction could dilute the message that new demand must be offset by reducing demand elsewhere.

An even wider application of the neutrality concept would mean that the treated wastewater from a new development could be discharged at some other point in the same or an adjacent catchment where environmental flow thresholds are not currently met, in order to improve flows and help meet Water Framework Directive objectives, or to improve low flow issues at a more local scale than WFD reaches. The amount of water discharged to help meet environmental flow requirements could be offset against the new demand, thus:

New demand for potable water – Discharge to support environmental flow requirement = Offsetting requirement

The Environment Agency does currently take into account the impact of discharges on water available for abstraction when determining licence applications, as well as the fraction of the abstraction to be returned locally, through application of the CAMS (Catchment Abstraction Management Strategy) and RAM (Resource Availability Methodology) processes. In many water bodies the availability of water either already licensed for abstraction or available for licensing is heavily dependent on discharges of treated wastewater upstream. Licensing strategy with respect to discharges has varied across the Environment Agency to date; in some regions discharges are counted as increasing the amount of water available for abstraction while in others they are incorporated into the benchmark flow used for setting the environmental requirements (on the basis that the environmental flow needs have adapted to the presence of historical discharges) and do not result in an increase to water available for abstraction.

The SAP Risk Tool that is now used to determine licence applications does consider the combined impact of the abstraction and discharge together on the impacted water body.

When considering new demand for new developments such as eco-towns, it may be straightforward for the Environment Agency to consider how water returned to the environment can be offset against new abstractions; this would particularly be the case if a new wastewater treatment works is to be built to serve the eco-town. It may be more difficult to apply the concept where a new abstraction is required for a smaller development and wastewater from it is routed into the existing sewerage network.

An example of a location where water available for abstraction is dependent on upstream discharges is on the River Itchen in Southern Region of the Environment Agency. Southern Water has large surface water and groundwater public water supply abstractions at Otterbourne. Further downstream, Portsmouth Water abstract from Gater's Mill. Water is discharged at the wastewater treatment works at Chickenhall, located between the two abstraction points. As part of the Water Resource Planning process several options are being considered to balance the deficit in the supply–demand balance, including moving the location of the Southern Water Otterbourne abstraction to a point downstream of the discharge.

Consideration of whether wastewater discharges can be considered for a particular development will depend on the size of the development and its spatial distribution (within one, or several river catchments), the complexity of the water resource system from which the new demand is met, and the need for environmental flows to be augmented locally.

Summary

- Discharges to the water environment are already considered in the water balance as part of the resource availability and licence determination process.
- The core concept of water neutrality: that increased demand from new development should be minimised as much as possible and then offset, may be diluted if neutrality is possible by allowing effluent returns to offset new or increased abstraction.
- However, water neutrality can be extended to include the distribution of water returned to the environment, as a means of managing river flow targets, within the context of the Environment Agency's existing resource management and licensing system. Whether this is feasible depends on the development in question – its scale, the complexity of the water resources network and the hydrological setting.

Both concepts will be taken forward to Task 2 of this project.

2.3.3 How does rainwater harvesting and greywater re-use fit into the neutrality concept?

The definition of water neutrality requires demand for water to be offset by making savings within the existing community.

Rainwater harvesting from roofs (and perhaps driveways, roads and pavements of developments) is a form of local, small-scale water resource management. Rainwater is collected and stored (usually in underground tanks) before being used to provide non-potable supplies for purposes such as toilet flushing, garden watering or car washing. The volume of rainwater available for supply depends on rainfall totals and patterns and the volume of storage available.

The collection of rainwater for non-potable use removes the rainfall from the local environment. This has the potential to reduce the volume of water that infiltrates into and through the soil, and thence into groundwater (subject to normal hydrological processes). Rainwater harvesting will also reduce the volume of water which might otherwise flow into surface water drains and be discharged to local watercourses (although sustainable drainage systems will aim to reduce runoff in any case). In these ways, therefore, rainwater harvesting could reduce groundwater recharge and river flows. The scale and magnitude of this impact will depend upon the context of the development within the local hydro(geo)logical setting and the design of the rainwater harvesting system will be a factor.

For example, consider a large urban extension development in a relatively small headwater catchment where surface runoff is important to maintaining low flows. The response of this catchment to summer rainfall could be significantly reduced if the development includes large areas for rainwater capture, as a large proportion of rainfall will be intercepted by rainwater harvesting systems. Contrast this with an ‘infill’ development in a large urbanised catchment which has a historical legacy of extensive surface water drains. The relative impact of rainwater harvesting in this context is much smaller.

Greywater recycling installed in a new development is clearly a re-use of wastewater. As such, it does not have the same catchment-related issues as rainwater harvesting. Greywater will result in a lower demand than would otherwise be the case. As such it will reduce the volume of wastewater returns. It also removes a proportion of relatively ‘clean’ wastewater from the effluent stream, therefore increasing the concentration of pollutants in domestic wastewater. This may have localised implications for wastewater treatment systems and effluent dilution; however, this will have negligible impact if properties fitted with greywater systems are only a small proportion of the total number of properties within the catchment of a wastewater treatment works.

Summary

- The possible effects of rainwater harvesting on local hydrology and hydrogeology should be assessed on a site-by-site basis, particularly where development-scale systems are being considered. Where there is little or no hydrological impact then rainwater harvesting can contribute to reducing demand.
- Greywater recycling systems do not have the same issues and can contribute to reducing demand in all developments, notwithstanding possible local effluent quality issues.

2.3.4 Should water neutrality consider leakage and other ‘losses’?

Figure 2.1 shows the breakdown of raw water abstracted by water supply companies, into components of use. The data are taken from the Ofwat 2006–07 *Security of Supply Report* (Ofwat 2007), based on the June 2007 returns from water companies).

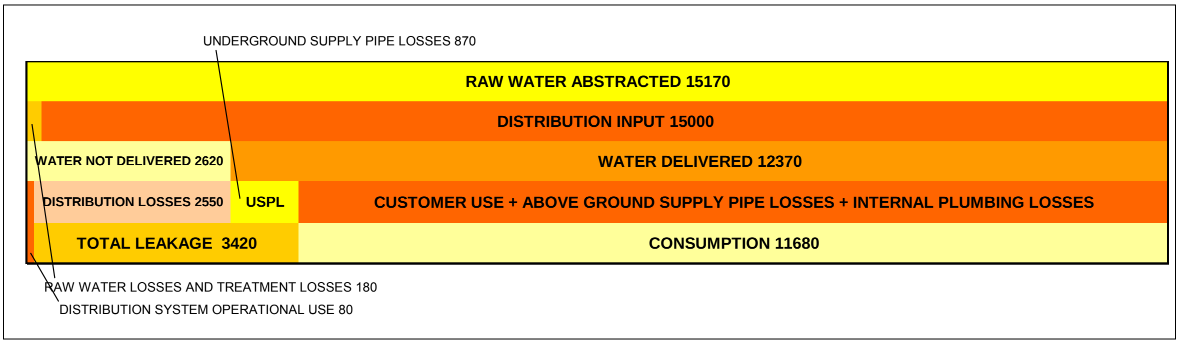

Figure 2.1 Breakdown of raw water abstraction (Ml/d) into standard components.

This breakdown shows that of the total 15,170 Ml/d raw water abstracted by water companies in England and Wales, on average 22.5% (3,420 Ml/d) is lost from the system as leakage. This figure is further broken down into two components: about three-quarters (74%) of leakage is from the distribution system which is the responsibility of the water companies, while one-quarter is lost due to leakage from customer supply pipes.

Leakage from distribution systems varies between water company areas, between water resource zones within each water company area, and typically within each water resource zone itself. Leakage is a function of topography, geographic spread and customer density (length of main per capita) as well as the condition of the network. Ofwat expects all companies to work towards their (sustainable) economic level of leakage – (S)ELL;[4] many companies are already operating close to this limit, while others have planned leakage reductions in the period to 2035 in draft Water Resource Management Plans. The approach that companies adopt to manage leakage will depend on local network circumstances and the relative costs and benefits of different leakage management options.

Table 2.1 shows actual leakage rates achieved by water companies, and targets to 2009–10.

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[4] In August 2008 Ofwat announced that it would be replacing the term ‘Economic Level of Leakage’ (ELL) with ‘sustainable, economic level of leakage (SELL). SELL takes account of social and environmental externalities in defining the appropriate level of leakage activity that a water company should undertake. By including these external costs (using a similar approach to that used elsewhere in water resource planning), it should become more economic to undertake greater leakage activity.

Table 2.1 Water company leakage performance and targets (Ml/d).

	Performance		Target		
	2005–06	**2006–07**	**2007–08**	**2008–09**	**2009–10**
Water and sewerage companies					
Anglian	215	200	210	210	210
Dŵr Cymru	225	210	205	195	195
Northumbrian – North East	155	145	155	150	150
Northumbrian – Essex & Suffolk	67	68	68	67	66
Severn Trent	540	525	505	500	500
South West	84	83	84	84	84
Southern	93	82	92	92	92
Thames	860	790	755	715	690
United Utilities	475	470	465	465	465
Wessex	73	72	74	74	74
Yorkshire	295	295	295	295	295
Water-only companies					
Bournemouth & W Hampshire	22	22	22	22	22
Bristol	53	54	54	54	54
Cambridge	13.9	13.4	14.0	14.0	14.0
Dee Valley	11.3	10.6	10.5	10.4	10.2
Folkestone & Dover	8.0	7.8	8.2	8.1	8.0
Mid Kent	28	27	27	27	27
Portsmouth	30	29	30	30	30
South East	69	69	69	69	69
South Staffordshire	73	73	75	75	75
Sutton & East Surrey	24	24	25	25	25
Tendring Hundred	5.1	5.1	5.1	5.1	5.1
Three Valleys	150	145	145	145	140
Water company total	**3575**	**3420**	**3410**	**3350**	**3320**

Where leakage reductions are already planned it would seem reasonable to exclude the reduction in demand as progress towards meeting neutrality. However, there will be scope within some water companies at local, sub water resource zone levels to improve leakage in the supply network, and these volumes of water saved could be offset against increased demand to help achieve water neutrality. In general, water companies would achieve further leakage reductions by increasing leak detection and repair activity and by maintaining a tighter control on the natural rate at which leakage increases.

