

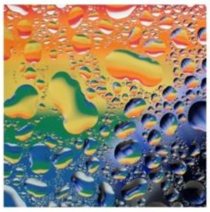

Research to produce indicators to assess current and future risk to the chemicals, paper and mining and quarrying industries from reduced water availability, and potential for uptake of water management measures in these industries

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Research to produce indicators to assess current and future risk to the chemicals, paper and mining and quarrying industries from reduced water availability, and potential for uptake of water management measures in these industries

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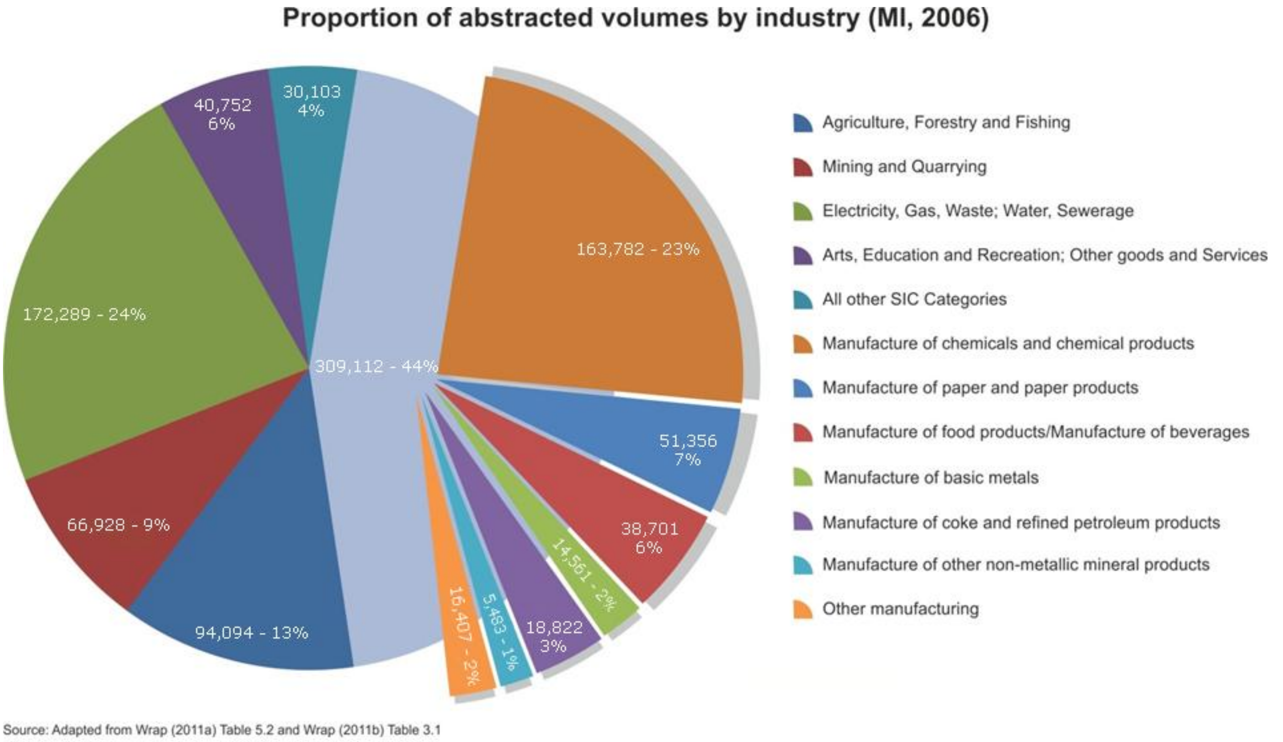
1. Introduction to development of indicators

The Adaptation Sub-Committee (ASC) to the Committee on Climate Change (CCC) has a statutory role under the Climate Change Act to provide an independent assessment to Parliament of UK Government's progress in implementing its National Adaptation Programme. Previous ASC reports (ASC, 2012) identified the key components for assessing preparedness for climate change. Building on these reports, the ASC has developed an adaptation toolkit to aid in the assessment of progress in adaptation to climate change in the UK. The first component of this toolkit concerns the monitoring of changes in climate risks using indicators. The ASC commissioned WRc to develop and evaluate a set of indicators in line with this adaptation toolkit and previous reports commissioned by the ASC.

This section of the report focuses on three water intensive industries selected by the ASC, specifically the manufacture of chemicals and chemical products (chemicals), mining and quarrying, and the manufacture of paper and paper products (paper).

Figure 1.1 Abstraction volumes by industry category[1] Lower bound from non-tidal resources excluding major non-consumptive uses and abstraction for public water



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[1] Water used in consumptive processes. Actual volume of water consumed and not returned to the environment may be lower as these figures are based on applying loss factors for each use and not actual company returns.

The decision by the ASC, to select these industries is based on previous reports (Wrap, 2011a) (Wrap, 2011b). These reports identify the chemicals, mining and quarrying, and paper industries as being among the largest abstractors for consumptive uses[2]. Only 'agriculture, forestry and fishing' and 'electricity, gas, waste, water, sewerage' are larger in abstraction volume for consumptive use, as shown in Figure 1.1. Chemicals and paper were the largest abstractors respectively (excluding major non-consumptive use) in the manufacturing industry. The mining and quarrying sector is identified as larger than the next largest manufacturing abstractor, coke and refined petroleum products.

The UK standard industry classification 2007[3] (SIC2007) has been used to identify the type of economic activity for business establishments and associated statistical data. This provides a proven uniform classification method for the analysis and presentation of data. See Table 1.1.

Table 1.1 SIC 2007 classifications for selected industries

	Chemicals	Mining and quarrying	Paper
SIC Code	20	05 - 09	17

Source: (ONS, 2009) (ONS, 2014)

Protecting freshwater resources requires diagnosing threats over a broad range of scales, from global to local. (Vörösmarty et al., 2010). Water use, in these industries, is from both direct abstraction and mains water (as well as any alternative sources that are already being used such as on-site rainwater harvesting, lagoons, or water reuse in processes). However, it is assumed that, for mains water use, the relevant water company has assessed the likely demand under their water resources management plan, and therefore it is more pertinent to focus on the direct abstraction component as an indicator.

The chemical industry consists of very diverse businesses. Though the total number of different substances produced in the chemical industry may be large, the number of unit processes and unit operations for the chemical reactions and processing and refining of products are typically limited. Water is essential in most chemical production units. It is used for; cleaning, transport, as a raw material, as a solvent and as part of a product. For a specific production, the choice of unit processes and operations together with the choice of raw material and process equipment define the required water quality and quantity, which can

2 For this report, consumptive water use is defined as water that is evaporated, transpired, incorporated into products or crops, consumed by humans or livestock, or otherwise removed from an immediate water environment.

3 ONS (2009) UK Standard Industrial Classification of Economic Activities 2007 (SIC 2007) [online] http://www.ons.gov.uk/ons/guide-method/classifications/current-standard-classifications/standard-industrial-classification/index.html

vary in a wide range. A major part of the overall water consumption is used for steam generation and cooling[4].

The use of water occurs in many steps of mining and quarrying operations. Water is used for; cooling equipment, crushing and grinding, transport of materials, separating waste from valuable minerals, cleaning and controlling dust. Climate change presents physical risks to mining and quarrying operations as these industries generally rely on fixed assets with long lifetimes and large supply chains.

The pulp and paper industry is a highly water dependant industry. In volume terms, water is the most significant material involved in the manufacturing process. Every paper mill has a unique water profile due to its location and the origins of its water, the destination of its effluent and the origin of its raw materials[5]. Water is used for the transfer of materials, cleaning, repulping recovered paper, as a solvent, heating and cooling.

An initial unconstrained list of indicators to assess the exposure and vulnerability of each sector to reduced water availability and reduced water quality was developed. An initial list was developed by the ASC and included as part of the tender process for this project. WRc expanded on this initial list using project experience and knowledge of available datasets. An interim project meeting, between WRc, the ASC and other concerned stakeholders, identified and refined the indicators to be selected for development in the final report. For each of these the data sources required were identified and an assessment of the likely quality of these carried out. The data quality assessment is concerned with the likely availability, completeness and reliability of the identified datasets. The assessment was used to inform a decision on whether or not each indicator should be shortlisted for development. The list of indicators to be developed were selected in agreement with the ASC following the delivery of an interim report by WRc and a technical steering meeting with industry representatives and other concerned stakeholders in January 2014. Appendix A contains the unconstrained list of indicators, including those suggested by the ASC, developed prior to the interim project meeting, identifies data sources for these indicators and provides an assessment of the likely quality of these datasets.

Indicators were developed to assess water scarcity as a result of both water quantity and water quality issues. Research has been carried out to assess the scale of impact climate change will have on river flows in England. For example, Prudhomme *et al*., (2012) demostrated that, while mixed patterns exists, especially for autumn and winter, all modelled scenarios inidcate a decrease in summerflow almost everywhere. The effects of climate change on water availability are explored in the Environment Agency's report "The case for change – current and future water availability" (EA, 2011). The modelled climate change

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4 EU Technology Platform proposal 'AquaFit4Use' [online] http://www.aquafit4use.eu/articles/chemical-industry.html

5 Confederation of Paper Industries [online] http://www.paper.org.uk/mythsandfacts/myth6.html

scenarios show a general decrease in summer flows throughout the UK, ranging from +20 to -80 per cent.

The Water Framework Directive (WFD) water body status gives an indication of the areas where water quality issues may be a more immediate business risk than water availability. Predicting the degree and probability of climate change impacts on water quality is a difficult task due to the wide range of natural variability in hydrology, chemistry and ecology. An EA report (EA, 2008) assesses the potential for climate change to impact on water quality including; the potential for lower minimum flows to result in higher concentrations of pollutants downstream of point discharges, enhanced growth of algal blooms affecting dissolved oxygen levels and, reaction to increased river and lake water temperatures. Whitehead *et al*., (2009) concluded that there could be 'significant water quality outcomes arising from a host of planned and inadvertent responses to climate change. Therefore, plans to address undesirable water quality impacts will require the integration of interventions across all sectors and institutions responsible for managing air, land and water resources.'

Developing the selected indicators required locating appropriate and robust datasets that: (i) have a reliable time series, in order to distinguish long-term trends from year-to-year variability, and (ii) are spatially disaggregated, to identify hot-spots of risk and provide information relevant at the local, as well as the national level (ASC, 2012). The selected indicators are derived from six key datasets which are described fully in Chapter 2 of this report. Each developed indicator is then presented with a summary of rationale for use, results, robustness and methodology for development in Section 3. Where possible, the outputs from indicator development have been mapped to allow a better spatial understanding of industry abstraction. The results of this mapping exercise are contained in Appendix C.

2. Description of source datasets used in indicator development

2.1 Overview

This section describes the datasets which underpin each indicator. It is necessary to describe the scope, limitations and suitability of the various datasets as they have implications for the robustness of the indicators presented in the next section. The underpinning data have been selected to provide the following information:

- Annual volume of water abstracted (surface and groundwater) in England by industrial sectors of interest;
- Location of water bodies in England and Wales;
- Identification of areas of constrained water resource availability;
- Identification of areas of poor water quality (as defined by the Water Framework Directive water body status);
- The number of businesses and employees in each industrial sector of interest;
- The financial value of each industrial sector of interest to the UK economy.

2.2 Volume of water directly abstracted by industry in England

2.2.1 Description

The National Abstraction Licencing Database (NALD) is the UK Environment Agency's (EA) record of abstraction licences against abstraction locations, authorised volumes and actual abstracted volumes from the environment in England and Wales, by source type (Ground Water, Surface Water, Tidal). An abstraction purpose description is also held against each licence.

2.2.2 Suitability

Since partial deregulation of abstraction licensing in England and Wales in 2008, licences are only required for abstractions over 20 m^3 per day. Mandatory reporting of actual abstraction quantities by licence holders to the EA is required under The Water Resources (Abstraction and Impounding) Regulations 2006. Therefore, a total volume directly abstracted by all industry is not available. Whilst the majority of mining, paper and chemicals manufacturing industry will be licensed, smaller operations may not require an abstraction licence. Dewatering activities at quarries are currently undertaken under an exemption from the requirement for an abstraction license.

2.2.3 Drawbacks

1. Information on industrial sector by abstraction licence is held using a proprietary classification system which can be attributed to SIC2007[6] but not without significant effort, sometimes on an individual licence basis. Much of this work was completed by WRc for Defra (WRc, 2014) to 2-digit SIC level, but should be validated against better industry data before more extensive use.

2. The reported volumes are likely to be incomplete as licence holders abstracting less than 100 m^3 per day are not required to report actual volumes abstracted following the introduction of risk-based regulation.

Table 2.1 Total number of abstraction licenses, by sector and year

Sector	2008	2009	2010	2011
Chemicals	125	118	122	120
Mining and quarrying	302	310	321	315
Paper	88	88	87	88

6 Standard Industrial Classification (SIC) 2007 is the latest revision of the classification system, first introduced into the UK in 1948, for use in classifying business establishments and other statistical units by the type of economic activity in which they are engaged.

Table 2.2 Percentage of licences abstracting less than 100m^3 per day, by sector and year

Sector	2008	2009	2010	2011
Chemicals	13.6%	2.5%	9%	5.8%
Mining and quarrying	8.9%	5.2%	6.5%	3.5%
Paper	2.3%	2.3%	4.6%	0%

2.2.4 Ownership

The Environment Agency owns and maintains this dataset.

2.2.5 Licencing and Cost

The ASC has been granted a licence at no cost to use the data from a recent extract from NALD. It may be necessary to re-licence the data every time the indicator is updated.

2.3 Water Resource Availability Status

2.3.1 Description

Catchment Management Abstraction Strategies (CAMS) allow for consideration of water availability for abstraction for each catchment area. For the purposes of this report, catchment areas are Water Framework Directive (WFD) 1st cycle surface water bodies[7]. The WFD defines a ‘body of surface water’ as a discrete and significant element of surface water such as a lake, a reservoir, a stream, river or canal, part of a stream, river or canal, a transitional water or a stretch of coastal water. Water bodies are the smallest hydrological boundaries used by the EA. In essence, they are non-overlapping surface water catchment boundaries which cover all of England. Each water body is given a CAMS resource availability status that is based on river flows and ground water levels coupled with knowledge of human influences. The assessment of availability is made on catchment characterisation of ecology, river flows, groundwater recharge, abstractions, discharges and requirements of the environment (EA, 2013). Table 2.3 provides a description for the status of the three CAMS.

Resource availability status is assessed at four different flow scenarios to account for year-round flow conditions. The standard scenarios assess resource availability at low, below average, average and above average flows (so-called Q95, Q70, Q50 and Q30). Following advice from the Environment Agency, the indicators presented here use the resource availability for each water body during below average flow (summer flow) Q70 conditions. The Q70 flow value is so called as it is the flow threshold for each water body which is exceeded 70% of the time (similar definitions apply to the other flow thresholds). Although the availability of water for abstraction varies through the year, the balance between available resource and demand for abstraction is of greatest significance during the summer. The EA’s assessment of future water availability (EA, 2011) concentrates on assessment for summer flows.

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[7] Temporal coverage: 01/01/2004 – 22/12/2015 http://data.gov.uk/dataset/water-framework-directive-river-waterbody-catchments-wms

Table 2.3 CAMS Water Resource Availability Status Definitions (EA, 2013)

CAMS Status	Licence Implications & Descriptions
Water available for licensing	More water than required to meet the needs of the environment.
Restricted water available for licensing	If all licensed water is abstracted there will not be enough water left for the environment. No new consumptive licences can be granted. It may also be appropriate to investigate the possibilities for reducing fully licensed risks.
Water not available for licensing	Water bodies where flows are below the indicative flow requirement to help support Good Ecological Status (as required by the Water Framework Directive)

2.3.2 Suitability

The CAMS are used to identify the balance between how much water is currently needed by the environment and for human use. The assessment identifies areas of current over-abstraction and over licencing (EA, 2013). This therefore shows the current vulnerability to water scarcity, which may increase with climate change.

2.3.3 Drawbacks

The assignment of status does not account for future projections of population, demand or climate change, meaning that the CAMS status represents the current water availability situation. However, as catchment flows are likely to be reduced in future climate change scenarios, the lower flow scenarios provide an indication of areas likely to suffer from potential unavailability at normal flows.

2.3.4 Ownership

The Environment Agency owns this dataset.

2.3.5 Licencing and Cost

The ASC has been granted a licence at no cost to use the CAMS status data at water body level. It may be necessary to re-licence the data on each occasion the indicator is updated. The necessary GIS files for the water bodies required to map the CAMS status also required a licence to be granted to the ASC from the EA.

2.4 Water Framework Directive (WFD) Water Quality Status

2.4.1 Description

Water quality status forms part of the WFD River Basin Management Plans. The status is the result of an assessment of the overall ecological, chemical and nutrient status for each water body in England & Wales[8]. The water body is assigned an overall status as good, moderate, poor or bad, in line with EA methodology (EA, 2013d). The EA has agreed with Ministers that 32% of waters will be of good status or potential by the 2015/6 River Basin Management Plan cycle (RBMP) (EA, 2013c). The EA use these data to direct investment for improving river water quality in England.

2.4.2 Suitability

The dataset is suitable for indicator developing as it is a complete record of water quality status for the majority of water bodies in England and updated on a cyclical basis, allowing for the assessment of emergent trends. The data are assigned to 1st cycle WFD water bodies, allowing alignment with both NALD and CAMS datasets. Assessing water quality and resource availability together allows areas at heightened risk from climate change to be highlighted.

2.4.3 Drawbacks

The WFD status is based on a methodology that makes an assessment of the overall ecological, chemical and nutrient status for a water body, this assessment does not take into account required industry standards for that water body. The EA has changed the methodology for assessing water quality status, in line with the WFD. Comparisons between methodologies are not advisable as the water body classification may change significantly. For this reason, this report uses 2012 classifications (latest available classifications) for each year under consideration. Updates to the classification status, using the revised methodology, are available in RBMP interim reports. There are also a small number of water body's which have not been assigned a water quality status.

2.4.4 Ownership

This dataset is owned and maintained by the Environment Agency.

2.4.5 Licencing and Cost

This dataset is freely available under a government non-commercial licence. The GIS files necessary for the water body mapping must be licenced. A licence has already been granted to the ASC from the EA at no cost.

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8 http://www.environment-agency.gov.uk/research/planning/34383.aspx

2.5 Loss Factor

2.5.1 Description

Loss factors are used to estimate how much water is not returned to the environment following abstraction, based on the purpose for which the licence is authorised (EA, 2013b) Loss factors are estimated by abstraction purpose as part of the abstraction licence management process. The purposes for which loss factors are estimated by the EA align with the licence purpose description field in NALD.

2.5.2 Suitability

The loss factors used by the EA are designed to estimate the proportion of water that is not returned to the immediate environment for each licence. Each purpose description in NALD is assigned one of four loss factor categories; see Table 2.4 (EA, 2013b). Purpose descriptions are, however, quite broad and used across multiple sectors. With so few loss factor categories, it is therefore likely that some industrial sites, even if assigned to the correct purpose, will be associated with a grossly erroneous loss factor. This coarseness conceals variations in consumptive losses within individual sectors, and similarly, any efficiency gains made by individual business units will be unaccounted for.

Table 2.4 Loss factors and uses (EA, 2013b)

Category	Loss factor	Type of use	Examples
High loss	1.0	Wholly consumptive	Dust suppression and other purposes where, due to evaporation, water after use is not returned either directly or indirectly to any source of supply.
Medium loss	0.6	Mainly consumptive	Boiler feed, conveying material, uses which incorporate water in the product.
Low loss	0.03	Mainly non-consumptive	Mineral washing, non-evaporative cooling
Very low loss	0.003	Essentially non-consumptive	Hydraulic testing, dewatering for drainage purposes

Whilst the EA loss factor estimates are the most consistent dataset currently available. An annual calculation of net abstraction for each sector - from EA data or from the sector trade body - would give more reliable loss factors[9]. WRc has presented a method for calculating net-abstraction for each SIC2007 sector to Defra using abstraction and discharge data (WRc, 2014). The results from a case study area for which the methodology was demonstrated are unsuitable for extrapolation and use for this study as they are based on a single River Basin District (RBD) in England. Ideal discharge data for England are not yet of sufficiently high quality or aligned to abstraction data to implement this approach easily at present.

The proposed amendments to Environmental Permitting Regulations (EPR) in 2016/17 present an opportunity to align and integrate the collection and storage of abstraction and discharge licence data. WRc has recommended to Defra that, in addition to streamlining licencing requirements, they consider collecting and holding data on industrial sector, purpose and so on for each licence holder and licence location. In this way, abstraction and discharge data for each industrial site would be available to calculate net abstraction directly to help shape future policy and avoid the need to use abstraction loss factor estimates (WRc, 2014).

2.5.3 Drawbacks

The calculated net abstraction figure is an empirically derived estimate of consumptiveness based on broad categorisations of abstraction purposes.

2.5.4 Ownership

The loss factors are publically available (EA, 2013b).

[9] Water net abstraction is gross water abstraction minus returned water.

2.6 Business Structure Database

2.6.1 Description

The Business Structure Database (BSD) contains a number of variables for almost all businesses across the UK. Businesses can be grouped at enterprise and local unit level. An enterprise is an organisation made up of one or more local units. For example, the Swindon branch of Smiths Newsagents would be a local unit, while Smiths is the enterprise. The database is derived from the Inter-Departmental business register and data from the Office of National Statistics (ONS) annual business surveys. The variables available include number of employees, ownership structure, annual turnover and industrial activity.

2.6.2 Suitability

This dataset can be readily used to characterise the size of each industry as it holds a comprehensive record of total employment by SIC2007 sector. Whilst the data are accessible at local unit level, owing to data protection rules, it is only possible to report figures which constitute 10 or more local units and 3 or more enterprises to prevent the identification of individual businesses/sites from reported data.

2.6.3 Drawbacks

Employee numbers extracted from the BSD do not necessarily reflect the size or output of a local unit, meaning that a high number of employees does not necessarily mean a high reliance on water abstraction for the business function, and vice versa.

The data can only be linked with water resource availability and data spatially using freely available Ordnance Survey post code centroids under the OS Open data licence[10] [11]. Both datasets are extremely large which take a very long time to spatially process, meaning that robust GIS software and rigorous spatial data management techniques must be employed.

2.6.4 Ownership

This dataset is owned and maintained by the ONS. It is not publically available, with access heavily restricted to approved projects and researchers. Only data which is non-disclosive can be made publically available.

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[10] License details available at http://www.ordnancesurvey.co.uk/docs/licences/os-opendata-licence.pdf

[11] All indicators using BSD data in this report are subject to the following copyright acknowledgements:
Contains Ordnance Survey data © Crown copyright and database right 2014
Contains Royal Mail data © Royal Mail copyright and database right 2014
Contains National Statistics data © Crown copyright and database right 2014

2.6.5 Licencing and Cost

Access to these data is heavily restricted to projects and researchers approved by the ONS. Access to the data has been granted for the purpose of this project, so is likely to be awarded again for subsequent updates of the indicators chosen.

2.7 Gross Value Added

2.7.1 Description

Gross Value Added (GVA) for each SIC2007 sector is a direct output from the Annual Business Survey conducted by the ONS. GVA itself is an economic measure of goods and services produced by a business and a major component of the national GDP figure. The variables collected by the survey include turnover, employment costs, capital expenditure and stocks (ONS, 2014).

2.7.2 Suitability

Normalisation of GVA by employment in each CAMS / WFD water quality status, quantifies, in financial terms, how much is at risk from potential water scarcity due to climate change. As GVA is calculated annually, GVA can be applied appropriately for each year of interest in the indicator.

2.7.3 Drawbacks

A national GVA figure must be used for each sector as the geographical breakdown of GVA provided by the ONS does not align with the BSD, CAMS or WFD Water Quality datasets. A national GVA figure also assumes that GVA per employee is the consistent across a sector for a given year. This assumption, though required to normalise the GVA data, is likely to be unrepresentative of industry operations and should be treated with caution.

2.7.4 Ownership

This dataset is owned by the ONS. It is publically available for download, at no cost, from the ONS website[12].

[12] http://www.ons.gov.uk/ons/datasets-and-tables/index.html

3. Indicators of Risk

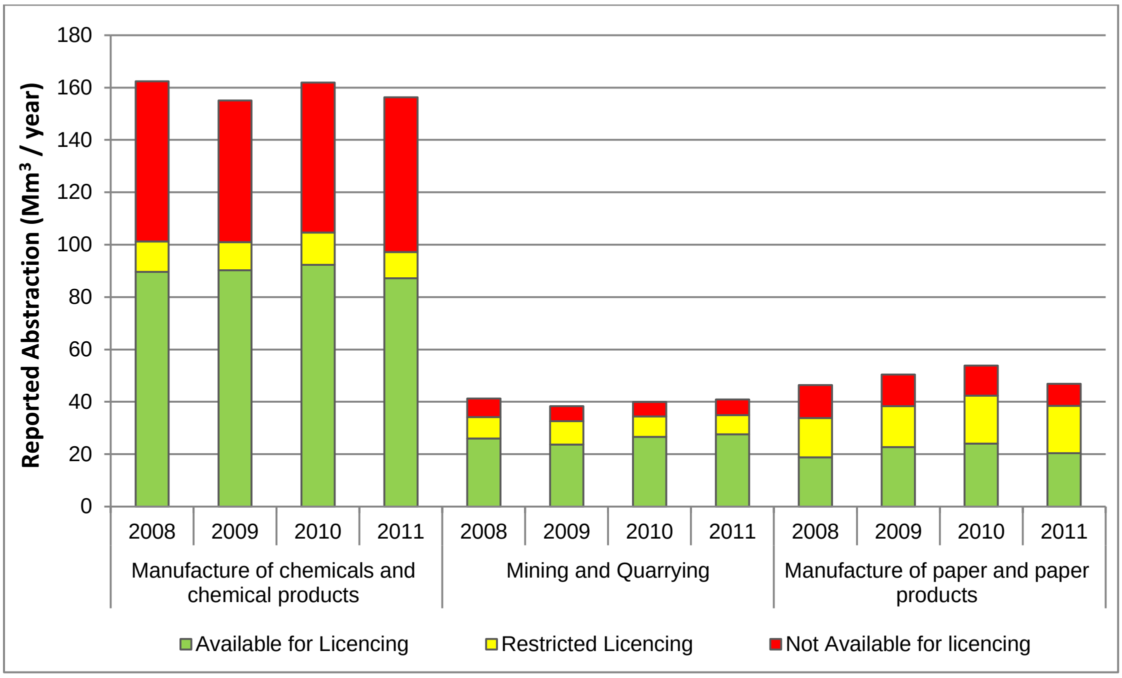
3.1 Indicator 1: Reported abstraction volumes by industry sector by CAMS resource availability status

3.1.1 Summary

Reported abstraction refers to the actual volume of water abstracted by an abstraction licence holder and reported annually to the EA. The actual volume of water abstracted in areas which are currently over-licenced and over-abstracted point towards the areas that are potentially vulnerable to water scarcity. Reported volumes are derived from the National Abstraction Licencing database. The resource availability indicator is taken from EA Catchment Abstraction Management Strategies (CAMS) maps.

For each sector, the majority of abstraction occurs in areas available for licensing (good water availability). With the exception of paper, there is a reduction in abstraction in 2009, most likely due to the economic situation. While paper abstraction has increased since 2008, the volume abstracted in areas not available for licensing has decreased. This indicator is recommended for use as it clearly shows the trends in volumes of water being abstracted and the proportions abstracted in each CAMS resource availability category.

Figure 3.1 Reported volumes abstracted by CAMS resource availability status



3.1.2 Robustness and Limitations

Resource availability

CAMS can be considered a robust source of data as it is the result of careful consideration of domestic, business and environmental (current) demands as well as the effects of low flows and over abstraction from surface and ground waters (EA, 2013).

