Cost Benefit Analysis of a Catchment Management Scheme using the Avoided Cost Method

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Abstract

Catchment-based management approaches to improving water quality have become a popular alternative in recent years to costly water treatment which deals with the consequences of water quality issues rather than tackling them at source. These schemes have the potential to deliver multiple benefits including improvements to water quality, carbon benefits, enhanced biodiversity, greater amenity value, reduced flood risk and benefits to the local economy. However, more evidence is needed to demonstrate their cost-effectiveness.

This paper reports on a cost-benefit analysis of a catchment management scheme called the Land Incentive Scheme (LIS) undertaken in the Derg catchment on the Ireland/Northern Ireland border. To calculate benefits, the Avoided Cost Method is used which provides a lower bound on the economic value of the water quality improvements secured by the scheme. Projected over a 30-year period, estimates of the benefits and costs of the LIS show that for every £1 invested there would be £3.36 worth of benefits. The majority of cost savings are achieved because regulatory breaches trigger substantial capital and operational spend that could be avoided with effective catchment management. This study shows that 'Avoided Cost' is a credible valuation method which can provide compelling evidence for water companies and policymakers to support investment in catchment-based approaches.

Keywords Agri-environment schemes; Avoided Cost Method; water treatment; catchment management; environmental valuation

JEL code Q50, Q53, Q57

1 Introduction

Catchment-based management approaches are attractive because they deal with water quality issues at source rather than resorting to costly capital-intensive solutions afterwards. Defra's White Paper (2011) recognises that these schemes have the potential to deliver multiple benefits including improvements to water quality, carbon benefits, enhanced biodiversity, greater amenity value, reduced flood risk and benefits to the local economy. It is argued that "facilitating greater local action" will multiply the benefits derived from the natural environment. There is a strong emphasis on partnership, the rationale being that supporting local partnerships that focus on local priorities will strengthen local action. It recognises that such partnerships may cross administrative boundaries so that "they can reflect natural features, systems and landscapes, and work at a scale that has most impact". It argues that forging effective local partnerships will engage and win the support of the local community by "raising awareness about the vital services and benefits that a healthy natural environment brings for people, communities and the local economy", leading to the development of a shared vision. It is argued that the approach provides a platform for engagement and discussion amongst multiple stakeholders of ways to tackle local issues. The White Paper also states the commitment of the government to establishing catchment-level partnerships to create and maintain healthy water bodies.

Catchment-based schemes run by some UK Water Companies have shown encouraging results, providing evidence for the efficacy of these approaches. In 2015, Anglian Water began a 5 - trial called 'Slug it Out' (SiO) to reduce metaldehyde concentrations in 7 reservoir catchments and 1 pumped catchment. The trial was highly successful with a significant reduction in metaldehyde levels in all natural catchments surrounding the reservoirs. There were no exceedances recorded in the 5-year period in 3 of the catchments nor in the one year pumped catchment trial. Overall, there was a 70% reduction in metaldehyde exceedances compared to the period before SiO was introduced. Anglian Water said that developing working relationships with the farmers was vital to the success of the scheme with 7 local Catchment Advisors working with the farmers and landowners to develop these relationships with one-to-one visits, on farm trials, events, newsletters, phone calls and soil health testing.

Other successful catchment management initiatives run by other UK water companies include free weed-wiper hire by Welsh Water and United Utilities, demonstrating that catchment management approaches can be effective in discouraging the use of pesticides that are more harmful to the environment in favour of those that are less harmful.

Adopting catchment-based approaches also contributes to the development of more appropriate River Basin Management Plans as required by the Water Framework Directive as transposed into UK law. Article 7.3 requires that Member States "ensure the necessary protection for the bodies of water identified with the aim of avoiding deterioration in their quality in order to reduce the level of purification treatment required in the production of drinking water", i.e., preventative action should be taken to avoid the deterioration of raw water rather than investing in capital-intensive solutions or relying on increased process intensity.

