ENVIRONMENT AGENCY

EA-Water Resources 90

REVIEW OF WATER COMPANY YIELDS

MARCH 1998

FOREWORD

"Only when the well runs dry do we realise the true worth of water" (Benjamin Franklin 1746).

An accurate assessment of the availability of water is essential to help water companies and the Environment Agency to ensure a more sustainable management of water resources. This report gives the first comprehensive and consistent estimate of the volume of water available to water companies in England and Wales.

I am delighted that all of the water companies have co-operated with the Environment Agency in reviewing the yields of their existing resources and systems using standard methods developed in partnership with the Agency.

The results contained in this report will be used by the water companies in the preparation of the water resources plans that they will submit to Ofwat and the Agency in June 1998. These plans will propose arrangements, including water conservation measures, for securing supplies in the longer term.

The report raises many important issues, including the impact on yields of changing levels of service, questions about the long term sustainability of some existing abstractions, and the problem of the temporary loss of resources due to planned or unplanned events. These will be debated further during the preparation of these plans.

This report is presented in two parts. The main text includes a commentary on methods and the company-wide results. In an appendix are the details of the yields of each company's sources grouped by resource zone.

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ENVIRONMENT AGENCY

REVIEW OF WATER COMPANY YIELDS

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EXECUTIVE SUMMARY

This report presents the water companies' best estimates of the current deployable output (DO) and water available for use (WAFU) from their surface and groundwater systems.

In October 1996, the Department of the Environment and the Welsh Office published *Water Resources and Supply: Agenda for Action*. Water companies were given the task of preparing estimates of the yields of their systems using up to date consistent assumptions and methodologies, taking account of their current operation and recent hydrometric data. The Environment Agency was asked to co-ordinate the work, collate the resulting information, and publish the results.

This report presents the results of the water companies' work, summarises the methods used and gives the results derived for both surface and groundwater systems. It also reviews the sustainability of groundwater abstractions in order to identify areas in which the calculated groundwater deployable outputs may not be available to water companies.

Table 1 summarises the overall estimate of total deployable output, outage and water available for use for each water company in England and Wales. A breakdown of these figures is given in Section 4.1 of the main report and Appendix 2.

Table 2 shows the values from this reassessment of yield compared with previous published estimates. The comparisons are based on deployable output because this is most closely comparable with previous calculations. In total, deployable output is some 5% lower than previous values. For a few companies, deployable output has increased. For most there has been a small decrease, but for a few the decrease is larger. The differences generally result from a combination of factors such as:

- changes to the sources available to the company
- inclusion of the impact of levels of service (frequency of customer restrictions) on the yields of surface water systems
- use of longer hydrometric records, taking account of recent and historic droughts
- experience of operation of groundwater sources during recent droughts
- adoption of new, standard methods for yield assessment
- for surface water systems, allowing for 30 days' emergency storage even at the end of severe droughts
- a more rigorous assessment.

The results of the study highlight a number of issues:

- Optimisation of system output - the optimisation of the output of a complex water resources system is difficult and more work may need to be done to identify consistent and robust methods for this.
- Conjunctive use - conjunctive use refers to the yield benefits that can be obtained by using several sources together. This includes combinations of sources of a single type (eg several surface water sources) and also combinations of groundwater and surface water sources. Some companies have made significant progress with the development of computer models of their conjunctive use systems. However, many companies rely on simple assumptions to combine the yields of multiple sources within a resource zone. This

may need more work.

- Definition of resource zones - all companies have defined resource zones, but they are not entirely consistent. In particular, some zones are very large; this may disguise the need for localised development to meet specific problems.
- Some of these yields could be improved by relatively minor improvements to water treatment works, pumping equipment, or infrastructure links within the system. Others are constrained by physical characteristics that are more difficult to overcome.
- Emergency storage - this has been introduced in the calculation of the yield of reservoir systems. In some cases, the inclusion of emergency storage of 30 days has a large impact on yield. The appropriateness of this value requires further analysis for each individual system.
- Sustainability of groundwater abstractions - the methods used to calculate the yield of groundwater sources do not take into account the overall availability of groundwater resources, which may constrain total deployable output in some catchments. While some progress has been made by using a simple accountancy method, more work will be needed to be certain about the identification of groundwater units that have unsustainable levels of abstraction.

This report provides a summary of the present availability of water resources to water companies in England and Wales. The methods used are consistent and robust, which means that, for the first time ever, comparisons can be made between companies and regions. While there are some parts of the methods where further work could be advantageous, this does not detract from the achievement of the water companies in reassessing their yields to a consistent standard in a limited period. Some of the questions and issues raised will need to be addressed in the water companies' resource plans. However, the results provide a technical basis for the assessment of the current resource-demand balance for each water company.

Agency Region	Water Company	Total deployable output Ml/d	Outage Ml/d	Water Available for Use Ml/d
Anglian	Anglian Water Services	1564.00	70.00	1494.00
	Cambridge Water plc	103.68	15.57	88.11
	Essex & Suffolk Water	541.68	14.60	527.08
	Tendring Hundred Water Services	37.80	1.55	36.25
Midlands	Severn Trent Water	2162.47	121.50	2040.97
	South Staffordshire Water	390.00	8.50	381.50
North East	Yorkshire Water	1460.70	68.50	1392.20
	Northumbrian Water	1436.12	60.60	1375.52
	Hartlepool Water	50.80	5.08	45.72
	York Waterworks plc	82.00	12.00	70.00
North West	North West Water	2201.44	54.35	2147.09
Southern	Folkestone & Dover Water	49.91	6.00	43.91
	Southern Water Services	811.25	42.83	768.42
	Mid Kent Water	195.57	6.27	189.30
	South East Water	190.40	10.00	180.40
	Portsmouth Water	264.21	6.91	257.30
South West	South West Water	483.98	9.69	474.29
	Wessex Water Services	426.10		426.10
	Bristol Water	341.50	4.94	336.56
	Bournemouth and West Hampshire Water	223.03	1.03	222.00
	Cholderton & District Water Company	0.77	0.00	0.77
Thames	Thames Water Utilities	2694.95	67.20	2627.75
	Three Valleys Water	898.32	102.61	795.71
	Mid Southern Water	217.70	18.00	199.70
	North Surrey Water	191.30	14.50	176.80
	Sutton & East Surrey Water	204.88	37.26	167.62
Welsh	Dŵr Cymru Welsh Water	1246.24	1.89	1244.35
	Dee Valley Water Co	81.70	0.80	80.90
NATIONAL		18552.50	762.18	17790.32

Table 1: Deployable output, outage and water available for use

Agency Region	Water Company	Previous yield Ml/d	New deployable output Ml/d	Difference Ml/d	Difference %	Distribution input 1996/97 Ml/d	Comments
Anglian	Anglian Water Services	1576.24	1564.00	-12.24	-0.78	1179.3	
	Cambridge Water plc	111.90	103.68	-8.22	-7.35	76.6	
	Essex & Suffolk Water	520.28	541.68	21.40	4.11	498.1	
	Tendring Hundred Water Services	42.20	37.80	-4.40	-10.43	34.1	
Midlands	Severn Trent Water	2263.10	2162.47	-100.63	-4.45	2022	Previous yield includes East Worcestershire Water Company
	South Staffordshire Water	356.90	390.00	33.10	9.27	352.6	
North East	Yorkshire Water	1568.11	1460.70	-107.41	-6.85	1350.5	
	Northumbrian Water	1474.00	1436.12	-37.88	-2.57	798.8	
	Hartlepool Water	51.00	50.80	-0.20	-0.39	36.3	Potable supply only
	York Waterworks plc	96.00	82.00	-14.00	-14.58	46.2	
North West	North West Water	2606.30	2201.44	-404.86	-15.53	2176.5	
Southern	Folkestone & Dover Water	49.27	49.91	0.64	1.30	50.9	
	Southern Water Services	847.78	811.25	-36.53	-4.31	622.3	
	Mid Kent Water	192.18	195.57	3.39	1.76	166.4	
	South East Water	177.02	190.40	13.38	7.56	172.7	
	Portsmouth Water	262.50	264.21	1.71	0.65	183.2	
South West	South West Water	605.90	483.98	-121.92	~ -5%	478.1	Previous yield based on peak 4 weeks and therefore not comparable
	Wessex Water Services	453.73	426.10	-27.63	-6.09	426.5	
	Bristol Water	370.00	341.50	-28.50	-7.70	325	
	Bournemouth and West Hampshire Water	226.87	223.03	-3.84	-1.69	163	
	Cholderton & District Water Company	0.77	0.77	0.00	0.00	0.7	
Thames	Thames Water Utilities	2754.61	2694.95	-59.66	-2.17	2857.7	
	Three Valleys Water	896.44	898.32	1.88	0.21	722.3	
	Mid Southern Water	303.22	217.70	-85.52	-28.20	222.9	
	North Surrey Water	181.19	191.30	10.11	5.58	137.1	
	Sutton & East Surrey Water	207.00	204.88	-2.12	-1.02	162.1	
Welsh	Dŵr Cymru Welsh Water	1312.46	1246.24	-66.22	-5.05	1031.2	
	Dee Valley Water Co	90.48	81.70	-8.78	-9.70	72.8	
NATIONAL		19,597.45	18552.50	-1,044.95	-5.33	16365.9	

Table 2 Comparison with previous deployable outputs

1 INTRODUCTION

In October 1996, the Department of the Environment and the Welsh Office published *Water Resources and Supply: Agenda for Action* (Ref 1). Among other actions, it stated that:

> *there is a need to prepare - by means of up to date consistent assumptions and methodology - fresh estimates of the current reliable yields of each discrete water resource system, taking into account its current operation and recent hydrometric data.*

Water companies were given the task of preparing estimates of the yields of their systems; the Environment Agency was asked to co-ordinate the work, collate the resulting information and publish the results by the end of 1997.

