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Valuing Environmental Impacts: Practical Guidelines for the Use of Value Transfer in Policy and Project Appraisal

Case Study 4 – Valuing Improvements in River Water Quality

Submitted to

Department for Environment, Food and Rural Affairs

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CASE STUDY 4: VALUING IMPROVEMENTS IN RIVER WATER QUALITY

- *Case Study 4 focuses on valuing improvements in river water quality in the context of the EU Water Framework Directive (Council Directive 2000/60/EC).*
- *It illustrates the use of value function transfer (Step 5) that accounts for spatial variation in use values.*

STEP 1: ESTABLISH THE POLICY GOOD DECISION-CONTEXT

The objective of the EU Water Framework Directive (WFD) is to ensure that water-bodies across Europe be of 'good ecological status' by 2015. The quality of the water of rivers, lakes and estuaries is an important indicator of overall environmental quality and increases in water quality lead to high amenity and recreational values and enhanced biodiversity and helps reduce the costs of treating water for domestic and industrial supply.

However the WFD recognises that in certain circumstances improvements in water quality may be costly to achieve and the high cost may justify derogations, which allow for a longer time frame to achieve good ecological status or for a less stringent environmental objective to be met. The decision to derogate or not partly depends on the comparison of the cost of the measures to improve water quality and the benefits of those measures (other justifications for derogations might include the distributional effects).

The scale of the implementation of the WFD implies that it is not realistic to undertake primary valuation for *all* assessments, particularly at the level of individual rivers. Here, value transfer is the more feasible approach for providing monetary valuation evidence for the benefits of achieving good ecological status.

This hypothetical case study illustrates how to use value transfer to estimate the benefit of water quality improvements from a change in waste water treatment. The value transfer uses a methodology that accounts for spatial variation in use values for a site specific policy good.

STEP 2: DEFINE THE POLICY GOOD AND AFFECTED POPULATION

<u>What is the good to be valued?</u>

The case study focuses on the River Aire in West Yorkshire, England (**Figure 1**). The policy good is broadly defined as river water quality, with the case study assessing the impact of improved wastewater treatment.

The current ecological water quality in the river is assessed in terms of four categories following UK Technical Advisory Group protocols (UKTAG, 2008) (**Table 1**).

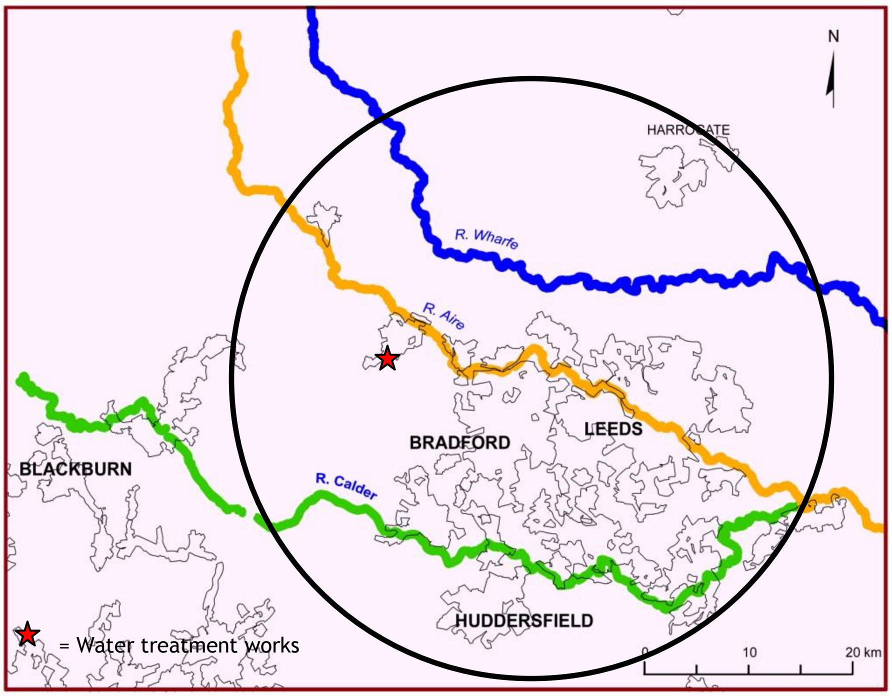
Table 1: Ecological river water quality classification for policy good

Ecological water quality classification	*'Excellent'*	*'Good'*	*'Fair'*	*'Poor'*
Ammonia (mgl^{-1})	<0.6	0.6 – 1.3	1.3 – 2.5	>2.5
Biological oxygen demand (BOD) (mgNl^{-1})	<4	4-6	6-9	>9

Source: UKTAG (2008)

The current water quality of the River Aire is shown in **Figure 1** along with the water quality for other rivers (the Rivers Wharfe and Calder) within the case study area. The Rivers Wharfe and Calder are considered to be substitute sites to the River Aire.

Figure 1: Location of rivers and current water quality



Source: Hime et al. (2009)

Notes: River water quality classification: Blue = 'excellent'; Green = 'good'; Yellow = 'fair'. The circle shows the boundary within which it is expected that the affected population will have positive willingness to pay for improvements in river water quality (see explanation in below in 'What is the affected population?')

As with all rivers, the policy good features a complex set of environmental attributes which provide a range of market and non-market goods and services. The focus of this case study is the final benefits to human populations in terms of recreation and environmental amenity value, including angling, informal recreation (e.g. walking) and potential non-use values which are dependent on water quality.

Who are the affected population?

The policy good is considered to be of local and regional importance due to the provision of recreation and environmental amenity to local residents. The affected population is likely to be composed of a mix of formal (e.g. fishing) and informal recreation users. The local and regional significance of the River Aire suggests that non-use values are likely to be confined to the same population as use values.

Empirical evidence indicates that spatial factors are likely to influence use values including potential distance decay effects, particularly with respect to the availability of substitute sites (e.g. the Rivers Wharfe and Calder). Specifically Bateman et al. (2006) found that for a 'medium' improvement in water quality in relation to an urban river (see Step 4 below), the willingness to pay (WTP) for the improvement decreased to zero at a distance of approximately 24 km from the river improvement site.