Abstraction information

There is a lack of coverage of abstraction volumes for each industry in the NALD database. Those abstracting less than 20m^3 per day do not require an abstraction licence from the EA. As a result, smaller business abstractions are not included in the total volume derived from NALD data. Additionally, under current licensing requirements, dewatering operations are currently exempt from the licensing requirements. There are data gaps where licences authorised to abstract less than 100 m^3 per day are not required to submit annual results. Where possible, a reported volume has been estimated using the average amount of authorised volume used by that licenced industry. Reported abstraction volumes for each licence are reported for each licence purpose. Where a reported volume is not explicitly linked to one or more purposes, a method of apportionment was used to estimate total volume for each purpose where the split between purposes was unknown.

As abstraction volumes are returned at a licence level, where a licence's abstraction points are split across multiple water bodies, there is uncertainty in the volume abstracted from individual water bodies as volumes are reported for licences rather than individual abstraction points. Where this was the case, the reported volume was evenly proportioned across each abstraction point in a licence to estimate the reported volumes abstracted from each water body. However, there is moderate to high confidence in the spatial alignment of abstraction points and water bodies. By projecting the location of each abstraction location in GIS, and using a spatial query to identify the water body, each license was assigned to the relevant water body (WRc, 2014).

3.1.3 Update Frequency

The indicator can be updated annually as NALD is updated through an annual data return from licence holders which specifies total volume abstracted by. CAMS status are updated as required by the EA, no set update cycle is defined (EA, 2013)

3.1.4 Methodology of indicator development

Alignment of licence purpose descriptions to SIC2007 is possible through multiple queries (WRc, 2014). Where a one-to-one relationship exists between NALD purpose and SIC2007 the alignment is straightforward, however manual alignment is required where a look-up table does not give an exact match. Abstraction point locations are assigned a WFD 1st cycle water body by spatial query. The reported abstraction volumes are calculated for each licence for each year in each water body. Where a licence has abstraction points in multiple water bodies, the volume is evenly apportioned across each abstraction point in the licence. Each water body is assigned a CAMS resource availability status allowing for calculation of total reported volumes for each CAMS status for each sector.

3.2 Indicator 2: Reported abstraction of water by industry sector by CAMS resource availability status and WFD water quality status

3.2.1 Summary

This is an extension of Indicator 1 showing the actual volumes abstracted in over-licenced and over-abstracted areas which are co-located with areas of moderate or poor water quality as designated by the Water Framework Directive (WFD). As the availability of water decreases in a river, it is likely that the biological, chemical and nutrient quality of water will degrade. The EA reviews and updates river water quality status annually which in turn directs investment and plans for improving water quality, which may include limiting abstraction. By assessing this indicator for each year it is possible to see the temporal trend of the volume of which is at risk from water scarcity from both potential resource unavailability due to climate change and poor water quality based licencing restrictions.

Water quality issues have the potential to present a more immediate business risk than water availability to certain industries. In many cases these may be aligned, however there may be some areas where there is a state of water scarcity, but not a quality issue and vice versa. Insufficient water quality can cause many different types of problems (AquaFit4Use, 2010):

- scale and fouling can restrict throughput and decrease performance;
- scale and fouling can cause corrosion;
- scale can cause abrasion;
- impurities can affect the colour, taste and other properties of the final product;
- ionic impurities can cause corrosion;
- impurities can cause abrasion;
- volatile organics can be toxic, generate smell and bad labour environment;
- bacteria/biofilm can restrict throughput and decrease performance;
- bacteria can cause corrosion;
- bacteria can cause diseases and generate smell and bad labour environment.

These problems will increase maintenance costs, increase the number of unplanned stops, decrease performance of the production and increase risks for the personnel and the environment.

Industry processes that require high quality water are particularly vulnerable to the possible deterioration in abstracted waters, due to climate change. The required quality of abstracted water varies significantly depending on the business and process type. However, in general, a higher quality of abstracted water is required for the chemicals and paper industries.

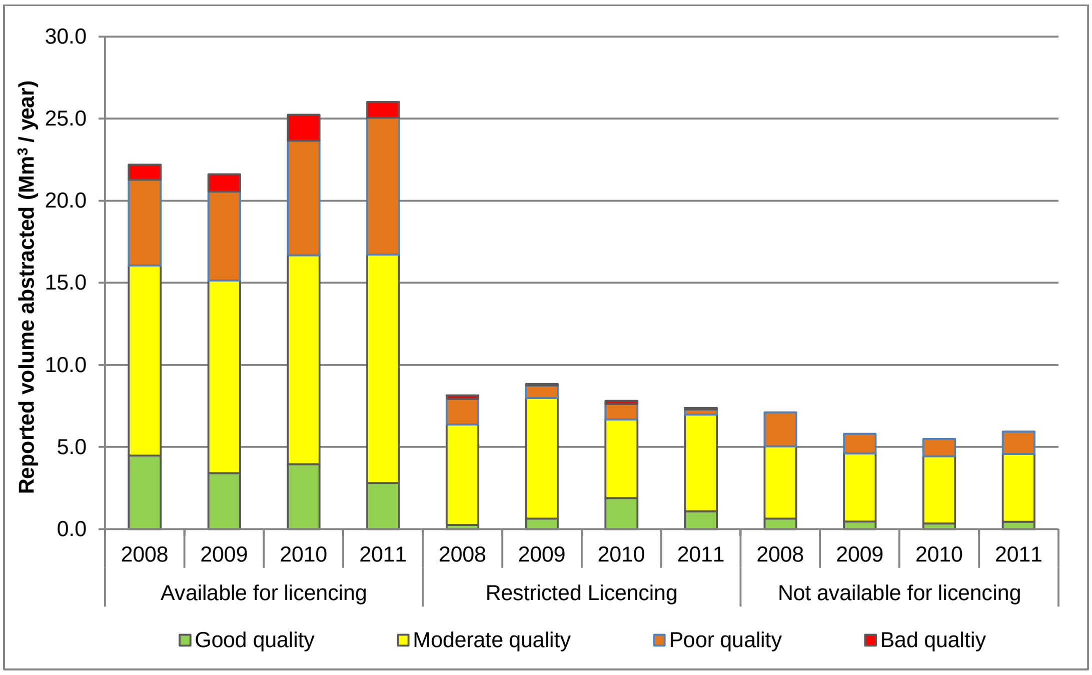
The chemicals industry has a high proportion of abstraction in areas of low water availability and poor water quality. Trends for the paper industry indicate a decline in volume being abstracted in areas of low water availably and poor / bad water quality. While the overall abstraction in the mining and quarrying industry is increasing, the abstraction in areas of low water availability and poor / bad quality appear stable. There are no licences abstracting in areas of good water quality for the paper sector. This indicator should be considered for use, as it assesses water scarcity in terms of both water availability and water that is at risk of being unfit for purpose.

Manufacture of chemicals and chemical products

Figure 3.2 Reported volumes abstracted by CAMS and WFD water quality status for Chemicals

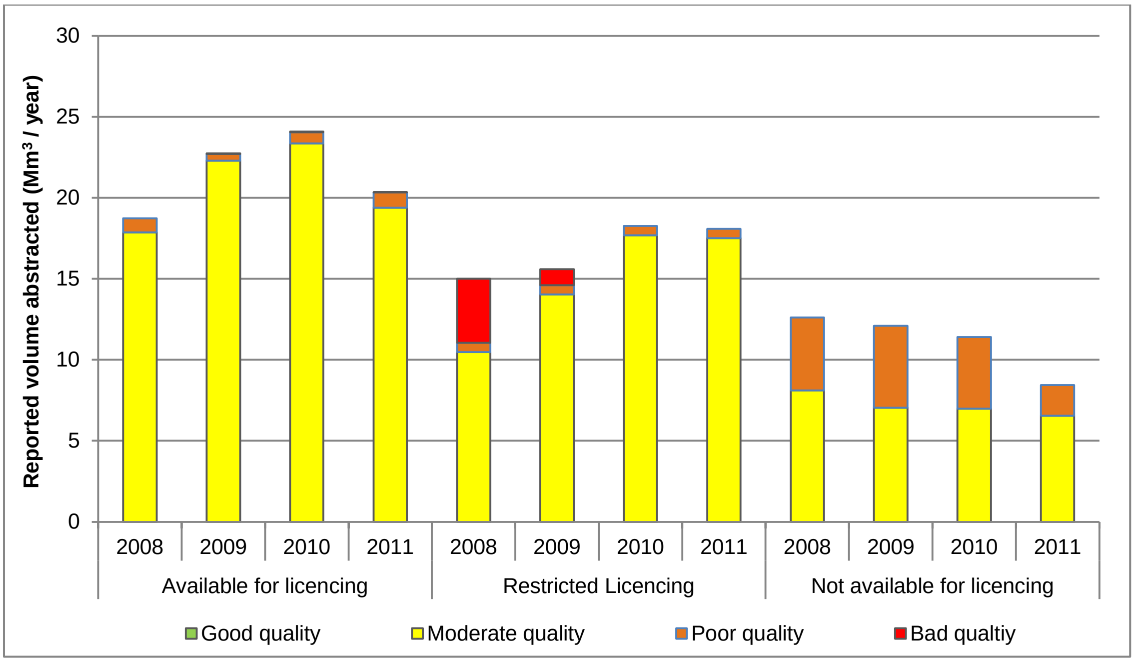
Mining and quarrying

Figure 3.3 Reported volumes abstracted by CAMS and WFD water quality status for mining and quarrying



Manufacture of paper and paper products

Figure 3.4 Reported volumes abstracted by CAMS and WFD water quality for Paper



3.2.2 Robustness and limitations

Temporal analysis of this indicator is limited by the change in EA methodology for assessing river water quality from their baseline assessment in 2009. Results from years prior to 2009 should not be compared with newer results as a change in classification, due to a change in methodology from the GQA[13], may not reflect changing environmental pressures.

3.2.3 Update Frequency

This indicator can be updated annually as annual abstraction data returns are received by the EA into NALD, along with annual publications of intermediate assessments of river water quality (EA, 2014).

3.2.4 Methodology of indicator development

The development of this indicator is similar to that described for Indicator 1 (see Section 3.1.4). For this indicator, each water body has been assigned a WFD water quality status allowing calculation, for each water body, of total reported volumes for each CAMS resource availability status - WFD water quality status combination, for each sector.

[13] The general quality assessment (GQA) scheme was previously used by the EA to assess river water quality in terms of chemistry, biology and nutrients. It is replaced by WFD methodology.

3.3 Indicator 3: Net volume of water abstracted by industry sector (consumptive use) by CAMS resource availability status and WFD water quality status

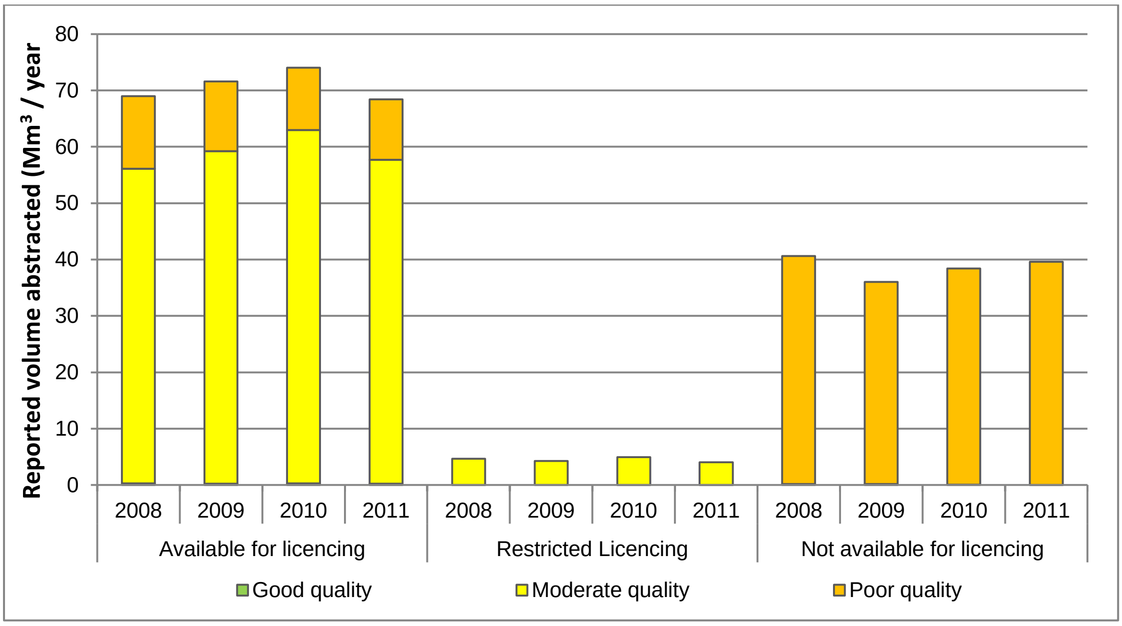
3.3.1 Summary

This indicator is an extension of Indicator 2 accounting for the volume of water returned to the environment after use; the volume retained for use by the industry is referred to as consumptive use. The overall effect of abstraction is reduced when quantities of water are returned after use, suggesting that less consumptive sectors would be less exposed to the risk of water scarcity as abstraction licence restrictions are expected to be less restrictive for less consumptive uses. This indicator shows how the consumptive profile of each sector has changed in areas potentially vulnerable to water scarcity. The volume of water returned to the environment is calculated using EA loss factors based on the licence purpose description from NALD.

In theory, this indicator is useful as consumptiveness is an important factor when assessing how much water is available for abstraction. However, with the current data quality, the indicator is not accurate as the loss factors will result in an unrealistic picture of industry abstraction profiles.

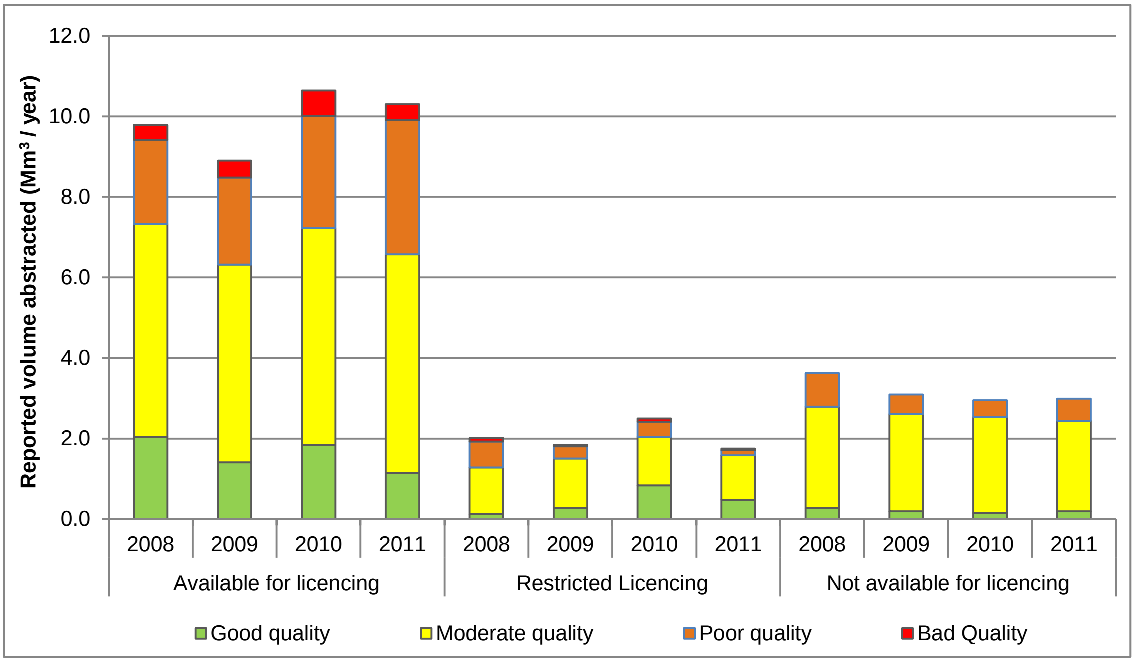
Manufacture of chemicals and chemical products

Figure 3.5 Reported net abstraction volumes by CAMS resource availability and WFD water quality status for chemicals



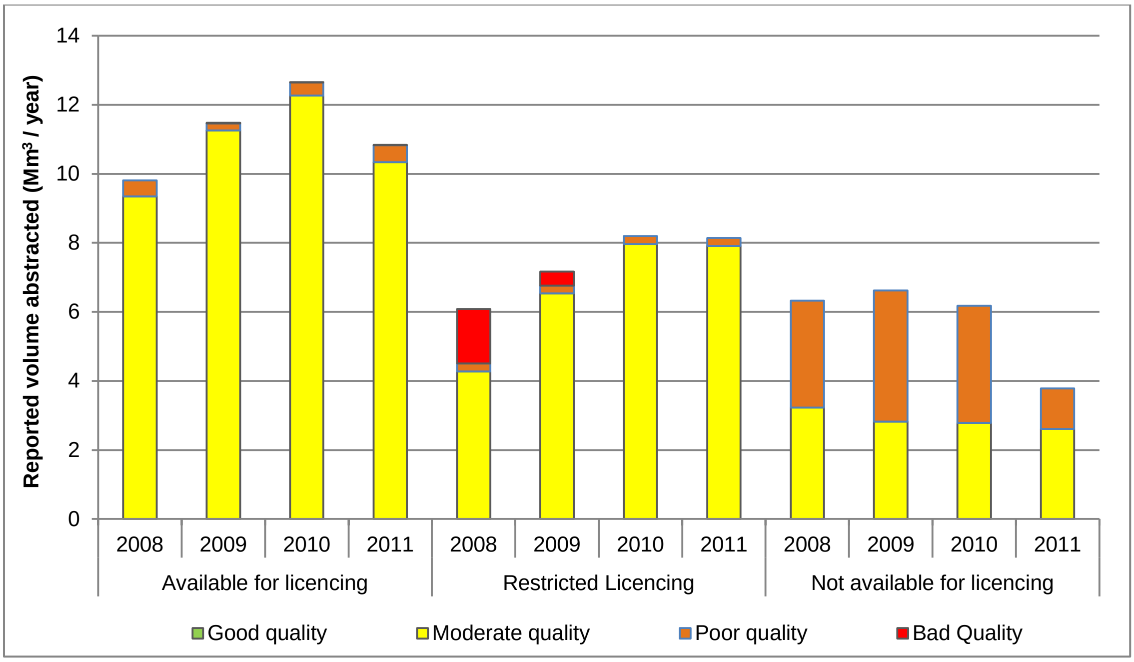
Mining and quarrying

Figure 3.6 Reported net abstraction volumes by CAMS and WFD water quality status for mining and quarrying



Manufacturing of paper and paper products

Figure 3.7 Reported net abstraction volumes by CAMS and WFD water quality status for paper



3.3.2 Robustness and Limitations

See sections 3.1.2 and 3.2.2 regarding the use of NALD, CAMS resource availability status and WFD water quality status.

Each licence was manually assigned a loss factor based on the purpose description and the EA recommendations on loss factor assignment. The loss factor relates to the purpose for abstraction and estimates how much water is consumed, i.e. not returned to the immediate environment (in the same water body).

This indicator is based on estimations of net abstraction for each licence, based on the licence purpose description. Furthermore, the calculation to estimate net abstraction is based upon estimated loss factors (Section 2.4) which assume that water use processes do not change over time and between industries. This means that this indicator should be seen as indicative of net abstraction, rather than a precise indication of consumptiveness.

Discharge data from each licence holder would improve this indicator, but its incorporation would require a major improvement in data quality to follow WRc's suggested methodology for calculating net abstraction presented to Defra (WRc, 2014) (see section 2.5).

3.3.3 Update Frequency

Loss factors are unlikely to be updated by the EA until significant changes in the management of measured volumetric discharge data are implemented.

3.3.4 Methodology of indicator development

The development of this indicator follows that described for Indicator 2 (see section 3.2.4), with the addition of a multiplicative loss factor term, based on the purpose assigned to the reported abstraction volume abstracted in that year.

3.4 Indicator 4: Number of businesses by industry sector by CAMS resource availability status and WFD water quality status

3.4.1 Summary

The number of local units located in current areas of restricted water availability is an indicator of the proportion of business at risk of potential water scarcity from future climate change. The numbers extracted from the BSD have to be reported separately for water stress and water quality in order to conform to ONS disclosure regulations[14]. The number of businesses is reported from both the BSD and NALD to gauge the level of agreement between the two datasets as they are likely to be overestimations and underestimations respectively. This means that the numbers extracted from the BSD and NALD represent the upper and lower bounds of the number of businesses that could be directly abstracting.

The number of BSD local units in the ‘Not Yet Assigned’ WFD water quality category have had to be suppressed as they risked identifying individual enterprises and local units. It was not possible to assign approximately 5.8% of postcodes to a CAMS resource availability status and 2% of postcodes to a WFD water quality status because of non-matching lookups between water body ID and status. This has resulted in more local units being assigned a WFD water quality status than a CAMS resource availability status.

Using NALD, the number of licences is fairly consistent between CAMS and WFD statuses for each industry. There are relatively few licences when compared to the number of local units in the BSD for each industry. In the mining and quarrying industry, the numbers of businesses remain consistent across the study period.

The BSD significantly over estimates the number of abstracting businesses, given that the paper sector is considered to be on the order of 50 abstracting businesses in England[15]. This overestimation is a result of the BSD data returning the total number of businesses in a particular industrial classification, and not just those businesses with an abstraction license. This indicator gives an unrealistic picture of industry profiles, indicating false trends in exposure to risk of water scarcity. For example, the BSD suggests that the number of local units in the paper sector is declining (Figure 3.8 and 3.9), while the number of NALD licences actually increases by one (Table 4.15). Whilst NALD is a possible underestimation of the number of businesses abstracting, it better reflects industry trends.

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[14] Data extracted from the BSD must be based on 10 or more local units (see Section 2.5) in order to be considered non-disclosive. When presented together, some combinations of water stress and water quality broke this disclosure rule, hence BSD data is presented separately for CAMS resource availability and WFD water quality status.

[15] This estimate was provided to WRc by a representative of the Confederation of Paper Industries at the interim project meeting.

Figure 3.8 Number of BSD Local units by CAMS resource availability status

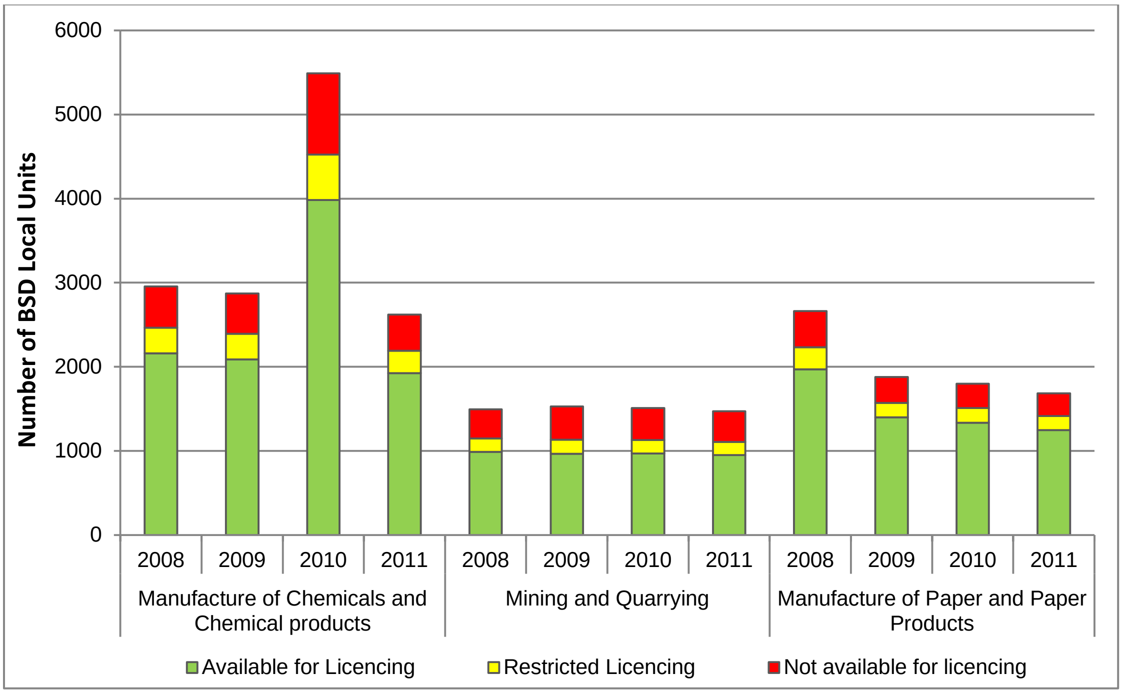
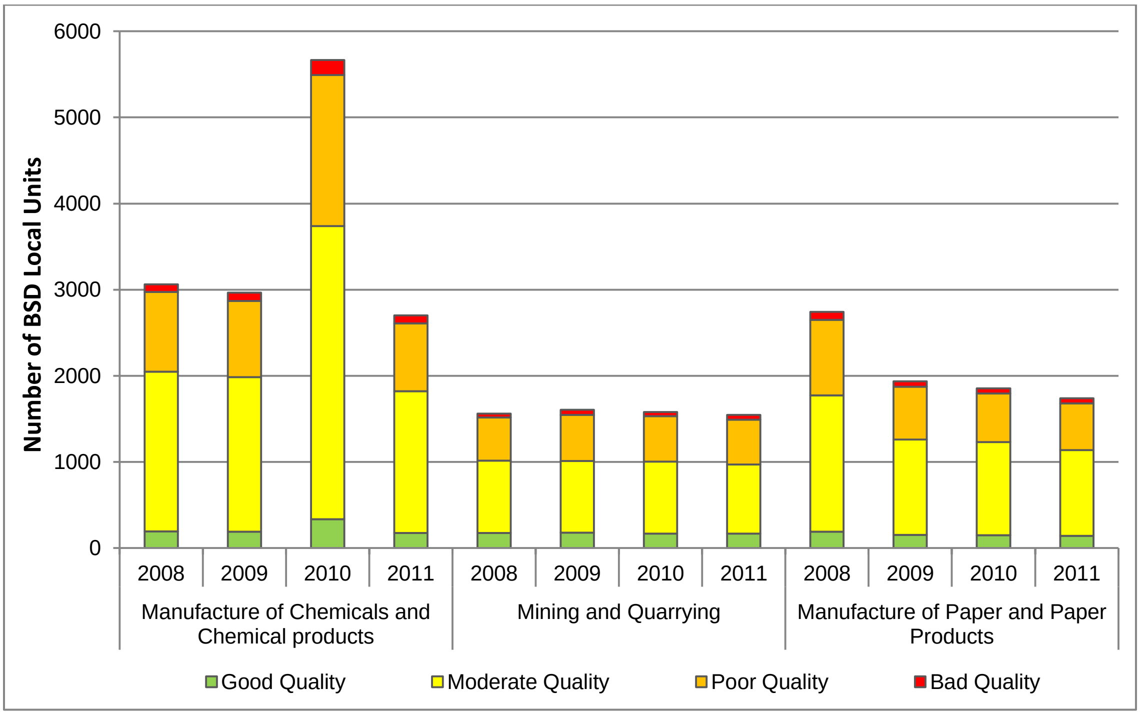
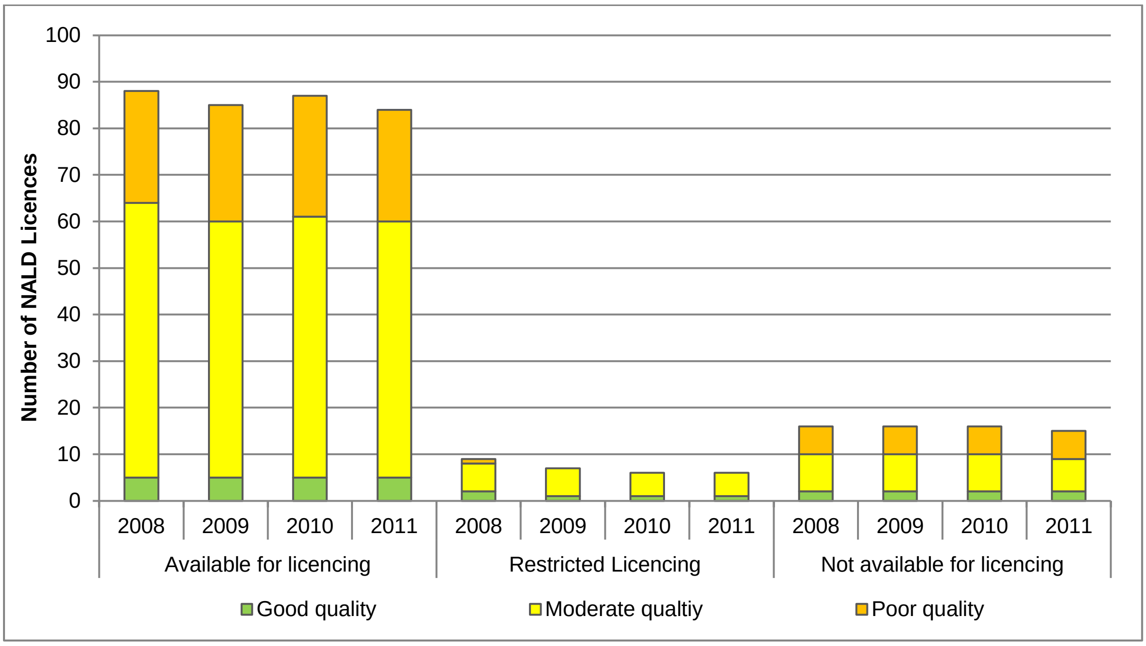