There may be more potential to save water through improved maintenance of customer supply pipes. At present Ofwat expects all water companies to offer free leak detection and repair services to customers. Individual water company policies on this vary; most offer free or subsidised repair for at least the first leak detected. Customer supply pipe leakage is expected to decrease further as more household properties become metered; however, this will depend on meter location. Meters installed in boundary boxes (usually in the pavement outside houses) will pick-up any supply pipe leakage and customers will have a clear financial incentive to stop any leaks. However, this will not be the case when meters are installed internally, within households.

In addition to customer demand and leakage, the water abstracted by water companies may also be:

- lost from raw water pipes and networks (e.g. the Elan Valley Aqueduct, that transfers water from mid Wales to Birmingham, is the largest raw water transfer in England and Wales);
- lost as part of the treatment process (e.g. when used as a filter washwater);
- used for operational purposes (e.g. flushing of mains after repair work).

While these uses are very small in total volumetric terms across England and Wales, there may be local situations where improved management of water supply systems could provide cost-effective means to contribute towards water neutrality. Such measures should be explored where this is the case.

Summary

- In general where water companies have plans in place to reduce losses from the distribution system these efficiency gains should not be set against new demand to achieve neutrality.
- However, within the locality of a planned new development there may be scope to reduce leakage rates and this should be considered on a case by case basis (e.g. if the development itself provides the opportunity for infrastructure improvements that would not otherwise take place).
- Customer supply pipe leakage represents a quarter of total leakage and could be improved. This might be considered as contributing to neutrality, but care must be taken to avoid double counting when considering the effect of metering on demand.
- Reducing other losses of water (e.g. reducing process losses at water treatment works) might contribute towards neutrality in certain areas where cost-effective reductions have been identified.

2.3.5 Should water neutrality take account of uncertainties in supply, demand and environmental variables?

Headroom is a tool for managing uncertainty in current and future supply and demand, including the uncertain impact of climate change on available resource and customer demand. Available headroom is the balance between supply and demand, taking into account losses, i.e.

Deployable output – Demand – Outage = Available headroom

Water companies have to plan to meet demand (plus an allowance for outage) plus an acceptable level of headroom – often referred to as ‘target headroom’. This target headroom figure is a calculated value, derived by taking account of a range of uncertainties that are beyond the control of the water company. In simple terms, there is a supply–demand deficit if available headroom is less than target headroom. In real-life terms, this means that customers may experience lower levels of service (i.e. more frequent hosepipe bans) than planned for by the water company.

Climate change uncertainty can often be the predominant component within target headroom. This is because of the large uncertainty in climate change predictions generally, and the uncertainty associated with the impact of climate change on water resources in particular.

Therefore the uncertainty associated with the effects of climate change on water resources and the demand for water are included within the 'standard' headroom calculation, which should be made before considering the uncertainty associated with any water neutrality activity.

As headroom uncertainty is always a required part of the normal water resource planning process, it is appropriate that it is considered in the analysis of water neutrality. As such, headroom uncertainty for water neutrality assessments should allow for uncertainties associated with:

- measures designed to minimise new demand;
- measures designed to offset this new demand (supply and demand side).

It will be necessary to agree the level of risk that should be incorporated into headroom analysis for water neutrality studies. Water companies typically plan to manage 95% of the headroom uncertainty in the early part of the planning period, but this might not be appropriate (or achievable) if the uncertainties associated with neutrality schemes are much higher than 'conventional' water resource management options.

Figure 2.2 illustrates the uncertainty around offsetting measures introduced to achieve neutrality with a new development. While these measures are planned to balance the new demand, if they are not as effective as expected then additional net demand will arise. A measure of this uncertainty, a target headroom allowance, is added to the supply–demand balance and may result in a deficit, which will need to be met with additional demand and offsetting measures, or new supplies.

Summary

Climate change uncertainty is accounted for within headroom. Water neutrality analysis should take account of uncertainty by incorporating the relevant aspects of the standard headroom methodology. The headroom required to account for uncertainties in achieving water neutrality is likely to be large compared to headroom calculated in 'normal' water resources planning, because the measures that are being implemented are relatively novel and risky. This will have implications for the appropriate level of risk that should be adopted in planning for neutrality.

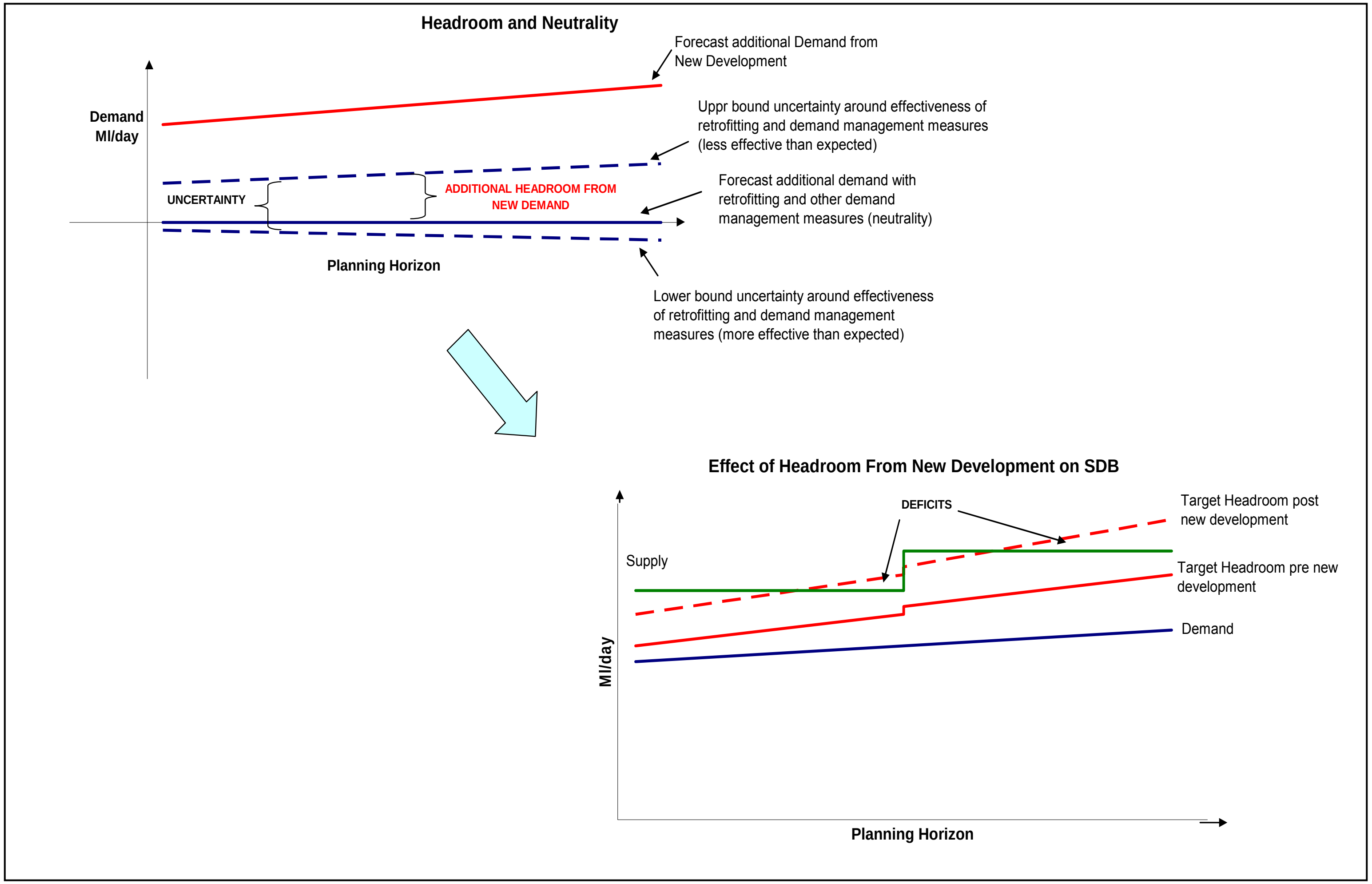

Figure 2.2 Headroom uncertainty.

SDB = supply–demand balance

2.3.6 Should water neutrality take account of water quality?

Water quality could be included in a consideration of water neutrality. However, it is regulated by the Environment Agency through the discharge consenting process, and the Water Framework Direction requires water quality objectives to be met for all water bodies by 2016. Therefore the specific issue of water quality and neutrality will not be taken further in this project. However, there are water quality issues associated with a number of the topics being dealt with in this study that need to be identified. For example:

- increased treatment costs if discharging around surface water intakes or into groundwater;
- reduced demand results in increased pollutant concentrations in effluent.

These should be considered in the approach to setting water neutrality goals, as described in Section 4.

2.4 What is the appropriate spatial context for defining water neutrality?

Water neutrality could be defined at a range of scales, although it should be noted that the primary aim of the water neutrality concept is to manage demand so that new development can be delivered in the context of the constrained resource situation in many areas of England and Wales. Therefore, the analysis of water neutrality has to be able to demonstrate that managing demand (or alternative measures, as discussed in this section) does reduce or remove the need for additional resource development.

Based on this assessment, water company water resource zones are likely to be the most appropriate 'default' context for water neutrality analysis. By using water resource zones it is possible to analyse water company data on supply and demand from their Water Resource Management Plans. These are publicly available documents. They usually provide all the information required to assess the feasibility of achieving water neutrality, although it is likely that a significant amount of data manipulation will be required. This was the case with the Thames Gateway study, and the methods of data analysis used are described in the main project report.

2.5 Defining the temporal context for water neutrality

2.5.1 Should water neutrality be met at all times?

The time period over which the water neutrality concept should be applied needs to be considered. Should water neutrality be achieved at a daily, monthly, or annual scale, or all of these? How should the dry year and peak periods used in water resource planning be used when considering water neutrality?

Where a new development is built, the demand for water will vary on a daily and seasonal basis and from year to year. In the water company standard process for water resource planning demand for water from household and non-household customers is considered for a theoretical dry year planning scenario and for the peak period (which is usually but not always within the design dry year) where the supply–demand balance is at its lowest. The critical period is often a dry period in summer when garden watering gives rise to higher than average household demand, while supply from direct river and groundwater abstractions will be lower than average.

