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DISCUSSION PAPER FOR WWF's ITCHEN INITIATIVE

SMARTER LICENSING TO REDUCE DAMAGING ABSTRACTION FROM ENVIRONMENTALLY FRAGILE RIVERS BY SOURCE SUBSTITUTION AT MINIMUM COST AND WITH MINIMUM POSSIBLE IMPACT ON WATER RESOURCES YIELD

. RIVER DART CASE STUDY

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Background

The Itchen Initiative is a WWF project that aims to develop solutions that will enable England and Wales to meet the challenges of water scarcity, to benefit both people and nature. The Initiative is named after the River Itchen, one of the world's most beautiful and iconic rivers, now threatened with over-abstraction of water, a growing population, and climate change. The Initiative is intended to inform, in particular, Defra's 2011 Water White Paper and Ofwat's review of the regulatory arrangements.

WWF commissioned a number of discussion papers to inform the Itchen Initiative process. This discussion paper considers potential use of a smarter licensing regime to reduce damaging abstraction from the river Dart, while minimising reductions in yield. WWF would like to thank South West Water for their contributions to the Itchen Initiative work.

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1. INTRODUCTION

This report summarises work undertaken by South West Water, and used by WWF's Itchen Initiative, to examine the costs, benefits and practicalities of using a simple form of scarcity pricing to change the order in which water is taken from different sources in an integrated (multiple source) water resources system, during a drought. A summary of the results obtained by South West Water's Supply Demand Strategy team using their water resources planning tools, and the conclusions that may be drawn from those results are included as a case study in WWF's Itchen Initiative Report. [1] This supporting report provides a fuller account of the work that was undertaken, and a more detailed analysis and interpretation of the results that were obtained. South West Water's own note on the work undertaken by themselves is included as Appendix 1 to this report.

2. CONTEXT

The Itchen Initiative advocates smarter and more environmentally sensitive use of water resources. Taking water from natural sources in a flexible and sensitive way, based on each source's particular capacity to supply when water is plentiful and its vulnerability to damage when it is not, is at the heart of the Itchen Initiative's thesis. Smart abstraction licences and permits based on these principles would include not just limitations on abstraction when flows or levels reach environmentally threatening levels, but more sophisticated regimes that signal environmental needs and resource availability throughout the flow range.

One of the suggestions proposed for consideration is a tiered abstraction permitting regime, wherein the volume of water that may be abstracted from a source is zero below some flow threshold, and rises commensurately with the source's capacity to supply without incurring damage as flow rises. A test of this tiered permitting approach, in which abstraction is managed by varying the volume that may be taken, was presented in the Itchen case study included in the Itchen Initiative Report, and in a detailed supporting paper.[2]

Another approach that may be taken to control abstraction from environmentally fragile sources is to use price to signal where and when water in the environment is scarce (with the unit cost of abstraction then being set high) and where and when it is plentiful (with the unit cost of abstraction then being set low). Here work being undertaken by South West Water on abstraction from the River Dart and adjacent sources within the Roadford Strategic Supply Area (SSA) has been used to illustrate the potential for using price to reflect the (relative) environmental value of water, and its variability from time to time and from source to source, and thence to change the preference with which water is taken from a set of possible sources (by order, and by amount).

Under the current approach to ending unsustainable abstraction, licences that are judged to be damaging (or potentially damaging) to the environment are revoked or amended, where there is a statutory basis and duty for such damage to be rectified, or where compensation funds accumulated

[1] LeQuesne, Fenn, Less & Timlett, 2011. The Itchen Initiative: smarter water management for people and nature. WWF, 2011.
[2] Fenn and Wilby, 2011. Smart licensing to reduce damaging abstraction from environmentally fragile rivers with minimum possible impact on water resources yield. R Itchen case study. Discussion Paper for WWF's Itchen Initiative..WWF, 2011.

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under the Environment Agency's Environmental Impact Unit Charge (EIUC) scheme permit the Agency to negotiate suitable revocations. When licence reductions from such measures occur, they typically produce a reduction in the water available for use (WAFU) in a resource zone[3]. Under circumstances where the contribution that may be made by demand side measures to the imbalance thus created is either insufficient or prohibitively expensive (or both), the reduction is generally off set by the development of a new resource[4], typically at a cost of between £1.5 million and £7 million per Ml/d. Such an approach can be thought of as a 'resource replacement' approach.

While there will frequently be a need for such 'resource replacement' approaches, whether instead of or as well as demand side measures, there is also an opportunity to complement them (if not replace them) with what may be called 'source prioritisation' approaches: the substitution of water from vulnerable sources at times of local scarcity by water from other sources of lower vulnerability at such times. The River Dart case study described below illustrates the potential of such an approach, using price as a means to signal the scarcity/vulnerability condition of water taken from an environmentally fragile source.