Economic appraisal: Avoided Cost Method

Although promising to deliver multiple benefits, there is a need for more evidence to demonstrate the economic efficiency of these approaches. This can be established through cost-benefit analysis whereby the costs of implementing a scheme are compared with the benefits. In most cases, the most tangible benefit is the delivery of enhanced raw water quality for abstraction as drinking water. One way of valuing water quality improvements is to use cost-based methods, due to the complexity of estimating the benefits of water quality, many of which are non-market. These include avoided cost and replacement cost, and are typically applied to valuing improved water quality, storm protection or climate regulation.

The Avoided Cost Method estimates the value of increased provision of an ecosystem service by calculating the costs avoided if the ecosystem service is protected. These methods do not yield full economic value of the ecosystem service but do provide useful lower bound estimates of value based on the assumption that its value, say the provisioning service of fresh water, is worth at least the additional costs that must be incurred to maintain this water at the required standard.

Examples of the approach include a recent study which estimated the value of ecosystem services provided by mangroves and found that without mangroves, flood damage costs would increase by more than US$65 billion a year, and 15 million more people would be flooded (Menéndez Fernández et al., 2019). Another study valued wetland wastewater purification by calculating the avoided costs of replacing natural wetland functions with man-made alternatives (Emerton, 2005). Replacement costs included a water treatment plant upgrade and the construction of elevated pit latrines to prevent sewage from low-cost settlements entering the wetland. Cleveland et al. (2006) use the Avoided Cost Method to value the pest control service provided by Brazilian free-tailed bats in Texas, USA by calculating the value of the cotton crop that would have been lost in the absence of the bats and the reduced cost of pesticide use attributable to the presence of bats.

The Derg Land Incentive Scheme

The Avoided Cost Method is used in this study to assess the water quality benefits from a catchment management initiative called the Land Incentive Scheme (LIS) undertaken as part of the €4.9M Interreg Source to Tap (StT) project in the Derg catchment on the Ireland/Northern Ireland border. Between July 2018 and December 2021, the LIS awarded €1.2 million in grants to 118 farmers to adopt sustainable practices for the protection of drinking water in the catchment. It also engaged in community outreach and provided citizen science and school education programmes to increase awareness of the connection between water quality in rivers and lakes and the quality of drinking water.

The scheme focused on pollutants with the highest risks to drinking water quality which were identified as MCPA, colour and turbidity. The herbicide MCPA, which is primarily used in Ireland to reduce rush cover in areas of rough grazing and pasture (Moran, 2015), poses the greatest threat to water quality in the catchment. Because of its high solubility and poor adsorption to soil, it is susceptible to transport into surface and groundwater bodies, where it can result in compromised water quality and legislative breaches (Morton et al., 2020). The regulatory limit in treated water intended for human consumption is 0.1 μg/l, the equivalent of one drop inside an Olympic-sized swimming pool. Following several breaches at Derg water treatment works (WTWs) in recent years, an Optionneering Report provided to the Drinking Water Inspectorate (DWI) recommended the construction a Powdered Activated Carbon (PAC) dosing facility to tackle exceedances which is currently underway at a cost of £4M.

In addition, a combination of peaty soils, especially in the upper reaches of the Derg catchment, sudden heavy rainfall events and forestry felling in the area have caused colour and turbidity as peaty sediment is washed into watercourses during flash floods or forestry operations. High levels of colour and turbidity can cause the formation of trihalomethanes (THMs) during the treatment process. THMs are disinfection by-products produced when water with high concentrations of organic compounds is treated with disinfectants. The risk of THM formation is increased when there are variations in colour over short periods as this requires constant amendments in disinfectant dosages which tends to be the case in the Derg catchment given the factors highlighted above. Although there is no legal limit for colour of treated water, THMs have a combined DWD limit of 100 μg/L. Exceedances in THMs at Derg WTWs led to recommendations presented to DWI to upgrade current processes through the construction of a new clarifier process to deal with THMs. The new capital works is estimated to cost £8M and is currently under construction.

The LIS measures offered to farmers reflected the priorities above. The most popular measures were watercourse fencing to stabilise riverbanks and prevent poaching by livestock, weed-wiping with glyphosate as an alternative to MCPA because of its low mobility in water (Glass, 1987), pesticide storage cabinets to prevent pesticide spillages, clean and dirt water separation and track improvements.