This report presents the results of the water companies' work. It summarises the methods used, and the results derived for both surface and groundwater systems. It also reviews the sustainability of groundwater abstractions in order to identify areas in which the calculated groundwater deployable outputs may not be available to water companies.

The Agency carried out a strategic audit of a sample of the assessments carried out by water companies. The audit examined the methods used and the assumptions made, and was aimed at ensuring that the calculated results are comparable. The audit did not check individual calculations for numerical errors. The results of the audits suggest that in almost all cases, the results presented here have been calculated in accordance with the defined methods.

The results presented here are the water companies' best estimates of current deployable output and water available for use. They have been calculated according to methods developed by water companies and the Agency as part of an ongoing research and development programme. As more information and better models become available, the yield values are likely to change. In some cases, water companies have already identified that a more certain estimate of yield could be established by carrying out extra work for which there was insufficient time. The results presented here will form the basis of future work and help to identify areas where more detailed study is required.

This work gives the existing yields of water resource systems. It does not take into account future developments, however simple, or the possible impact of climate change. There is considerable uncertainty associated with climate change; this will be addressed in subsequent water company plans.

It should be noted that the yield figures published in this document are a survey only of water company yields; other abstractors also have legitimate water demands.

2 DEFINITIONS

In this report, the following definitions have been used.

A **Resource Zone** is defined as:

- the largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall (*note: there should be no transfer constraints within a zone*)

The definition of yield for the purpose of the current review is the **deployable output** of an active or group of active sources.

For **groundwater sources**, the deployable output is defined as:

the output for specified conditions and demands of a commissioned source or group of sources as constrained by:

- licensed quantities;
- water quality;
- environment (constraints in licence);
- treatment;
- raw water mains and/or aqueducts;
- pumping plant;
- transfer and/or output main;
- well construction;
- aquifer properties.

For **surface water systems**, the **deployable output** is defined as:

- the constant rate of supply that can be maintained from the water resources system except during periods of restriction within the following constraints:

  - given level of service
  - the historic period for which data is available or could be derived
  - supply without storage entering the emergency storage zone
  - supply within the defined physical capacities of the existing system adopted for the simulation
  - source operation in accordance with the licence, or, for specified scenarios, a drought order or permit.

A **conjunctive use system** is a water supply system which relies on more than one source of water. This can include systems containing both surface water and groundwater sources.

Outage is defined as:

- a temporary loss of deployable output due to planned or unplanned events. Planned events are those such as maintenance of sourceworks; unplanned events are exclusively pollution, turbidity, nitrate, algae, power failure and system failure.

Water Available for Use is defined as:

- the total deployable output of a resource zone less deductions made for allowable outage.

3 METHODS

The yield reassessment methodologies take into account the comments made by respondents to the consultation carried out by the Agency in Annexes D and E of *Agenda for Action* (Ref 1).

3.1 Surface Water Yield Assessment

Surface water yield assessments carried out by water companies were based on the recommendations of *Water Resources and Supply: Agenda for Action*, and subsequent refinements as outlined in Ref 2.

Values of deployable outputs were calculated for surface water reservoir systems for three scenarios. The scenarios are:

Scenario 1 the deployable output is the constant rate that can be maintained from the system throughout the entire period of simulation, with no demand restrictions or drought orders/permits to authorise additional abstraction or reduce compensation discharges or prescribed flows. This scenario compares closely to the traditional "hydrological yield" approach, except for the addition of the concept of emergency storage.

Scenario 2 Water company defined -in this case, the water company's proposed frequency and magnitude of demand restrictions and environmental drought orders

Scenario 3 Agency defined reference scenario. The reference scenario allows comparison between different companies on a consistent basis. Restrictions are:

1 in 10 years: 5% demand restriction applied at any time of the year for a minimum of 3 months and a maximum of 12 months

1 in 40 years: further 5% demand restriction and appropriate environmental drought orders/permits, again for a minimum of 3 months and maximum of 12 months. The inclusion of drought orders or permits in this assessment is for indicative purposes only and does not imply that they would be granted automatically.

3.2 Groundwater Yield Assessment

The groundwater yield reassessments were based on the recommendations of Annex D of *Agenda for Action*, and subsequent refinements published as Ref 2. The Agency recommended use of the UKWIR methodology developed jointly by water companies and the Agency (Ref 3), and water companies have quoted results for average and average day peak week deployable outputs.

3.3 Information captured

This study has collected and collated the following information:

- abstraction licence information;
- surface water and groundwater source deployable outputs;
- outage estimates; and
- water available for use.

In total, this work covers around 3000 public water supply abstraction licences. Of these, about 2200 licences are for groundwater sources and 800 are associated with surface water systems. The supply areas of the 28 water companies currently operating in England and Wales have been divided by the water companies into about 140 resource zones.

Water company information, including source deployable outputs, can be found in Appendix 2.

3.4 Strategic Audits of Water Company Yield Reassessments

As part of this work, the Agency employed a consultant (Sir William Halcrow and Partners Ltd) to carry out a strategic audit of a sample of the water company calculations. The audit was intended to help water companies and the Agency to ensure that the methods used were consistent, and to ensure that any complex areas or misunderstandings could be dealt with before the work was completed. The audit took the form of detailed interviews with those carrying out the work, focussing on areas that could cause problems. The audit looked at compliance with methods; no numerical checks were made. In total the audits covered some 150 groundwater sources, and 45 surface water systems.

The audits were carried out prior to the submission of water company results. In some cases, issues were raised which formed the basis of dialogue between the Agency and water companies during the yield reassessment process. Most of these were dealt with satisfactorily. In general, the overall level of understanding of and compliance with Agency guidelines was good.

4 SUMMARY AND DISCUSSION OF RESULTS

Each water company has divided its supply area into Resource Zones and has produced results based on these. A Resource Zone is defined as the zone in which all customers experience the same risk of supply failure from a resource shortfall. The number of Resource Zones for each company depends, among other factors, on the size of the company, the geography of the area and the company's infrastructure.

Deployable outputs have been calculated for each source or group of sources. Details of these are included in Appendix 2. The deployable output values have been aggregated by the companies to give a Resource Zone deployable output. Outage has also been calculated by companies for each Resource Zone.

4.1 Water Available for Use

Table 4.1 summarises current estimate of total deployable output, outage and water available for use (WAFU) on a water company basis. The WAFU figures were calculated by the water companies as total deployable output less estimates of outage on a resource zone basis. In the calculation of WAFU, the deployable outputs for groundwater sources relate to average outputs, whereas the surface water outputs are given for Scenario 2, the water company defined scenario.

For ease of use, the results are grouped by Environment Agency Region. It should be noted that some water companies supply areas within two or more Agency Regions; such companies have been grouped with their main Agency Region.

For surface water reservoirs, details of the level of service scenarios are given in section 3.1.

4.2 Comparison with previous estimates

Table 4.2 shows the latest reassessment of total water company yields compared with previous estimates (mostly 1994 values from the National Rivers Authority document "Water: Nature's Precious Resource"). The comparisons are based on deployable output, because water available for use has not been calculated in the past. Differences generally result from a combination of factors such as:

- changes to the sources available to the company
- inclusion of the impact of levels of service (frequency of customer restrictions) on the yields of surface water systems
- use of longer hydrometric records, taking account of recent and historic droughts
- adoption of new, standard methods for yield assessment
- for surface water systems, allowing for 30 days' emergency storage even at the end of severe droughts
- a more rigorous assessment.

Detailed discussions for each water company are provided in Appendix 2.

