Valuing the net benefits of ecosystem restoration:

The Ripon City Quarry in Yorkshire, Ecosystem Valuation Initiative Case Study No. 1

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Table of Contents

Executive Summary

1 Background 4

2 Methods 5

2.1 Scope of the study 6

2.1.1 The extension sites 7

2.2 Stakeholders 7

2.3 Changes to ecosystems 8

2.4 Changes in ecosystem services 8

2.5 Baseline versus wetland restoration scenario 8

2.6 Choosing between restoration options 9

2.7 Phasing 10

3 Costs and benefits 10

3.1 Costs 10

3.1.1 Costs of foregone agricultural output 10

3.1.2 Costs of restoration 11

3.1.3 Costs of aftercare programmes 12

3.1.4 Foregone agricultural ecosystem services 12

3.2 Benefits 12

3.2.1 Flood control 14

3.2.2 Carbon sequestration 15

3.2.3 Biodiversity 16

3.2.4 Recreation 17

3.2.5 Aesthetic/landscape beauty 18

3.2.6 Sand and gravel ... 18
4 Results ... 19
4.1 Cost-benefit analysis ... 19
4.2 Distributional analysis ... 21
4.3 Sensitivity analysis ... 22
4.4 Key points ... 24
5 References ... 26

List of Figures

Figure 1 Map of Ripon Quarry - current and extension sites ... 6
Figure 2 Present value of ecosystem service benefits and costs of Ripon extension restoration ... 19

List of Tables

Table 1 Area and land use of extension sites ... 9
Table 2 Gross returns by crop on Newby Estate Farm and Mr. Rogers' Farm ... 11
Table 3 Costs of restoration at Ripon site ... 11
Table 4 Post-restoration land use and ecosystem services (ES) ... 13
Table 5 Present value by category (£2009, 3% discount rate, 50 years) ... 20
Table 6 Financial NPV assumptions and result ... 22
Table 7 Sensitivity analysis ... 24

Executive Summary

Aggregate Industries UK, a subsidiary of Holcim, restores ecosystems as part of its quarrying operations. In support of a request to extend an existing quarry in North Yorkshire, the company proposed to create a mix of wetlands for wildlife habitat as well as an artificial lake for recreation, following the extraction of sand and gravel from land currently used for agriculture. Stakeholders were consulted to determine their preferences for restoration.

In collaboration with IUCN, ecosystem valuation was undertaken to assess the types and scale of economic benefits associated with wetland restoration. The study showed that the value of biodiversity benefits that would be generated by the proposed wetlands (£1.4 million), the recreational benefits of the lake (£350,000) and increased flood storage capacity of the overall area (£224,000) would, after deducting restoration and opportunity costs, deliver net benefits to the local community of about £1.1 million. The value of carbon sequestration in these wetlands was found to be relatively small, while the marginal benefits associated with wetlands far exceeded the current benefits derived from agricultural production.

The study further shows that the costs of ecosystem restoration and aftercare are small, compared to both the economic benefits of wetland restoration and the financial returns from sand and gravel extraction. This example illustrates that compensation for adverse environmental impacts is not only an important means for companies to maintain their license to operate, but can deliver overall improvements in ecosystem services with substantial economic benefits at modest expense. The company hopes to do more ecosystem valuation to demonstrate to planning agencies and the public that it makes valuable investments in ecosystems following extractive activities. Future access to minerals depends on companies leaving sites in which it operates with any ecosystem no worse off and preferably even better off.

1 Background

Aggregate Industries UK (under the trading name Brown and Potter) operates the Ripon City Quarry, in the Yorkshire Dales in England, mining sand and gravel since 1964. Because remaining reserves were forecast to be exhausted in 2009, an extension to the existing quarry was proposed and the permit was approved in April 2010. The extension includes three separate areas of land adjacent to the current extraction area. Extension of the site allows the production of sand and gravel for a further seven years. The extension will use the existing plant and processing area including the site entrance.

The proposed extension includes three distinct areas known as Canal Field, Bridge Field and Newby Gravel Beds. These sites are currently used for agriculture despite the regular intrusion of water from elevated river levels. The existing quarry, plant and extension sites lie between the River Ure and a canal, and flood regularly when the river level rises following heavy rainfall. Extraction on the sites is to proceed sequentially beginning with Bridge Field and ending with Newby Gravel Beds, moving away from the plant. Restorations is also to be undertaken gradually, with earlier quarried sites being restored with overburden and top soil from later quarried sites.

Aggregate Industries UK has undertaken a valuation study to measure and quantify in monetary terms the impacts that the quarrying and restoration operations will have on biodiversity and the ecosystem services provided to local communities and regionally. The sites to be worked are expected to provide, after closure of the quarry operations and the completion of ecological restoration, a range of improved ecosystem services including wetland habitat for wildlife, recreational opportunities, flood control and carbon sequestration. By building a reputation for environmental responsibility, Aggregate Industries UK aims to improve its license to operate, to save costs associated with future planning procedures, to streamline decision-making and to be in a better position to negotiate appropriate aftercare programmes. Eventually, the company hopes to use ecosystem valuation as a tool to identify restoration options with the greatest biodiversity and local livelihood benefits.

The expected changes in ecosystems include the introduction of wetlands and a lake in an area that was previously predominantly used for agriculture and livestock pasture. Potential changes in ecosystem services include increased provision of:

- wildlife habitat
- flood control
- recreational opportunities
- landscape beauty
- carbon sequestration

