JBA consulting

Agricultural Local Resource Options Screening Study Methodology

Report

March 2024

Prepared for:
Environment Agency

www.jbaconsulting.com

Environment Agency

Document Status

Issue date	11/03/2024
Issued to	EA LRO Project Team
BIM reference	CX-JBAU-XX-XX-RP-HO-0001-S1-P02-LRO methodology
Revision	1
Prepared by	Miranda Foster BSc PhD Principal Hydrologist Evangelia Kordomenidi BSc MSc CIWEM C.WEM CSci Technical Director
Reviewed by	Peter May BSc FGS CGeol Associate Director Evangelia Kordomenidi BSc MSc CIWEM C.WEM CSci Technical Director
Authorised by	Peter May BSc FGS CGeol Associate Director

Carbon Footprint

The format of this report is optimised for reading digitally in pdf format. Paper consumption produces substantial carbon emissions and other environmental impacts through the extraction, production and transportation of paper. Printing also generates emissions and impacts from the manufacture of printers and inks and from the energy used to power a printer. Please consider the environment before printing.

Contract

JBA Project Manager	Insert name of Project Manager
Address	Insert address of PM's office (on one line)
JBA Project Code	2023s1608

This report describes work commissioned by Mima Boardman on behalf of Environment Agency, by an instruction dated December 2023.

Purpose and Disclaimer

Jeremy Benn Associates Limited ("JBA") has prepared this Report for the sole use of the Environment Agency and its appointed agents in accordance with the Agreement under which our services were performed.

JBA has no liability for any use that is made of this Report except to (insert the "Client") for the purposes for which it was originally commissioned and prepared.

No other warranty, expressed or implied, is made as to the professional advice included in this Report or any other services provided by JBA. This Report cannot be relied upon by any other party without the prior and express written agreement of JBA.

Acknowledgements

Thet abstractors for their invaluable input to the methodology development

Stakeholders who participated in workshop and interviews

EA Project team for help with data and facilitating engagement with Stakeholders

---

Copyright

© Jeremy Benn Associates Limited 2024

Contents

List of Figures

List of Tables

Abbreviations

ADA	Association of Drainage Authorities
ALS	Abstraction Licensing Strategies
ASR	Aquifer Storage Recovery
BNG	Biodiversity Net Gain
CAPEX	Capital Expenditure
CBA	Cost Benefit Analysis
CEA	Cost Effectiveness Analysis
Ciriabest	CIRIA's Benefits Estimation Tool
CMS	Catchment Management System
EA	Environment Agency
EIA	Environmental Impact Assessment
ESS	Ecosystem Services
FTE	Final Treated Effluent
ICM	Integrated Catchment Management
IDBs	Internal Drainage Boards
LCCA	Life Cycle Cost Analysis
LROs	Local Resource Options
MAR	Managed Aquifer Recharge
MCDA	Multi Criteria Decision Analysis
NALD	National Abstraction Licence Database
NBS	Nature Based Solutions
NGOs	Non-governmental Organisations
NPV	Net Present Value
OPEX	Operational Expenditure
ROI	Return on Investment
RWH	Rainwater Harvesting

SROI	Social Return on Investment
TCO	Total Cost of Ownership
UKIA	UK Irrigation Association
WAG	Water Abstractor Group
WRMPs	Water Resource Management Plans
WwTWs	Wastewater Treatment Works

Definitions

Flood flow / high flow: Flood flow, also referred to as high flow, describes periods when river or stream flows significantly exceed the normal flow rate, typically as a result of heavy rainfall or snowmelt. During these times, the amount of water moving through the watercourse increases dramatically, potentially leading to flooding if the water exceeds the channel's capacity. In the context of water resource management, capturing flood flows can be a strategy for augmenting water supplies, particularly for agricultural purposes, by storing excess water during periods of high flow for use during drier conditions.

LROs: A water resources solution that improves resilience or supply of water for a small group of farmers in their area.

WAG: Water Abstractor Group: A group of farmers that have formed in response to concerns about future water supplies with the intention of improving the outlook for water supplies in the area by working together.

Water Sharing: Water sharing refers to the practice of distributing water resources among multiple users or sectors within a defined area or community to meet diverse needs. This can involve formal or informal agreements that outline the terms for sharing available water, including quantities, timing, and responsibilities.

Water Trading: Water trading is a mechanism that allows water rights or entitlements to be bought, sold, or leased, offering flexibility in water management by enabling the reallocation of water among users

WRMPs: Water Resource Management Plans. These can be individual water company WRMPs or regional WRMPs. Each WRMP describes how supply and demand forecasts are made, and establishes a supply demand balance, including allowances for uncertainty. If there is a supply demand deficit, options required to secure future supplies are optimised and an investment plan established.

Executive Summary

The “Local Resource Options for agricultural water resources" report aims to present a methodology for Agricultural Local Resource Options (LROs) to identify, screen, and rank water resource options sustainably.

The project was developed in response to growing concerns over water scarcity, regulatory changes, and the agricultural sector's sustainability. It introduces a comprehensive methodological framework designed for Water Abstractor Groups (WAGs) to identify, assess, and implement Local Resource Options (LROs). By focusing on stakeholder engagement, flexibility, and pilot testing, the framework aims to foster resilience and efficiency in agricultural water use.

The methodology for developing the LRO framework is focused on a structured, collaborative approach. It involves engaging with stakeholders to identify and assess potential water resource options, using a combination of technical analysis and participatory methods. The steps include identifying water needs, screening possible solutions, evaluating feasibility, and detailed analysis of prioritised options.

From the stakeholder engagement exercise (including, WAG groups, regulators, academia and farming businesses) during the development of the framework, three top priorities have emerged, shaping the direction of the LRO initiatives:

- Concerns Over Licence Security and Regulatory Environment: A widespread concern among stakeholders is the potential loss of water abstraction licences, highlighting the need for secure, sustainable water management practices. Stakeholders have also stressed the importance of regulatory awareness and the necessity for LRO projects to adeptly navigate and adapt to regulatory landscapes. Addressing uncertainties surrounding the duration of water abstraction licences is crucial for stakeholders' long-term investment decisions, indicating a need for regulatory adjustments to foster sustainable investments in water management.
- Willingness to Collaborate: Stakeholders have shown a significant willingness to engage in and support LRO initiatives, underscoring the importance of involving groups already active in or interested in water management solutions. This collective effort is crucial for the success and sustainability of these initiatives.
- Re-use and management of Drainage and Floodwater: Stakeholders have expressed a keen interest in exploring the innovative use of drainage systems and the management of floodwater as sustainable water resource options. This approach not only addresses the direct challenges of water scarcity and flooding but also represents a shift towards adaptive, integrated water management strategies that can enhance agricultural resilience against climate variability.

In weaving these priorities into the LRO methodology, the framework is intended to work as a practical tool designed to be both scalable and repeatable, aiming to assist WAGs in making informed decisions about resource management, the approach was developed with a view to being simple, pragmatic, and flexible so that it can be scalable. The assumption

underpinning this guidance is that the individuals tasked with executing this framework possess the requisite technical knowledge—or have access to professionals with such knowledge—to perform these analyses accurately. This includes an understanding of the principles behind water resource management, economic evaluation, and environmental impact assessment.

The LRO framework offers a pathway towards sustainable water resource management in agriculture. By fostering collaborative, adaptive, and integrated water management strategies, it contributes to the long-term viability of agricultural practices, enhancing the resilience of agricultural systems and the communities they support in the face of environmental and climate challenges.

1 Introduction

1.1 Document aim

In the face of rapidly evolving climate challenges and the increasing demands of a growing global population, the management of agricultural water resources has never been more critical. This report embarks on a pioneering journey to develop a robust methodology for selecting Agricultural Local Resource Options (LROs). Our aim is to equip Water Abstractor Groups (WAGs) with a scalable and scientifically grounded approach to identify, screen, and rank water resource options.

This report aims to deliver a framework that serves as a foundational step towards a more water-secure future for agriculture. It is designed to transparently navigate the thought process behind the development of the LRO framework and outline its potential for replication and scalability across various catchments. Through this report, we propose a methodology that not only meets the immediate project objectives but also sets the stage for future advancements in local water resource management for agriculture.

1.2 Project Background

At the UK Farm to Fork summit held at 10 Downing Street on 16 May 2023, the Prime Minister announced commitments to help grow a thriving British food and drink sector and maintain agricultural production at current levels. This included a commitment to “support farmer-led groups to identify local water resource schemes, building on the success of projects like Felixstowe Hydrocycle” (DEFRA 2023), since referred to as Local Resource Options (LROs).

The inclusion of agriculture into water resource and drought planning is still an emerging area of interest, and aside from a few LROs coming out of projects like ‘Reclaim the Rain’, ‘Fresh 4C’s and ‘Water for tomorrow’ there are very few examples within the UK. The aim of this project is therefore to create a scalable and repeatable LRO selection methodology, which can support farmers and farmer led groups address the water resource supply issues they face, then test this with a single catchment within the influence of Cambridge Water’s supply. The development of the methodology in the current project forms part of a wider process for engaging abstractors, educating them about current and future investment need and encouraging collaboration in planning related work, funding and delivering new schemes.

1.3 Project scope

The JBA scope includes developing a systematic approach for identifying and selecting appropriate Local Resource Options for a small group of farms. This involves establishing a screening framework methodology to initially filter potential options, followed by a ranking framework methodology to prioritize and rank these options according to specified criteria.

The developed methodologies are to be validated through implementation in a pilot area, where the practical application of the framework can be observed and assessed. In this case we have engaged with farming abstractors from the river Thet, in East Anglia, close to the source of 10% of Cambridge Water Companies supply and have focused the pilot on an area in the Thet catchment. The pilot testing is crucial for gathering data and insights, which will be integral in refining the methodologies.

Finally, an essential part of the scope is capturing the lessons learned throughout the process. This not only includes documenting the efficacy of the framework and its applicability to the pilot area but also recording any challenges, unexpected outcomes, and areas for improvement that could enhance the scalability and repeatability of the methodologies for future use by other WAGs.

1.4 Deliverables

This project aims to deliver a clear, scalable methodology for the assessment and ranking of local resource options to be used by WAGs and associated consultants. Key deliverables are:

- A report documenting the development of the methodological framework.
- **A methodological framework report.**
- An associated spreadsheet as a template to guide consultants through the process of screening and ranking options.
- A separate report on the Thet Pilot Project
- Lessons learnt from the stakeholder engagement and the Thet Pilot project.

1.5 Current report structure

The current report presents the developed framework for screening and ranking options. It provides the following:

- **Overview of Local Resource Options (LROs):** Chapter 3 provides a detailed exploration of LROs. It outlines the various types of LROs available. This overview includes a non-exhaustive list and sets the stage for understanding the diversity and potential of LROs in addressing agricultural water resource challenges, laying the foundation for the subsequent methodological framework.
- **A methodological framework for screening and ranking options:** Chapter 4 is a foundational section which introduces a structured approach for identifying and evaluating potential water resource options. It outlines the process of screening for viability based on preliminary criteria, followed by a ranking exercise based on assigned weights. This framework serves as the backbone of the report, guiding stakeholders through a systematic evaluation to determine the most sustainable and efficient water resource solutions.
- **A stakeholder engagement plan (Appendix A):** Recognizing the importance of stakeholder involvement in the success of LRO initiatives, this section provides a template for engaging various stakeholders throughout the process.

- **Examples of Process Charts on Navigating Detailed Options on Specific LROs (Appendix B):** To facilitate the practical application of the framework, this appendix offers process charts illustrating the steps to navigate through the evaluation of specific LROs. It is noted that these charts serve as general guides, offering perspective on the steps and considerations essential to the evaluation process. They are intended to be adapted and tailored to meet the specific requirements and unique contexts of individual Water Abstractor Groups (WAGs) and their respective projects.
- **Yield assessment (Appendix C):** Critical to the selection of LROs is an understanding of their potential water yield. This section provides guidelines for conducting yield assessments and methods available, incorporating considerations of climate variability, water demand, and the technical capabilities of different options.
- **Cost Assessment (Appendix D):** Addressing the economic viability of LROs, this appendix delves into methodologies for performing cost assessments. It covers capital and operational expenses, assessing benefits and the overall economic feasibility of LROs.
- **Template of proposed context of report (Appendix E):** This is high level and a general guide for main themes that need to be included as a minimum. Each study will differ depending on level of complexity of LROs.

2 Background and context

2.1 Water resource management in agriculture

In the UK, the agricultural sector faces distinct challenges in terms of management of water resources, accentuated by regulatory, environmental and climate change pressures. Agricultural water use is intricately tied to the licencing regime that governs water abstraction, a system increasingly under scrutiny as the EA strives to balance the needs of agriculture with the ecological health of water bodies. Recent years have seen a move towards licence reductions in areas where water resources are at risk, placing additional pressures on farmers who rely on consistent water supply for irrigation and livestock. This regulatory shift, aimed at promoting sustainable water use, has underscored the urgent need for the agricultural sector to adopt more efficient water management practices.

These challenges are further compounded by a changing climate. The necessity for a better understanding of local resource options becomes clear in this context. Farmers and water managers need tools and methodologies that can help identify sustainable water sources, optimize usage, and navigate the complex regulatory landscape. Use of winter water for storage and re-use has been flagged up by stakeholders (specifically the farming community) as a potential area for further review to offset summer restrictions, such as Water Resources Act 1991 Section 57 notices to restrict spray irrigation.

Moreover, the sector must grapple with the broader implications of climate change, which are expected to exacerbate the frequency and severity of extreme weather events, further complicating water management. However, while hotter, drier summers will present greater challenges, the forecast of wetter winters highlights the need for longer term strategies, to exploit this changing seasonal distribution and availability of water. The development of a robust methodology for assessing local resource options is not just a matter of regulatory compliance or operational efficiency; it is a critical step towards securing the future of British agriculture in an era of environmental uncertainty. This approach must be grounded in a deep understanding of local conditions, including soil types, crop water needs, and the potential for non-traditional water sources, such as reclaimed wastewater or rainwater harvesting, to supplement traditional water supplies.

In essence, the agricultural water resource management situation presents a complex challenge that requires innovative solutions, collaboration across sectors, and a forward-looking approach that prioritizes sustainability and resilience.

2.2 Current regulatory landscape

The regulatory framework governing water resources in England is deeply influenced by factors such as licence restrictions, the impacts of changing climate, and the importance of public water supply specified in legislation. These elements collectively shape the operational environment for agricultural water management and the implementation of Local Resource Options (LROs). In England, water abstraction licences issued by the Environment Agency are pivotal in managing the access to and usage of water resources.

Recent years have seen a tightening of these licence restrictions in response to the growing concerns over water scarcity and the need to protect aquatic ecosystems. For agricultural stakeholders, this means navigating a more stringent regulatory landscape where the sustainability of water use is paramount. This is why seeking alternative LROs is necessary as part of adaptation planning, to ensure a reliable water supply for agricultural activities. The changing climate exacerbates the challenges within the regulatory landscape, particularly through increased variability in rainfall patterns and more frequent extreme weather events. These climate-induced shifts demand a dynamic approach to water management, one that can adapt to fluctuating water availability and safeguard against both droughts and floods. The regulatory framework is gradually evolving to incorporate climate resilience measures, for example the Environment Agency’s change to Environmental Permitting Regulations for water which is expected in 2025.

Water companies play a significant role in the overall management of water resources, holding substantial allocations for public water supply. Their dominance in the water resource landscape can pose challenges for agricultural water users, particularly in regions where competition for water resources is intense. The regulatory emphasis on ensuring sufficient water for domestic consumption often places additional pressures on agricultural stakeholders to optimize their water use efficiency and explore LROs that can provide alternative sources or enhance the sustainability of their water use practices.

In navigating this complex regulatory landscape, it is important for agricultural stakeholders to engage proactively with the regulatory process, advocate for policies that support sustainable water management, and invest in the development and implementation of LROs.

2.3 Agricultural water in the context of integrated catchment management

Integrated Catchment Management (ICM) emerges as an important aspect in the context of agricultural water management within this project. It enhances a holistic comprehension of water systems' interlinked nature, acknowledging that alterations in one segment of the catchment can have substantial effects on others. This understanding is vital for navigating the complexities associated with the management of agricultural water, particularly under the challenges posed by climate change and variability. ICM also promotes the involvement and cooperation of stakeholders across various sectors and governance levels, resonating with the project's focus on engaging stakeholders in the collective journey towards sustainable agricultural water management solutions. Incorporating ICM principles into the Local Resource Options (LRO) methodology could amplify the project’s capacity to foster sustainable management of agricultural water resources. This not only contributes to the resilience of agricultural systems but also supports the livelihoods of the communities dependent on them.

2.4 Local Resource Options

2.4.1 What is a Local Resource Option?

A Local Resource Option (LRO) is a water resource solution that improves resilience or supply of water for a small group of farmers working together in their area and involves identifying and developing local water resources that mostly fall outside the main strategic river and groundwater water resources. However, licenced resources can be considered where LROs are designed to make better use of existing licenced volumes. A particular feature of LROs is that they should benefit a group of farmers who plan to work together to manage and share the resource but recognising that other may benefit, such as PWS, the environment, and amenity.

Examples of LROs include building new farm storage reservoirs or increasing the size of existing reservoirs, rainwater harvesting, improving existing water supply assets, exploiting land drainage water which would otherwise go to waste, conjunctive use of groundwater and surface water resources, and options to trade and share water to better use existing supplies. They may also include the use of treated wastewater and aquifer recharge, though the barriers to these options are likely to be greater.

A well quoted example that involves several options is the Felixstowe Hydrocycle project (Felixstowe Hydrocycle Ltd 2024) in which a farmer-led water supply and management company was set up to work in partnership with the Environment Agency, the Suffolk County council, and East Suffolk Internal Drainage Board (IDB), to secure sustainable water supplies. Drainage water, which is usually pumped out to sea is instead brought inland and stored for irrigation.

2.4.2 Opportunities

LROs offer many benefits which complement the more traditional licenced single water resource supply options that form part of the strategic water resources planning. The Felixstowe Hydrocycle project brought many opportunities to a catchment which was already over-exploited. Its primary purpose being to increase water availability for irrigation, thus increasing sustainability and securing employment opportunities, and providing additional benefits for public water supply and the aquatic environment by reducing erosion caused by pumping drainage water into a saltmarsh.

2.4.3 Barriers

The development of LROs faces notable hurdles, particularly from regulatory, land ownership, and financial perspectives.

2.4.3.1 Regulatory barriers

One of the major potential barriers to the development of options is the complexity of the legislation and policy.

- Licencing - water availability. Many abstractors are already seeing reductions or potential reductions to their licences, so there may not be available water in some catchments according to the Abstraction Licensing Strategies (ALS).
- Planning and other permissions: High costs and complexity of obtaining planning permission, archaeological and environmental impact assessments, and the challenges of navigating through gravel and mineral abstraction policies.
- Water trading: Regulatory barriers significantly influence the implementation and effectiveness of water-sharing agreements, especially during drought conditions. These barriers may include stringent water abstraction limits, complex licencing requirements, and restrictions on water transfer between different catchments or user groups. It is noted that restrictions on inter-catchment transfers are not only a matter of resource allocation but also concern the prevention of resource loss and the control of Invasive Non-Native Species (INNS). These restrictions aim to mitigate risks associated with the unintended spread of INNS, which can have detrimental impacts on local ecosystems, biodiversity, and water quality.

2.4.3.2 Land Ownership

Land ownership can significantly impact the feasibility and development of LROs in agriculture. The disparity between those who require access to water resources for agricultural purposes and those who own the land where these resources are found, or could be developed, is a fundamental barrier. Additionally, tenant farmers, who operate land they do not own, face unique challenges in investing in and developing infrastructure for LROs due to their lack of ownership over the land. This can lead to challenges in negotiating access rights, easements, and in some cases, outright purchase of land needed for the construction of infrastructure such as reservoirs, boreholes, or water conservation systems. To address this issue, fostering cooperative agreements or partnerships between landowners and water users can be pivotal. Creating legal frameworks that support such collaborations, possibly through government mediation or incentives, might ease the process. Additionally, exploring community-based water management schemes where benefits are shared among stakeholders can also offer a viable solution to the land ownership challenge.