3. A TEST OF THE COSTS AND BENEFITS OF SCARCITY-BASED CHARGING ON ABSTRACTION FROM THE RIVER DART, DEVON

The test area

Figure 1 is a simplified schematic of part of South West Water's Roadford Strategic Supply Area, around the River Dart catchment in South Devon. The Littlehempston Water Treatment Works which serves Totnes, Torbay and the surrounding area is served by five separate sources, three of which (River Dart, Dart boreholes and Rannies groundwater) take water from the Dart catchment and two of which (Burrator transfer, Gunnislake transfer) take water from other catchments. The River Dart source is a flashy run-of-river source with no significant storage, whereas the two groundwater sources and the two inter-basin transfer schemes supported by releases from Burrator and Roadford reservoirs benefit from storage capacity[5]. The Burrator and Roadford schemes serve Plymouth as well as Totnes and Torbay.

At present, and subject to licence limits and the need to conserve sufficient water in storage to meet high demand in annual peak demand periods, and in the event of a drought, water is generally taken from the five sources in order of least operating cost [6], with the Rannies groundwater and Dart borehole sources being least cost, the River Dart next, Burrator next and Gunnislake/Roadford last.

[3] Through a reduction in deployable output (DO).
[4] The lost resource could instead be replaced by a demand management scheme, but such schemes tend to be of limited 'yield' and of too high a cost (under prevailing approaches to quantifying yield and cost in the round). In practice, therefore, new resource schemes tend to be those that fill the void created by sustainability reductions.
[5] Burrator Reservoir is a so-called single season storage facility, which generally provides storage sufficient to cover rainfall deficits over only a single summer season. Roadford Reservoir is a multi-season facility which is able to ensure supplies over more than one year.
[6] Licence charges are fixed costs (being based on licensed quantities, not the quantities actually abstracted), so treatment, pumping and carbon costs determine the order of variable cost and use.

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This order of source usage is taken to be the base scenario, for cost, yield and storage impacts analysis.

Whilst the River Dart, and the species it supports, is vulnerable to abstraction at low flows, the existing licence includes no hands off flow protection. The licence has daily maximum and annual maximum authorised quantities of 27.28 Ml/d and 9,410.4 Ml/a respectively. The permitted abstraction constitutes as much as 30% of total flow in low flow spells (30% at the Q99, 20% at the Q95).

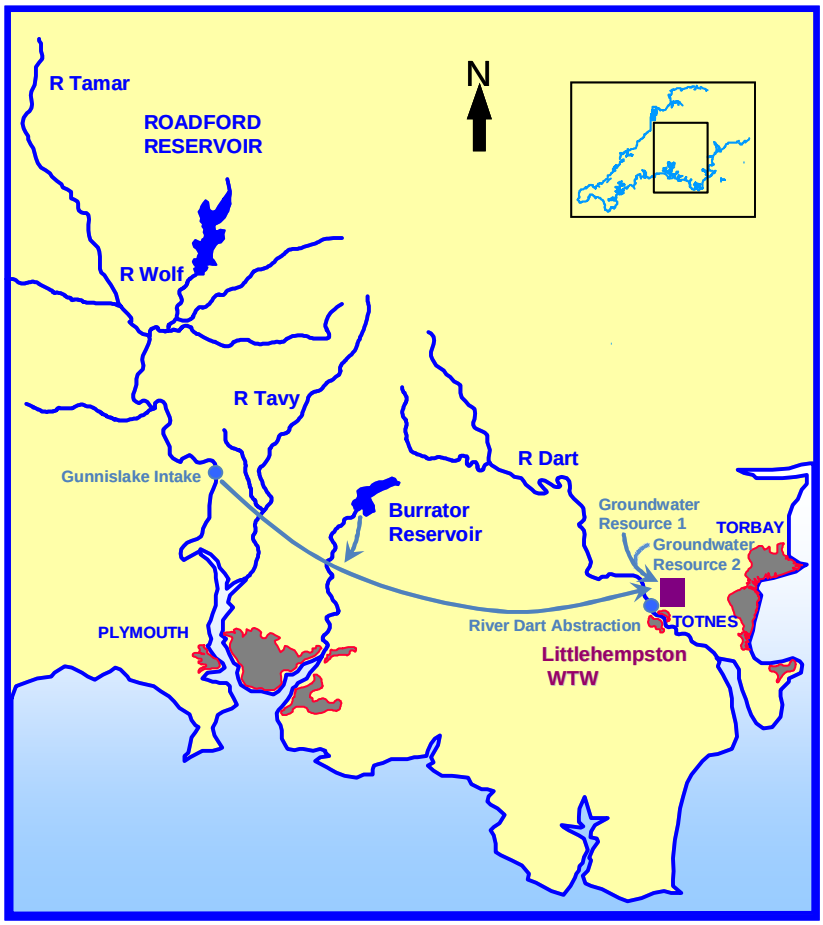

Figure 1: Schematic map of the water resources system of the River Dart and the adjacent area