Agency Region	Water Company	Total deployable output Ml/d	Outage Ml/d	Water Available for Use Ml/d
Anglian	Anglian Water Services	1564.00	70.00	1494.00
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North East	Yorkshire Water	1460.70	68.50	1392.20
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	Hartlepool Water	50.80	5.08	45.72
	York Waterworks plc	82.00	12.00	70.00
North West	North West Water	2201.44	54.35	2147.09
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	South East Water	190.40	10.00	180.40
	Portsmouth Water	264.21	6.91	257.30
South West	South West Water	483.98	9.69	474.29
	Wessex Water Services	426.10		426.10
	Bristol Water	341.50	4.94	336.56
	Bournemouth and West Hampshire Water	223.03	1.03	222.00
	Cholderton & District Water Company	0.77	0.00	0.77
Thames	Thames Water Utilities	2694.95	67.20	2627.75
	Three Valleys Water	898.32	102.61	795.71
	Mid Southern Water	217.70	18.00	199.70
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	Sutton & East Surrey Water	204.88	37.26	167.62
Welsh	Dŵr Cymru Welsh Water	1246.24	1.89	1244.35
	Dee Valley Water Co	81.70	0.80	80.90
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Table 4.1: Deployable output, outage and water available for use for each company

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	Essex & Suffolk Water	520.28	541.68	21.40	4.11	498.1	
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Midlands	Severn Trent Water	2263.10	2162.47	-100.63	-4.45	2022	Previous yield includes East Worcestershire Water Company
	South Staffordshire Water	356.90	390.00	33.10	9.27	352.6	
North East	Yorkshire Water	1568.11	1460.70	-107.41	-6.85	1350.5	
	Northumbrian Water	1474.00	1436.12	-37.88	-2.57	798.8	
	Hartlepool Water	51.00	50.80	-0.20	-0.39	36.3	Potable supply only
	York Waterworks plc	96.00	82.00	-14.00	-14.58	46.2	
North West	North West Water	2606.30	2201.44	-404.86	-15.53	2176.5	
Southern	Folkestone & Dover Water	49.27	49.91	0.64	1.30	50.9	
	Southern Water Services	847.78	811.25	-36.53	-4.31	622.3	
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	South East Water	177.02	190.40	13.38	7.56	172.7	
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South West	South West Water	605.90	483.98	-121.92	~ -5%	478.1	Previous yield based on peak 4 weeks and therefore not comparable
	Wessex Water Services	453.73	426.10	-27.63	-6.09	426.5	
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	Bournemouth and West Hampshire Water	226.87	223.03	-3.84	-1.69	163	
	Cholderton & District Water Company	0.77	0.77	0.00	0.00	0.7	
Thames	Thames Water Utilities	2754.61	2694.95	-59.66	-2.17	2857.7	
	Three Valleys Water	896.44	898.32	1.88	0.21	722.3	
	Mid Southern Water	303.22	217.70	-85.52	-28.20	222.9	
	North Surrey Water	181.19	191.30	10.11	5.58	137.1	
	Sutton & East Surrey Water	207.00	204.88	-2.12	-1.02	162.1	
Welsh	Dwr Cymru Welsh Water	1312.46	1246.24	-66.22	-5.05	1031.2	
	Dee Valley Water Co	90.48	81.70	-8.78	-9.70	72.8	
NATIONAL		19,597.45	18552.50	-1,044.95	-5.33	16365.9	

Table 4.2 Comparison with previous deployable outputs

Note: Distribution input 1996-97 from Ofwat *1996-97 Report on leakage and water efficiency*

The values calculated by water companies in this work are their best estimates of current deployable output based on the specified methods and existing data. As more information becomes available or models are refined, deployable output values will be recalculated and refined. Some water companies have already identified that further work is required on yield reassessment; this will form part of their water resources plan.

It should be noted that a large change in deployable output does not necessarily present problems for a water company; the importance of the change will depend also on the demand for water. As an indication of the water needed by each company, 1996/97 distribution input figures are included in the table.

4.3 Outage estimates

Water company outage estimates range from a maximum of 100% of total deployable output for a small resource zone to 0% for water companies which operate with small sources with no history of pollution incidents. The approach taken to the calculation of outage can be grouped under 3 broad categories. These are:

a) use of UKWIR outage methodology (ref 4)
b) modification of UKWIR outage methodology
c) estimates based on historical operational experience of the way that the resource zones operate

Very few companies used the UKWIR outage methodology or their own variant of its methods. The guidelines for the work asked for the companies' best estimates of outage, without specifying a method. Most companies made an assessment based on historical operation. This includes consideration of historical pollution incidents, aggregation of records of outage events, plant, power, and system failures, pollution risks, ammonia and turbidity problems.

4.4 Security of supply

Water Resources and Supply: Agenda for Action (Ref 1) expresses the view that there is a need for a greater dialogue between water companies and their customers on the balance to be struck between higher security of supply and higher costs.

Levels of service are primarily a matter between the water company, its customers and Ofwat. The Agency will have to consider the position carefully if companies change to provide a higher level of service and then require additional abstraction licences to provide a more reliable supply.

For surface water systems, deployable output has been calculated for the three scenarios defined in Section 3.1. The results are shown in Table 4.3, while the assumptions used by different companies are given in Table 4.4.

The estimates have been constrained to some extent by the availability of sufficient past hydrological data. Results from the three scenarios vary. For some companies, the assumption of restrictions during the worst droughts on record results in a higher yield than if the system is operated without restriction. However, some companies achieve a lower yield when restrictions are applied periodically. Reasons for these differences are complex but they include the

characteristics of the reservoir system, the relative severity of different droughts, and the way that the companies have calculated reservoir control curves. This is an area that needs more work.

Agency Region	Water company	Company deployable output for scenarios			Difference between S2 and S1 %	Difference between S3 and S1 %	Difference between S3 and S2 %
		1	2	3			
Anglian	Anglian Water Services	1547.55	1564.00	1564.05	1.06	1.07	0.00
	Cambridge Water plc	no surface water storage - not appropriate					
	Essex & Suffolk Water	519.68	541.68	541.68	4.23	4.23	0.00
	Tendring Hundred Water Services	37.55	37.80	37.85	0.67	0.80	0.13
Midlands	Severn Trent Water	2162.47	2162.47	2302.57	0.00	6.48	6.48
	South Staffordshire Water	359.00	390.00	390.00	8.64	8.64	0.00
North East	Yorkshire Water	1600.70	1460.70	1525.70	-8.75	-4.69	4.45
	Northumbrian Water	1436.12	1436.12	1436.12	0.00	0.00	0.00
	Hartlepool Water	not appropriate					
	York Waterworks plc	no surface water storage - not appropriate					
North West	North West Water	2187.44	2201.44	2228.44	0.64	1.87	1.23
Southern	Folkestone & Dover Water	no surface water storage - not appropriate					
	Southern Water Services	801.85	811.25	804.35	1.17	0.31	-0.85
	Mid Kent Water	195.27	195.57	195.57	0.15	0.15	0.00
	South East Water	179.90	190.40	190.40	5.84	5.84	0.00
	Portsmouth Water	no surface water storage - not appropriate					
South West	South West Water	481.58	483.58	485.28	0.42	0.77	0.35
	Wessex Water Services	426.10	426.10	430.50	0.00	1.03	1.03
	Bristol Water	334.10	341.50	355.00	2.21	6.26	3.95
	Bournemouth and West Hampshire Water	no surface water storage - not appropriate					
	Cholderton & District Water Company	no surface water storage - not appropriate					
Thames	Thames Water Utilities	2659.45	2694.95	2716.35	1.33	2.14	0.79
	Three Valleys Water	not appropriate					
	Mid Southern Water	no surface water storage - not appropriate					
	North Surrey Water	no surface water storage - not appropriate					
	Sutton & East Surrey Water	132.88	132.88	132.88	0.00	0.00	0.00
Welsh	Dŵr Cymru Welsh Water	1241.94	1246.24	1310.06	0.35	5.49	5.12
	Dee Valley Water	75.20	81.70	83.30	8.64	10.77	1.96

Table 4.3: deployable outputs with different levels of service

Agency Region	Company	Restrictions
Anglian	Anglian Water Services	Hosepipe ban 1 in 35 years, non-essential use restrictions 1 in 75 years. Environmental drought orders 1 in 75 years.
	Cambridge Water plc	Not appropriate - no surface water systems
	Essex & Suffolk Water	As reference scenario. May change on completion of customer surveys.
	Tendring Hundred Water Services	As Anglian Water for Ardleigh Reservoir (jointly managed).
Midlands	Severn Trent Water	No restrictions on customer demand. For Severn resource zone, a voluntary 5% reduction on all Severn abstractions applies.
	South Staffordshire Water	No restrictions on customer demand.
North East	Yorkshire Water	5% demand restriction 1 in 16 years; further 5% demand restriction 1 in 60 years, with environmental drought orders and permits.
	Northumbrian Water	No restrictions.
	Hartlepool Water	Not appropriate.
	York Waterworks plc	Not appropriate.
North West	North West Water	Hosepipe ban frequency 1 in 20 years.
Southern	Folkestone & Dover Water	Not appropriate
	Southern Water Services	5% demand restriction on average 1 in 10 years; further 4% 1 in 20 years; 30% restriction 1 in 100 years. On Isle of Wight, sprinkler or hosepipe ban 1 in 10 years, voluntary savings 1 in 20 years, a risk of rota cuts or standpipes 1 in 100 years.
	Mid Kent Water	5% demand restriction 1 in 10 years. Further 5% demand restriction not more than 1 in 40 years.
	South East Water	No customer restrictions. Gains in deployable output obtained by obtaining permission for relaxation of licence constraints.
	Portsmouth Water	Not appropriate
South West	South West Water	Major publicity campaign requesting voluntary savings 1 in 10 years. Hosepipe ban (max duration 6 months) 1 in 20 years, giving 5% reduction in demand. Non-essential use ban (max duration 4 months) 1 in 40 years, giving a further 5% demand reduction. Rota cuts and standpipes unacceptable. Drought orders or permits not more than 1 in 20 years.
	Wessex Water Services	No customer restrictions.
	Bristol Water	Drought orders for non-essential use.
	Bournemouth and West Hampshire Water	5% demand reduction 1 in 20 years, 10% 1 in 40 years.
	Cholderton & District Water Company	Not appropriate.
Thames	Thames Water Utilities	Controls based on the Lower Thames Control Strategy 1997: media campaign, water efficiency at unrestricted frequency; enhanced media campaign, voluntary sprinkler bans at unrestricted frequency; hosepipe bans, non-essential use ban, drought orders and permits 1 in 50 years.
	Three Valleys Water	Not appropriate.
	Mid Southern Water	Not appropriate.
	North Surrey Water	Not appropriate.
	Sutton & East Surrey Water	8% reduction in demand 1 in 10 years.
Welsh	Dŵr Cymru Welsh Water	No restrictions.
	Dee Valley Water	Level of service equivalent to hosepipe ban for 1 month in 71 year record.