2.4.3.3 Funding

Although government has occasionally provided capital grants to farmers to develop on-farm reservoirs and efficient irrigation equipment, and the Farming Innovation Programme is another source of funding, securing adequate funding represents a critical barrier to the implementation of LROs, particularly for initiatives that require substantial initial investment in infrastructure and technology. The high upfront costs associated with developing alternative water sources, such as aquifer recharge, rainwater harvesting systems, or recycling facilities, can be prohibitive for individual farmers or small agricultural collectives. Addressing this barrier requires innovative funding strategies that may include a mix of public and private investments, grants, and loans. Furthermore, establishing public-private partnerships can attract investments from businesses that have a vested interest in sustainable agriculture and water management. Crowdfunding and community-supported initiatives may also provide alternative funding avenues, especially for smaller-scale projects that benefit local communities. The Water Management Grant provides capital funding to farmers for the development of on-farm reservoirs and efficient irrigation equipment. This grant, part of the Farming Investment Fund, is available to horticultural and arable businesses growing, or intending to grow, irrigated food crops, ornamentals, or forestry nurseries. Another example of a source of funding is the Farming Innovation Programme.

2.4.3.4 Specific barriers to irrigation reservoirs

In 2014 a survey of farmers[1] who had built or planned to build reservoirs highlighted the main drivers for development as improving security of supply, expanding irrigated areas, and increasing supplies to existing systems (Cranfield University 2014). However, major challenges facing farmers included the cost of obtaining capital, technical studies, engineering design, obtaining planning permission, environmental studies, archaeological studies, electricity supply connections, finding a suitable site, and obtaining an abstraction licence. Additionally, long delays in reservoir safety approval and in obtaining grants were significant challenges. Although these issues were reported 10 years ago, recent stakeholder engagement suggested that all these barriers are still in place. The uncertainties of changes in short term time-limited abstraction licences also discourage farmers from making long-term investments in reservoirs.

2.5 Water Abstractor Groups

Water Abstractor Groups (WAGs) emerge as facilitator entities in overcoming barriers. There are at least 10 active WAGs in England, at the moment, some with a more formal structure than others. More details about the groups are available from the UKIA (UKIA, n d, See also Leathes, Knox and Kay 2008):

- Broadlands Agricultural Abstractors (BAWAG)
- East Suffolk Water Abstractors Group (ESWAG)
- Fenland Agricultural water Group (FAWG)
- Lark Abstractors Group (LAG)
- Lincoln Water Transfer Ltd (LWT)
- North Northumberland Agricultural Abstractors Group (NNAAG)
- Nott Time Limited Abstractors Group (Notts TLAG)
- Thet Abstractors Group (TAG)
- Wissey Abstractors Group

[1] Unpublished survey, CLA 2023.

- Herefordshire Water Abstraction Group (HWAG)

Other groups are in an embryonic phase, examples include Doncaster and Merseyside abstractors.

Groups comprise mostly irrigation farmers who individually or collectively abstract and manage water resources. Some groups are more mature than others and are able to help members access funding, conduct feasibility studies, and leverage resources. This can be more effective than individual farmers or small collectives might manage on their own.

WAGs can facilitate pooling of resources to share the costs associated with the development of LROs, reducing the financial burden on individual members. The collective nature of WAGs, combined with their local knowledge and vested interest in sustainable water resource management, makes them ideal candidates for potential public-private partnerships and innovative financing mechanisms such as green bonds or impact investments. Furthermore, WAGs can potentially leverage their collective bargaining power to negotiate better terms with landowners, including tenant farmers, for projects that require land for infrastructure development. They can also invest in shared research and pilot studies to explore the viability of new LROs, spreading the cost and risk among the group. This collaborative approach not only enhances the financial feasibility of LROs but also fosters a sense of community and shared responsibility for sustainable water resource management. Through strategic partnerships, innovative financing, and collective action, WAGs can significantly contribute to overcoming the funding barrier, making the development of LROs a more attainable goal for the local agricultural community. WAGs are encouraged to communicate with the Water for Food Group, an independent forum of stakeholders and policy advisors from the agricultural and horticultural sectors which aims to raise the profile of water for food production.

For the purposes of this report, WAG refers to a group of farmers who have joined together to engage in a LRO screening study undertaken in the area, irrespective of whether they are an official entity.

3 Local Resource Options

3.1 General

To better understand the methodological framework, an overview of the types of LROs is provided in this chapter. The table below is a synthesized overview of LROs. This table is the culmination of analysis and stakeholder feedback, and therefore does not represent an exhaustive list. Additional options exist encouraging multi-sector collaboration with agriculture; however, these are not considered within this report. Each LRO type is dissected across various parameters including technical considerations, water resource benefits, policy frameworks, capital costs, environmental impacts, and their social ramifications. This tabular approach aims to provide a clear snapshot of potential benefits and implementation challenges associated with each LRO. The subsequent sections will delve into the details of each LRO, expanding upon the information that this table succinctly introduces.

3.2 Supply Options

This section offers a high-level summary of the main supply options, but it is not an exhaustive list. It is likely that most supply LROs will consist of one or more local water sources, and some means of water storage to enable water to be stored and used during the growing season when less water is available. Local stakeholders are likely to have a good understanding of the limitations of the local regulatory environment, the types of options suitable for their area, and of any innovative supply options that should be considered.

The following sections describe some of the more common LROs to consider. However, several components may be combined to improve the LRO initiative, such as combining reservoir storage with capturing floodwater and conjunctive use of surface and groundwater. An LRO may also include demand-based options, discussed in section 3.3.

3.2.1 Rainwater harvesting

Rainwater harvesting (RWH) involves collecting and using rainwater from roof surfaces via gutters and downpipes. Harvested water is stored in tanks or reservoirs, varying in size from a few hundred litres up to thousands of cubic metres suitable for small-scale agricultural or horticultural use.

RWH is an LRO well suited to the protected horticulture and nursery sector, which is expanding and uses irrigation to extend the growing season for soft fruit and vegetables. It offers an important alternative for alleviating water scarcity for soft fruit businesses while helping to alleviate local flooding and typically has a small land footprint that excludes the possibility of a reservoir.

There are various types of rainwater harvesting system from gravity to pumped systems: gravity fed, directly pumped, and indirectly pumped, which are described in detail in

“*Rainwater Harvesting: an on-farm guide*”, a booklet produced by the Environment Agency, (2009).

Soft fruit and vegetables are particularly vulnerable to water shortages because all crop water requirements must come from irrigation and the soil reservoir around each plant is small. One day without irrigation in warm weather can be disastrous for high value crops such as strawberries. RWH can be adapted to localities with hard, impervious surfaces (roofs and hard standing for vehicles) and infrastructure to collect and store water. In countries subject to heavy rainstorms, runoff water is also collected from fields and stored in reservoirs for later use.

The amount of rainfall stored is maximised where large roof and paved areas are available and is frequently used in horticulture, where runoff from greenhouses or polytunnels can be captured. Rainwater captured in this way does not need an abstraction licence so long as water is not mixed with that from other sources (Environment Agency 2021). It is a suitable option when the local catchment has no or limited licence availability. However, it is not a reliable water source as it depends on the unreliable nature of rainfall. Its role must be to supplement (and reduce dependence) on more reliable, often costly water sources, such as public mains water or direct licenced abstraction from water bodies.

RWH is analogous to solar and wind in the energy sector. When conditions are favourable, they provide a valuable source of cheap energy, but they cannot be relied on to supply all energy needs all of the time.

Cranfield University is working with Berry World (a major soft fruit consortium) and the UK Irrigation Association (UKIA) to produce a spreadsheet-based business RWH tool to support informed decision-making and managing risk under increasing water scarcity and climate uncertainty. The tool is designed to help growers assess the size of reservoir storage needed to meet crop water requirements that best fit with available rainwater capture from polytunnels given levels of drought risk (using the D-Risk tool (https://www.d-risk.eu). Cranfield developed D-Risk to help farmers growing irrigated field crops understand the risks to their business from droughts and the cost and benefits of sizing and building water storage infrastructure. The RWH tool is expected to be available for dissemination and use in late 2024.

Stakeholder comment: Potential gain from this system is high.

Potential issues arise from water quality/contamination. Lack of understanding of options/technologies available to monitor and improve water quality.

3.2.2 Groundwater sources

Water can be abstracted from groundwater sources such as boreholes, springs, or wells. These sources draw on underground aquifers which may be drawn down in the summer months and are typically recharged during the winter. Groundwater abstractions must be licenced (see “*Get advice before you apply for a water abstraction or impounding licence*”), so new abstractions will only be permitted in areas with water available. Groundwater availability within an operational catchment is detailed within the relevant abstraction licencing strategy (ALS). Where only limited water is available as identified in the ALS, new licences could be issued for abstraction in winter to fill storage for use in summer, much like surface water licences. This could help alleviate groundwater flooding by abstracting water when levels are high and alleviate pressure on groundwater sources in summer.

The behaviour of groundwater sources can vary significantly between different aquifers, with low groundwater levels limiting the availability of water during droughts periods. Water is abstracted from boreholes by submersible pumps. The quality and quantity of water available is determined by the pump size, aquifer storage and transmissivity, depth and construction of the borehole, and water level. A qualified professional such as a hydrogeologist or a geologist should be consulted to assess the feasibility and potential yield of a borehole, although an idea of the suitability of the area for boreholes can be gained if there are neighbouring boreholes. Existing groundwater licences within an area can be viewed on the EA Water Trading Map (please see Section 3.4.1), can be used to get an idea of existing sources and abstractions on a more local scale. Boreholes should also be drilled by qualified professionals. The British Geological Survey can provide a report outlining the likelihood of obtaining a licence and estimating the likely yield for a small fee. The webpage *"I want a Borehole",* [2] produced by the UK Groundwater forum outlines the steps required to construct a water supply borehole.

3.2.3 Exploiting drainage water

Internal Drainage Boards (IDBs) are public bodies responsible for managing water levels for both environmental and agricultural needs. They also carry out works to reduce flood risk, mainly through pumping water, but also by the operation of sluices and weirs.

Excess drainage water has long been considered a good water source if only it can be captured. It is most prevalent in the winter, but not forgetting that flood events also occur in the spring and summer months as the climate changes. Typically, drainage water is pumped out to sea, but its potential as an LRO for farm irrigation is significant. The challenge is to capture and store water as and when it is available.

The Felixstowe Hydrocycle project successfully exploits this resource by pumping drainage water into storage in the upper catchment, which is used for downstream irrigated agriculture. The project also brings multiple environmental benefits. It reduces erosion in saltmarshes but allows sufficient flows to maintain the integrity of the saltmarshes and mudflats in the river estuary. The scheme cost approximately £2 million to establish, jointly funded by the group of farmers and an EU grant established by Fresh4C, with Members pay 20p/m^3 for water delivered to their reservoir (Larner 2023). This covers the running costs and also repays loans in 14-years. Licences are required for abstracting drainage water. This kind of project works well in catchments that are already over-abstracted and from which no new abstraction licences are available.

Working with the local IDBs is essential as they have statutory responsibilities to manage water levels for the environment and to reduce flood risk. However, IDBs have no statutory

2 http://www.groundwateruk.org/I-want-a-borehole.aspx

duty to manage drainage water as a water resource. Although some are mindful of the needs of irrigators in their catchment, it does present a regulatory barrier to using drainage water for irrigation.

Stakeholder comment: Potential gain from this system is high.

3.2.4 Capturing flood flows in rivers

Flood flows (also called high flows, mostly occur in the winter, though some also occur in the summer) that generally would flow or be pumped out to sea have led several stakeholders to suggest that this could be captured to refill farm reservoirs, or potentially stored on the floodplain. This may require changes to existing abstraction licences or a new abstraction licence. In February 2024, the Environment Agency published guidance for abstracting floodwater outside of licence conditions during flood events (Environment Agency, 2024). Note: this is not regulatory at present but a short-term position statement and may change in future. This states that up to 5,184 m^3 per day can be abstracted in addition to normal licenced quantities on a single occasion when a flood warning is in place. If abstractors intend to make regular use of this then licences would need to be varied to use this type of water frequently.

High-flow abstraction from rivers or floodplains will need land for storage to make water available during summer months and pumping systems that can capture high volumes of water in a relatively short period. Flood flow analysis would assess the economic viability of such systems, the frequency and severity of flooding and the investment necessary to capture the flows. This option has significant health and safety risks and can cause water quality issues as well as increased sediment loads in the water which can damage pumps and increase reservoir maintenance needs. Water quality issues may mean that this water is not suitable or needs treatment for use on crops that are not cooked prior to consumption (e.g., lettuce).

Stakeholder comment: Potential gain from this approach is high.

Real-time technology will be essential to maximise opportunities. There is a lack of data on flood flows on which to base cost-benefit analysis. Should floodwater abstraction be licenced in circumstances where it is provides ecosystem services that help to relieve flooding downstream and reduces summer abstraction thus making more water available for the aquatic environment downstream and for leisure purposes.

3.2.5 Treated effluent re-use

Treated wastewater effluent is recognised as an important resource, especially in our changing climate, provided the water quality is appropriate for agricultural purposes. Effluent re-use has the advantage that it can maximise available water when there is little water available and can reduce the need for large scale infrastructure developments. Wastewater is also a reliable source, with water available all year round, although more water will be available in wet periods and in the future as the population continues to grow and water companies increase water treatment. There are, however, issues of negative public perception: the ‘yuck factor’, as well as treatment costs and the need for storage and piping. In addition, this option can remove water from the environment (as in many rivers effluent can make up a significant proportion at low flows) and can impact on upstream and downstream abstractors requiring careful consideration. Effluent re-use is becoming much more prevalent in England and forms a key part of the supply side options currently being investigated within the WRMPs by the Water Companies as a secure supply to ensure resilience to population growth and climate change (e.g., Anglian Water and Affinity Water). This may help change or shift public perceptions in future and provide valuable experience around how this kind of option can be applied from a legislative and technical perspective.

The UKWIR (Jeffrey et al. 2014) offers several case studies of successful and unsuccessful applications of effluent reuse, including some in agricultural settings. It concludes that in the right circumstances, and with the right planning and implementation, effluent re-use can supply agricultural needs safely. The EA has also previously issued guidance for Spreading treated sewage effluent (Final Treated Effluent, or FTE) on land during prolonged dry weather for agriculture during droughts (Environment Agency 2018). This guidance has been withdrawn, however may be re-instated during drought conditions and can be used for reference to understand the conditions that may apply to this kind of LRO. The EA has been having discussions on the longer-term use of FTE for agricultural use with the Public Water Supply sector, however changes to policy and permitting may be required in future to make this LRO more accessible.

The Consented Discharges To Controlled Waters database (which is available online through The Rivers Trust CaBA Data Portal) [3] can be used to identify where Wastewater Treatment Works (WwTWs) are located nearby to understand if this option is viable within an area of interest. It should be noted however that most WwTWs are located downstream in catchments therefore may be more suitable for lowland areas, and many WwTWs in rural areas are small and may not have a large enough capacity to provide water for agriculture.

3.2.6 Farm storage reservoirs

On farm storage is the most obvious option for balancing supply and demand for water on farms enabling water capture in the winter months to provide water in the summer when supplies are limited, and demand is high. They are widely used on farms and new ones are encouraged by government offering, at times, grants up to 40% of the capital cost. However, grant aid is limited to annual storage. As the climate changes and demand increases, LROs could provide the additional storage needed to secure supplies over longer periods. Farmers are already thinking about storage to cover two or more dry years when it may not be possible to fill every year or more practicably to allow resilience to a multi-year drought. With the option to share water and share storage some farmers are thinking about building larger storage volumes to provide security and resilience. LROs could enable larger reservoirs to be built, expansion of existing reservoirs, changing

3 https://www.arcgis.com/home/item.html?id=1f28f6aa7c694fa6babd91e54edb2bcb accessed on 28/03/2024

operations to improve resilience or expanding capacities through joining up of reservoirs across an area, where site conditions and water resources allow.

The Environment Agency and Cranfield University publication, "*Thinking about an irrigation reservoir*?" is a comprehensive and simple guide booklet published by the Environment Agency to support farm reservoir planning and the onward issues of getting all the right permissions (abstraction licence, environmental approval, archaeology, legal agreements) design, construction, and commissioning. A supplement which updates this booklet is also available on the UKIA website.

Stakeholder comments: Potential gain from this approach is high.

Reservoirs can improve current licence use with additionally available water. However, there are serious local authority and environmental planning permission and timing issues to enable grant aid to align with the availability of construction companies, usually in the summer months.

- Capital investment is required vs payback period, e.g. can the marketplace afford to pay more for products/crops to ensure the long-term security of production and thus supply?
- Could a model similar to Biodiversity Net Gain (BNG) used by developers and public water supply be available? Developers have to invest in BNG schemes as part of housing/commercial developments, which could be extended to ensure water security, as this would help farmers justify building reservoirs.

3.2.7 Managed aquifer recovery and aquifer storage and recovery

Managed aquifer recharge (MAR), known as water banking consists of water management methods that recharge an aquifer using either surface or underground recharge techniques.

There are opportunities at some sites to increase natural recharge, particularly in areas where Nature Based Solutions (NBS) are used to control flooding (JBA Consulting 2021), which can increase infiltration into aquifers. This is considered to be the safer option. Some 8 percent of Thames Water's public supply comes from MAR and subsequent recovery (Harris et al. 2005).

In Aquifer storage recovery (ASR), freshwater is injected into an aquifer for temporary storage and later recovery. Although this is common practice in the US and Israel, and trials are taking place as part of the Felixstowe project, serious concerns exist that this direct approach can irreparably pollute the aquifer if the injected water differs in quality from that in the aquifer.

Both options allow for storing water in aquifers during periods of surplus for retrieval during times of scarcity. It has seen various degrees of implementation across the globe, demonstrating its viability as a tool for sustainable water management. Publicly accessible studies and data showcase both the potential benefits of ASR, such as increased water security and improved management of water resources, and the challenges, including technical complexities and the need for detailed understanding of local aquifer systems.

The technical summary of ASR by the Environment Agency, 1999, gives an overview of ASR, and its pros and cons, with links to a more detailed technical report. An ASR scheme could be used as part of an LRO to store water abstracted from rivers, drainage water re-use, or any of the above sources and allow the water to be used when required for irrigation or other use.

Both recharge methods assume enough storage in an aquifer and that it can be recovered when needed at the required rate.

Stakeholder comment: Potential gain is high.

However, there is a lack of understanding of how both recharge methods work in practice and how effective they would be in specific areas. A qualified professional such as a hydrologist, hydrogeologist or a geologist should be consulted to assess the feasibility and potential yield of a MAR scheme and how this should be operated with adequate monitoring to reduce pollution risks. It is also unclear how such facilities would be regulated, e.g. from an abstraction licence and wider regulatory perspective. Despite these problems, the potential contribution of MAR to local water availability could be significant.

3.2.8 Improve connectivity of existing sources, and conjunctive use schemes

These LRO approaches can split into two types:

- **Schemes that improve connectivity**, involves linking existing water sources to allow for shared use among different users, through pathways such as aggregating existing licences enhancing both water availability and the reliability of these sources. These schemes will have to consider how water can be shared through investigating existing or new pipe networks, crossing roads and possibly neighbour’s land.
- **Conjunctive use schemes** extend this concept by integrating various water sources, including groundwater, river abstractions, and reservoirs, into a cohesive system. These strategies necessitate the development of physically connecting schemes, known as Water Transfer Schemes. These can be organised at national, regional, or local levels, offering a scalable solution to water management challenges in agriculture.

3.3 Demand options

Demand reduction should always be the first step in meeting any deficit between the current yield and current or future yield requirements. This does not make more water available in a catchment as a supply option does. Rather it enables existing supplies to be used more effectively. This will generally be the most cost efficient and environmentally positive solution. It is unlikely that demand options will be considered to be LROs, but demand management can reduce the magnitude of any supply solutions needed.

On a farm, demand reduction can take many forms: from the fixing of leaks in irrigation systems and stock water pipes, to changing the timing of irrigation, using more efficient irrigation systems, or even the use of cover crops to reduce evaporation.

3.3.1 Leakage reduction

Although this is a significant issue in public water supply, where leakage occurs 24-7-365 days, it is not perceived as a significant issue on irrigation systems. Most systems are relatively new and only operate intermittently. Losses can occur during drain-down when moving equipment or pipe bursts, but the amounts involved are not significant. Generally, leakage is well managed on farms and monitored via water meters at key locations in the pipe systems.

Stakeholder comment: Potential gain is low.

3.3.2 Other demand options

Generally, infield irrigation in England is not wasteful, provided it is well managed and maintained, as the nature of supplementary irrigation usually means that farmers tend to under-irrigate rather than over-irrigate. The main driver to reduce water use is the energy cost of applying the water which can be a much as 80 percent of the total running cost for an irrigation system. However, protected cropping requires full irrigation and the opportunities to lose water by applying too much or breaks in drip lines and uneven emitter discharges can be significant if the system is not well monitored or maintained. Many glass house irrigation systems have complementary recovery systems that recover nutrients as well as water.