The test design

To examine the benefits of introducing a hands-off flow condition, for comparison against the existing abstraction regime, and against scarcity-priced variants, a Scenario A test was included in the analysis, with abstraction from the River Dart being prohibited when its flow falls to the Q95 flow (1.53 m^3/s, or 132.2 Ml/d). The Q95 is the flow that is equalled or exceeded 95% of the time, over the long run, and hence is so low a flow as to have a chance of not being achieved in only 5% of all cases.

For the principal purpose of this study, the operating preference was changed to provide greater protection to the River Dart by making its water the most expensive of all when flows in it fall to critical low flow levels. Given the existing order of usage (groundwater sources first, then the River

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Dart, then Burrator, then Gunnislake/Roadford), the change made has the effect of mandating the use of stocks from Burrator and Roadford storage before abstracting from the River Dart at times of low flow[7].

Two low flow thresholds were used for the purposes of this test: the Q95 for test Scenario B and the Q70 for test Scenario C. The Q70 is the flow that is equalled or exceeded 70% of the time, and is correspondingly greater than the Q95 in magnitude terms (Q70 = 4.135 m^3/s, Q95 = 1.53 m^3/s). The Scenario C test accordingly raises the unit cost of abstracting water from the River Dart to the highest of all sources at a relatively high flow level (and hence provides high protection to low flows in the river). The Scenario A and Scenario B tests which use the Q95 as the low flow threshold hence protect the lowest flows in the river more than does the existing (Base Scenario) abstraction regime, but make no change to the priority order for the use of River Dart water when flow is higher than the Q95 flow, compared to the existing regime. Scenario C, which uses the Q70 as the flow threshold for price differentiation, provides significantly more environmental protection[8].

South West Water modelled the Dart area of the Roadford SSA to simulate abstraction from the five sources in the test area to meet realistic demand under 1995/96 drought conditions. The demand profile used for each of the two years of the simulation period was taken to be that of forecast demand for 2010/11 in South West Water's final Water Resources Management Plan for 2010 to 2035. The 1995/96 drought is deemed to correspond to a relatively severe event, it being the second most severe drought experienced in 54 years of record.

The model was run using the four abstraction priority regimes defined above (base, A, B and C scenarios), which, using the following numerical code for the five available sources, can be summarised as follows (in order of increasing cost):

For 1 = Rannies groundwater; 2 = Dart boreholes; 3 = River Dart; 4 = Burrator transfer; 5 = Gunnislake/Roadford transfer, and where sources grouped within brackets have equal priority of use:

Base scenario: (1,2), 3, 4, 5.

Scenario A: (1,2), 3a, 4, 5; with 3a being abstraction from the River Dart at flows greater than Q95, and with a hands-off flow on abstraction from the River Dart at flows of and below the Q95.

Scenario B: (1,2), 3a, 4, 5, 3b; with 3a being abstraction from the River Dart at flows greater than Q95, and 3b being abstraction from the River Dart for flows at and below the Q95.

Scenario C: (1,2), 3a, 4, 5, 3b; with 3a being abstraction from the River Dart at flows greater than Q705, and 3b being abstraction from the River Dart for flows at and below the Q70.

[7] Subject to licence and operating rules. In practice, stocks in Burrator reservoir fall in line with flows in the R Dart in low flow periods, so raising the abstraction priority order of Burrator over R Dart has little practical effect.

[8] A range of other prioritisation schemes might be used, to explore the different effects of each, and to determine a net best arrangement.

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4. RESULTS AND OBSERVATIONS

Table 1 below (taken unchanged from Appendix 1) summarises the results obtained from the simulation tests using abstraction scenarios A, B and C, in comparison to the base scenario, with existing daily (27.28 Ml/d) and annual (9,410.4 Ml/a) licensed maximum abstraction values observed.

Table 2 provides equivalent results for scenarios A, B and C with the existing daily and annual maximum abstraction values removed. In all cases, the values shown relate to operation over the two years of the 1995/96 drought.