2 Methods

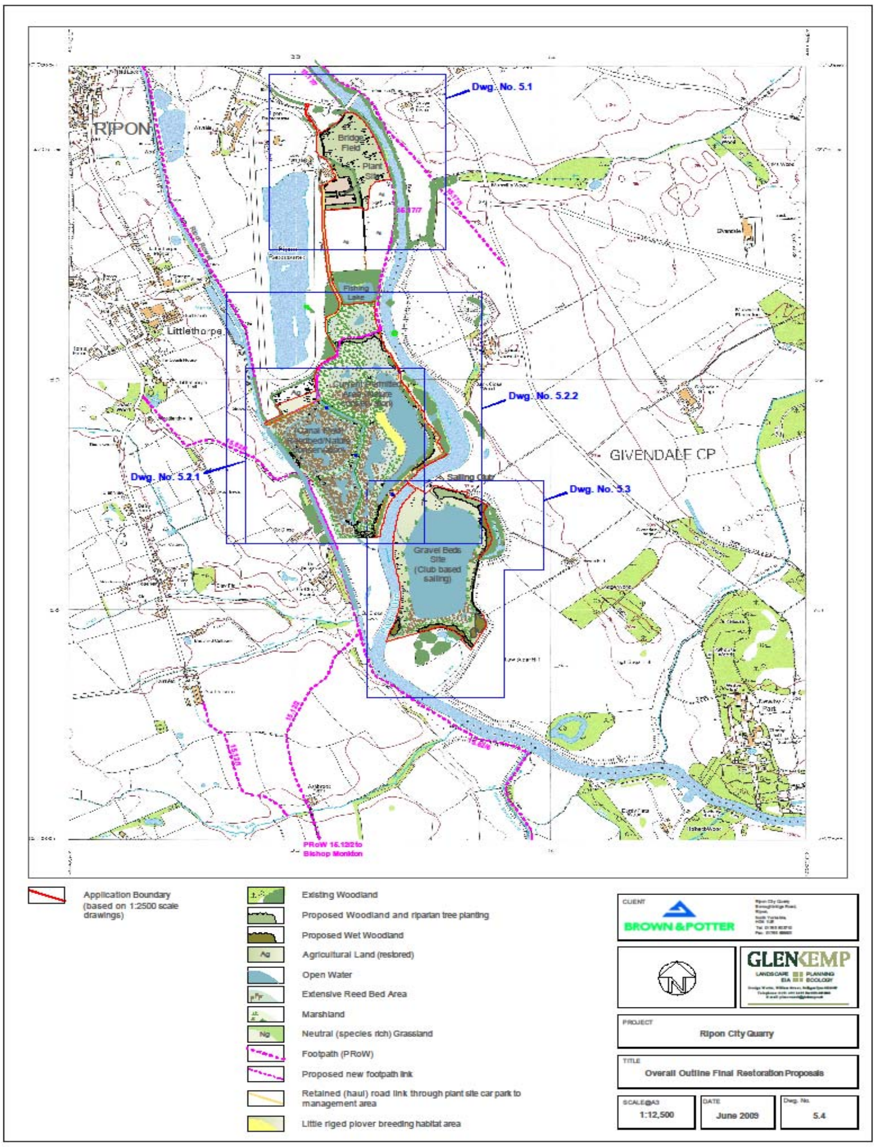
This analysis identifies and compares the most significant costs and benefits associated with extension of the quarry and subsequent ecological and agricultural restoration. The net benefits (benefits minus costs) of the “business as usual” scenario (no quarry extension and no restoration) are compared to the proposed quarry extension and ecosystem restoration. The focus is on incremental changes in the provision of ecosystem services associated with the extension of the quarry and subsequent restoration, rather than measuring Total Economic Value (TEV). This valuation of ecosystem services is used in a cost-benefit framework and is undertaken primarily from the perspective of society, i.e. the broader local community.

As resources and time were limited, the benefits transfer approach [see EVI Guide, Annex A; Navrud and Brouwer, 2007] is used. Benefit transfer provides unit estimates of the value of particular ecosystem services based on estimates calculated in more detailed studies of similar sites. This study identifies relevant estimates from the UK of the value of recreational opportunities associated with man-made lakes, flood control, carbon storage and provision of wildlife habitat in a predominantly agricultural landscape.

2.1 Scope of the study

This analysis includes the three sites proposed for the extension of the quarry which together cover an area of roughly 38 hectares. The three sites are treated separately as the post-extraction restoration plans differ for each site. Figure 1 below shows the location of the existing quarry and plant and the extension sites after restoration. The analysis includes all significant costs and benefits incurred within the boundaries of the extension sites, but does not include the existing quarry or processing plant. Benefits generated within the restored extension sites are included in the analysis as well as off-site benefits to the local community and further downstream.

Figure 1 Map of Ripon Quarry - current and extension sites



All costs and benefits are adjusted to £ 2009 using a GDP deflator. The time horizon applied is fifty years, but the sensitivity analysis looks also at 10 and 30 year time horizons. The baseline discount rate used is three percent. The Green Book of HM Treasury (2002) recommends application of a declining long-term discount rate, i.e. 3.5 percent for years 0-30 and 3 percent for years 31-60.

2.1.1 The extension sites

Bridge Field (5.4 ha) lies north of the existing plant and the River Ure acts as its eastern boundary. It is currently used for agriculture. It will be the first site to be quarried (duration 18 months), and will be restored to agricultural use (in large part due to its Agricultural Land Classification). In return for access to the aggregates on the site, the landowner (Mr Rogers) will receive royalties from extraction. The land will be restored to a quality sufficient for agricultural use. There are no aftercare requirements.

Canal Field (12 ha) lies to the south of the plant and borders the canal and Ripon Racecourse. This site is also currently used for agriculture and is to be worked following Bridge Field for 16 months. The site will be restored to reedbeds and will be managed for biodiversity and for flood control. This site is also owned by Mr Rogers.

Newby Gravel Beds (20.6 ha) is the largest and final area to be worked (4 years). It is currently open grassland meadow which is used for livestock grazing. Adjacent areas include some agricultural land, wet woodland, ponds, etc. Following extraction, this area will be converted to an 11 hectare lake to be used primarily for recreational sailing. The establishment of the lake is expected to have some off-site ecological benefits in adjacent areas, e.g. providing water to wet woodlands which are currently not receiving enough water. This site is owned by the Newby Estate.

2.2 Stakeholders

Aggregate Industries UK wishes to extend the quarry in order to extend the life of the existing plant and to extract sizeable reserves of aggregates which, despite regular flooding of the site, are profitable to extract. There has been some concern from the local community about the short term noise and dust associated with extraction and transport of material. There is also concern from a small number of people whose properties overlook the extension sites and whose view would be negatively affected despite advance plantings and efforts to screen extraction areas from view. The landowners of the extension sites are to receive, in compensation, royalties from extraction. In order to ensure long-term maintenance of restored areas, a 50 year aftercare programme is required for the reedbeds (Canal Field). The wetland areas established are to be managed by the North Yorkshire Wildlife Trust (NYWT). Aftercare on NGB is the responsibility of Newby Estate which owns the land.

There has been some controversy between stakeholders over the specific type of wetland to be established (wet grassland versus reedbeds). The decision to establish reedbeds appears to be political rather than based on the ecological merits of the wetland restoration options.

Finally, as the existing quarry and extension sites lie in a floodplain between the River Ure and a canal, the land provides a reservoir at times of flooding. Temporary storage and the gradual release (via pumping) of the water help in the regulation of the waterway and provide important flood control functions both locally and downstream. As such, the local council and the Environment Agency have been supportive of the planning application primarily for the additional flood control functions of the wetlands and lake to be established.