- **In-field technologies**, such as soil moisture probes and weather stations enable farmers to control and improve timing of water applications that take account of crop transpiration rates, soil infiltration rates, and evaporation. The use of Remote Sensing and drones can help identify problem areas in large fields that are not easily identified from ‘walking the crops’. GPS controlled rain guns can prevent unnecessary overlaps of spray patterns, keep applications within field boundaries, and adjust equipment for varying wind conditions.
- **Drip irrigation** has a role to play in both protected and field cropping. However, such systems do not automatically make irrigation more efficient. They are best suited to vegetables and high value fruit crops grown in marginal soil and water scarcity conditions or in protected cropping.
- **Sophisticated electrical pumping systems** are increasingly used fitted with inverters to match supply and demand with maximum pumping efficiency. More about saving energy rather than water but they do complement each other.
- **Better weather forecasting** would benefit supplementary irrigators though this is difficult to achieve in practice more than a few days ahead, particularly with local forecasting at field level.

Stakeholder comment: Potential gain is medium.

- **Drought tolerant crops**: Crop research suggests that you cannot have high yield and drought tolerance at the same time, so farmers have choice. Drought tolerance would be the safe option, while high yield would be more profitable but more risky option.
  Crop quality (taste, texture, appearance) would change and crop choice would also be driven by market/consumer demand. Politics are involved in the use of technology to improve crop characteristics, such as gene editing.
- **Stakeholder comment:** Very high potential gain but a long-term solution
- **Agronomic good soil and water practices:** Potential gains from adopting Good Farming Practices such as agroecological farming practices, soil health improvement technologies, crop rotation and diversification. A need to understand "best" crop rotation: length of rotation, what crops are in the rotation and the use of cover crops.
- **Stakeholder comment:** Potential gain is medium.
- **Balancing business profitability and adopting best practices**: These are time sensitive, i.e. long-term profitability could be better, but this may impact short-term profitability. This is potentially a problem for tenant and landlord relationships, i.e. difference in opinion/understanding on what best practice is and therefore effect this can have on level of rent expectations. Better education of "absent" landlords and agents is required.
- **Stakeholder comment:** Potential gain is medium/high.

3.4 Sharing, trading, aggregated licencing

3.4.1 Water rights trading

In England, trading rights to abstract water temporarily or permanently is an option that has been on the table for some time. In 2021, Wheatley Watersource, set up a pilot project in East Suffolk in collaboration with Anglian Water and Essex and Suffolk Water supported by the Environment Agency. The Agency also publishes "*Help for water rights trading map*" as a means of connecting farmers who wish to trade.

Water rights trading enables allocating water resources through market-based mechanisms, where rights to use water can be bought and sold by farmers, thereby promoting a more adaptable and efficient use of water within the agricultural sector. This approach can facilitate better use of existing water resources and incentivise conservation of water. The effectiveness of water rights trading as a tool within the LRO methodology will depend on the establishment of clear, enforceable legal frameworks and governance structures to manage the trading system, along with comprehensive catchment and site-specific data to inform decision-making.

Water rights trading offers a flexible approach to water management, enabling adjustments for seasonal changes, droughts, and shifts in agricultural demands without significant infrastructure overhauls. Market-based allocation can be a more effective and adaptable method than traditional administrative allocation, potentially easing conflicts over water usage and supporting environmental sustainability if regulated properly. However, the implementation faces challenges, including the need for a robust legal and institutional framework, concerns over equity and the risk of market concentration favouring wealthier entities, and the significant administrative and transaction costs involved.

The formalities for trading can be cumbersome, and many abstractors have cited issues, such as slow transaction times to complete trades and a lack of flexibility to meet their needs, particularly under drought conditions. The simple fact that water cannot be easily transferred across different catchments, like trading among water companies whose pipe network are interconnected, is perhaps the biggest constraint to agricultural water trading.

3.4.2 Water sharing

An alternative approach that is gaining traction is water-sharing. These are both formal and informal arrangements among groups of farmers where land is rented with a given water allocation either for a single cropping season or longer period to fit in with business plans. This approach is simple to administer, allows a degree of flexibility, and builds on local trusted farmer relationships.

This approach emphasises the potential gains from for communal management of water resources, enabling farmers and agricultural stakeholders to share access to water through agreed-upon schedules, quantities, and conditions. Water sharing arrangements can be particularly beneficial in regions where water scarcity poses a significant challenge to agricultural productivity and sustainability. It does not only foster a sense of collective responsibility and cooperation among water users but also encourages the adoption of water-efficient practices and technologies to maximise the utility of shared resources. However, the success of water sharing as an LRO hinges on the development of transparent, fair, and enforceable agreements that clearly define the rights, responsibilities, and obligations of all parties. Additionally, the implementation of such schemes must be supported by accurate and timely information on water availability and demand, necessitating investments in monitoring and data management systems.

Figure 3-1 demonstrates the potential significant benefits from water sharing as the size of the sharing group increases for different dry years (Chengot et al. 2021).

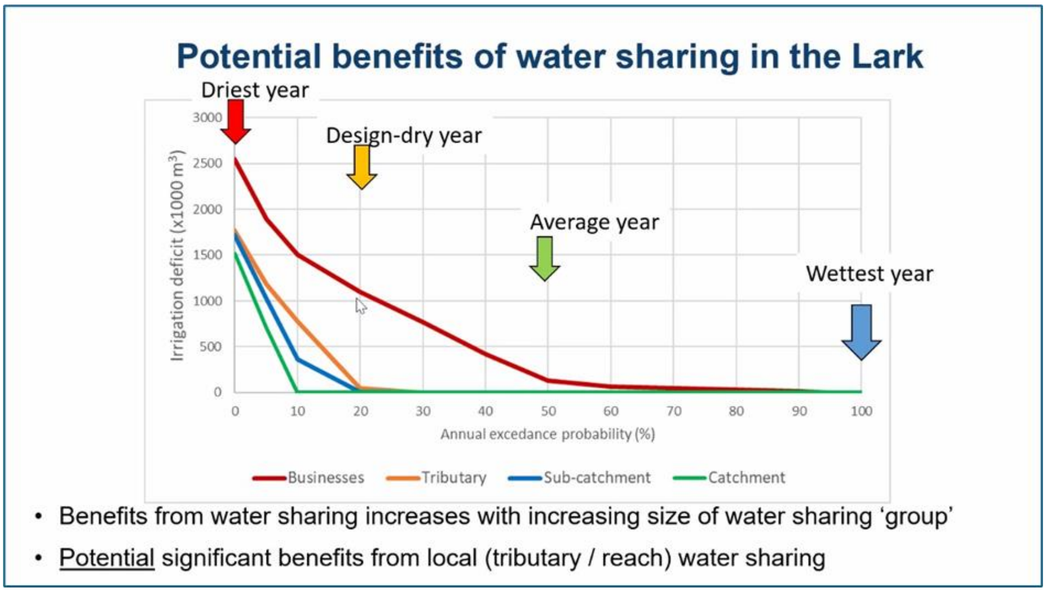


Figure 3-1: Water sharing benefits

Key points to consider:

- Complexity in Agreement Formation: Establishing fair and effective water sharing agreements requires negotiation and consensus among all parties, which can be complex and time-consuming.
- Risk of Inequity: Without proper oversight, there's a risk that dominant users could influence agreements to their advantage, potentially marginalizing smaller or less powerful stakeholders.
- Dependency and Reliability Concerns: Dependence on shared water sources can pose risks if the water availability decreases or if some users do not adhere to the agreed terms.
- Implementing a robust governance structure to monitor compliance, resolve disputes, and enforce agreements is critical for the success of water sharing initiatives.
- Data and Monitoring Requirements: Effective water sharing requires accurate, real-time data on water availability and usage, necessitating significant investment in monitoring and information systems.
- Adaptation to Legal and Regulatory Frameworks: Water sharing schemes must abide by existing licence conditions and be compatible with existing legal and regulatory frameworks governing water rights and usage, which may require reforms or adaptations.
- These schemes may have impacts on the environment where abstractors use their full licenced amount more regularly/continuously. This will need to be carefully considered and mitigated as necessary.

Table 3-1: Summary of LRO Supply Options

LRO Type	Technical Considerations	Potential Water Resource Benefit	Planning Considerations	Policy Aspects	Likely Capital Cost	Environmental Impacts	Potential for Environmental Benefit	Social Impacts	Barriers to Implementation	Expected Gain (from Stakeholder comments)
Rainwater Harvesting	Simple to complex systems; quality and storage capacity	Can significantly augment water supply	Site-specific design and land use	Encouragement through local incentives	Low to Medium	Minimal; depends on use and treatment	High; reduces runoff and demand on conventional sources	Enhances resilience; community engagement	Initial cost; space for storage; area for collection; public perception; lack of awareness	Low/ Medium
Groundwater Sources	Hydrogeological assessment; sustainable yield consideration	Dependable supply if managed sustainably	Water table impact; aquifer recharge	Licencing; sustainable extraction limits	Medium to High	Potential depletion; water table lowering	Managed recharge can enhance aquifer levels	Critical for rural livelihoods; water security	Over-exploitation; contamination risk; groundwater management conflicts; equity concerns	Medium/ High
Farm Storage Reservoirs	Land availability; evaporation losses	Enables water availability year-round	Large footprint; visual impact	Planning permission; water capture rights	High	Habitat displacement; evaporation	Water security enhances local habitats	Economic stability; agricultural productivity; potential for other uses (e.g. solar panels, recreation)	High upfront investment; land use; competing land uses; community opposition	High
Managed Aquifer Recovery (MAR)	Technical feasibility; aquifer compatibility	Enhances aquifer recharge and water availability	Geological assessments; monitoring systems	Regulatory frameworks for recharge methods	Medium to High	Potential alteration of aquifer characteristics	Improved water quality and availability	Supports community well-being; water security	Technical complexity; cost; public acceptance; regulatory hurdles	Medium/ High
Conjunctive Use Schemes	Integration complexity; resource management	Optimizes water use and reliability	Coordination among water users and sources	Integrated water resources management policies	Medium to High	Varies by scheme; can reduce stress on individual sources	Balances ecosystem demands	Enhances water access and equity; community cooperation	Governance; stakeholder alignment; institutional barriers; coordination challenges	Medium/ High
Water Rights Trading	Market mechanisms; pricing transparency	Encourages efficient water use	Regulatory oversight; market facilitation	Legal frameworks for rights and transfers	Variable	Depends on changes in water use patterns	Can lead to more sustainable water allocation	Economic flexibility; incentivizes conservation	Market participation; fairness concerns; access to market; understanding of rights	Low
Water Sharing	Agreement flexibility; measurement and monitoring	Improves water use efficiency and access	Community-based agreements; governance structures	Often informal; may lack formal policy support	Low	Minimal; encourages efficient use	Enhanced resilience to water scarcity	Community solidarity; improved relations	Trust and cooperation among participants; misunderstandings; unequal access	Medium
Use of Land Drainage Water	Water quality management; conveyance systems	Converts waste to resource; enhances irrigation supply	Coordination with drainage authorities; quality standards	Water reuse regulations; quality standards	Medium	Nutrient loading; salinity issues	Nutrient recycling; reduced freshwater demand	Agricultural sustainability; reduced water costs	Quality concerns; infrastructure cost; community perceptions of water quality; regulatory complexity; coastal location driven	High

LRO Type	Technical Considerations	Potential Water Resource Benefit	Planning Considerations	Policy Aspects	Likely Capital Cost	Environmental Impacts	Potential for Environmental Benefit	Social Impacts	Barriers to Implementation	Expected Gain (from Stakeholder comments)
Use of Flood Water	Capture and storage capacity; rapid response systems	Mitigates flood risk; augments water supply	Infrastructure resilience; floodplain management	Flexibility in abstraction rules; emergency provisions	High	Altered flood dynamics; potential habitat impact	Flood risk reduction; groundwater recharge	Flood mitigation; community protection	Infrastructure investment; operational readiness; social acceptance; displacement concerns; infrastructure impacts	High

4 LRO screening and ranking framework

4.1 General

The process for screening and ranking LRO options is described in this section. It describes the stages of each step, and data required to make decisions at each stage. The screening and ranking process is an iterative one, with the results of one stage sometimes requiring users to return to a previous stage to carry out further analyses.

4.2 Assumptions

It is assumed that the process starts with a WAG already set up. This methodology will be led by a consultant with experience in water resource options scoping and assessment. This consultant will use the methodology along with discussions with the WAG on their priorities, farms, and environment. Some WAGs will already have a proposal for a particular water resource option, whereas others will not. This process aims to be user friendly and robust without being overly prescriptive: in the case of WAGs who have started the process with a clear idea of the option they wish to evaluate, it is expected they will also consider other potential options, and maximise demand savings, but the process will not require that they put a disproportionate effort into options that have already been discounted.

4.3 Criteria for screening and ranking

Data collection and analysis plays a pivotal role in determining the criteria for screening and ranking potential water management solutions. Initially, high-level criteria based on broad data sets help screen out unviable options. These criteria might include environmental impact, technical feasibility, and initial cost estimates. For example, options might be screened based on their potential to significantly alter local ecosystems or exceed budget constraints. Following the initial screening and as the process progresses, more detailed data analysis and stakeholder engagement informs the ranking of viable options, focusing on criteria such as operational costs, water yield estimates, and regulatory compliance challenges. The criteria for screening and ranking are interconnected. The initial screening uses broad criteria to eliminate unfeasible options, which then informs the refinement of more detailed criteria for the subsequent ranking phase. This means that the insights gained during the screening phase are crucial for adjusting and fine-tuning the criteria used to rank the remaining options more precisely. The screening process sets the stage, providing a focused context within which the ranking criteria are developed and applied in a coherent and effective way.

4.4 Guidance philosophy and limitations

It is important to clarify that this report does not present a detailed methodology for conducting intricate analyses such as costing assessments, yield assessments, and environmental impact evaluations. Rather, the goal is to offer strategic direction and resources that can assist WAGs and their consultants in navigating these complex evaluations.

The JBA approach is premised on the understanding that the professionals supporting WAGS, come equipped with a foundational level of technical knowledge and expertise necessary to undertake such detailed assessments. It is recognised that each LRO presents its unique set of challenges and requirements, making it impractical to prescribe a one-size-fits-all methodology for these analyses.

Particularly with regards to stage 5: Detailed evaluation, instead of detailing exhaustive procedures, this section aims to guide users towards relevant resources, methodologies, and best practices that align with their specific needs and the unique characteristics of their LRO options. This guidance is designed to:

- Highlight key factors that should be considered during costing and yield assessments.
- Suggest established methodologies and analytical tools that have been recognised for their effectiveness in similar contexts.
- Identify authoritative sources of information, data, and expertise that can support the accurate and comprehensive evaluation of LRO options.

Associated appendices providing guidance on yield and cost assessment methodologies are included in Appendices C and D.

4.5 Proposed process overview

The framework involves a structured collaborative approach, engaging stakeholders in identifying and assessing potential water resource options through technical analysis and participatory methods.

The process is inherently iterative, characterised by continuous feedback loops rather than a linear progression, emphasizing WAG group engagement as a driving force.

Key stages of the process include:

- Stage 1: Define Scope and Objectives - Establish the project's geographical focus and objectives, ensuring alignment with the broader goals of sustainable water management and agricultural support. Also, a long list of LRO options will be presented and used for the screening exercise.
- Stage 2: Data collection and analysis: To gather comprehensive data and perform initial analyses that will inform the screening and selection of potential LROs. This involves collecting data on water resources, agricultural needs, environmental considerations, and stakeholder inputs. Ibn practice different levels of data analysis

will be involved in all stages through to detailed assessment, this was a lesson learnt highlighted from the Pilot project.

- Screening and Selection - Employ the screening framework to filter potential LROs based on criteria such as water resource benefit, cost, environmental impact, and WAG preference. There are criteria that are based on objective factors that will influence the process but some of the criteria will emerge from consultations with the
- Stage 3: Ranking and Prioritization - Utilize a ranking framework to evaluate and rank the screened options, further refining the selection based on more detailed criteria including technical feasibility, regulatory compliance, and community acceptance as well as assigned weights.
- Stage 4: Detailed Evaluation - Conduct in-depth analyses of the prioritised options, including yield analysis, cost analysis, environmental and social considerations and look at climate change aspects.
- Stage 5: Implementation Planning - Plan for the real-world application of the selected LROs, focusing on practical considerations such as site-specific challenges, funding routes, regulatory approvals, and stakeholder collaboration. This is not part of the current study but an important step to have a clear vision on while the rest of the process is taking place.

Key Components of the Framework are:

- Involvement of the WAG groups and other stakeholders throughout the process to ensure that the developed LROs are grounded in local realities and have the support of the community.
- Flexibility to adapt the framework based on real-world feedback and changing environmental or regulatory conditions.
- Emphasis on sustainable and collaborative water management models that optimise resource use and enhance the resilience of agricultural practices against climate variability.

The aim is not to provide an exhaustive process that must be followed- it is assumed that most groups will be starting from a position of some knowledge- have some idea of the solutions they wish to consider. This was the case in the Pilot study. The method is designed so that users can add in additional innovative and location specific resources above and beyond those presented. This process is to guide them to make best decisions, and to consider other options they may not have considered. We aim to outline the benefits and risks with each type of option and provide a process for the WAG to determine which LRO could be the right solution, but not to force the members of the WAG into an LRO.

This process is shown in the flowchart below.

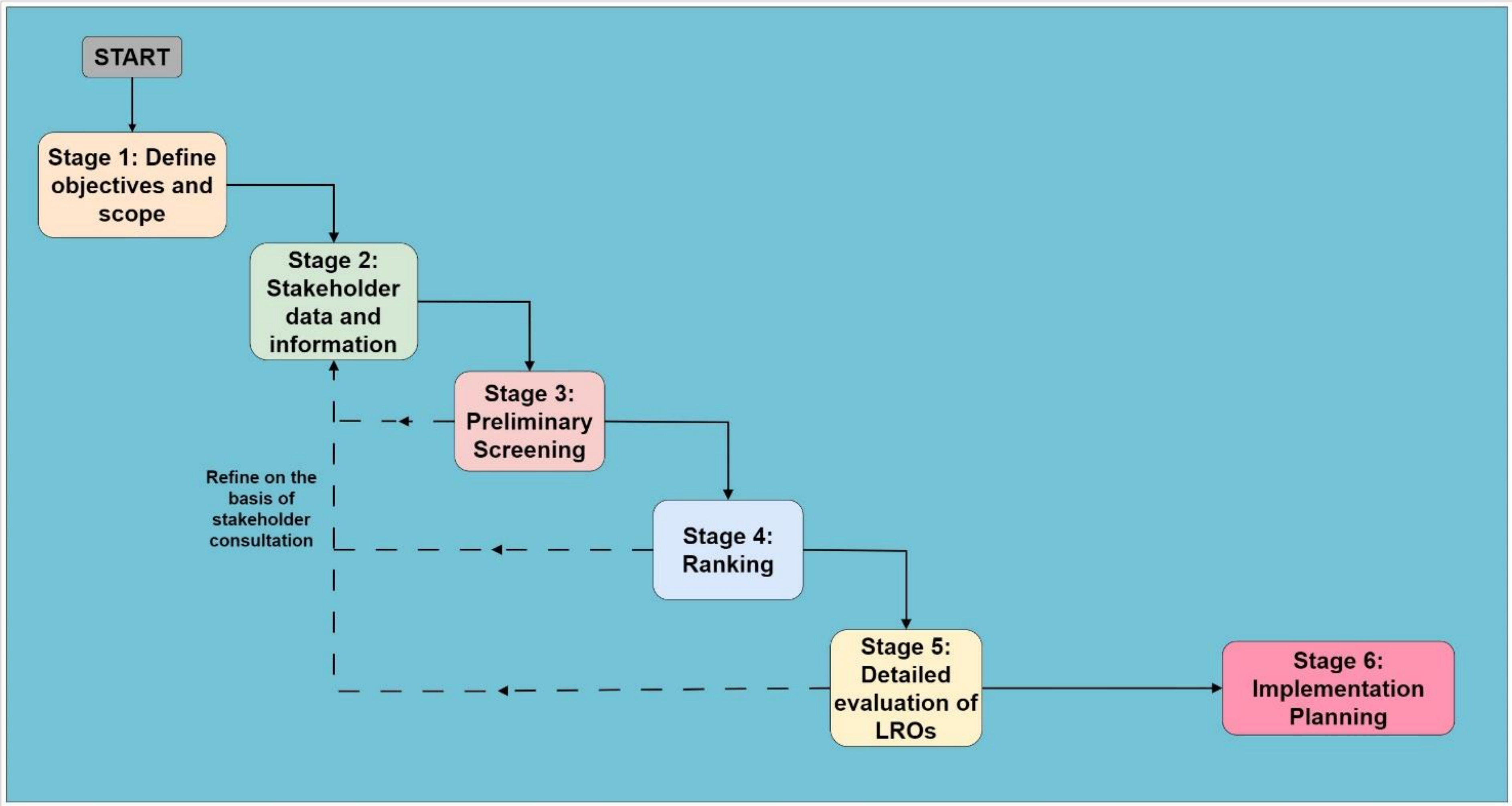


Figure 4-1: Overview of LRO assessment.