Run	Additional reduction in Roadford storage over the 2 year drought (1995-96)	Extra water pumped to support reduction in Dart abstractions over 2 year drought	Estimated future cost of additional water pumped over 2 year drought (based on an assumed unit rate of £52/Ml)	Estimated carbon cost of additional water pumped over 2 year drought (& estimated cost in Carbon Reduction Commitment emissions allowances, at £12/tCO_2)
Base	0	0	0	0
Scenario A: No abstraction when flows in the River Dart are <Q95 (Hands off Flow). Abstraction from flows >Q95 is cheaper than alternative sources.	4%	1320	£68,640	494 tCO_2 (£5928)
Scenario B: When flows in the River Dart are <Q95 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q95 is cheaper than alternative sources.	4%	1320	£68,640	494 tCO_2 (£5928)
Scenario C: When flows in the River Dart are <Q70 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q70 is cheaper than alternative sources.	13%	5574	£289,848	2086 tCO_2 (£25,032)

Table 1: Results from Scenario A, B and C abstraction regimes, compared to the existing regime (Base Scenario), with existing daily and annual abstraction maxima retained.

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Run	Additional reduction in Roadford storage over the 2 year drought (1995-96)	Extra water pumped to support reduction in Dart abstractions over 2 year drought	Daily maximum abstraction from the River Dart
Base	0	0	27 Ml/d (annual volume abstracted is within the annual 9410 Ml limit)
Scenario A: No abstraction when flows in the River Dart are <Q95 (Hands off Flow). Abstraction from flows >Q95 is cheaper than alternative sources.	1%	227 Ml	50 Ml/d (annual volume abstracted remains within the annual 9410 Ml limit)
Scenario B: When flows in the River Dart are <Q95 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q95 is cheaper than alternative sources.	1%	227 Ml	50 Ml/d (annual volume abstracted remains within the annual 9410 Ml limit)
Scenario C: When flows in the River Dart are <Q70 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q70 is cheaper than alternative sources.	13%	5547 Ml	28 Ml/d (annual volume abstracted remains within the annual 9410 Ml limit)

Table 2: Results from Scenario A, B and C abstraction regimes, compared to the existing regime (Base Scenario), with existing daily and annual abstraction maxima removed.

Abstraction from the River Dart in the base scenario

Under the base scenario, daily abstraction volumes from the River Dart over the course of the two year drought are greater under low flow conditions (when demand is high) than it is under high flow conditions (when demand is lower). This illustrates the nature of the problem under review, and points to the need to find a means of arresting the least-cost incentive to take high quantities of low cost water from at-risk sources at just the time those sources are at most risk.

Impacts on abstraction from groundwater

In all model runs, abstraction from the two groundwater sources is the cheapest and first option. Under the tests conducted, there is accordingly no impact on groundwater yields and reserves.

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Impacts on storage in Burrator reservoir

Whilst the stated priority list places transfers from Burrator reservoir before abstraction from the River Dart at low flows, stocks in Burrator reservoir declined in line with flow in the River Dart, during the 1995/96 sequence modelled. When the low flow control on abstraction from the River Dart became operative (whether as a hands off flow, in Scenario A, or a higher unit cost to abstract, in Scenario B), stocks in Burrator reservoir were unavailable for transfer to Littlehempston. The schemes tested thus had no impacts on storage in Burrator reservoir.

Impacts on storage in Roadford reservoir.

When the low flow control on abstraction from the River Dart became operative (whether as a hands-off flow, in Scenario A, or a higher unit cost to abstract, in Scenario B), transfers from Gunnislake/Roadford made good the reduction in water taken from the River Dart, to the full extent required to meet prevailing demand. The impacts of the various regimes on storage in Roadford reservoir are shown in Tables 1 and 2, and are discussed below. With existing licence limits retained, the stocks in Roadford are reduced by 4% (1320 Ml) when the Q95 is used as the low flow threshold and by 13% (5574 Ml) when the Q70 is used as the low flow threshold. With existing licence limits relaxed, to enable unrestricted abstraction from the River Dart at above those low flow thresholds, the reduction in storage in Roadford reservoir falls to 1% (227 Ml) with the Q95 as the operative low flow control, but remains at 13% (5547 Ml) with the Q70 as the low flow control.

Results from the use of hands-off flow and higher price devices to manage abstraction below the Q95 flow

Comparison of the results for Scenario A versus those for Scenario B in both Tables 1 and 2 indicates that the Scenario A regime, with hands-off flow protection to flows of and below the Q95, and the Scenario B regime, with highest unit cost abstraction rates when flow falls to and below the Q95, deliver identical results. This is because under the prioritisation order used in the test, demand is met by drawing water from the cheapest sources in order of their cost (lowest first), to the extent of their capacity, and in the case modelled, cheaper water from source 5 (Gunnislake/Roadford transfer) is available in sufficiently high quantities so as to make higher cost abstraction from the River Dart unnecessary. In the particular case and test, the two controls achieve the same outcome.

