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Thinking Catchments: a holistic approach to asset management in the water sector

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ABSTRACT
The hypothesis of this work is that the application of life-cycle thinking at a catchment scale will assist in the evaluation of natural capital and the integration of natural assets into the asset management portfolio of water industries. Drawing from literature on asset management and ecosystem services, this paper demonstrates the need for a holistic asset management strategy in the water sector. Through a detailed analysis, an approach coupling Integrated Catchment Management and Life Cycle Thinking is proposed. Within the paper, the background to the challenges facing the sector is described, followed by an analysis of the methods used to define the approach and the techniques required to undertake the analysis. The main focus of the work is the water sector in the UK. In order to evaluate the approach research is undertaken with Wessex Water Services Ltd.

Keywords: asset management, ecosystem services, catchment, life cycle thinking.

INTRODUCTION
The industrial sector, and industries focused on commodity management, have recognised the considerable indirect and direct impacts they have on natural capital and the role the latter plays in their viability. Despite this interdependent relationship and natural assets being fundamental for human wellbeing and economic growth, natural capital is inadequately valued compared to social and financial capital. It is the view of the authors that by valuing natural capital business could benefit and improve. To achieve this, it is necessary to have a means to value natural capital. A major challenge at present is the absence of a stantardised methodology or of a framework which adequately reports or accounts for natural capital (i.e. Earth's natural assets- soil, air, water, flora and fauna and their resulting ecosystems services) in the global financial system, as an economic, ecological and social asset.

As a result, a number of initiatives, methodologies and tools have emerged over the last few years, most of them being from the industrial sector (Maxwell et al., 2014). Private and public sectors are encouraged to create the conditions necessary to maintain and enhance natural capital, whilst governments develop relevant regulating frameworks (Natural Capital Declaration, UNEP, 2012). For the water sector, the Urban Water Blueprint report (McDonald and Shemie, 2014) shows how investing in nature can help addressing current challenges in drinking water security provision. This work applies a structured methodology at a city level in order to evaluate a set of solutions to the growing number of water-related issues.

Asset management in the water sector
Services in the water sector depend heavily both on natural assets (e.g. water), as well as on the function and performance of physical assets. Indeed, there has been a drive by regulators across Europe to improve the quality of the aquatic environment, most recently in response to the Water Framework Directive (WFD, 2000/60/EC). Achieving WFD water quality standards would bring significant social and environmental benefits. Thus, there is a growing case for understanding the dependencies water industries have on natural assets, the risks and opportunities associated with this relationship and their real value.

In the UK water sector, asset management strategies (Kwok et al.2010a), are the key drivers of current practice and future planning. Based on the guidelines provided in each strategy, asset management has evolved over the past years, and is being used to form a structural framework to meet regulations and improve business efficiency (Too, 2011). Following the definitions for asset management and asset systems as described in the British and International Standards, PAS 55/ BSI ISO55001, water industries (e.g. Waternet in Netherlands and Wessex Water in the UK) have created frameworks underpinned by systems thinking, to secure the provision of qualitative services to their customers and assets' viability. The boundaries of these systems are drawn where the physical asset systems (e.g. capital, operation and refurbishment costs of infrastructure) is at the centre, whilst the wider environment is treated as an externality.

Nevertheless, for asset management to become a true value-adding pursuit within a corporate framework, it must be primarily concerned with filling a strategic role. Asset management strategies have evolved from the specific conditions in which the organisation operates (Woodhouse 2006). According to literature (Palmer 2010), energy policy, climate change regulation, capital costs and strategic resources are the major challenges affecting the future of their asset investment. Facing these challenges, the water industry may need to adopt a more integrated approach in their asset management strategies and investment plans. This need for an integrated approach is highlighted in a recent report published by the UK Water Industry Research (UKWIR, 2014). The findings from the report are aimed at encouraging the UK water industry to work collaboratively with stakeholders of the watershed (i.e. the boundary between separate hydrological catchments) areas under their service in order to fully consider and seek to achieve a balance between social and environmental costs (e.g.. wider environmental impacts of carbon emissions, increased bills etc.) of their services at a local scale. They are advocated to define their strategic goals around a different center other than the physical asset, for example the environment, or society, in order to ensure alignment with the UN Natural Capital Declaration and meet the requirements for truly sustainable solutions.