The dynamic and iterative character of these projects was particularly evident in the Pilot study. Figure 4-2 shows how the whole process unfolded for the Pilot. Initial data that laid the groundwork for baseline conditions were subsequently revisited for other project facets. For instance, hydrological data initially deployed for licence verifications were later re-evaluated in the context of flood storage LRO considerations. The iterative nature of the methodology ensures that decision-making processes are informed by the most current data, accommodating new insights and findings. The need for constant interaction with the WAG group is also emphasized, either for data validation, to seek feedback on the decision support methodology and /or general validation of data and options.

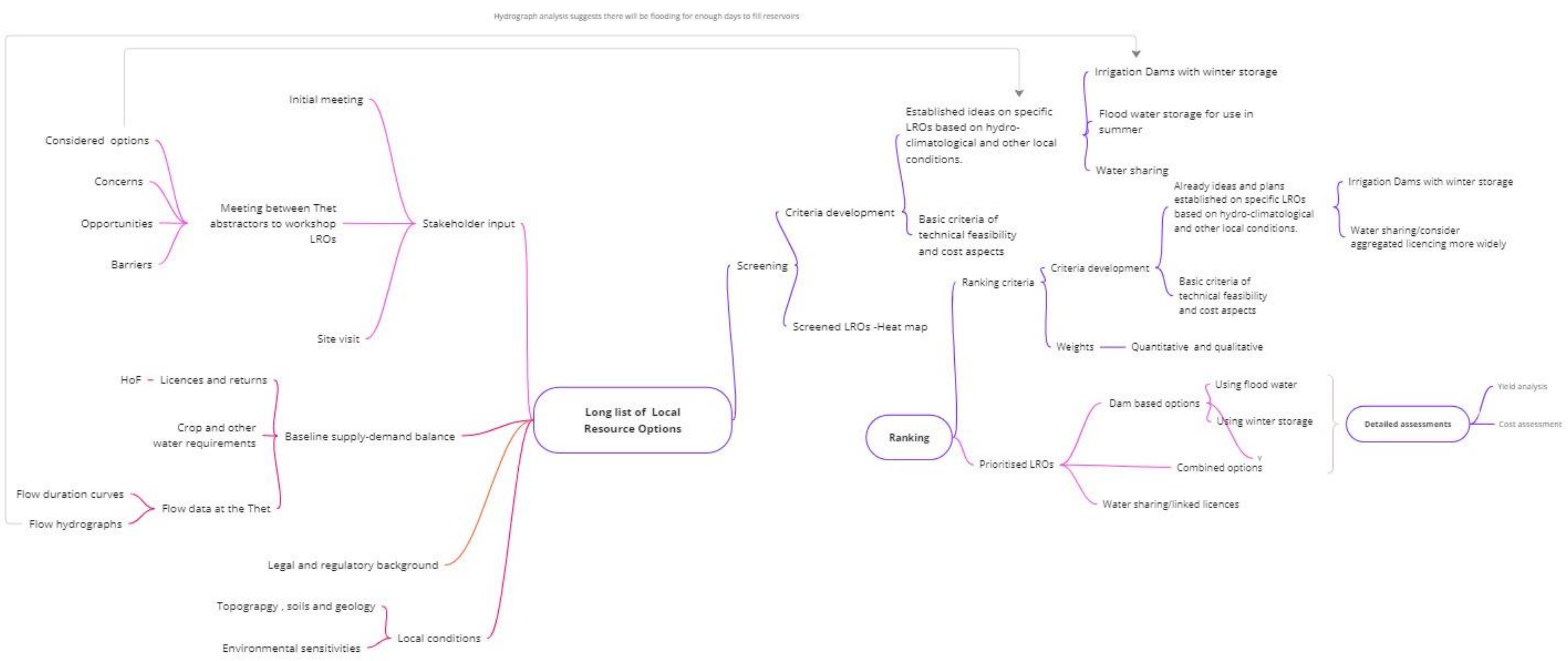


Figure 4-2: Mind map demonstrating the interconnectivity of the LRO assessment process

5 Stage 1: Define scope and objectives

5.1 Overview

Setting clear, actionable objectives is essential. But in order to define objectives this requires a deep understanding of the local context, a clear vision for sustainable water management, and an inclusive approach that considers the needs and perspectives of all group members. The objectives should address both the immediate and long-term needs of water management in agriculture, focusing on sustainability, efficiency, and compliance with environmental regulations. Objectives might include reducing dependency on certain water sources, identifying alternative water resources, and enhancing water use efficiency among agricultural stakeholders.

The setting of objectives is a crucial step undertaken by the WAG with the help of their consultants, necessitating a comprehensive understanding of both the immediate local environment and broader goals for sustainable water management. These objectives must be inclusive and reflective of the collective aspirations and requirements of its members.

To more effectively address these needs, the objectives should:

- Develop objectives that resonate with the entire group's interests and the broader community they serve.
- Address Varied Time Scales: This distinction ensures a strategic approach that tackles immediate water scarcity issues while planning for long-term sustainability and resilience against environmental and regulatory changes.
- Incorporate Future-Proofing Measures: Emphasise the importance of including objectives that prepare the WAG for future challenges. This involves exploring innovative water resource management practices, adopting new technologies, and ensuring flexibility to adapt to legislative changes and environmental uncertainties.

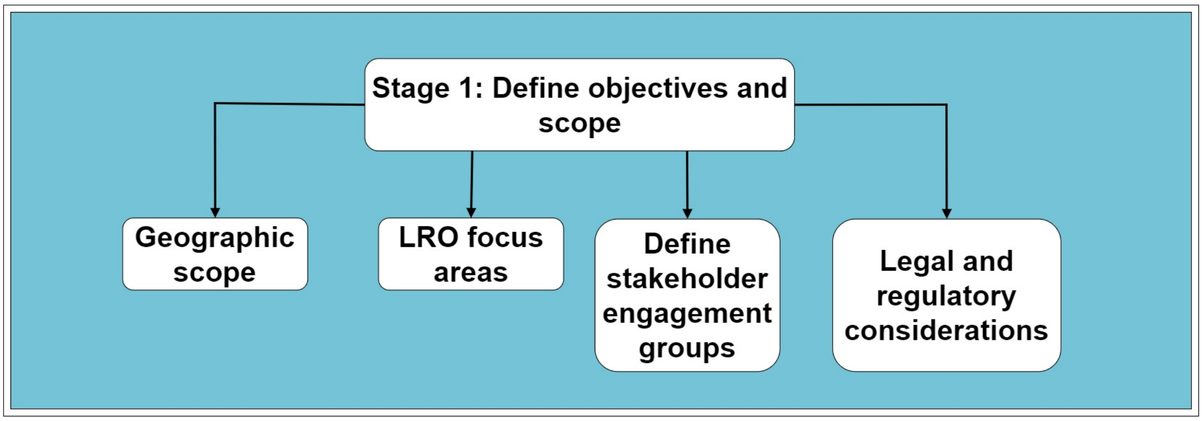


Figure 5-1: Process for definition of scope for LRO assessment

5.2 WAG involvement

To effectively navigate the complexities of local water resource management it is crucial to leverage the collective knowledge and capabilities of Water Abstractor Groups (WAGs). The engagement with the farming community, WAG groups and other stakeholders for the development of this framework emphasized that WAGs as active, empowered stakeholders in the decision-making process are critical for the success of the project. The goal is to foster a sense of ownership and commitment to the success of LROs, thereby enhancing the sustainability and efficacy of water management initiatives. Early involvement and engagement with several members of the groups will help understand the different perspectives, challenges and established practices and relationships which can help inform the process.

5.3 Geographic Scope

The exact geographic boundaries of the study area should be selected based on criteria such as water stress, agricultural significance, and the potential for implementing LRO strategies. The scope should prioritise areas where the introduction of LROs could yield significant benefits in terms of enhancing water security, supporting sustainable agricultural practices, and maintaining or enhancing ecosystem health.

5.4 Legal and regulatory considerations

Identifying and understanding the legal and regulatory framework governing water use in the area is necessary. This ensures that the LRO methodology aligns with existing laws and policies, facilitating smoother implementation and adoption of recommended practices and technologies. Engaging with regulatory authorities, water users, and environmental groups to gauge the regulatory environment's receptiveness to innovative water management strategies will be important for this. Active engagement with regulatory authorities at both national and local levels is important. Collaboration with these authorities from the outset helps to clarify regulatory expectations, identify potential legal hurdles early in the planning process, and seek guidance on navigating complex regulatory landscapes.

5.4.1 Local planning regulation

Local planning requirements play a critical role in the development and implementation of LROs. These requirements can vary significantly between regions, influenced by local environmental priorities, development plans, zoning laws, and community interests. Key considerations include:

- Zoning Regulations: Identifying zoning restrictions that may affect the construction of water storage facilities or changes in land use essential for implementing certain LROs.
- Environmental Impact Assessments (EIAs): Many local jurisdictions require comprehensive EIAs for projects that could significantly impact local ecosystems.

Understanding the criteria for these assessments and the process for their submission and approval is essential.

- Public Consultation Processes: Local planning often mandates public consultation, providing an opportunity for community members to voice their opinions on proposed projects. Engaging effectively with the community can garner support and identify potential opposition early in the process.

Engaging with local planning authorities early to seek advice, clarify requirements, and understand the approval process.

5.4.2 EA and other regulatory bodies

- Collaborative Planning: Involve the Environment Agency in the planning and strategy development phases of LRO projects. Their expertise in water management, environmental protection, and regulatory compliance can contribute to more robust and sustainable LRO strategies.
- Regulatory Guidance: Seek the Environment Agency's advice on navigating the regulatory landscape, understanding licensing processes, and adhering to environmental regulations. Their input can help shape LRO initiatives to align with regulatory expectations and environmental objectives.
- Data Sharing and Analysis: Collaborate on data sharing, including hydrological data, environmental assessments, and water usage statistics. The Environment Agency's access to comprehensive datasets can enhance the accuracy of LRO assessments and decision-making.

5.5 Time horizons

Time horizons in the context of LROs can range from immediate interventions to address acute water shortages to long-term strategies ensuring water security under future uncertainties. There are implications of short, medium, and long-term planning horizons on investment decisions and project outcomes. Different time horizons influence various aspects of project planning and execution. The agricultural community's feedback during development of the framework highlights the challenges associated with long-term solutions, notably the variability and uncertainty of licensing volumes over extended periods. Consequently, addressing the spectrum of immediate to future needs requires a proportional escalation in investment and effort for longer-term initiatives. To effectively incorporate varying time horizons in the evaluation process it is proposed to include time horizons as a factor in the project evaluation criteria for screening and ranking. This would enable options with a smaller benefit, but that could be implemented quickly, to fill the gap before larger options with a longer lead time could be implemented.

5.6 Stakeholder mapping and early engagement

This task includes identifying all relevant stakeholders, which could range from other local farmers and agricultural businesses to environmental groups and government agencies and linking up with them.

Key stakeholders in the process include the WAG groups who will have a vested interest the process and also regional water resource (WR) groups, who are able to share information, provide advice and may also have an insight into options that may be available/ feasible and potential for combined /multisector solutions.

Although stakeholder engagement is thoroughly discussed in section 6.7, there are some key actions that need to be taken at this stage to ensure early engagement. Stakeholder mapping will involve categorizing stakeholders according to their influence and interest in the project, which helps in understanding their needs, expectations, and potential impact on the project's success.

Early engagement with stakeholders establishes a channel for communication and builds trust from the onset. Engaging stakeholders early often leads to better alignment with community values, compliance with legal and regulatory frameworks, and the identification of mutual benefits.

6 Stage 2: Information Gathering

6.1 Overview

In order to select potential water supply options and screen them for suitability to meet the demand needs of the WAG, a large amount of information is required. Figure 6-1 summarises the types of information required to assess water resources options which may form part of an LRO. Table 6-1 presents a summary of key data and possible sources for those, which has been compiled based on our experience with the Pilot Study. In practice, there may be multiple times during all phases of the project that there will be a need to go back to the data information and analysis stage to either further review data, critically assess data discrepancies and /or look for alternative sources. There needs to be sufficient time allowed in the programme to account for this and interactions with WAG members to clarify data and get anecdotal information to explain discrepancies.

The different data categories are further discussed in the following sub-sections.

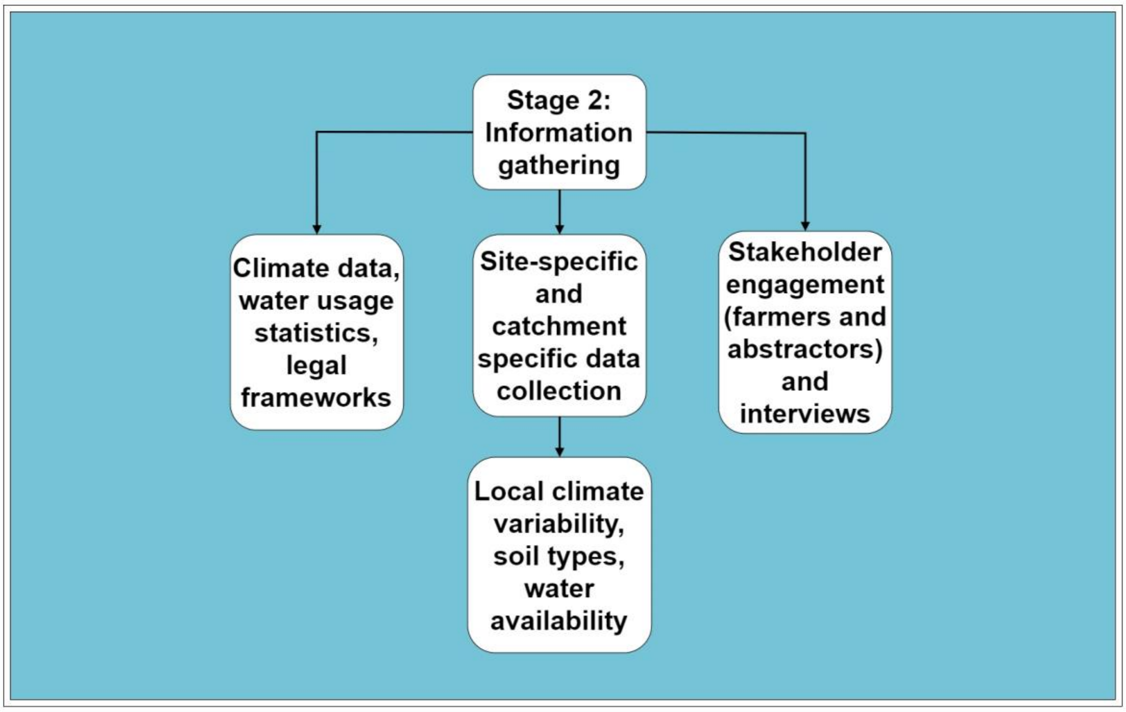


Figure 6-1: Required information for LRO assessment

Table 6-1:Summary of Key Data

Data Category	Purpose	Data Limitations	Use in Analysis	Data Source
Hydrological and Climatological Data	To assess weather patterns, precipitation, evaporation, and hydrological cycles.	Seasonal variations may not be captured in available models.	Water balance studies, hydrological analysis, climatic variability on water availability.	DEFRA Hydrology Explorer (2021) – Rainfall, River Flow, River Level, NRFA, Groundwater Level, Water Quality
Soil and Geological Information	To determine the water retention and filtration properties, and aquifer characteristics.	Inadequate resolution for localized geological variations.	Critical for site selection for LROs and understanding groundwater recharge and storage potentials.	BGS 1:625000 scale Bedrock Geology UK; BGS 1:625000 scale Superficial Geology UK; Details local geological and hydrogeological mapping; UK Soils Observatory Soilscapes Cranfield
Current Water Use and Demand	To quantify existing water usage and forecast future demands based on agricultural practices.	Projections may not fully account for technological changes.	Fundamental for identifying discrepancies between supply and demand and planning for future LROs.	Environment Agency; Local data from farmers or WAGs; Source protection Zones
Water Resource Availability	To identify existing water sources and their seasonal variability.	Potential oversight of lesser-known or emerging water sources.	Used to identify viable LRO options and to assess the sustainability of water sources.	Environment Agency (2021) Groundwater Management Units coloured according to water resource availability colours (shapefile); Environment Agency (2022) Water Resource Availability and Abstraction Reliability Cycle 2 (shapefile)
Abstraction licencing data /Licence return data /environmental flow designations	To ensure LROs comply with current water abstraction, environmental protection, and land use laws.	Emerging regulations or policy reforms may introduce new constraints.	Necessary for the legal feasibility of LROs and navigating the permitting process.	Environment Agency; Local data from farmers or WAGs
Land-use	To evaluate how current and projected land uses impact water resources and LRO opportunities.	Changes in land-use patterns may not be promptly reflected in data sets.	Impact of agricultural and development activities on water demand and availability, and for informed LRO site selection.	The UKCEH Land Cover Maps (LCMs) map UK Land Cover
Stakeholder Inputs	To integrate local knowledge and stakeholder priorities into the LRO planning process.	May not capture the full spectrum of community perspectives.	Integral for ensuring LROs meet the needs and gain support from local communities and water users.	Data obtained through workshops and interviews
Environmental Designations	To understand protected areas and their requirements for conservation. Includes SSSI's, RAMSAR, priority species and habitats, SAC's, SPA's etc.,	Changes in designation status or conservation priorities may not be up to date.	Important for planning LROs in a way that minimizes environmental impacts and complies with protections.	Natural England (2024) Sites of Special Scientific Interest (England) (shapefile); Natural England (2024) Special Areas of Conservation (England) (shapefile); Water Resource Regional Groups

Data Category	Purpose	Data Limitations	Use in Analysis	Data Source
Internal Drainage Boards	To ensure any LROs are in line with water level management practices & to review potential for using drainage water as part of LROs	Variability in data reporting standards across different IDBs.	For alignment of LROs with existing drainage practices and for opportunities in water reuse.	Environment Agency (2024) Association of Drainage Authorities: Administrative Boundaries – Internal Drainage Districts in England (shapefile)
Canal Network	To evaluate existing water conveyance infrastructure and potential for integration.	Limited information on the operational status and maintenance of canal networks.	To assess the feasibility of using canals for water distribution as part of LROs.	Environment Agency (2020) WFD River, Canal and Surface Water Transfer Bodies Cycle 2 Classification 2019 (shapefile)

6.2 Catchment data

As background to the study, it is useful to know specific information on existing storages and licences in the area. This is a quick way to determine what sources are currently favoured. The type of information can include:

- The number and volume of existing farm irrigation water storage reservoirs in the area. There's no singular data source for the actual number or total volume of on-farm irrigation reservoirs. Some data comes from reported winter abstractions for spray irrigation, see point below.
  - Information for Licences and Actual Abstracted Water: The Environment Agency (EA) holds a database of large, raised reservoirs and manages a National Abstraction Licencing Database (NALD) which records permitted maximum annual abstraction and actual abstractions by month. This database is crucial for understanding both licenced and actual water abstraction volumes for spray irrigation. The proportion of irrigation water that is abstracted in winter months for storage can indicate presence and use of reservoirs. If study is procured in conjunction with the Environment Agency, then output from NALD can be provided directly to the farms involved. If not, farmers should give their returns data to the consultant directly. Information on other licences in the area, including for other purposes can be found through the EA trading map, and via the CAMS Abstraction Licencing Strategy documents which are available on .gov.uk.
- GIS analysis on environmental and other designations.

6.2.1 Regional WR groups data

The regional water resource management plans can be useful sources of information and may already hold relevant data, so it is useful to consult with these stakeholders early in the process. Analysis of current and future water availability could offer a foundational understanding of the hydrological dynamics within the catchment. The regional plans projections on water demand now and in the future, including insights into consumption trends across different sectors (public water supply, agriculture, industry, etc.), provides useful context of wider conflicts for resources in the region and also deficits. In addition, environmental assessments detailed in the regional plan, including the impact of water abstraction and usage on local ecosystems, could be important for the LRO study. This information helps identify environmental constraints and ensure that proposed options do not adversely impact biodiversity or water quality. Input from the environmental destinations work could also be

6.3 Demand and water use data

6.3.1 Farm water requirements

An understanding of the volume and seasonality of water required is necessary to understand the yield that must be supplied by any options.