Figure 3.9 Number of BSD Local units by WFD water quality status



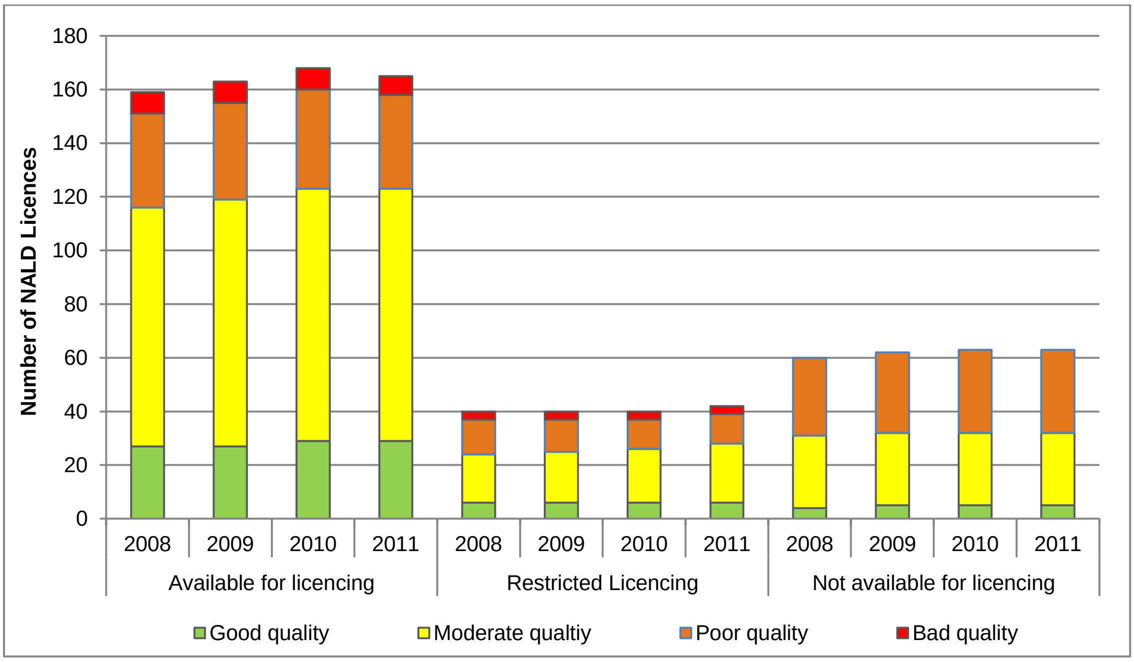
Manufacturing of chemicals and chemical products

Figure 3.10 Number of NALD licences by CAMS and WFD water quality status for chemicals



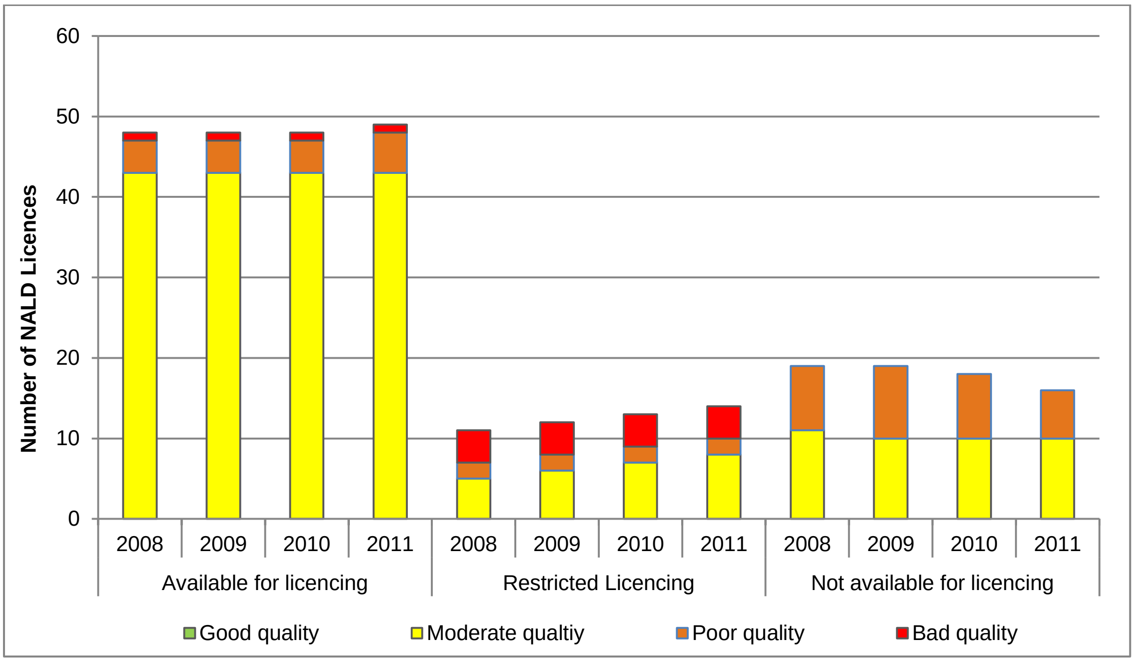
Mining and quarrying

Figure 3.11 Number of NALD licences by CAMS resource availability and WFD water quality status for mining and quarrying



Manufacture of paper and paper products

Figure 3.12 Number of NALD licences by CAMS and WFD water quality status for paper



3.4.2 Robustness and Limitations

See sections 3.1.2 and 3.2.2 regarding use of NALD, CAMS and WFD water quality status.

The BSD is likely to contain an over-estimate of the number of businesses abstracting as it is a comprehensive record of every single local unit in each SIC2007 sector, while the number of licences by sector in NALD is a likely underestimation of the number of businesses abstracting.

The Ordnance Survey freely provides the coordinates of the centroids of each postcode in the UK which meant that each postcode could be accurately assigned to a water body. Due to the different geographical boundaries between water bodies and postcodes, and uncertainty in exact business location, there is some small uncertainty in water body assignment.

3.4.3 Update Frequency

This indicator can be updated annually with updates to NALD and the BSD.

3.4.4 Methodology of indicator development

This indicator requires two different methodologies to support the use of NALD and BSD. For NALD, each water body is assigned a CAMS resource availability and WFD water quality status. The number of unique licences in each water body is counted for each year, the total of which is then calculated for each CAMS resource availability and WFD water quality status combination.

For the BSD, each local unit is reported as an entity in the database. A count of the number of records in each SIC2007 in England provides a count of the number of local units. Each postcode in the BSD is assigned a water body, CAMS and WFD water quality status based on the water body the centroid of the postcode is in. The total number of local units is then calculated for each CAMS and WFD water quality status combination.

3.5 Indicator 5: Number of employees by industry sector by CAMS resource availability status and WFD water quality status

3.5.1 Summary

This indicator assesses the total number of employees employed by each sector in each CAMS status and WFD water quality status area. By assessing the number of employees located in current areas at risk of potential water scarcity from future climate change as an absolute count. The number of employees, per sector and year, are derived from the BSD. The numbers of employees are reported separately for resource availability and water quality in order to comply with ONS disclosure regulations.

The majority of employees in the chemicals industry are located in areas of poor or moderate water quality. The same applies for the mining and quarrying and paper industries, though the trend is for employee numbers in these areas to be declining. There is no obvious trend of the number of employees in areas of moderate and poor water quality in each of the chemicals and paper industries, while there is a slow decline in the mining and quarrying industry. By mapping indicator 5 against indicator 1, an interesting observation can be made in the chemicals industry. Over 30% of reported abstraction is in areas classed as ‘not available for licensing’ however, less than 20% of the employee population are located in these same areas. This feature is likely due to the type and size of plant operating in certain areas classed ‘not available for licensing’. This relationship is illustrated in Figure 3.15 and Table B.24.

Whilst the number of employees is linked to the number of BSD local units, this indicator can be considered more useful than indicator 4. When considered with indicators 1, 2 and 6 it illustrates abstraction volume and GVA per sector employee in the different areas of water quality and availability. The number of employees accounts for the large variation in business unit sizes that is lacking in the number of business units alone.

Figure 3.13 Number of employees by CAMS resource availability status

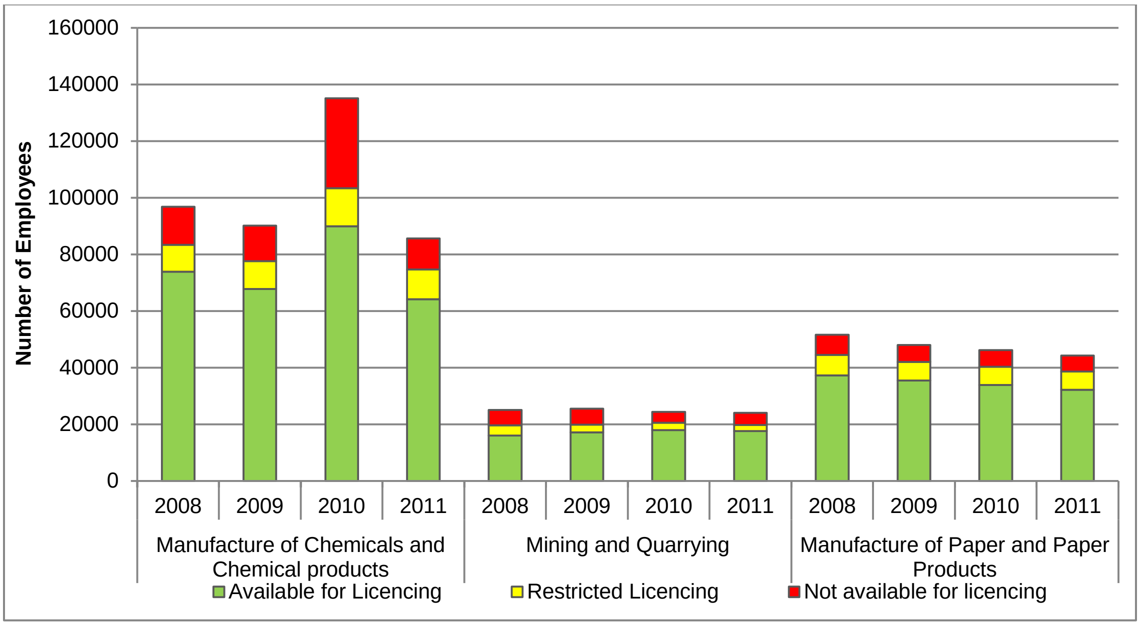
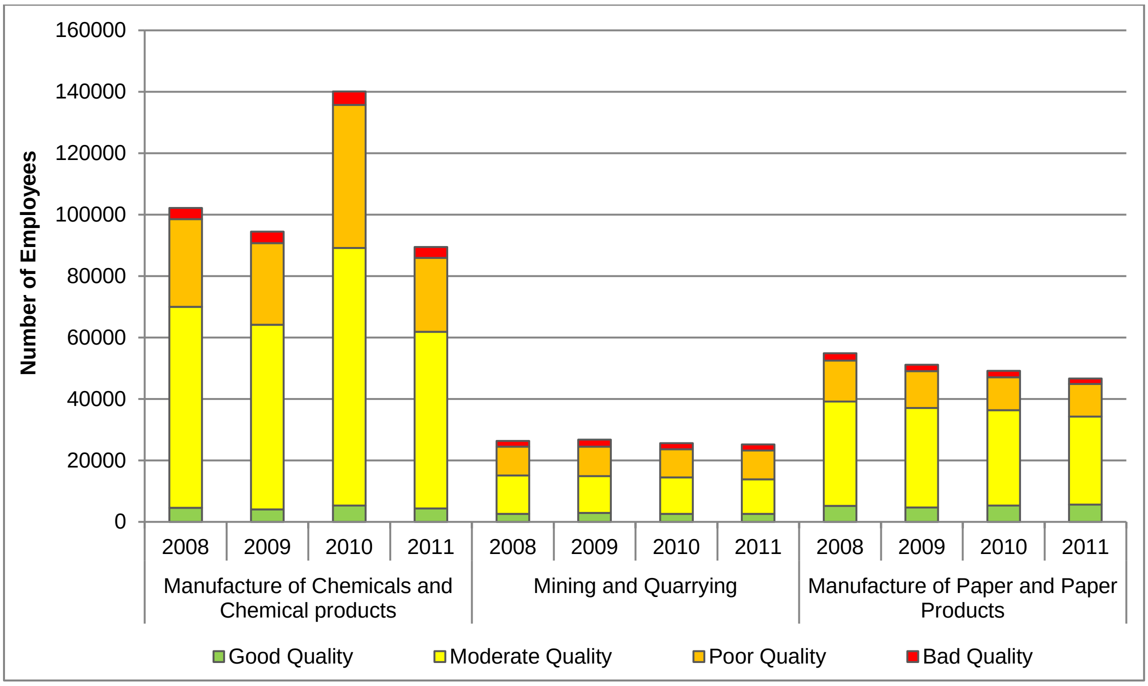


Figure 3.14 Number of employees by WFD water quality status



3.5.2 Robustness and Limitations

The indicator is based on highly reliable underpinning data from the Business Structure Database (BSD). The BSD holds employee numbers for each local unit in England and Wales. The survey is conducted annually by the ONS, with each local unit aligned to a

SIC2007 code and a post-code. As a result, assessment of change in employee numbers can be considered to be robust and should be reliable for future assessments.

The Ordnance Survey freely provides the coordinates of the centroids of each postcode in the UK which meant that each post code could be accurately assigned a water body. Due to the different geographical boundaries between water bodies and postcodes, and uncertainty in exact business location, there is some small uncertainty in water body assignment.

The indicator is an enumeration of the numbers of employees in each CAMS status and WFD water quality area, no consideration is given to whether the organisation abstracts water or not. The BSD is anonymised to the extent that it is not possible to distinguish between business which do and do not abstract within each SIC2007 sector. This results in a potential overestimation of the number of employees which are at risk of water scarcity.

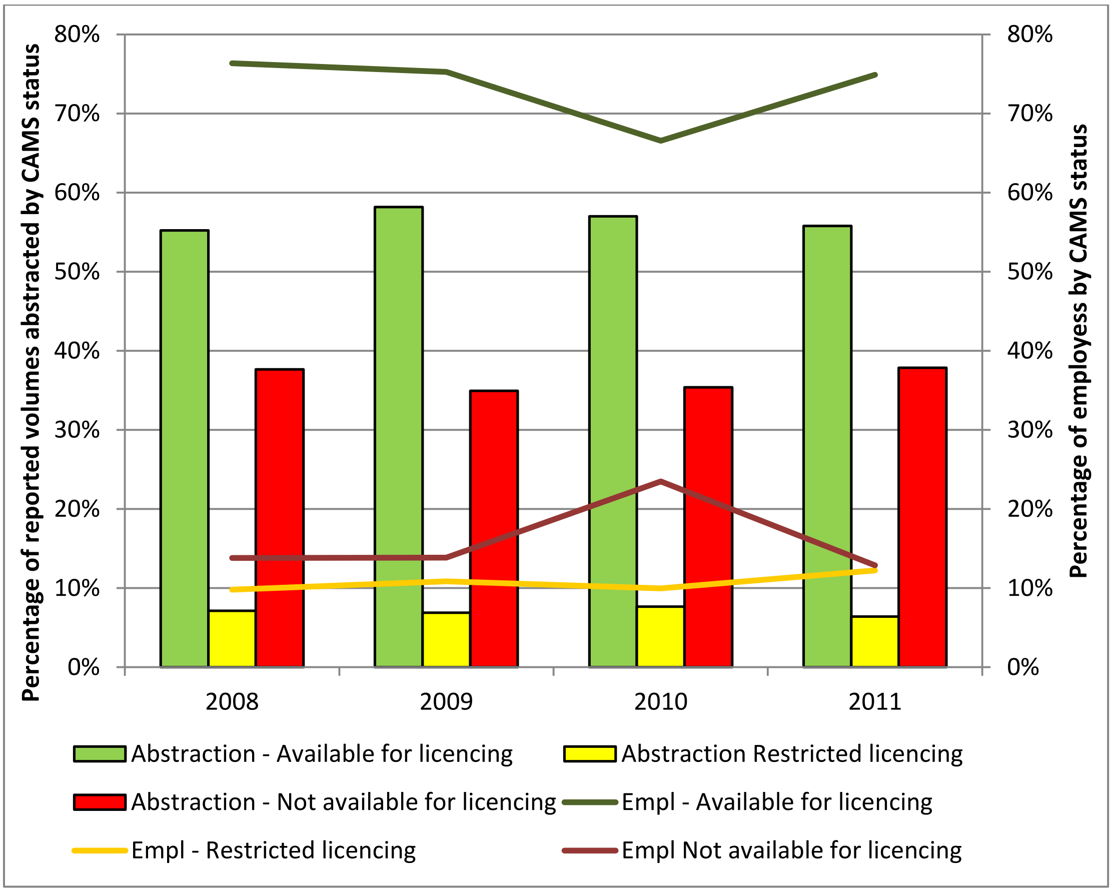
3.5.3 Update Frequency

This indicator can be updated annually in line with ONS updates to the BSD, as well as annual updates to NALD, CAMS resource availability status (Section 3.1.3) and WFD water quality status (Section 3.2.3).

3.5.4 Methodology of indicator development

The centroid of each postcode (available as open data from the Ordnance Survey) is linked to a WFD water body using a spatial join in GIS. Using employee data from the BSD, total employee numbers for each sector is calculated for each CAMS resource availability status and WFD water quality status from the BSD.

Figure 3.15 Comparison showing relationships between abstraction volume locations and employee locations for chemicals, by CAMS status



(Empl – Employees)

3.6 Indicator 6: Sector annual GVA, normalised by employee numbers, by CAMS resource availability status and WFD water quality status

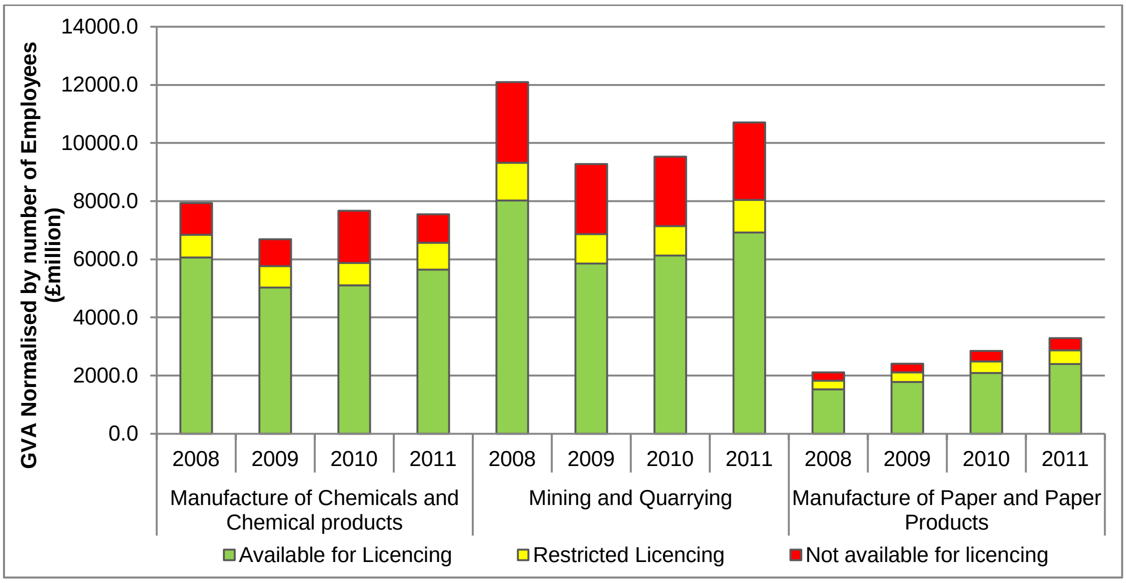
3.6.1 Summary

This indicator categorises the value which is at risk from potential water scarcity for each sector. The total national Gross Value Added (GVA), normalised by employee numbers, is calculated for each CAMS status and WFD water quality status in each sector[16]. The total GVA per employee in current areas of restricted resource availability quantifies how much economic activity is at risk of potential water scarcity from future climate change.

The general trend in GVA is an increase every year after 2008. The trend in the mining and quarrying industry and paper industry shows an increasing normalised GVA in each water stress and water quality status.

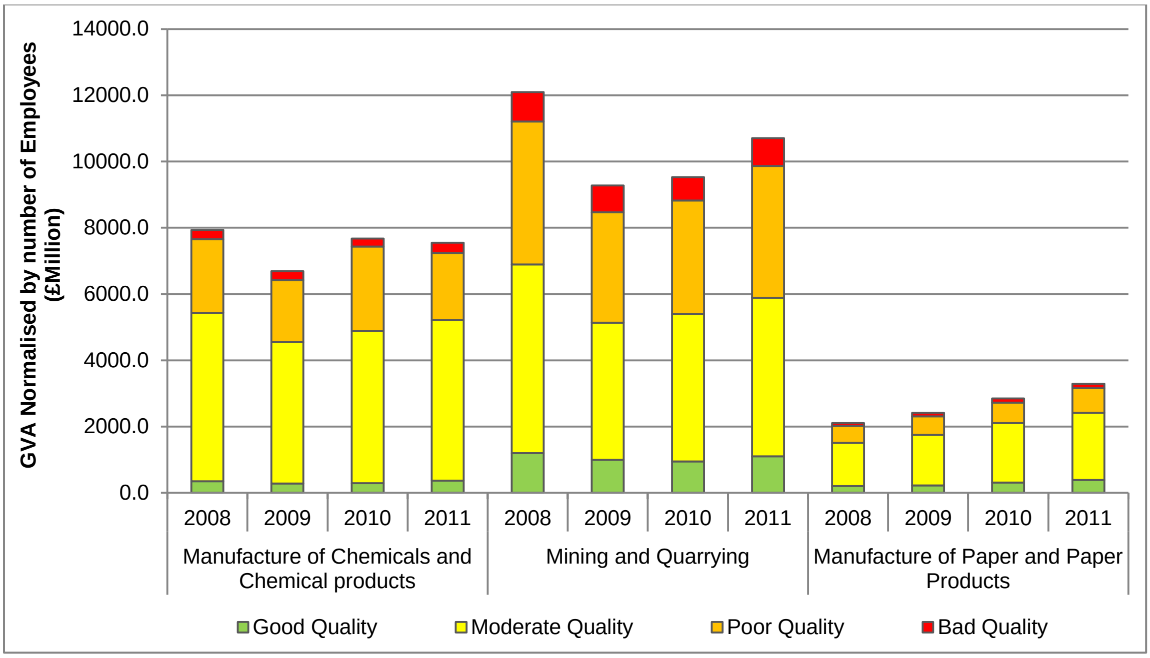
The indicator potentially (see 3.6.2) shows the amount of GVA at risk from water scarcity in the English economy. It can be used to assess trends in industrial processes and the size of economic outputs. For example GVA per employee is increasing for the paper industry, whilst the number of employees is decreasing.

Figure 3.16 GVA normalised by number of employees by CAMS resource availability status



[16] The indicator is generated by normalising the national GVA for a sector by the national number of employees in that sector. This 'GVA per employee' is then multiplied by the number of employees located in each CAMS and WFD status for each water body.

Figure 3.17 GVA normalised by number of employees by WFD water quality status



3.6.2 Robustness and Limitations

GVA is derived from the Annual Business survey conducted by the ONS. GVA is an economic measure of goods and services produced by a business and a major component of the national GDP figure. Because the underlying data is core to producing nationally important statistics, the data is robust for current and future assessments of the indicator. As the GVA value for each sector is normalised by the number of employees, this indicator is subject to the same robustness and limitations described in Section 3.5.2. Caution should be exercised when assessing trends, as GVA per employee is likely to vary significantly between industries and individual businesses within those industries.

3.6.3 Update Frequency

This indicator can be updated annually with updates to the BSD and the Annual Business Survey results.

3.6.4 Methodology of indicator development

As an extension of indicator 6, the national GVA for each sector was divided by the total number of employees in each sector and then multiplied by either the number of employees in each CAMS resource availability category or the number of employees in each WFD water quality category for each year.

4. Indicators of action

Ideally, a series of indicators would be developed to assess the actions of the identified industries, in response to the risk of water scarcity. To achieve this, WRc developed an initial matrix of adaptation measures, with the aim of identifying the uptake levels for the different demand reductions, and alternative source options, addressing water quantity and quality issues for each of the three sectors. The measures were sourced from Best Available Technique (BAT) Reference Documents (BREFs) and an online search for industry case studies. The matrices of possible action measures are developed from categories that include:

- Demand management actions such as water efficiency measures, the measuring and monitoring of water use and leakage management;

- Alternative supplies including; uptake of storage reservoirs, rainwater harvesting, dewatering, desalination, directly abstracted or mains water supplies;

- Water reuse; technologies to reuse water within the business thus reducing reliance on total water volume either from mains water or direct abstraction;

- Alternative manufacturing technology; changing machinery and production processes to reduce reliance on total water volume either from mains water or direct abstraction;

- Changes to production volume or relocation; in some circumstances it may be appropriate to consider a long term strategy to relocate or change production levels due to business risk from water scarcity.

Following consultation with the industrial sectors, it became clear that no robust datasets, or information sources to allow measurement of current uptake rates, are available. As a result, it is not possible to develop any meaningful indicators of action using existing, processed data. Qualitative assessments based on available case studies are neither of sufficient scope nor quality to provide value to this section of the report, and do not allow for robust indicators to be developed. Appendix D contains the matrices generated in the attempted development of indicators of action.

There is potential that in the future, industry bodies may collect and collate information of sufficient detail and quality to allow for the monitoring of adaptation measures uptake. The Cefic (European Chemical Industry Council) flagship initiative[17] is focussing on water use at

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17 http://www.cefic.org/sustainability/Flagship-initiatives/

operating sites in the chemicals sector. The initiative aims to determine key performance indicators to measure the uptake of sustainable practices at operating sites.

5. Indicators of impact

Indicators of impact track the realised impacts of climate change on the economy, society and environment. These impacts are the net result of the risk factors and the effect of adaptation actions. There are currently no developed indicators for this section of the report.