Table 4.4 Water company defined levels of service.

In most cases, an enhanced level of service to water company customers means that there is a lower deployable output of the resource. For example, the "no restrictions" deployable output is generally lower than the deployable output that can be achieved if demand is restricted through the worst droughts on record. The nature of this relationship depends on the characteristics of the water resources system and the relative severity of different historic drought events. It is clear that the balance between restrictions and resource yield is an important part of the debate on available water resources. The Agency wishes to allocate resources most appropriately and therefore will have to consider the position carefully if companies wish to develop additional resources as a result of changing to a different level of service.

5 SUSTAINABILITY OF GROUNDWATER ABSTRACTION

The Agency's aim in water resources is to achieve reliable, environmentally sustainable and socially acceptable water resource management in England and Wales. Recent public attention on water resources has served to illustrate the often fragile balance which exists between the demands for a safe, reliable system of public water supply and those of the environment.

Almost all abstractions of water, from rivers or groundwater, affect river flows. The Agency acknowledges that there are some instances where abstraction is having an impact on the ecology of conservation sites. These impacts are being investigated by the Agency in conjunction with English Nature, the Countryside Council for Wales, and other conservation organisations. The water company reassessment of yields do not take into account of these impacts, except where environmental constraints on abstraction are defined in licences.

The UKWIR method for groundwater yield assessment is based on borehole and aquifer characteristics, and cannot address the issue of overall groundwater unit sustainability. Therefore the yields calculated by water companies may not all be achievable in practice, because of unacceptable environmental impacts. These may appear as either:

- local effects giving site specific problems (eg low flows in spring fed Chalk rivers near public water supply sources), or
- more widespread effects across aquifer units giving broader catchment reductions in groundwater level or spring flows into receiving waters causing ecological degradation. In extreme cases, over abstraction can lead to a steady long term decline in groundwater levels and river flows, effectively 'mining' groundwater.

Out of the total number of groundwater licences held by water companies, only a small proportion will be affected by such sustainability problems.

5.1 Site specific problems

Site specific problems are being addressed by the Agency and water companies in a number of ways. The Agency is working with English Nature, the Countryside Council for Wales, and water companies and others to:

- identify perceived problems of low flows due to local abstractions

- quantify whether overabstraction is having an impact on groundwater levels and whether that impact is significantly affecting the ecology of the site.
- select a cost effective option to solve or ameliorate the problem, such as reduction of abstraction, licence revocation, relocation of abstraction or river support pumping.

Solutions have been found and are being implemented at a number of sites. Other cases will be investigated as part of the environmental obligation to be placed on water companies during 2000-2005, as part of the 1999 review of water companies' price limits. A number of solutions may be funded by water companies and implemented during the 5 years from 2000 to 2005.

5.2 Groundwater unit assessment

Groundwater units may have levels of abstraction which lead to unacceptable lowering of water tables or depletion of river flow. Usually, no single abstraction is the cause of these problems; the total impact of all abstractions leads to these unacceptable impacts. It should be noted that it is not only water companies that abstract groundwater; in tackling such problems, it will be necessary to consider all abstractors.

The Agency has reviewed each of the aquifer units in England and Wales to establish whether:

- long term reductions in groundwater levels are occurring
- adequate water resources have been reserved for river and other environmental needs.

A simple "water accountancy" procedure has been used considering factors such as the natural recharge to the aquifer, the quantity taken by existing licensed abstractions and the environmental requirement for water, primarily for river flows. The procedure allows each aquifer unit to be placed into one of the three categories defined as follows:

Category 1	no overall sustainability concerns
Category 2	at sustainable limit
Category 3	sustainability concerns

This is a generalised approach; the nature of the method means that it is not definitive and more work would be needed to ascertain the environmental needs of any aquifer unit that has been placed in Category 3. Similarly, the overall balance of an aquifer unit may place it in Category 1, but there may be site specific problems associated with particular abstractions. Groundwater sustainability maps for each Environment Agency Region are given in Appendix 2.

6. TECHNICAL ISSUES

The reassessment of water company yields has highlighted a number of technical and methodological issues which could be addressed by future work.

For **groundwater yield assessment**, the UKWIR methodology could benefit from further refinements in some areas:

- spring sources
- groundwater sources adjacent to rivers
- clarification for group licences

The calculation of the yield of **surface water direct intakes** has presented particular problems in this work. The methods are simple but basing the yield on the worst historic flow has been questioned; for example, in a repeat of such a flow event, would a drought order or permit be justified?

For **reservoir yield**, there have been few attempts at the rigorous validation of simulation models. This would involve, for example, demonstrating that the model replicates reservoir levels over the last few years with an acceptable degree of accuracy. Another area of variability is the generation of synthetic inflow and river flow sequences to extend hydrological records. While the methods for this are generally well understood, a considerable variety of methods have been used; validation of the results also varies. Guidelines on the adjustment of demand profiles for the impact of demand restrictions and level of water company meter penetration of domestic customers would also be useful.

Other areas where further work would be beneficial are:

- Optimisation of system output - the optimisation of the output of a complex water resources system is difficult and more work may need to be done to identify consistent and robust methods for this.
- Conjunctive use - conjunctive use refers to the yield benefits that can be obtained by using several sources together. This includes combinations of sources of a single type (eg several surface water sources) and also combinations of groundwater and surface water sources. Some companies have made significant progress with the development of computer models of the conjunctive use systems. However, many companies rely on simple assumptions to combine the yields of multiple sources within a resource zone. This may need more work.
- Definition of resource zones - all companies have defined resource zones, but they are not entirely consistent. In particular, some zones are very large; this may disguise the need for localised development to meet specific problems.
- Some of these yields could be improved by relatively minor improvements to water treatment works, pumping equipment, or infrastructure links within the system. Others are constrained by physical characteristics that are more difficult to overcome.
- Emergency storage - this has been introduced in the calculation of the yield of reservoir systems. In some cases, the inclusion of emergency storage of 30 days has a large impact on yield. The appropriateness of this value requires further analysis for each individual system.
- Sustainability of groundwater abstractions - the methods used to calculate the yield of groundwater sources do not take into account the overall availability of groundwater

resources, which may constrain total deployable output in some catchments. While some progress has been made by using the simple accountancy method described above, more work will be needed to be certain about the identification of groundwater units that have unsustainable levels of abstraction.

7 CONCLUSIONS

This report provides a summary of the present availability of water resources to water companies in England and Wales. The methods used are consistent and robust, which means that, for the first time ever, comparisons can be made between companies and regions. While there are some parts of the methods where further work could be advantageous, this does not detract from the achievement of the water companies in reassessing their yields to a consistent standard in a limited period. Some of the questions and issues raised will need to be addressed in the water companies' resource plans. However, the results provide a technical basis for the assessment of the current resource-demand balance for each water company.

REFERENCES

1 Department of Environment and the Welsh Office, **Water Resources and Supply: Agenda for Action**, London, October 1996.

2 Environment Agency, 1997. **Reassessment of Water Company yields** (reproduced as Appendix 1).

3 Beeson, S., van Wonderen, J., Mistear, B. **A Methodology for the Determination of Outputs of Groundwater Sources**. United Kingdom Water Industry Research Limited, London, 1995.

4 **Outage Allowances for Water Resource Planning**. United Kingdom Water Industry Research Limited, London, 1995.

GLOSSARY

Conjunctive use	a water supply system which relies on more than one source of water. This can include systems containing both surface water and groundwater sources.
Deployable output	Groundwater: the output of a commissioned source or group of sources as constrained by licence (if applicable), water quality, environment, treatment, raw water mains, pumping plant and/or well/aquifer properties, transfer and/or output main for specified conditions and demands. Surface water: the constant rate of supply that can be maintained from the water resources system except during periods of restriction within the constraints of level of service, historic period for which data is available, supply without storage entering the emergency storage zone, supply within the physical capacities of the system, operation in accordance with the licence, and water quality or environmental considerations.
Emergency storage	A reserve storage in a reservoir aimed at accommodating the operational uncertainty regarding the duration of a particular drought. It will normally be 30 days supply.
Hydrometric data	Measurements of the hydrological cycle, including river flow and groundwater levels.
Levels of service	The defined frequency of formal restrictions on customer supply.
Ml/d	Megalitres per day. 1 Megalitre = 1 million litres (1000 m^3)
Outage	A temporary loss of deployable output due to planned or unplanned events. Planned events are those such as the maintenance of sourceworks; unplanned events are exclusively pollution, turbidity, nitrate, algae, power failure and system failure.
Potential yield	The deployable output that could be achieved following some sort of development to the infrastructure of the source or group of sources.
Resource Zone	the largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall (*note: there should be no transfer constraints within a zone*)
Water available for use	The deployable output of a source less deductions made for allowable outage.