Farms that already irrigate will have a good idea of the volume of water they currently use and future needs. Farms that currently abstract will have returns data that they supply to the Environment Agency, generally on a monthly basis. Those that use stored rainwater should have their own records or idea of volumes that they use. This should be combined with any PWS use (meter data) to give an outline of current requirements that can be cross referenced with rainfall data to define historic irrigation requirements.

If changes in water use are expected, e.g. inclusion of irrigation, then the demand can be estimated according to soil types, farm type (e.g. livestock, crop or mixed), irrigation methods and acreage.

If the reservoir is to be shared, then water requirements from all sharing parties must be considered.

6.3.1.1 Crop water requirements

Knox and Kay (2008) proposed a method for carrying out a farm irrigation audit, which includes how to calculate crop water requirements.

Information to collect:

Background

- Historical irrigation abstractions on a weekly or monthly basis
- Crop type, irrigated area (ha), and total depth of irrigation water applied (mm) for each field in each year
- 'Other' agronomic factors that influence irrigation practices e.g. misting, cooling, transplanting, irrigation to assist in crop lifting, and seedbed preparation
- Irrigation training for farm managers and operators.

Irrigation network and equipment

- Pressure at the pump, head of each field, and at the raingun or sprinkler (weekly)
- Metered irrigation water use – volume pumped and the volume supplied to each field (each irrigation)
- Infield water distribution uniformity (annually).

Soil and water management

- Soil type and soil conditions in the field (annually)
- Crop being grown, planting date, crop cover, harvesting date (seasonally)
- Weather data (daily rainfall and ET) preferably close to the field (daily).

Use the information to:

- Compare scheduled and metered water use
- Estimate costs, benefits and value of irrigation (£ per m^3 of water)
- Correlate irrigation water use against climate.

Figure 6-2: Methodology by Knox and Kay (2008) for conducting your own irrigation audit to determine water use and efficiency on farms in terms of irrigation.

The irrigation water need (IN) = Crop water need (ET crop) – Effective rainfall (Pe). The loss of water through percolation and evapotranspiration should also be considered.

Effective rainfall, Pe = total rainfall – runoff – evapotranspiration – percolation

Calculating evapotranspiration (ET) can be done using an atmometer placed on the outer edge of a field.

The water use of a crop per week can be calculated by multiplying the ET reading by the crop coefficient (Kc).

Kc is determined by considering the type of crop and the growth stage that the crop is currently in (Table 6-2).

Table 6-2: Value of crop coefficient (Kc) for three different crop types. Source: Irmak et al. (2005)

Corn		Soybean		Wheat	
Growth Stage	*Kc*	*Growth Stage*	*Kc*	*Growth Stage*	*Kc*
2 leaves	0.10	Cotyledon	0.10	Emergence	0.10
4 leaves	0.18	First Node	0.20	Visible Crown	0.50
6 leaves	0.35	Second Node	0.40	Leaf Elongation	0.90
8 leaves	0.51	Third Node	0.60	Jointing	1.03
10 leaves	0.69	Beginning Bloom	0.90	Boot	1.10
12 leaves	0.88	Full Bloom	1.00	Heading	1.10
14 leaves	1.01	Beginning Pod	1.10	Flowering	1.10
16 leaves	1.10	Full Pod	1.10	Grain Fill	1.10
Silking	1.10	Beginning Seed	1.10	Stiff Doug	1.00
Blister	1.10	Full Seed	1.10	Ripening	0.50
Dough	1.10	Beginning Maturity	0.90	Mature	0.10
Beginning dent	1.10	Full Maturity	0.20		
Full dent	0.98	Mature	0.10		
Black layer	0.60				
Full maturity	0.10				

Table 6-3: Main crop types and their water needs. Source: Ware (2021)

Crop	Water Needs mm/total growth
Alfalfa	800 - 1600
Banana	1200 – 2200
Barley/Oats/Wheats	450 – 650
Beans	300 – 500
Cabbage	350 – 500
Citrus	900 – 1200
Cotton	700 – 1300
Maize	500 – 800
Melon	400 - 600
Onion	350 - 550
Peanut	500 – 700
Pepper	600 – 900
Potato	500 – 700
Rice (paddy)	450 – 700
Sorghum/Millet	450 – 650
Soybean	450 – 700
Sugarcane	1500 – 2500
Sunflower	600 – 1000
Tomato	400 – 800

6.3.1.2 Calculating livestock water requirements

Table 6-4 highlights the estimated water use for general agricultural practices produced by the Environment Agency. The table can be accessed using this link[4], and filled in online by individuals looking to calculate their water use.

4 https://assets.publishing.service.gov.uk/media/5a7f18fa40f0b62305b850da/LIT_10146.pdf accessed on 28/03/2024.

Table 6-4: Estimates of water use for general agriculture according to the Environment Agency

Use	Maximum number at any one time	Amount of water needed (in cubic metres)	Total volume per day (in cubic metres)	Number of days a year water is needed (if less than 365)	Total volume per year (in cubic metres)
People		0.2m³ per person (45 gallons per day)	m³		m³
Dairy cows, when water is used for cooling milk		0.13m³ per cow (30 gallons per day)	m³		m³
Dairy cows, when refrigerated bulk cooling is used		0.06m³ per cow (15 gallons per day)	m³		m³
Other cattle		0.04m³ per cow (10 gallons per day)	m³		m³
Horses		0.04m³ per horse (10 gallons per day)	m³		m³
Pigs		0.01m³ per pig (3 gallons per day)	m³		m³
Sheep		0.006m³ per sheep (0.2 gallons per day)	m³		m³
Poultry		0.0002m³ per bird (0.05 gallons per day)	m³		m³
Crop spraying for weed and pest control		0.13m³ per acre (30 gallons per day)	m³		m³
Other uses	–	–	m³		m³
Total			m³		m³

6.4 Desired water storage capacity based on agricultural needs and seasonal variation

The following factors should be considered when determining the size of reservoir or aquifer storage required for an LRO.

- Start with assessing the total seasonal irrigation need in a dry year for chosen return period – this will be dependent on crop types and total irrigated area.
- Future expansion, changes in cropping intensity, and changes in need due to climate change should be taken into consideration.
- Larger reservoir – gives scope for expansion or selling water; more protection against climate change; and water can be carried from one year to the next thus enabling the use of a less reliable water source or smaller abstraction licence.
- Smaller reservoir – if a summer abstraction can be kept then a small reservoir can be used as a backup source for periods when short-term abstraction restrictions are enforced.

There is a different level of detail required on this for screening, ranking and then detailed assessment. Several techniques are recommended in Appendix C.

6.5 Climate data

Climate data may be required as input to both supply aspects and demand aspects of the water balance and yield assessments. The type of data required will depend on the proposed sources and type of assessment selected.

Table 6-5: Climate data sources for Water resource option evaluation

Data	Purpose	Source of data	Type of LRO source
Rainfall	Yield estimation	HADUK rainfall https://www.metoffice.gov.uk/research/climate/maps-and-data/data/haduk-grid/datasets	Rainwater harvesting Reservoir or river abstraction if rainfall/runoff modelling used
Potential Evapo-transpiration	Yield estimation Crop water requirements	EA PET dataset https://www.data.gov.uk/dataset/7b58506c-620d-433c-afce-d5d93ef7e01e/environment-agency-potential-evapotranspiration-dataset	Reservoir or river abstraction if rainfall/runoff modelling used Any (crop water assessment)
River flow	Yield estimation	https://nrfa.ceh.ac.uk/data/search. Low flows software	River abstraction, reservoir

6.6 Site specific data

Any relevant local data on metrics such as soil types, local water availability and use, existing local abstractions and resources, and any threats to existing abstractions or licences should all be considered.

The Environment Agency Abstraction Licensing Strategies and data from the British Geological Survey such as geological maps can be used to find out if groundwater options are suitable in a given area, and in later stages, for yield estimation. Information on sites of interest can also be sourced from magic.defra.gov.uk.

Sites thought to be suitable for new abstractions, or new storage reservoirs should also be noted, and their characteristics recorded so that it may be used in decision-making.

6.7 Stakeholder engagement

6.7.1 Overview

Stakeholder engagement is at the heart of the success of any LRO initiative. Stakeholders are the experts on the local area, water requirements, and current and future issues as exemplified by the pilot study in the Thet catchment. This phase involves the identification, consultation, and involvement of all parties who may benefit from the LRO together with those who may be affected by the project, from inception through to implementation and monitoring. Effective engagement ensures that diverse perspectives are considered, fostering inclusive decision-making and enhancing project outcomes. A detailed stakeholder engagement plan to use as a starting point is provided in Appendix A.

6.7.2 Identifying Stakeholders

The first step is to identify a broad range of stakeholders, some examples including:

- Local farmers and agricultural businesses dependent on water resources.
- Government agencies responsible for water, agriculture, and environmental regulation, notably the Environment Agency, Natural England, Defra and more.
- The Water for Food Group and its constituent members such as NFU and UKIA.
- Other non-governmental organizations (NGOs) focusing on environmental conservation and sustainable agriculture. Examples include the Rivers Trust, Wildlife Trusts and community charities.
- Local communities and groups whose livelihoods might be impacted – to discuss possible mitigation and alternative options.
- Researchers and academic institutions with expertise and interest in the process.
- IDBs, Canals and Rivers Trust, local councils, parish councils, local businesses if relevant.

This may have already taken place as part of Stage 1.

6.7.3 Engagement Strategies

Developing tailored engagement strategies for different stakeholder groups is essential. This includes:

- Workshops and Meetings: Facilitating discussions to gather inputs, share project information, and address concerns.
- Surveys and Questionnaires: Collecting data on stakeholder preferences, expectations, and suggestions.
- Advisory Committees: Establishing committees that include stakeholder representatives to provide ongoing feedback and guidance.
- Public Information Sessions: Informing the wider community about project goals, benefits, and potential impacts.

6.7.4 Incorporating Stakeholder Feedback

Stakeholder feedback should be actively incorporated into project planning and decision-making. This involves:

- Regularly reviewing and adjusting project plans based on stakeholder inputs.
- Developing mechanisms for ongoing communication and feedback throughout the project lifecycle.
- Addressing conflicts and concerns through transparent and participatory processes.

Stakeholder engagement is not a one-time activity but a continuous process that requires dedication and commitment. By prioritizing meaningful engagement, LRO projects can achieve sustainable outcomes that are supported by the community and stakeholders, ensuring long-term success and resource sustainability.

7 Stage 3: Preliminary Screening

7.1 Overview

The screening process describes the evaluation of potential options, and deciding which ones move forward into the next stage, and which are discounted.

The criteria for screening and ranking are likely to be similar, and the processes are likely to be iterative, although the relative importance of some of the screening metrics may change at different stages of the process.

The spreadsheet tool developed for this project contains number of suggested metrics for screening, but these are not all applicable in all circumstances, and users may wish to remove some metrics, and/or add others more relevant to their circumstances.

It has been assumed that initially, individual options are assessed and screened, but in subsequent iterations, the most favourable sources and storage options may be grouped together, and another round of screening/ranking may be applied.

Screening will be carried out at a high level, using initial data collection and analyses, with greater data requirements and more data analyses required at each stage of the screening, ranking and evaluation process.

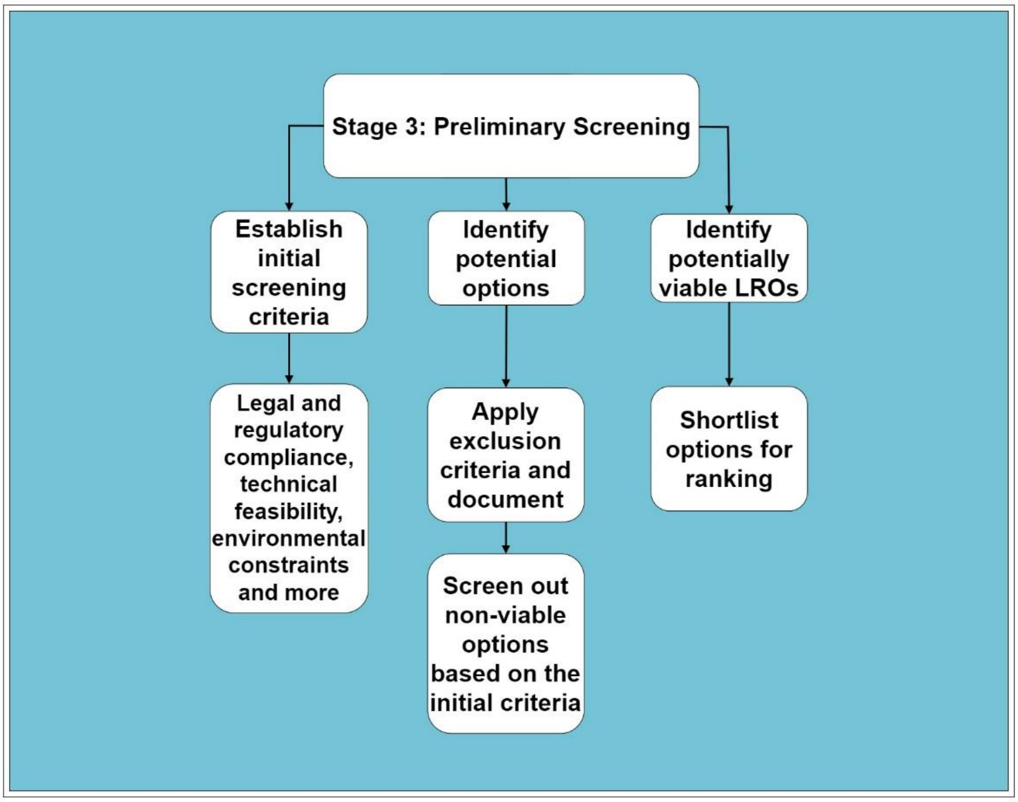


Figure 7-1: Flow chart of Screening Process

7.2 Establish initial screening criteria

Before embarking on the screening process, the criteria for screening potential options in or out should be agreed. Possible metrics are listed below, in no particular order;

- Infrastructure Requirements
- Water Source Reliability and yield
- Climatic Suitability
- Stakeholder preference/WAG group preference/User preference
- Environmental Impact
- Existing water rights
- Required Permits and Licences
- Water Resource Benefit
- Synergies with Other Initiatives
- Associated flood risk benefit
- Biodiversity Impacts
- Carbon Footprint
- Community Acceptance
- Operational Complexity
- Scalability
- Energy Requirements
- Innovation and Technology
- Capital Costs
- Operational Costs

7.3 Identify potential Options

7.3.1 Potential Options

In sections 3.2 and 3.33.3 options that could potentially meet the demands of farmers and WAGs were described. The type of supply option available may depend on the geology and soil type of a catchment. They will also be dependent on the water availability within the catchment; is it already considered over-licensed in some or all of the flow regime? Is it considered a priority catchment? Will the option be licensable and have a good probability of being granted? We have suggested some common water supply options, but the nature of the LRO process is that when stakeholders work together, innovative or unusual options may be found, and so the options discussed should not be considered an exhaustive list. A preliminary assessment of each option's feasibility should be made, including technical, economic, and environmental aspects. This stage filters out unviable options and identifies those worth further investigation. Technical analysis includes consideration of water yield, quality, and the infrastructure required for each option. Environmental impact assessments are conducted to evaluate the potential effects on local ecosystems and biodiversity and different permits and licences required. Legal and regulatory considerations are also examined in detail to ensure compliance and mitigate risks.

7.3.2 Initial assessment of water resource benefit

A high-level yield assessment involves evaluating the potential water yield from each option against the water demand of agricultural activities. This includes analysing historical data, precipitation patterns, and water table trends to estimate the availability and sustainability of water sources. At this stage, no detailed modelling is required, rather some comparative water resource benefit assessment between options, and simple water balance approaches can be employed. Specific tasks that could help with this stage are:

- Data Collection and Analysis: Gathering historical climatic data, water usage records, and soil moisture levels to understand the patterns and fluctuations in water availability.
- Water Balance analysis: Calculating the water balance by assessing the input (precipitation, surface water inflow, groundwater recharge) and output (evaporation, transpiration, water withdrawal for agriculture) to estimate the net water availability in the area. This helps in understanding the sustainability of water sources over time. This could be as simple as aggregating the potential yields from all identified sources and comparing the total with the estimated agricultural water demand in a spreadsheet-based analysis.
- Demand Forecasting: Estimating future agricultural water demand based on crop types, irrigation methods, projected climate changes, and agricultural expansion plans. This step is vital for assessing whether the potential water yield can meet the long-term water needs of agriculture. This is discussed more on section 6.3.
- Risk Analysis: Identifying potential risks associated with each water source, including water quality issues, overexploitation risks, and the impact of competing water uses. This is important to assist with identifying how resilient the source is.
- Include early discussion with Environment Agency.

It's important to acknowledge that this is an initial look into yield estimation, providing a framework for data gathering that will inform more granular analyses for options that come up high in the ranking exercise. This will involve more sophisticated modelling techniques.

7.3.3 Costing

At the screening stage, only a high- level scoring of relative costs for different types of option is required. More detailed cost calculations will be undertaken for options taken forward to the ranking stage. This is to understand relevant differences of costs between options.

7.3.4 Regulatory requirements

7.3.4.1 Planning process

Some water resource options, such as irrigation reservoirs or pipelines require planning permission, and this can take several years to obtain. For developments requiring planning permission, it may be useful to have a pre-planning application in the early stages, once the optimum resource option has been selected, so that any issues raised can be addressed prior to submission of the application. However, it is noted that there is no time limit for replying to pre-planning applications whereas government agencies have specified deadlines for replying to official applications.

7.3.4.2 Abstraction Licence

Options which require new abstraction licences, or changes to existing licences, will need to be supported by robust evidence of the need for the abstraction, and the environmental impacts. At this stage there is a need to include screening criteria related to abstraction licencing (and other licencing if needed) and possibly consider timing to obtain licences The licence application may require detailed and complex environmental assessments. Options which require planning permission and abstraction licences will not be ruled out during screening, but the score allocated will indicate the complexity and likely timescales of implementation.

7.3.5 Preliminary screening to identify potentially viable LROs

For the preliminary screening, metrics such as those listed in section 7.2, or other metrics agreed by the WAG and stakeholders should be used. For each potential resource option, a score is assigned for each chosen metric, and the scores are summed to see which options should go through to the next stage and which should be screened out.

In the example in Table 7-1, all options have a score between 1 (worst) and 5 (best) for selected metrics. The scores are colour coded with red, amber, yellow, light green, dark green, representing the range from worst to best, and the final column shows the total scores.

The Aquifer Storage Recovery scores lowest, with a total score of only 12, and this one will be screened out in this instance. The Flood water use option also scores fairly low, at 15, but this one may be left in for further evaluation, as there is little water available for abstraction in the catchment according to the CAMS Abstraction Licencing Strategy, so flood abstractions may present an opportunity to abstract water during flood events in a location where abstractions would otherwise not be allowed.

Options which score highly in most metrics, but which would not provide enough supplies to meet the required demand may be screened out, or allowed to stay if they may provide the required benefit when combined with others.

The screening criteria provided can be accessed in the LRO spreadsheet tool, but it should be remembered that this tool and the screening process are simply there to support decision making by the WAG and stakeholders, and to hopefully highlight any options that they had not initially considered.

Table 7-1: Example of Options Screening scoring heat map

LRO name	Infrastructure Requirements	Water Source Reliability	Environ-mental Impact	Cost	Permits and Licences	Water Resource Benefit	**Total score**
Aquifer Storage Recovery	1	1	2	2	2	4	**12**
Farm Storage Reservoir	5	4	3	3	3	5	**23**
Linking sources	4	3	3	2	4	4	**20**
Rainwater Harvesting	5	2	5	5	5	3	**25**
Drainage water use	3	5	5	3	5	4	**25**
Flood water use	2	2	5	2	2	2	**15**

8 Stage 4: Ranking

8.1 Overview

Options shortlisted from the screening stage are then further evaluated and ranked in order to select preferred options. At this stage, the individual options included at the screening stage may be grouped with, for example, drainage water reuse, linking sources and a farm storage reservoir combined into a single LRO. This grouping may also be carried out at a later iteration of the process, if there are several potential sources and storage options, and the WAG is not yet ready to determine the best combinations. The ranking process can be used to evaluate the relative benefits of different option combinations.

Similar to the screening stage, the metrics which will be used to evaluate the LROs must be selected, and these are used to score and select the most suitable option(s). More details about the costs, benefits and impacts of the options should be gathered, and more complex methods are used at this stage to more accurately differentiate between options. Multi-Criteria Analysis (MCA) decision making tools are used.