2.3 Changes to ecosystems

The main physical changes to the extension sites are:

- the elimination of agriculture and its associated ecosystem services
- the short-term establishment of extraction
- the establishment of reedbeds
- the establishment of a lake surrounded by reedbeds and wet woodland

2.4 Changes in ecosystem services

Changes in the ecosystem services provided on Bridge Field are marginal as the site is to be restored to agriculture after extraction. Some incremental short-term flood control occurs and agricultural ecosystem services cease during extraction.

Canal Field is currently used for annual cropping. The ecosystem services associated with agriculture include crop production and some flood control. Following extraction, reedbeds will be established. The ecosystem services associated with this type of wetland are predominantly of the non- use type as the area will be managed by the NYWT for biodiversity, i.e. there will be no (or limited) access for recreation. The ES consistent with this are the flood control functions, the provision of habitat for wildlife and carbon sequestration.

Newby Gravel Beds is currently used for livestock rearing and very low lying areas are in arable reversion, i.e. they have been taken out of crop production due to regular flood damage and are allowed to naturally regenerate to grassland. ES services associated with pasture include the production of livestock products (meat) and flood control. Following extraction, just under half of the area (11 of 21 ha) will become a lake. The remaining area will be restored to wetland. Unlike the reedbeds in Canal Field, this area will be managed for recreation and as a result the main ES provided from this area will be recreational. In addition, the lake will also provide important flood control functions and NGB as a whole will provide some wildlife habitat. There are also significant off-site benefits of increased water flow to the adjacent wet woodland, but due to lack of data, these benefits are not quantified.

2.5 Baseline versus wetland restoration scenario

Both Canal Field (12 ha) and Bridge Field (5.4 ha) are part of Mr Rogers' farm. Both fields are currently under arable cropping, and the typical rotation consists of winter wheat, winter barley and oil seed rape. It is assumed that in the Business as Usual scenario this pattern of land use would continue.

The area of the extension in NGB is 20.6 hectares. The area is currently in grass for grazing sheep for meat production (13.8 hectares). The remainder (6.8 ha) is in arable reversion. The RSPB recommends grazing as the preferred management method. It is assumed that in the 'Business as Usual' scenario this pattern of land use would continue.

Table 1 below summarises current land use and land use after restoration. In short, Bridge Field will revert to agriculture. Most of Canal Field will become reedbeds with some open water and marsh and one hectare of agriculture. The greatest change affects NGB where much of the area of extraction will become a lake, fringed with reedbeds, marsh and wet woodland. Just over five hectares of the raised part of the site will revert to agriculture.

Table 1 Area and land use of extension sites

Site	Total area (ha)	Current use	Area of extraction (ha)	Use after restoration	Area by use (ha)
Bridge Field	5.4	agriculture	4.7	Agriculture	5.4
Canal Field	12	agriculture	8.3	Reedbed	8.3
				Marsh/grassland	1
				Open water	1.65
				Wet woodland	0.05
				Agriculture	1
Newby Gravel Beds	20.6	livestock (13.8 ha)	16.25	Lake	11
				Reedbeds	1.2
		arable reversion (6.8 ha)		Marsh/grassland	1.8
				Woodland/ wet woodland	1.85
				Agriculture	5.15
Total	38		29.25		38.4

2.6 Choosing between restoration options

Aggregate Industries UK had originally intended this study to provide a methodology to help select the restoration option with the greatest ecological and economic benefits amongst a range of possible restoration options. However, the differences between the restorations options of reedbeds and wet grasslands are difficult to measure and value in economic terms, particularly when relying on other studies. As this study did not use stated preference methods to quantify stakeholder preferences and willingness to pay for restoration options, the study was not able to serve as a tool to choose between restoration options.

In this case, cost-effectiveness analysis rather than valuation and cost-benefit analysis may be useful. If an ecological objective was identified, by comparing the costs of all the restoration options which achieve that ecological objective, a company could choose the most cost-effective way of obtaining a pre-agreed level of biodiversity.

2.7 Phasing

The phasing of costs and benefits is determined by the phasing of extraction and restoration which is summarised in the Gantt chart in Appendix 1. To simplify the analysis, the following schedule of extraction and restoration is used. Extraction begins in Year 1 in Bridge Field which is worked for 18 months. Restoration for continued agricultural use of Bridge Field is undertaken in Year 3 using the soil/overburden from Canal Field and some soil/overburden from NGB. Extraction from Canal Field begins in Year 3 (15 months). Restoration (reedbeds, grassland with some open water) takes place when soil/overburden is available from NGB in Year 5. Extraction in NGB occurs from Years 5-8 (50 months). The restoration of NGB takes place in Year 8.

The benefits associated with restoration are assumed to begin the year following completion of restoration at each site.

3 Costs and benefits

3.1 Costs

The costs associated with the extraction plus restoration scenario include the value of the agricultural production which is foregone, the costs of restoration and the costs of managing the wetlands and lake. These costs are discussed in detail below.

3.1.1 Costs of foregone agricultural output

The opportunity cost of the land to be restored to wetlands is the financial returns foregone by not choosing to pursue the most profitable alternative use of that land. For the extension sites the current alternative use is arable cropping and livestock production. Despite flooding in the area, annual cropping in Bridge Field and Canal Field (owned by Mr. Rogers) has been profitable, and gross margins per hectare are presented in Table 2 below.[1]

[1] 'Gross margin' is the gross income from an enterprise less the variable costs. It does not include fixed or overhead costs such as depreciation, interest payments, or permanent labour. While it would be desirable to include labour costs, this data was not available. The result is that agricultural profitability will be overestimated, but this is considered to be acceptable as the bias is <u>against</u> ecosystem restoration for which labour costs are included.

Table 2 Gross returns by crop on Newby Estate Farm and Mr. Rogers' Farm

Farm	Activity	Gross margin (£/ha)
Mr. Roger's farm*	Wheat	690
	Barley	650
	Oilseed rape	838
	Annual return	2,178
Newby Estate	Livestock	340
	Arable reversion	280

Source: Data from Environmental Statement, 2008.

*crops are grown sequentially over one year.

3.1.2 Costs of restoration

The costs of wetland restoration include the costs associated with labour and material used in restoration. Labour is valued at £65/person/day. Materials include reeds and seeds (for wet grassland option). The main input into restoration of Bridge Field and to a lesser extent Canal Field is soil, which is taken from NGB and is not valued as it is transferred within the extension sites. Creation of the lake requires no action following extraction. Pumping ceases and the lake is fills naturally as water rises to the level of the water table. Restoration costs and the basic parameters in the calculation are summarised in Table 3. Costs are adjusted by the expected mortality rates of seedlings planted.