If the balance of available supply (plus headroom) to projected demand for the peak period is in deficit at any time over the forecast, then measures will need to be taken to address this deficit. In standard water resource planning the costs and benefits of demand management measures and new supplies (or optimising the water resource system) are considered. To achieve neutrality new demand needs to be offset with demand management measures and no use of new resource, but this could be averaged over the dry year. This is illustrated in Figure 2.3, which shows demand from a new development in a dry year.

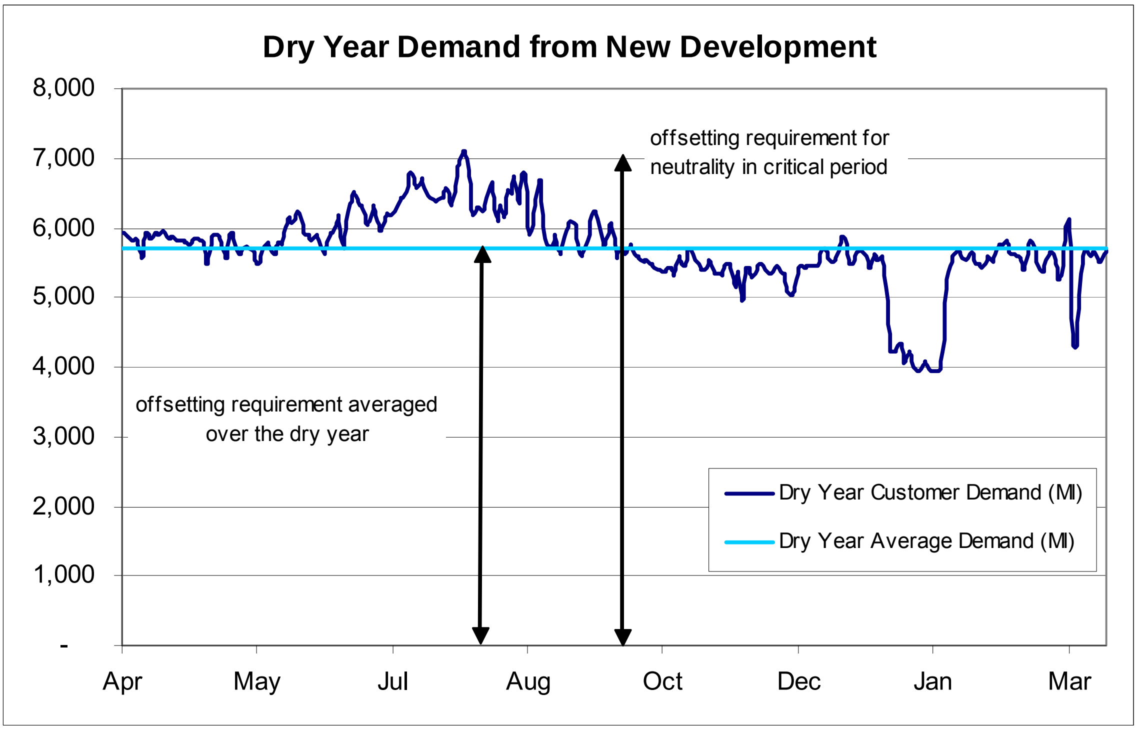

Figure 2.3 Customer demand in a dry year from a new development.

In this example to achieve neutrality over a year an offset of about 5.7 Ml/d would be required, and this could be offset by implementing a range of measures which have an approximately constant impact in savings over time, and do not vary seasonally (e.g. dual flush toilets).

If, on the other hand, the new demand in the peak period (7.1 Ml/d) is to be offset within the peak period then other measures targeted at reducing demand in the peak period in existing houses and other buildings would need to be considered (e.g. meter tariffs which may reduce garden watering).

The decision on whether neutrality should be achieved in the peak period or on an annual average basis could depend on whether:

- the water resource zone in question has a dry year and/or peak period supply–demand deficit;
- the deployable output of the relevant source(s) that may need to supply the new development is dry year or peak period critical.

If offsetting and neutrality can be realised at an annual timescale it may be possible to permit additional supply during a period where water resource is available for abstraction (e.g. additional pumped storage during winter) which would be used at periods of high demand, or by balancing demand and supply within the distribution system (i.e. using service reservoir storage).

Alternatively, it may be possible to allow neutrality to be achieved ‘on average’ over longer periods in areas where there is limited water stress or environmental sensitivity, whereas neutrality would need to be achieved within much tighter timescales (within stricter standards) in areas of high water stress, or where environmental sensitivity is greatest. The application of such environmentally based criteria for the definition of appropriate levels of water neutrality is discussed further in Sections 3 and 4.

Summary

The dry year annual average demand scenario is considered the most appropriate ‘default’ context for analysing water neutrality, however it may be necessary to achieve water neutrality for the peak period demand scenario if:

- the deployable output in the water resource zone in question is peak period critical;
- peak period demands cannot be managed via storage provision (as either additional ‘winter storage’ or storage in the distribution system).

Offsetting of peak period demand will require focused activity to minimise the demand for garden watering and other outdoor uses of water in existing and new households.

2.5.2 What monitoring is necessary to ensure that water neutrality is being achieved?

The process of setting targets for water neutrality, then monitoring how effective the new development is in meeting the targets, should be considered. At the planning stage there will be uncertainty about the demand forecast and how effective retrofitting and other demand management measures will be in reducing demand over the forecast period.

Demand and demand offsetting will need to be monitored through the project to determine whether forecast values, and neutrality, are being met. Monitoring retrofit activity could be used as an indicator of demand offsetting, but the effect of retrofitting on per capita consumption will also need to be monitored. Forecasts will need to be revised and new targets set for offsetting, in a cyclical process through the planning horizon as indicated in Figure 2.4. This could be subject to regular reviews, for example once every five years (to coincide with the Periodic Review). It is likely that this would be carried out at the water resource zone level.

The Thames Gateway study demonstrated the challenges of achieving water neutrality from the start of building a new development; even the scenarios with the most ambitious demand management targets did not balance new demand with savings until the fourth year of the programme. This was because of the assumptions in this study associated with timescales required for water companies to implement new metering tariffs (in line with Periodic Review cycles) and government timescales for Code for Sustainable Homes targets to be in place. This study demonstrates that retrofitting activity is likely to be required some time (e.g. 3–4 years) before new development takes place in order to enable water efficiency to be maintained throughout the development period. It is also likely that new households will need to be built to advanced levels of the Code for Sustainable Homes in the early years of development.

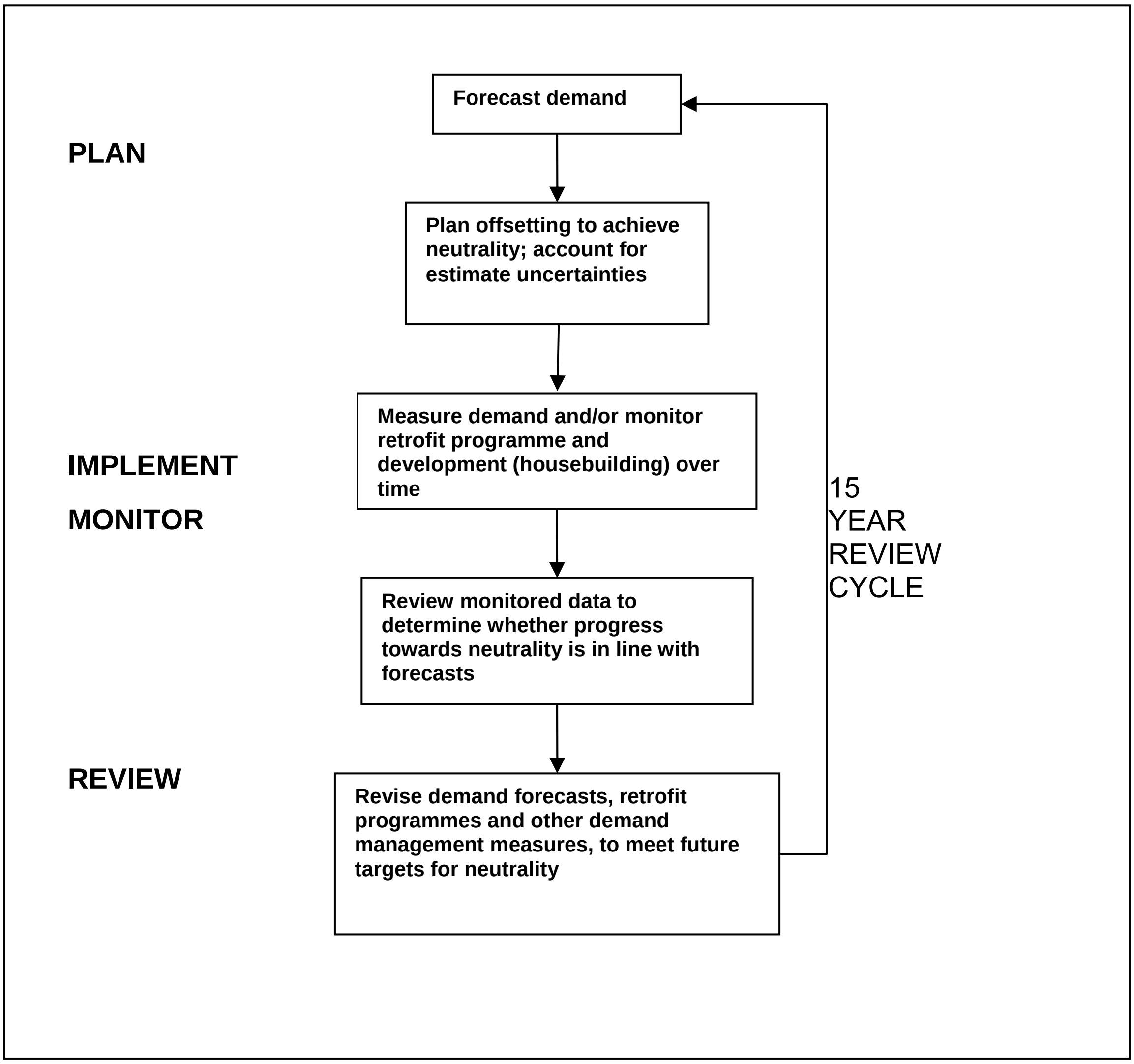

Figure 2.4 Process for monitoring and review of water neutrality targets.