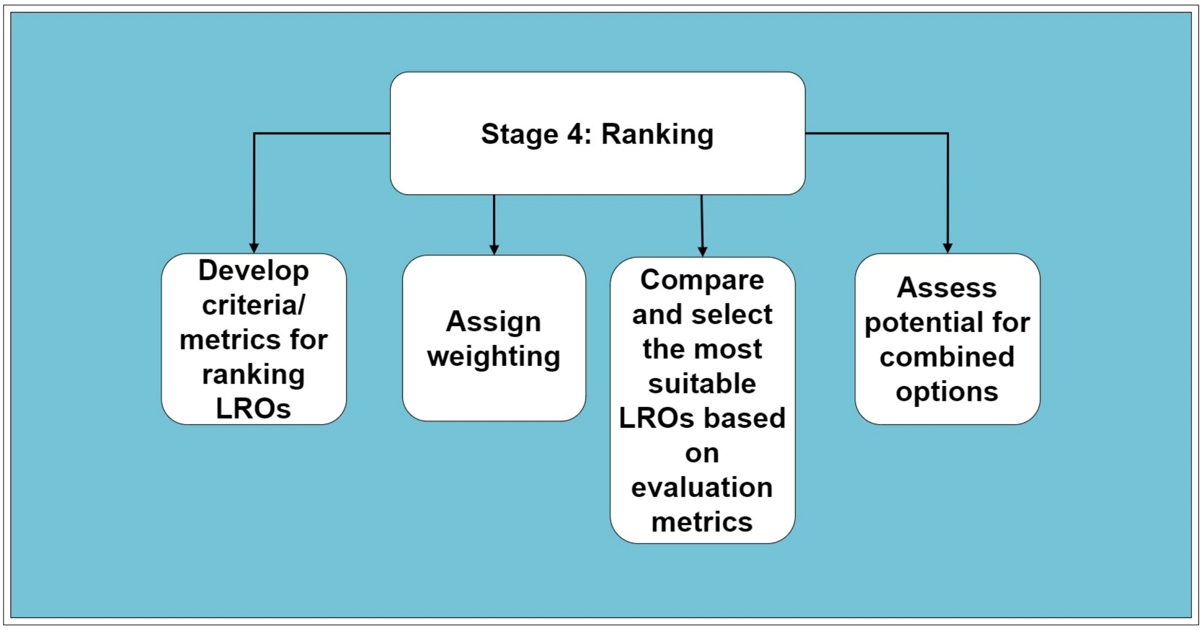


Figure 8-1:Flow chart of Ranking Process

For the ranking, additional analyses must be carried out for each option to gain a better understanding of its likely performance with respect to the ranking criteria. This will need further estimates of yield, costs, and environmental appraisals, but these are still at a relatively high level, with full yield assessment and costs only carried out at the detailed evaluation stage.

If the timing of implementation is a factor, the ranking criteria can contain an indication of this, with a metric for the lead time of options included. This will allow options that can be implemented early to be prioritised, and these can then be followed by those that require long term strategic alignment.

8.2 Application of Decision-Making Tools

There are many established decision-making tools that can be used to rank water resource options. Tools range in complexity, from simple ranking of options based on only a few criteria, to complex optimisation algorithms, such as those used by water companies producing statutory Water Resource Management Plans (WRMPs). The Catchment Management System (CMS) developed for the "*Water for Tomorrow*" is a GIS based tool to visualise and explore data for an option of portfolios under different environmental and climate change scenarios. This is fully described in *Guidance Note 11 in the Water for Tomorrow Guidance Resource Pack*. It is freely available online, and provides a useful visualisation, but is more complex than the scalable, useable solution required for this project. The University of Manchester, who worked on the project have also developed the "polyvis tool", which enables plotting of multi-criteria analyses, and filtering based on user preferences. This can be used when stakeholders are comparing the relative benefits of different options.

The goal of the decision-making tool developed for this project is to enable the users to evaluate and rank potential water resource options in order to select the most appropriate option, or suite of options, to fulfil the needs of the WAG. The spreadsheet tool developed allows users to compile the information required for decision making and rank the options. The spreadsheet and its use are fully described in section 10. The spreadsheet includes suggested ranking and weighting criteria, but the users are free to adjust these to better suit their situation.

8.3 D-Risk tool

Another simple tool that could be useful when assessing one option relative to another for relative water resource benefit and impacts of different options could be D-Risk , developed by Cranfield university. It is a web-based decision support tool to help agribusinesses and water and catchment managers evaluate the impacts of abstraction licence changes on their short-term irrigated cropping programmes, and functionality to inform longer-term strategic options for reconciling drought risk with water availability including collaborative water sharing or co-management of water allocations. D-Risk is a simple webtool specifically designed to help understand complex abstraction and drought-related risks.

8.4 Develop ranking criteria

This should be a collaborative process developed alongside the WAG group and, with important stakeholders involved. This will enable the identification of a comprehensive set of evaluation criteria that align with these objectives. For small WAGs with a relatively low water demand, and sources close to these demands, the criteria may simply be resource availability, cost, water resource benefit, environmental benefit/costs. WAGs with more complex options to evaluate may need to consider a wide range of options, and a wider range of screening criteria. Potential criteria are listed below.

- Technical Feasibility: Availability of technology, ease of implementation, maintenance requirements.
- Water resource benefit
- Financial Viability: Initial costs, operating and maintenance costs, cost-effectiveness.
- Environmental Impact: Effects on water quality and quantity, biodiversity, soil health.
- Social Acceptability: Community support impacts on livelihoods, equity considerations.
- Adaptability: Flexibility to adapt to changing conditions and water availability.
- Regulatory Compliance: Alignment with water use regulations and policies.
- Risk Mitigation: Ability to reduce risks from droughts, floods, or climate change.
- Efficiency: Water use efficiency, energy efficiency in water pumping and distribution.
- Long-term Sustainability: Prospects for long-term viability and resilience.

Like the screening process, a value must be assigned to each ranking metric for each option. This can either be the estimated construction, operating costs, or yield, or a score related to these metrics.

For the ranking process, each evaluation metric is also weighted, with more important metrics carrying greater weight than less important ones. The Rank Sum weighting method (Ezell, 2021) has been used in the spreadsheet tool, in which the weighting applied to the scores for each metric are proportional to the rank of that metric in relation to all the metrics, as assigned by the stakeholders.

In Table 8-1, values or scores have been attributed to ranking metrics combinations of the supply options carried forward from the example screening stage. Further analyses to establish water resource benefits and costs have provided information, which has been used in the scoring of the ranking criteria.

This information is plotted in a polyvis plot in Figure 8-2, with options coloured according to the water resource benefit provided (in m^3/day). The trade-offs between different desirable metrics can be clearly seen using this plot. In this example, the LROs evaluated show that rainwater harvesting (option 5, red) is best for all metrics apart from water resource benefit, which is small, so this option is red. The option with the largest water resource benefit (option 4, green), is also the most expensive, due to the additional costs of the larger storage reservoir that provides the extra resource benefit.

Table 8-2 shows the Grouped LRO options shown in Table 8-1, with the costs and water resource benefit normalised according to the same 1-5 scale as the other metrics, and showing the ranking of the importance of the metrics, associated weights, and the final ranked scores for the five options. The top scoring option is option 5, rainwater harvesting. This scores most highly even though it has the lowest yield benefit, as it scores so highly for the other metrics. The next ranked option is option 4, which is the same as option 3, but has a far larger reservoir. This may prompt the WAG to further investigate other combinations including larger reservoirs. In this example, implementing option 5 in the short term could provide a small benefit, and this could be added to by implementing one of the more complex options in the coming years.

8.5 Select most suitable LROs

Table 8-1: Example ranking criteria and scores for combination LROs

LRO	Option ID (PVID)	Infrastructure Requirements (score)	Water Source Reliability (score)	Environ-mental Impact (score)	Construction cost (£)	Permits and Licences (score)	Water Resource Benefit/ m^3/d
25,000m^3 farm Storage Reservoir, drainage water reuse, 15km pipe	1	3	4	3	150,000	4	400
25,000m^3 farm Storage Reservoir, drainage water reuse, 15km pipe + rainwater harvesting	2	3	3	3	153,000	4	420
25,000m^3 farm Storage Reservoir, drainage water reuse, 15km pipe + rainwater harvesting + flood water use	2	3	4	3	160,000	3	420
45,000m^3 farm Storage Reservoir, drainage water reuse, 15km pipe + rainwater harvesting + flood water use	4	3	4	2	220,000	3	650
Rainwater harvesting and tank 500m^3 tanks	**5**	5	**5**	5	2,000	5	3

Table 8-2: Example ranking criteria and scores for combination LROs

LRO		Option ID (PVID)	Infrastructure Requirements (score)	Water Source Reliability (score)	Environ-mental Impact (score)	Cost (£) - normalised	Permits and Licences (score)	Water Resource Benefit (m^3/d)-normalised	total	rank
	ranking of metrics		5	2	4	3	6	1		
	weighting of metrics		0.10	0.24	0.14	0.19	0.05	0.29		
25,000m^3 farm Storage Reservoir, drainage water reuse, 15km pipe	option 1	**1**	3	4	3	2.273	4	3.077	3.17	3
25,000m^3 farm Storage Reservoir, drainage water reuse, 15km pipe + rainwater harvesting	option 2	**2**	3	3	3	2.218	4	3.231	2.96	5
25,000m^3 farm Storage Reservoir, drainage water reuse, 15km pipe + rainwater harvesting + flood water use	option 3	**2**	3	4	3	2.091	3	3.231	3.13	4
45,000m^3 farm Storage Reservoir, drainage water reuse, 15km pipe + rainwater harvesting + flood water use	option 4	**4**	3	4	2	1.000	3	5.000	3.29	2
Rainwater harvesting and tank 500m^3 tanks	option 5	5	5	5	5	4.964	5	0.023	3.57	1

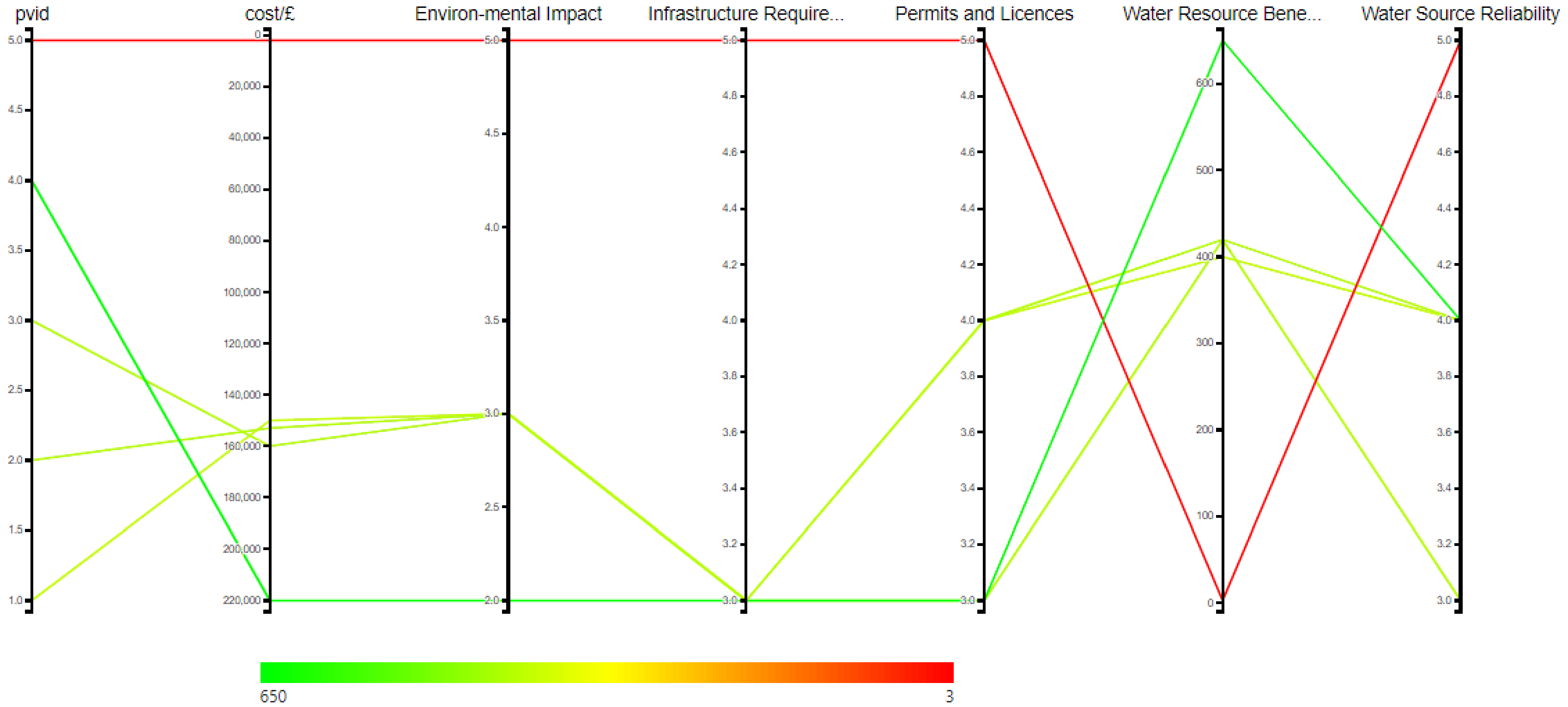


Figure 8-2:Polyvis plot of ranking criteria

9 Stage 5: Detailed Evaluation of LROs

9.1 Overview

At this stage, further evaluation is carried out for each LRO being considered. Potential individual water resource options should be grouped into LROs, and their combined costs, benefits and environmental impacts evaluated in greater depth. Analyses such as modelling the water resources benefit using gauged or modelled flow data, and more thorough costings of the combined options would be needed. Some of the individual options may appear in more than one LRO, and some variations of individual options may be tested, for example reservoirs of different sizes, or a reservoir and a MAR scheme could be included indifferent LROs to store drainage water from the same source.

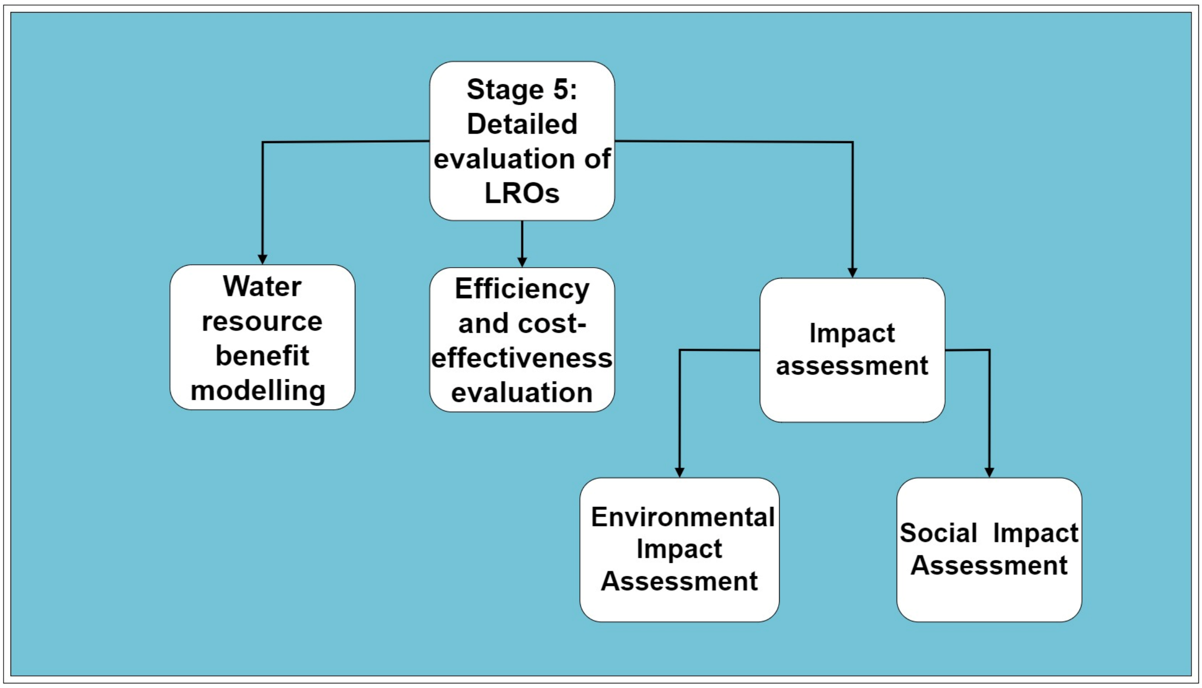


Figure 9-1: Flow chart of the evaluation process of LROs

9.2 Model Water Resources Benefit

Initial estimates of the water resources benefit of individual options will be estimated for the screening stage. To calculate the water resource benefit of Combined LROs, some modelling may be necessary. This will vary in complexity depending on the nature of the options included. Methods from the UKWIR (Aldrick et al. 2014) handbook should be used. Conjunctive use LROs should be modelled using water resources simulation software, or simpler spreadsheet models, depending on the degree of complexity of the system. The yield estimation should consider the seasonality of both flows and demand, and the impact of future climate change.

Example of suitable modelling for an LRO river abstraction and storage reservoir of different sizes.

- Hydrological modelling: Use catchment models to simulate the movement of water through the landscape and understand how the LRO will interact with the catchment area. There are often models available by the EA and/or other organisations that could be used as a starting point.
- Groundwater Models: If groundwater is a significant factor, create models to predict how the LRO will affect aquifer recharge and sustainability. There are often models available by the EA and/or other organisations that could be used as a starting point.
- Hydrological data analysis and spreadsheet -based analysis: Where relevant hydrological data (flows, volumes, and groundwater levels) are available, a detailed analysis can offer insights into the potential yield of the LRO. Spreadsheet-based water balance analysis can also be a useful tool for understanding the inputs and outputs of the system, helping to estimate the water resource benefits accurately.
- Water resource modelling of conjunctive users: Modelling the water resources for conjunctive use scenarios requires an integrated approach that considers both surface and groundwater resources. This involves detailed modelling to understand the interactions between different water sources and their collective impact on the water resource benefit of the LRO.

9.2.1 Links with regional modelling

9.3 Evaluate costs

Evaluating the cost of different LROs involves a comprehensive analysis that encompasses initial capital expenditure, operational and maintenance costs, and potential long-term benefits or savings. The objective is to provide a detailed and comparative assessment of the economic feasibility of each option. This process will aid in identifying the most cost-effective solutions that meet the water resource management goals. Below is a structured approach to evaluating the costs associated with different LROs:

- Capital Expenditure (CAPEX): The initial investment required for infrastructure development, such as wells for groundwater extraction, dams and reservoirs for surface water storage, systems for rainwater harvesting, and facilities for wastewater treatment and recycling. This includes the costs of land acquisition, construction, and equipment installation.
- Operational Expenditure (OPEX): The ongoing costs associated with operating and maintaining the water management systems. This covers energy costs for pumping water, maintenance of infrastructure, water treatment costs, and manpower.
- Environmental and Social Costs: Assessing the indirect costs related to environmental degradation, such as loss of biodiversity, soil salinization from

improper irrigation practices, and potential displacement of communities. These costs also consider the investment needed for environmental restoration and social compensation programs.

- Economic Analysis: Conducting cost-benefit analyses to compare the financial feasibility of different options, considering the life cycle costs, the economic value of water saved or generated, and the return on investment. This analysis helps in prioritizing options that offer the best value for money while achieving sustainability goals.
- Financing and Incentives: Exploring funding mechanisms, including government subsidies, grants, and loans, as well as incentives for adopting sustainable water management practices. Understanding the financial support available can significantly influence the selection of water resource management options by reducing the financial burden on agricultural stakeholders.
- Additional items potentially beneficial for the study would be looking at:
- Opportunity costs: Consider the opportunity costs, which represent the benefits forgone by choosing one option over another. This includes the potential income from alternative uses of the resources (e.g., land or capital) invested in the LRO.
- Sensitivity analysis: Perform sensitivity analysis to understand how changes in key assumptions (e.g., discount rate, operational costs, water savings) affect the cost-effectiveness of each LRO. This analysis is crucial for assessing the robustness of the cost estimates and identifying which variables have the most significant impact on the outcome.

Evaluating the cost of different LROs requires a detailed and methodical approach that considers all relevant financial aspects, from initial investment to long-term operational expenses. By combining these analyses with a thorough understanding of the benefits and potential savings associated with each option, decision-makers can identify the most cost-effective solutions for sustainable agricultural water resource management.