Table 3 Costs of restoration at Ripon site

Restoration option	Labour (£/ha)	Material (£/ha)	Total cost (£/ha)	Mortality rate (%)	Adjusted cost (£/ha)	Assumptions
Reedbeds	1,735	2,500	4,235	25%	5,294	For 1,500m2, use 40 person days of labour (£65/day) and reeds cost £2.5/m2. Need 4 reeds per m2 @ £0.60/reed.
Wet grassland - by hand	3,200	1,600	4,800	0	4,800	Data from other Aggregate Industries UK site. Labour to prepare and spread seed = £0.32/m2. Need 3-5 g seed/m2 @£32/kg seed.
Wet grassland - by tractor	na	1,600		0	-	Data not available.
Lake	0	0	0		0	Following excavation, pumps stop pumping water and hole fills with water to create lake.
Agriculture						Data not available.

Source: Local costs of material and labour provided by D. Shannon, personal comm. March 2010.

3.1.3 Costs of aftercare programmes

Aggregate Industries UK has agreed to provide £200,000 up front to finance the 50 year aftercare programme required on Canal Field. The North Yorkshire Wildlife Trust will implement the aftercare programme. Assuming a two percent annual return on this capital, roughly £4,000 will be available annually for aftercare[2]. As there will be 11 ha of wetland of various types on Canal Field, this amounts to roughly £360/ha/per year for the maintenance of wetlands. In the economic analysis, this estimate is used as the basis for recurrent costs on wetland area on NGB as well, even though aftercare there is the responsibility of the Newby Estate. It is expected that the costs of maintaining wetland areas is the same across the sites. Who bears these costs will affect the analysis only at the distributional level.

3.1.4 Foregone agricultural ecosystem services

Many agricultural ecosystems provide important ecosystem services other than food production (e.g. landscape beauty), recreational opportunities in the borders (e.g. rambling), hydrological regulation, erosion control, maintenance of agro-biodiversity and wild biodiversity if there are areas managed for wildlife, particularly pollinators, as in land certified as Conservation Grade. However, for the Ripon site, these benefits are assumed to be limited as arable cropping is intensive monoculture and there are no significant borders for biodiversity or recreation. The land does provide flood water storage, and this is taken account in the calculation of the incremental flood water storage associated with restoration.

3.2 Benefits

The benefits of the extraction and restoration scenario include benefits associated with flood control, carbon storage, the provision of habitat for wildlife and recreational opportunities. Table 4 below summarises information on the ecosystem services and scale for each site. Note that for some types of ecosystem restoration (e.g. wetland managed for biodiversity) the primary ecosystem service provided is identified and valued on the basis of this ecosystem service. In other cases, multiple ecosystem services may be valued, e.g. flood control and recreation on the lake. In the former case, the value of a wetland is based on a single ecosystem service, and other services are included in the value estimate. The estimates of value calculated in meta-analyses are often average rather than marginal values. This implies that values of individual ecosystem services cannot be summed to obtain the value of the

[2] Alternatively, one could assume a declining annuity with the fund exhausted in year 50 which would provide a higher level of financial resources available for wetland management each year.

wetland. It is difficult to separate the value of individual ecosystem services because (a) they are often interconnected, e.g. flood control, reduced erosion and water filtration, and (b) when asked to value certain attributes of wetlands, people often have difficulty separating the functions of wetlands and as a result state a WTP for multiple services of wetlands, i.e. existence and use values are difficult distinguish between when applied to the concepts of biodiversity which is not often well understood.

The Environment Agency recommends that the predominant service (e.g. flood control, recreation, habitat) provided by a wetland be identified and the value for that service is assumed to include other services, e.g. reduced erosion, water filtration. This does not, however, apply to carbon sequestration which is independent of other wetland services. This study adopts this practice when original studies state that value estimates are for the wetland as a whole. However, when original studies are very precise and estimate marginal value, e.g. the value of a man-made lake, it is considered appropriate to add flood control benefits. All assumptions are stated in the text to avoid confusion.

Table 4 Post-restoration land use and ecosystem services (ES)

Site	Use after restoration	Area by use (ha)	Predominant ES	Other ES	Proposed primary use
Bridge Field	Agriculture	5.4	crop production		food
Canal Field	Reedbed	8.3	biodiversity	flood control, carbon sequestration	protected area
	Marsh/grassland	1			
	Open water	1.65			
	Wet woodland	0.05			
	Subtotal wetland CF	11.0			
	Agriculture	1	crop production		farming
Newby Gravel Beds	Lake	11	recreation	flood control	boating
	Reedbeds	1.2	biodiversity	flood control, carbon sequestration	birdwatching, angling
	Marsh/grassland	1.8			
	Woodland/ wet woodland	1.85			
	Sub-total wetland NGB	4.85			
	Agriculture	5.15	livestock		meat production
Total	**Total**	38.4			

Details of the benefits to people of the ecosystem services of restored areas are provided below.

3.2.1 Flood control

Flood risk mitigation is an important service provided by wetlands. Wetlands help in flood alleviation by storing floodwater, reducing peak flood water flow and flowing water discharge rates following heavy rain and storms. Wetlands act as natural reservoirs, storing water in their soils or in surface water, reducing runoff and releasing water gradually. The provision of these services reduces the need for costly infrastructure to protect the five million people who are at risk of flooding in England and Wales (EFTEC, Just Ecology and Turner, 2006).

The quarry extension sites are located in a traditional washland area which is a semi-natural floodplain designed for flood control and used at time of high flow to reduce flooding elsewhere in the catchment. The extension sites are bounded by the canal and the Rive Ure (which flows into the Ouse at York) both of which overflow their banks regularly. On average, the floodplain is inundated once every two to three years. For the 100 year flood, the depth of the water over the floodplain is estimated to be one metre. In autumn 2000, there was widespread serious flooding in the area.

The Environment Statement hydrological report confirms that the extension of the quarry has no negative impact on flood plain conveyance or storage in the short term. In fact, as the average depth of excavation will be six to seven metres, floodplain storage will increase rapidly once extraction begins (assuming that when flood waters flow onto flood plain that they will be allowed to flow into the excavations).

In the medium and long term, the area of flood plain storage gradually increases as each extension site is worked, and becomes permanent with wetland restoration. This is seen as contributing to the Environment Agency's strategy to increase washland capacity in the Ouse basin.