APPENDIX 1 - 1997 GUIDELINES

ENVIRONMENT AGENCY

REASSESSMENT OF WATER COMPANY YIELDS

ENVIRONMENT AGENCY

February 1997

CONTENTS

EXECUTIVE SUMMARY

This document presents the assumptions and methodologies to be used by water companies for preparing estimates of the current reliable yields of each discrete water resource system as required by the Government in *'Water Resources and Supply: Agenda for Action'*. (Reference 1).

The methodologies presented take into account the comments made by respondents to the consultation carried out by the Environment Agency in Annexes D and E of *'Agenda for Action'* and wherever possible use the terminology developed jointly between the regulators and water companies.

Water companies are now asked to provide the following information and to prepare estimates of yield for each of their sources as follows:

By 30 March 1997

(i) A programme of work for completing the yield estimates by mid November 1997.

By mid November 1997

(ii) Maps of each company supply area showing the Resource Zones within the company.

(iii) Completed Forms RZ1 showing the allocation of sources, yield estimates, outage and water available for use to each Resource Zone.

(iv) Completed Forms SW1 for each surface source or groups of surface or conjunctive use sources showing the estimate of yield for each of three scenarios.

(v) Completed UKWIR (UK Water Industry Research Limited) Forms detailing the average deployable output and average day peak week deployable output for each groundwater source or group of sources in close proximity. Where the output of a group of groundwater sources is constrained the results should be recorded on Form GW1.

(vi) For comparative purposes, the Agency will also ask water companies to provide their previous estimates of yield for each source or group of sources.

(vii) Water companies may also provide estimates of the potential yield of sources where this is seen as a possible option for closing the Supply/Demand balance.

The Agency wishes to acknowledge the co-operation of water companies in the research and development and refinement of the methodologies set out in this document.

Reassessment of Water Company Yields

1. INTRODUCTION

In October 1996, the Department of the Environment and the Welsh Office published *'Water Resources and Supply: Agenda for Action'* (reference 1). Among other actions, it identifies the need to:

- *prepare, by means of up to date consistent assumptions and methodology, fresh estimates of the current reliable yield of each discrete water resource system, taking into account its current operation and recent hydrometric data:*

  - *action by individual water companies with co-ordination by the Environment Agency and publication of the results by the Agency by the end of 1997;*

and to:

- *test the fresh estimates of current reliable yields against climatic change scenarios:*

  - *action to be led by the Environment Agency, in full consultation with the water companies and in close contact with Government and centres of excellence on climatic change studies*

Annexes D and E of *'Water Resources and Supply: Agenda for Action'* outlined the principles for the assessment of yields of groundwater and surface water systems respectively. Both of these annexes were open to consultation and comments were sought from all organisations with an interest in these matters. Many comments were received, the majority being from water companies.

In preparing this document, the Environment Agency has considered all of the views raised. Inevitably, some were contradictory and the Agency has developed a view on the calculation of yield which should allow the results to be compared between different water companies on a consistent basis. Revised versions of Annexes D and E are included as Appendices 1 and 2. These are intended to be read in conjunction with the main body of this document and together they should provide sufficient information to allow calculation of fresh estimates of the current reliable yield of groundwater and surface water sources as required by *'Agenda for Action'*.

2. PRINCIPLES AND RESPONSIBILITIES

'*Water Resources and Supply: Agenda for Action*' clearly identifies that water companies are responsible for the reassessment of the yields of groundwater and surface water sources. The Environment Agency is responsible for defining the methods that should be used and for publishing the results by the end of 1997. However, the Agency will be prepared to work closely with companies where it needs to be involved in agreeing an approach to local circumstances which are not covered in this document. In general, the Agency will assume that the methods defined are appropriate and it will be for water companies to demonstrate that an alternative method will provide an acceptable level of accuracy and comparability.

As the co-ordinator and publisher of the results of this work, the Agency will need to ensure that the calculated yields are comparable between water companies and that the methods used are documented and auditable. The Agency will therefore ask water companies for detailed information about assumptions used in the course of the work. The Agency will be using consultants to help to draw the work together and to assist in the quality assurance of the documentation and results of the work. The precise role of the consultants will vary with each region of the Agency.

'*Water Resources and Supply: Agenda for Action*' specifies that the information resulting from this work should be published by the end of 1997. In order to achieve this target, the Agency will need final results by the middle of November 1997 at the latest. The Agency will not delay publication of the results to wait for the output from a particular water company.

As detailed methods and assumptions will sometimes have to be agreed between the water companies and the Agency, close co-operation and exchange of interim results will be essential to ensure that the final results can be accepted without further discussion. The Agency is aware of its responsibilities in this area and will do all it can to work with the water companies to enable them to meet the November deadline. Early identification of issues or problems by water companies will be vital.

For comparative purposes, the Agency will also ask water companies to provide their previous estimates of yield for each source or group of sources.

It should be noted that the work to be published by the end of 1997 concerns only the fresh estimates of the current reliable yields of the systems. Testing against climate change scenarios is another important piece of work which is currently being progressed through collaborative research between the Agency and the water industry. The Agency will be discussing the practical application of the research and a timetable for action with water companies and other interested parties in the near future.

3. DEFINITIONS

The terminology used in this work will wherever possible be that developed jointly between the regulators and water companies. The definition of yield for the purpose of this review is the deployable output of an active source or group of active sources as shown schematically in Figure 1. Other key definitions are given below and in the Appendices.

The Agency intends to publish estimates for the deployable outputs of all water company systems and estimates of water available for use within each Resource Zone (either for individual sources or groups of sources as appropriate).

A **Resource Zone** is defined as:

- the largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall *(commentary: there should be no transfer constraints within a zone)*.

For **Groundwater Sources**, the **deployable output** is defined as:

- the output for specified conditions and demands of a commissioned source or group of sources as constrained by:
  - licensed quantities;
  - water quality
  - environment (constraints in licence);
  - treatment
  - raw water mains and/or aqueducts
  - pumping plant
  - transfer and/or output main
  - well construction
  - aquifer properties

Water companies should calculate the deployable output of groundwater sources in accordance with the UKWIR methodology (reference 2). Details of the methods to be used are presented in Section 4.1 and Appendix 1.

For **Surface Water Systems**, the **deployable output** is defined as:

- the constant rate of supply that can be maintained from the water resources system except during periods of restriction within the following constraints:
  - given level of service
  - the historic period for which data is available or could be derived
  - supply without storage entering the emergency storage zone
  - supply within the defined physical capacities of the existing system adopted for the simulation

- source operation in accordance with the licence, or, for specified scenarios, a Drought Order or Permit

The method used will be to simulate the realistic operation of the water resources system in question preferably using a simulation model with a daily or other appropriate timestep. Further details and definitions are given in Section 4.2 and Appendix 2.

Water available for use is defined as:

- the deployable output of a source less deductions made for allowable outage.

It is expected that water available for use will normally be estimated for each Resource Zone rather than for each individual source. This means that water companies will need to provide zonal estimates of outage, together with documentation of the methods used, and maps of the zones.

Outage is defined as:

- a temporary loss of deployable output due to planned or unplanned events. Planned events are those such as maintenance of sourceworks; unplanned events are exclusively pollution, turbidity, nitrate, algae, power failure and system failure.

While the Environment Agency intends only to publish deployable outputs and water available for use, water companies may also usefully calculate and quote other yield values, such as potential yield (refer to Appendices 1 and 2 for definitions). Much of this work may be needed to identify options for closing the Supply/Demand balance as part of the Periodic Review.

4. GENERAL COMMENTS

The detailed methodologies are presented in Appendices 1 and 2 which together with the following general comments should enable water companies to prepare estimates of deployable output for groundwater, surface water and conjunctive use systems and the water available for use within each Resource Zone.

4.1 Groundwater

Water companies are requested to calculate source output for all groundwater sources using the standard UKWIR methodology. Results should be quoted for both average and average day peak week deployable output and reported on the standard UKWIR form.

Multiple sources that are in close proximity will be treated as a single source. Where group licences include sources that are remote, the deployable output should be calculated separately using UKWIR methods. Documentation must make it clear that the outputs relate to the same group licence and should additionally give the group deployable output.

Where groundwater models are available, these may be used in addition to the UKWIR approach and in conjunction with long recharge series to examine levels of service. This is optional and implications should be discussed with Environment Agency regional contacts.

Water companies are requested to calculate and quote groundwater source output at the individual source level and subsequently to group sources into Resource Zones to estimate outage.

It is the Agency's intention only to publish deployable output and water available for use. However if a water company is planning a development which will increase deployable output (for example, enhanced treatment work capacity), these results should also be presented as potential yields.