Hypothesis & Aim

The hypothesis of the research presented in this paper is that the application of life cycle thinking at a catchment scale could prove a valuable tool for the evaluation of natural capital and the integration of land as a part of the physical asset management portfolio for water industries. The research demonstrates that a wider context that considers benefits provided by the natural environment (i.e. ecosystem services approach) needs to be adopted and a holistic structured approach introduced, whilst justifying the reasoning for the selection of each method. Integrated Catchment Management (ICM) and Life Cycle Thinking form the basis of the research. To evaluate the approach, collaboration is undertaken with Wessex Water Services Ltd for a selected catchment (case study). The outcomes of the research project will be embedded in their strategic plan for the Asset Management Programme 6 (AMP6, 2015-2020), which proposes an innovative programme, emphasising the mix of conventional end-of-pipe investment with novel approaches, such as catchment (land) management solutions.

The following sections of the paper give an insight to the methods used to create a holistic asset management strategy in the water sector. The methodological choices are described and the use of the concepts formulating the basis of the work are justified, followed by a description of the selected case study.

METHODS

The work links various disciplines which range from asset, water and environmental management, to ecosystem services, cost estimation and systems thinking, offering transdisciplinary research.

Transdisciplinarity is a goal-oriented process rather than a knowledge production process per se (Walter et al., 2007, Krimsky, 2000). It is a way of placing the research problem, topic, or question at the centre of research process or a “new way of thinking” (Giri 2002), which has emerged as a way to address complex issues and requires innovation and flexibility (Leavy, 2011). A systems view is a powerful concept to be used in complex research projects (Schwaninger et al., 2007).

The design of transdisciplinary research requires an evolving methodology that follows an iterative or responsive process (Wickson et al., 2006) and ensures that the research questions stay at the centre of the research process. Moreover, the design strategy should be holistic and involve a synergetic approach to research (Leavy 2011).

The methods applied are selected in relation to the specific issue under study and for their utility in eliciting or analysing data. Transdisciplinary research often involves multi- or mixed-methods designs, constructed in service of the research goals, as they provide a practical and holistic approach to research problems, emphasising pragmatism (Hesse-Biber & Leavy 2011). Therefore, the use of each method informs the use of the other methods, rather than being simply additive.

Transdisciplinary research topics may be organised around a “site”, i.e. a conceptual space where disciplines assemble (Krimsky 2000). Thus, situational context becomes important in studies of the concrete real world, whose results need to be comparable or transferable. This is a strong argument for the use of the case study method in transdisciplinary research projects (Walter et al., 2007).

Case studies aim to illuminate the general by looking at the particular. The rationale behind concentrating efforts on a single case is that there may be insights to be gained from looking at the individual case that can have wider implications (Denscombe 2010). Many of the features associated with a case study are not necessarily unique; however, when combined, they give the approach its unique character.

Transdisciplinary research can largely be evaluated with respect to effectively addressing the issue, its focus on the research objectives and using appropriate strategies (Leavy, 2011). The case study method can serve evaluation needs by being able to assess outcomes and test hypotheses (Yin 1993). To achieve that, a major prerequisite is development of causal relationships, which will then become the main vehicle for developing generalisations.

Life Cycle Management tools (e.g. LCA, LCC) could prove useful for water-related transdisciplinary research, provided their iterative character in the sustainability assessment of impacts of a product/system/activity using both quantitative and qualitative tools. Case studies can illustrate how effective life cycle management approach (i.e. joint use of LCA and LCC) could become in practice, when used to evaluate sustainable alternatives for product systems (Klöpffer et al., 2008).

RESULTS and DISCUSSION

In this section, the approach created is described through and analysis of the underpinning literature. The various findings from the different literature domains are then assembled to build the rationale of the approach. The selected case study is then used to ascertain whether the concept and specific tools are applicable.