Summary

Some form of monitoring and assessment will be required to assess whether neutrality is being achieved and maintained. This needs to be carried out in the context of planned offsetting and other approaches to achieving neutrality and performance will need to be assessed retrospectively. This performance assessment will then trigger further actions, if required.

2.5.3 Should the water neutrality concept be applied 'forever'?

Water neutrality will only provide an effective solution in the context of new development and constrained water resource availability if the appropriate approach to water neutrality is established at the outset of the development and then maintained into the future. Therefore, the appropriate level of water neutrality should take account of the current understanding and the related uncertainty associated with a range of issues such as:

- the current and future extent and effectiveness of water efficiency activity in terms of retrofits and new building standards;
- the rate of new development;
- the increase in demand following initial water efficiency activity;
- the effect of climate change on the availability of resources and the demand for water.

The uncertainty associated with these issues should be addressed within the headroom component required in water neutrality assessment, as described in Section 2.3.5. These uncertainties are large and, as discussed previously, it may not be desirable that water neutrality programmes offset all of this uncertainty into the distant future. Therefore, a similar process to that set out in water company water resource planning could be adopted so that:

- robust water neutrality analysis is undertaken;
- uncertainty is estimated;
- an acceptable proportion of uncertainty is planned for and factored in to the neutrality analysis (therefore there is a proportion of the uncertainty that is not planned for);
- the analysis is revisited at regular (e.g. five-yearly intervals) and uncertainty is reassessed and the approach to accounting for this uncertainty is reconsidered. This may result in modifications to water neutrality strategies (e.g. more retrofitting or higher targets for new builds), which will then be reviewed at the next review point.

2.6 Summary and proposed way forward

This section brings together the summaries from the individual sections in the preceding part of the report, and then presents an outline of the 'way forward' for more detailed consideration in Sections 3 and 4.

2.6.1 Summary

Should water neutrality consider all abstractions?

The issue of neutrality is considered particularly relevant to public water supply abstractions because abstraction for public water supply is the largest volumetric component of total abstraction other than for energy production (which is returned close to source and generally beyond the tidal limit).

Abstraction for industrial use can also be significant and will vary as a proportion from location to location, so may need to be considered in some cases of new development. Spray irrigation is a small component of abstraction nationally but will be significant at a local scale when considering some new developments. Therefore, water neutrality should focus on public water supply abstraction in particular, but also give due regard to abstraction for industrial use and for spray irrigation if these are significant in specific development locations or at specific times of the year.

Should water neutrality consider wastewater flows?

- Discharges to the water environment are already considered in the water balance as part of the resource availability and licence determination process.
- The core concept of water neutrality: that increased demand from new development should be minimised as much as possible and then offset, may be diluted if neutrality is possible by allowing effluent returns to offset new or increased abstraction.
- However, water neutrality should be extended to include the distribution of water returned to the environment, as a means of managing river flow targets, within the context of the Environment Agency’s existing resource management and licensing system. Whether this is feasible depends on the development in question – its scale, the complexity of the water resources network and the hydrological setting.

How does rainwater harvesting and greywater re-use fit into the neutrality concept?

- The possible effects of rainwater harvesting on local hydrology and hydrogeology should be assessed on a site-by-site basis, particularly where development-scale systems are being considered. Where there is little or no hydrological impact then rainwater harvesting can contribute to reducing demand.
- Greywater recycling systems do not have the same issues and can contribute to reducing demand in all developments, notwithstanding possible local effluent quality issues.

Should water neutrality consider leakage and other ‘losses’?

- In general where water companies have plans in place to reduce losses from the distribution system these efficiency gains should not be set against new demand to achieve neutrality.
- However, within the locality of a planned new development there may be scope to reduce leakage rates and this should be considered on a case by case basis (e.g. if the development itself provides the opportunity for infrastructure improvements that would not otherwise take place).
- Customer supply pipe leakage represents a quarter of total leakage and could be improved. This might be considered as contributing to neutrality, but care must be taken to avoid double counting when considering the effect of metering on demand.
- Reducing other losses of water (e.g. reducing process losses at water treatment works) might contribute towards neutrality in certain areas where cost-effective reductions have been identified.

Should water neutrality take account of uncertainties in supply, demand and environmental variables?

Water neutrality analysis should take account of uncertainty by incorporating the relevant aspects of the standard headroom methodology. Climate change uncertainty is accounted for within headroom. The headroom required to account for uncertainties in achieving water neutrality is likely to be large compared to headroom calculated in ‘normal’ water resources planning, because the measures that are being implemented are relatively novel and risky. This will have implications for the appropriate level of risk that should be adopted in planning for neutrality.

What is the appropriate spatial context for defining water neutrality?

The water company water resource zone is likely to be the most appropriate scale for analysing water neutrality.

Should water neutrality be met at all times, and how will this be assessed?

The standard ‘dry year’ and ‘critical period’ planning scenario should be used in water neutrality assessments. Offsetting the critical period demand will require different approaches to offsetting over the annual average.

The appropriate approach to use will depend on the development in question and its context in the natural and built environment. The selection of the relevant approach will be discussed further in Section 4.

Some form of monitoring and assessment will be required to assess whether neutrality is being achieved and maintained. This needs to be carried out in the context of planned offsetting and other approaches to achieving neutrality, and performance will need to be assessed retrospectively. This performance assessment will then trigger further actions, if required.

2.6.2 Proposed way forward – an outline

The scoping task has confirmed that an expanded definition of water neutrality is appropriate, given that water neutrality should:

- Give due regard to abstraction for industrial use and for spray irrigation if these are significant in specific development locations or at specific times of the year.
- Consider local catchment issues associated with rainwater harvesting.
- Be extended to include the distribution of water returned to the environment, as a means of managing river flow targets.
- Consider the potential contribution of leakage (below SELL) and reductions to other ‘losses’, in specific development locations.
- Consider uncertainties via headroom.
- Be delivered at the appropriate scale and context within the framework described in Sections 3 and 4.

- Be maintained over appropriate periods and durations (as demonstrated via appropriate monitoring and review), within the framework described in Sections 3 and 4.

All of this needs to be undertaken within the context of the Environment Agency's existing resource management and licensing system. Section 3 now proposes a range of water neutrality definitions that are set within this existing framework.

3 Deriving water neutrality standards

3.1 Introduction

Water neutrality is a concept and policy driver that is aimed at increasing water efficiency in new and existing development. As a result, the concept of water neutrality should focus on minimising demand from new development, and then seek to offset as much of this new demand as possible by reducing demand in existing development.

The majority of water that supplies new and existing development comes from public water supplies, abstracted, treated and distributed by water companies. The majority of these public water supplies provide water to homes (i.e. household demand) and other premises (i.e. non-households). Water neutrality standards should therefore focus on managing water demand in households and non-households, but give consideration to other options (as discussed in Section 2) where appropriate.

For example, it should be recognised that there may be options to manage water resources in a more 'elegant' way which could achieve similar objectives to water neutrality: i.e. to allow new development in water resource constrained areas. These elegant water resource management options could include the use of wastewater returns, the use of winter storage or the decentralisation of water supply abstraction (e.g. away from one large, high-impact abstraction to several small abstractions with low/negligible impact). Other more esoteric options such as the modification of land-use patterns to increase runoff could also be considered if appropriate within the wider catchment management context.

3.2 Setting water neutrality targets

Water neutrality is a concept and an aspiration, and in many instances targets set for new developments would not reach 100% water neutrality, but some lower level of offsetting would be appropriate. The factors that influence water neutrality will be different for each development. They will depend on the nature of development itself and existing development nearby (i.e. the offset potential), and the condition of the water environment where the development is to be located (i.e. environmental drivers).

The offset potential for the development will depend on factors such as:

- the relative size of the development compared to existing development within the water resource zone;
- the per capita consumption (pcc) rates in the existing housing stock, which will depend on the extent of water metering in the water resource zone, and other factors, such as the 'human geography' of the area (e.g. population/housing density, socio-economic make-up, etc.);
- the pcc rates predicted for the new development; in particular the Code for Sustainable Homes level which is being planned.

The factors which influence the offsetting potential are considered in detail in Section 3.3.2, and in a quantitative assessment in Section 4.

The assessment will allow the development to be placed on a scale of offset potential, where high potential indicates that a large proportion of new demand could be offset. Lower offset potential indicates that some but not all of the new demand could be offset. For example, demand in the pre-existing development may already low as a result of high meter penetration, retrofitting of water efficient appliances already in place, and/or a programme of demand management measures that has already been implemented by the water company.

Water neutrality drivers will indicate how important or useful it is to progress to higher levels of offsetting for each development. Environmental drivers are likely to be a key factor, but other drivers are likely to be relevant, including:

- climate change mitigation (i.e. reducing carbon emissions from treatment and pumping of potable water and wastewater);
- political or social will;
- cost-effectiveness.

This study focuses on the environmental drivers for water neutrality, as these are likely to be of primary importance in setting water neutrality targets. The most relevant indicator of environmental condition in this context is considered to be the water body characterisation derived for the Water Framework Directive. Where water bodies within the water resource zone (and impacted by any proposed new abstraction) are already environmentally stressed then this will drive the need for water neutrality. Conversely, where there are flow surpluses in the relevant catchments the environmental driver will be less strong. Where available catchment resource is sufficient to meet abstraction for new demand (and it can be abstracted at a suitable location) the environmental driver for offsetting or neutrality will be low.

Environmental drivers are discussed further in Section 3.3, and the balance of environment against offset potential is presented. In Section 4 a method for quantitative assessment is developed.

3.3 Considerations for setting neutrality targets

This section considers the factors which affect the offset potential and the environmental drivers for water neutrality in more detail.

3.3.1 Environmental drivers

The existing water resource GIS system provides a means of assessing the current flow status of water bodies as defined by the Water Framework Directive and the UK TAG methodology, which sets the thresholds for resource availability categories.

The GIS system has populated all licensed abstractions and discharges in England and Wales, as well as natural flow estimates for each water body. It is possible to determine the surplus or deficit flows within each water body relative to an environmental flow indicator that must be achieved to ensure the WFD target to support good ecological status is met. This provides an indication of the level of environmental stress already present within the water body, and the amount of water resource, if any, which might be available for new abstraction to meet demand for a new development. The resource categories are shown in Table 3.1.