On the basis of this assumption, a radius of 30 km is used. This is larger than the maximum distance of to account for the distance from the 'edge' of the improved stretch in the example rather than the central point of the stretch. The radius of 30 km means an area[1] of 2,827 km^2. This area is indicated by the boundary circle in **Figure 1** (see also **Figure 2** for the improved stretch). This includes the urban population areas of Leeds, Bradford and Huddersfield and is assumed to account for the full effect of distance decay in recreational and environmental amenity use value for the policy good and the substitute sites.

In addition, it is necessary to consider how the presence of substitute sites may affect WTP for improvements in river water quality. As indicated in Figure 1, the case study area for the River Aire includes two further rivers (the River Wharfe and the River Calder) that are of comparable or better quality in terms river water quality. How to account for the effect of substitute sites is addressed in Steps 3 and 4.

STEP 3: DEFINE AND QUANTIFY THE CHANGE IN THE PROVISION OF THE POLICY GOOD

The change to be valued is an improvement in river water quality in the River Aire, for a stretch of the river downstream from a treatment works in the centre of Leeds. The improvement is the result of an increase in the level of water treatment to implement the WFD.

Water quality measurement data for the past 10 years which are available from the Environment Agency for England and Wales (based on water quality samples from 1986-1997) can be translated to the ecological water quality classifications set out in Table 1. This provides the baseline for the analysis.

The change in provision of the good is 'quantified' as the change from the baseline to the status envisaged under the implementation of the WFD, which can be shown as a 'step change' from one classification level to another (e.g. 'fair' to 'good'). The water quality ladder (Hime et al., 2009) shown in **Table 2** links the ecological water quality classifications and chemical measures of biological oxygen demand and ammonia from Table 1 to qualitative indicators of water quality (abundance of aquatic plants, species of fish, and species of bank side vegetation)[2].

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[1] Calculation of the area of the circle = πr^2 = 3.14 x 30^2 = 2,827 km^2

[2] Note that the complete water quality ladder describes the ecological water quality classifications across a wider set of chemical, physical and ecological (flora and fauna) parameters (see Technical Report and Hime et al., 2009).

Table 2: Linking chemical measures of water quality to ecological classification – 'water quality ladder'				
Ecological water quality classification	***'Excellent'***	***'Good'***	***'Fair'***	***'Poor'***
Ammonia (mg per litre)	<0.6	0.6 – 1.3	1.3 – 2.5	>2.5
Biological oxygen demand (BOD) (mgN per litre)	<4	4-6	6-9	>9
Aquatic plants	Water plants No algae (vegetation cover = 50%)	Water plants (vegetation cover = 60%)	Algae (vegetation cover = 70%)	Algae (vegetation cover = 85%)
Fish species	Trout Chubb	Bream Roach Carp	Bream Carp	None
Bank side vegetation	Sweet-grasses Common reed Willow	Sweet-grasses Common reed Willow	Common reed Willow	Willow

Source: Adapted from Hime et al. (2009)

For the purposes of this case study, the change in provision of the policy good is assumed to be an improvement in quality from 'fair' to 'excellent' in the River Aire, due to a reduction in ammonia (from 1.3 - 2.5 mg per litre to 0.6 - 1.3 mg per litre) and BOD (from 6 - 9 mgN per litre to 4 - 6 mgN per litre). In qualitative terms, this is expected to result in a reduction algae and vegetation cover in the river and establishment of water plants, along with increased abundance of species of fish such as Trout and Chubb, and greater variety in bank side vegetation.

<u>Location of river water quality improvements</u>

The improvement in water quality in the River Aire is relevant to only a stretch of the river downstream of the water treatment works. This is indicated by the change from 'fair' (yellow) to 'excellent' (blue) in **Figure 2** for a single stretch of the river.

To aid the exposition of the case study and to illustrate the use of a function transfer approach that accounts for spatial factors in the analysis, three simplifying assumptions are made:

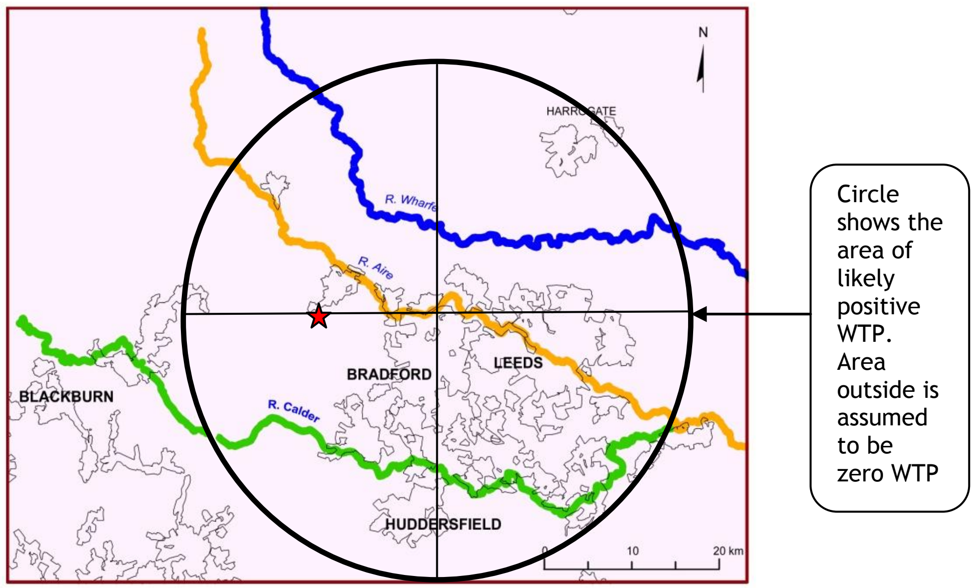
a) The rivers within the case study area (the Aire, Wharfe and Calder) are divided into nine equal 'stretches' (lengths of river), each of which is assumed to have an access point in the centre (further explanation is provided in **Box 1**). This permits the stretch of the River Aire with improved water quality to be identified as in Figure 2 (the stretch of the river that changes from 'fair' (yellow) to 'excellent' (blue)).
b) In relation to the substitute sites that individuals may visit for recreation, it is assumed that only the closest substitute site, i.e. the *nearest* stretch of the alternative river, is of importance[3].
c) Accounting for the availability of substitutes implies a 'buffer zone' around the case study area (this area is shown by the rectangle in **Figure 2**). It is calculated as 10km from the central point of

[3] This assumption is made to enable a relatively straight forward WTP function to be applied in Step 5. Adding further substitute options would increase the level of complexity of the analysis but not add to the explanation of function transfer approach taken. It should also be noted that the analysis does not account for other amenity substitutes (i.e. non-river sites). If individuals perceive non-river sites as potential substitutes to the amenity derived from local rivers then the abundance and quality of these will also influence WTP. This is more likely to be the case for the general population rather than specialist users such as anglers.