9.4 Environmental impact assessment

This assessment aims to ensure sustainable water management practices that balance agricultural needs with ecological preservation. The following steps outline a systematic approach to evaluating the environmental impacts of LROs:

- Gather data on the current state of the environment in the area where the LRO will be implemented. This includes understanding the existing water resources, biodiversity, soil conditions, and any other ecological attributes.
- Highlight areas of ecological importance, such as wetlands, protected habitats and species, or areas of high biodiversity, which might be affected by the LRO.
- Direct and Indirect Impacts: Identify both the direct and indirect environmental impacts of each LRO. Direct impacts might include changes to water quality or habitat destruction, while indirect impacts could encompass downstream effects on ecosystems or altered water flow regimes.

- Positive and Negative Impacts: Assess both the beneficial and adverse environmental effects. Positive impacts might include improved water quality or enhanced habitat connectivity, while negative impacts could involve habitat fragmentation or increased pollution. Where possible, quantify the impacts using indicators such as water quality parameters, species population changes, or carbon footprint. Qualitative analysis might be necessary for impacts that are difficult to quantify, like landscape aesthetic changes or cultural heritage impacts.
- Cumulative Impact Assessment: Evaluate the cumulative environmental impact when multiple LROs are considered together, understanding how individual effects might compound or interact.
- Mitigation Measures: Propose strategies to avoid, minimize, or mitigate negative environmental impacts. This might include modifications to the LRO design, implementing buffer zones, or adopting management practices that protect sensitive species.
- Enhancement Measures: Identify opportunities to enhance positive environmental outcomes, such as restoring degraded habitats or improving water use efficiency to benefit downstream ecosystems.

9.5 Social impact assessment

It is likely that for some of the higher ranked options that have gone through to the detailed assessment phase, some social impact assessment input may be required. The Social Impact Assessment could be a vital component of evaluating an LRO, aimed at understanding the LROs' wider societal implications. Building on insights gathered from prior stakeholder engagement, this task will delve into the social repercussions of the LROs implementation. It will identify potential benefits, such as job creation, which can bolster local economies and fortify community resilience against water-related challenges. Moreover, this assessment will look at the equity of benefit distribution, such as social inclusiveness and equitable advantages to all community sectors.

The social impact assessment of an LRO will typically employ a mixed-methods approach that combines both qualitative and quantitative research techniques to capture a comprehensive picture of the LRO's social dimensions. Here is an outline of the methodological approaches that may be used:

- Stakeholder Interviews: Conducting in-depth interviews with a diverse range of stakeholders, including residents, farmers, business owners, and public officials, to gather detailed insights into their perspectives and concerns regarding the LRO.
- Focus Groups: Organizing focus group discussions to explore the community's views on the LRO and its potential social impacts, facilitating an exchange of ideas among different community members.
- Case Studies: Developing case studies of similar LROs implemented elsewhere to understand potential social impacts and glean lessons learned.

- Surveys and Questionnaires: Distributing structured surveys to collect data on community attitudes, perceptions, and expectations related to the LRO.
- Social Network Analysis: Mapping community networks to understand the social structures that may be affected by the LRO and identify key influencers.
- Demographic Analysis: Reviewing demographic data to identify which community groups might be impacted and whether some groups may benefit more than others.
- Social Impact Matrices: Creating matrices to systematically compare and visualize the social impacts across different demographic and socio-economic groups.

10 LRO spreadsheet - identification, screening and ranking tool

10.1 Overview

The tool's design facilitates a data-driven approach to LRO selection, from initial site-specific information gathering and LRO identification through to detailed assessment and prioritization based on a range of criteria including economic, environmental, and social factors. The detailed assessment charts and prioritized options provide a clear, visual summary of the findings, aiding decision-makers in navigating the complex trade-offs involved in selecting the most appropriate LROs for their specific contexts.

10.1.1 Introduction

Provides users with an overview of the tool, including its purpose, how to use it, and the methodology behind the assessment and selection of LROs. Includes key describing which cells should be filled in by the user and which are automatically completed or are to be left alone.

Environment Agency

JBA consulting

- **This tool has been developed to help indentify and screen appropriate Local Resource Options (LROs)**
- **This spreadsheet should be used in conjunction with the available documentation and reports**

	Cells that need to be completed
Example	User entered cells (text colour changes to blue)
	Cells that will be automatically completed, linked to another cell
	Background and information (for example, headings)
	Cells relating to options chosen by user (conditional formatting)
	Guidance and information
	Lookup data

- A blank copy of the tool should always be used and saved accordingly.
- A number of different LROs and criteria have been included, however this does not form an exhaustive list of all possible LROs and considerations. These can be changed and additional ones added depending on the specific area
- Criteria Selection: Define a set of evaluation criteria based on your methodology document, such as cost, effectiveness, ease of implementation, sustainability, and stakeholder acceptance. Each criterion should align with your own and wider objectives for water resource management.

Version control

This spreadsheet was developed as part of the Agricultural LROs project (2023s1608 - EA SE)

Version	Changes	Developed By	Date	Checked	Date	Approved	Date
1	Initial development and set-up	EK, MF, RB	Mar-24	EK	Mar-24	EK	Mar-24
2	Following EA comments						
3							
4							
5							
6							
7							
8							
9							
10							

Figure 10-1: Spreadsheet tool – Introduction.

10.1.2 Flow Chart & Instructions

Visual representation of the process flow, guiding users through the steps involved in evaluating and selecting LROs using the tool. Explains the generic process for the LRO assessment through a flow chart and includes summarised instructions of what to expect in each tab within the spreadsheet along with links leading to them.

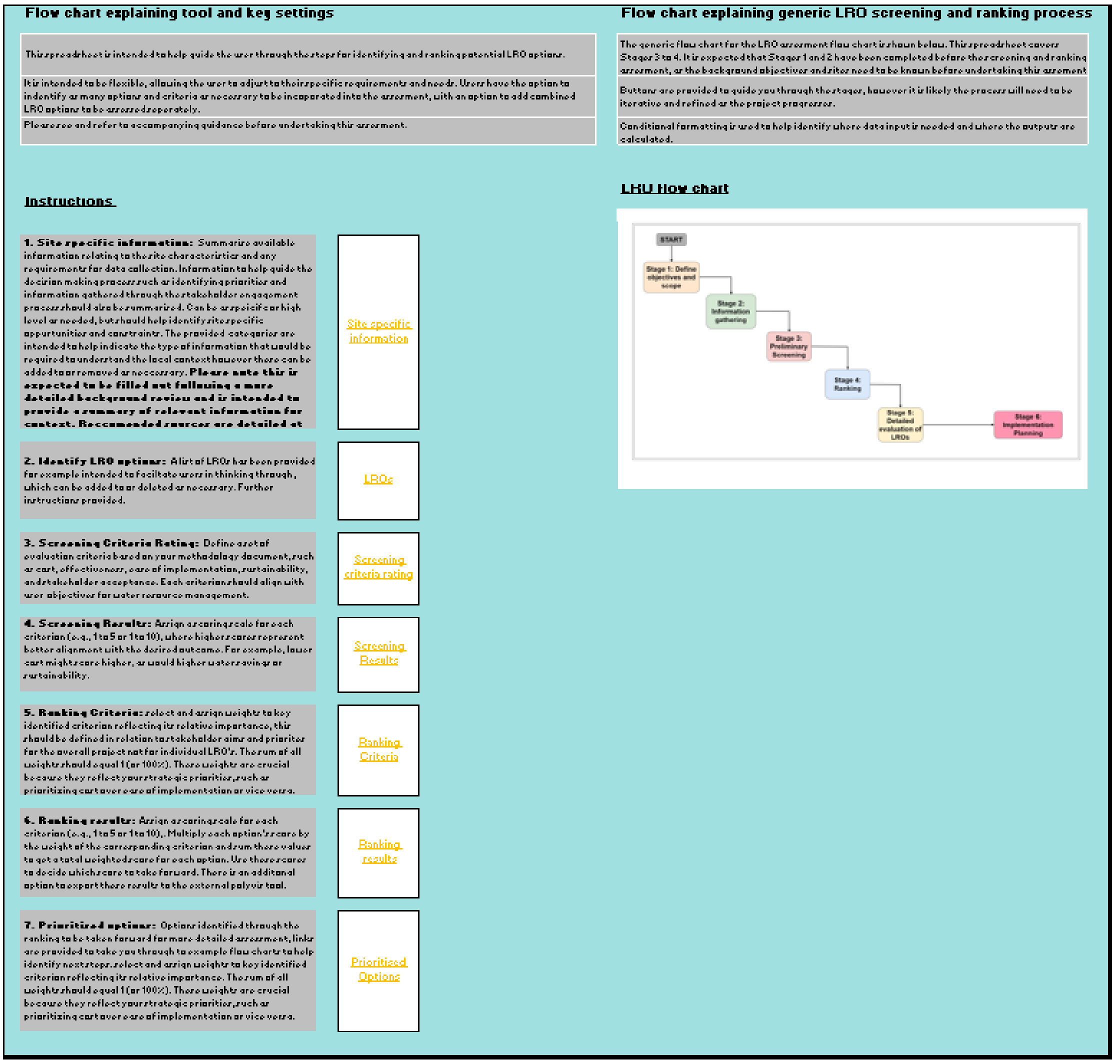


Figure 10-2: Spreadsheet tool – Flow Chart & Instructions

10.1.3 Site specific information

A template for inputting key information about the site(s) under consideration for LRO implementation, including geographical, hydrological, and agricultural details. This sheet aims to capture detailed, site-specific data that might affect LRO decisions. It also includes a list of recommended data sources to guide the user.

This sheet is intended to provide a summary of relevant information to help understand the local context in which the LRO is being examined. For a a more comprehensive and detailed assessment please see the accompanying report: LYI-JBA-00-00-RP-Z-0001-S0-P01.01-E0900-XXX-XXX-Pilot-Study-report.docx

Topic	Details	References
Site specific information		
Area		Environment Agency Catchment Data Explorer https://environment.data.gov.uk/catchment-planning/OperationalCatchment/3256
Climate		Met Office Climate PDF's https://www.metoffice.gov.uk/binaries/content/assets/metofficegovuk/pdf/weather/learn-about/weather/regional-climates/eastern-england_-climate-met-office.pdf
Topography		Environment Agency LiDAR (2022)
Soils		Soilscapes Cranfield https://www.landis.org.uk/soilscapes/
Geology		BGS GeoIndex https://mapapps2.bgs.ac.uk/geoindex/home.html?_ga=2.1529142.645660594.1711556242-1353944972.1711556242
Hydrogeology		Hydrogeological Maps - Southern East Anglia, 1:125,000 https://largeimages.bgs.ac.uk/iip/hydromaps.html?id=southern-east-anglia.jp2
Hydrology		NFRA Gauge Map https://nrfa.ceh.ac.uk/data/search
Environmental designations revelant to the site		http://designatedsites.naturalengland.org.uk/UnitDetail.aspx?UnitId=1026676 https://designatedsites.naturalengland.org.uk/UnitDetail.aspx?UnitId=1030413
Water resource availability		
Land-use		Land Cover Map 2021 https://catalogue.ceh.ac.uk/documents/017313c6-954b-4343-8784-3d61aa6e44da
Flood risk		https://flood-map-for-planning.service.gov.uk/location
Main water users		
Public water supply information		
IDBs in the area?		https://www.ada.org.uk/idb-map/
Canal network nearby?		

Reccomended data sources

Data Category	Purpose	Data Limitations	Use in Analysis	Data Source
Hydrological and Climatological Data	To assess weather patterns, precipitation, evaporation, and hydrological cycles.	Seasonal variations may not be captured in available models.	Water balance studies, hydrological analysis, climatic variability on water availability.	DEFRA Hydrology Explorer (2021) - Rainfall, River Flow, River Level, NRFA, Groundwater Level, Water Quality
Soil and Geological Information	To determine the water retention and filtration properties, and aquifer characteristics.	Inadequate resolution for localized geological variations.	Critical for site selection for LROs and understanding groundwater recharge and storage potentials.	BGS 1:625000 scale Bedrock Geology UK; BGS 1:625000 scale Superficial Geology UK; Details lockal geological and hydrogeological mapping; UK Soils Observatory Soliscapes Cranfield
Current Water Use and Demand	To quantify existing water usage and forecast future demands based on agricultural practices.	Projections may not fully account for technological changes.	Fundamental for identifying discrepancies between supply and demand and planning for future LROs.	Environment Agency; Local data from farmers or WAGs; Source protection Zones
Water Resource Availability	To identify existing water sources and their seasonal variability.	Potential oversight of lesser-known or emerging water sources.	Used to identify viable LRO options and to assess the sustainability of water sources.	Environment Agency (2021) Groundwater Management Units coloured according to water resource availability colours (shapefile); Environment Agency (2022) Water Resource Availability and Abstraction Reliability Cycle 2 (shapefile)
Abstraction licencing data /environmental flow designations	To ensure LROs comply with current water abstraction, environmental protection, and land use laws.	Emerging regulations or policy reforms may introduce new constraints.	Necessary for the legal feasibility of LROs and navigating the permitting process.	Environment Agency; Local data from farmers or WAGs
Land-use	To evaluate how current and projected land uses impact water resources and LRO opportunities.	Changes in land-use patterns may not be promptly reflected in data sets.	Impact of agricultural and development activities on water demand and availability, and for informed LRO site selection.	The UKCEH Land Cover Maps (LCMs) map UK Land Cover
Stakeholder Inputs	To integrate local knowledge and stakeholder priorities into the LRO planning process.	May not capture the full spectrum of community perspectives.	Integral for ensuring LROs meet the needs and gain support from local communities and water users.	Data obtained through workshops and interviews
Environmental Designations	To understand protected areas and their requirements for conservation. Includes SSSI's, RAMSAR, priority species and habitats, SAC's, SPA's etc.,	Changes in designation status or conservation priorities may not be up to date.	Important for planning LROs in a way that minimizes environmental impacts and complies with protections.	Natural England (2024) Sites of Special Scientific Interest (England) (shapefile); Natural England (2024) Special Areas of Conservation (England) (shapefile); Water Resource Regional Groups
Internal Drainage Boards	To ensure any LROs are in line with water level management practices & to review potential for using drainage water as part of LROs	Variability in data reporting standards across different IDBs.	For alignment of LROs with existing drainage practices and for opportunities in water reuse.	Environment Agency (2024) Association of Drainage Authorities: Administrative Boundaries – Internal Drainage Districts in England (shapefile)
Canal Network	To evaluate existing water conveyance infrastructure and potential for integration.	Limited information on the operational status and maintenance of canal networks.	To assess the feasibility of using canals for water distribution as part of LROs.	Environment Agency (2020) WFD River, Canal and Surface Water Transfer Bodies Cycle 2 Classification 2019 (shapefile)

Figure 10-3: Spreadsheet tool – Site specific information.

10.1.4 LROs

Contains a database or list of potential LROs with descriptions, potential benefits, and initial feasibility assessments. This sheet may allow for the addition of new LROs or the modification of existing entries.

Instructions: Additonal rows can be added to these tables through the normal means through selecting and pulling down the row above, the tables on the screening and ranking results tabs will update automatically. LRO's can also be deleted in the same way and the tables on the screening and ranking results tabs will be updated, however, the other columns within the screening and ranking are not dynamic, so if additional options are added in after these have been filled they will not update automatically, it is reccomended therefore that if options need to be removed at this stage that the revelant rows are hidden. *This column can be hidden once finished.*

Single Options

LRO ID	LRO Title	LRO Description
LRO1	Aquifer Storage and Recovery	Storing excess water in aquifers during times of surplus for use during periods of scarcity. E.g., through Managed Aquifer Recharge
LRO2	Farm Storage Reservoirs	Creating reservoirs on farms to collect and store rainwater or surface water.
LRO3	Linking sources / aggregating licences	Linking existing/ new solutions
LRO4	Rainwater Harvesting	Collecting and storing rainwater from roofs or other surfaces for agricultural use.
LRO5	Conjunctive Use Schemes	Managing a combination of surface water and groundwater to optimize availability and reliability.
LRO6	Micro-Irrigation Systems	Drip or trickle irrigation systems that deliver water directly to the plant roots, minimizing waste.
LRO7	Soil Moisture Monitoring	Using sensors to determine the precise water needs of crops, optimizing irrigation schedules.
LRO8	Water-Efficient Technologies	Adopting technologies and practices that reduce water use, such as smart irrigation systems.
LRO9	Water Rights Trading	Rights to water resources can be bought and sold, providing flexibility and potentially more efficient use.
LRO10	Water Sharing Agreements	Collaborative approaches among users to share water resources sustainably.
LRO11	Leakage Control	Implementing measures to reduce water loss in irrigation systems.
LRO12	Improving Irrigation Techniques	Adopting precision irrigation technology like drip systems and soil moisture sensors. Implementing water-saving practices such as mulching and using cover crops to reduce evaporation. Scheduling irrigation based on actual crop needs and weather forecasts to avoid overwatering. Upgrading irrigation equipment to more efficient models and regularly maintaining existing systems to ensure optimal performance.
LRO13	Agroecological Farming Practices	Practices that sustainably manage land and water resources, such as crop rotation and maintaining soil health.
LRO14	Water recycling	Implementing systems for treating and reusing wastewater
LRO15	Flood water use	Combining flood risk management with water storage and conservation efforts to mitigate impacts while enhancing water availability.
LRO16	Use of drainage water	Use of water from IDBs or other drainage water that would be moving to sea
LRO17	*Example Additional*	...

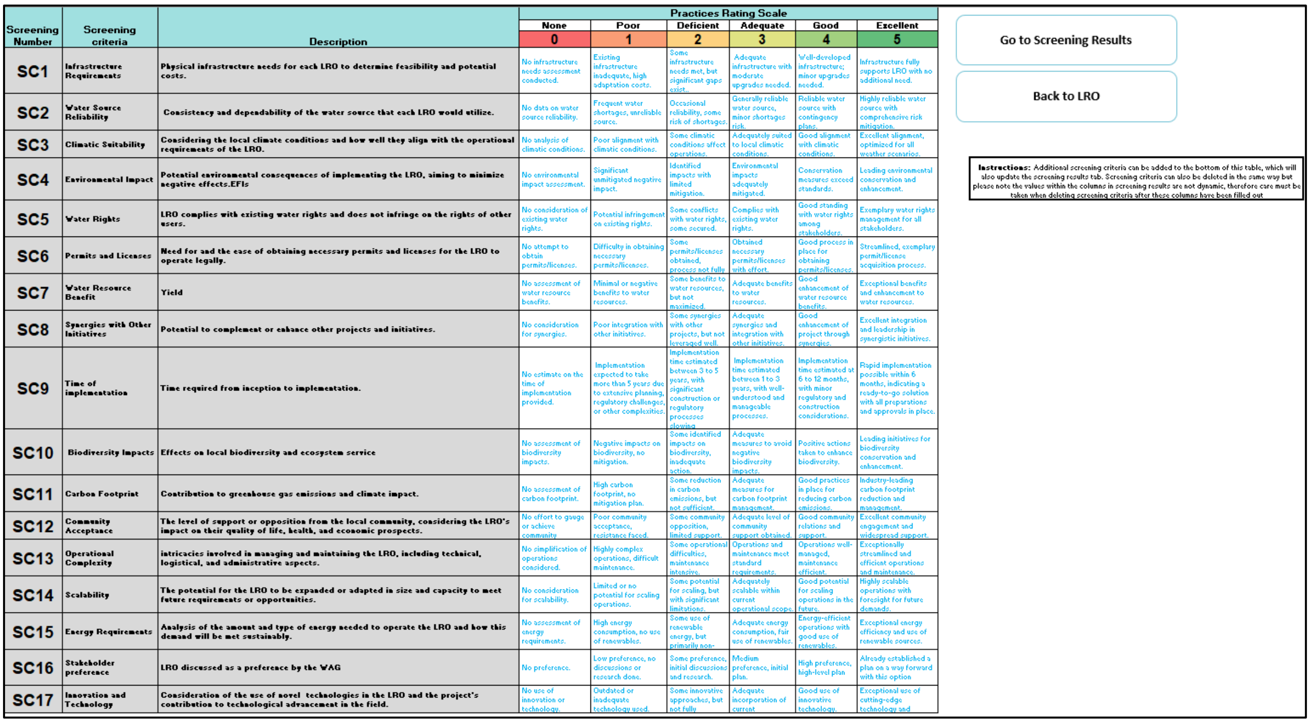
Com

LRO ID	LRO Title
LRO2 + LRO15	Farm Storage Reservoirs + Flood water use

Figure 10-4: Spreadsheet tool – LROs.

10.1.5 Screening criteria rating

Enables users to define and rate the criteria used to screen LROs for suitability in a specific context, potentially based on factors such as cost, efficiency, sustainability, and impact on water availability.