4.2 Surface Water Reservoir Systems

Methods for the calculation of the yield of surface water reservoir systems are based on those outlined in research carried out for the National Rivers Authority (reference 3). However, the methods have been modified to make them less prescriptive and easier to apply.

Water companies are expected to group surface water sources into models of systems where appropriate. In most cases the groupings will be obvious, but where there is scope for debate, discussions should be held between water companies and the Environment Agency region.

The basic method for the calculation of deployable output for surface water systems is the use of a system simulation model which reflects the realistic operation of the system in question. The model should, where possible, operate on a daily or other appropriate timestep and simulate behaviour of the system over a long period. Where possible, this should include the drought of the early 1930s (or a longer historic period if adequate data can be made available) and continue to 1996. The principle behind this method of analysis is to examine the behaviour of the existing reservoir system through historic climatic conditions. This means that where river flows are significantly affected by artificial influences (abstraction, effluent, and impounding reservoirs) naturalisation should be carried out to ensure that the simulation model is looking only at river flows as a response to natural variability. Where it has been necessary to naturalise river flows, it will usually be necessary for the simulation to reflect the current artificial influences in order to estimate the present deployable output. The Agency will need to be involved in naturalisation of river flow sequences carried out by water companies and may be able to assist with the provision of data.

It is appreciated that in some cases the extension of river flow records will be required. The Agency will co-operate in the extension of flow records and will provide advice and expertise on appropriate methods for extension and the accuracy of existing flow records. It is essential that any extended river flow records are agreed between the water company and the Agency at an early stage, so that this does not stand in the way of progress with calculation of deployable output.

In some cases it may not be possible to extend river flow records with an appropriate level of accuracy. If the water company believes this to be the case, it should agree at an early stage an alternative approach with the Environment Agency region concerned. The justification for such an alternative approach must be documented fully and presented with the resulting deployable output calculations. If records do not include the 1930s drought, consideration should be given to estimating the significance of this drought and its possible impact on system deployable output.

The model used should model the complete system including treatment works capacity, but not supply distribution networks. The Agency does not wish to specify particular software and appreciates that most water companies will already have existing computer programs for reservoir simulation. These must be auditable and prouce replicable results; water companies will be expected to demonstrate that a particular model is suitable for the purpose. Models should carry out simulations at an appropriate timestep, based on realistic operation of the system.

Any control rules for the operation of the system should be agreed locally between the water company and the Agency. Costs (for example, of pumping and water treatment) must not be a constraint in the calculation of deployable output and therefore control rules must not reflect cost considerations. However, if a calculated deployable output is in practice unattainable because of excessive cost, the water company should agree an appropriate method of operation with the Agency and recalculate the deployable output accordingly.

Simulation of water resource systems should use the same demand profile for every year of the simulation. The profile should adjust average daily or monthly demand by monthly factors reflecting water company policy during a drought, taking into account current water company penetration of domestic water meters. The demand profile will be determined by the water company based on recent demands and agreed locally with the Environment Agency. Its derivation should be documented.

Each system modelled must incorporate emergency storage. This is a reserve store aimed at accommodating the operational uncertainty regarding the duration of a particular drought and goes some way towards allowing for the drought being more severe than any previously experienced. A value of 30 days of supply should be used for emergency storage; alternative values can be agreed with the Environment Agency region. Unless constrained by some other conditions, there is no reason why dead storage should not be part of emergency storage. If this is the case, it must be agreed with the Agency and there must be a plausible way to use the emergency storage.

The Agency wishes to minimise the volume of work for water companies and has tried to minimise the number of yield scenarios required. However, three values of deployable output are needed based on simulations using the same demand profile. Results should be recorded on Form SW1 shown in Appendix 3. The levels of service scenarios which should be modelled are:

(i) No Restrictions

In this case, the deployable output is the constant rate of supply that can be maintained from the system throughout the entire period of the simulation, with no demand restrictions or drought orders/permits to authorise additional abstraction or reduce compensation discharges or prescribed flows.

(ii) Water Company Proposed Levels of Service

In this case, the water company will propose a frequency and magnitude of restrictions to supply which it proposes to offer its customers. These could include demand restrictions (hosepipe bans, non-essential use bans, other demand management measures) with a defined frequency. Demand restrictions will have an associated percentage reduction in demand. If the water company believes it to be appropriate, proposed restrictions can also include drought orders/permits to authorise additional abstraction or reduce compensation discharges or prescribed flows. These restrictions should also have a defined frequency and magnitude. All assumptions made for this scenario must be fully documented.

As these restrictions are to be proposed by the water company, there is no need to agree them with the Environment Agency, although the Agency is willing to discuss the issues involved if the water company considers it to be appropriate. The deployable output for this scenario is the constant rate of supply which can be sustained throughout the simulation (the value before demand restrictions are applied).

(iii) Reference Scenario

This reference scenario will allow comparison between different companies on a consistent basis and therefore the standards of service to be used have been defined by the Agency. They are:

1 in 10 years:	5% demand restriction applied at any time of year for a minimum of 3 months and a maximum of 12 months.

1 in 40 years:	further 5% demand restriction and drought orders/permits as above, again for a minimum of 3 months and a maximum of 12 months. The level of these drought orders/permits will be specified locally by the Agency. The definition of drought orders/permits in this way does not mean that the Agency will automatically approve such applications; they are being used for indicative purposes only. In some resource systems, it may not be appropriate to define additional drought orders/permits beyond existing licence conditions.

Again, the deployable output is the constant rate of supply which can be sustained throughout the simulation (the value before the 5% and 10% demand restrictions are applied).

As with groundwater systems, outage will be estimated on a Resource Zone level. The results of the calculations of deployable output should be recorded on the forms provided in Appendix 3. This form incorporates the minimum level of detail required to audit and publish the deployable outputs of surface water systems; for more complex systems it is envisaged that additional reports will be prepared by water companies to ensure that the results are auditable and that all assumptions are transparent.

It is the Agency's intention only to publish deployable output and water available for use. However, if a water company is planning a development which will increase deployable output (for example, enhanced treatment work capacity), these results should also be presented as potential yields.

4.3 Direct River Abstractions

In many cases, direct river abstractions with no storage will be part of some sort of conjunctive use scheme, and their operation should be modelled with the rest of the scheme. However, some direct river abstractions are truly stand-alone systems. For such abstractions, the deployable output is the minimum historic daily rate which could be abstracted within the licence conditions and the physical system constraints. Agreement must be reached between the water company and the Environment Agency region on an appropriate period for analysis.

4.4 Conjunctive Use Schemes

Many water company systems include the conjunctive use of surface and groundwater sources. Where possible, these should be modelled to maximise deployable output. Where the company considers that this incurs excessive cost they should agree an appropriate method of operation with the Agency and recalculate the deployable output accordingly.

It is appreciated that conjunctive use models are complex and difficult to develop, and the Agency will not expect new models to be developed in the timescales of this project. Where conjunctive use models are not available, the Agency will expect the deployable outputs of the surface and groundwater systems to be calculated using the methods defined above. In such cases water companies should provide justification for the gain in deployable output from conjunctive use operation.

4.5 Agency Lead Systems

In general, it is the responsibility of water companies to calculate the deployable outputs of water resource systems. However, in some cases, the Environment Agency takes the lead in system operation. The Agency will take the lead in the determination of the deployable outputs of the Severn system, Kielder Reservoir, the Dee, and the Trent-Witham-Ancholme Scheme. For all of these systems, the Agency will work closely with the relevant water company or companies.

4.6 Headroom

The Agency takes the view that headroom is an important part of the water resource planning process, but is not part of the calculation of deployable output. Deployable outputs are used together with other information about demands and options to determine appropriate levels of headroom and therefore the timing of additional resource development.

4.7 Resource Zones

As described above, water companies should allocate groundwater and surface water sources to Resource Zones using Form RZ1 shown in Appendix 3. Maps should also be provided for each water company supply area showing the geographic boundaries of each Zone.

5. WORK PLANS

The Agency is aware of the short timescale for this work, and will co-operate with the water companies to expedite the production of the required deployable outputs and estimates of water available for use. As the body with responsibility for publishing the results of this work, the Agency will need to monitor and report progress on the calculation of deployable outputs. Therefore the Agency needs water companies to prepare detailed work plans for the exercise. These should be agreed locally with the Environment Agency before 30 March 1997. The Agency will expect to be kept informed of progress against the plans and to be notified of any problems as soon as possible.

6. AGENCY CONTACTS

Environment Agency contacts are listed in Appendix 4.