At the interim project meeting, the possibility was discussed of developing an indicator that tracks the number of occurrences where a 'Hands-off' Flow requirement, on an abstraction license, is realised. This is the number of times abstraction has to cease due to low flow in the water body. These restrictions impact on industry production, unless adaptation measures are implemented to mitigate such restrictions. The Environment Agency does not maintain a centralised database concerning the implementation of Hands-off Flow restrictions.

Correspondence with the EA has suggested that it may be possible to obtain information for development of an indicator by looking at time series data from key gauging stations which have a number of conditioned licences linked to them, and overlay this with the Hands-off Flow thresholds[18]. It may then also be possible to determine if the frequency and duration of Hands-off Flow being reached is changing and hence use this as a lagging indicator. Changes in licence conditions – due to replacement or RSA[19] (Restoring Sustainable Abstraction) implementation – would need to be accounted for as these would impact on the restrictions being implemented. This methodology would only be suitable for surface water abstractions, although it should be noted that groundwater licenses may also have Hands-off Level conditions.

[18] Personal communication with Paul Birchall, of the Environment Agency, who has suggested that a case study to ascertain if this methodology is viable would be useful.

[19] http://www.environment-agency.gov.uk/business/topics/water/32026.aspx

6. Conclusion for indicator development

A suite of indicators to assess the exposure and vulnerability of each sector to reduced water availability and reduced water quality have been developed. For each of these indictors, datasets were utilised that: (i) have a reliable time series, in order to distinguish long-term trends from year-to-year variability, and (ii) are spatially disaggregated, to identify hot-spots of risk and provide information relevant at the local, as well as the national, level. The data sources were subject to a data quality assessment. The data quality assessment concerned the availability, completeness and reliability of the identified datasets.

Following the development of six indictors. WRc suggest the use of four for future development;

- indicator 1 – Reported abstraction volumes in areas of restricted water availability;
- indicator 2 – Reported abstraction of water in areas of restricted water availability and poor or moderate WFD water quality;
- indicator 5 – Number of employees by industry sector in areas of restricted water availability and poor or moderate WFD water quality;
- indicator 6 – Sector annual GVA normalised by employee numbers in areas of restricted water availability and poor or moderate WFD water quality.

The further development of indicators 3 and 4 is not recommended. The uncertainty that exists concerning the use of EA loss factors (indicator 3) in determining net abstraction does not allow for a reliable indicator. Additionally, the continued use of generic loss factors would preclude this indicator from illustrating any reduction in the consumptiveness of a business unit. The total number of business generated by indicator 4 is not representative of the actual number of abstracting businesses. The large variation in business unit size is not accounted for in this indicator and as a result, indicator 4 is not a suitable choice to monitor the change in risk due to climate change.

Based on the development of these indicators, and their supporting datasets, WRc have identified areas where improvements can be realised:

- existing datasets which hold abstraction and discharge volumetric data are not well suited to estimating net abstraction by industrial sector. Attempts to estimate net abstraction by sector using loss factors have proved difficult and introduced additional unavoidable systematic errors;

- the accuracy of the net abstraction calculation by sector would be improved if:
    - information on abstraction and discharge licences were co-located and cross-referenced by licence holder;
    - all abstraction points were assigned a SIC code or NALD purpose by licence holders;
    - abstraction licensees were required to report volumes abstracted for each abstraction point;
    - abstraction licence and discharge permit holders were compelled to comply with their licence reporting requirements and submit a data return annually to the relevant environmental regulatory body;
    - assumed loss factors were validated for key consumptive sectors;

- the use of ONS data would be improved by the development of queries that discriminate between business units with and without an abstraction license. This would allow for a significantly improved estimation of businesses, employees and GVA at risk;

- there currently exists no suitable database for the development of an indicator to monitor the uptake of adaptation measures. Links should be fostered with industries and initiatives supported, such as the Cefic Flagship Initiative, to identify opportunities for research and development of indicators of action for national industries;

- greater interaction between industry representatives and other concerned stakeholders would serve to create a mutually beneficial and rigorous approach in addressing the risks posed by water scarcity.

The selected indicators are developed from data sets that are routinely collected, show good spatial coverage, and have the ability to show trends in risk from water scarcity and the uptake of adaptation measures. Therefore, they are considered as suitable candidates to assess the risk of water scarcity from climate change to water intensive industries.

7. Introduction to assessment of adaptation measures

This section of the report sets out a selection of feasible, industry specific measures, to adapt to potential water stress as a result of climate change. Input was sought from representatives of the relevant industry associations[20] in identifying potential data sources and the selection and evaluation of adaptation measures.

The implementation of these adaptation measures may be the result of drivers other than water efficiency, such as the need to reduce or prevent discharges of wastewater or effluent. When considering adaptation, consideration must be given to overall costs (including capital, operating and maintenance costs) and potential benefits that will accrue to the business (including cost reduction, reputational value and other environmental improvements). In addition, there are process safety and operability conditions to consider in the introduction of new measures.

Given the process variation within and between the sectors under consideration, a qualitative assessment of adaptation measures has been made. This assessment draws upon engineering judgement as well as information sourced from UK and international case studies. While it has not been possible to undertake a detailed, measure specific Cost-Benefit Analysis (CBA), a simplified analysis of selected measures is presented in Chapter 12.

[20] Mineral Products Association (MPA), the Chemicals Industries Association (CIA) and the Confederation of Paper Industries (CPI).

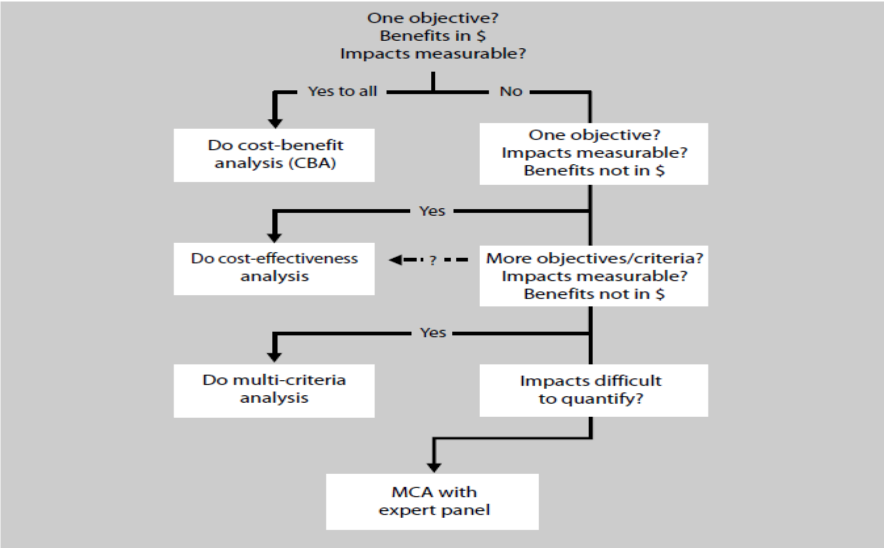
8. Selection of assessment method

The four primary evaluation methods in assessing adaptation measures are (Niang-Diop, 2011):

- Cost-benefit Analysis (CBA);
- Cost effectiveness Analysis (CEA);
- Multi criteria Analysis (MCA); and
- Expert judgement.

Three of these methods, CBA, CEA and MCA are common with the United Nations Framework Convention on Climate Change (UNFCC) report (UNFCC, 2002). A decision tree for selecting an appropriate assessment method is given in Figure 8.1. Expert judgement may be used where other methods of analysis are inappropriate (Niang-Diop, 2011)

Figure 8.1 Selecting the method for assessment of adaptation measures



Source: UNFCC 2002

8.1 Cost-Benefit Analysis (CBA)

One of the key factors in choosing a particular water sustainability measure is the overall cost, including capital costs and on-going operating and maintenance costs versus the perceived benefits of the measure. There will need to be a consideration of the overall cost of the measure (including capital, operating and maintenance costs) and the potential benefits that will accrue to the business (including cost reduction, reputational value and environmental improvements). Cost benefit analysis (CBA) is an economic tool for evaluating all the relevant costs and benefits of a proposed plan of action.

CBA identifies potential low-regrets and cost effective adaptation measures and this provides a key input in gathering a comprehensive adaptation strategies for the three sectors. A methodology to assess the costs and benefits of a selection of feasible measures for the mining and quarrying, chemicals manufacturing, and paper manufacturing industries has been developed as part of this project and delivered in Chapter 12.

The processing of a CBA requires the estimating and calculating of all costs and benefits in monetary terms. In most cases, it is straightforward to identify and estimate the costs of adaptation measures; the challenge lies in assessing the potential benefits. The implementation of these water reduction measures or actions will often be driven by other factors such as the need to reduce or prevent discharges of wastewater or effluent. In addition, there are process safety and operability conditions to consider in the reduction of water use in production. Most case studies that were reviewed in this project revealed that the primary objective of implementing measures was not water savings; reduction in consumption was an unintended consequence. Therefore, when considering some adaptation measures, businesses need to take a holistic assessment of all the benefits including energy savings, improved process efficiency and environmental improvement.

At inception, the expectation was that an adaptation cost curve would be developed for each of the industries under study, to assess the potential for additional uptake of adaptation measures and the extent to which these address the risk. The intention was to determine the level of investment to be made in each adaptation measure and the timing of this investment to ensure the maximum benefit is achieved at reasonable cost. However, given the large variation between processes and water use within each sector under study, coupled with the sparse availability of sufficient quality data, a full cost benefit analysis of adaptation measures could not be prepared for this project. Instead, qualitative assessments of a number of adaptation measures was undertaken. This includes an indication of cost (High, Medium or Low) and the potential forms of the benefits. This information was based on expert judgement, published literature including case study data, and valuable input from representatives of the relevant trade associations representing the industry sectors of interest for this study. It was intended to populate, where possible, an indication of adaptation measure uptake (increasing, decreasing or stable). It was not possible to identify any sources of information that could be used to populate this data field. The uptake of specific measure does not appear to be monitored, focus instead tends to be on monitoring sustainable water management approaches.

Following this qualitative assessment, a ‘high level’ CBA was prepared for selected measures in each industry, see Chapter 12. The purpose of this CBA is to provide a likely ranking of these measures based on their cost effectiveness.

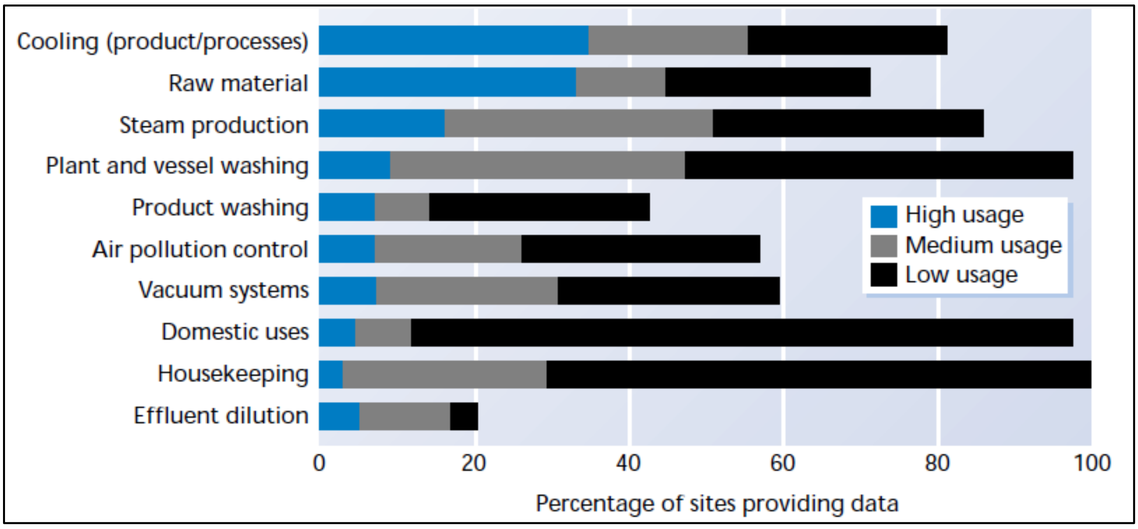
9. Chemical manufacturing industry

9.1 Water use in the chemical industry

The chemical industry includes producers of commodity chemicals such as organic and inorganic chemicals and industrial gases; and speciality chemicals such as pharmaceutical products and essential oils. It also includes mixing, blending, diluting or converting basic chemicals to make chemical products and preparations, e.g. paints, pesticides, inks, detergents and cosmetics. Water is used, for example, as a heat transfer agent for heating or cooling, feedstock for boiler plants, a carrying agent for transport of insoluble materials, a component of a substance, a solvent and washing/cleaning agent and, as an air contaminant abatement fluid.

In England, the 'Manufacture of chemicals and chemical products' (SIC division 20) is the largest sub-sector in terms of volume directly abstracted, representing over one-half of the total volume directly abstracted by the manufacturing sector for consumptive uses. However, there is a high variance in the specific water consumption within this sector, i.e. there is a significant difference in the lower and upper bound values for consumptive use due to the diverse product range and process requirements, ranging from 0.02 m^3/tonne product to 964.94m^3/tonne product (Wrap, 2011b) (Envirowise, 2003). Figure 9.1 provides a useful insight into how water is used by the industry by illustrating the percentage of sites using water for each of the purposes identified.

Figure 9.1 Penetration of water using processes in the chemical sector (survey)



Source: (Environmental Technology Best Practice Programme, 1997)

The cost of water use in the industry may be substantial, including supply, treatment and disposal charges as well as hidden costs such as lost materials in the effluent stream.

Therefore implementing changes in operating practices and other longer-term efficiency measures can lead to significant benefits. There are a number of techniques that can result in reduced water use and increased resilience to decreased water availability and quality. These techniques are collated in Table 9.1.

The implementation of these techniques (Defra, 2012) will often be driven by the need to reduce or prevent discharges of wastewater or effluent. Consideration should be given to the overall costs of the measure (including capital, operating and maintenance costs) and the potential benefits that will accrue to the business (including cost reduction, reputational value and other environmental improvements). In addition, there are process safety and operability conditions to consider in the reduction of water use in production.

The selection of specific measures for implementation is best conducted using a site/catchment specific cost-benefit analysis (CBA) considering the above factors. A range of likely measures was selected by WRc and subject to a ‘high level’ CBA, the purpose of which is to determine a likely order of measures and their suitability for uptake. The results of this CBA are outlined in Chapter 12, with further details concerning other measures supplied in Appendix E.

9.2 Case studies

The review of a number of case studies has been undertaken to understand the context and benefits of embedding water saving measures within the chemical industry. A selection of the most pertinent are outlined below:

Reducing freshwater withdrawal (Agency for Environmental Protection and Technical Services of Italy, 2007)

With a total water intake in excess of 800 million m^3 in 2012, Solvay Chemicals established a number of screening tools to assess and mitigate water risks. In Aretusa, Tuscany (Italy), the Solvay plant replaced abstraction of groundwater from the Cecina river basin for use as process water, with treated waste water from the local domestic wastewater treatment plant (WWTP). Savings of 4 million m^3 per annum (approximately 0.5% of total intake) have been realised in water abstraction from groundwater in the region of Bassa Val di Cecina. In addition, the quality of the surrounding coastal waters has been improved as they no longer receive the WWTP effluent.

Water saving initiatives (Envirowise, 2006)

Hampshire Cosmetics manufactures over 1,100 personal care products from its state-of-the-art facility at Waterlooville, Hampshire. The business established a water efficiency team, which closely monitors site water use and communicates results with posters and in the company newsletter. It has carried out a number of water-saving initiatives including:

- Using water from the two chillers as make-up water for the main production chiller plant, saving 0.42m^3 an hour for two hours a day;

- Installing 'hippo' bags in toilet cisterns, saving approximately 400 m^3 a year;

- Installing spray fittings on taps to reduce water consumption.

In addition, the business uses reverse osmosis technology to produce high purity water for the manufacturing process. Evaluating and altering current membrane arrangements maximised the percentage of water recovery, saving up to £20,000 per annum.

Overall, the benefits of Hampshire's Cosmetics' water management initiatives have included reduced water costs and increased water recycling within the process (www.NIbusinessinfo.co.uk).

Sustainable water management (DSM, 2013)

DSM aims to achieve a situation where its operations have no adverse effect on the quality and quantity of water in the regions in which the company operates. In regions that face water scarcity, as defined by the Global Water Tool[21], DSM actively assesses the local impact of its operations and promotes an overall sustainable water management system in cooperation with other stakeholders in the watershed area and in the supply chain. In these water risk assessments, DSM undertakes a water risk assessment using a dedicated Sustainable Water Management methodology that includes water governance capability, (local) stakeholder integration, business risks related to existing and future operations, and value chain and ecosystem impact.

DSM supports UN CEO Water Mandate

"Sustainability is a core value and growth driver for DSM. Our mission is to create brighter lives for people today and generations to come. One of the essential elements in people's lives is water. It is becoming increasingly scarce and polluted. But increasingly water is also becoming too abundant due to natural effects, increased by climate changes and therefore threatening lives within our society. DSM truly values initiatives like the United Nations Global Compact CEO Water Mandate, to the principles of which I express my continued support. We need to keep each other focused on the essentials in life. The topic of water and sustainable water management has our full attention."

Feike Sijbesma, CEO of Royal DSM

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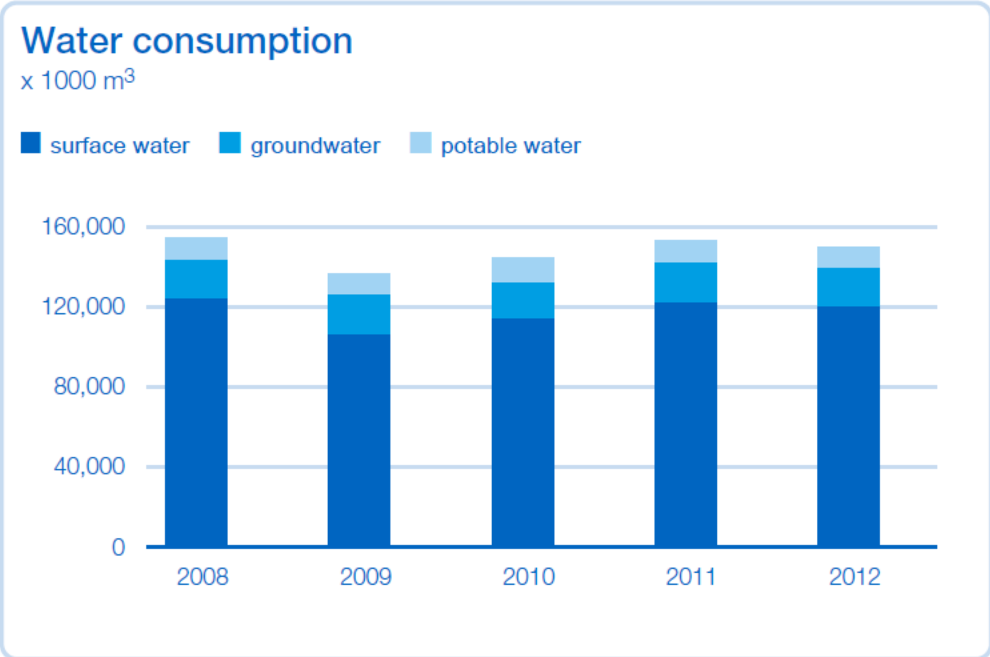
[21] http://www.wbcsd.org/work-program/sector-projects/water/global-water-tool.aspx

As part of its roadmap to sustainable water management, DSM has confirmed an overall water intensity target of reducing water withdrawal by 15% from 2010 consumption levels by 2015, and is contributing to the development of the ISO 14046 water footprint standard.

Figure 9.2 DSM water consumption by source and year



Source*:* (DSM, 2013)

Implementation of the European Water Stewardship standard (BASF, 2013)

BASF Tarragona plant in Spain was awarded the first European Water Stewardship (EWS) standard in 2013, verifying excellent water management initiative performance. Developed by governments, businesses and NGOs under the leadership of the independent organisation European Water Partnership (EWP) and effective from 2011, the EWS standard aims to lower the quantity of water used by companies and farms (at the river basin level) whilst simultaneously safeguarding the integrity of local ecosystems within the vicinity of the site.

Located in an area of water scarcity, the Tarragona BASF plant has many diverse chemical activities in which water abstracted from the Ebro River may be used as a coolant, solvent and cleaning agent, as well as directly in chemical production.

BASF has implemented the standard at the plant in order to promote and communicate its global water goals, which include the reduction by 50% of abstraction of drinking water from supply sources for production by 2020 compared with 2010. Emissions to water of organic substances and nitrogen are to be reduced by 80% and the emissions of heavy metals by 60% compared with 2002. Amongst others, the assessment of the standard requires a water recycling strategy and a cohesive crisis management strategy to be in place. The principles and requirements of the standard help BASF to raise awareness around water as a resource, and related long term risks in availability, providing additional benefits of public acceptance and investors' confidence.

Tarragona demonstrates diversification of water sources, re-use of WWTF effluent, improvement in programs of water usage, as well as an evaluation of supply and discharge related risks, and water risk assessments of chemical production activities.

9.3 Qualitative assessment of water reduction measures

Table 9.1 provides a qualitative assessment of a number of water efficiency measures in relation to the estimated proportion of uptake in the UK (increasing, decreasing or stable), indicative costs (High, Medium and Low) and potential form of benefits. Information contained in this table has been based on expert judgement, published literature and case studies.

Due to a lack of sufficient quality data, it has not been possible to fully populate Table 9.1.

Table 9.1 Qualitative assessment of water consumption reduction measures in the chemical industry

Measures to reduce water consumption	Estimated proportion uptake in UK	Implementation Costs (H/L/M)*	Form of benefits							
			Reduced water use	Reduced wastewater loads	Energy savings	Reduced environmental impacts: pollution/ run-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
Minimise the presence of water in the process including water used in product purification and equipment cleaning			✓	✓						
Dry techniques where appropriate to abate particulate and gaseous exhaust streams			✓	✓	✗	✓				
Reduce process drag-out and maximise reuse in rinsing		Low	✓			✓	✓			
Recycle or reuse water (e.g. from condensates, process and scrubbing) back to processes, or cascade to secondary uses such as equipment cleaning			✓	✓				✓	✓	
Good water management including sub-metering of key activities such as rinsing		Low	✓					✓	✓	✓

Measures to reduce water consumption	Estimated proportion uptake in UK	Implementation Costs (H/L/M)*	Form of benefits							
			Reduced water use	Reduced wastewater loads	Energy savings	Reduced environmental impacts: pollution/ run-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
Eliminate equipment cleaning between batches of the same product unless essential. Consider reduced level of cleaning where this is not possible e.g. weekend shutdowns.		Negative	✓	✓	✓	✓				
Dry pre-cleaning and cleaning methods where possible			✓	✓			✓			
Prevent water pollution incidents, spills and leaks to avoid water use in cleaning		Negative					✓		✓	✓
Use water free techniques for vacuum generation			✓							
Use counter-current washing systems and water sprays rather than jets					✓					
Employ closed-loop cooling water cycles, or use indirect cooling techniques			✓	✓						
Maximise water re-use through identifying the lowest water quality that can be used for each activity in the process		M		✓	✓					
Facilitate re-use through provision of storage tanks		H		✓						

Measures to reduce water consumption	**Estimated proportion uptake in UK**	**Implementation Costs (H/L/M)***	**Form of benefits**							
			Reduced water use	Reduced wastewater loads	Energy savings	Reduced environmental impacts: pollution/ run-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
Utilise separators to facilitate the collection of water insoluble materials		M				✓				
Optimising heat use and improving operation of the system					✓		✓			
Use of recirculating cooling				✓						
Reusing (waste) water from within or outside the industry plant for use in cooling towers		M	✓	✓						

10. Mining and quarrying industry

10.1 Water use in the mining and quarrying industry

The typical process steps at any mining operation are: extraction, mineral processing, shipment of product and management of residue.

Mineral processing is usually carried out close to its extraction, to reduce transportation cost of the material by separating the valuable materials from the rest (the tailings). Typical mineral processing techniques include comminution, screening and hydrocycloning, gravity concentration, flotation, sorting, magnetic or electrostatic separation, leaching thickening and filtration. The management of tailings depends on the method of mineral separation as this affects their physical characteristics.

Although a lot of a quarry's water demand can be met through dewatering and rainwater collection, there are some uses – such as washing products, and for production of blocks of concrete that may occur on-site that require clean water. It is usual to find cement works located in or near chalk and limestone quarries; brickworks located on or near clay pits; asphalt plants located on or near hard rock aggregate quarries and other heavy industry or power generators located near coal mines. (Note: dewatering, particularly in sand and gravel deposits, will have an effect on groundwater levels and flow directions in the surrounding area, resulting in the formation of a 'zone of dewatering influence' within the water table[22])

Consumptive water uses at quarries include dust suppression, vehicle and road cleaning, water that is evaporated by industrial drying processes (e.g. in the production of asphalt and specialist silica sands) and with water that becomes part of the product leaving the site (washed aggregate, and concrete products). There will also be evaporative losses from washed aggregate stockpiles, and other wet surfaces. Water may also be consumed in mineral washing, lubrication and cooling of saws and other cutting equipment.

Many quarries will recirculate water through site lagoons, and use the resulting water for further processing on site. However, net losses can be reduced through measures outlined in Table 10.1.

The selection of specific measures for implementation is best conducted using a site/catchment specific cost-benefit analysis (CBA) considering the above factors. A range of likely measures was selected by WRc and subject to a 'high level' CBA, the purpose of which

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[22] Capita Symonds (2007) Mitigating the Impacts of Quarry Dewatering in Sand and Gravel Deposits. http://sustainableaggregates.com/library/docs/mist/l0037_ma_4_2_014_v1.pdf

is to determine a likely order of measures and their suitability for uptake. The results of this CBA are outlined in Chapter 12.

10.2 Case studies

A number of case studies have been undertaken to demonstrate the benefits of incorporating water efficiency measures within the operation of business in the mining and quarry industry. A selection of these are outlined below:

Rainwater Harvesting (NIEA, 2008)

Northstone (NI) Limited Concrete Division incorporated a rainwater harvesting system into their new Tile Plant in Toomebridge (2008). Rainwater is now captured from the factory's roof; the newly installed syphon system directs rainwater to storage tanks with a holding capacity of 120m^3. The syphon system provides better control and reduces the volume of storm water directed into the local drainage system. The company has benefited from financial savings from recycling and at the same time has reduced the environmental impact of its abstraction activity.

"We decided to venture into rain water harvesting for re-use of rainwater in the tile manufacture process, not only because of the cost benefits to be gained from recycling rainwater, but also because it reduces our environmental impacts. We are also aware that reduction of surface run off water on the site automatically reduces any potential pollution (spill) spread." – Brian Watt, Production Director (New Tile Plant, Toomebridge Northstone (NI) Ltd., Concrete Division)

Sustainable Drainage System (SUDs) (NIEA, 2008)Norman Emerson Group's Tandragee Quarry incorporated a sustainable drainage system to capture run off from the wheel washing plant. Water would be pumped from a borehole to a reservoir before it was used. Any excess water would collect in a settlement tank before being fed back to a reservoir. This enclosed system negated the need for discharge consent, providing financial savings and recycling 80% of the water, reducing the impact on the groundwater aquifer due to reduced pumping from the borehole.

This enclosed system also meant that water being used in the concrete batching plant was recycled, reducing the amount of water required from the borehole.

"Keeping our vehicles, our haul roads and public highways clean are stipulations all quarry operations have to abide by. By achieving this in a sustainable manner we are putting lest pressure on the water table and preventing risk of contamination – all of which are vital importance in maintaining good relations with our local neighbours and regulators." – Colin Emerson (Operations Director, Norman Emerson Group)

On Site Water Management (NIEA, 2008)

The water management system operated by Creagh Concrete at the Draperstown Pit ensures that no offsite discharge occurs, reducing the potential for water pollution of nearby streams or nearby Lough Fea (a public water supply and renowned for trout fishing) and Teal Lough (ASSI, SAC), Lough Patrick, Cow and Mill, which range from around 1.5 km to 6 km from the site. There are no significant water courses within the site and the nearest water course is the Black Water which flows from the SE to NW is a closest about 300 m from the sand and gravel operation. The principle route for surface water drainage from the area around the quarry is a small tributary which flows on the SE boundary within a shallow valley.