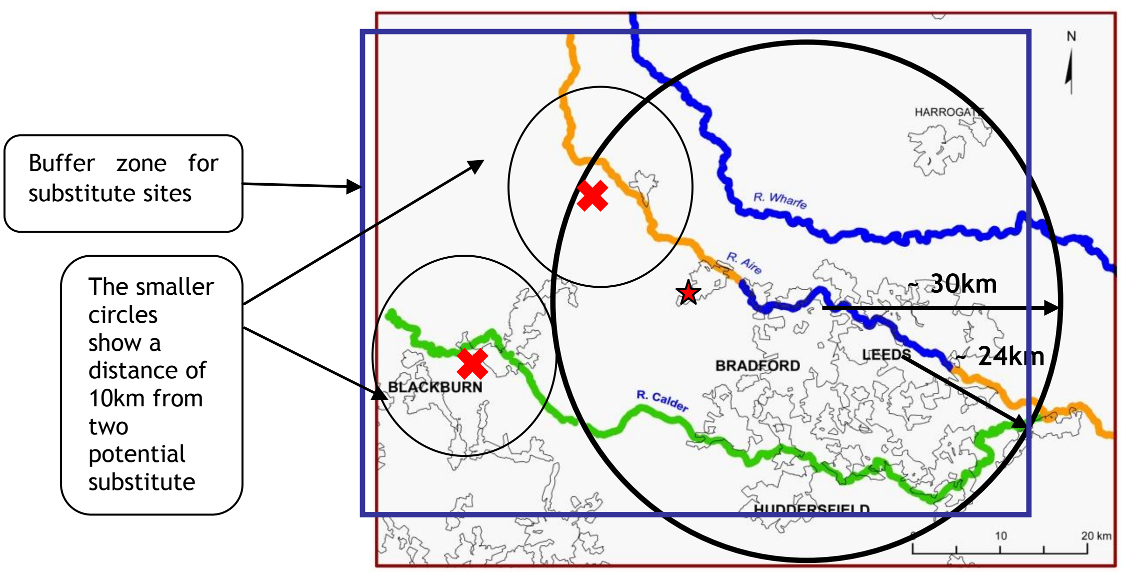
each substitute stretch of river. A distance of 10km is applied as this has been estimated as the mean (average) distance anglers travel to go fishing (EA, 2001). It is assumed that this group are more likely to travel to use a site such as a river than the general population.

Figure 2: Change in the provision of the policy good (River Aire water quality)

(a) Baseline: without-WFD measure



(b) Change in policy good: with-WFD measure



Source: Hime et al. (2009)

Notes: River water quality classification: Blue = ‘excellent’; Green = ‘good’; yellow = ‘fair’

STEP 4: IDENTIFY AND SELECT MONETARY VALUATION EVIDENCE

Potentially relevant studies

A number of UK studies have sought to estimate the value of water quality improvements in terms of river ecology or improvements in chemical pollution. These are summarised in **Table 3.** The appropriateness of each study is considered in the following.

Matching the study good to the policy good

Table 3 summarises existing studies with varying applicability to the policy good (River Aire):

- The Green and Tunstall (1991) study is rejected due to its age and the outlying nature of it value estimates in relation to more recent comparable studies.
- The Bateman et al. (2006) study is not viewed as a good match to the policy good on the basis that the study site was a severely polluted urban river; i.e. the definition and baseline for the study good do not match the policy good. However, as noted in Step 2, expectations as to the spatial area and distance decay values are based on this study, since it is the only study to have specifically investigated these issues in a UK river water quality context.
- The Johnstone and Markandya (2006) study focuses on a select user population group (recreational anglers), while the affected population in this case study is broader (i.e. local residents). Thus, the affected populations of the study and policy goods do not match. Using the (likely higher) estimate for anglers to the broader population could over-estimate aggregate benefits.
- Hanley et al. (2006) provide a definition of the study good that could be mapped to the 'water quality ladder' in relation to the change in provision of the policy good. However the study results do not allow for control of the availability of substitute goods which is identified to be an important consideration for the policy good in Step 3.
- Nera (2007) explicitly focuses on the benefits to river quality from WFD measures both nationally and locally (for rivers within 30 mile radius). This provides an 'ideal' match to the change in provision of the policy good and the affected population. However the study focuses on improvements to *all* rivers at the local level – which is appropriate given the decision-context the study was designed for - rather than an improvement in just one river as is the focus in this case study. Hence, the definition of the study good is broader than that of the policy good; the former is concerned with simultaneous changes to multiple sites at the local scale, the latter is concerned with an independent change at one site at the local scale.
- Ferrini et al. (2008) focus on the 'generic' features of English rivers, and account for river quality (as measured by the 'water quality ladder'), substitute sites, and distance. The study provides a WTP function that allows for key adjustments:
  - ⇒ The baseline and change in provision of the policy good in terms of river quality which is defined in accordance with Table 2 and the water quality ladder;
  - ⇒ The length of river improved;
  - ⇒ Spatial variation in WTP on the basis of distance from the river;
  - ⇒ Availability, quality and distance to substitute river stretches; and
  - ⇒ Socio-economic characteristics.

This permits the control of the main factors that could be expected to cause the value of the change in the policy good to differ from the study good context (see Step 4 of the main guidelines document).