The Catchment as a System

Catchment management is about using land in ways that benefit the water environment. Historically, water authorities in the UK organised themselves at the river basin scale in order to control land use around water sources and prevent contamination of groundwater. However, after privatisation (in 1989) the focus shifted to upgrading water and sewage treatment infrastructure to provide greater guarantees that drinking water and effluent standards would be met within short timescales (Rouse, 2013). Nevertheless, there has recently been an upsurge interest in catchment management, as a less resource-intensive way to protect water bodies (UKWIR, 2014).

Catchments are the natural boundaries for water bodies (i.e. the natural water cycle), wherein the ecosystem functions related to water take place. Such a regional territory consists of a number of natural, semi-natural and artificial landscapes, composed of a mosaic of interacting ecosystems (or subsets). Regional watersheds have been characterised as pertinent spatial units for studying the interactions between humans and the environment (Billen et al., 2011), since they have historically acted as determinant factors of settlement location choice or agricultural and commercial activities. Therefore, the catchment is a single integrated system which includes both natural elements (biosphere) and infrastructure (technoshpere). In other words, the three sustainability pillars (environment, economy, society) co-exist and interact within the boundaries of a catchment. Sustainable Development recognises that social and economic progress should be simultaneous and integrated with the vitality of supporting ecosystems (World Commission on Environment and Development, 1987).

There is a growing recognition that to meet the goal of sustainable catchment management, there is a need for improved 'integrated' catchment management (ICM) (Macleod et al., 2007). ICM is a conceptual framework rather than a fixed formula for solving water-related problems that requires different conceptualisations of catchment processes (Macleod et al., 2007, Toit 2005). The use of appropriate scientific tools that would enable the integration between policies, science and their implementation is essential for sustainable catchment management.

To achieve an integrated approach, the specific characteristics of the distinct subsets comprising the watershed and their interactions should be identified and thoroughly studied. Sustainably managing an integrated system conveys the sustainable management of each of its elements, not only individually, but also as a whole. The interdependencies and interconnections among the elements of a system need to be identified in advance. The integration of water utility systems in the frame of a catchment is essential for their capacity to support human well-being (Everard 2012). Water infrastructure integrates multiple pressures from the catchment within it is built, and thereafter it becomes disproportionately vulnerable to climatic, hydrological, chemical, ecological and morphological pressures that affect its performance and service delivery.

The main water environment problem in the majority of the river basins districts (RBD) in the UK is water quality issues (Martin-Ortega et al., 2012). The agricultural sector is the major contributor to diffuse pollution. Significant improvements to farm practices are therefore needed to protect water quality. Nevertheless, the assessment of sustainable resource management and the design of relevant policies should occur at a local level and involve alliances of a wide range of stakeholders (Herath et al., 2007). Towards this direction, water industry in the UK is encouraged to work collaboratively with stakeholders of the catchment areas under their service (UKWIR, 2014), in order to fully consider and seek to achieve a. wider environmental and societal benefits of their services at a local scale.

Life Cycle Thinking

In the context of progress of sustainability science, life cycle thinking (LCT) may play a crucial role (Sala et al., 2013a, 2013b). Applying LCT offers a way of incorporating sustainable development in decision-making processes (Valdivia et al., 2013). This means going beyond the traditional introverted focus of industries and taking into account the environmental, social, and economic impacts of a product/activity over its entire life cycle and value chain.

The main tools widely used to date to cover the sustainability pillars are: Life Cycle Assessment (LCA), Life Cycle Costing (LCC) and social LCA. The latter is out of the scope of this work. Life Cycle Assessment (LCA) is a technique used to quantify the environmental impacts associated with all the stages of a product, service or process from cradle-to-grave. An LCA must be carried out in accordance with the technical norms established by the ISO (ISO 14040 and ISO 14044). LCA is an engineering tool that studies a whole system, highlights areas where the efficiency of existing systems could be improved and allows comparisons between alternatives.