"A number of lagoons have been created within the site voids created by the extraction process. There are no discharges of water from the site directly other than those which would percolate through the sand and gravel or evaporate. Water is collected, pumped, settled and reused in the washing process. Re-use is increasingly important to our operations demonstrating efficient and sustainable water usage" – Colm Scullion, Sand Pit Manager Creagh Concrete Products Ltd.

"Our inclusive and proactive approach to water management has delivered benefits beyond our expectations. By an inclusive approach we mean tackling a reduction in the use of potable water, reducing abstraction, and reducing and enhancing the quality of any discharges. Reduction in the use of potable water has reduced our water charges by some 80%, whilst reducing abstraction has reduced energy costs associated with borehole pumps. Reduced discharge volumes and enhanced quality has improved relationships with statutory authorities and public alike with significant long term benefits for the Company and its employees for example in the securing of two major planning consents in a respectably quick time period. Why? Because statutory consultees know we have a reputation of delivering on our commitments and then going one step further.

Does it pay off? Yes, our costs are down, our image with pressure groups is enhanced, and, crucially we are able to sustain our aggregate reserves by successful planning applications, and of course we are not incurring negative costs such as legal fees, and fines" - Pat Lyons, General Manager, Tarmac Ltd.

Water recycling system (SustainabilityWestmidlands.org.uk, 2009)

At Cauldon Works in Staffordshire abstraction from the River Hamps was reduced by 90% from 290,000m^3 in 2006, to only 13,500m^3 two years later and 0m^3 in 2009 and 2010 (Lafarge Cement UK, 2010). This was achieved through development of a former shale quarry into a water source from recycled water and additionally provided an environmental benefit by creating a new water habitat. A water recycling system has been installed and the lake now forms the hub of a gravity drainage system. Floating pumps provide the water the works need for cooling. The main benefits of the water management scheme have been:

Environmental: Major reduction in water 'footprint'; creation of significant wildlife habitat.

Community: Improved stakeholder relationships (reduced risk to local properties during drought/flood); enhanced external appearance of worked out quarry; bird hide built in partnership with Staffordshire Wildlife Trust – enjoyed by Lafarge visitors and walkers.

Economic: Reduced pumping has resulted in net energy savings of around £14,000/year.

10.3 Qualitative assessment of water reduction measures

Table 10.1 provides a qualitative assessment of a number of water efficiency measures in relation to the estimated proportion of uptake in the UK (increasing, decreasing or stable) an indicative cost (High, Medium and Low) and the potential form of the benefits achieved. Information contained in this table has been based on expert judgement, published literature and case studies, and has been peer reviewed by representatives of the mining and quarrying trade association, the Mineral Products Association (MPA).

Due to a lack of sufficient quality data, it has not been possible to fully populate Table 10.1.

Table 10.1 Qualitative assessment of water consumption reduction measures in the mining industry

Measures to reduce water consumption	**Estimated proportion uptake in UK**	**Indication of Costs H/L/M***	**Form of benefit**							
			Reduced water use	Reduced wastewater loads	Energy savings	Reduced enviro'tal impacts: pollution/ un-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
Understanding and measuring water use throughout the site		L								✓
Efficient dust suppression technologies. This may include the use of hydraulic spinning systems rather than splashplates, and the use of chemical additives		M	✓			✓				
Efficient wheel washing technologies. This may include closed loop recirculating systems, or waterless systems that use angled steel grids to clean debris from tyres		M	✓	✓		✓				
Controlling leakage from pumps, pipes and equipment		L			✓					
Using water efficient mineral processing technologies		H	✓				✓			
Optimising recirculation and reuse of run-off and grey water from quarry buildings		M	✓	✓		✓				
Using the latest methods for drainage and settlement lagoon design that result in relatively clean water being kept away from sources of sediment. Note, the use of flocculants is no longer		H		✓		✓	✓			

Measures to reduce water consumption	**Estimated proportion uptake in UK**	**Indication of Costs H/L/M***	**Form of benefit**							
			Reduced water use	Reduced wastewater loads	Energy savings	Reduced enviro'tal impacts: pollution/ un-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
encouraged										

11. Paper and pulp manufacturing industry

11.1 Water use in the paper and pulp industry

Water use is one of the main elements for paper production and it is an important resource for the industry from the beginning to the end. The paper and paper products manufacturing process are generally split into five types of mill, based on the processes undertaken:

- Kraft pulping process[23]
- Sulphite pulping process[23]
- Mechanical pulping and chemi-mechanical pulping
- Recycled fibre processing
- Papermaking and related processes.

Paper is essentially a sheet of fibres with a number of added chemicals that affect the properties and quality of the sheet. Besides fibres and chemicals, manufacturing of pulp and paper requires a large amount of process water and energy in the form of steam and electric power. Pulp for papermaking may either be produced from virgin fibre (by chemical or mechanical means) or may be produced by the re-pulping of recovered paper. A paper mill may simply reconstitute pulp made elsewhere or may be integrated with the pulping operations on the same site. Mills can therefore be classified also as integrated or non-integrated pulp or paper mills:

Non-integrated pulp mills (market pulp) are only manufacturing pulp that is then sold on the open market.

Non-integrated paper mills are using purchased pulp for their paper production.

In integrated pulp and paper mills, the activities of pulp and papermaking are undertaken on the same site. Across Europe kraft pulp mills are operating in both non-integrated and integrated manner whereas sulphite pulp mills are normally integrated with paper production.

[23] This assessment covers all measures outlined in the BREF. However, those applicable to Kraft and Sulphite mills are not relevant for UK adaptation assessments as there are no mills of this type in the UK.

Mechanical pulping and recycled fibre processing is usually an integrated part of papermaking but has become a stand-alone activity in a few cases across Europe.

Mills may also be classified based on the product they are producing – for instance packaging board, newsprint, tissue or specialist mills. Differences in water demand within and between these types of mill arise from a number of areas including:

- The grade of paper being produced. For some grades 'white water' quality is less critical and can be reused more readily. 'White water' are paper mill waters which have a white, cloudy appearance due to a fine dispersion of fibres and other paper making ingredients, picked up when separated from the furnish (paper making mixture) on the paper machine, washers, etc.

- High quality papers require greater volumes of white water and clarification systems and cannot produce the required quantities, hence fresh water is required.

- Colour changes and shorter production runs associated with high quality papers result in more frequent plant wash-down.

- Tissue products, and some specialist products, are very lightweight and hence per tonne of product the water consumption appears high.

Water consumption varies considerably across mills, with figures ranging between 8 m^3 and 500m^3 per tonne of product (Envirowise, 2002). Figures higher than about 50 m^3 are normally due to the fact that clean cooling water is included. There is also a difference in water management between integrated and non-integrated pulp mills. In an integrated mill, the pulp will come from the pulp process to the papermaking process at about 4% consistency. In non-integrated pulp mills the market pulp has to be de-watered and dried (EU Joint Research Centre, 2000).

There are a number of actions that can be taken to reduce water usage in the pulp and paper processing depending on the process being undertaken. This is summarised in Table 11.1.

Table 11.1 Actions to reduce water usage in different processes

Water use reduction measures	Kraft mill	Sulphite mill	Mechanical pulp mill	Recovered paper processing	Paper making
Dry debarking	✓	✓	✓		
Delignification before the bleach plant	✓				
Efficient brown stock washing and closed cycle brown stock screening	✓	✓			

Water use reduction measures	Kraft mill	Sulphite mill	Mechanical pulp mill	Recovered paper processing	Paper making
Recycling of alkaline bleach filtrate	✓				
Effective spill monitoring, containment and recovery	✓	✓	✓		
Reuse of condensates from the evaporation plant	✓				
Capacity sizing of black liquor evaporation plant and recovery boiler	✓				
Collection and reuse of clean cooling waters	✓				
Reuse of condensate from evaporation of weak liquor		✓			
Minimisation of reject losses by using efficient reject handling stages			✓		
Water recirculation in mechanical pulping			✓		
Counter current white water system from paper mill to pulp mill			✓ if integrated		✓ if integrated
Recycling of process water				✓	✓
Counter current flows of process water				✓	
Installation of water efficient machinery for balanced white water, filtrate and broke storage system					✓
Understanding and measuring water use throughout the site	✓	✓	✓	✓	✓
Improve production scheduling				✓	✓
Efficient plant wash-down				✓	✓
Good housekeeping for leaks, boiler maintenance and flow rate control	✓	✓	✓	✓	✓

11.2 Case studies

A number of case studies have been undertaken to demonstrate the benefits of incorporating water efficiency measures and longer-term measures within the operation of business in the paper and pulp industry. A selection of these is outlined below:

Using recovered effluent (Envirowise, 2002)

The Chesterfield Paper Mill, owned by SCA Hygiene Products, manufactures tissue-based products from recovered fibre. The mill uses fresh water from a nearby reservoir. During 2000, the mill undertook a project to reduce the use of fresh water (for diluting thick stock from 12% solids to 5% solids) by replacing it with recovered effluent that had received primary treatment.

At the beginning of the project, the mill estimated it was using 17 m^3/ADt of product. Using recovered effluent instead of fresh water has allowed the mill to reduce its specific water consumption by just over 2 m^3/ADt, a reduction of nearly 12%. There was no reduction in water supply costs as a result of this project because the company pays an annual fixed fee for water from the reservoir. However, the project has significantly reduced the volume of effluent discharged by the mill, resulting in a substantial reduction in trade effluent and the associated charges.

The Iggesund Paperboard mill (Envirowise, 2002)

The Iggesund Paperboard mill in Workington, which has a workforce of 420 and a production capacity of 200,000 tonnes/year, uses 100% virgin fibre to manufacture folding box board. Product uses include graphical applications and as packaging for food, pharmaceuticals, toys, chocolate and tobacco products.

As part of its Millennium project, the mill carried out significant process and product development during 1999 and 2000 with the aim of improving product quality and increasing mill capacity. The main investment was a comprehensive rebuild of the mechanical pulp mill, including the introduction of a new hydrogen peroxide bleaching plant.

One of the project's objectives was to reduce both Specific Water Consumption and the loss of raw material to effluent. The main drivers for reduced water consumption were to:

- allow the mill to develop new products and increase production capacity while utilising the existing effluent treatment system;
- reduce the potential to breach the volume limits in the mill's authorisation to discharge effluent.

Throughout the project, care was taken to protect the process and the product from any potentially detrimental effects of using less water. During the design stage of the project, a comprehensive audit was carried out to characterise the mill water system. The quality and quantity of all water streams (incoming fresh water to final treated effluent) were determined, including all internal water circuits in the pulp mill and board machine. The heat balance in all process areas and the water balance in terms of pulp mill, board machine, white water and broke storage capacities were studied.

Water use reduced through:

- introduction of two drum filters to recover fibres and water of a suitable quality to be used for dilution and washing in the pulp mill;
- increased storage capacity for white water;
- heat recovery from cooling waters to allow their re-use in the machine shower systems;
- mechanical seals on pumps to reduce fresh water leakage;
- introduction of silo and tank buffer capacity to reduce the demand for fresh water use during periods of process instability.

The measures introduced as part of the Millennium project have reduced fresh water use by over 30% and reduced raw material losses by 50%. Specific Water Consumption has decreased by around 38% from 40 m^3/tonne to around 25 m^3/tonne. The following initiatives have been implemented to maintain improvements:

- new water meters have been installed to improve measurement of water use in critical process areas;
- the mill-wide computer operating system and database have been updated to provide pulp mill and board machine operators with a more comprehensive overview of the process;
- an analysis system has been developed to monitor water quality with regard to the specific process requirements.

11.2.1 Other international case studies

Holmen Paper mill, Madrid (Holmen, 2012)

Following a series of efficiency measures, specific water consumption is now among the lowest in Europe. To further reduce the need for fresh water, the mill, in co-operation with the water supplier, has developed advanced technology to use treated municipal wastewater. Following comprehensive studies, trials and engineering work, the mill started using treated wastewater in production in June 2012. This is wastewater, which is treated in accordance with very exacting requirements. In 2013, the mill will gradually replace all fresh water with treated wastewater/“recovered water”. The fresh water released using the new technology is equivalent to the annual needs of 80 000 households. Holmen Paper Madrid will consequently become the first mill in Europe to manufacture paper based entirely on recovered paper and "recovered water".

A North American paper mill (Nalco, 2012)

The mill produces towel from recycled, sorted office waste (SOW) and de-inked market pulp. Over 17,034 m^3 of fresh water are consumed each week as part of the production process. The company has made reduction of freshwater usage a major goal for the organisation. DAF technology was implemented to improve control and reduce variability in the effluent water quality. This reuse of the DAF effluent reduced fresh water consumption at the mill by 16% from over 889,572 m^3/year to 749,512 m^3/year, an annual saving of $535,000.

11.3 Qualitative assessment of water reduction measures

Table 11.2 provides a qualitative assessment of a number of water efficiency measures in relation to the estimated proportion of uptake in the UK (increasing, decreasing or stable) an indicative cost (High, Medium and Low) and the potential form of the benefits achieved. Information contained in this table has been based on expert judgement, published literature and case studies and peer reviewed by representatives of the paper and pulp trade body, The Confederation of Paper Industries (CPI).

Due to a lack of sufficient quality data, it has not been possible to fully populate Table 11.2.

Table 11.2 Qualitative assessment of water consumption reduction measures in the paper and pulp industry

Measures to reduce water consumption	Estimated proportion uptake in UK	Indication of Costs (H/L/M)*	Form of benefit							
			Reduced water use	Reduced wastewater loads	Energy savings	Environmental impacts: pollution/run-offs	Improved process efficiency	Improved stakeholder relationship/PR	Increase productivity	Staff education
Delignification before the bleach plant		H		✓	✓		✓			
Efficient brown stock washing and closed cycle brown stock screening		H	✓	✓	✓		✓			
Recycling of alkaline bleach filtrate		H	✓	✓			✓			
Effective spill monitoring, containment and recovery		M	✓	✓	✓	✓			✓	✓

Measures to reduce water consumption	**Estimated proportion uptake in UK**	**Indication of Costs (H/L/M)***	**Form of benefit**							
			Reduced water use	Reduced wastewater loads	Energy savings	Environmental impacts: pollution/run-offs	Improved process efficiency	Improved stakeholder relationship/PR	Increase productivity	Staff education
Reuse of condensates from the evaporation plant		M	✓	✓			✓			
Capacity sizing of black liquor evaporation plant and recovery boiler		M				✓	✓		✓	
Collection and reuse of clean cooling waters		M	✓							
Reuse of condensate from evaporation of weak liquor		H		✓						
Minimisation of reject losses by using efficient reject handling stages				✓	✓	✓	✓			
Water recirculation in mechanical pulping		H	✓	✓						
Counter current white water system from paper mill to pulp mill		M	✓				✓			
Recycling of process water		H	✓	✓						
Counter current flows of process water		M			✓					
Installation of water efficient machinery for balancing white water, filtrate and allow for storage to control wastewater discharge		L	✓							
Understanding and measuring water use throughout the site		Low	?	?						✓
Improve production scheduling		Cost savings	✓	✓			✓		✓	
Efficient plant wash-down		Medium	✓		✓				✓	
Good housekeeping for leaks, boiler maintenance and flow rate control		Low	✓	✓			✓			

12. Cost benefit analysis for selected adaptation measures

A cost benefit assessment (CBA) for a range of feasible and applicable measures was undertaken as part of this project to assess the cost effectiveness of options to reduce water consumption for each of the sectors. The output of this will provide a key input in gathering more comprehensive adaptation strategies for the three sectors and future work in this area.

A key challenge for the CBA was lack of adequate data and uncertainty around available data. Consequently a ‘high level’ approach to the CBA was developed where ranges in the key costs and benefits were applied in order to gain a sense of the possible magnitude of costs and benefits and also the Net Present Value (NPV) and the Benefit Cost Ratio (BCR) . The costs and benefits estimates have been based on results from various case studies and reports and WRc expert judgment; and have been adapted to a ‘typical’ industry with defined assumptions and limitations. These estimates have not been normalised to account for differences in site conditions and/or specific objectives of schemes so they may not be representative of all sites. The wide range in the estimated costs and net benefits (high and low estimates) shows the uncertainty around these estimates and the fact the costs and benefits of measures will be site-specific in nature.

The cost benefit analysis has been built on the following key assumptions and parameters:

- Costs and benefits were defined over a 10-year period of analysis. For measures which involve assets with shorter lives, the costs of maintaining or replacing is included in the overall timeframe of the analysis. For assets with longer life than the period of analysis, the residual value will be included in the analysis;

- A private discount rate of 10% was used to convert all future values into their present values;

- The component of cost included in the analysis are capital cost, operational costs (day-to-day and recurring costs associated with operating the systems – energy costs, labour costs etc.) and replacement and maintenance costs;

- The benefits included mainly reduction in water use (which is measured as the cost savings in abstracting water), energy savings (measured as savings in electricity/fuel costs) and disposal cost savings (measured as reduction in volume of effluent sent for disposal). Not all these benefit elements are applicable for each of the measures analysed;

- Social and environmental impacts including carbon costs (both operational and embodied) of measures are excluded from the analysis;

- It is assumed that all the industries have a proportion of their water use directly abstracted and therefore measures will effectively reduce the volume of water abstracted. There will be percentage reduction in water use associated with each measure; this assessment has been based on analysis of various case studies and projects and WRc expert judgment;

- For a robust CBA, *uncertainty* is addressed by calculating low and high estimates for each measure. High scenario typically refers to 'worst case' scenario where costs are proportionally high costs to deliver the same benefits and a Low scenario represents 'best case' scenario where costs are low to deliver the same benefits;

- The impact of climate change over the 10 year period has not been accounted for in this analysis;

- A 'typical' industry for each sectors was defined in terms of volume of water consumption (m^3/year) or consumptive use in products (m^3/tonne), production capacity (tonne/year) and proportion of volume abstracted (m^3/year).

The results of the analysis for each sector are described in the sections below. Additional information is presented in Appendix G.

12.1 Chemical Industry

This analysis has been based on an industry that uses about 300,000m^3 of water per annum and about 20% of that amount is abstracted. It is assumed that reduction in water use as a result of implementing each measure will lead to a reduction in water abstracted.

The main adaptation measures assessed are:

- Installation of cooling towers to reduce process water usage;

- Re-use of wash water in products;

- Rainwater harvesting for effluent tank cleaning;

- Dry vacuum pumps to reduce water use;

- Monitoring water consumptions through leak detection and reduction.

The results of the analysis is summarised in the table below:

Table 12.1 Results of cost benefit analysis of selected measures in the chemical industry

	Annual cost (£/yr)		NPV (£)		BCR		Average Water Savings (m^3/yr)
	Low	High	Low	High	Low	High	
Monitoring water consumption through leak detection and reduction	1,300	5,800	103,200	58,000	3.7	2.0	30,000
Dry vacuum Pumps	620	1,300	21,700	15,100	3.4	2.2	7,200
Re -use of wash water in products	10,200	25,000	219,200	69,500	3.2	1.3	3,000
Cooling Towers to reduce process water usage	159,000	238,500	1,404,460	610,300	1.9	1.3	24,000
Rainwater harvesting: Above ground tank	360	2,100	-4,357	-11,700	0.7	0.4	1,825

The results shows that all the monitoring consumption through leak detection and reduction delivers the highest benefit cost ratio (i.e. highest benefit for each £ spent) and highest annual water savings.

With the exception of rainwater harvesting, all the other measures are also showing a positive NPV and BCR greater than 1 for both the high and low estimate scenarios.

12.2 Paper and pulp industry

This analysis has been based on a paper and pulp business that uses about 250,000m^3 of water per annum and about 15% of that amount is abstracted. It is assumed that reduction in water use as a result of implementing each measure will lead to a reduction in water abstracted. The main adaptation measures assessed are:

- Re-use of condensates from the evaporation plant – cost and benefits of this option has been based on a 25,000l/h evaporator condensate flowrate, at 60°C, 360 days/year operation and with an average recovery rate of 80% (i.e. that amount of permeate recovered as clean water is 80% of the feed volume);

- Recycling and use of water – this involves the treatment of raw water or recycle process water to provide boiler feed using membrane filtration;

- Rainwater harvesting using gravity system – this consist of an above-ground tank so that collected water can be fed to and used under gravity;

- Good housekeeping – including installing meters to monitor consumption and finding and fixing leaks.

The results of the analysis is summarised in the table below:

Table 12.2 Results of cost benefit analysis of selected measures in the paper and pulp industry

	Annual cost (£/yr)		NPV (£)		BCR		Average Water Savings (m^3/yr)
	Low	High	Low	High	Low	High	
Good Housekeeping	680	2,800	22,000	1,500	4.2	1.0	7500
Recycling and use of water: Membrane filtration	1,600	3,700	24,500	10,500	3.1	1.4	9,375
Re-use of condensates from evaporation plant	13,000	37,000	740,000	76,500	3.0	1.6	42,000
Rainwater harvesting technology: Gravity System	1,200	4,000	-7,300	-28,000	0.4	0.3	180

The results shows that good housekeeping delivers the highest benefit cost ratio (i.e. highest benefit for each £ spent). Although installing an evaporation plant is expensive, it will deliver significant water savings in the long term. With the exception of rainwater harvesting, all the other measures are also showing a positive NPV and BCR greater than 1 for both the high and low estimate scenarios.

12.3 Mining industry

This analysis has been based on a paper and pulp business that uses about 400,000m^3 of water per annum and about 30% of that amount is abstracted. It is assumed that reduction in water use as a result of implementing each measure will lead to a reduction in water abstracted. The main adaptation measures assessed are:

- Use of rainwater from quarry buildings – above ground tank supplying 5000litres of water;

- Wheel washing technology;

- Good housekeeping – identifying and fixing leaking standpipes, taps and hoses.

The results of the analysis is summarised in the table below:

Table 12.3 Results of cost benefit analysis of selected measures in the mining industry

	Annual cost (£/yr)		NPV (£)		BCR		Average Water Savings (m^3/yr)
	Low	High	Low	High	Low	High	
Good Housekeeping	680	3,300	30,900	15,800	7.2	2.8	12,000
Wheel washing technology	4,000	6,500	25,000	1,200	1.6	1.0	115
Rainwater harvesting from quarry buildings	380	1,200	3,900	-2,900	2	0.76	1,825

The results shows that good housekeeping delivers the highest benefit cost ratio (i.e. highest benefit for each £ spent) and highest annual water savings. With the exception of rainwater harvesting, all the other measures are also showing a positive NPV and BCR greater than 1 for both the high and low estimate scenarios.

12.4 Key conclusions from the CBA

Some key conclusion from this analysis:

- All the analysis in the three sectors shows that implementing simple, low cost measures such as approached to improve water efficiency on site through good housekeeping, monitoring consumption through leak detection and reduction is cost beneficial and deliver significant savings in water consumption.

- Although investment in water efficiency plant and machinery and other technologies to enable storage and re-use of water is high, it will deliver long term water savings, especially where there is a significant reduction or a complete cessation in abstraction for a given period of time. The choice of such investment will also depend on a number of factors such as feasibility of the reduction measure, location, types of process and the nature of the constraints.

- A key input in this analysis is the volume abstracted for each business. A high level switching value analysis shows that changing the consumptive volume and proportion of water abstracted has a significant impact on the benefits. This shows the more dependent a business is on abstracted water, the greater the incentive of taking measures to reduce consumption. This may be more significant for such businesses situated in water stress areas.

- The results show the cost and benefits of measures independently and does not account for overlaps in measures. However it is recognised that in some cases there may be synergies between different measures i.e. a combination of measures delivering a high water savings than individual measures. These need to be taken into consideration when deciding on measures to implement.

- The results of the analysis showed that for some of the measures, the significant benefit is not water savings; reduction in consumption is an 'unintended consequence'. Therefore, when considering some adaptation measures, businesses need to take a holistic assessment of all the benefits including energy savings, improved process efficiency and environmental improvement.

- The analysis did not account for the impact of climate change over the period of analysis due to lack of data. However climate change may significantly affect the type of investment that businesses make over time. For example, for businesses that may face more severe constraints on water use as a result of climate change over time, their primary response may be investment in relatively expensive and long term machinery and technology to enable storage or re-use of process or wastewater.

- It is to be noted cost and benefit estimates for this analysis have not been normalised to account for differences in site conditions and or specific objectives of schemes so they may not be representative of all sites. Caution should be taken when using these values

13. Water Stewardship

Water stewardship is[24]:

"The use of water that is socially equitable, environmentally sustainable and economically beneficial, achieved through a stakeholder-inclusive process that involves site and catchment-based actions. Good water stewards understand their own water use, catchment context and shared risk in terms of water governance, water balance, water quality and important water-related areas; and then engage in meaningful individual and collective actions that benefit people and nature."

This level of water management is seen as the 'gold standard' in managing water supplies, and takes the concept beyond a company's own operations. There are examples of water stewardship approaches to managing water scarcity from across the world, including the UK[25].

The concept of managing water at a catchment scale provides complexity as it involves stakeholders with differing priorities and needs working together to result in an improved environment without limiting the economic output of their own businesses. In the UK proposed abstraction reform may result in increasing levels of water stewardship action.

Under the current system for managing abstraction of water from rivers and aquifers, abstractors are licensed to abstract a fixed volume of water, regardless of availability in the catchment they are operating. Much of the licensed abstraction volume is not used, but the regulator cannot make it available to other catchment users who may require it, and there is little incentive for abstractors to manage water efficiently.

Growing pressures on our water resources have resulted in the Government taking action in an effort to reform the system. A number of options for reform of the water abstraction licensing system are set out in a consultation document[26]. The proposals in the consultation include:

- linking the volume of abstraction allowed more closely with how much water is available; and

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[24] http://www.allianceforwaterstewardship.org/about-aws.html#what-is-water-stewardship

[25] http://www.molsoncoors.com

[26] https://consult.defra.gov.uk/water/abstraction-reform

- enabling quicker and easier trading of water, giving license holders a greater incentive to use their water responsibly.

The '**Water Shares'** option, one of two presented, would result in abstractors having a percentage share in the available water resource, rather than an absolute amount, encouraging abstractors to take a shared responsibility for water resources in catchments. There are also plans to improve the link between abstraction charges and usage, and introduce a new risk based approach to licence conditions; these could be altered as and when catchment conditions change in order to protect the environment.

This reform could have significant benefits for industrial abstractors in promoting water stewardship and adapting or mitigating for water scarcity risks. Improved trading opportunities would allow the realisation of asset values in existing water access rights (and the consequential release of unused headroom) which could push cost-benefit assessment of other adaptation choices (such as water efficient plant and machinery) to a more favourable outcome and bring forward such investments. Secondly, the greater flexibility to abstract more during periods of high flow could encourage increased use of winter storage. This could result in access to alternative sources of water available during times of restriction and provide additional benefit to water management measures.

There are risks associated with such reform that have been expressed by industry. Of primary concern is access to finance. Reduced predictability, or security, of water supply (which could occur as a result of changing license conditions, or trading limitations) poses a significant business risk which could result in difficulty accessing finance for investment.

Overall, water stewardship approaches and the introduction of abstraction trading through abstraction license reform should result in more options being available to individual businesses for managing their water. Businesses will move from a position of having only adaptation measures to consider, to a position of choosing between:

- Water source choices – with the additional potential provision of winter storage due to relaxed licence restrictions during periods of high flow;

- Licence requirement choices – with the potential to acquire or release right to allocations of water;

- Adaptation choices – which may look more favourable for longer term investment decisions including changing production processes.