The Environment Statement hydrology report states that the restoration proposals for the extension areas provide increased run-off potential and a very large, permanent volume of storage for flood water. The total area of water surface of the sailing lake will be around 11 hectares and the level of the water is expected to follow the level of the water table. In addition, roughly seven hectares of reedbeds are to be established on Canal Field, with a ground level no more than 100 mm above the water table. As the water table is assumed to be one metre below ground level, the **volume of additional water storage after restoration is estimated to be 0.17 million m^3**. Discharge from the open water bodies will be via a control structure that will allow stored water to be utilised and mitigate the effect of the additional water stored. As agriculture is assumed to maintain the land at ground level, the estimate of volume of flood water storage after restoration is taken to be an incremental value, i.e. the difference between flood water storage under agriculture and following restoration.

In a meta-analysis of wetland values, Brander *et al.* (2006) estimate the combined value of flood protection and storm buffering of wetlands to be almost **£3,900 per hectare per year** (cited in O'Gorman and Bann 2008). Moreover, the study finds that the value of wetlands which provide flood protection benefits is 14 percent higher than wetlands which do not provide this service.

In an earlier meta-analysis, Woodward and Wui (2001) estimate the value of maintaining wetlands for flood protection to be **£892 per hectare per year (£ 2009)**. This estimate is significantly lower than Brander *et al.* (2006), in part because it separates the valuation of flood control from storm buffering. As discussed above, this value is an average rather than a marginal value of wetlands whose primary service provided is flood control. While Woodward and Wui (2001) calculate the values of other services provided by wetlands, these average values cannot be summed for the different services provided.

This study applies the lower per hectare value of flood control of **£892 per hectare per year** from Woodward and Wui (2001) in the restored areas of NGBs and during extraction in Bridge Field. This estimate excludes the storm buffering value and is therefore appropriate as it is not known what the effects of restoration on storm buffering will be. The value of flood storage is also applied to the area of the lake (even though lakes are not technically considered wetlands) as it contributes significantly to incremental flood storage capacity in the area (Hydrological Report of ES 2008). Flood control is not explicitly included in the estimation of service values in Canal Field because the provision of habitat for wildlife is the primary wetland service targeted there. The estimates of the value of biodiversity applied in this study include other wetlands services including flood protection and enhanced water quality (Christie *et al.* 2004).

3.2.2 Carbon sequestration

Converting land from crop production to wetland is expected to change the GHG balance. Plants remove (sequester) carbon from the atmosphere by the process of photosynthesis. CO2, the most common GHG, is sequestered in biomass and soils in wetlands at higher rates than in cropping systems. We can therefore expect the establishment of wetlands on agricultural land to increase carbon sequestration. Secondly, agriculture can be a source of other GHGs, namely nitrous oxide and methane, which have a greater effect on global warming, per unit emitted (Murray *et al.* 2009). As a result, the discontinuation of agricultural production reduces emissions of these gases. On the other hand, wetlands have anaerobic conditions which produce methane and nitrous oxide as well, and the net change in emissions of these gases associated with conversion from agriculture to wetland is determined by local conditions. In general, however, young wetlands sequester more carbon than more mature wetlands and we thus expect constructed or restored wetlands to act as larger carbon sinks. However, rewetting of organic soils is expected to increase emissions of methane (IPCC 2006). Moreover, depending on soil type, a large proportion of carbon sequestration takes place in soil and this is generally in equilibrium (annual benefits are therefore small) (Andrews, 2006 cited in O'Gorman and Bann 2008). In general, the capacity of a wetland to absorb CO_2e should be assessed at the local level.

There is no data on the carbon content of the extension sites or the expected rate of carbon sequestration in reedbeds in the UK. The IPCC Guidelines for National GHG Inventories (2006) provide methodologies for calculating the net GHG emissions of some types of wetlands, but unfortunately restored and constructed wetlands are not included due to limited empirical studies (IPCC 2006).

There is limited empirical work on carbon sequestration in wetlands in the UK. Andrews (2006) estimated a carbon burial rate for the Humber estuary salt marsh of 0.16 ton/ha/yr. O'Gorman and Bann

(2008) assume that similar habitats in the UK, including freshwater wetlands, have comparable burial rates. To compare, the moorlands of the Peak District sequester on average 0.25 ton C/ha/yr.

This study uses Andrews' (2006) carbon sequestration estimate of **0.16 ton carbon/ha/yr** following O'Gorman and Bann (2008). As this estimate is for established wetlands it is a conservative estimate for this study which assesses carbon sequestration in restored wetlands (carbon sequestration slows as the habitat matures).

In order to value the carbon sequestration services of restored wetlands, a shadow price for carbon is applied, as recommended by DEFRA (2007). The shadow price of carbon reflects the costs of damage associated with climate change which is caused by the release of carbon dioxide into the atmosphere. The carbon price is expressed as carbon dioxide equivalent (CO_2e) to allow comparison with other greenhouse gases. The 2008 shadow price of carbon is £26.5/ton CO_2e and is assumed to rise at two percent per annum in real terms (DEFRA, 2007). The shadow price of carbon in 2009 is calculated to be £27/ton CO_2e. The annual value of carbon sequestered in the restored wetlands is £15.85 per hectare.

3.2.3 Biodiversity

The wetlands to be established following extraction in Canal Field are to be managed for biodiversity rather than recreation. While there may be some recreational benefits such as bird viewing and rambling around the wetlands, the area may be restricted access in order to provide optimal conditions for wildlife. For this reason and due to difficulties separating values for different services provided by a single ecosystem, the Canal Field reed beds are valued based on biodiversity and carbon sequestration.

Biodiversity in a broad sense is most frequently valued through the provision of wildlife habitat and species. These are non-market ecosystem services that are best measured using stated preference techniques which are able to measure both use and non-use values. Stated preference surveys, however, often encounter difficulty as biodiversity is a complex concept that is not easily understood by the public. Nevertheless, a number of studies have been undertaken in the UK, some focusing on the value of conserving particular habitat types (other focus on species or biological diversity itself).

Christie *et al.* (2004) use contingent valuation to measure the WTP for a range of policies that avoid or reduce biodiversity decline in Cambridgeshire (low biodiversity area) and Northumberland (high biodiversity area). Of most relevance to the Ripon quarry extension sites was a proposed habitat recreation scheme that would enhance biodiversity by creating new wetland habitats on existing farmland. The wetlands would provide habitat for a wide range of plants, insects, small mammals and birds, including a number of rare species. The new wetlands would also provide important ecosystem services of flood protection and enhanced water quality. The **annual WTP amounts per household over a five year period** were **£62.5 (£ 2009) in Cambridgeshire** and **£53.4 (£ 2009) in Northumberland**.