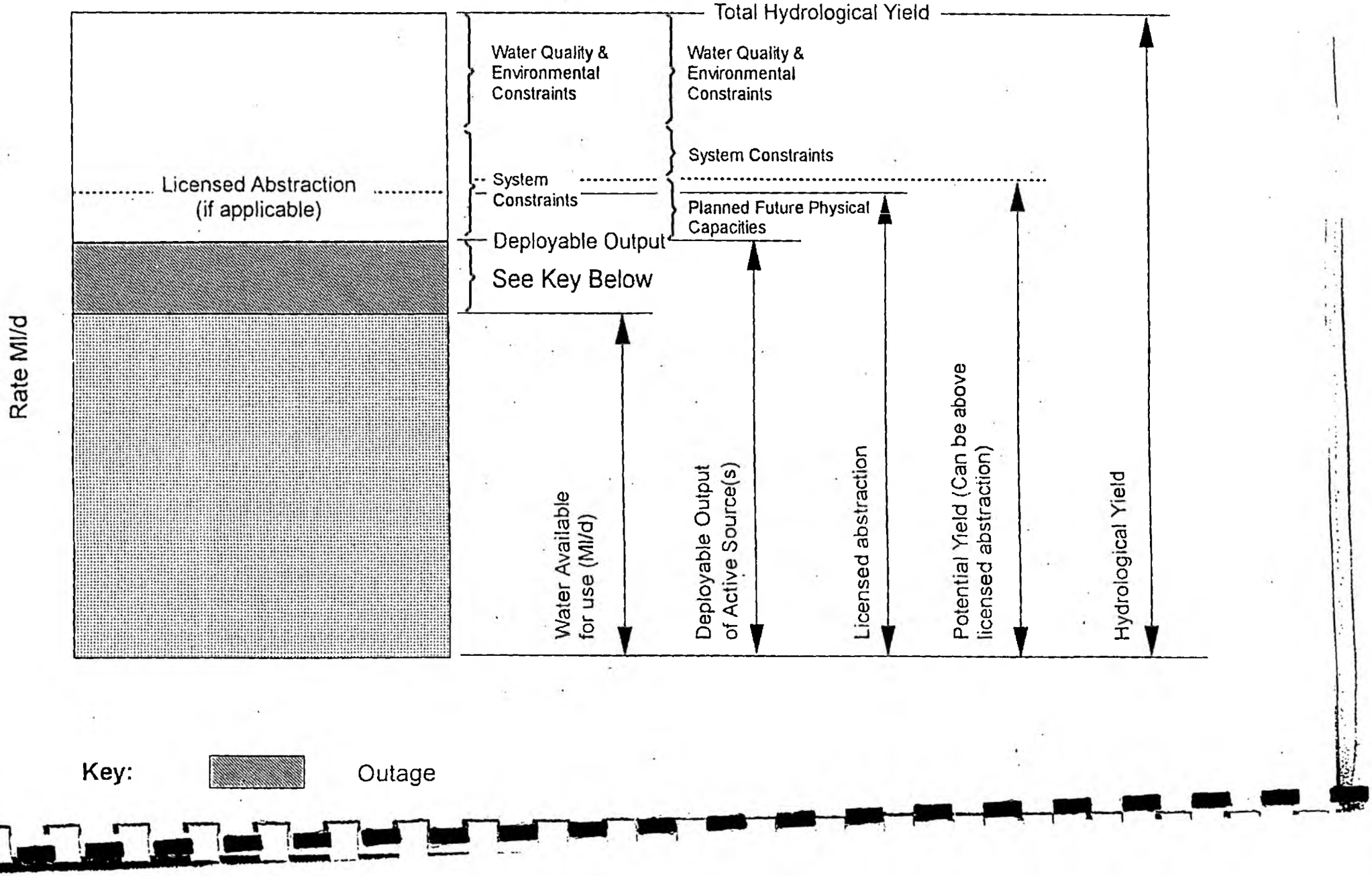
7. REFERENCES

1. Department of Environment, Water Resources and Supply: Agenda for Action, London, October 1996

2. Beeson, S., van Wonderen, J., Mistear, B. A Methodology for the Determination of Outputs of Groundwater Sources, UK Water Industry Research Limited, London, 1995.

3. Drayton, R., Lambert, A. Surface Water Yield Assessment, NRA Note 313, Bristol, 1995.

Figure 1. Terms used in the definitions of the output of an active source or group of active sources



Appendix 1: Groundwater Yield Assessment

1. INTRODUCTION

A distinction should be made at the outset between:

(i) the yields produced by discrete sourceworks, drawing on groundwater, and
(ii) the yield available from the resource of groundwater in a defined area of aquifer.

This appendix is concerned principally with the former which should be assessed by the water companies irrespective of any constraints which could arise from consideration of the latter. Such constraints will be considered by the Agency during the development of its water resources strategies. These constraints will take the form of proposals for reducing abstraction where unacceptable depletion of river flows or decline in groundwater levels have occurred or may develop in the future eg. where licence entitlements are not yet fully utilised. These proposals will fall into one of two categories; the first category will be fully investigated cases for which a solution will have been proposed by the Agency in consultation with the appropriate company (or companies) for implementation by 2005. The second category will comprise cases for which advance warning is being given by the Agency for remedial action after 2005 subject to the results of full investigations which can only be completed post 1999. The Agency will endeavour to produce an approximate figure for the possible loss of resource which could arise.

2. YIELD DEFINITIONS

The water industry and regulators have been developing a glossary of definitions for use in water resources planning and operations. These are summarised on Figure 1. Key definitions based on this diagram as applied to groundwater yield are as follows:

Deployable Output — The output for specified conditions and demands of a commissioned source or group of sources as constrained by:

- licensed quantities;
- water quality
- environment (constraints in licence);
- treatment
- raw water mains and/or aqueducts
- pumping plant
- transfer and/or output main
- well construction
- aquifer properties

Potential Yield	The yield for specified conditions and demands of a commissioned source or group of sources as constrained only by well construction and/or aquifer properties. This particular definition of yield is included here for completeness only and an assessment of it is not obligatory. It may be added where it is seen as a possible option for closing the Supply/Demand balance.
Hydrological Yield	The natural output of a source that can be supported by the catchment or aquifer feeding the source. This particular definition of yield is included here for completeness only and an assessment of it is not required.
Outage	A temporary loss of Deployable Output due to planned or unplanned events. Planned events are those such as maintenance of sourceworks; unplanned events are exclusively, pollution, turbidity, nitrate, algae, power failure and system failure.
Planning Allowance	These are not recognised as part of the methodology for estimating water available for use.
Water Available for Use	The Deployable Output of a source less deductions made for allowable outage. This will be the yield figure used in producing the companies' water resource plans but will be dealt with at Resource Zone level to accommodate the benefits available from alternative sources (including surface water) through integrated supply/distribution systems.

3. METHOD FOR GROUNDWATER SOURCES

The approach that will normally be required for determining the yields of groundwater sources will be that set out in the report of a recent project commissioned by the water industry through UKWIR (Beeson et al 1995). A range of assessment forms and diagrams is included in that report and are considered suitable for use without general amendment.

In summary, the average deployable output and the average day peak week (ADPW) deployable output should be determined for each discrete source which in the simplest case would be a single well, but often will be a group of wells in close proximity to each other, say within a few hundred metres. The relevant groundwater conditions for these outputs are as follows:

- the average deployable output of the source during a period when groundwater levels were at a minimum during the worst drought on record, an important estimate for the supply/demand balance for the company.

- the average day peak week (ADPW) deployable output of the source during the period of the worst historic drought, but not necessarily when groundwater levels were actually at an all-time low. This estimate of yield is particularly relevant to the ability of the source to meet short term demand and to the design of the distribution system;

Situations can occur where a number of discrete groundwater sources are regarded operationally as a group because, for example, they are covered by a group licence or linked by infrastructure which constrain group output to less than the sum of the outputs of the individual sources. In such cases, a group identification cover sheet should be completed (See Appendix 3, Form GW1) giving the above two estimates of deployable output for the group and commenting on the constraining factor.

4. TYPE OF ANALYSIS

The methodology for the assessment of the output of groundwater sources requires consideration of:

- the ability of the source to meet short-term (average day peak week demand - ADPW) and average demands under drought conditions; and

- the operational constraints on output, including pump capacity and intake level, abstraction licence conditions, treatment works capacity.

5. WATER LEVEL AND DEMAND CONDITIONS

The output of a groundwater source is determined by a complex interplay between the aquifer characteristics, particularly storativity and transmissivity, and a number of factors including:

- the water level in the well during a severe drought;
- the peak and average rates of pumping; and
- the well construction and associated hydraulics.

6. DROUGHT CONDITIONS

The water level for the source is defined by the year when groundwater levels fell to their all-time minimum values in the area of the source, as indicated by long term records, on a monthly or more frequent basis, from one or more local observation wells. Although a few records with more than 100 years of data exist, more records date from the 1960's or early 1970's giving between 35 and 25 years of record. However, at least two widespread severe groundwater droughts have occurred within the last 25 years so that many records show significant drought minima.

The drought of 1988 - 1992 was remarkably protracted causing groundwater levels to reach an all-time low in some areas of the UK, notably in east and south west England. In the south of England the 1976 drought had a greater impact on levels and in some areas to the west and north 1984 was more extreme. Due to this geographical variability in severity and to the relative shortness of most groundwater level records the concept of return period or frequency of occurrence has not been included as part of the UKWIR methodology.

7. PEAK AND AVERAGE RATES OF PUMPING

Peak output and average output place particular demands on groundwater sources during periods of drought and both need to be taken into consideration in the supply/demand balance and the design of distribution systems.