14. Conclusion for assessment of adaption measures

This section of the report sets out a selection of feasible, industry specific measures, to adapt to potential water stress as a result of climate change. These measures were selected primarily based on a review of existing case studies and Best Available Techniques (BAT) reference documents (BREF), relevant to selected industries (manufacture of chemicals and chemical products, mining and quarrying and manufacture of paper and paper products).

Given the large variation in water using processes, between and within these sectors, it is recommended that the selection of specific measures for uptake is made on a site by site basis, following industry best practice.

For the purposes of this section of the report, a simplified cost benefit analysis (CBA) was undertaken of a selection of measures likely to be considered as part of an adaptation programme.

The key findings of this section of the report show that:

- The chemical, mining and quarrying and paper industry have identified the need to improve water efficiency and increase security of supply;
- There are many opportunities for sites to reduce water consumption and mitigate the impact of water scarcity;
- Industry and site specific information is available and actively promoted by the relevant industry associations, though detailed costs, benefits and monitoring of uptake is less well documented;
- Site specific analysis should be conducted to identify process appropriate adaptation measures for uptake.

Finally, experience applying best available techniques is scarcely documented to a sufficient level of detail. A mechanism allowing for these experiences to be shared across sites, regions and industries would be of real benefit.

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Appendix A List of indicators considered

Table A.1 List of indicators proposed in tender documentation

Indicators of exposure and vulnerability (risk)	Indicators of action	Indicators of realised risks
Initial list supplied in tender documentation		
Water abstraction by sector	Uptake of water resource management measures by sector	
Water consumption by sector	Uptake of storage reservoirs by sector	
Proportion of operating cost that is accounted for by water by sector	Proportion of business with water meters installed	
Water abstraction and consumption in areas at current or future water stress by sector		
Number of water intensive businesses located in areas at current or future risk of water scarcity (being developed by the ASC)		
Rate of development of water intensive industries in areas at current or future water stress (being developed by the ASC)		

Table A.2 List of indicators proposed in by WRc at interim meeting

Indicator of risk	Potential data source(s)	Likely data quality
Mains water use by industry sector	Information from water companies	Varying, not all companies store information about customers by industrial sector, or at a sufficient resolution to allow these categories to be separated into discrete sectors. In addition, companies will have assessed likely future demand and how to ensure supply through water resource management plans.
Volume of water permitted to be abstracted by industry sector	Information held by Environment Agency. An abstraction license is required for abstraction of greater than 20 cubic metres per day. Abstraction from freshwater sources would be relevant, rather than tidal sources.	These data should be available although there have been two significant revisions to license conditions since 2006 which limit the time-series that should be used. The weakness of this indicator is that actual abstractions can vary significantly from the authorised volume and therefore this does not give a clear picture of real vulnerability.

Indicator of risk	Potential data source(s)	Likely data quality
Volume of water actually abstracted by industry sector.	Information held by Environment Agency. An abstraction license is required for abstraction of greater than 20 cubic metres per day. Abstraction from freshwater sources would be relevant, rather than tidal sources.	These data should be available although it is unlikely to be complete. Not all abstractors return information to the regulator on the volume of water actually abstracted .There are methodologies for gap filling this information which can provide an estimate of the complete picture by sector. Sectors included within the abstraction database do not align directly to SIC. However, previous work undertaken by WRc enables the alignment licenses to SIC07.
Net volume of water abstracted by industry sector (consumptive use)	Application of loss factors to abstraction data by purpose and sector.	The suitability of particular loss factors will introduce increased uncertainty into the analysis. Differences in consumptive use may exist between different products of the same industry sector.
Volume of water actually abstracted in water stressed areas	Information held by Environment Agency as above. Information on water stress from Environment Agency analysis published in 2013. This is held spatially within the EA's WRGIS.	The abstraction data required is as above. Actual abstraction volumes are returned at a license level. A license may contain multiple abstraction points in different water bodies, introducing uncertainty to the volume abstracted from individual water bodies Selection and definition of water stress categories required, as well as access to spatial dataset from EA.

Indicator of risk	Potential data source(s)	Likely data quality
Net volume of water abstracted by industry sector (consumptive use) in water stressed areas.	Information held by Environment Agency as above. Loss factors by sector and purpose as above.	The abstraction data required is as above. Water stress information as above. Water loss factor information as above.
Volume of water actually abstracted in areas of poor or moderate WFD water quality	Information held by Environment Agency as above. WFD water quality status results from Environment Agency.	Actual abstraction volumes are returned at a license level. A license may contain multiple abstraction points in different water bodies, introducing uncertainty to the volume abstracted from individual water bodies. The required water quality will vary significantly between industry sectors and between uses within individual sectors, therefor selection and definition of water quality categories will need to be assessed.
Net volume of water abstracted by industry sector (consumptive use) in areas of poor or moderate WFD water quality	Information held by Environment Agency.	The abstraction data required is as above. Actual abstraction volumes are returned at a license level. A license may contain multiple abstraction points in different water bodies, introducing uncertainty to the volume abstracted from individual water bodies. The required water quality will vary significantly between industry sectors and between uses within individual sectors The suitability of particular loss factors will introduce increased uncertainty into the analysis.

Indicator of risk	Potential data source(s)	Likely data quality
Volume of water actually abstracted in areas of water stress and poor or moderate WFD water quality	Information held by Environment Agency.	Data assessment as above.
Net volume of water abstracted by industry sector (consumptive use) in areas of water stress and poor or moderate WFD water quality	Information held by Environment Agency.	Data assessment as above.
Number of businesses located in areas of water stress	BIS and ONS business population data sets. It is understood that the ASC may be collecting these data separately. It may be possible to use the number of abstraction licenses by sector as a proxy for this information.	It is understood that the ASC may be collecting these data separately. It may be possible to use the number of abstraction licenses by sector as a proxy for this information.
Number of businesses located in areas of poor WFD water quality.	It is understood that the ASC may be collecting these data separately.	Trend in abstraction licensing is likely to be an indicator of industrial growth in the area.

Appendix B Data Tables

B1 Indicator 1

B1.1 Manufacture of chemicals and chemical products

Table B.1 Reported volumes abstracted by CAMS resource availability status for chemicals (Mm^3 per year)

CAMS Resource Availability status	2008	2009	2010	2011
Available for licencing	89.6	90.2	92.3	87.1
Restricted licencing	11.6	10.7	12.4	10.0
Not available for licencing	61.1	54.2	57.3	59.1

B1.2 Mining and quarrying

Table B.2 Reported volumes abstracted by CAMS resource availability status for mining and quarrying (Mm^3 per year)

CAMS Resource Availability status	2008	2009	2010	2011
Available for licensing	26.0	23.7	26.6	27.5
Restricted licensing	8.1	8.8	7.8	7.4
Not available for licensing	7.1	5.8	5.5	5.9

B1.3 Manufacture of paper and paper products

Table B.3 Reported volumes abstracted by CAMS resource availability status for paper (Mm^3 per year)

CAMS Resource Availability status	2008	2009	2010	2011
Available for licencing	18.7	22.8	24.1	20.3
Restricted licencing	15.0	15.6	18.3	18.1
Not available for licencing	12.6	12.1	11.4	8.4

B2 Indicator 2

B2.1 Manufacture of chemicals and chemical products

Table B.4 Reported volumes abstracted by CAMS resource availability status and WFD water quality status for chemicals (Mm^3 per year)

CAMS Resource Availability Status	WFD Water Quality	2008	2009	2010	2011
Available for licencing	Good	0.4	0.4	0.4	0.3
	Moderate	71.2	72.7	75.8	70.8
	Poor	18.0	17.2	16.0	16.1
	Bad	0.0	0.0	0.0	0.0
Restricted licencing	Good	<0.1	0.0	<0.1	<0.1
	Moderate	11.6	10.7	12.4	10.0
	Poor	0.0	0.0	0.0	0.0
	Bad	0.0	0.0	0.0	0.0
Not available for licencing	Good	0.0	0.0	0.0	0.0
	Moderate	0.5	0.5	0.2	0.2
	Poor	60.6	53.7	57.1	59.0
	Bad	0.0	0.0	0.0	0.0

B2.2 Mining and quarrying

Table B.5 Reported volumes abstracted by CAMS resource availability status and WFD water quality status for mining and quarrying (Mm^3 per year)

CAMS Status	WFD Water Quality	2008	2009	2010	2011
Available for licencing	Good	4.5	3.4	4.0	2.8
	Moderate	11.6	11.7	12.7	13.9
	Poor	5.2	5.4	7.0	8.3
	Bad	0.9	1.0	1.6	1.0
Restricted Licencing	Good	0.3	0.6	1.9	1.1
	Moderate	6.1	7.3	4.8	5.9
	Poor	1.6	0.8	0.9	0.3

CAMS Status	WFD Water Quality	2008	2009	2010	2011
	Bad	0.2	0.1	0.2	0.1
Not available for licencing	Good	0.6	0.5	0.3	0.4
	Moderate	4.4	4.1	4.1	4.1
	Poor	2.1	1.2	1.1	1.4
	Bad	0.0	0.0	0.0	0.0

B2.3 Manufacture of paper and paper products

Table B.6 Reported volumes abstracted by CAMS resource availability status and WFD water quality status for paper (Mm^3 per year)

CAMS Status	WFD Water Quality	2008	2009	2010	2011
Available for licencing	Good	0.0	0.0	0.0	0.0
	Moderate	17.9	22.3	23.4	19.4
	Poor	0.9	0.4	0.7	0.9
	Bad	0.0	<0.1	<0.1	<0.1
Restricted Licencing	Good	0.0	0.0	0.0	0.0
	Moderate	10.5	14.0	17.7	17.5
	Poor	0.6	0.6	0.6	0.6
	Bad	3.9	1.0	0.0	0.0
Not available for licencing	Good	0.0	0.0	0.0	0.0
	Moderate	8.1	7.0	7.0	6.5
	Poor	4.5	5.1	4.4	1.9
	Bad	0.0	0.0	0.0	0.0

B3 Indicator 3

B3.1 Manufacture of chemicals and chemical products

Table B.7 Reported net abstraction volumes by CAMS resource availability and WFD water quality status for chemicals (Mm^3 per year)

CAMS Status	WFD Water Quality	2008	2009	2010	2011
Available for licencing	Good	0.29	0.26	0.31	0.23
	Moderate	55.81	58.95	62.64	57.49
	Poor	12.86	12.35	11.09	10.69
	Bad	0.0	0.0	0.0	0.0
Restricted available	Good	<0.1	0.00	<0.1	<0.1
	Moderate	4.66	4.28	4.96	4.01
	Poor	0.00	0.00	0.00	0.00
	Bad	0.0	0.0	0.0	0.0
Not available for licencing	Good	0.00	0.00	0.00	0.00
	Moderate	0.18	0.15	0.04	0.03
	Poor	40.44	35.90	38.35	39.58
	Bad	0.0	0.0	0.0	0.0

B3.2 Mining and quarrying

Table B.8 Reported net abstraction volumes by CAMS resource availability and WFD water quality status for mining and quarrying (Mm^3 per year)

CAMS Status	WFD Water Quality	2008	2009	2010	2011
Available for licencing	Good	2.05	1.41	1.84	1.14
	Moderate	5.28	4.91	5.38	5.43
	Poor	2.09	2.16	2.79	3.34
	Bad	0.36	0.42	0.63	0.39
Restricted	Good	0.12	0.27	0.84	0.48

CAMS Status	WFD Water Quality	2008	2009	2010	2011
licencing	Moderate	1.16	1.23	1.21	1.10
	Poor	0.64	0.30	0.37	0.12
	Bad	0.09	0.04	0.08	0.04
Not available for licencing	Good	0.27	0.19	0.15	0.19
	Moderate	2.52	2.42	2.38	2.25
	Poor	0.84	0.49	0.42	0.55
	Bad	0.0	0.0	0.0	0.0

B4 Indicator 4

B4.1 Manufacturing of chemicals and chemical products

Table B.9 Number of NALD licences by CAMS resource availability and WFD water quality status for chemicals

CAMS Resource Availability Status	WFD water quality	2008	2009	2010	2011
Available for licencing	Good	5	5	5	5
	Moderate	59	55	56	55
	Poor	24	25	26	24
	Bad	0	0	0	0
Restricted licencing	Good	2	1	1	1
	Moderate	6	6	5	5
	Poor	1	0	0	0
	Bad	0	0	0	0
Not available for licencing	Good	2	2	2	2
	Moderate	8	8	8	7
	Poor	6	6	6	6
	Bad	0	0	0	0

Table B.10 Number of BSD local units by CAMS resource availability status for chemicals

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licencing	2,160	2,089	3,984	1,926
Restricted licencing	305	303	541	263
Not available for licencing	490	480	966	432

Table B.11 Number of BSD local units by WFD water quality status for chemicals

WFD Water Quality	2008	2009	2010	2011
Good	191	188	335	174
Moderate	1,858	1,797	3,403	1,646
Poor	924	883	1,754	789
Bad	89	98	174	92

B4.2 Mining and quarrying

Table B.12 Number of NALD licences by CAMS resource availability and WFD water quality status for mining and quarrying

CAMS Resource Availability Status	WFD water quality	2008	2009	2010	2011
Available for licencing	Good	27	27	29	29
	Moderate	89	92	94	94
	Poor	35	36	37	35
	Bad	8	8	8	7
Restricted Licencing	Good	6	6	6	6
	Moderate	18	19	20	22
	Poor	13	12	11	11
	Bad	3	3	3	3
Not available for licencing	Good	4	5	5	5
	Moderate	27	27	27	27
	Poor	29	30	31	31
	Bad	0	0	0	0

Table B.13 Number of BSD local units by CAMS resource availability status for mining and quarrying

CAMS Resource Availability Status	2008	2009	2010	2011
Available for Licencing	990	966	970	952
Restricted licencing	160	167	161	154
Not available for licencing	343	397	378	366

Table B.14 Number of BSD local units by WFD water quality status for mining and quarrying

WFD Water qualify	2008	2009	2010	2011
Good	175	178	168	167
Moderate	838	832	834	803
Poor	504	537	527	520
Bad	45	58	50	55

B4.3 Manufacture of paper and paper products

Table B.15 Number of NALD licences by CAMS resource availability and WFD water quality status for paper

CAMS Resource Availability Status	WFD water quality	2008	2009	2010	2011
Available for Licencing	Good	0	0	0	0
	Moderate	43	43	43	43
	Poor	4	4	4	5
	Bad	1	1	1	1
Restricted licencing	Good	0	0	0	0
	Moderate	5	6	7	8
	Poor	2	2	2	2
	Bad	4	4	4	4

CAMS Resource Availability Status	WFD water quality	2008	2009	2010	2011
Not available for licencing	Good	0	0	0	0
	Moderate	11	10	10	10
	Poor	8	9	8	6
	Bad	0	0	0	0

Table B.16 Number of BSD local units by CAMS resource availability status for paper

CAMS Resource Availability Status	2008	2009	2010	2011
Available for Licencing	1,969	1,399	1,334	1,247
Restricted licencing	264	171	175	168
Not available for licencing	431	307	288	269

Table B.17 Number of BSD local units by WFD water quality status for paper

WFD Water Quality	2008	2009	2010	2011
Good	188	152	147	142
Moderate	1,583	1,108	1,083	995
Poor	877	613	563	543
Bad	96	62	60	57

B5 Indicator 5

B5.1 Manufacture of chemicals and chemical products

Table B.18 Number of employees by CAMS resource availability status for chemicals

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licencing	73,903	67,824	89,925	64,167
Restricted licencing	9,501	9,802	13,473	10,486
Not available for licencing	13,388	12,502	31,750	11,051

Table B.19 Number of employees by WFD water quality status for chemicals

WFD Water quality status	2008	2009	2010	2011
Good	4,517	4,047	5,258	4,375
Moderate	65,480	60,143	83,901	57,467
Poor	28,517	26,483	46,513	24,067
Bad	3,674	3,799	4,375	3,608

B5.2 Mining and quarrying

Table B.20 Number of employees by CAMS resource availability status for mining and quarrying

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licensing	16,094	17,217	17,961	17,601
Restricted licensing	3,556	2,632	2,584	2,173
Not available for licensing	5,441	5,690	3,901	4,352

Table B.21 Number of employees by WFD water quality status for mining and quarrying

WFD Water quality status	2008	2009	2010	2011
Good	2,612	2,876	2,551	2,582
Moderate	12,420	11,960	11,937	11,247
Poor	9,415	9,604	9,174	9,350
Bad	1,934	2,351	1,900	1,981

B5.3 Manufacture of paper and paper products

Table B.22 Number of employees by CAMS resource availability status for paper

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licensing	37,335	35,507	33,880	32,261
Restricted licensing	7,245	6,491	6,457	6,400
Not available for licensing	7,044	6,011	5,888	5,652

Table B.23 Number of employees by WFD water quality status for paper

WFD Water quality status	2008	2009	2010	2011
Good	5,232	4,684	5,305	5,586
Moderate	33,914	32,349	31,031	28,705
Poor	13,321	11,967	10,697	10,573
Bad	2,374	2,154	2,076	1,826

B5.4 Abstraction volume to employee ratio for the manufacture of chemicals and chemical products

Table B.24 Reported abstraction volumes (Mm^3) per 1,000 employees

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licensing	1.21	1.33	1.03	1.36
Restricted licensing	1.22	1.09	0.92	0.95
Not available for licensing	4.56	4.33	1.80	5.35

B6 Indicator 6

B6.1 Manufacturing of chemicals and chemical products

Table B.25 GVA normalised by number of employees by CAMS resource availability status for chemicals (£ millions)

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licensing	6,061.6	5,033.7	5,106.1	5,650.5
Restricted licensing	779.3	727.5	765.0	923.4
Not available for licensing	1,098.1	927.9	1,802.8	973.1

Table B.26 GVA Normalised by number of employees by WFD water quality status for chemicals (£ millions)

WFD Water quality status	2008	2009	2010	2011
Good	350.9	286.5	288.1	368.8
Moderate	5,087.2	4,258.4	4,597.4	4,844.9
Poor	2,215.5	1,875.1	2,548.7	2,029.0
Bad	285.4	269.0	239.7	304.2

Table B.27 GVA per m^3 abstraction reported by CAMS resource availability status for chemicals (£/m^3)

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licensing	65.2	55.1	55.3	69.9
Restricted licensing	64.5	67.1	61.7	99.3
Not available for licensing	17.3	16.9	31.5	17.7

Table B.28 GVA per m^3 abstraction reported by WFD water quality status for chemicals (£ millions/ m^3)

WFD Water quality status	2008	2009	2010	2011
Good	828.2	784.7	693.3	1,322.2
Moderate	58.8	50.2	52.0	64.5
Poor	27.2	26.1	34.8	29.1
Bad	0	0	0	0

B6.2 Mining and quarrying

Table B.29 GVA normalised by number of employees by CAMS resource availability status for mining and quarrying (£ millions)

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licencing	8,021.5	5,857.9	6,127.3	6,926.6
Restricted licencing	1,296.4	1,012.7	1,017.0	1,120.5
Not available for licencing	2,779.2	2,407.4	2,387.7	2,662.9

Table B.30 GVA normalised by number of employees by WFD water quality status for mining and quarrying (£ millions)

WFD Water quality status	2008	2009	2010	2011
Good	1,197.7	996.0	951.3	1,099.1
Moderate	5,695.2	4,141.9	4,451.3	4,787.6
Poor	4,317.2	3,326.0	3,421.0	3,980.1
Bad	886.8	814.2	708.5	843.3

Table B.31 GVA per m³ abstraction reported by CAMS resource availability status for mining and quarrying (£/ m³)

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licensing	300.1	224.3	235.8	273.8
Restricted licensing	48.5	38.8	39.1	44.3
Not available for licensing	104.0	92.2	92.0	105.3

Table B.32 GVA per m³ abstraction reported by WFD water quality status for mining and quarrying (£/ m³)

WFD Water quality status	2008	2009	2010	2011
Good	216.8	219.3	153.8	259.3
Moderate	250.4	177.4	205.8	205.7
Poor	473.6	449.5	381.5	407.9
Bad	2,021.3	708.3	398.2	814.1

B6.3 Manufacturing of paper and paper products

Table B.33 GVA normalised by number of employees by CAMS resource availability status for paper (£ millions)

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licencing	1,526.7	1,783.9	2,087.4	2,396.7
Restricted licencing	296.3	326.1	397.8	475.5
Not available for licencing	288.0	302.0	362.8	419.9

Table B.34 GVA Normalised by number of employees by WFD water quality status for paper

WFD Water quality status	2008	2009	2010	2011
Good	201.4	220.9	307.7	393.9
Moderate	1,305.5	1,525.3	1,799.6	2,023.9
Poor	512.8	564.3	620.4	745.5
Bad	91.4	101.6	120.4	128.7

Table B.35 GVA per m^3 abstraction reported by CAMS resource availability status for paper (£ millions/m^3)

CAMS Resource Availability Status	2008	2009	2010	2011
Available for licensing	79.1	92.7	111.3	137.7
Restricted licensing	15.3	16.9	21.2	27.3
Not available for licensing	14.9	15.7	19.3	24.0

Table B.36 GVA per m^3 abstraction reported by WFD water quality status for paper (£/ m^3)

WFD Water quality status	2008	2009	2010	2011
Good	0	0	0	0
Moderate	34.8	34.3	37.5	50.1
Poor	83.8	91.0	108.6	234.8
Bad	22.5	94.2	3,376.4	346,524.8

Appendix C Data Maps

C1.1 Manufacture of chemicals and chemical products

Figure C.1 Chemicals – Map of reported abstraction in 2011 by CAMS resource availability status

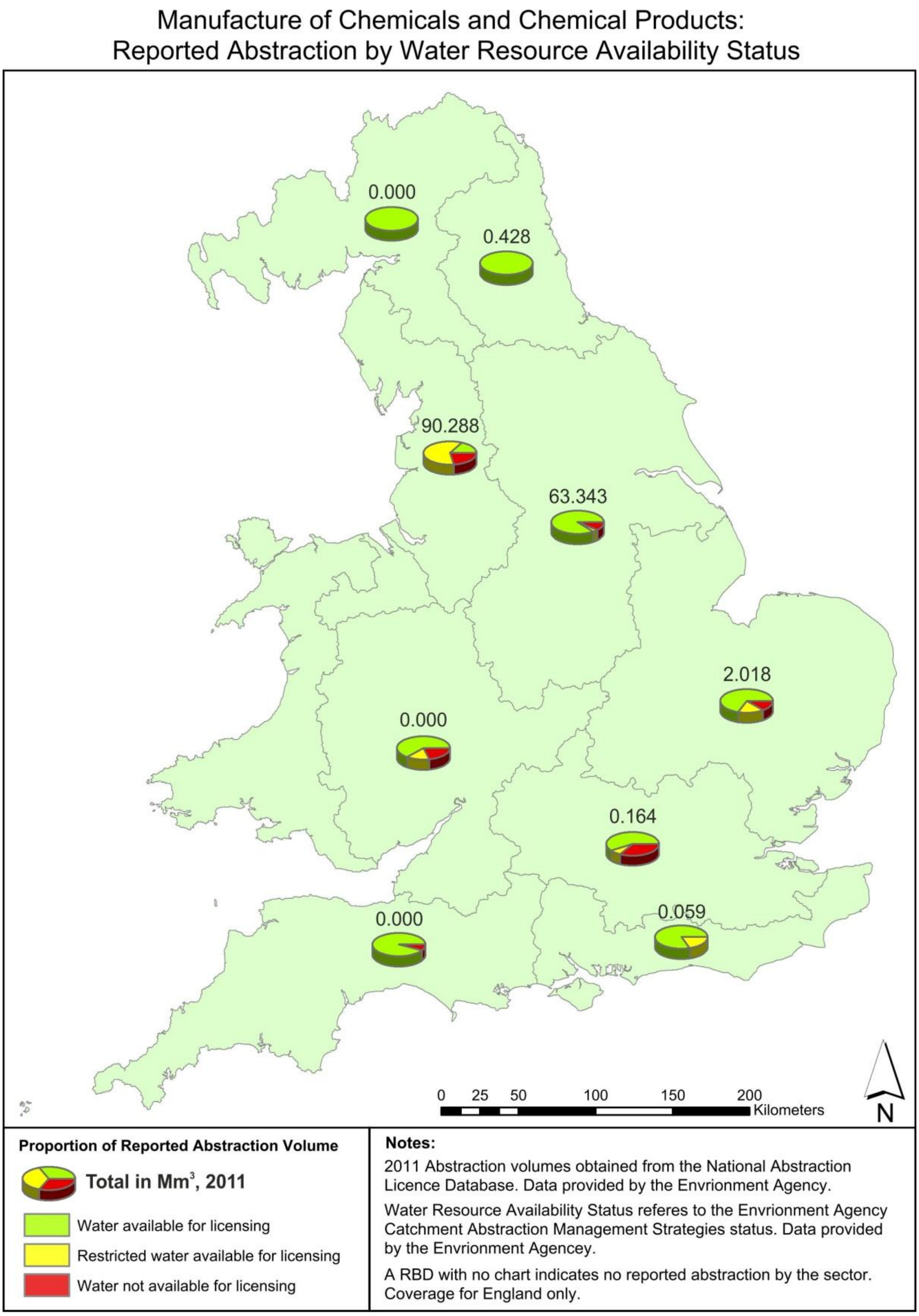


Figure C.2 Chemicals – Map of reported abstraction in 2011 by WFD water quality status

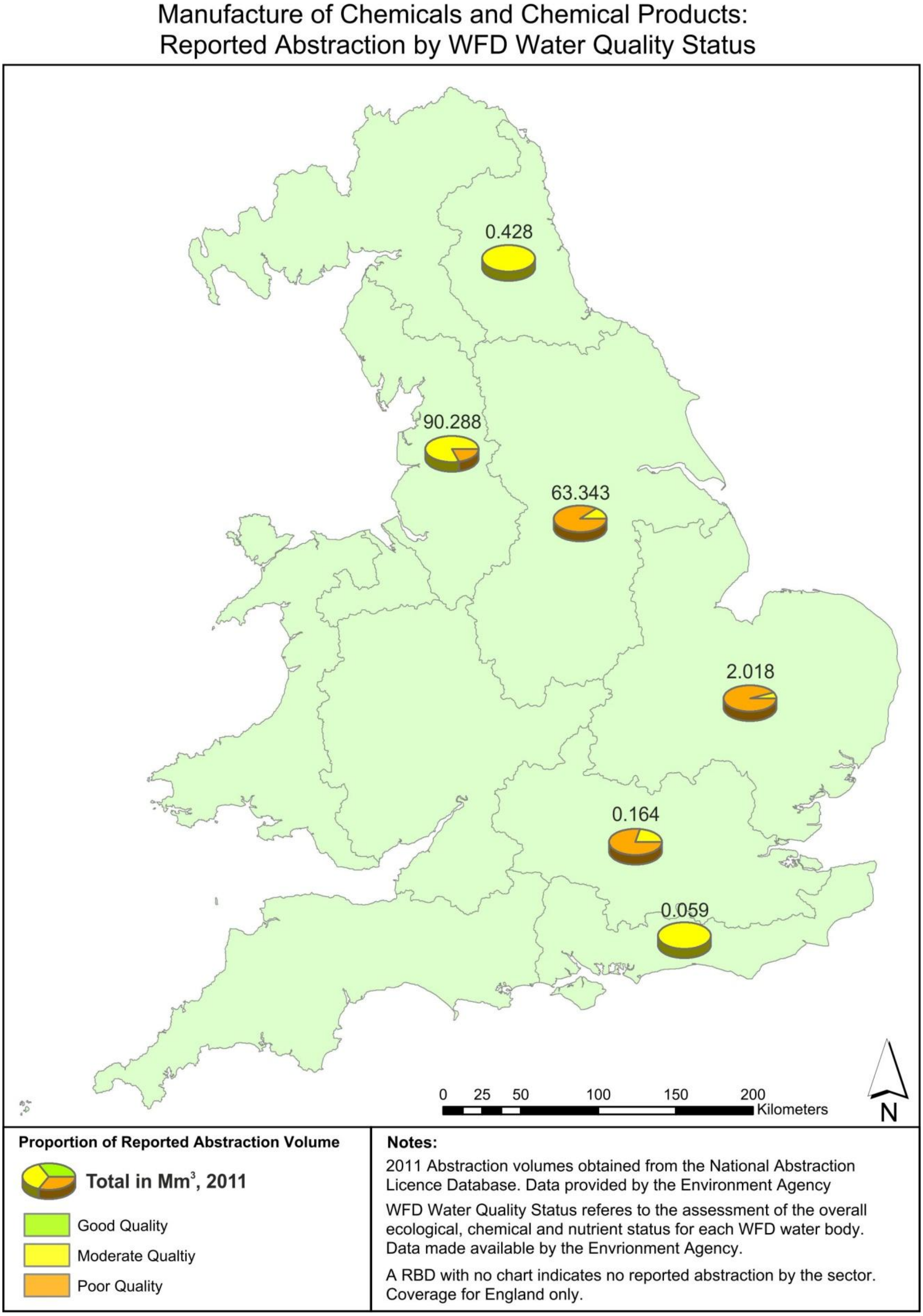


Figure C.3 Chemicals – Map of net abstraction in 2011 by CAMS resource availability status