In the water industry LCA has been applied at a strategic and/or regional level, at project and process level and at a very specific level (Friedrich et al., 2007). LCA has proved well-suited for application in the water sector and has been characterised as a particularly useful tool for organisations wishing to look holistically to the environmental impacts, investigate alternative solutions, and go beyond regulatory compliance (Siebel et al., 2008, Narangala and Trotter, 2006).

The economic counterpart of LCA is Life Cycle Costing (LCC). LCC is an assessment of a product's cradle-to-grave costs and is a traditional way of accounting the total costs of built assets (e.g. equipment, infrastructure). The current need to include 'externalities' (costs borne by other bodies) of the systems under study have driven methodological improvements in LCC and the development of concepts suitable for an assessment of the economic implications of a product life cycle in a consistent sustainability framework (e.g. environmental LCC). For water industry, external costs may be those related to land use, environmental conservation or prevention of pollution.

As described previously, there are a number of techniques and approaches that are pertinent to achieve a holistic asset management strategy. In the next section, the creation of the holistic asset management strategy is provided.

Creation of holistic asset management methodology

The present research project introduces holistic asset management (HAM) as a key element for effective and sustainable management of water resources. The catchment scale is adopted as appropriate for the application of HAM (Figure 1.1). Catchments are envisaged as hybrid and complex systems. Their limited boundaries allow for the capture of interdependencies between biosphere and technosphere and the identification of key-issues affecting the efficiency of the system and its capability to meet statutory standards. The principles of Integrated Catchment Management (ICM) form the ground of the methodology. The selected approach enables sustainable management of water resources for a range of uses and several stakeholders; thus the 'synergetic' tackle of the pre-identified key issues of a catchment.

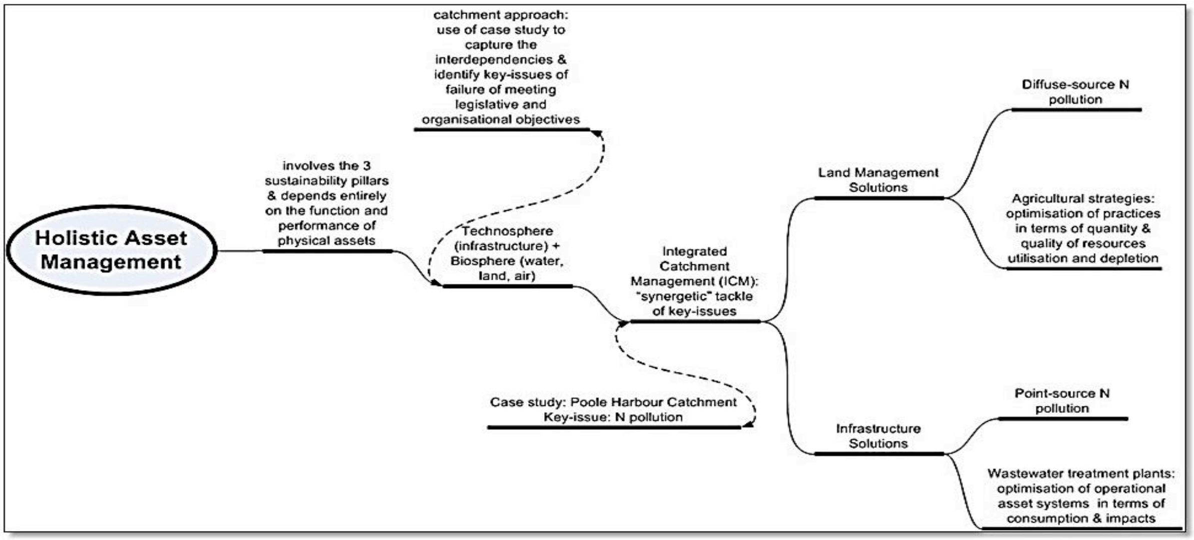


Figure 1.1:**:** The rationale of the research project: holistic asset management through integrated catchment management.