The study was intended to develop a cost-effective and robust framework for valuing biodiversity change. To do so, Christie *et al.* (2004) test for benefit transfer between their two case study areas. The mean WTP for all policy programmes included in the study was significantly different between the two case study sites, and as a result the study does not recommend the transfer of their estimates to other parts of the UK. However, the Cambridgeshire and Northumberland data sets used were not equivalent and when this difference is controlled for by looking at individual policy scenarios (this valuation uses WTP estimate from the habitat recreation policy scenario), there was found to be no significant differences in mean WTP values, providing some evidence to support the use of benefits transfer. Moreover, the Christie *et al.* (2004) study assessed the scope for benefit transfer from the two sites to sites throughout the UK. In this North Yorkshire application, the high degree of similarity between the populations of North Yorkshire (the quarry site) and Northumberland (Christie *et al.*'s study site) should reduce the margin of error associated with benefit transfer undertaken throughout the UK. The transferability of bid curves was also analysed, and benefit transfer using bid curves was rejected due to significant differences in the curves. This finding provides additional support for the use in this paper of mean WTP rather than WTP functions.

This study applies the **annual WTP amounts per household over a five year period of £53.4 (£ 2009) in Northumberland** in the calculation of biodiversity benefits for the Canal Field extension. Northumberland lies directly north of Yorkshire and is similar in terms of the socio-economic characteristics of its population. Moreover, the question addressed is the same in the two studies, i.e. identifying values for the conversion of arable land to wetland. In the original study household WTP was aggregated over the population of Northumberland because the study assessed the value of a restoration programme applied throughout Northumberland. As this study focuses on the restoration of specific wetlands, household WTP is aggregated based on the population of the City of Ripon. The population was estimated to be 15,922 in the 2001 UK Census, and this estimate is divided by average household size for England and Wales (2.36 people per household) to estimate 6,747 households affected.

3.2.4 Recreation

The primary benefit of the lake on Newby Gravel Beds will be additional recreation. The main benefits to local recreation will be the creation of a sailing facility, suitable for users of all capabilities, representing an enhancement of the existing capacity of the river (which is suitable only for dinghies). It is not yet clear whether the lake will be stocked for angling.

The economic analysis of recreational value is based on the potential of the lake area for recreation. At the time of the extension application, the Sailing Club had been offered use of the lake, but there was no great enthusiasm as apparently river sailing and lake sailing are considered to be very different types of sailing. It is therefore likely that the lake will be available for other groups for sailing or for other recreational activities such as angling. As the lake will be surrounded by reedbeds and wet woodland, there are opportunities for bird watching as well.

Little empirical work has been done on the recreational value of lakes in the UK. Maxwell (1994) used contingent valuation to estimate the WTP for development of Marston Vale Community Forest and annual WTP for a range of activities to be provided by the forest. The study looks at the benefits of boating specifically. The study asks visitors of the forest in Marston Vale about their willingness to pay for boating activities if a new lake were to be created. The value of boating was estimated to be £4.93 (£ 2009) per resident per year.

This study applies the WTP of £4.93 per resident per year to a projected use of the lake by 1,000 households in the year following lake establishment. The lake is part of the Newby Estate which includes a historic home and gardens which have 160,000 visitors per year. The presence of the Ripon race course nearby and the historic city of Ripon with its famous cathedral bring a significant number of visitors to the area. Boating is potentially a popular past time, and the number of households using the lake for boating each year is predicted to increase by ten percent for the first ten years and five percent thereafter.

3.2.5 Aesthetic/landscape beauty

Overall, the restoration of the three extension sites has been assessed as appropriate to the landscape character which is defined by the River Ure and its riparian woodland and the historical washlands features. The impact of the restoration is seen as a further incremental shift in the local balance between wetland, including recreational wetland, and agricultural land uses within the local floodplain area. It increases the area of characteristic river floodplain wetland mosaic of appropriate riparian habitats, including priority BAP habitats, which already exist, or are being created, in this section of the River Ure. In the longer term, in terms of visual amenity and ecological interest, the restoration results in a beneficial change of moderate and local significance. As the change in landscape aesthetics is marginal, it is not included in the quantitative analysis.

3.2.6 Sand and gravel

The benefits associated with the sale of the gravel and sand have not been included in the economic analysis. If the benefits of mineral extraction were included, it would be appropriate to subtract the implicit value of the resource in the ground. Economic theory tells us that stocks of non-renewable resources in the ground have a value that is based on the option to extract those resources for future use. By extracting now, we forego the option of future use. In theory, the difference between the value of the mineral in the ground and at the quarry gate is the marginal cost of extraction. The price in the ground has traditionally been known as the royalty as it is the value of the underground property right (Neher, 1990). In the absence of local data on marginal extraction costs and quarry-gate prices of sand and gravel, the value of the mineral in the ground which is foregone with extraction is assumed to cancel out the value of the sand and gravel minus extraction costs.

The financial benefits of mineral extraction are, however, included in the financial analysis. The extraction of sand and gravel produces a stream of annual revenues for the duration of extraction. Net returns per ton during the previous stage of extraction ranged from £2.41 in August 2008 when the site was "healthy" to £0.31. (Shannon, personal comm. 2010) Changes in overheads affect net returns, and flooding reduces the output of the quarry (periods of no extraction due to submersion and pumping of water) while the same or greater costs are incurred. This analysis assumes a net return of £2.00 per ton in £2009. The quarry expects to extract 170,000 tons per annum for seven years.

4 Results

4.1 Cost-benefit analysis

The results of the cost-benefit analysis are summarised in Figure 2 and Table 5 below. The net benefits of the restoration scenario using a three percent discount rate and 50 year time horizon are significant at £1.1 million. The positive results are driven by the very large biodiversity benefits of the wetlands on Canal Field and NGB worth roughly £1.4 million. Recreational values are calculated for the lake and despite being limited to the benefits of boating are still significant. There are potentially further benefits associated with angling (if the lake is stocked) and rambling as well. Flood storage is important, but alone does not compensate for the loss of agricultural revenue.