The cost, benefits and consequences of protecting flows in the River Dart at and below the Q95

The results presented in Table 1 for Scenario B tell us that with existing daily and annual abstraction maxima retained (at 27.28 Ml/d and 9410 Ml/a respectively):

- the additional (pumping and carbon) costs of protecting low flows (<Q95) in the River Dart is around £75,000 over the two years of the drought event modelled; the cost derives from transferring water from Roadford/Gunnislake for a total of 48 days, to make good lost resources from the River Dart at 27.28 Ml/d, at an average cost of £1,541 a day[9]
- the stocks in Roadford reservoir are reduced by 4%, compared to the base scenario, as a result. This reduces water available for use elsewhere.

[9] Carbon costs have been included at £12/tCO_2.The cost is expected to rise to £16/tCO_2 by 2014, and perhaps higher thereafter.

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Extrapolating, and noting that by definition, flow typically falls to and below the Q95 on 182 days per decade, the cost of protecting low flows in the River Dart from abstraction when flow falls to the Q95 would be around £282,000 a decade. If the River Dart licence was revoked, the replacement cost of the 27 Ml/d resource loss would probably be in the order of £50 million to £100 million. Source substitution based on simple scarcity pricing would appear to have merit as an alternative solution to the low flow abstraction problem (even under a rising cost of carbon).

The cost, benefits and consequences of protecting flows in the River Dart at and below the Q95, with existing licence limits relaxed

The results presented in Table 2 for Scenario B tell us that with existing daily and annual abstraction maximum values removed, to enable the (relatively cheaper) resources of the River Dart at higher flows to be used without daily abstraction limitation:

- maximum daily abstraction from the River Dart at flows >Q95 would be 50 Ml/d, compared to the current maximum of 27 Ml/d. This may be environmentally undesirable, particularly at flows above but close to the Q95. The relative unattractiveness of this option needs to be balanced against the gain achieved by taking more water at flows above the Q95 than at present against the correspondingly reduced need to take water from Gunnislake/Roadford (see below), with consequentially reduced impact on the loss of water available for use elsewhere. The use of a higher threshold for lower cost abstraction than the Q95 (even when the Q95 is used as the low flow protection threshold) commends itself here. Fine tuning of unit costs of abstraction throughout the flow range, as opposed to the use of just one rate below the threshold, and one above, merits investigation.

- inter-basin transfers from Gunnislake/Roadford reduce from 1,320 Ml to 227 Ml over the course of the two year event (compared to the retention of existing licence limits situation), with pumping and carbon costs falling commensurately, and with less demand on reservoir stocks that may be used elsewhere.

- the stocks in Roadford reservoir would be reduced by only 1% compared to the base scenario.

The cost, benefits and consequences of protecting flows in the River Dart at and below the Q70

The results for Scenario C in Tables 1 and 2 are identical, because the unfettered daily maximum abstraction from the model turns out to be 28 Ml/d (close to the existing daily limit of 27.28 Ml/d), and the total annual volume abstracted is lower than the existing annual licensed quantity of 9,410 Ml/a. That this is so reflects the fact that the requirement for additional abstractions (over and above those from the two (cheaper) groundwater sources) occurs when flows in the River Dart are within the Q95 to Q70 flow band.

The results show that to provide protection to low flows in the River Dart at flows of and below the higher protection level of the Q70 (4.135 m^3/s, 357.3 Ml/d):

- the total additional (pumping and carbon) operating cost would be around £315,000 for a two year 1995/96 drought, with transfers from Gunnislake/Roadford being required to support lost yield from the River Dart at 27.28 Ml/d for 204 days over the two years of the drought period.

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- extrapolating, and on the basis that over a decade the number of transfer days required to support the Q70 is 1096, the costs of protecting flows below the Q70 would be around £1.689 million per decade.

- stocks in Roadford would be reduced by 13% as a consequence of providing this support, to the detriment of the use of those resources elsewhere.

As is to be expected, it is apparent that the use of a higher standard of protection for low flows in the River Dart has a greater knock on consequence for the availability of resources elsewhere. It is also clear that to achieve the maximum benefit from river yields during flows of >Q70 requires careful design of the prioritisation arrangements. The ability to store such cheap river water for use in dry and drought spells would provide useful balancing potential too, if such storage could be provided at an acceptable financial and environmental cost.