In order to test the approach to AM on a pragmatic basis, an action research framework is selected. Poole Harbour Catchment is used as a case study to the check the applicability of new tools and methods. The main objective of the work is to provide sustainable solutions to tackle diffuse nitrogen pollution deriving from agricultural activities. The project evaluates diverse scenarios and proves whether it is beneficial for Wessex Water to invest in land conservation and internalise land as part of its physical assets; thus, include land management in its strategic asset management planning.

The novelty of the approach is the application of life cycle thinking at a catchment scale. Outcomes will be formed with the joint use of life cycle management tools (e.g. LCA and LCC) and based on the assessment of both environmental and financial aspects. The synergetic use of these methods provides a holistic means of assessing benefits and damages of a system in a format that is easy to communicate. It also allows various options to be investigated and the most sustainable solution to be selected for future implementation. A portfolio presentation of the results from the application of a joint LCA and LCC conceptual model will evince the trade-offs of each of the land management option and assess the impacts and costs of its implementation in long-term.

The case study: Poole Harbour Catchment

The test-bed for the application of HAM is a well-studied catchment within the service territory of Wessex Water. The Poole Harbour Catchment (PHC) is a rural (80% agricultural land use) catchment located in the Dorset area (South-West England). The area contains many sites of local, regional, national and international importance and is designated as protected area under a number of conventions. The PHC was selected as a pilot catchment to participate in the Catchment Based Approach Initiative (CBAI) launched in 2012. Investigation of the environmental status of the watershed and identification of pressures within its boundaries reviled nitrogen pollution as its key environmental issue. The Nitrogen Reduction Strategy (NRS) report (2013) recommends that action should be taken to ensure future urban and rural development does not result in a net increase in nitrogen load.

According to their current strategic planning, Wessex Water Services Ltd has focused on infrastructure solutions (i.e. nitrogen removal wastewater treatment plants) to address the problem and meet statutory standards, managing to achieve large declines in the discharge of inorganic nitrogen from point sources. Despite the actions taken, the combined influence of background factors and current nitrogen management in the catchment cannot yet result in a decline in the water's nitrate concentrations. Therefore, land management solutions may prove more efficient, since it seems that land status influences the performance of the built assets and company's service delivery.