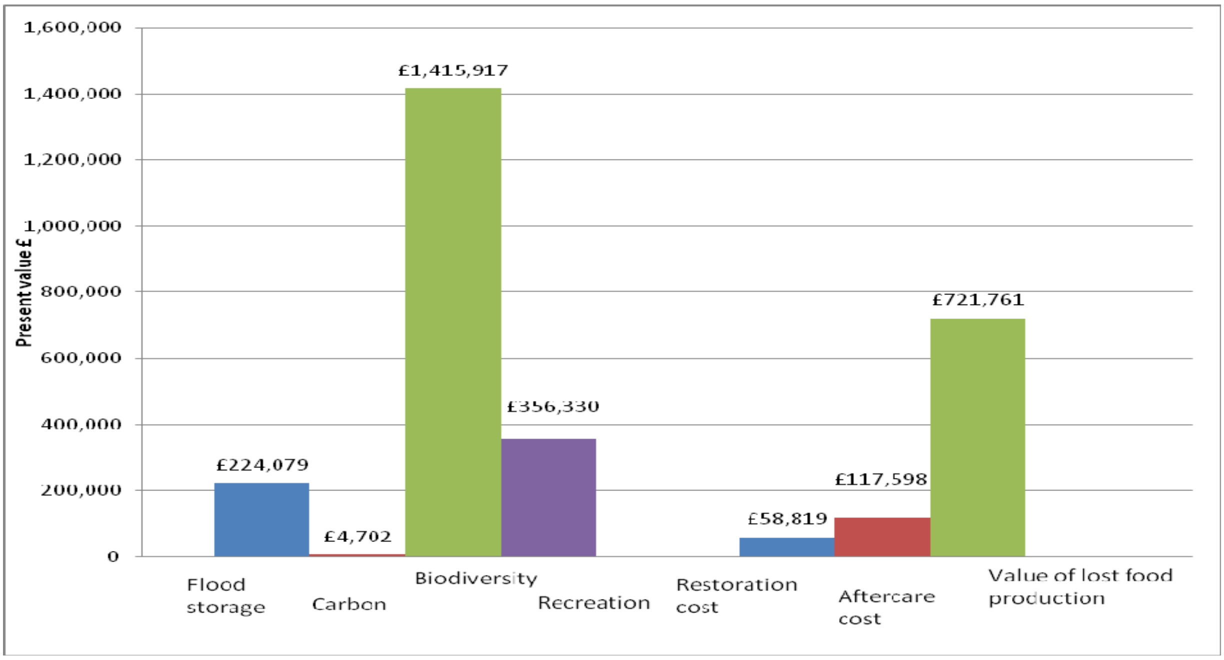


Figure 2 Present value of ecosystem service benefits and costs of Ripon extension restoration

Looking at costs, the greatest economic costs associated with wetland restoration are not the costs of restoration or aftercare of restored areas. It is the foregone profits from agriculture which are by far the largest cost component at £721,761. In the negotiations for the extension of the quarry there was some doubt as to whether Bridge Field would be available for extraction in light of very high commodity prices in the last three years.

Looking at the results by extraction site, the conversion of Bridge Field to extraction and the subsequent restoration to agriculture produces few benefits over and above the sand and gravel extracted. There is a temporary increase in flood water storage during excavation, but this does not compensate for the loss of agricultural output in the same period and the costs associated with restoring the land to agriculture. As a result the NPV is negative at -£40,637. However, if the financial benefits of extraction were included in the analysis, the NPV would be positive (£419,928).

Table 5 Present value by category (£2009, 3% discount rate, 50 years)

		Total	Bridge Field	Canal Field	Newby Gravel Beds
Costs	Restoration	58,819	4,942	42,042	11,835
	Recurrent	117,598	-	84,600	32,998
	Opportunity cost	721,761	43,718	570,591	107,452
	Subtotal costs	898,177	48,659	697,233	152,285
Benefits	Flood storage	224,079	8,024	-	216,054
	Carbon sequestration	4,702	-	3,263	1,439
	Biodiversity	1,415,917	-	982,655	433,262
	Recreation	356,330	-	-	356,330
	Subtotal benefits	2,001,028	8,024	985,919	1,007,085
Net benefits		1,102,850	- 40,635	288,686	854,800
	Sand and gravel *	1,737,490	460,562	371,196	905,732
Net benefits with sand and gravel		2,840,341	419,928	659,882	1,760,532

* The benefits of sand and gravel extraction are financial. Discount rate is 8%.

On Canal Field, the costs of restoring and maintaining wetlands are the highest (£42,042) of the three sites because it has the largest area of restored wetland. The opportunity costs are also relatively high. This is because agriculture on Canal Field was highly productive and crop prices have been relatively high in recent years. On NGB, on the other hand, land has already been taken out of production due to the effects of floods on crop and livestock production. The value of benefits associated with biodiversity and other ecosystem services on Bridge Field are very large (£982,655). Values associated with carbon sequestration (£3,263) are insignificant. As discussed earlier, the important flood control benefits of wetlands are not explicitly included in the valuation of Bridge Field because the WTP estimates used to value biodiversity on this site include a range of ecosystem services. To avoid double counting, flood control was not valued separately.

The total costs in NGB were low due to the low productivity of agriculture (so low opportunity cost) on this particularly low lying land and the absence of significant restoration costs to establish the lake. In comparison, the benefits of recreation and flood storage associated with the lake and biodiversity benefits from the surrounding wetlands are significant with a value of just over £1 million. The NGB site has the highest net benefits due to low costs incurred to restore the area.

The opportunity costs for the land to be restored varied significantly across the sites; opportunity costs provide important information to estimate the net benefits of land use change and hence are essential for land use planning. The relatively low opportunity cost of land across the sites may seem to suggest that the UK should convert much of its agricultural land to wetland since the economic benefits of wetland biodiversity are greater than the benefits currently associated with agriculture. This is, of course, not the case because the values estimated here are marginal costs and benefits which reflect the costs and benefits of converting one hectare of agricultural land to one hectare of wetland at current levels of land use for each. The fact that the marginal value of wetlands is currently greater than agricultural land is due to unimpeded conversion in the UK of wetlands to agriculture over the last few centuries. This uncontrolled conversion has resulted in the currently suboptimal balance of wetland and agriculture, and the findings of this study suggest that the population would benefit from some restoration of wetlands on low productivity agricultural land. However, as this process occurs, the marginal value of agricultural land will increase (as agricultural land declines in area) and the marginal value of wetlands will fall (as are under wetlands expands) until a new balance is reached.

4.2 Distributional analysis

The results above are based on the perspective of society, i.e. all costs and benefits are taken into account. From the perspective of Aggregate Industries UK, there is little opportunity to capture any of the ecosystem benefits flowing from the wetlands because the land reverts to the original owners after extraction. The company simply gains the net profits of extraction minus the costs of restoration, the cost of paying landowners royalties for the duration of the extraction and the cost of the aftercare programme. Aggregate Industries UK is to provide £200,000 up-front, the annual returns on which should provide for the aftercare of the wetlands on Canal Field. Based on the assumptions presented in Table 6 below, the present value of the investment is roughly £1.7 million. The discount rate used in the financial analysis is increased from three to eight percent which is equivalent to the opportunity cost of capital which is used in standard financial accounting.