Table 3.1 WFD Water Body Status classification.

Classification		Water Body Status	CAMS colour
Fully licensed flows and recent actual flows >	Natural flows	Large surplus of water. New abstraction licences may be considered. Upstream discharges > abstractions.	Grey
Fully licensed flows and recent actual flows >	Environmental Flow Indicator (EFI)	Surplus of water. New abstractions may be considered.	Green
Fully licensed flows < AND Recent actual flows >	EFI EFI	Approximate equilibrium. No available new resource.	Yellow
Fully licensed flows << AND Recent actual flows >	EFI EFI	Water body is over-licensed. No available new resource.	Orange
Fully licensed flows << AND Recent actual flows <	EFI EFI	Flow recovery may be necessary. No available new resource.	Red
Fully licensed flows << AND Recent actual flows <<	EFI EFI	Flow recovery may be necessary. No available new resource.	Purple

A high level, first-pass consideration of environmental stress within a water resource zone of interest would look at the distribution of flow deficits in water bodies within the zone. The sum of these deficits across each water resource zone would give an indication of the level of environmental stress in the catchments contributing to each water resource zone, and the levels of water neutrality or offsetting which would be likely as targets for new developments within these water resource zones. A map of England and Wales showing the spatial distribution of flow deficits by water resource zone could therefore be used as an initial indicator for developers, water companies and local authorities when discussing planned developments, and indicates likely aspirational targets for water neutrality.

A more quantitative calculation of environmental stress is discussed in Section 4.1.

3.3.2 Offset constraints

This section discusses the possible constraints to achieving water neutrality by minimising and offsetting demand at a new development.

Ratio of new build to existing households

Clearly if demand from a new development is to be offset by reducing existing demand then the number of households within the water resource zone, or zones, where the development is to be located is a key factor. Previous work by Entec (the Thames Gateway report) showed that between 3 and 8 households would need to be retrofitted with a variety of water efficient appliances to offset the demand from each new build house.

This ratio of retrofits per new house may be applied to any new development. The exact number of retrofits required per new household would depend upon the retrofitting measures used and the water efficiency standards to which new homes are built. Therefore the ratio would be relatively small (i.e. closer to 3) if an extensive retrofit programme is undertaken alongside the development of new homes to very high water efficiency standards.

Hence, where new developments are to be located close to or as extensions to existing urban areas with higher population density, there will be potential for offsetting more homes locally, than if a rural or suburban location is planned.

Where larger developments are located over parts of more than one water resource zone then offsetting can be considered across all of the water resource zones, increasing the offsetting potential.

Another consideration when looking at the area from which offsetting will occur, is other new developments planned in the area over the same timescale, and whether they will be seeking to offset within the same or overlapping areas.

In general, potential for offsetting depends on the ratio:

The number of houses in the new development : number of existing households within water resource zone(s)

Per capita consumption rates in existing households and new development

Current and forecast per capita consumption rates for existing households within the water resource zone(s) where the development is to be located will be a factor in determining offset potential. Water resource zones with high current and forecast consumption rates (e.g. Portsmouth Water's resource zones) will have greater offset potential than water zones with relatively low per capita consumption rates (e.g. Tendring Hundred Water's resource zone).

The per capita demand for water in the new development will depend on the type of households to be built, the occupancy rates, and the water efficiency standard of the new homes as measured by the Code for Sustainable Homes rating. The regulatory minimum standard is for 125 l/person/day, which equates to Level 1/2 of the Code. Houses built to this standard will require more offsetting than those built to Level 5/6 (80 l/person/day) to achieve the same level of water neutrality.

Current and planned meter penetration

The opportunity to increase the future meter penetration in existing households in a water resource zone increases the offset potential. Therefore water resource zones with low current meter penetration have higher offset potential than zones that already have high meter penetration.

In general the potential for offsetting depends on the ratio

Existing unmeasured households in the water resource zone : Existing total households in the water resource zone

3.4 Presenting the environmental drivers and offset potential

A visual assessment of the environmental drivers and potential for offsetting is shown in Figure 3.1. A measure of the environmental drivers for implementing water neutrality is along the x-axis, with higher environmental stress (indicated by zero or negative available resource for new supply) increasing along the x-axis. The potential for offsetting demand or achieving water neutrality is measured along the vertical scale, with higher offsetting potential in the upper half of the diagram.

So, for example, a development to be situated in a water resource zone where the relevant subcatchments are currently subject to high environmental stress but where the potential for demand minimisation and offsetting is high such that water neutrality could be achieved, would be plotted in the top-right quadrant of the figure.

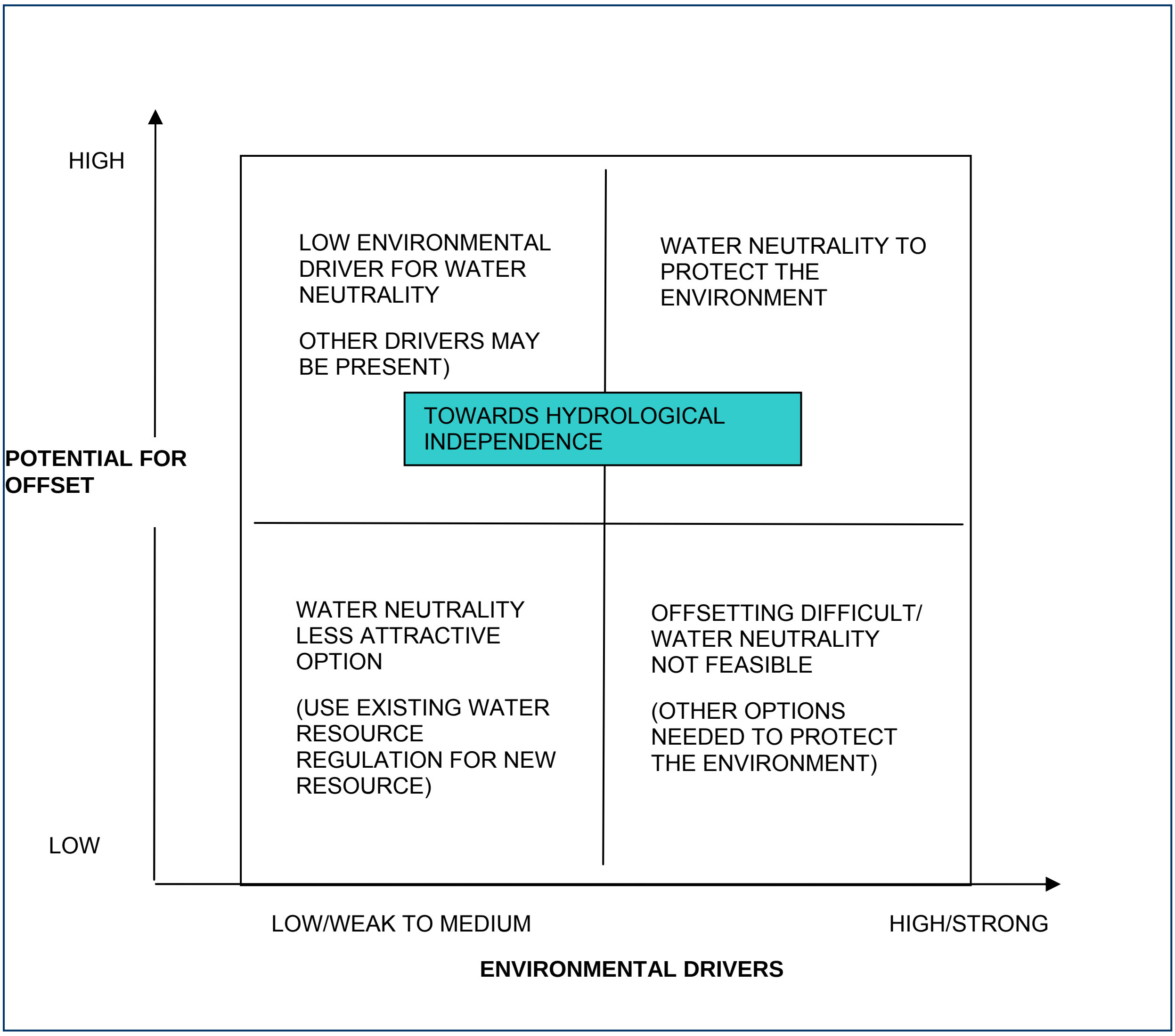

Figure 3.1 Drivers and potential for offsetting and water neutrality.

- Low offset potential and low environmental drivers – in this lower-left quadrant of the diagram environmental drivers are identified as low, meaning that there is likely to be some surplus water within the water resource zone which can be licensed for new supply without impacting on flow targets and the environmental stress of any catchments; in addition scoping work has shown that water neutrality cannot be achieved for the new development, and there is limited opportunity for offsetting demand, because of one or more of the constraints discussed in Section 3.3.2. In this case it would be appropriate to apply existing Environment Agency water resource regulation to licence the new supply.

- Development constraints – the lower-right quadrant signifies that there are environmental drivers within the water resource zone(s) considered, so that only limited or no new water is likely to be available for licensing. In addition, constraints on offsetting demand in the new development have been identified which mean that there is lower potential for offsetting and water neutrality. In this situation, options for the 'elegant use of water resources' should be considered. These could include relocating existing discharges to allow re-use of discharged water for new supply, or making more effective use of winter storage.
- Towards hydrological independence – for developments falling into these two quadrants it is identified that there is the potential to achieve high offsetting levels or perhaps 100% water neutrality, so that the development would have no impact on the hydrological regime – no new water supply would be required. In the upper-right quadrant the baseline environmental stress is high, and this is the driver for setting neutrality targets as high as reasonably possible. In the upper-left quadrant environmental drivers are lower. As a result it may be possible to apply the concept of 'elegant management of water resources', for example through the effective use of storage. The requirement for offsetting is not driven by the environment in this quadrant, so while some target for offsetting is likely to be appropriate, this will need to be driven by other factors apart from the environment (e.g. political/social will).

4 Identifying appropriate water neutrality approaches

The environmental drivers and offsetting constraints which might apply to a particular new development were discussed in Section 3.3.2, and illustrated diagrammatically in Figure 3.1. This section considers a more quantitative assessment of the constraints and opportunities for water neutrality, and will enable specific targets to be set. These approaches are set out in Figure 4.1, which also summarises the structure of this section.