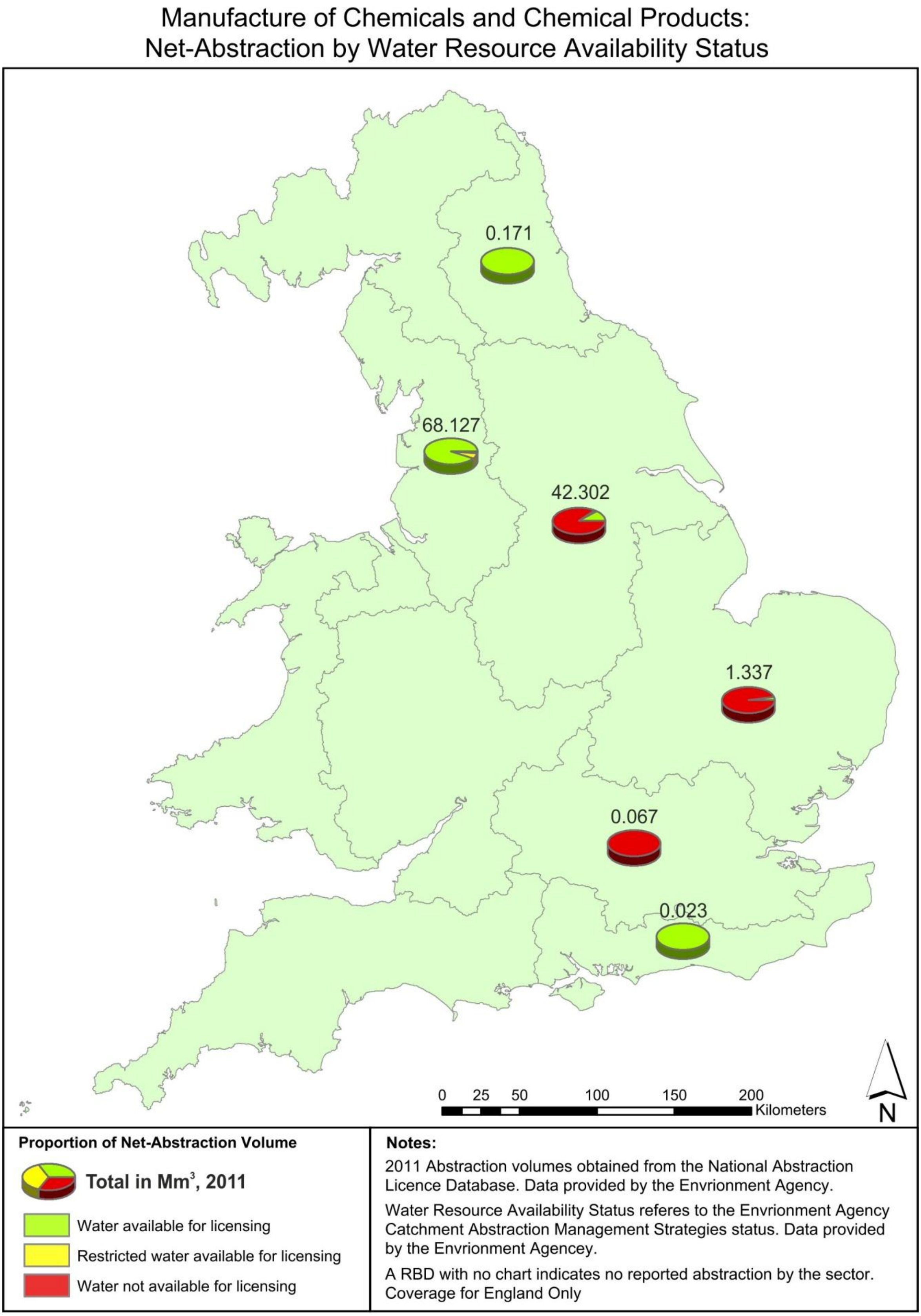
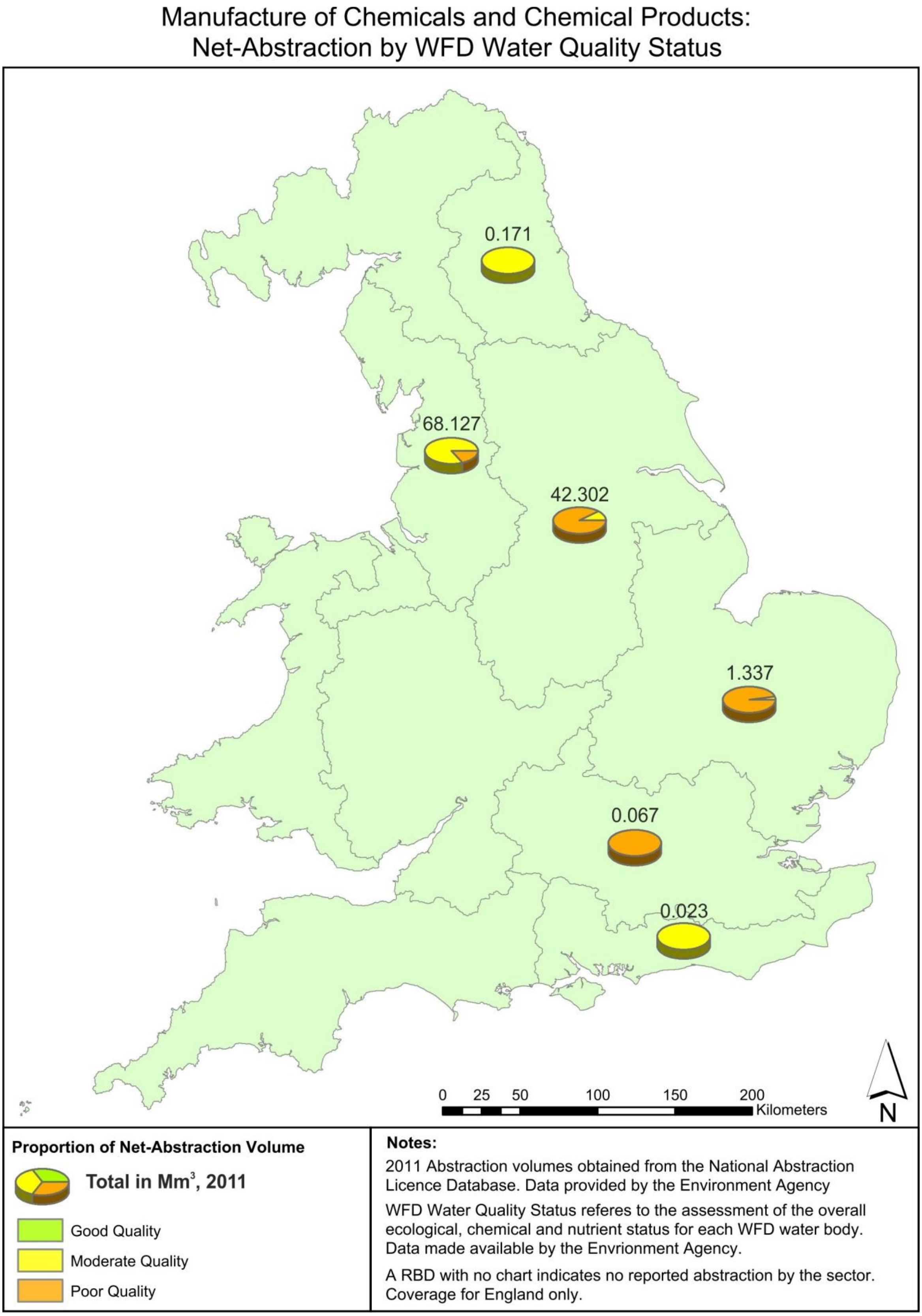


Figure C.4 Chemicals – Map of net abstraction in 2011 by WFD water quality status



C1.2 Mining and quarrying

Figure C.5 Mining and quarrying – Map of reported abstraction in 2011 by CAMS resource availability status

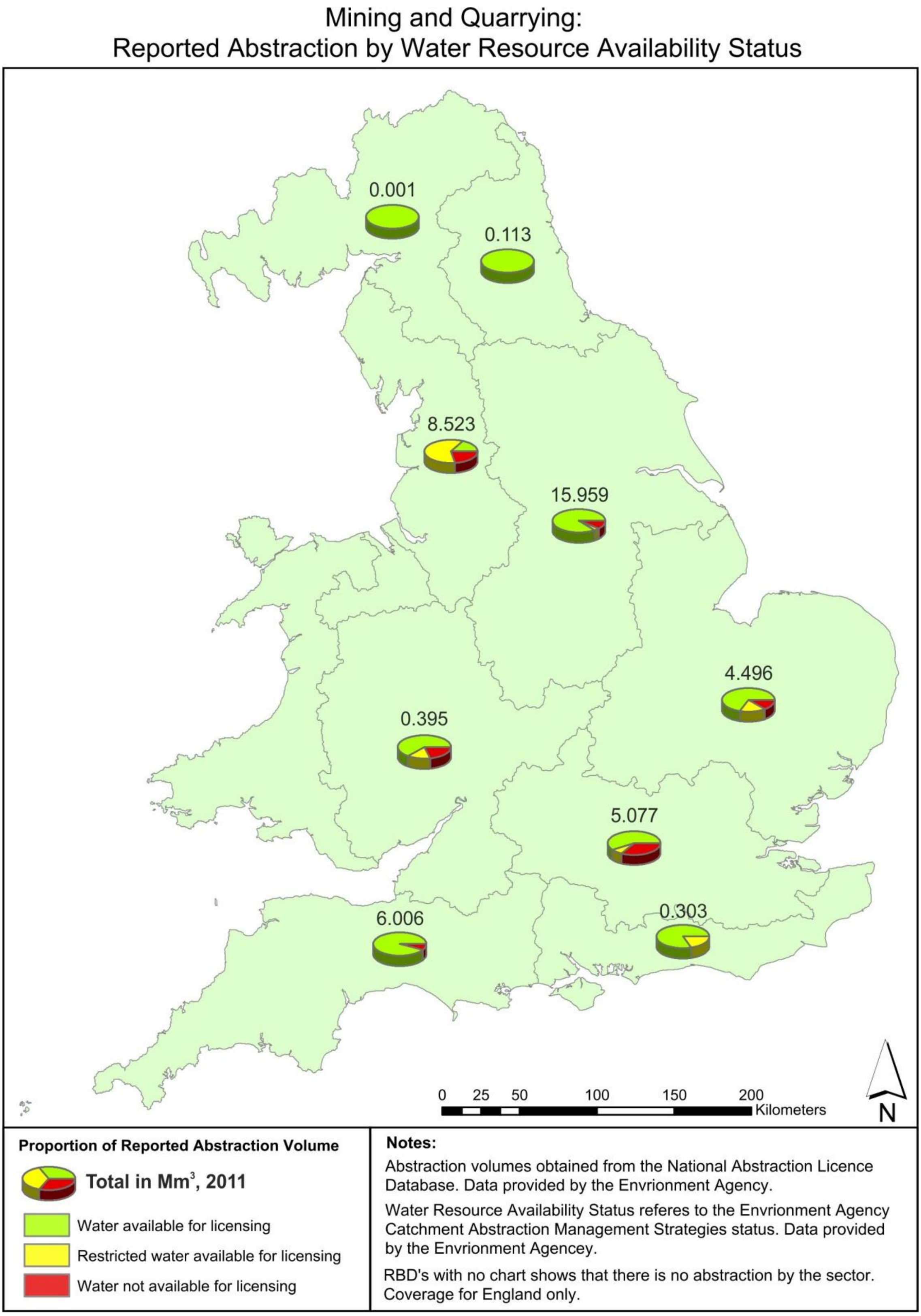


Figure C.6 Mining and quarrying – Map of reported abstraction in 2011 by WFD water quality status

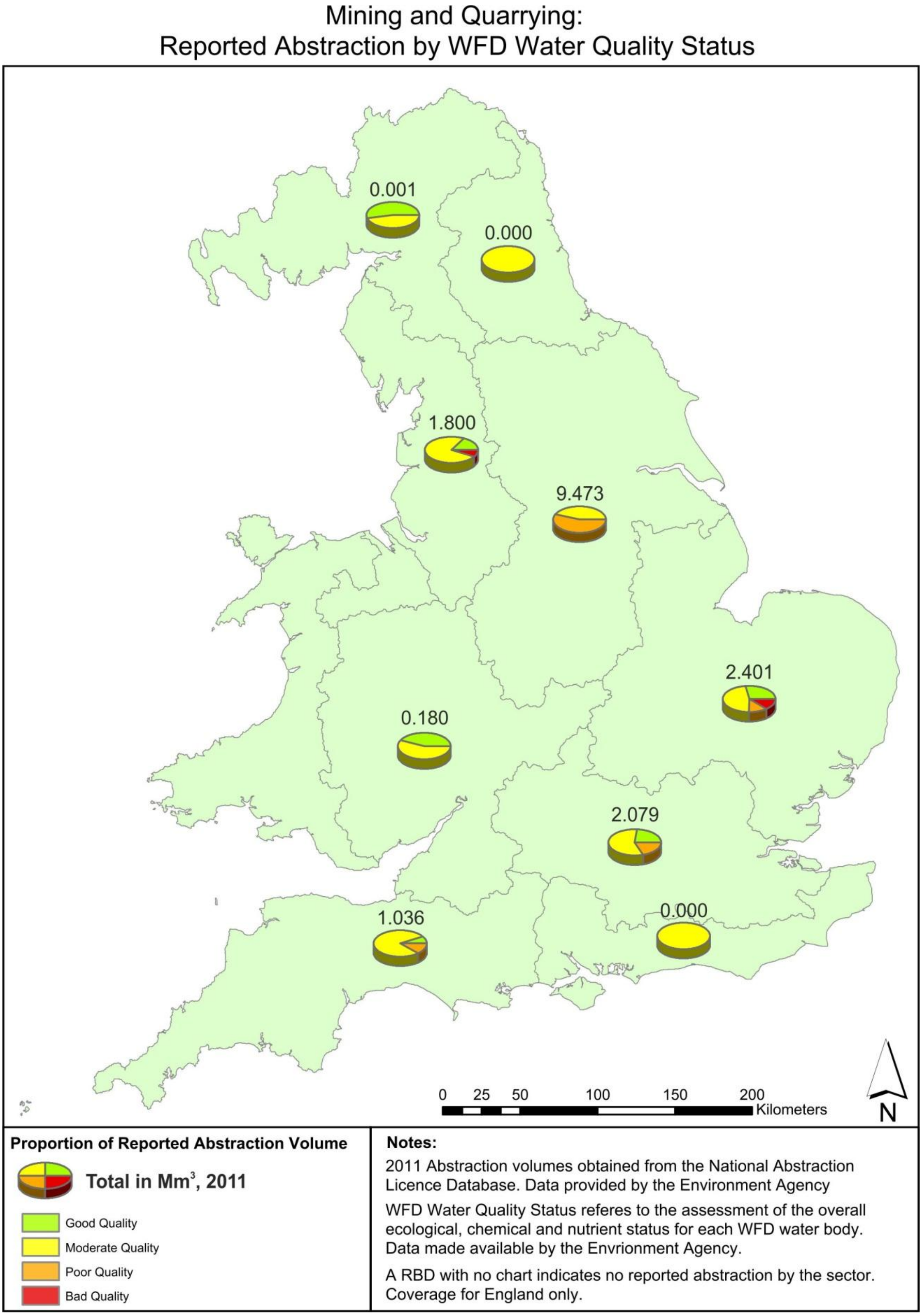


Figure C.7 Mining and quarrying – Map of net abstraction in 2011 by CAMS resource availability status

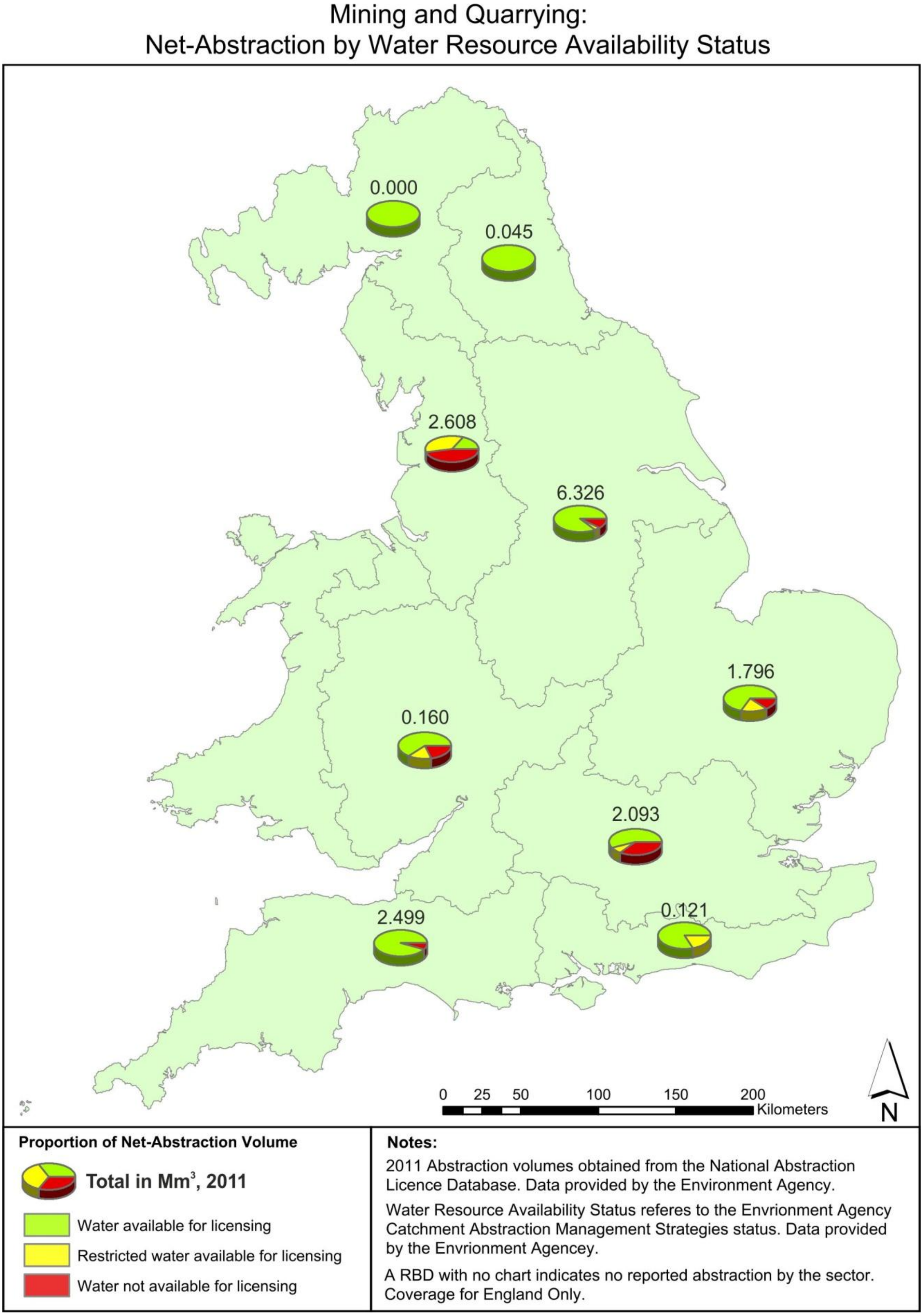
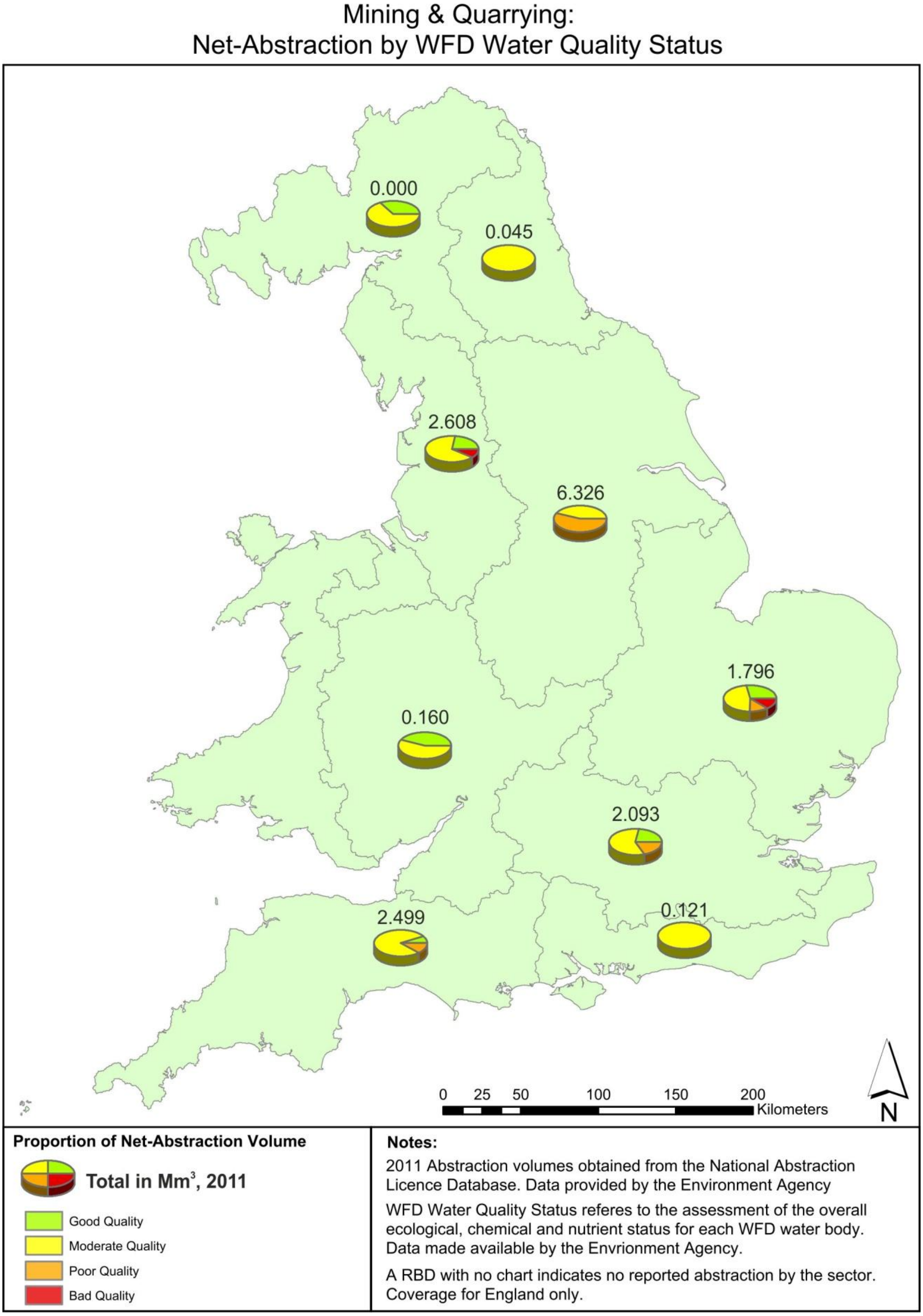


Figure C.8 Mining and quarrying – Map of net abstraction in 2011 by WFD water quality status



C1.3 Manufacturing of paper and paper products

Figure C.9 Paper – Map of reported abstraction in 2011 by CAMS resource availability status

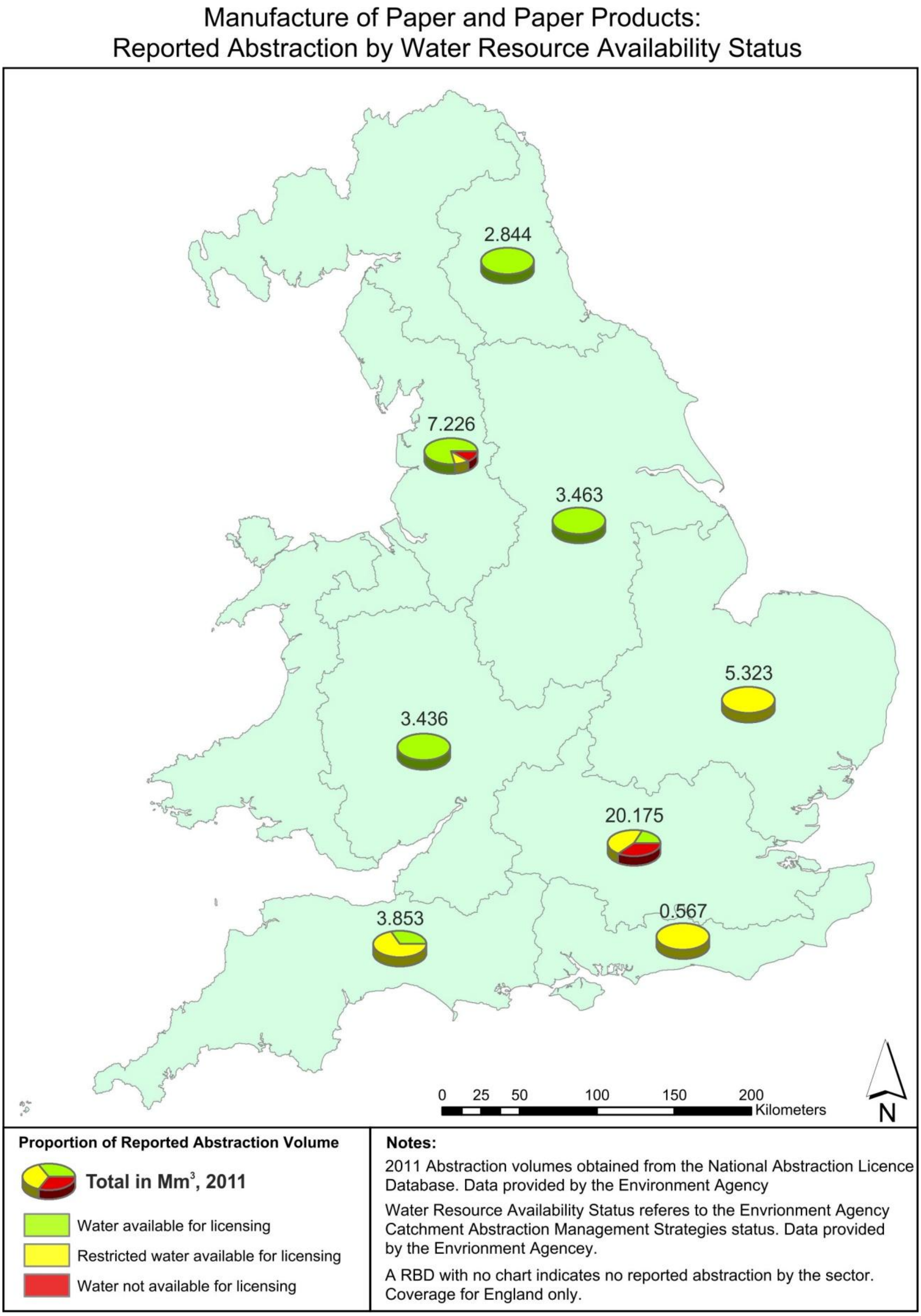


Figure C.10 Paper – Map of reported abstraction in 2011 by WFD water quality status