The monitoring programme

To monitor the impact of the LIS in the Derg, a Before-After-Control-Impact (BACI) monitoring programme was used to capture the concentrations of MCPA, colour and turbidity before and after the scheme. The neighbouring Finn catchment, which is hydrologically similar, was used as a control to isolate the impact of the LIS over extraneous factors such as rainfall variability in line with best practice.

The MCPA results showed reductions of 24% and 21% in time-weighted and flow-weighted mean concentrations respectively compared to the control catchment (Cassidy et al., 2022). The decline in MCPA is a successful result considering a very limited time period for monitoring post-implementation of measures with uptake being slow to begin with which is typical of new catchment schemes (UKWIR, 2012a) and compounded by disruptions due to COVID-19. No statistically significant declines in colour and turbidity concentrations were observed though it may take several years for the impact of LIS measures on colour/turbidity concentrations to become evident (e.g., as riverbanks consolidate post-implementation of fencing). More monitoring is currently being undertaken to establish long term trends.

Glyphosate sampling was also conducted to check for pollution swapping of MCPA for glyphosate. Results showed no pollution swapping between MCPA and glyphosate (Cassidy et al., 2022).

The focus of this paper is to explore the following question: Can catchment management approaches compete successfully with traditional capital-based solutions in tackling water quality issues? The Derg study, because of the need to take action in response to recent exceedances at Derg WTWs, provides an ideal test case in which to examine this question. The Avoided Cost Method calculates the water treatment cost savings from the LIS at Derg WTWs. These savings can then be compared to LIS costs in a cost-benefit analysis to establish value for money.

This paper has two main contributions. First, it shows how the Avoided Cost Method can be used to calculate lower bound estimates of the value of enhanced drinking water quality, highlighting potential difficulties and limitations. Second, it provides hard evidence to water companies and policymakers for the adoption of catchment-based approaches by demonstrating the escalation of costs associated with regulatory breaches in drinking water quality that could be avoided with effective, long-term catchment management.

The remainder of the paper is organised as follows: Section 2 examines the methodology used in the cost-benefit analysis. Section 3 presents results and Section 4 provides discussion and conclusions.

2 Methodology

2.1 Use of a Cost Benefit Analysis

This section describes the methodology used for the cost-benefit analysis (CBA) of the LIS. At a time when public spending is increasingly under scrutiny, it is essential to make informed decisions regarding the adoption of such schemes in the future. CBA enables an evaluation of the LIS to be undertaken in a transparent and consistent manner, comparing the costs and benefits of a 'business as usual' (BAU) scenario without the LIS and the intervention scenario with LIS type measures in place.

An initial qualitative assessment was carried out to assess all benefits derived from the LIS. These included water quality benefits for abstraction, educational benefits from the community outreach programme, enhanced biodiversity, recreational benefits for anglers and erosion control. It was beyond the scope of this project to monetise all the benefits and instead the focus of the research was on the most significant benefit which is enhanced raw water quality for abstraction as drinking water with a secondary focus on educational benefits from the community outreach, school visits and citizen science.

In evaluating a scheme, the time period for the benefit assessment must be defined. The key determinant in the choice of time period is how long the benefits are expected to accrue. Some benefits will only accrue in the first few years, while others will continue to deliver benefits for decades. Weed-wiping will produce long-term benefits only if farmers make a long-term shift from MCPA to glyphosate. To accommodate all long-term benefits from the LIS measures, including galvanised steel fencing and tree planting, the time period chosen for this evaluation was 30 years (2019 to 2048) with a 3.5% per annum discount rate as per Green Book (2022) recommendations.

2.2 Model assumptions

To value the impact of improving the water quality within the Derg with respect to drinking water provision, it is first necessary to define the change in question. What are the costs of treating the water to make it suitable for drinking water without the LIS (the 'business as usual' scenario) and the costs of treating the water with the LIS (the intervention scenario)? The difference in treatment costs between these two scenarios represents the water quality benefits of the LIS via the Avoided Cost Method and can be compared to the costs of delivering the LIS in the Cost-Benefit Analysis (CBA).