The methodology for the assessment of the deployable output of groundwater sources for the condition of peak week demand requires inspection of the distribution input record to determine the ADPW for the worst drought to have affected the area of the particular source. The high pumping rates during such periods are critical short term conditions for groundwater sources and can cause water levels to drop to levels which can be difficult to sustain. The sustainable rate of peak output identified from the pumping records under these critical conditions is an important factor for meeting short term peaks in demand, typically during hot, dry weather.

In the case of average demand, critical output assessments are based on monthly distribution input data for those months when groundwater levels were at a minimum during the worst drought on record. For those aquifers which recess rapidly, it is more appropriate to determine the output from weekly rather than monthly data.

These historic values of average and peak deployable output under drought conditions are based on operational experience and should be constrained if necessary to ensure that the quoted figures of 'deployable output' make due allowance for all current constraints ie,:

- licensed quantities;
- environmental constraints in the licence
- quality constraints;
- sourceworks constraints (which may have been imposed since the drought year used for the study).

8. WELL CONSTRUCTION AND POTENTIAL YIELD

The average and peak week deployable outputs described above are based on the historic operational performance of the groundwater source and do not necessarily represent the potential yield of the well or borehole. The potential yield of a source is the yield corresponding to the deepest advisable pumping water level (DAPWL) below which undesirable effects begin to occur due to constraints of well construction and/or aquifer properties.

In some cases the DAPWL will be controlled by features of the well construction, such as the base of the solid casing or the top of an adit, in other cases by features of the aquifer system, such as the base of the effective aquifer or the base of the confining layer. If these features are not constraints, the DAPWL should be set to a depth so as to prevent a significant reduction in output were the level to reduce further.

9. OTHER CONSIDERATIONS

Further consideration can be given to defining deployable output and potential yield using an analytical rather than operational approach where for example, the source has not been fully utilised and representative operational data are not available. An analytical approach uses measurements of drawdown for a range of outputs from short term (circa 100 minutes) yield - drawdown tests and their extrapolation by calculation for continuous pumping lasting 200 days (average demand) or 7 days (peak demand).

10. AUDITABILITY

A key factor of any methodology will be the requirement to demonstrate the assumptions and constraints used in the yield assessment calculations. The audit trail must be capable of inspection and verification by independent certifiers and the regulators. The methodology has tabular and graphical forms of assessment which provide the basis for a suitable form of audit. Attention will focus in the audit on the constraints on the deployable output, particularly where this is significantly below the potential yield of the source or the licensed quantity.

REFERENCE

Beeson, S., van Wonderen, J., Mistear, B. A Methodology for the Determination of Outputs of Groundwater Sources, UK Water Industry Research Limited, London, 1995.

Appendix 2: Surface Water Yield Assessment (including Conjunctive Use Systems)

1. INTRODUCTION

The purpose of this appendix is to outline the principles for the assessment of surface water deployable output.

2. YIELD DEFINITIONS

The definitions for surface water yield are in line with those which the industry have been developing for water resources planning and operational purposes. These are summarised in Figure 1 and given below:

Deployable Output — The term to be used to describe the useable yield of a system is the deployable output. Deployable output is the constant rate of supply that can be maintained from the water resources system, except during periods of restriction within the constraints listed below:

- based on a given level of service;
- simulating over the historic period for which data is available;
- without storage entering the emergency storage zone;
- within the defined physical capacities (of the existing system) adopted for the simulation;
- operating the source in accordance with the licence or for specified scenarios, a Drought Order or Permit;
- water quality.

Potential Yield — If some future physical capacities are included in the simulation then the resulting yield would be the Potential Yield with those assumed capacities. This particular definition of yield is included here for completeness only and an assessment of it is not obligatory. It may be added where it is seen as a possible option for closing the Supply/Demand balance.

Hydrological Yield — The Hydrological Yield is a special case of deployable output; being the maximum Potential Deployable Output, unconstrained by treatment or outlet capacities. This particular definition of yield is included here for completeness only and an assessment of it is not required.

Outage	A temporary loss of deployable output due to planned or unplanned events. Planned events are those such as maintenance of sourceworks; unplanned events are exclusively, pollution, turbidity, nitrate, algae, power failure and system failure.
Planning Allowance	These are not recognised as part of the methodology for estimating water available for use.
Resource Zone	The largest possible zone in which all resources, including external transfers, can be shared and hence the zone in which all customers experience the same risk of supply failure from a resource shortfall *(commentary: there should be no transfer constraints within a zone)*.
Water Available for Use	The Deployable Output of a source less deductions made for allowable outage. This will be the yield figure used in producing the companies' water resource plans but will be dealt with at Resource Zone level to accommodate the benefits available from alternative sources (including surface water) through integrated supply/distribution systems.

3. TYPE OF ANALYSIS

The methodology for the assessment of surface water deployable output should:

- simulate the realistic operation of the water resources systems in question;
- calculate the deployable output as the supply which can be met with a given Level of Service.

4. SIMULATION

The deployable output of the system in question should be simulated over as long a period as possible. Some water resources systems could fail to meet demand during dry periods occurring before the start of the specific hydrological record. These so called critical periods may occur as far back as the late 1800's in some cases and consideration should therefore be given to generating flow records back to the appropriate period.

5. AUDITABILITY

A key feature of any methodology will be the requirement to demonstrate the assumptions and constraints used in the assessment calculations. The audit trail must be capable of inspection by independent certifiers and the regulators.

6. STANDARDS OF SERVICE

Standards of Service should be linked to control rules to be used in the simulation of the system's operation. For example, one control rule could indicate the storage for the time of year when hosepipe bans should be introduced by the water company. Others could define introductions of bans on non-essential use or rota cuts.

During the simulation, supply is cut back when storage crosses the control rule line when drawdown is taking place and supply is increased when the control rule line is crossed on recovery of storage.

The standards of service appropriate to the simulation are the frequencies with which restrictions are required. If the frequencies of restrictions are high then the Deployable Output is increased and vice-versa.

7. RESTRICTIONS IN SUPPLY

It will be necessary to quantify the cutbacks in supply when supply restrictions are imposed in the simulation under scenario (ii) (see Section 4.2). The amount of cut backs are likely to vary between companies and regions of the country. Typical ranges for the following cutbacks will need to be specified where necessary based on historic experience or detailed assumptions:

- voluntary restrictions;
- hosepipe bans;
- non-essential use;
- rota cuts/standpipes.

8. CONTROL RULES

Control rules for some systems can be complex and it is not appropriate to specify how they should be calculated. In some cases a trial and error approach may be necessary.

9. EMERGENCY STORAGE

'Emergency Storage' is a reserve storage aimed at accommodating the operational uncertainty regarding the duration of a particular drought and should be allowed for in calculating Deployable Output. In practice an operator cannot run the risk that a drought will be no more severe than has been experienced in the historical or extended historical record.

Emergency Storage is calculated as the volume of water required to meet a specified demand for a certain number of days.

The number of days to use is a function of what other emergency back-up is available to the supply system and on analysis of dates associated with the historic end of droughts. The assumption is subjective but, for example, a typical value of Emergency Storage might be 30 days of supply but could be more or less depending on reservoir characteristics.

10. ENVIRONMENTAL IMPACT

The impact of a system's operation on the environment is a key factor in calculating the Deployable Output. A number of factors would need to be taken into account in deriving the frequency at which environmental impact might be acceptable through the use of drought orders/permits. In broad terms, the more severe the drought then the greater the impact which the Agency would be prepared to accept that the aquatic environment should undergo, if matched by increasingly severe demand restrictions.

Form GW1

Appendix 3: Forms

Environment Agency Reassessment of water company yields

Groundwater Grouped Source

Water Company	

Groundwater group name		Reference	

Sources:

Licence number	Source name

Group average deployable output (Mld)	
Group average day peak week (Mld)	

Completed by		Signed		Date	

Notes:

1 Any supporting information should be attached.

Form SW1

Environment Agency Reassessment of water company yields

Surface Water Yield Assessment
(including groundwater when part of a conjunctive use scheme)

Water company	

System name		Reference	

Sources comprising the system:

Licence number	Source name	Surface/ Ground/ Reservoir	Comments

Hydrological Records used:

From	To	Comments (naturalised, denaturalised, modelled etc)

Form SW1 (continued)

Deployable output

Scenario	Deployable Output Mld	Assumptions (refer to detailed notes below)
(i)		no restrictions in supply or drought orders/permits
(ii)		water company defined:
(iii)		5% demand restriction 1 in 10 years, further 5% 1 in 40 years, drought orders/permits specified by the Environment Agency and described in "other comments" below

Other comments:

Full report reference:

Completed by		Signed		Date	

Notes:

1 Schematic diagram of system should be attached.

Form RZ1

Environment Agency Reassessment of water company yields

Resource Zone Scenario ( )
(enter (i), (ii) or (iii))

Water company	

Resource zone name		Reference	

Sources:

Licence number	Source name	Surface/Ground/ Reservoir	Deployable Output Mld
		Total Deployable Output Mld	

Form RZ1 (continued)

Outage Mld	
Justification and assumptions	

Water available for use (Mld) [total Deployable Output - outage]	

Completed by		**Signed**		**Date**	

Notes:

1 Resource Zone map showing source location should be attached.
2 For conjunctive use schemes, quote total deployable output rather than individual values.
3 Any supporting information should be attached.