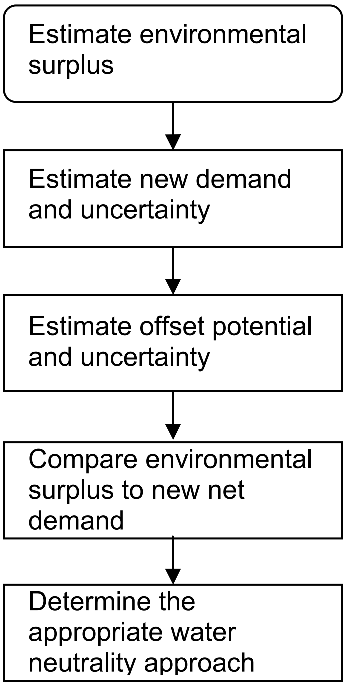

Figure 4.1 Outline method for identifying appropriate water neutrality approaches.

4.1 Estimating the environmental surplus

Section 3.3.1 considered how mapping of water body flow status could be used as a high level indicator of aspirational water neutrality targets, based on environmental surplus at the water resources zone level. At this stage, a more detailed assessment will consider:

- The environmental surplus available within water bodies that are currently used for abstraction to the proposed development area. This will provide an indication of the water available for abstraction without significant infrastructure investment (although there may be a requirement for additional intra-zonal transfers).
- The environmental surplus within water bodies that are not currently used for abstraction. This will provide and indication of the water available for abstraction, but that would require investment in abstraction works, treatment works and supply infrastructure to provide additional public water supplies.

The assessment should take account of the actual abstraction scenario, and consider water availability during low flows, based on Q_{95}. This would mean that the analysis of environmental surplus considers the additional abstraction that may be possible within existing licences and identify where new abstraction licences are required and whether such abstractions could be maintained continuously. The value of the environmental surplus may change over time if, for example, the Habitats Directive Review of Consents, or climate change, reduces the amount of water that may be taken from the environment.

The environmental surplus parameter provides a fixed reference point in the subsequent assessment of offset potential. However, if the demand assessment described in Section 4.2 indicates that additional abstraction may be required, then alternative approaches to offset demand, or alternative supply-side options, may need to be considered. Where this is the case, it may be appropriate to consider the benefits of creating additional winter storage (as part of a wider assessment of supply-side options). The assessment will be undertaken on a zone by zone basis. Where necessary it may be appropriate to consider the environmental surplus in neighbouring zones (in the same way as described above), so that opportunities for transfers between water resource zones can be considered.

4.2 Determining net additional water demand

4.2.1 Potential demand from new development

The growth in demand from the new development should be estimated, based on design parameters from the different Code for Sustainable Homes levels of efficiency in the water neutrality assessment. This is illustrated in Table 4.1, which shows how a new development of 20,000 new homes may be built-out to different levels of the Code over the next 10 years.

Table 4.1 Example of Code for Sustainable Homes (CSH) build-out rates.

Year	CSH L1/2	CSH L3/4	CSH L5/6
2010	1500	500	0
2011	1000	800	200
2012	500	1100	400
2013	0	1400	600
2014	0	1100	900
2015	0	800	1200
2016	0	500	1500
2017	0	200	1800
2018	0	0	2000
2019	0	0	2000

The forecasting of how the Code for Sustainable Homes will be adopted is still somewhat subjective, so it is recommended that a range of build-out rates are considered, including ‘optimistic’ and ‘pessimistic’ rates as a minimum. Of course any site-specific information (e.g. local authority planning conditions) should be taken into account where appropriate.

Demand from new non-households will also have to be estimated. Information on non-household development is often much less detailed than household development; however, there will often be an indication of whether new schools, surgeries or community centres will be built, and an indication of office floor space. There is published information available to estimate demand from these sorts of new non-households.

4.2.2 Uncertainty associated with demand from new development

Forecasting the demand for water is an uncertain activity. The Code for Sustainable Homes (CSH) sets out design standards for new homes. Currently, it is not possible to predict whether occupants of these new homes will use water according to these design standards. It is quite possible that their water-using behaviour will result in consumption rates more typical of the national average. It is reasonable to assume that there is greater uncertainty around the lower consumption targets in new households than around consumption in the general population. For the purposes of this study the following levels of uncertainty have been adopted:

- Uncertainty around new household demand at CSH Levels 1/2 should be comparable to existing water company estimates of demand uncertainty.
- Uncertainty around new household demand CSH Levels 3/4 should be ±5% above existing water company estimates of demand uncertainty.
- Uncertainty around new household demand at CSH Levels 5/6 should be ±10% above existing water company estimates of demand uncertainty.

These uncertainty values are important in the analysis of offset potential, and while the figures above are indicative, further investigation is recommended to provide more robust estimates of such uncertainties.

This uncertainty should be added as a factor to the demand derived from the Code for Sustainable Homes build-out rates, as illustrated in Table 4.1. Table 4.2 illustrates a calculation for new household demand, plus uncertainty, based on the CSH build-out rate presented in Table 4.1 and a theoretical occupancy rate of 2.0.

Table 4.2 New demand and uncertainty from new development.

Year	New demand	Cumulative new demand (Ml/d)	Uncertainty (Ml/d)	New demand + uncertainty (Ml/d)
2010	0.48	0.48	0.02	0.50
2011	0.45	0.93	0.05	0.98
2012	0.42	1.35	0.07	1.42
2013	0.39	1.74	0.17	1.91
2014	0.38	2.12	0.21	2.33
2015	0.36	2.48	0.37	2.85
2016	0.35	2.82	0.42	3.24
2017	0.33	3.15	0.47	3.62
2018	0.32	3.47	0.52	3.99
2019	0.32	3.79	0.57	4.36

4.2.3 Potential for offsetting

Section 3.3.2 described the factors that will affect the offsetting potential, namely current rates of per capita consumption and meter penetration in a water resource zone, as well as the ratio of new households to existing households. It is difficult to define specific thresholds for these parameters; however, as a guide the following points should be considered.

It is likely that greater effort from Government and regulators will be focused on reducing average per capita consumption (pcc) towards the target of 130 l/person/day, as stated in Defra's Future Water strategy document. Therefore an estimate of potential pcc reduction could be derived by calculating the weighted average pcc in a water resource zone (taking account of the current pcc in metered and unmetered households, and the current numbers of households in these two classes), and then subtracting the 130 l/h/d target value.

Metering is forecast to contribute to a reduction in per capita consumption; therefore this estimate of potential pcc reduction should be revised downwards if current meter penetration in the water resource zone in question is higher than the national average of around 30% (an estimate of 5 l/h/d for every 10% above the 30% average has been used in this study, but further research would be required to derive a more robust estimate of this variable).

Retrofitting water efficiency devices into existing households will be a complex and expensive task that will require significant effort and co-ordination from a number of stakeholders, as well as strong levels of buy-in from the public. Not all retrofits will work or be kept in place, and many households will not be suitable or accessible for installation. There is also likely to be an upper limit on the number of retrofits that can be carried out in a particular period of time. All these factors will affect the uptake rate of retrofits.

The Thames Gateway Water Neutrality study (Environment Agency 2007) found that retrofitting in around 50% of existing households was necessary to achieve neutrality. This is considered to be an upper limit on what is likely to be possible without fundamental changes in our approach to water resource management as well as public attitudes to water use. It is likely that higher uptake rates (i.e. up to the 50% level) will be possible in larger water resource zones (i.e. where the ratio of new to existing households is lower). It is also likely that the uptake limit will be reached earlier in smaller water resource zones, thus constraining offset potential.

Based on this review, there are five single value parameters that will influence offset potential. Theoretical values for these parameters are given below using the case study presented earlier, i.e. 20,000 new homes in a water resource zone with 100,000 existing households:

- New to existing ratio — 0.20 (i.e. very high)
- Current per capita consumption — 140 (i.e. relatively low)
- Current meter penetration — 30% (i.e. similar to current national average)
- Maximum retrofit — 30% (i.e. mid range, relatively optimistic rate)
- Retrofit reduction — 10 l/h/d (i.e. 140–130, no metering allowance)

This approach used a high level estimate of retrofit reduction (i.e. 10 l/h/d in the example). This number will need to be evaluated for each specific resource zone, but this figure is relatively conservative in the context of the estimated savings in the published literature (e.g. Environment Agency 2007).

4.2.4 Offset uncertainty

There is considerable uncertainty around the effectiveness of water efficiency programmes in existing households, due to a lack of large-scale studies and the relatively large degree of inherent uncertainty in water efficiency activity. Useful guidance on the uncertainty associated with retrofit programmes is presented in the outputs from UKWIR (2007) and Waterwise (2008). References such as these should be used to estimate the uncertainty associated with the specific retrofits planned in a particular water resource zone.

In order to illustrate how uncertainty should be taken account of in this study, an indicative value of ±30% is used in the example data presented in Table 4.3 to derive a 'worst case' offset value (i.e. a 30% reduction is applied to the calculated retrofit savings).

Table 4.3 Example offset calculation.

Year	Annual retrofit numbers	Cumulative retrofit numbers	Offset (Ml/d)	Uncertainty (Ml/d)	Worst case offset (Ml/d)
2010	5000	5000	-0.05	-0.02	-0.04
2011	6000	11000	-0.11	-0.03	-0.08
2012	7000	18000	-0.18	-0.05	-0.13
2013	8000	26000	-0.26	-0.08	-0.18
2014	10000	30000	-0.3	-0.09	-0.21
2015	12000	30000	-0.3	-0.09	-0.21
2016	15000	30000	-0.3	-0.09	-0.21
2017	15000	30000	-0.3	-0.09	-0.21
2018	15000	30000	-0.3	-0.09	-0.21
2019	16000	30000	-0.3	-0.09	-0.21

This analysis only considers offset potential from existing households. There may be potential demand reductions as a result of retrofitting water efficiency measures into existing non-households. There is much less data available on this; however, the Thames Gateway Water Neutrality study estimated savings of up to 40% were possible in existing non-households, based on studies undertaken by CIRIA. This is considered to be an upper estimate of non-household savings. A single figure allowance of non-household offset should be estimated using this published information and water resource zone specific information on existing non-households, where possible. More robust estimates of the savings that may be available from existing non-households could be obtained by considering the numbers and types of such premises within standard use categories – for example using the water industry 'SIC' classification.