This rough calculation suggests that increasing the duration of legally required aftercare programmes does not affect financial profits significantly. If no aftercare had been required, the present value of profits would be £1.48 million rather than £1.3 million with aftercare. Moreover, the costs of restoration are very low relative to the net profits of extraction.

Table 6 Financial NPV assumptions and result

Assumptions	Value	Unit
Output	170,000	tons/yr
Total extraction	1,168,000	tons
Profit	2	£/ton
Years of extraction	6.87	year
Capital for aftercare	200,000	£
Cost of restoration	69,131	£
Royalties paid to landowners	10%	% of net returns per year (own assumption)
NPV 8 yrs, discount 8%	£1,303,401	

The other important stakeholders are the landowners. This analysis assumes that royalties of 10 percent will compensate them fully for foregone agricultural profits during excavation and beyond for those sites restored to wetlands. If this were not the case, they would not permit extraction on their land.

Finally, from the perspective of the local community, the major costs are associated with the short-term noise and dust of extraction, short-term impairment of views for a few properties, the short-term inconvenience of moving the sailing club clubhouse and a change to the route of the walking path along the canal. The benefits are improved wildlife habitat in the area, improved recreational opportunities, potential economic opportunities associated with the wetlands and lake (particularly for Newby Estate) and improved flood management facilities.

4.3 Sensitivity analysis

To assess the robustness of the results, sensitivity analysis is used to determine the effect changes in key assumptions and parameters have on the estimated values.

The benefits associated with biodiversity benefits of wetland restoration are based on a "borrowed" estimate of household WTP for the conversion of agricultural land to wetland. This study has assumed that the affected population in this study is the number of households of the City of Ripon. If only half of these households were willing to pay £63 per annum for five years, the benefits of wetland restoration would fall to just under £400,000. If only a quarter were willing to pay, the value of benefits would fall further to roughly £40,000.

Similarly, companies which undertake restoration of damaged land are often concerned about the costs associated with restoration and aftercare. If the cost of restoration of reedbeds is double the estimated cost, the benefits associated with wetland restoration fall from £1.102 million to £1.048 million, a very marginal decrease. If restoration costs are ten times higher than estimated, benefits fall further to roughly £620,000, but are still positive overall. Economic benefits are negative on Canal Field where most wetlands are established. The low cost of lake establishment on NGB maintains the positive economic benefits overall on the three sites despite this dramatic increase in restoration costs. Very high mortality of reeds would have the same effect of reducing net benefits of reedbed restoration, but it would take severe and frequent flooding to raise the costs sufficiently to render restoration not worthwhile.

Table 7 summarises the results of additional sensitivity analysis. Note that changing the assumptions regarding biodiversity benefits has the greatest impact on the results. Changing the discount rate, time horizon, value of benefits associated with flood control, biodiversity and recreation reduce the economic benefits calculated, but not sufficiently to make the present value of benefits negative.

Table 7 Sensitivity analysis

		Original assumption	Revised assumption	Revised NPV	Effect on NPV
Benefits	Flood control				
	£/per ha	862	400	979,225	- 123,626
	Biodiversity				
	no. of hhs WTP	6,747	3,374	394,892	- 707,959
	no. of hhs WTP	6,747	1,687	40,913	-1,061,938
	Recreation				
	no. of hhs boating	1000	500	924,685	- 178,165
	rate of growth of demand y2 onwards	10%	2%	877,274	- 225,577
Costs	Restoration costs				
	cost of reedbed (£/ha)	5,294	10,000	1,064,697	- 38,153
	cost of lake (£/ha)	0	5,000	1,059,433	- 43,417
	Opportunity cost				
	returns to agric (£/ha)	2,178	3,267	795,696	- 307,154
	returns to livestock (£/ha)	340	510	1,049,124	- 53,726
Underlying assumptions	discount rate (%)	0.03	0.08	731,100	- 371,750
	discount rate (%)	0.03	0.15	441,302	- 661,548
	time horizon (years)	50	10	1,102,850	- 161,336
	time horizon (years)	50	30	1,040,579	- 62,272

4.4 Key points

The key findings of this study can be summarised as follows:

Wetland restoration following extraction produces significant benefits to society, the largest of which is the provision of wildlife habitat. The value of flood control and recreational opportunities are also significant. The value of carbon sequestration in restored wetlands was small.

Investment in wetland restoration increases the wellbeing of people locally and regionally even when the economic benefits of the extraction of sand and gravel are not included in the analysis. This suggests that the benefits associated with wetlands are greater than the benefits associated with agriculture, even at times when commodity prices are very high and land is classified as highly productive (Bridge Field and Canal Field).

How people use wetlands affects the values that are attributed to wetlands. To maximise the contribution of wetlands to human well-being, local surveys of people's preferences would be useful. For example, the value of the lake established and the surrounding wetlands can be increased by stocking the lake and allowing angling. The economic benefits associated with angling can be captured via fishing licences or entry fees.

In choosing between restoration options, it is important to have good data on both cost and benefits for each option. While it is relatively straightforward to quantify the economic costs and the ecological benefits of different types of restoration, it is far more difficult to estimate the economic value of differences in relatively small ecological differences. Therefore, it may be preferable to use cost effectiveness analysis which uses least cost analysis to determine the least cost alternative (restoration option) for meeting a stated level of benefits (based on physical measure of ecological quality).

The financial analysis suggests that legal requirements to restore land and increases in the length of aftercare programmes have little effect on the profitability of mineral extraction. The costs of restoration and aftercare are very small compared to both the benefits of restoration and the profitability of mineral extraction.

The distributional analysis suggests that both Aggregate Industries UK and the wider community gain from extraction followed by wetland restoration and lake creation. However, there are short-term effects of noise, dust and impaired views that negatively affect some residents and these effects have not been monetised. Economic valuation can incorporate these effects if willingness to accept compensation surveys are undertaken. This analysis has not monetised all effects, and this should be taken into account in reviewing the results.

There is little scope for Aggregate Industries UK to capture a share of the economic value of the benefits of wetland restoration and lake establishment as the land reverts to its original owners following extraction. However, there is scope for the owners, Newby Estate for the lake and surrounding wetlands, to introduce fees for boating, and angling if there is demand for it.

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