In order to define the BAU and intervention scenarios and project them over the 30-year time frame, assumptions were made about several variables or factors that will impact on the final CBA values. A combination of sources was used to derive the most accurate assumptions which included the following:

- The monitoring programme: showed reductions of 24% and 21% in time-weighted and flow-weighted mean concentrations of MCPA respectively These are encouraging results but continued, long-term support would be needed to make sufficient progress to avoid MCPA exceedances; no evidence of pollution swapping with glyphosate was found. However, the potential danger of pollution swapping highlights the importance of emphasising pesticide reduction strategies across the board wherever possible, for example, by encouraging topping where possible instead of pesticide use and by engaging with the amenity sector and the general public to promote minimal and correct usage; more data is needed to established impact of LIS on colour and turbidity so the analysis assumes that a 5% reduction in colour/turbidity will be achieved over time. However, this is insufficient to prevent exceedances in THMs.
- The Process Evaluation: This was conducted to scrutinise the scheme for information and insights to improve the delivery and efficiency of similar schemes in the future. It involved in-depth interviews with key players on the project. As highlighted, the main measure offered to reduce MCPA concentrations was weed-wiping with an alternative chemical called glyphosate. However, the Process Evaluation found that, given status-quo bias, it is likely that a sizable proportion of farmers will revert to MCPA use following closure of the LIS given its limited time frame so further action would be needed.
- Discussions with NI Water experts including scientists and engineering project managers, quality and compliance staff, Business Unit staff, and outsourcing partners and catchment staff. This was to:
    - understand the relationship between parameter concentrations and treatment costs at the WTWs
    - discuss assumptions about anticipated GAC filter (used to remove MCPA) degeneration under both scenarios
    - discuss feasible future catchment-based measure and associated spend under the intervention scenario
- Information on the expected life fencing, pesticide storage units and other LIS measures given their contribution to the water quality improvements secured through these measures, for example, Clipex fencing is assumed to last 30 years while wooden post and wire fencing which is assumed to last for 15 years with a residual value in benefits equivalent to an additional 2 years
- Additional validating data supplied by the telemetry team, NI Water
- Evidence from similar projects by UK water companies, e.g., SiO and PestSmart
- Other sources, e.g., research on whether glyphosate will continue to be re-licensed in the future. Glyphosate is currently approved for use in the EU until 15 December 2023 having received a one-year extension following its five-year approval by the

European Commission in 2017, and in the UK until December 2025. The use of glyphosate has drawn controversy. In March 2015, IARC (International Agency for Research on Cancer) classified glyphosate as "probably carcinogenic to humans" and ahead of the 2017 EU renewal of glyphosate, a European Citizens Initiative co-initiated by HEAL (Health and Environment Alliance) was signed by over one million people calling to ban the pesticide. However, given a recent positive review of glyphosate by the Assessment Group on Glyphosate (AGG, 2021), there is little evidence that glyphosate will be totally banned though a partial ban may be imposed that will not apply to agriculture.

As highlighted above, given the time limitations facing the current LIS, it was not feasible to achieve reductions in MCPA and THM concentrations to the point at which regulatory compliance could be guaranteed. Whilst but monitoring showed encouraging reductions, the need for ongoing support for farmers to reduce concentrations further is clear which would require additional investment. To achieve compliance in THMs, the LIS measures taken will not be sufficient to guarantee regulatory compliance and the need for additional capital investment is assumed. A hybrid approach is recommended going forward that will combine capital expenditure at the WTWs with continued LIS investment, with the focus of the former ensuring THM compliance via a new clarifier, and the latter ensuring MCPA compliance via catchment management approaches. Because the new clarifier is included under both scenarios, the costs cancel out.

Given that ensuring regulatory compliance is non-negotiable, both the BAU and intervention scenarios must execute strategies that are likely to achieve this goal. Therefore, the scenarios which form the basis of the forthcoming analysis are:

Business as usual: This assumes no LIS. The clarifier and PAC facility are constructed to meet regulatory compliance in MCPA and THMs and there is no future LIS investment.