Table 3: Summary of existing studies and study good(s)

Reference	Study good context and methodology	Definition of the Good	Study good site	Consideration of substitutes	Mean WTP	Population considered (sample)
Green and Tunstall (1991)	The valuation of river water quality improvements CV	Perceived water quality according to a 3 point scale	Increase in river water quality (described in terms of birds, fish and safety to paddle)	No	£135-£166 per month for improvement in water quality	Users of river corridors, those living adjacent to accessible river corridors & those living away from them, visitors to 12 sites
Bateman et al. (2006)	Benefits of urban river water quality improvements CV and CR	Three different improvements (small, medium, large) in terms of ecology	River Tame (urban polluted river)	No	£9.60 – £22.89 per year CV £8.64 - £31.50 per year CR	n=675 n=518 useable
Johnstone and Markandya (2006)	Valuing river characteristics TC and RUM	River quality described in terms of, BOD, Ammonia, N, P, DO, number of fish & fish species, HMS and flow	River sites across England	No	Range of WTP values for different river types £5.78 - £47.31 per trip for 10% increase in quality	Survey of anglers n=300
Hanley et al. (2006)	Value of improvements in river ecology CE	Moderate changes in ecology	River Wear in County Durham & River Clyde in Central Scotland	No	Both rivers - increase in ecology from 'fair to good' = £20.17 (SE £3.03) per household per year	House survey; 210 responses for each river
NERA (2007)	Benefits of water quality improvements from WFD measures CV and CE	Quality: high (high or good ecological status), medium (moderate or bad), low (poor)	England and Wales, rivers nationally and locally (within 30 miles)	The approach used does not specifically account for substitutes however as the scenarios used describe all rivers in England & Wales all sites should be accounted for.	Range of values and function based from CV and CE. Mean WTP for an improvement in national water quality of 95% by 2015 ranged from £49.20 – £293.70 per household per year	n= 1500 respondents from 50 locations
Ferrini et al. (2008)	Benefits of water quality improvements from WFD measures CV	Fish population, aquatic plant description, BOD see Hime et al. (2009) for full definition	Generic river across England	Yes	WTP estimated as a function of river quality and quantity of improvement, substitutes, distance and socio-economic characteristics	n = 1500

Notes: CE = choice experiment; CR = contingent ranking; CV = contingent valuation; RUM = random utility model; TC = travel cost; BOD = biological oxygen demand; DO = dissolved oxygen; N = nitrogen; P = phosphates; HMS = human modification score

Selecting appropriate evidence

Overall the Ferrini et al. (2008) study provides the most suitable evidence for estimating the change in provision of the policy good for the purposes of this case study. It permits for a practical demonstration of a function transfer approach that explicitly accounts for spatial factors in terms of variation in use value with distance from the policy good site and substitute sites.

While the Nera (2007) study was specifically designed for the assessment of the implementation of WFD, applying its results here would imply using the evidence 'out of context' (as discussed above). However, the study provides a very useful basis for a 'sense-check' on the value transfer estimates.

STEP 5: TRANSFER EVIDENCE AND ESTIMATE MONETARY VALUE

WTP function

As identified in Step 4, Ferrini et al. (2008) provide a WTP function for estimating the value of improvements in water quality in a single river that accounts for the influence of the spatial factors. The function permits estimation of WTP for water quality improvements for households in each 1 km^2 within the affected population area. This means that analysis needs to calculate 2,827 separate WTP values for each km^2 in the relevant area. The value for each km^2 is then multiplied by the number of households in that km^2. The aggregate value of the improvement in river quality is the sum of these across the 2,827 km^2 (see Step 6).

An approximation of the Ferrini et al. model can formally be described as:

$$WTP_{PG} = \left(\frac{\beta_1 \Delta Ql_{PG} \times \beta_2 \Delta Qn_{PG} \times \beta_3 \ln D_{PG}}{(\beta_4 Ql_{Sub} \times \beta_5 Qn_{Sub} \times \beta_6 \ln D_{Sub})} \right) \times \beta_7 S_i$$

Variable definitions are provided in **Table 4**. Note that this is a reduced form of the Ferrini model (see also **Technical Report**, Section 4 for further details).

Using the WTP function

Practically applying this model requires the following steps in analysis:

i). Determine the change in river water quality for the policy good in terms of the water quality ladder (see **Step 3**);
ii). Determine the location of the improvement in river water quality for the policy good; i.e. the stretch of **river** (see **Step 3**);
iii). Calculate the distance from the policy good site (the stretch of river) to each 1km^2 within the affected population area[4] (see **Box 1**);

[4] This can be calculated using GIS. This example uses 1 km^2 grids as the 'spatial unit'. More generally Super Output Areas (SOAs) are the smallest spatial unit for the collection and publication of 'small' area statistics. The SOA

iv). Determine the nearest substitute site (the closest stretch alternative stretch of river to the policy god site) for each 1 km^2, calculate the distance to the 1 km^2 area, and determine the river water quality of the substitute;

v). Collect data on the average household income in the 1 km^2 areas (to use in the value transfer function)[i] and

vi). Estimate WTP for each 1 km^2 on the basis of the data collected in (i) to (v) km^2 grid square using the WTP function.

Table 4: WTP function for river water quality improvement

Variable	*Coefficient value*	*Value of explanatory variable*	*Variable description*
WTP_{PG}	N/A	N/A	Independent variable - household willingness to pay per year for a specified improvement in water quality at policy good site
ΔQl_{PG}	B_1 = 0.20	ΔQl_{PG} = 2	Change in water quality at policy good site (from yellow to blue)
ΔQn_{PG}	B_2 = 0.4	ΔQn_{PG} = 1	Quantity of water quality change in terms of number of stretches of river improved.
ln D_{PG}	B_3 = -0.0000771	D_{PG} = ln (0.43 km to 57 km) A range of values as distance differs for each outset point (see below and Box 1)	Natural log of distance (km) to policy good site (measured from 1km^2 grids)
Ql_{Sub}	B_4 = 0.281 (for quality = blue) B_4 = 0.184 (for quality green) B_4 = 0.099 (for quality yellow)	Ql_{Sub} = 1 (for blue if R. Wharfe; for green if R.Calder; for yellow if R. Aire)	Water quality at the nearest substitute site
Qn_{Sub}	B_5 = -0.85	Qn_{Sub}= 1 Nearest stretch of substitute river	Quantity of water quality at nearest substitute site, in terms of stretch of river
ln D_{Sub}	B_6 = 0.00009	ln D_{Subs} = ln (0.12 km to 86 km) A range of values as distance differs for each outset point	Natural log of distance to nearest part of substitute site
S_i	B_6 = 0.001	S_i = 11,000 – 44,000 Range of values as average household income varies over 1km^2 grids to the nearest 1000.	Average household income (for each 1km^2 grid)

layers form a hierarchy based on aggregations of Output Areas (OAs). See Office for National Statistics (accessed July 2009): http://www.neighbourhood.statistics.gov.uk/dissemination/Info.do?page=aboutneighbourhood/geography/superoutputareas/soafaq/soa-faq.htm