5. CONCLUSIONS

The results from the simple scarcity pricing test conducted on the River Dart indicate that there is scope for price to be used as a means to incentivise the use of some sources, and to disincentive the use of others, to good environmental effect. The test conducted was extremely limited. Hence the design of any scheme to protect low flows in vulnerable rivers would need to be carefully crafted, ensuring that water resource managers would in fact act in the way a modelling algorithm automatically achieves all too easily; and to ensure the avoidance of unintended consequences like allowing high rates of abstraction to the river's detriment at flows just above the threshold of vulnerability defined. There would be little gain in resolving an over-abstraction problem in one flow range only to create another in a different flow range. The knock-on consequences of taking water from other sources to support lower abstraction from one or other sensitive source also need to be factored into play. Saving one source at the expense of another, or at the cost of reduced deployable output from the water resources system as a whole, would not be a satisfactory solution. So whilst the preliminary results from the simple study described in this paper give cause for hope that price may be used as a means to signal relative environmental vulnerability, the details of a workable price-based solution for this and other particular cases will need careful attention.

Notwithstanding these caveats, a number of conclusions follow from the results produced thus far:

- The 'source prioritisation' approach modelled in this case suggests that environmental benefits could be achieved for a fraction of the costs of 'resource replacement' approaches. While replacement of a 27 Ml/d resource may cost up to £100 million through a resource replacement approach, the source prioritisation approach modelled here was able to provide Q95 low flow protection over a 2 year drought for £75,000 in additional operating costs (£315,000 for Q70 protection). It is important to note that these costs would only be required in dry years where the Dart levels fall significantly. Given that flows of and below the Q95 typically occur on only 182 days per decade (5% of the time), the total cost of substituting water from Roadford instead of abstracting water at Q95 low flows in the Dart would be in the region of £282,000 over a decade; a fraction of the cost of the 'resource replacement' option. For Q70 protection, the equivalent cost would be £1,689 million per decade; still a fraction of the traditional replacement cost. It should be noted that the modelling work conducted did not evaluate the costs of this scheme in reduced deployable

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output elsewhere in the supply zone, but with Roadford stocks being reduced by 1%~4% (according to daily licence limits on abstraction from the River Dart at flows >Q95), the initial results are encouraging. The knock-on impacts of protecting lows flows to a Q70 standard would be greater (reducing storage in Roadford by 13%), and would require in-depth investigations before adoption.

- The principal drawback of this approach is that it may not provide sufficient protection to low flows in the River Dart in the case of the most severe droughts, when all available sources of water may be required for public water supply. These events are, by definition, rare, although they may potentially become less so under climate change. The possible need for investment in 'resource replacement' schemes to ensure protection for critical resources under climate change is not denied. But 'source substitution' offers at least a complementary and supportive option, whatever the future may bring.

- The potential for a source prioritisation approach to be effective is dependent, by definition, on a range of available sources to meet supply. The extent to which this is the case will vary between supply zones. The more integrated or inter-connected the resource zone within which sensitive sources lie, the greater is the possibility for protecting those sensitive sources at times of scarcity, by source substitution and/or resource levelling.

- Equally, the greater the capacity to store water taken from periodically sensitive sources at times when those sources are not under stress, and have water available for abstraction, the greater their resource can be used and the less the resource of other sources would need to be used. Such storage may, but may not, take the form of large strategic reservoirs. One other option would be to develop an integrated system of small-scale storage facilities, sized to exploit the available surplus from sensitive sources. Another option would be to use aquifer-storage recovery, where local hydro-geological conditions permit.

- The tests run with South West Water were rapid and preliminary and formed part of a wider programme the Company was undertaking to explore future potential water resource and environmental options. More in-depth and extensive analysis leading to the development of efficient operating rules will generally be needed to identify optimal environmental options with least impact on cost and deployable output.

- The annual charge paid by South West Water to the Environment Agency for the abstraction from the River Dart at Littlehempston in 2010/11 was £119,531. This is more than the additional cost that would have resulted from the use of Roadford water rather than the River Dart water under the 1995/96 model. This implies that, in this case at least, a 'scarcity charge' on the use of water from the Dart set at the same level as the current abstraction charge would have the potential to modify behaviour to achieve some environmental outcomes.

If such 'source prioritisation' approaches are to be successful, they depend on the availability and assessment of a range of options across networks. This type of approach is, therefore, significantly more likely to be successful if applied in 'whole of catchment' or 'whole of network' approaches, rather than through a site-by-site approach.

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Appendix 1: South West Water's summary of the work undertaken for the River Dart case study

The following note was prepared by Jo Robinson of South West Water's Supply Demand Strategy Group, to report the work undertaken by South West Water and used by the Itchen Initiative. This work was part of a wider programme being undertaken by the Company to explore future potential water resource and environmental options.

South West Water Smart Licensing Test

1. Aims and Objectives

Smart Licensing is a concept based on the application of variable abstraction licence charges whereby the unit cost of abstraction rises as water scarcity increases.