Intervention: This assumes the LIS under Source to Tap (2019-2021). Given that regulatory compliance in THMs cannot be guaranteed through LIS measures, the intervention scenario also assumes the construction of the new clarifier. To meet regulatory compliance in MCPA, the LIS will be extended to promote a permanent shift away from MCPA use via current LIS measures and additional initiatives identified through the Process Evaluation.

Table 1: BAU and Intervention Scenarios

Business As Usual Scenario	**Intervention Scenario**
No LIS implemented	LIS implemented under StT (2019-2021)
Construction of clarifier to deal with THM exceedances	Construction of clarifier to deal with THM Exceedances
Construction of PAC facility to deal with MCPA exceedances	No PAC facility constructed
No LIS investment (2022-2048)	Continued LIS investment (2022-2048) to deal with MCPA exceedances

The additional investment in catchment management would take into account all the learning from the Process Evaluation and would involve the following elements:

- Continued support for farmers post StT to ensure a long-term shift away from MCPA use via subsidised weed-wiper and topping contractor costs, free weed-wiping hire enabling a 'try before you buy', weed-wiper grants and weed-wiper training
- Continued education of farmers post StT about the high levels of MCPA in the catchment via events and information bulletins demonstrating issues and tracking progress on raw water quality
- The provision of pesticide storage units to help reduce spillages on farms that did not receive them within the current LIS, and the provision of drip trays and spill kits
- Regular pesticide disposal schemes for farmers wishing to clear out unwanted pesticide products including MCPA.

2.3 Evaluating the benefits of the LIS

2.3.1 Enhanced water quality for abstraction

Improving the quality of the raw water abstracted from the Derg WTWs will deliver benefits through a reduction in the treatment costs necessary to meet the standards of the DWI. The Avoided Cost Method is used to estimate a lower bound of the economic benefit of the improved water quality delivered by the LIS measures. This calculates the cost savings that would be achieved over the given time period as a result of reducing the concentrations of MCPA, colour and turbidity, including costs avoided by preventing regulatory exceedances through catchment action. The results enable a direct comparison to be made between capital-intensive and catchment-based solutions, which, when combined with LIS cost data, provides a useful value for money metric.

Savings include capital, operational and other exceedance related costs as follows:

Capital cost savings: To remove MCPA, the water is passed through Granular Activated Carbon filters (GACs). However, they represent a costly investment, both in terms of the initial capital outlay to build the filtration units and the ongoing cost of regenerating or replacing the GAC (classified under capital expenditure). Lower MCPA concentrations reduce capital expenditure since GAC regeneration/replacement will occur less frequently. The decision to regenerate or replace is made on the basis of an iodine number test which assesses the residual activity in the GAC.

NI Water provided historical data on the dates on which GAC was replaced or regenerated in each of the five filtration units at the Derg WTWs with the corresponding iodine numbers. The original goal was to analyse this data alongside MCPA sample data to estimate the relationship between GAC degeneration and MCPA levels. However, due to widespread inconsistencies in the iodine numbers and inadequate historic MCPA sample data, this was not possible, and it was necessary to rely on the expert opinion of staff in NI Water's scientific team and outsourcing partner (for GAC regeneration) to estimate GAC filter regeneration/replacement rates at the Derg WTWs.

Operational cost savings: These are the savings accruing in the day to day running costs at the WTWs under the intervention scenario as colour and turbidity concentrations are reduced compared to the BAU and include the chemicals alum and lime, and sludge disposal.

Alum causes suspended solids to clump together and settle at the bottom of the tank in a process called coagulation. Coagulation control is important to maintain water quality, especially given that the Derg is a 'flashy' catchment with rapidly changing levels of colour. However, it has been many years since the system has been updated and coagulation control is sub-optimal. This is compounded by the fact that there are so many variables at work that accuracy is difficult to achieve. The clarifier, which is currently under construction at the Derg WTWs, includes a systems' upgrade to enhance optimisation. Data on alum flow in millilitres per second is recorded at 15-minute intervals 24/7 by the online system at the Derg WTWs and is stored on NI Water's online SCADA (Supervisory control and data acquisition) telemetry system.