Assumptions

Step 3 details four simplifying assumptions for the analysis here:

- Length of stretches of river;
- The closest alternative stretch of the river is the substitute site; and
- The buffer zone for substitute sites.
- There is one access point for each stretch of river, which is located at the centre of the river stretch. This means that only the straight line distance from the river stretch to the 1 km^2 needs to be calculated in (iii) and (iv) above (see Box 1).

A further important point to highlight is that:

The WTP function and coefficients of the function that are applied in this case study are 'illustrative'. The analysis has been simplified to demonstrate the principles of function transfer approach that accounts for the influence of spatial factors. The function described in this example should not be used in a real world value transfer application.

The coefficient values from the Ferrini et al. model in **Table 4** are specified on the following basis:

- As distance from the policy good increases, WTP decreases;
- As distance from the nearest substitute site increases, WTP increases; and
- As quality improvement increases, WTP increases.

Estimating WTP for improvements in water quality for each 1km²

Table 4 documents the application of the simplified Ferrini et al. model, describing the function variables and the values for the coefficients and explanatory variables in the case study example:

- The change in water quality is defined as a move from 'fair' (yellow) to 'excellent' (blue) (see **Step 3**).
- The policy good river (River Aire) and substitutes (Rivers Wharfe and Calder) are divided into equal lengths to form nine river stretches or three along each river (see **Box 1** for a further discussion of river access point considerations) such that the quantity change is '1 stretch'.
- Distance to the policy good site and the nearest substitute is measured using an overlay to the case study area map with a 1km^2 grid (see **Figure 3**). The straight line distance (km) from the centre of each 1km^2 is calculated from GIS.
- The nearest substitute site will have a quality of blue if the nearest substitute is one of the three rive stretches on the River Wharfe; green if the nearest substitute is one of the three rive stretches on the River Calder and yellow if the nearest substitute site is on either of the unimproved stretches of the River Aire (see **Figures 1 & 2**).
- A single socio-economic variable is considered - total household income - with average values for each grid square sourced from ONS Census ward data (derived from the Office of National Statistics 2001 Census: Standard Area Stastistics England and Wales). Mean annual household income within each square ranges from £11,500 to £44,500.
- The map area shown within **Figure 3** is 70km x 60km, or an area of 4,200 km^2. Within this area, 2,827km^2 are within the 'user' population area (as defined in Step 2 and shown in Figures 1 and 2). To determine the WTP over the entire map area shown 4,200 separate WTP calculations would

need to be made, one for each 1 sq km grid. WTP should decrease to £0 outside of the boundary circle.

- The population data for the area show that 28% of the 1 km^2 grid squares (1,176 squares in total) contain an average population of zero. This can be explained due to the high degree of rural area in the affected population area (data from 2001 ONS census).

Figure 3 illustrates the approach for calculating the distance to the policy good site for a particular 1 km^2 area. **Box 2** illustrates the calculation of WTP for a 1 km^2 area.

Box 1: Calculating distance and access to the policy good site and substitutes

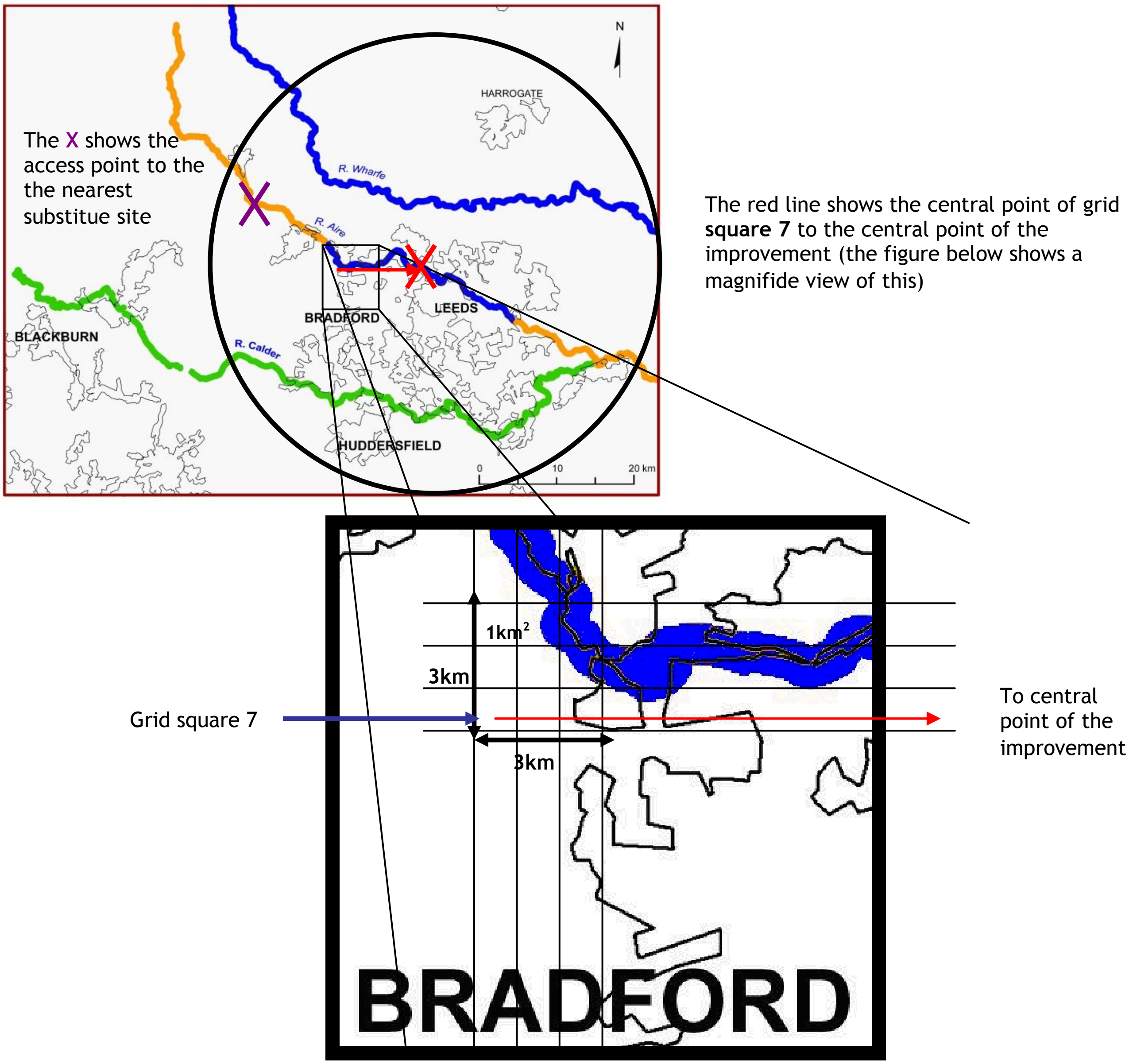
Methods for calculating the distance to the policy good river and its substitutes using a 1 km^2 grid include:

- Distance from each grid square to a known river access point can be collected by:
  - ⇒ Visiting the area and surveying access points; or
  - ⇒ Using desk-based tools such as map websites to define the access points.

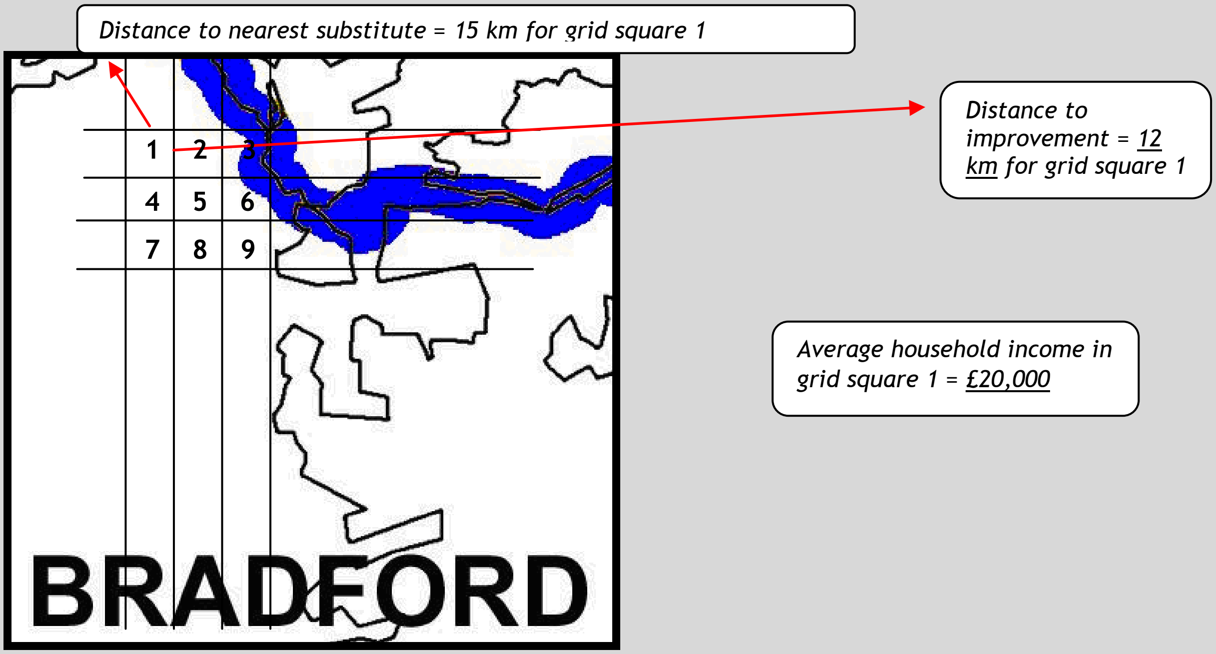
- Distance from each grid square to an assumed number of access points can be defined by either:
  - ⇒ Roads and paths that cross rivers in the area within 100m; or
  - ⇒ An assumption that there is an access point for every x km of river within the study area and defining this as a central point with each length of river.
  - ⇒ In the case study it is assumed that there is a single access point for every 45km length of river to allow nine river stretches to be defined (the central point of which is assumed to be the access point).

Evaluating all access points on each river of interest, while accurate, is time consuming (either in terms of desk based work or field survey). The most practical option to consider is to assume a certain number of access points as defined by particular criteria.

Figure 3: Calculation of straight line distance to the improvement in river water quality (shown on approx. 9 km^2 section of the case study map)