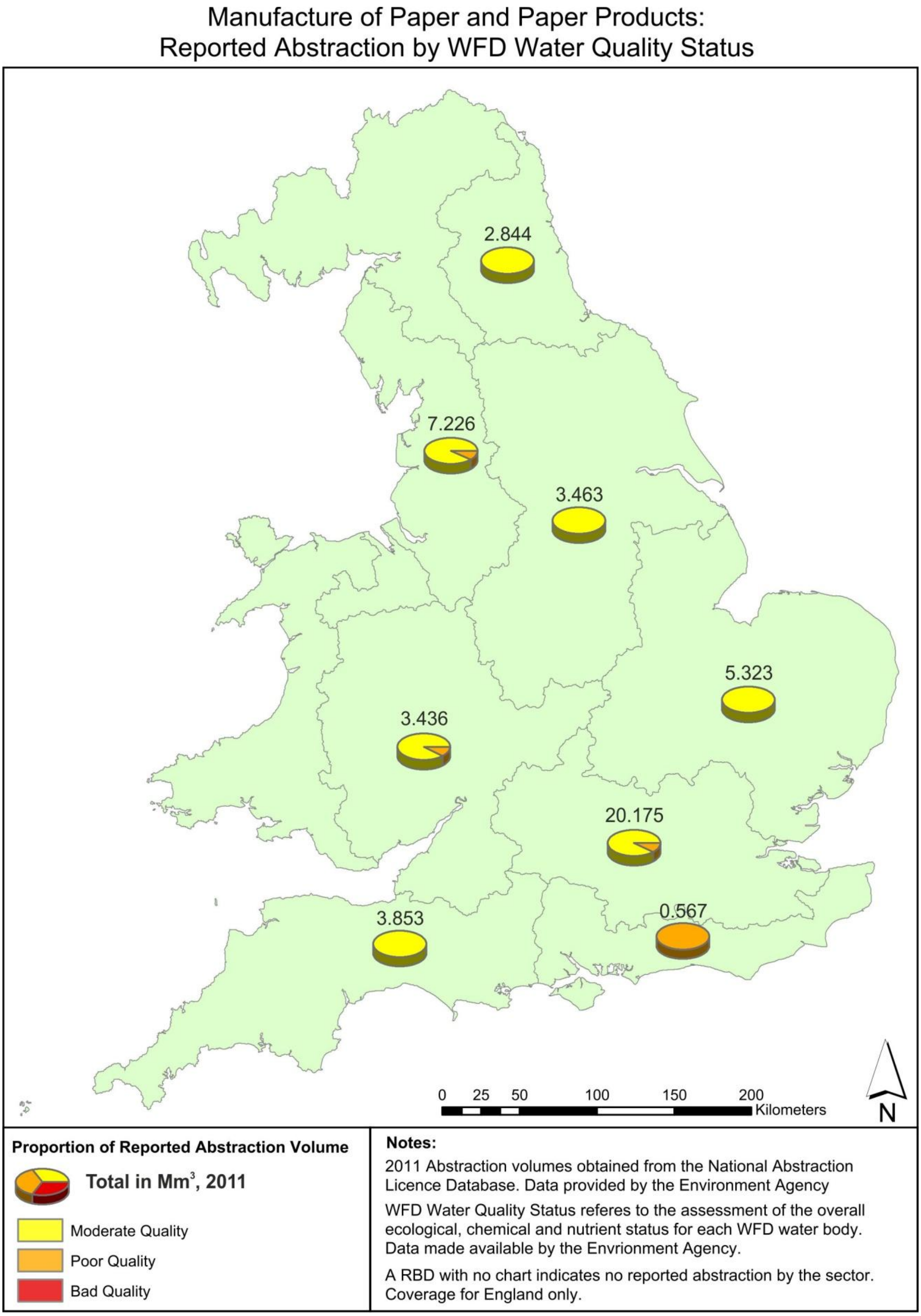
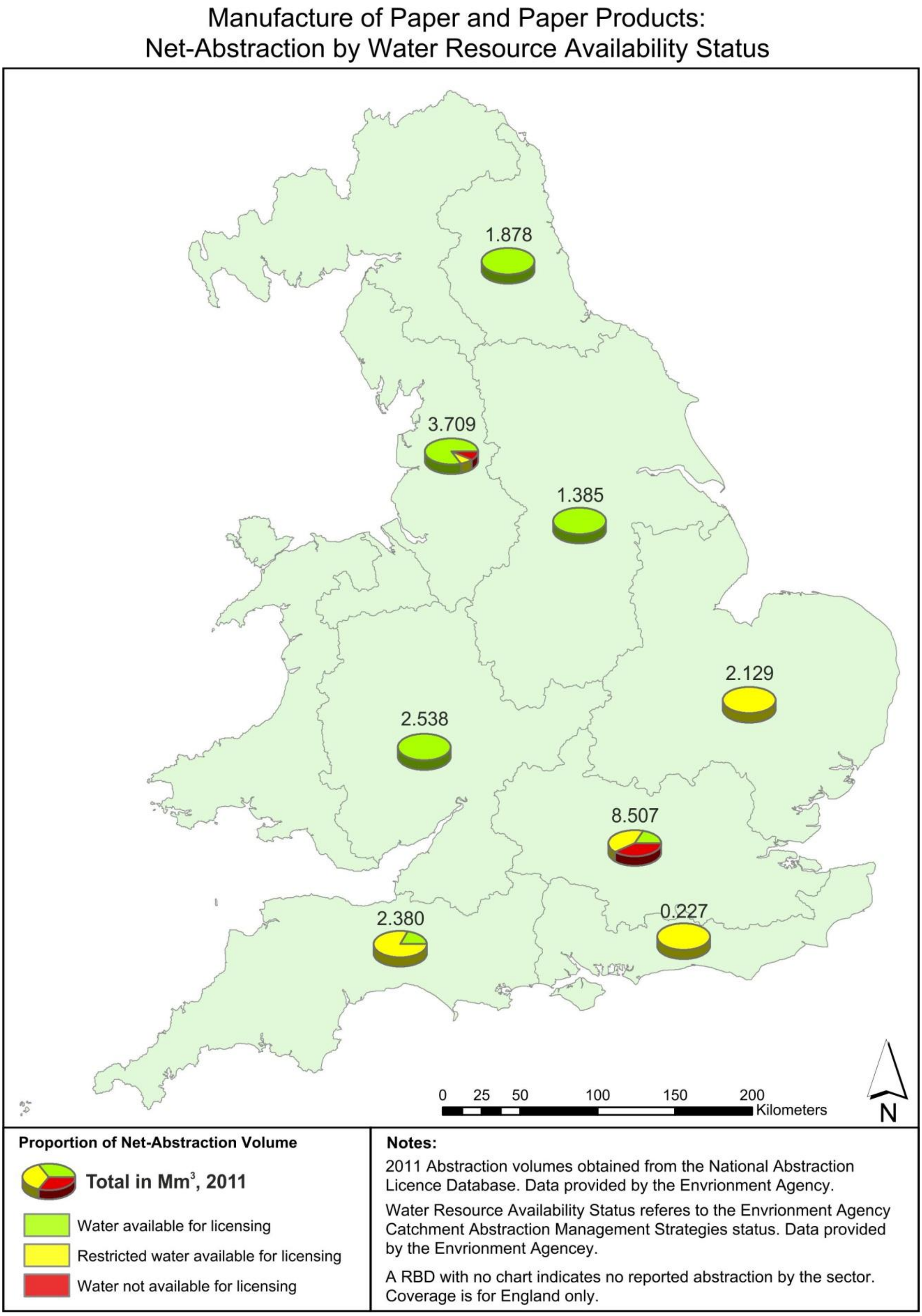


Figure C.11 Paper – Map of net abstraction in 2011 by CAMS resource availability status



Appendix D Adaptation Measures

D1.1 Manufacturing of chemicals and chemical products

Table D.1 Possible adaptation measures for chemical industry

Measures to reduce water consumption	Estimated proportion uptake in UK	Indication of Costs	Form of benefits							
Description	Trend	(H/L/M)*	Reduced water use	Reduced wastewater loads	Energy savings	Reduced environmental impacts: pollution/ run-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
Minimise the presence of water in the process including water used in product purification and equipment cleaning			✓	✓						
Dry techniques where appropriate to abate particulate and gaseous exhaust streams			✓	✓	✗	✓				
Reduce process drag-out and maximise reuse in rinsing		Low	✓			✓	✓			
Recycle or reuse water (e.g. from condensates, process and scrubbing) back to processes, or cascade to secondary uses such as equipment cleaning			✓	✓				✓	✓	
Good water management including sub-metering of key activities such as rinsing	↗?	Low	✓					✓	✓	✓
Eliminate equipment cleaning between batches of the same produce unless essential. Consider reduced level of cleaning where this is not possible e.g. weekend shutdowns.		Likely cost savings	✓	✓	✓	✓				
Dry pre-cleaning and cleaning methods where possible			✓	✓			✓			
Prevent water pollution incidents, spills and leaks to avoid water use in cleaning		Likely cost savings					✓		✓	✓
Use water free techniques for vacuum generation			✓							
Use counter-current washing systems and water sprays					✓					

Measures to reduce water consumption	Estimated proportion uptake in UK	Indication of Costs	Form of benefits							
Description	Trend	(H/L/M)*	Reduced water use	Reduced wastewater loads	Energy savings	Reduced environmental impacts: pollution/ run-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
rather than jets										
Employ closed loop cooling water cycles, or use indirect cooling techniques			✓	✓						
Maximise water re-use through identifying the lowest water quality that can be used for each activity in the process		M		✓	✓					
Facilitate re-use through provision of storage tanks		H		✓						
Utilise separators to facilitate the collection of water insoluble materials		M				✓				
Optimising heat use and improving operation of the system					✓		✓			
Use of recirculating cooling				✓						
Reusing (waste) water from within or outside the industry plant for use in cooling towers		M	✓	✓						

D1.2 Mining and quarrying

Table D.2 Possible adaptation measures for mining and quarrying industry

Measures to reduce water consumption	Estimated proportion uptake in UK	Indication of Costs	Form of benefits							
Description	Trend	(H/L/M)*	Reduced water use	Reduced wastewater loads	Energy savings	Reduced environmental impacts: pollution/ run-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
Understanding and measuring water use throughout the site	↗	H								✓
Efficient dust suppression technologies. This may include the use of hydraulic spinning systems rather than splash plates, and the use of chemical additives			✓			✓				
Efficient wheel washing technologies. This may include closed loop recirculating systems, or waterless systems that use angled steel grids to clean debris from tyres			✓	✓		✓				
Controlling leakage from pumps, pipes and equipment					✓					
Using water efficient mineral processing technologies			✓				✓			
Optimising recirculation and reuse of run-off and grey water from quarry buildings			✓	✓		✓				
Using the latest methods for drainage and settlement lagoon design that result in relatively clean water being kept away from sources of sediment. Note, the use of flocculants is no longer encouraged				✓		✓	✓			

D1.3 Manufacturing of paper and paper products

Table D.3 Possible adaptation measures for paper industry

Measures to reduce water consumption	Estimated proportion uptake in UK	Indication of Costs	Form of benefits								
Description	Trend	(H/L/M)*	Reduced water use	Reduced wastewater loads	Energy savings	Reduced environmental impacts: pollution/ run-offs	Improved process efficiency/Productivity	Improved stakeholder relationship/PR	Sustainability/H&S	Staff education
Delignification before the bleach plant		For O2 delignification, €35-40m with 2.5-3m/year		✓	✓		✓			
Efficient brown stock washing and closed cycle brown stock screening		Screening:€4-6m at new mills, €6-8m at existing mills €0.3-0.5 m/year to operate	✓	✓	✓		✓			
Recycling of alkaline bleach filtrate		H	✓	✓			✓			
Effective spill monitoring, containment and recovery		M €0.8-1.5m for handling syst, + 4-6m if additional evaporation required,€0.1-0.4m/year	✓	✓	✓	✓			✓	✓
Reuse of condensates from the evaporation plant		M €1-4m + 0.3-0.7m/year	✓	✓			✓			
Capacity sizing of black liquor evaporation plant and recovery boiler		M ~€1m				✓	✓		✓	
Collection and reuse of clean cooling waters			✓							
Reuse of condensate from evaporation of weak liquor				✓						
Minimisation of reject losses by using efficient reject handling stages		No data		✓	✓	✓	✓			
Water recirculation in mechanical pulping		€10-12m	✓	✓						
Counter current white water system from paper			✓				✓			

Measures to reduce water consumption	**Estimated proportion uptake in UK**	**Indication of Costs**	**Form of benefits**							
Description	Trend	(H/L/M)*	**Reduced water use**	**Reduced wastewater loads**	**Energy savings**	**Reduced environmental impacts: pollution/ run-offs**	**Improved process efficiency/Productivity**	**Improved stakeholder relationship/PR**	**Sustainability/H&S**	**Staff education**
mill to pulp mill										
Recycling of process water			✓	✓						
Counter current flows of process water					✓					
Installation of water efficient machinery for balancing white water, filtrate and allow for storage to control wastewater discharge		€0.1-0.25m	✓							
Understanding and measuring water use throughout the site			?	?						✓
Improve production scheduling			✓	✓			✓		✓	
Efficient plant washdown			✓		✓				✓	
Good housekeeping for leaks, boiler maintenance and flow rate control			✓	✓			✓			

Appendix E The manufacture of chemicals and chemical products

The following describes a selection of these measures in greater detail:

a) Dry vacuum pump

The investment in a dry vacuum pump is typically far higher than that in a water ring pump. However, the total cost may be balanced due to the cost required in treating the liquid ring water. The example below is of an installation where three water ring pumps were replaced by two new dry running vacuum pumps (Table E.1 Comparison of operating costs of two vacuum generation techniques

The operating costs of the old and the new installations are compared. The investments in the new vacuum generation technique including safety equipment and installation were net EUR 89500 (in 1999). The payback time was one year. The driving force for installation, in addition to operational savings, was the reduction of wastewater loads and the associated costs with their treatment and disposal.

Table E.1 Comparison of operating costs of two vacuum generation techniques

		Amount/year	Costs EUR/year
Old installation with water ring pumps:			
Energy requirement	27 kW × 8000 h	216000 kWh	13250
Water requirement (EUR 1.12/m^3)	2.8 m^3/h × 8000 h	22400 m^3	25100
Created waste water (EUR 3.07/m^3)	2.8 m^3/h × 8000 h (COD: 1200 mg/l)	22400 m^3	68770
Total			*107120*
New installation with dry running vacuum pumps (no effluents):			
Energy requirement	35 kW × 8000 h	280000 kWh	17180
Total			*17180*
Operating cost savings			*89940*

b) Extraction separation of pollutants can minimise waste water

In order to extract a substance, an extraction solvent must be added to form a second liquid phase solution. Generally the desired substance is then separated from the solvent by distillation and the solvent is recycled only a small amount of liquid waste is generated. If water is used as the solvent, then it can be biologically treated once any highly concentrated waste components have been separated.

c) Reduction of water consumption for cooling

Reduction of water use in cooling is also of particular interest to the chemical industry. The volume of water required differs between the various cooling water systems. For 'once-through' systems (direct and indirect), the use of water depends on the requirement of the process (condenser), the temperature of intake water**,** the maximum allowed temperature increase of the receiving water and the maximum allowed temperature of cooling water when it is discharged.

Reduction of water requirements for cooling can be made through:

- Optimising heat use and improving operation of the system;
- Use of recirculating cooling water;
- Re-using (waste) water from within or outside the industry plant in cooling towers – subject to organic content (COD).

d) Alternative water supply

Businesses can use low quality water for some applications such as toilet flushing, cleaning and wet air pollution control. Alternative water sources include:

- Rainwater harvesting for cleaning and toilet flushing;
- Conditioning and softening water using physical methods (e.g. magnetic treatment), rather than ion exchange, to eliminate brine water;
- Wash water, cooling water and condensing water for lower-grade cleaning.

Appendix F The manufacture of paper and paper products

Some benefits of these water reduction measures are outlined below:

a) Wet debarking – dry debarking

Water is re-circulated and results in decrease in water use from 0.6 to 2 m^3 per m^3 of solid wood, to 0.1 to 0.5 m^3 i.e. about a 75% reduction. The investment cost of a dry drum debarker does not differ significantly from a wet system (about 15 million euros for a 1500 air-dried tons per day (ADt/d) system). Converting an existing wet system to a dry system will costs about 4-6 million euros. TSS[27], BOD[28] and COD[29] load, as well as organic compounds in wastewater decrease under dry debarking. There will also be increased energy yield (increase energy consumption for dry debarking process offset by energy production when bark is burnt)[30].

b) Capacity sizing of black liquor evaporation plant and recovery boiler

Press washing can reduce the amount of water from 6-10 m3 / tonne pulp to 2-3 m3 / tonne pulp. This will increase the amount of chemicals and contaminants eventually burnt in the recovery boiler.

c) Discharges from the bleach plant

Water is critical to operating an effective bleach plant. In a conventional open bleach plant, all water entering the bleach plant is discharged as wastewater or exits with the pulp. If the bleachery can be wholly or partially closed, this would result in substantial reductions in discharges containing organic substances, nutrients and metals. This r reduction in flow may vary from 5-10 m3/tonne pulp to 25 m3 /tonne pulp.

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[27] Total suspended solids, matter suspended or dissolved in water or wastewater.

[28] Biological oxygen demand, is the amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample

[29] Chemical oxygen demand, is a measure of the capacity of water to consume oxygen during the decomposition of organic matter and the oxidation of inorganic chemicals

[30] http://ietd.iipnetwork.org/content/dry-debarking

d) White water management

Benefits from white water management include:

- Removal of suspended solids to eliminate plugging of shower nozzles;
- Elimination of dissolved solids build-up;
- Reduction of problems with slime, foam, corrosion, odour and chemical precipitation;
- Improved retention and reduced retention aid usage;
- Recovery of fibre, fines and filler materials;
- Reduced fresh water usage;
- Minimised primary treatment cost for raw water;
- Retention of white water heat value and reduced heating costs;
- Reduced effluent volume and associated treatment costs;
- Reduced pumping requirements;
- Lowered installed cost with minimal space requirements;
- Improved quality and performance efficiency of the paper machine.

Appendix G Additional CBA material

Table G.1 General assumption used in CBA

	Low	Central	High
Cost of water (£/m^3)[31]	0.4	0.6	0.8
Cost of effluent (£/m^3)	0.2	0.5	0.7
Discount rate	10%		

Table G.2 Site/Industry specific assumptions used in CBA

Industry	Water consumption per year (m3/year)	Proportion of water abstracted per year (%)	Volume of water abstracted per year (m3/yr)
Chemicals	300,000	20%	60,000
Paper and pulp	250,000	15%	37,500
Mining and quarrying	400,000	30%	120,000

[31] The cost of water is sourced from other WRc work in progress concerning the economics for supply pipe leakage, and is derived from responses to a survey of the water industry.

Table G.3 CBA outputs by industry and adaptation measure

Measure	Capital cost (£)	Ongoing costs (£/yr)	Water savings (m^3/yr)	Energy savings (£/yr)	Reduced effluent costs (£yr)
Chemicals industry					
Monitoring water consumption through leak detection and reduction	£4,425	£1,050	30,000		
Dry vacuum Pumps	£7,500	£150	7,200		
Re-use of wash water in products	£150,000	£3,500	3,000	£21,000	£27,000
Cooling Towers to reduce process water usage	£1,920,000	324,020	24,000	£450,000	
Rainwater harvesting: Above ground tank	£5,000	£2,000	1,825		
Paper and pulp industry					
Monitoring water consumption through leak detection and reduction	£1,500	£1,500	7,500		
Recycling and use of water: Membrane filtration	£12,000	£1,000	9,375		
Re-use of condensates from evaporation plant	£90,000	£27,000	42,000	£48,000	£21,000

Rainwater harvesting technology: Gravity System	£3,500	£500	180		
Mining and quarrying					
Monitoring water consumption through leak detection and reduction	£2,000	£750	12,000		
Wheel washing technology	£42,000	£2,000	115	£10,000	
Rainwater harvesting from quarry buildings	£5,000	£1,000	1,825		

Table G.4 Additional data used in CBA preparation

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Chemicals industry				
Cooling Towers	Install cooling tower to reduce process water usage	$3,200,000 Investment = $40,033	Cost savings (savings, fuel saving, electricity savings) = $750,000/yr Water savings = 72204m3/yr	

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Greywater	Re-use of wash water in products		Reduced product losses = £168,000 Reduced effluent treatment cost = 27,000/yr Reduced water costs = £7000/yr Reduced energy costs = 21,000/yr	
Rain water harvesting	Using collected rain water for effluent tank cleaning			
Dry vacuum Pumps	Water is re-circulated on vacuum systems in the acrylate plants, rather than once-through use, and steam ejectors have been replaced with dry vacuum pumps	Capital cost = $9,650 – $20,000	Switching to dry vacuum pumps has reduced water use by 7200m3/year	
Better Production scheduling	Improvement in plant wash-downs and the use of triggered hoses		Reduction in water use= 50%	
Flow restriction on vessel cooling lines			5% reduction in water use	

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Monitoring water consumptions through Leak detection and reduction	Fit sub-meters to monitor consumption for each production area Measure flows using simple mechanical meters or more expensive electromagnetic and ultrasound meters	Number of meters to install = Cost per meter installation: £250 - £1,400	Once leak is fixed, water consumption fell by 50%. Saving 25,000m3/yr, worth around £18,500/yr	

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Paper and pulp industry				
Reuse of condensates from the evaporation plant	These plants find application in evaporator and condensate treatment processes followed in Pulp and Paper industry. To produce clean condensates that can be reused in the pulp mill The benefits of condensate recovery can be two-fold with savings in water consumption as well as in the recovery of heat energy.	Capital cost indication (depending on supply) = £150,000 Plant operating cost= £46,640/year **B**ased on a 25,000 l/hour evaporator condensate flow rate, at 60°C, 360 days/year operation and with a recovery rate of 90% (i.e. the amount of permeate recovered as clean water is 90% of the feed volume).	**Energy saving**[32] Recovering the hot condensate for re-use captures valuable heat energy which may otherwise be lost in disposal to drain or effluent treatment value typically **£2.23/m^3** **Water purchase saving** The volume of water recovered via RO is saved in the purchase of fresh water. Value typically **£0.60/m^3** **Disposal costs saving** Shows a possible 90% reduction in the volume of effluent sent for disposal, depending on the effluent loading and location**.** **V**alue typically **£0.70/m^3** **Softened water saving** RO permeate is a source of good quality softened water, this reduces costs incurred in softening incoming towns or well water, and the disposal of regeneration chemicals **value typically £0.08/m^3**	

[32] http://www.pcimembranes.pl/article.html,content:62,page:4

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Recycling and use of water **Technology:** Tertiary treatment technologies Membrane filtration	Treat raw water or recycle valuable process water to provide boiler feed, process water or cooling tower make-up. Water recycling is an attractive proposition for industries such as P&P that withdraw large volumes of water or have highly polluted waste streams and are subject to increasing charges for disposal	Capital cost = ~£3000		
Rainwater harvesting Technology: Gravity system	Gravity systems consist of an above ground tank, typically located outside the building and at a level above the points of use so that collected water can be fed to end uses under gravity. These systems require no pump and no (or only basic) controls.	Capital cost: £2300-£5000 Operating cost = 0		Volume of water re-used: 0.18 million litres

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Good housekeeping[33]*	Finding and fixing of leaks Establishing water management programme Minimising hose use	Cost of staff time, monthly site checks, replacing valves (£ few hundred) Installing sub meters (approx. £200 each) Repair of any underground leaks detected from monitoring (£1000s)	Benefits are dependant on leaks and savings potential identified. Programme may result in 10% water savings (completely estimated – huge variability)	

[33] ETBPP G111 http://infohouse.p2ric.org/ref/23/22977.pdf

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Mining and quarrying				
Use of rainwater harvested from quarry buildings.[34]	RWH (aboveground tank) – supplies 1000 litres per day for domestic supply (approx. 167 flushes of 6 litre WC)	£10,000 cost of system and installation and modification of internal pipework £750 – tank clean and chlorination every 5 years. £300 – new pump every 3 years[35] £750 – annual maintenance contract 1.5 – 2.0 kWh per day to pump 1,000 litres[36]	Water savings – 365m^3/yr	

[34] http://www.multiquip.com.au/WMP.pdf

[35] http://www.rainwaterharvesting.co.uk/pumps/17/

[36] http://www.kingspanwater.com/home-and-garden/faqs.htm#3

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Wheel washing technology[37]		Approx. $70,000 - $100,000[38]	Energy savings: £10,000 energy[39] Water savings: 40% water savings (vs original)[40]	
Efficient dust suppression[41]		Cost of dust suppression unit on crusher given in table 1 (approx. $2500)[42]		

37 http://www.strategicforum.org.uk/HowToBrochure.pdf

38 http://www.drdust.com/pdf/How%20to%20Design%20and%20Install%20a%20Wheel%20Wash.pdf

39 http://www.agg-net.com/files/attachments/articles/wheel_wash_plays_key_role_at_cumbrian_asphalt_plant.pdf

40 http://www.wrap.org.uk/sites/files/wrap/Water%20efficiency%20during%20construction%20RE%20Business%20Case_0.pdf

41 http://www.strategicforum.org.uk/pdf/Final_Report_in_WRAP_Template_FINAL_13_Jul_2011_132e1f6ea11053.pdf

42 http://www.okinternational.org/docs/Guidance%20for%20Controlling%20Silica%20Dust%20from%20Stone%20Crushing%20with%20Water%20Spray%20Technology%20-%20for%20Employers.pdf

Adaptation Measures	Description of measure	Cost	Benefits	Estimated volume of water saved
Water efficient mineral processing	Installation of stone-washing screen to remove fines and clay		Reduced transport of fine materials. Lower cleaning costs Water savings: For every tome of stone requiring washing, 2m^3 of water is needed (recycling can reduce this)[43]	
Good housekeeping*[44]	Identifying/fixing leaking standpipes, taps, hoses Obtain a good understanding of mine layout, its associated water circuits and extent to which "good" housekeeping is implemented on site; and Identify "good" housekeeping and operating practices which can reduce the water use.[45]	As part of housekeeping programme, regular (monthly) walk arounds are recommended. Repair of leaks. Metered standpipes could be used at cost of £242 to £618 per standpipe	The benefits of leak detection and repairing are difficult to quantify, even Wrap case studies (see comment for link) do not assign values to case studies.	This will have to be a pure estimation due to lack of available information

*'Good housekeeping' are measures for improving work environment and reducing pollution load. These include regular maintenance programs, eliminating excessive floor washing and all sources of spillage and water leakages, closing/sealing running water taps.

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[43] http://www.agg-net.com/resources/articles/sustainable-development-initiatives-at-oparure-quarry

[44] http://www.wrap.org.uk/sites/files/wrap/Auditing%20of%20water%20use%20on%20construction%20sites%20-%20Phase%201%20and%202.pdf

[45] http://www.bullion.org.za/documents/Water%20Use%20Efficiency%20Mining%20Guidelines.pdf