Lime is dosed to optimise pH levels for coagulation. There was no daily data for lime use, but only a weight indicator which cannot be relied upon to provide accurate daily usage. It was therefore necessary to use monthly data on lime usage provided by NI Water based on stock inventory levels.

Energy costs were also available but were excluded since having higher concentrations of colour, turbidity or MCPA will have a minimal impact on the amount of electricity used. However, these are relevant where investment must be made in a new capital works solution involving additional electricity costs.

After the water treatment process, the settled sludge is retained in the bottom of the tank for tanker removal and disposal. Again, no variable exists on the WTWs system to measure daily sludge levels but information on monthly sludge disposal in tonnes was provided by NI Water.

Estimating the operational cost savings associated with lower concentrations in colour and turbidity involves the following steps:

1. Identify all costs relevant to the reduction in colour and turbidity in abstracted water (cost of alum, lime and sludge disposal per tonne) and collect all available data on monthly (or where possible, daily) alum and lime usage, and sludge disposal in tonnes.
2. Collect all sampling data on raw water colour and turbidity levels at the WTWs.
3. Track, via regression analysis, raw water parameter data against chemical usage to establish a relationship between the two, i.e., how much does alum dosing increase as colour concentrations increase?
4. Apply cost data from step 1 above to establish a per unit cost of reducing colour and turbidity concentrations.
5. This is then applied to the monitoring results to obtain operational cost savings from the LIS.

NI Water provided data on alum and lime usage, and sludge disposal as well as corresponding costs per tonne. The telemetry team at NI Water provided data from their SCADA system on raw water colour (mg/l Pt/Co) and turbidity (NTUs) at 15-minute intervals, 24 hours a day. Detailed analysis of alum flow data found significant discrepancies between the amount of alum recorded by the Acromatic (the automatic dosing system at the Derg WTWs) and inventory stock records. A staff member at the Derg WTWs emphasised that because of sub-optimal coagulation control, the data may not provide a very accurate picture of the relationship between colour/turbidity and the amount of alum used. This was because the Acromatic could not keep up with the flashiness in the catchment which, at times, necessitated manual interventions by WTWs staff. Unfortunately, because of the discrepancies between SCADA and inventory stock levels, the daily data was abandoned in favour of monthly data which reflects more accurately how much alum is in fact used at the WTWs.

To establish per unit costs of reducing colour and turbidity, monthly alum and lime usage and sludge levels were tracked against monthly colour and turbidity data for a five-year period from 2016 to 2020.

Exceedance prevention savings: Given MCPA and THM exceedances, an escalation of additional costs is triggered under the BAU scenario. These additional costs represent a potentially substantial contribution to overall cost savings under a successful intervention scenario but are conditional on concentrations being reduced to the point at which the raw water entering the WTWs is likely to be treated effectively with no exceedances in MCPA or THMs. Again, where applicable, these costs would be captured as 'avoided costs' under the intervention scenario.

In the Derg WTWs, the MCPA exceedance costs included:

- upgrades to more costly GAC filters,
- feasibility and treatability studies,
- trials with associated report writing, and
- the development and design of a new PAC dosing facility with associated operational costs.

THM exceedance costs included:

- a complete review of current processes,
- the design and construction of a new clarifier and associated operational costs.

2.3.2 Educational benefits

These are cultural services provided by the ecosystem and include the benefits arising from citizen science opportunities, school visits and wider community outreach where the focus is on the water environment. This is because the ecosystem, here the rivers and lakes, provide the inspiration and basis for learning. There is no obvious economic technique to value educational benefits. However, the UK National Ecosystem Services Assessment (2011b) argues that for school visits, it should be assumed that the cost of conducting school visits is at least worth the cost of investment, i.e. staff time, materials and travel costs, and this could be viewed as a lower bound on value as long as they are conducted economically. This is the approach also taken by Yorkshire Water in its Total Impact and Value Assessment (Yorkshire Water, 2018).

The same can be said for citizen science and wider community outreach. The community outreach undertaken supported uptake of the LIS by getting the message out about the scheme, for example, school children brought LIS leaflets home and this led to a few phone calls to the project officers and subsequent engagement with the scheme.