Life Cycle Thinking in the Poole Harbour Catchment: scenarios under evaluation

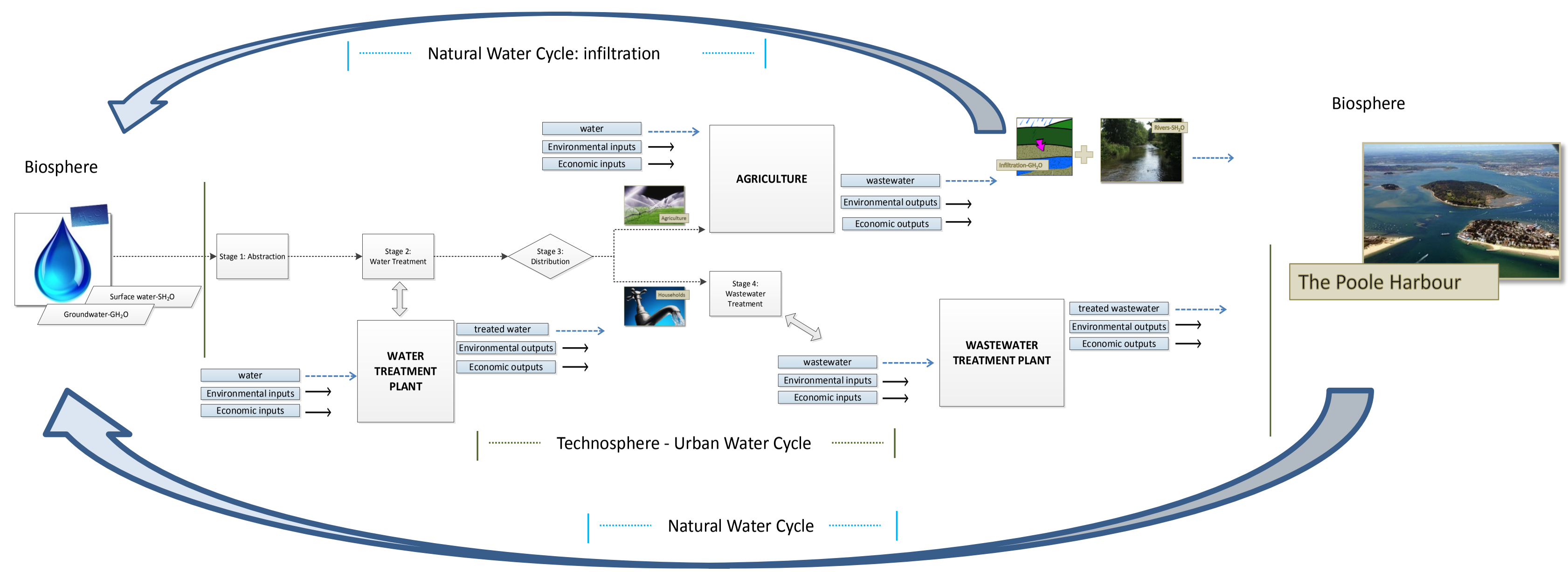
In order to assess the value of the adapted strategies in the catchment, it is crucial to identify the relations between its various elements. The catchment under study is described as an integrated system, based on the consequential relationships among its diverse elements with the use of a modified flow chart (Figure 1.2, scenario A0). It provides an insight to the water circulation in the Poole Harbour Catchment (PHC) and assists in explaining the relations and interdependencies among its elements, both natural and artificial. The sketch is a simplified representation of the stages of the urban water cycle within the boundaries of the catchment under study. The origin of the water available for use in the urban cycle is both surface and groundwater. In order to serve the scope of the research project, it is supposed that, after abstraction and treatment, water is allocated only for agriculture and urban use (households). Each of these two categories produces different wastewater, in terms of its quality and quantity, as well as character, referring to the differentiation between diffuse pollution (agricultural wastewater) and point pollution (households/wastewater treatment plants). The wastewater produced by the urban parts of the catchment is transferred and treated in the wastewater treatment plants through the pipeline network. After treatment (Stage 4), effluent of certain quality is poured in the Poole Harbour. Water allocated to the agricultural sector is used for irrigation, farming and livestock. The return flow to the environment follows the natural water cycle in two directions: infiltration to the chalk aquifers and/or surface run-off in the rivers. The quality of this effluent is controlled by the intensity of the agricultural activities. Surface water outflows in the Harbour, contributing to its nutrient load. The infiltrated water reaches the aquifers and is then abstracted (Stage 1) to re-participate in the urban water cycle. Its quality –in terms of nutrient content- may influence the operation of the water treatment plants (Stage 2), in terms of energy and chemical consumption. The remarkable slow travel time of water in the chalk aquifer (1m/year) enhances the need for using techniques that could capture the life-cycle of the natural processes occurring in the catchment.

The scenarios under evaluation are formulated to serve research, industrial and policy purposes. Two potential agricultural strategies (A1, A2) will be tested and evaluated for their effectiveness to reduce diffuse nitrogen pollution in the catchment and will then be compared with its current status (A0). The benchmark is the reduction of diffuse pollution by ≈550 tonnes of N/year across the catchment. The selected strategies represent suggestions made in the NRS report. These include the establishment of winter crops (wheat winter production) and the adoption of site-specific management along the catchment. The outcomes of the strategies under investigation will be compared with those of conventional practice, such as the construction of a wastewater treatment plant. Scenarios will not be formulated regarding the point-source nitrogen pollution, as it does not contribute more than 15% of the total nitrogen load. Further to this, both aforementioned scenarios (A1, A2) assume the operation of the existing nitrogen removal wastewater treatment plant at the current level of efficiency (7mg N/l discharge quality), which results in 330 tonnes of N/year. The table included in Figure 1.2 summarises the parameters associated with both scenarios.