Box 2: Example calculation of WTP for nine 1km² within the case study area

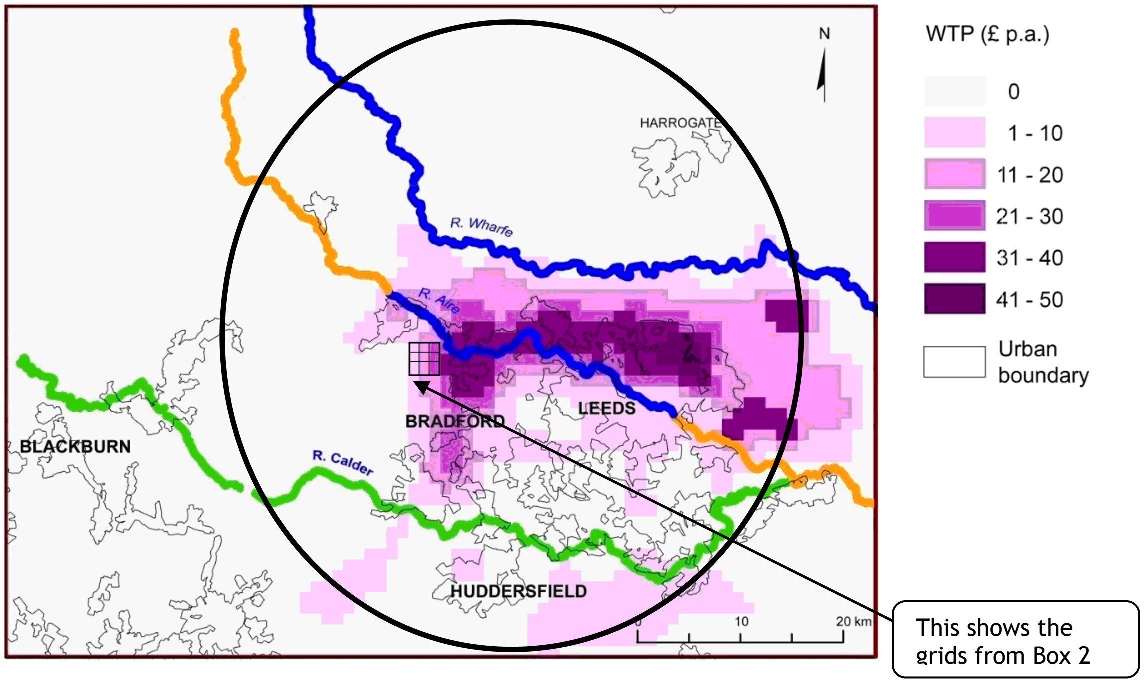


Grid sq.	Top of WTP function (policy good) $(\beta_1 \Delta Ql_{PG} \times \beta_2 \Delta Qn_{PG} \times \beta_3 \ln D_{PG})$	Bottom of WTP function (substitute) $(\beta_4 \Delta Ql_{Sub} \times \beta_5 \Delta Qn_{Sub} \times \beta_6 \ln D_{Sub})$	Coefficient of mean income x mean income $\beta_7 S_i$	WTP /hh/yr
1	0.20 x 2 x 0.4 x 1 x -0.0000771 x ln(<u>5</u>) =-0.0000199	0.099 x 1 -0.85 x 1 x 0.00009 x ln(**<u>31</u>**) = -0.0000260	0.001x **<u>11400</u>** =11.4	£8.70
2	0.20 x 2 x 0.4 x 1 x -0.0000771 x ln(4) =-0.0000171	0.099 x 1 -0.8 x 1 x 0.00009 x ln(**32**) =-0.0000262	0.001x **16000** =16	£10.42
3	= -0.0000136 x (D_{PG} = 3)	= -0.0000265 x (D_{Sub}=33)	0.001 x 40000 = 40	£20.47
4	= -0.0000221 x (D_{PG} = 6)	= -0.0000262 x (D_{Sub}=32)	0.001 x 11400 = 11.4	£9.60
5	= -0.0000199 x (D_{PG} = 5)	= -0.0000265 x (D_{Sub} =33)	0.001 x 17000 = 17	£12.75
6	= -0.0000171 x (D_{PG} = 4)	= -0.0000267 x (D_{Sub} =34)	0.001 x 34000 = 24	£21.77
7	= -0.0000240 x (D_{PG} = 7)	= -0.0000265 x (D_{Sub} =33)	0.001 x 11000 = 11	£9. 97
8	= -0.0000221 x (D_{PG} = 6)	= -0.0000267 x (D_{Sub} =34)	0.001 x 18000 = 18	£14.90
9	= -0.0000199 x (D_{PG} = 5)	= -0.0000269 x (D_{Sub} =35)	0.001 x 32000 = 32	£23.59

WTP for each grid cell is calculated as the top half of the function divided by the bottom half of the function multiplied by the product of the coefficient for income and average household income. For cell 1 this is: WTP = (-0.0000199/-0.0000260) x 11.4 = £8.70. Calculations for other cells illustrate how WTP varies with the distance to the policy good (D_{PG}) and nearest substitute site (D_{Sub}).

Based on Figure 3 and Box 2, estimated WTP per household per year (for each 1 sq km area) can be illustrated graphically via a 'value map', illustrating the decay in use values as distance from the policy good site increases and distance to substitute sites decreases (**Figure 4**).

Figure 4: Distribution of WTP for improvement in river water quality (£/household/year)



STEP 6: AGGREGATION

The annual benefit of an improvement in river water quality for the stretch of the River Aire is calculated by multiplying the estimated annual household WTP for each km^2 by the number of households in that km^2 and summing across the entire affected population area.

Table 5 illustrates the aggregation process carrying through the example grid squares detailed in **Box 2.** Population numbers are derived from the Office of National Statistics 2001 Census: Standard Area Statistics (England and Wales).

Table 5: Total WTP by grid square (£/yr)			
Grid square	*Average WTP (£/hh/yr) in the grid*	*Population within each grid square*	*Total WTP for each km^2 (£/yr)*
1	£8.70	3,000	£26,108
2	£10.42	2,000	£20,849
3	£20.47	5,000	£102,357
4	£9.60	5,000	£48,000
5	£12.75	1,500	£19,119
6	£21.77	3,000	£65,314
7	£9.97	5,000	£49,857
8	£14.90	1,000	£14,897
9	£23.59	3,000	£70,785
…	…	…	…
square n	*£5.00*	*4,000*	*£20,000*
TOTAL		***~1.25 million***	***£4,050,000***

Summation of total WTP for each km^2 provides an estimate of the annual benefit of the improvement in river water quality in the River Aire as a result of improved waste water treatment. Estimated annual benefits are approximately £4 million. Over 10 years, this equates to approximately £33.8 million present value benefit.