The aim of this work is to assess the impact of Smart Licensing compared with the current practice of charging an annual abstraction licence, to determine whether a sliding scale of charges for water abstracted would make a difference to the use of water from a Smart Licensed source.

A water resources model set up to optimise on relative costs, was used to aid an appraisal of the potential of Smart Licensing for a South West Water public water supply abstraction during a drought year.

The concept of Smart Licensing was applied to abstractions from the River Dart which supplies Littlehempston Water Treatment Works (WTW). Supply to Littlehempston can also be provided by several alternative sources:

- Dart Boreholes and Rannies groundwater source.
    - Cheapest water relative to alternative sources.
- Burrator Reservoir
    - Single season reservoir with direct gravity supply.
    - Net storage 4210 Ml.
- Pumped abstractions from the River Tamar at Gunnislake supported by augmentation releases from Roadford Reservoir.
    - Multi-season strategic reservoir.
    - Roadford net storage 34500 Ml.

2. Modelling

The South West Water water resource optimisation model was run for several scenarios to test the concept of Smart Licensing.

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The flow in the River Dart was split into bands based on percentile flow values[10]. A rising scale of abstraction charge was applied to each flow band with the highest costs applied to the band encompassing the lowest river flows.

The model was run for the relatively severe drought of 1995-96 using the current forecast demand data for 2010-11. Running a two year period was necessary in order to determine the longer term impact on increased augmentation releases from Roadford Reservoir. Roadford is a multi-season reservoir and therefore the impact of increased use in a drought year may also have implications for storage in subsequent years.

2.1 Modelled Scenarios

Base Run Scenario: Model run with current abstraction licence conditions.

Scenario A: No abstraction when flows in the River Dart are <Q95 (Hands off Flow). Abstraction from flows >Q95 is cheaper than alternative sources.

Scenario B: When flows in the River Dart are <Q95 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q95 is cheaper than alternative sources.

Scenario C: When flows in the River Dart are <Q70, the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q70 is cheaper than alternative sources.

In all scenarios, the current River Dart abstraction licence conditions are assumed to be in place.

The model was also run under each scenario with no daily and annual licence limits thereby making the constraint the maximum amount of water required to meet demand at the WTW. The aim of this was to see how this would affect the volume of abstraction from the River Dart over a two year drought period.

3 Results

The results of the model runs, along with general observations of how the system would operate in practice, provide an insight into how Smart Licensing may work in this example.

3.1 Impact on Groundwater Abstractions

[10] Percentile flow values were obtained from the CEH UK National River Flow Archive and are calculated using the long run record of gauged daily flow for the River Dart at Austin's Bridge. (http://www.ceh.ac.uk/data/nrfa/data/time_series.html?46003)

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There is no impact on groundwater abstractions between model scenarios because the groundwater source is assumed to be the cheapest source of water relative to the alternatives in all model runs.

3.2 Impact on Burrator Abstractions

There is minimal impact on abstractions from Burrator between the Base run and the Scenario A, B and C runs. This is because Burrator reservoir storage usually drops at the same time as flows in the Dart are low and hence there is no surplus water available from the reservoir in addition to that required to meet local demand.

3.3 Impact on River Tamar/ Roadford Abstractions

In a drought the main alternative source to abstraction from the Dart is pumped abstraction from the River Tamar at Gunnislake supported by augmentation releases from Roadford Reservoir. Therefore, in a drought, Smart Licensing has an impact on both the storage of the strategic reservoir (and hence Water Available for Use) and pumping costs, as shown in Table 1.

As can be seen in Table 1, the cost of any additional pumping required from Gunnislake is significant. Any additional energy costs will also attract a carbon emissions charge of £12/tCO_2 from 2012 under the Carbon Reduction Commitment (CRC). This is predicted to rise to £16//tCO_2 by 2014. To put these additional costs in context, the 2010/11 abstraction charge for the River Dart licence was £119,531.

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Run	Additional reduction in Roadford storage over the 2 year drought (1995-96)	Extra water pumped to support reduction in Dart abstractions over 2 year drought	Estimated future cost of additional water pumped over 2 year drought (based on an assumed unit rate of £52/Ml)	Estimated carbon cost of additional water pumped over 2 year drought (& estimated cost in Carbon Reduction Commitment emissions allowances)
Base	0	0	0	0
Scenario A: No abstraction when flows in the River Dart are <Q95 (Hands off Flow). Abstraction from flows >Q95 is cheaper than alternative sources.	4%	1320	£68,640	494 tCO_2 (£5928)
Scenario B: When flows in the River Dart are <Q95 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q95 is cheaper than alternative sources.	4%	1320	£68,640	494 tCO_2 (£5928)
Scenario C: When flows in the River Dart are <Q70 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q70 is cheaper than alternative sources.	13%	5574	£289,848	2086 tCO_2 (£25,032)

Table 1: Key Results for Modelled Scenarios

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3.4 Difference between 'Hands off' and High Cost Abstractions at Low Flows

As can be seen in Table 1, there is very little difference between model outputs for Scenario A assuming a Hands off Flow <Q95 and Scenario B with available, but more expensive, abstractions at flows <Q95. This is because the cost of water from the alternative pumped source is still cheaper than from the River Dart.