4.3 Results of water neutrality assessment

4.3.1 Weak environmental drivers and low offset potential

The outputs from the analyses described in Sections 4.1 and 4.2 can be brought together in a single graph to present the relative effects of new demand and offset potential in relation to environmental surplus. Figure 4.2 illustrates this graph for the theoretical case study analysed earlier in this section.

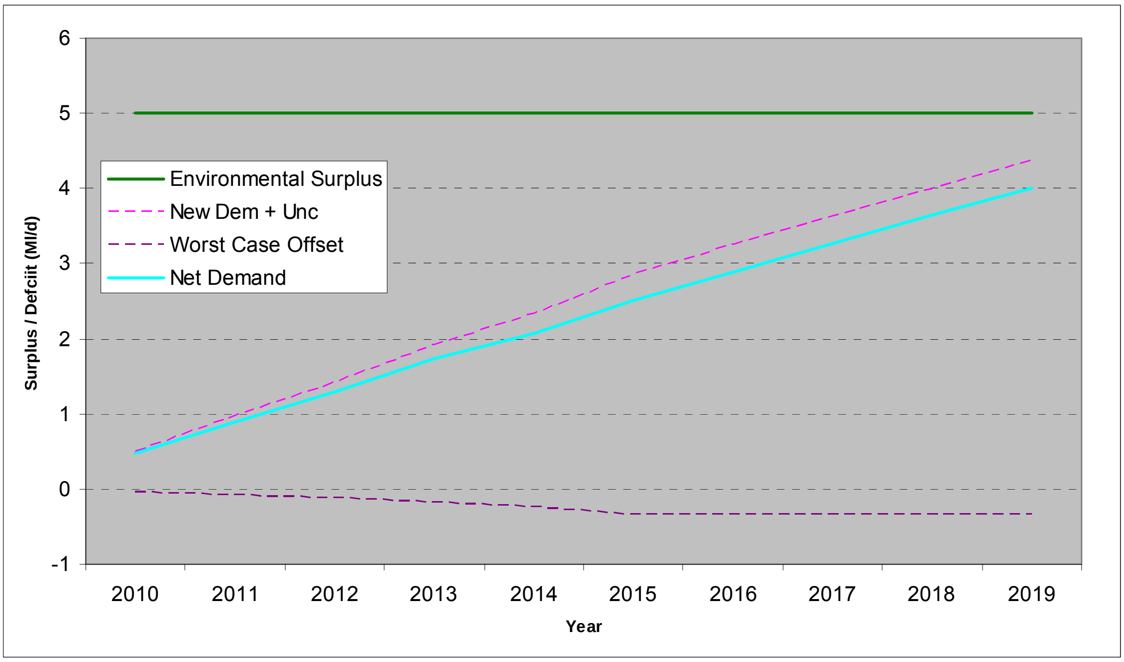

Figure 4.2 Graph illustrating water neutrality situation for theoretical case study.

It is clear from the graph that there is relatively low offset potential in this water resource zone, as the blue 'net demand' line is close to the 'new demand & uncertainty' line, and the 'worst case offset' line is only just below zero.

The environmental surplus value in this case study has been set to 5 Ml/d. In this example, this is relatively high, and in fact there is enough environmental surplus to support the additional demand without the need for any offsetting. However, this would not be the case with a more pessimistic forecast of Code for Sustainable Homes build-out rates. For example, net demand would be 0.75 Ml/d greater than the environmental surplus if all new homes were only built to the CSH Level 1/2 standard, and there was no offsetting.

This illustrates that in this example, some action is required to keep the net demand below the environmental surplus, but that this could be achieved either by building new homes to higher standards or by reducing demand in existing households. There is no consideration of non-households in this simple example.

This example would fall in the lower-left quadrant of Figure 3.1, that is environmental drivers in this case are relatively low (relatively high environmental surplus), and there are constraints on offset potential (i.e. high new to existing home ratio and relatively low current per capita consumption).

4.3.2 Strong environmental drivers and high offset potential

The ‘opposite’ scenario is presented in Figure 4.3, which characterises the upper-right quadrant in Figure 3.1.

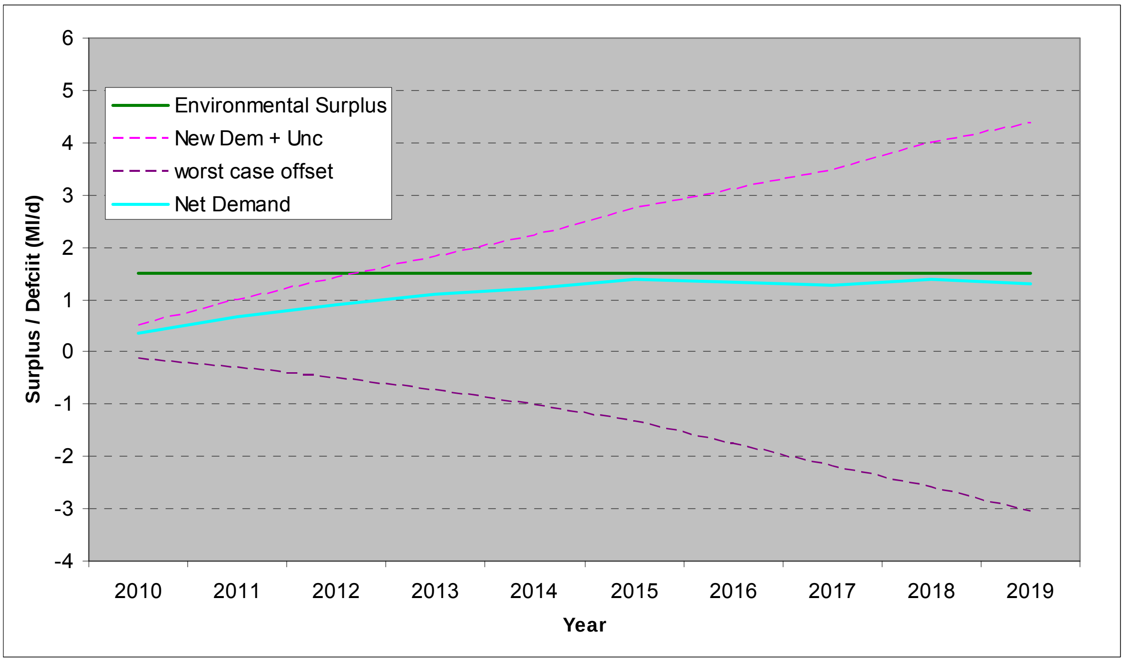

Figure 4.3 Graph illustrating water neutrality situation – strong environmental drivers and high offset potential.

In this example, the environmental driver for water neutrality is high (i.e. there is a relatively small environmental surplus of 1.5 Ml/d). Figure 4.3 illustrates that offset potential is high, at approximately 3.0 Ml/d (including an uncertainty allowance) by the end of the 10 year period (upper dashed line). This means that the new demand, plus the associated uncertainty can be offset so that the net demand remains below the environmental surplus level. Offset potential is much higher in this second theoretical example because:

- it is a much larger water resource zone of 500,000 existing households, therefore the new to existing homes ratio is much lower (0.04 instead of 0.2);
- current per capita consumption is relatively high at 165 l/h/d, and meter penetration is low at 25%, which means that there is potential to offset up to 35 l/h/d in existing households.

Even in this scenario there are alternative ways to minimise the net demand. The annual rate of retrofit is only 5000 households per year in the first few years, rising to 10,000 after that. Increasing this rate (say to 20,000 households per year) would mean that fewer new homes would need to be built to higher standards of the Code for Sustainable Homes.

4.3.3 Weak environmental drivers and strong offset potential

In the upper-left quadrant of Figure 3.1 there is a lot of potential to move towards high levels of water neutrality, but few environmental drivers to do so. This situation is illustrated in Figure 4.4 using comparable data to the preceding examples.

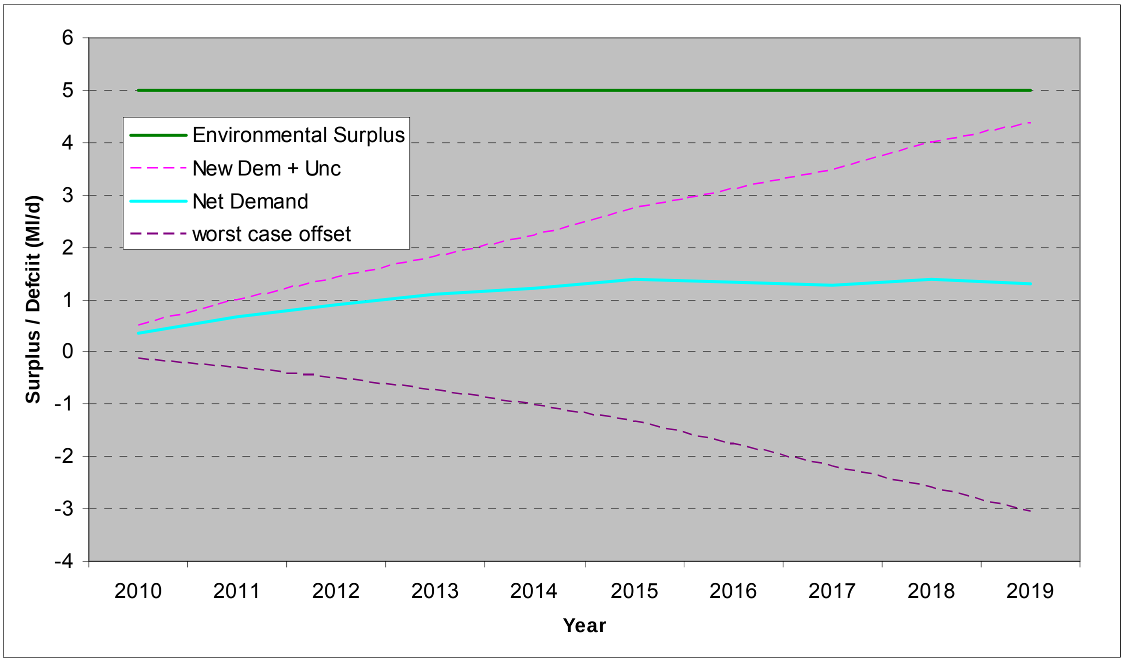

Figure 4.4 Graph illustrating water neutrality situation – weak environmental drivers and high offset potential.