2.4 Evaluating the costs of the LIS

Costs were recorded for all aspects of the LIS and community outreach. The LIS costs include staff time spent in initial training and in the development, design and implementation of the LIS with associated administration and recording. They include external costs such as external consultancy and website costs in designing the scheme, the cost of advertising (e.g., radio and newspaper adverts), publicity (e.g., room hire, hospitality, printing of promotional materials) and travel and other miscellaneous costs.

Costs of the community outreach covered staff time developing and delivering the schools and citizen science programmes with associated administration. They covered all external costs including web design, publicity, advertising, travel and other miscellaneous costs. Staff time for both the LIS and community outreach included an allowance for time spent by all relevant partners.

It is assumed that the follow-on LIS would commence immediately following closure of the current scheme and would continue to run throughout the entire evaluation period, i.e., up to 2048. Following discussions with NI Water catchment staff, investment would be £200,000 per year in years 4-8 and £100,000 per year in years 9-30. The present value of the total cost of additional LIS investment is estimated to be £2 million between 2022 and 2048. The follow-on scheme would capitalise on the learning and trust-building of the current scheme, and it is anticipated that there would be considerable savings made through simplifying structures and administration, by focusing on a smaller number of measures and targeting these more effectively. It is also important to note that the benefits of weed-wiping and topping are cumulative. As more rush and other weeds are eliminated over time, the cost of treatment would continue to fall and MCPA peaks will continue to reduce.

3 Results

The CBA undertaken for the LIS and community outreach involved comparing the benefits of the scheme to the costs of running the scheme.

3.1 LIS benefits

3.1.1 Water quality benefits

Table 3.1 shows total monetised water quality benefits from the LIS as present values which includes all cost savings at the Derg WTWs from the LIS over a period of 30 years. Capital cost savings are £3.7M and include the capital costs associated with construction of the PAC facility and GAC filter savings through less frequent replacement and regeneration of filters. Operational cost savings are £7.4M and include cost savings in alum, lime and sludge disposal, and the additional operational costs associated with the PAC facility. When MCPA levels are kept below regulatory levels, other additional cost savings accrue, for example, treatability and feasibility studies and trials, amounting to an additional £1.1M in cost savings. This amounts to estimated total water treatment cost savings of £12.2M.

Table 3.1: Water treatment Cost Savings from the LIS (Present Values)

	£'000
Capital Cost Savings:	
PAC facility – capital	3,608
GAC filter savings	105
Operational Cost Savings:	
PAC facility - operational	7,359
Alum	22
Lime	6
Sludge disposal	21
Other exceedance-related savings	1,120
Total water treatment savings	**12,241**

3.1.2 Educational benefits

The only non-market benefits to be monetised in this study are the educational benefits. As suggested by the UK National Ecosystem Assessment (2011b), the educational costs should form a lower bound on benefits, i.e., it is assumed that this opportunity to learn will at least cover itself. The total educational benefits of the community outreach were assumed to be equivalent to the cost of investment which was estimated to be £144K.

Table 3.2: Water Quality and Educational Benefits of the LIS (Present Values)

	£'000
Water quality benefits	12,241
Educational benefits	144
Total Benefits	**12,386**[1]

Total water quality and educational benefits yield total benefits of £12.4M.

3.2 LIS costs

Total costs in present values for the LIS came to an estimated £1.6M. This included grants to farmers, salaries, development and design costs, publicity and travel costs. Community outreach includes school visits, the citizen science programme and other educational outreach in the community. Total costs were £144K and covered staff time, the development of the programmes, travel and other expenses. In total, the present value for the costs for the LIS and community outreach undertaken as part of Source to Tap project was an estimated £1.7M (Table 3.3). All these costs were incurred in the lifetime of the project (2019-2021). The present value of the total cost of additional LIS investment beyond the lifetime of the StT project is estimated to be £2M between 2022 and 2048. This gives an estimate for total costs of the LIS and community outreach including additional investment of £3.7M.

[1] Does not add up due to rounding.