STEP 7: SENSITIVITY ANALYSIS

Key sensitivities in the case study example analysis include:

- The assumed spatial area for which positive WTP is relevant; e.g. approximately 24-30km distance from policy good based Bateman et al. (2006);
- The value of WTP function coefficients based on 95% confidence intervals. Sensitivity analysis can be used to calculate the benefit estimate at the lower bound of all coefficients to give a 'conservative estimate' (see **Box 3**);
- Assessing different specifications for measure of distance to the policy good site and substitutes; e.g. road length or journey time as an alternative to straight line distance (as discussed in **Box 1**); and
- Comparison to value estimates from other studies identified in the survey of literature as the basis of a 'sense check' (**Box 4**).

Box 3: Conducting sensitivity analysis by varying model coefficients

Following Table 4, a change in the value of the coefficient for substitute site water quality (Ql_{Sub}) from 0.099 to 0.05 (lower bound estimate from 95% confidence interval) yields the following change in the value of individual WTP in grid square 1:

Cell	Top of WTP function (policy good) $(\beta_1 \Delta Ql_{PG} \times \beta_2 \Delta Qn_{PG} \times \beta_3 \ln D_{PG})$	Bottom of WTP function (substitute) $(\beta_4 \Delta Ql_{Sub} \times \beta_5 \Delta Qn_{Sub} \times \beta_6 \ln D_{Sub})$	Coefficient of Mean Income x Mean income $\beta_7 S_i$	WTP /hh/yr
1	0.20 x 2 x 0.4 x 1 x -0.0000771 x ln(5) =-0.0000199	**0.05** x 1 -0.85 x 1 x 0.00009 x ln(31) = -0.0000131	0.001x 11000 =11.4	£8.70 changes to **£17.23**

The result shows that by reducing the influence of the quality of the substitute site on WTP generates a higher value for the policy good.

STEP 8: REPORTING

The following draws out the main conclusions from this case study using a function transfer approach that accounts for spatial variation in economic values:

- Methodology: this approach requires the identification of a suitable WTP function from the available literature that accounts for the influence of spatial factors on unit values; in this case distance to the policy good site and distance to and quality of the closest substitute site. The example here relies on the outputs from Census data and use of GIS to calculate distances to the policy good site and substitutes. It also requires the analyst to identify substitutes for the policy good.

- Key principles highlighted: the example shows how unit values can vary over a spatial area on the basis of distance to the policy good site and substitutes. In turn this has significant implications for the estimation of aggregate values in comparison to assuming a constant unit value across the affected population.

- Limitations: time and information required to carry out this level of value transfer is significantly greater than simpler approaches. Furthermore, as an illustrative example, the analysis invokes a number of simplifying assumptions to aid the exposition, such as only accounting for the nearest substitute site, and applies a WTP function and coefficients that cannot be used in real world value transfer applications.

Box 4: A sense check on estimated values

Comparison to Nera (2007)

As discussed in Step 4, Nera (2007) study values improvements in terms of a much broader study good than the policy good of interest in this case study. Given this, on the basis of scope sensitivity (see **Technical Report**) the expectation would be that the larger good (simultaneous changes to multiple sites at the local scale as valued by Nera (2007)) would be valued greater than the smaller good (an independent change at one site at the local scale as in this example). On the basis of **Table 3** and **Box 2**, this is found to be the case.

Comparison to Hanley (2006)

Hanley et al (2006) estimated mean WTP for water quality improvements resulting from the WFD for individual rivers in the region of £20 per household per year (see **Table 3**). Again this is consistent with the values detailed in **Box 2**. This unit value can be applied to illustrate the importance of the aggregation approach, by comparing:

1) Aggregation via a function transfer approach accounting for spatial factors (as per this case study); and
2) Aggregation via a unit value transfer approach with no account for spatial variation in use values.

Aggregation approach	***Total population of study area***	***Unit value £/hh/yr***	***Calculation of Total value***	***Annual benefit (£/yr)***	***Value discounted over 10 years***
1) Function transfer - accounting for spatial factors	~1.25 million	WTP estimated for 1 km^2 areas	WTP for each 1 km^2 x population of each 1 km^2 area	~ *£4m*	~ £34m
2) Unit value transfer - no accounting for spatial factors	~1.25 million	Mean WTP: ~£20	Mean WTP x total population	~ *£26m*	~ £217m

As shown above, the difference in aggregate values estimated by approaches (1) and (2) is large. The annual benefit estimate using unit value transfer is over eight times the annual benefit estimated via the function transfer approach.

REFERENCES

Bateman I.B., Cole, M.A, Georgiou, S. and Hadley, D.J. (2006) 'Comparing contingent valuation and contingent ranking: A case study considering the benefits of urban river water quality improvements, *Journal of Environmental Management*, 79, 221-231.

Environment Agency (2001). Survey of Rod Licence Holders, R & D Technical Report W2-057/TR

Ferrini, S., Fezzi, C., Day, B.H. and Bateman, I.J. (2008) Valuing Spatially Dispersed Environmental Goods: A joint revealed and stated preference model to consistently separate use and non-use values *CSERGE Working Paper EDM 08-03,* Centre for Social and Economic Research on the Global Environment, University of East Anglia.

Green C.H. and Tunstall, S.M. (1991) 'The evaluation of river water quality improvements by the contingent valuation method', 1135-1146.

Hanley N., Wright, R.E. and Alvarez-Farizo, B. (2006) 'Estimating the economic value of improvements in river ecology using choice experiments: an application to the Water Framework Directive., 183-193.

Hime, S., Bateman I.J., Posen, P. and Hutchins, M. (2009) 'A transferable water quality ladder for conveying use and ecological information within public surveys, ChREAM project, Centre for Social and Economic Research on the Global Environment (CSERGE), University of East Anglia.

Johnstone C. and Markandya, A. (2006) 'Valuing river characteristics using combined site choice and participation travel cost models', Journal of Environmental Management, 80, 237-247.

NERA (2007) *The Benefits of Water Framework Directive Programmes of Measures in England and Wales*, Final Report to Defra, CRP Project 4b/c.

UK Technical Advisory Group (UKTAG) – Water Framework Directive (2008) *Phase 1 Report - Environmental standards and conditions for surface waters*. Available from :
http://www.wfduk.org/UK_Environmental_Standards/LibraryPublicDocs/UKTAG%20ReportAug%202006UKEnvironmentalStandardsandConditionsFinalReport