Comparing the upper dotted 'new demand' line and the green 'environmental surplus' line indicates that there is sufficient 'spare water' within the water resource zone to accommodate the additional demand (plus an uncertainty allowance) without the need to offset. The high offset potential of this theoretical water resources zone (which uses the same values of per capita consumption and meter penetration as the previous example), means that it is possible to offset most of the new demand that is generated from development. However, there is clearly no environmental driver to do this, in this case.

4.3.4 Strong environmental drivers, low offset potential

The final example describes the situation characterised by the lower-right quadrant in Figure 3.1, where there are strong environmental drivers to minimise additional abstraction (i.e. low environmental surplus), but low offset potential. This is illustrated in Figure 4.5, which is again based on relevant data used in the earlier examples.

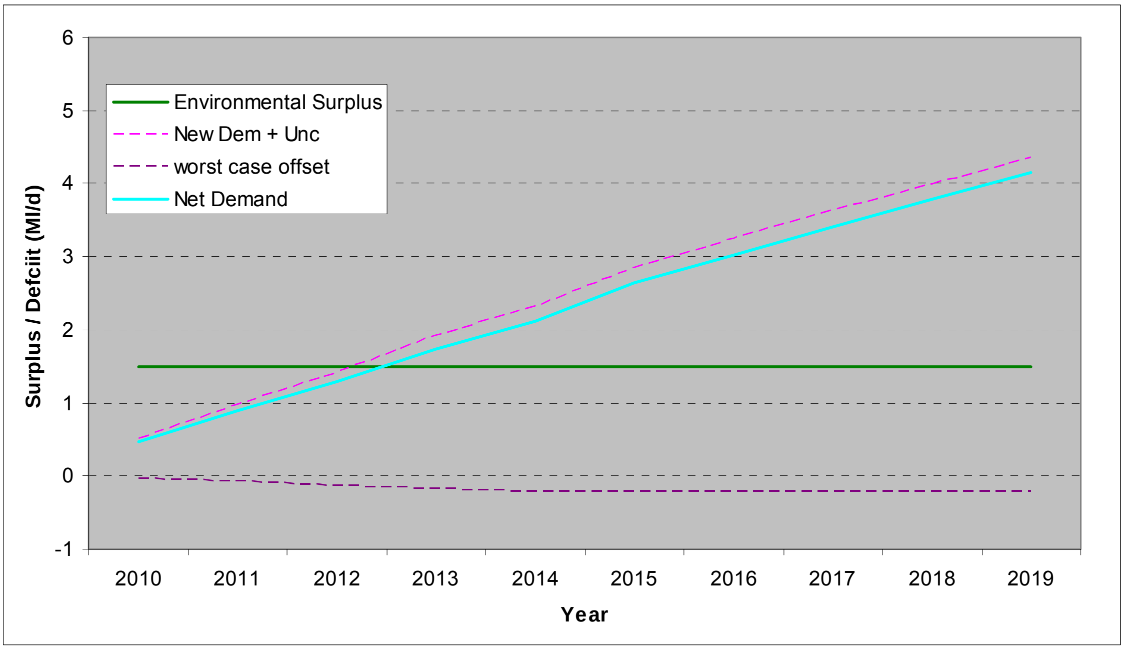

Figure 4.5 Graph illustrating water neutrality situation – strong environmental drivers low offset potential.

The turquoise ‘net demand’ line in Figure 4.5 rises rapidly above the green ‘environmental surplus’ line because there is relatively little environmental surplus, and because it is only possible to offset a small amount of the new demand. In this case, new demand is based on a relatively optimistic build rate of Code Level 5/6 new homes, so there are limited opportunities to reduce net demand further in new or existing households. Further offsetting options in existing non-households would need to be considered alongside other options that either offset the new demand (e.g. leakage reduction), or increased the environmental capacity (supply-side options, including storage).

4.4 Summary

This section has presented a framework for considering how environmental surplus can be compared against the demand arising from new development and the reduction in demand that is possible by retrofitting water efficiency measures into existing properties.

Theoretical case studies have been presented that characterise the four potential scenarios identified in Section 3.2 and Figure 3.1. There are clear imperatives in two of these scenarios, driven by high levels of environmental stress:

- Where there is a high offset potential in the water resource zone, demand must be managed to ensure any net additional demand does not exceed the environmental surplus.
- Where there is a low offset potential in the water resource zone, alternative options must be considered to ensure that the net zonal demand does not exceed the environmental surplus. These options must include demand and supply-side measures, as appropriate.

There is greater flexibility in demand management (as a response to development) when environmental stress is weaker. Demand may be allowed to rise where there is a low potential for offsetting, but the focus should still be on managing demand to maintain an environmental surplus, where possible. Where the offset potential is high, but there are a lack of environmental drivers, then options are available to manage supply and demand in the most cost-effective and sustainable way.

Where there is flexibility in managing the supply–demand balance in the context of new development, then other tools, not considered in this study, must be used to identify the optimum solution.

4.4.1 A probabilistic approach

A more sophisticated approach to the above calculations could use a Monte Carlo assessment and take account of the uncertainties in estimates of offsetting potential and new demand by applying a probability distribution for their likely values. The assessment would output the probability distribution of the residual demand, i.e. the likelihood that water neutrality could be achieved given the uncertainties involved. However, it should be recognised that greater understanding of the uncertainties is required to enable robust application of Monte Carlo simulation.

5 Conclusions and recommendations

5.1 Scoping water neutrality

This study has concluded that:

- Water neutrality should focus upon the water supplied to households and non-households as part of the public water supplies provided by water companies, while recognising that managing other abstractions (e.g. to industry and agriculture) and other components of public water supply abstractions (e.g. leakage) can contribute to achieving water neutrality in certain circumstances.
- Water neutrality can take account of the distribution and balance of flows in the natural environment (e.g. by considering the effects of wastewater returns on river baseflows), and need not always be focused solely on offsetting demand from new development by reducing demand in existing development. However, the analysis and assessment of such flows should not interfere or overlap with the existing management of water resources, as carried out by the Environment Agency.
- Water neutrality should take account of the available headroom in the existing supply–demand balance. In addition, the uncertainty associated with moving towards water neutrality has to be accounted for and it should be recognised that this uncertainty will be relatively large as a result of the challenging nature of water neutrality. Climate change will be an important consideration in both contexts.
- Water neutrality should typically be analysed at the water company water resource zone level. This is appropriate given that this is often the basic unit for water resource management and also therefore means that suitable data will be available at this level. Data based on other spatial denominations (e.g. Water Framework Directive water body flow data or local authority housing growth data) should be factored up or down to the appropriate water resource zone for further analysis.
- Water neutrality should typically be analysed based on water company data for the dry year annual average scenario. In some cases (e.g. where the water resource situation is critical in the peak period) then analysis should be carried out using data for this scenario also.
- Water neutrality targets (e.g. for the retrofitting and the water efficiency of new homes) should be set prior to the start of new development and then reviewed on a regular basis throughout the life of the development and beyond.

5.2 Deriving water neutrality standards

This study has introduced the concept of using drivers and constraints to identify appropriate approaches to setting water neutrality standards, and has explored this concept by considering environmental drivers and offsetting constraints. It is proposed that environmental drivers are based upon Water Framework Directive water body classifications and offsetting constraints are based on the extent to which existing demand can be reduced. Figure 3.1 presents a conceptual diagram of how the balance between environmental drivers and constraints influences the approaches that are appropriate to achieving water neutrality.

Other drivers and constraints have been identified and require further consideration.

This study has presented an outline framework for considering how environmental surplus can be compared against the demand arising from new development and the reduction in demand that is possible by retrofitting water efficiency measures into existing properties.

Theoretical case studies have been presented that characterise the four potential scenarios identified in Figure 3.1. There are clear imperatives in two of these scenarios, driven by high levels of environmental stress:

- Where there is a high offset potential in the water resource zone, demand must be managed to ensure any net additional demand does not exceed the environmental surplus.
- Where there is a low offset potential in the water resource zone, alternative options must be considered to ensure that the net zonal demand does not exceed the environmental surplus. These options must include demand and supply-side measures, as appropriate.

There is greater flexibility in demand management (as a response to development) when environmental stress is weaker. Demand may be allowed to rise where there is a low potential for offsetting, but the focus should still be on managing demand to maintain an environmental surplus, where possible. Where the offset potential is high, but there are a lack of environmental drivers, then options are available to manage supply and demand in the most cost-effective and sustainable way.

Where there is flexibility in managing the supply–demand balance in the context of new development, then other tools, not considered in this study, must be used to identify the optimum solution.

5.3 Recommendations

This study has necessarily been constrained by time and budget. As a result, some of the ideas presented in this report need further development. In particular the concepts developed in Sections 3 and 4 of the study could be tested more fully using actual data for a particular development.

Other suggestions for further work include:

- The appropriate flow/abstraction scenario for defining water body status should be considered further.
- The role of other drivers in determining suitable offsetting levels should be considered further – particularly climate change mitigation (carbon reduction).
- The definition of uncertainty around water efficiency activity has not been well defined in research undertaken to date. As a result conservative (i.e. high) uncertainty estimates should be used and these may reduce the attractiveness of water neutrality.
- The pros and cons of a probabilistic approach to water neutrality uncertainty should be considered.

6 References

Communities and Local Government, 2007. *Homes for the Future: More Affordable, More Sustainable.*

Environment Agency, 2007. *Towards Water Neutrality in the Thames Gateway: Modelling Baseline, Business as Usual and Pathway Scenarios*. Environment Agency Science Report SC060100/SR1.

Ofwat, 2007. *Security of Supply Report 2006/07.*

Therival, R., Drury, C. and Hepburn, R., undated. *Achieving Water Neutrality in the South East Region: Discussion Paper.*

UKWIR, 2007. *A Framework for Valuing the Options for Managing Water Demand.*

Waterwise, 2008. *Evidence Base for Large-Scale Water Efficiency in Homes.*

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