In order to ensure that the scenarios would be rigorously compared before any conclusions for their value are drawn, functional unit -equal to 1 m^3 of water-, systems boundaries and impact categories assessed are the same for all the scenarios evaluated. The selected variables are the drivers of the data requirements for the research project. Further methodological choices will be made and tailored to fit the joint LCA and LCC framework.

Land Management Strategies	Benchmark (N load, tonnes/year)	Diffuse pollution (N load, tonnes/year)	Pot-source pollution (N load, tonnes/year)	N-removal treatment plant discharge effluent quality (mg/l)	Environmental Assessment: Method	Environmental Assessment: Parameters	Environmental Assessment: AoP*	Economic Assessment: Methods	Economic Assessment: Parameters	Economic Assessment: AoP
Current status (A0)	2280tn/yr	1950 tn/yr	330 tn/yr	7 mg/l	Life Cycle Assessment (LCA) & Water Footprint Assessment (WFA)	Water consumptive &degradative use, land cover, soil deterioration, air emissions, chemical	Resources efficiency, Ecosystems	Life Cycle Costing (LCC) & evaluation tools	benefits for the environment, efficiency, response time	Resources efficiency, Ecosystems
Scenarios										
Winter cover crops (A1)	1730 tn/yr	1400 tn/yr	330 tn/yr	7 mg/						
Site-specific management (A2)	1730 tn/yr	1400 tn/yr	330 tn/yr	7 mg/						

*AoP= Areas of Protection



CONCLUSION

The paper outlines a new approach to asset management in the water sector. The approach applies life cycle thinking at a catchment level. Drawing from literature from diverse fields, the underpinning research shows the need for a holistic approach to asset management and stresses that strategic planning of water industries should be based on an integrated management, which aims at the original reduction of the pollution, instead of its sterile tackle, under the legislative 'distance-to-target' threat. Methodological choices are made in order to pull together life cycle assessment (LCA) and life cycle costing (LCC) for the selected scale. Scenarios for different land management strategies have been formulated and are being examined for the Poole Harbour Catchment. The environmental impacts and costs for each scenario are calculated based on the joint LCA and LCC framework as formed for the needs of the research project. A portfolio presentation of the results will highlight trade-offs and assist in the evaluation of the outcomes of its strategy. Valuation methods and tools have been selected to serve the scope of the project. The most sustainable and pragmatic 'modus operandi' will be applied to the selected pilot catchment, as part of the strategic asset management plan of Wessex Water Services Ltd. The structured conceptual approach and the evaluation of diverse scenarios aims to prove whether it is beneficial for the industrial partner to internalise land as part of its asset management portfolio and how conservation strategies could have a material impact on both ecosystem and provision services at a catchment basis.

The adoption and implementation of the suggested holistic asset management (HAM) approach is orientated to tackle pre-identified key-issues at a catchment scale. It could be seen as an innovative tool to meet legislative standards and even go beyond regulatory compliance. The structured methodology involves all three sustainability pillars (People, Planet, Prosperity) in a format that is easy to communicate to policy-makers and replicate to other cases. On the down side, its implementation may be more complicated compared to the conventional end-of-pipe investment solutions adopted to date. Moreover, its outcomes involve higher risks. Nonetheless, the benefits for the environment and the customers can be significant.

In the grounds of a demanding and challenging urban and rural context, UK water industry is struggling to balance between costumers' provision, statutory requirements and performance indicators. In order to pull together the pieces of this jigsaw puzzle, water companies could swift the centre of their strategic goals around the environment or society. The catchment-based approach could assist at joining the pieces and revealing the bigger picture, whilst engaging a wide range of stakeholders. The application of Life Cycle Thinking at this scale of analysis could be a step towards achieving balance between social and environmental costs of different management strategies. A structured framework could also assist 'external reporting' to regulatory bodies, whilst the adoption of a common methodology for assessing, evaluating and calculating environmental benefits and costs could drive to the implementation of truly sustainable solutions.

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