3.5 The Influence of Daily and Annual Licensed Limits

Table 2 shows the results of model runs with no daily or annual abstraction constraints.

Run	Additional reduction in Roadford storage over the 2 year drought (1995-96)	Extra water pumped to support reduction in Dart abstractions over 2 year drought	Daily maximum abstraction from River Dart
Base	0	0	27 Ml/d (annual volume abstracted is within the annual 9410 Ml limit)
Scenario A: No abstraction when flows in the River Dart are <Q95 (Hands off Flow). Abstraction from flows >Q95 is cheaper than alternative sources.	1%	227 Ml	50 Ml/d (annual volume abstracted remains within the annual 9410 Ml limit)
Scenario B: When flows in the River Dart are <Q95 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q95 is cheaper than alternative sources.	1%	227 Ml	50 Ml/d (annual volume abstracted remains within the annual 9410 Ml limit)
Scenario C: When flows in the River Dart are <Q70 the cost of abstracting River Dart water exceeds that of the alternative sources. Abstraction from flows >Q70 is cheaper than alternative sources.	13%	5547 Ml	28 Ml/d (annual volume abstracted remains within the annual 9410 Ml limit)

Table 2: Key Results for Modelled Scenarios with no Daily or Annual Licence Constraints on the River Dart Abstraction

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As can be seen from the table, in Scenarios A and B, removing the licensed daily abstraction limit influences the total amount abstracted from the Dart and hence minimises the pumping required from the River Tamar. This is because additional water can be abstracted from the Dart when the flow is in the Q70-Q95 band and this water is therefore cheaper than alternative sources.

In contrast, running the model with no licensed daily maximum or annual constraints when flows <Q70 are more expensive than alternative sources (Scenario C) has very little impact on the total amount abstracted from the Dart. This is because the requirement for additional abstractions occurs when flows in the River Dart are within the Q95-Q70 flow band. In Scenario C, this water is more expensive and therefore the model is using water abstracted from the alternative source.

4 Other Considerations

4.1 Impact on Water Available for Use

The results suggest that in a dry summer, additional water required by Littlehempston WTW to offset the River Dart abstraction costs is likely to be released from Roadford reservoir. This in turn will ultimately impact on Water Available for Use (WAFU). Roadford is a multi season strategic reservoir and increased use of this source may bring forward the need for future supply/demand schemes in the Roadford Strategic Supply Area, for example, Roadford pumped storage.

4.2 Power Costs versus Abstraction Costs

If an alternative source is pumped, in order for Smart Licensing to be effective there will need to be an alignment between power costs and abstraction costs, particularly as power costs are predicted to keep rising in the future.

4.3 Carbon Costs

If the alternative source is pumped the environmental costs of abstracting from one source compared to the carbon costs of abstracting from an alternative source must be considered. This will become more important from 2012 as emissions charges associated with the Carbon Reduction Commitment are implemented by the Government.

4.4 Source Management

Rivers in the some areas of the UK are characteristically flashy in nature and respond rapidly to rainfall. This flashy nature will make operational implementation and cost optimisation of Smart Licensing difficult to manage. This situation will be exacerbated if flow bands are high (e.g. Q70) as during typical summers river levels will be continually crossing between the different flow bands.

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4.5 Treatment Issues

In order to optimise the performance of a WTW there may be a requirement to blend water from different sources which will in turn influence the choice of abstraction source. Additional capital outlay may be required to minimise this issue.

Cost savings from cheaper abstractions at higher flows may be over-ridden by the higher costs of treating water at these flows.

5 Conclusions

- The success of the use of Smart Licensing on certain abstractions will ultimately depend on the alternative sources available.
- Smart Licensing could be an option where the alternative supply has similar base costs (i.e. no additional pumping and/or treatment costs) and where this alternative is a river source as opposed to a reservoir source (therefore avoiding any impact on WAFU).
- Smart Licensing may also be appropriate where a water company can benefit from the cheaper costs of abstraction at higher flows during the winter by storing this for the summer via a pumped storage scheme.

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