Table 3.3: LIS and Community Outreach Costs (Present Values)

	£'000
LIS	1,577
Community outreach	144
Additional LIS investment	1,966
Total costs	**3,688**[2]

3.3 Cost-Benefit Analysis Result

Over a 30-year period from 2019 to 2048, comparing the benefits and costs of the LIS including future LIS investment costs gives a Net Present Value of £8.7M and a Benefit Cost Ratio of 3.36. That means that for every £1 invested there will be an estimated £3.36 worth of benefits.

Table 3.4: NPV and Benefit Cost Ratio of LIS and Community Outreach (Present Values)

	£'000
PAC facility - capital	3,608
GAC filter savings	105
PAC facility - operational	7,359
Alum	22
Lime	6
Sludge disposal	21
Other exceedance-related savings	1,120
Total water treatment savings	12,241
Educational Benefits	144
Total Benefits	**12,386**
LIS Costs	1,577
LIS Extension Costs	1,966
Community Outreach Costs	144
Total Costs	**3,688**
Net Present Value	**8,698**
Benefit Cost Ratio	**3.36**

Base year=2018; Period of analysis=2019-2048

There are several other non-market benefits which should also be considered alongside the results presented above. Those above focus only on savings from lower concentrations of MCPA, colour and turbidity, but it is likely there will be other water quality benefits, e.g., reduced ammonia and coliforms for drinking water abstraction. Recreational benefits to anglers, biodiversity benefits, erosion/flood control and non-use benefits should also be noted as positive benefits.

[2] Does not add up due to rounding.

4 Discussion and conclusion

The goal of this study was to undertake a cost-benefit analysis of the LIS and community outreach programme under the Source to Tap project to act as a test case for catchment-based approaches. The most significant benefit was higher water quality for abstraction as drinking water which was measured by examining savings in water treatment costs as a result of the LIS. To capture these benefits, two scenarios were compared: the business as usual and intervention scenarios which examined what would happen in the absence/presence of the LIS. It was further assumed that each scenario must achieve regulatory compliance in both MCPA and THMs which required that the LIS be extended to enable it to compete with planned capital-based solutions at the Derg WTWs.

The analysis identified a hybrid strategy as the best solution combining catchment management approaches to deal with MCPA exceedances with capital-intensive approaches to ensure THM compliance. This study has shown that cost savings from catchment management are most clearly demonstrable where regulatory exceedances in a catchment are likely to trigger substantial capital and operational expenditure. The second most significant benefit was educational, via school visits, citizen science opportunities and other community outreach. Only water treatment savings and educational benefits were monetised for the purposes of this study. Several additional benefits were also delivered through the LIS example, the biodiversity benefits and recreational benefits to anglers from enhanced water quality.

The analysis showed that the benefits of the LIS would cover the costs over three times over. Projected over a 30-year period, estimates of the benefits and costs of the LIS including future additional investment in catchment management costs gives a Net Present Value of £8.7M and a Benefit Cost Ratio of 3.36. That means that for every £1 invested there will be £3.36 worth of benefits. The majority of cost savings are achieved because regulatory breaches trigger substantial capital and operational spend that could be avoided with effective catchment management.

In recent years, markets have been established for ecosystem services which creates the possibility of 'stacking' whereby multiple buyers pay separately for the ecosystem services that arise from the same parcel of land or body of water (Smith et al., 2013). For example, to fund river restoration work via the creation of riparian zones, the water quality benefits are purchased by the water company, the biodiversity benefits are purchased by a wildlife charity on behalf of its membership and carbon benefits from tree-planting are purchased by a local business keen to promote its eco-credentials. Although still in the early stages, the government is committed to this approach emphasising "real opportunities for land managers to gain by protecting nature's services, and trading nature's benefits with businesses, civil society and the wider public sector" (Defra, 2011).

Catchment approaches have great potential but require a significant investment of time and resources to effect and sustain the long-term behavioural change needed to tackle water quality challenges effectively. It can take years to build up trust with farmers and the local community, to work through conflicts and create win-win solutions, but many schemes suffer from restrictive short-term funding schedules. This hampers their effectiveness so that they are unable to compete with costly capital-based solutions. Instead, engagement must be sustained and built upon to ensure long term success which will deliver substantial water treatment cost savings and multiple additional benefits.

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