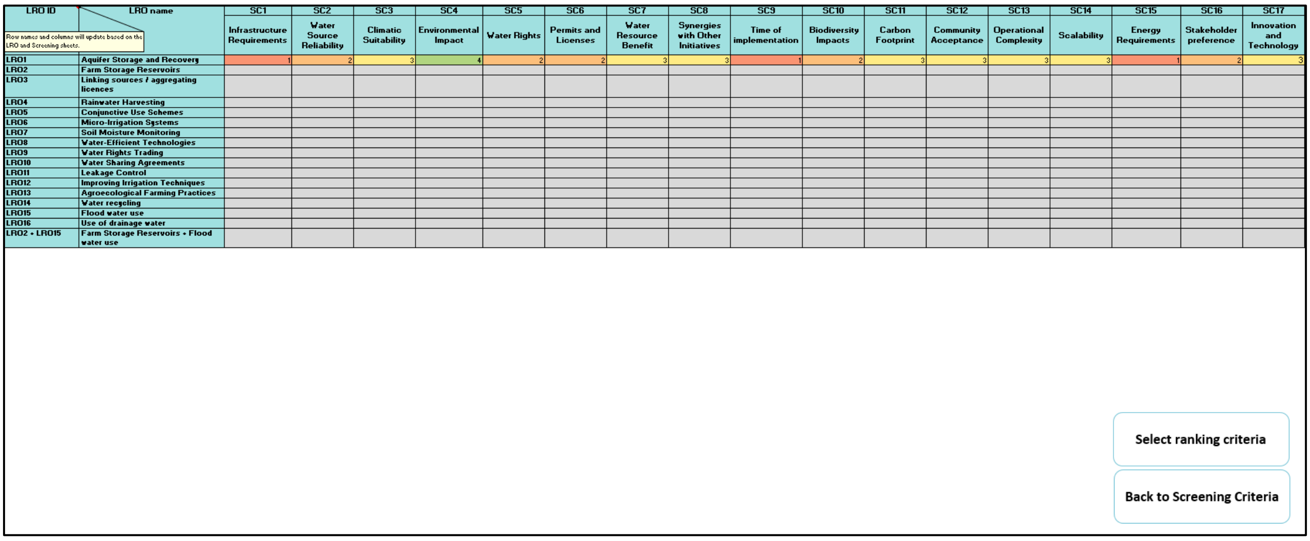


Screening Number	Screening criteria	Description	None 0	Poor 1	Deficient 2	Adequate 3	Good 4	Excellent 5
SC1	Infrastructure Requirements	Physical infrastructure needs for each LRO to determine feasibility and potential costs.	No infrastructure needs assessment conducted.	Existing infrastructure inadequate, high adaptation costs.	Some infrastructure needs met, but significant gaps exist..	Adequate infrastructure with moderate upgrades needed.	Well-developed infrastructure; minor upgrades needed.	Infrastructure fully supports LRO with no additional need.
SC2	Water Source Reliability	Consistency and dependability of the water source that each LRO would utilize.	No data on water source reliability.	Frequent water shortages, unreliable source.	Occasional reliability, some risk of shortages.	Generally reliable water source, minor shortages risk.	Reliable water source with contingency plans.	Highly reliable water source with comprehensive risk mitigation.
SC3	Climatic Suitability	Considering the local climate conditions and how well they align with the operational requirements of the LRO.	No analysis of climatic conditions.	Poor alignment with climatic conditions.	Some climatic conditions affect operations.	Adequately suited to local climatic conditions.	Good alignment with climatic conditions.	Excellent alignment, optimized for all weather scenarios.
SC4	Environmental Impact	Potential environmental consequences of implementing the LRO, aiming to minimize negative effects.EFIs	No environmental impact assessment.	Significant unmitigated negative impact.	Identified impacts with limited mitigation.	Environmental impacts adequately mitigated.	Conservation measures exceed standards.	Leading environmental conservation and enhancement.
SC5	Water Rights	LRO complies with existing water rights and does not infringe on the rights of other users.	No consideration of existing water rights.	Potential infringement on existing rights.	Some conflicts with water rights, some secured.	Complies with existing water rights.	Good standing with water rights among stakeholders.	Exemplary water rights management for all stakeholders.
SC6	Permits and Licenses	Need for and the ease of obtaining necessary permits and licenses for the LRO to operate legally.	No attempt to obtain permits/licenses.	Difficulty in obtaining necessary permits/licenses.	Some permits/licenses obtained, process not fully	Obtained necessary permits/licenses with effort.	Good process in place for obtaining permits/licenses.	Streamlined, exemplary permit/license acquisition process.
SC7	Water Resource Benefit	Yield	No assessment of water resource benefits.	Minimal or negative benefits to water resources.	Some benefits to water resources, but not maximized.	Adequate benefits to water resources.	Good enhancement of water resource benefits.	Exceptional benefits and enhancement to water resources.
SC8	Synergies with Other Initiatives	Potential to complement or enhance other projects and initiatives.	No consideration for synergies.	Poor integration with other initiatives.	Some synergies with other projects, but not leveraged well.	Adequate synergies and integration with other initiatives.	Good enhancement of project through synergies.	Excellent integration and leadership in synergistic initiatives.
SC9	Time of implementation	Time required from inception to implementation.	No estimate on the time of implementation provided.	Implementation expected to take more than 5 years due to extensive planning, regulatory challenges, or other complexities.	Implementation time estimated between 3 to 5 years, with significant construction or regulatory processes slowing	Implementation time estimated between 1 to 3 years, with well-understood and manageable processes.	Implementation time estimated at 6 to 12 months, with minor regulatory and construction considerations.	Rapid implementation possible within 6 months, indicating a ready-to-go solution with all preparations and approvals in place.
SC10	Biodiversity Impacts	Effects on local biodiversity and ecosystem service	No assessment of biodiversity impacts.	Negative impacts on biodiversity, no mitigation.	Some identified impacts on biodiversity, inadequate action.	Adequate measures to avoid negative biodiversity impacts.	Positive actions taken to enhance biodiversity.	Leading initiatives for biodiversity conservation and enhancement.
SC11	Carbon Footprint	Contribution to greenhouse gas emissions and climate impact.	No assessment of carbon footprint.	High carbon footprint, no mitigation plan.	Some reduction in carbon emissions, but not sufficient.	Adequate measures for carbon footprint management.	Good practices in place for reducing carbon emissions.	Industry-leading carbon footprint reduction and management.
SC12	Community Acceptance	The level of support or opposition from the local community, considering the LRO's impact on their quality of life, health, and economic prospects.	No effort to gauge or achieve community	Poor community acceptance, resistance faced.	Some community opposition, limited support.	Adequate level of community support obtained.	Good community relations and support.	Excellent community engagement and widespread support.
SC13	Operational Complexity	intricacies involved in managing and maintaining the LRO, including technical, logistical, and administrative aspects.	No simplification of operations considered.	Highly complex operations, difficult maintenance.	Some operational difficulties, maintenance intensive.	Operations and maintenance meet standard requirements.	Operations well-managed, maintenance efficient.	Exceptionally streamlined and efficient operations and maintenance.
SC14	Scalability	The potential for the LRO to be expanded or adapted in size and capacity to meet future requirements or opportunities.	No consideration for scalability.	Limited or no potential for scaling operations.	Some potential for scaling, but with significant limitations.	Adequately scalable within current operational scope.	Good potential for scaling operations in the future.	Highly scalable operations with foresight for future demands.
SC15	Energy Requirements	Analysis of the amount and type of energy needed to operate the LRO and how this demand will be met sustainably.	No assessment of energy requirements.	High energy consumption, no use of renewables.	Some use of renewable energy, but primarily non-	Adequate energy consumption, fair use of renewables.	Energy-efficient operations with good use of renewables.	Exceptional energy efficiency and use of renewable sources.
SC16	Stakeholder preference	LRO discussed as a preference by the WAG	No preference.	Low preference, no discussions or research done.	Some preference, initial discussions and research.	Medium preference, initial plan.	High preference, high-level plan	Already established a plan on a way forward with this option
SC17	Innovation and Technology	Consideration of the use of novel technologies in the LRO and the project's contribution to technological advancement in the field.	No use of innovation or technology.	Outdated or inadequate technology used.	Some innovative approaches, but not fully	Adequate incorporation of current	Good use of innovative technology.	Exceptional use of cutting-edge technology and

Figure 10-5: Spreadsheet tool – Screening criteria rating.

10.1.6 Screening results

Automatically calculates and displays the results of the initial screening process, identifying which LROs meet the predefined criteria and warrant further consideration.



LRO ID	LRO name	SC1 Infrastructure Requirements	SC2 Water Source Reliability	SC3 Climatic Suitability	SC4 Environmental Impact	SC5 Water Rights	SC6 Permits and Licenses	SC7 Water Resource Benefit	SC8 Synergies with Other Initiatives	SC9 Time of implementation	SC10 Biodiversity Impacts	SC11 Carbon Footprint	SC12 Community Acceptance	SC13 Operational Complexity	SC14 Scalability	SC15 Energy Requirements	SC16 Stakeholder preference	SC17 Innovation and Technology
LRO1	Aquifer Storage and Recovery	1	2	3	4	2	2	3	3	1	2	3	3	3	3	1	2	3
LRO2	Farm Storage Reservoirs																	
LRO3	Linking sources / aggregating licences																	
LRO4	Rainwater Harvesting																	
LRO5	Conjunctive Use Schemes																	
LRO6	Micro-Irrigation Systems																	
LRO7	Soil Moisture Monitoring																	
LRO8	Water-Efficient Technologies																	
LRO9	Water Rights Trading																	
LRO10	Water Sharing Agreements																	
LRO11	Leakage Control																	
LRO12	Improving Irrigation Techniques																	
LRO13	Agroecological Farming Practices																	
LRO14	Water recycling																	
LRO15	Flood water use																	
LRO16	Use of drainage water																	
LRO2 + LRO15	Farm Storage Reservoirs + Flood water use																	

Figure 10-6: Spreadsheet tool – Screening results.

10.1.7 Ranking criteria

Users can specify and weigh various criteria for ranking the screened LROs, facilitating a comparative analysis based on multiple dimensions of performance. The Rank Sum weighting method (Ezell, 2021) has been used in the spreadsheet tool, in which the weighting applied to the scores for each metric are proportional to the rank of that metric in relation to all the metrics, as assigned by the stakeholders. The sheet does however include nots on different weight assignment methodologies for the user to consider.

Rank number	Criterion	Description	Rank	Weight	Scoring 0	1	2	3	4	5
RC1	Water resource benefit	Assessing the ability to [...] source in a manner tha[...] over the long term wit[...] depletion. (Comment: Based on stakeholder engagement.)	1	0.17	No benefit	Low yield	Low/medium	Medium	Medium/High	High
RC2	Cost	The financial investment required for implementation and ongoing maintenance of the LRO.	2	0.15	>£10m	£5m-£10m	£1m-£5m	£500,000-£1m	£100,000-£500,000	<£100,000
RC3	Compliance with Water Licensing Regulations	Ensuring the water resource option aligns with legal frameworks and regulations governing water use.	4	0.12	No attempt to obtain permits/licenses.	Difficulty in obtaining necessary permits/licenses.	Some permits/licenses obtained, not fully compliant.	Current licences and permits acquired. Future licences with LRO needed.	Most necessary licences and permits acquired, some only allowed once LRO is approved	Fully compliant, no licences needed
RC4	Technical Feasibility	The practicality of implementing the option with current technology and within the specific local context.	3	0.14	Not feasible.	Feasible with significant difficulty .	Feasible with moderate difficulty	Feasible with some minor issues to resolve.	within current capabilities and reasonable cost.	Feasibility is not an issue and is within easy technical reach.
RC5	Environmental Impact	The potential effects of the LRO on local ecosystems, including impacts on biodiversity and natural habitats.	5	0.11	No environmental impact assessment.	Significant unmitigated negative impact.	Identified impacts with limited mitigation.	Environmental impacts adequately mitigated.	Conservation measures exceed standards.	Leading environmental conservation and enhancement.
RC6	Community and Ecosystem Effects	Evaluating the impacts of the LRO on local communities and ecosystems, ensuring that there are no adverse effects on other water users or habitats.	6	0.09	No assessment of community or ecosystem impacts.	Negative impacts on communities or ecosystems, no mitigation.	Some identified impacts on communities or ecosystems, inadequate action.	Adequate measures to avoid negative community and ecosystem impacts.	Positive actions taken to enhance communities and ecosystems.	Leading initiatives for community and ecosystem conservation and enhancement.
RC7	Water Savings per Pound Invested	Efficiency measurement of how much water is saved relative to the cost involved in the LRO.	7	0.08	No savings - investment leads to no water saved.	Very low savings per pound invested	Low to moderate savings per pound.	Moderate savings per pound.	High savings per pound	Very high savings per pound invested.
RC8	Time to Implement	The timeframe required to put the water resource option into operation, from planning through to execution.	8	0.06	No estimate on the time of implementation provided.	Implementation expected to take more than 5 years due to extensive planning, regulatory challenges, or other complexities.	[...]ion time estimated between 3 to 5 years, with significant construction or regulatory processes slowing	Implementation time estimated between 1 to 3 years, with well-understood and manageable processes.	Implementation time estimated at 6 to 12 months, with minor regulatory and construction considerations.	Rapid implementation possible within 6 months, indicating a ready-to-go solution with all preparations and approvals in place.
RC9	Regulatory Compliance	Adherence to all relevant legal, environmental, and regulatory requirements.	9	0.05	No compliancy	Limited compliancy.	Partial compliancy.	Adequate compliancy	Good compliancy	Fully compliant.
RC10	Synergies with Other Initiatives	Potential to complement or enhance other projects and initiatives.	10	0.03	No consideration for synergies.	Poor integration with other initiatives.	Some synergies with other projects, but not leveraged well	Adequate synergies and integration with other initiatives.	Good enhancement of project through synergies.	Excellent integration and leadership in synergistic initiatives.
RC11	Effectiveness in Reducing License Strain	The ability of the LRO to alleviate pressures on existing water licenses, ensuring sustainable use of water resources in agricultural practices.	11	0.02	Slight reduction in license strain.	Slight reduction in license strain.	Moderate reduction in license strain but not significant.	Good reduction in license strain, some relief provided.	Significant reduction in license strain, greatly assists current license holders.	Completely alleviates license strain, no additional pressure on water resources.

Notes on weight assignement methodologies
Equal Weighting: Each criterion is given the same importance.
Rank Sum Weighting: The most important criterion gets a weight of n (the number of criteria), the next important gets n-1, and so on, then these numbers are normalised to sum to 1. **This method is pre-programmed into the sheet, note the ranking should be based on the overall aims and priorities of the stakeholders rather than being LRO specific.**
Direct Assignment: Stakeholders or experts assign a weight to each criterion based on their knowledge or preference, then these weights are normalised.
Pairwise Comparison: A more complex method where each criterion is compared against every other criterion to establish which of the two is more important, and by how much.

Go to ranking results

Instructions: Additional ranking criteria can be added to the bottom of this table, which will also update the screening results tab. Ranking criteria can also be deleted in the same way but please note the values within the columns in screening results are not dynamic, therefore care must be taken when deleting screening criteria after these columns have been filled out.

Figure 10-7: Spreadsheet tool – Ranking criteria.

10.1.8 Ranking results

Outputs the results of the ranking process, showcasing how each LRO stacks up against others based on the applied criteria. Includes charts which show how each LRO compares in terms of water resource benefit and cost, as well as a radar diagram to assess how each option performs for each metric.

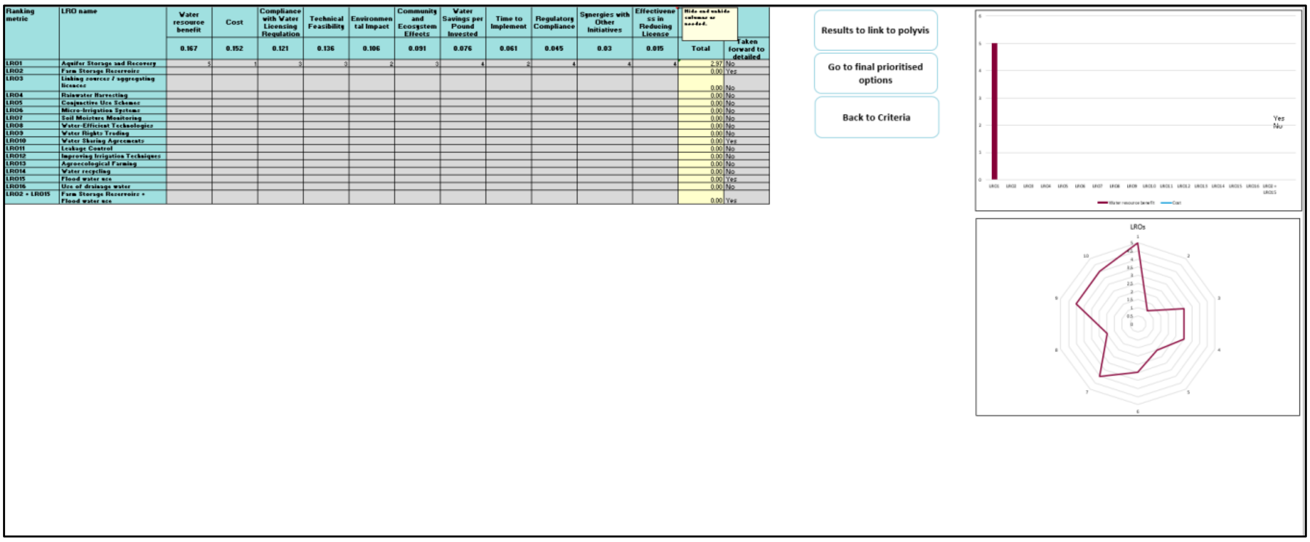
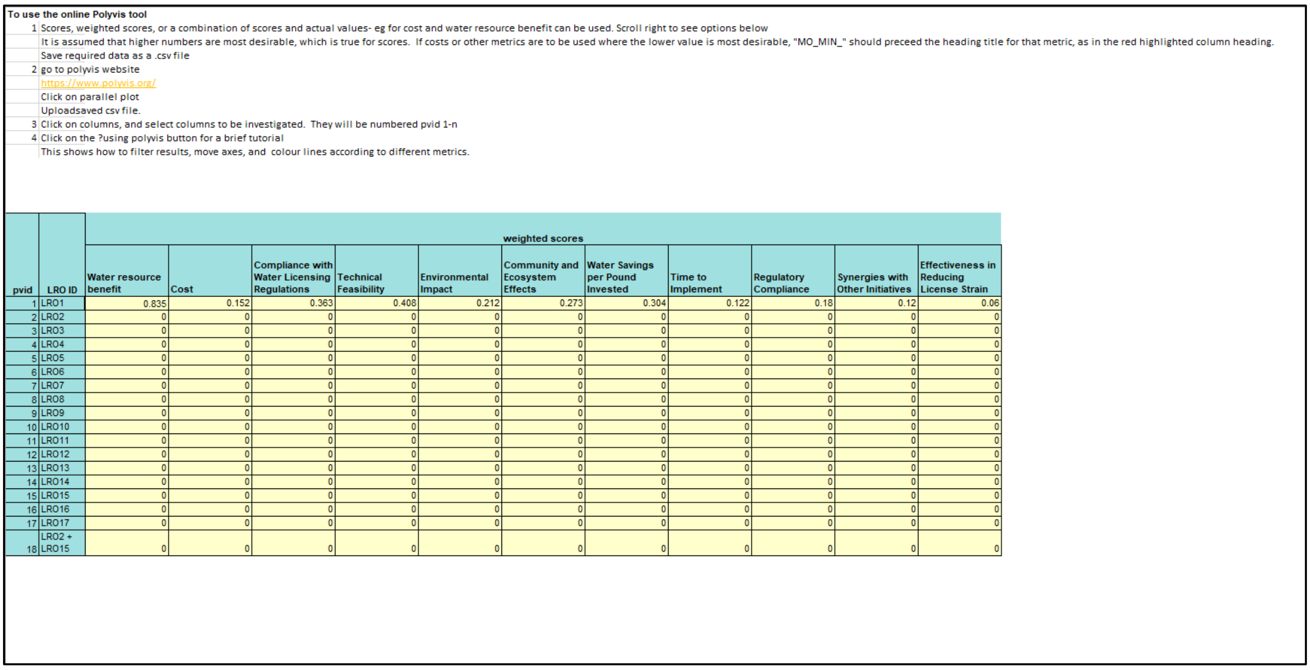


Figure 10-8: Spreadsheet tool – Ranking results.

10.1.9 Ranking for Polyvis

Instructions on how to export the relevant ranking results for use on the Polyvis tool website. Tables are provided with the LRO options ranked with weighted scores and raw scores with their ranked and actual values. These scores can then be copied and pasted into a separate csv. for use in the Polyvis tool.



To use the online Polyvis tool

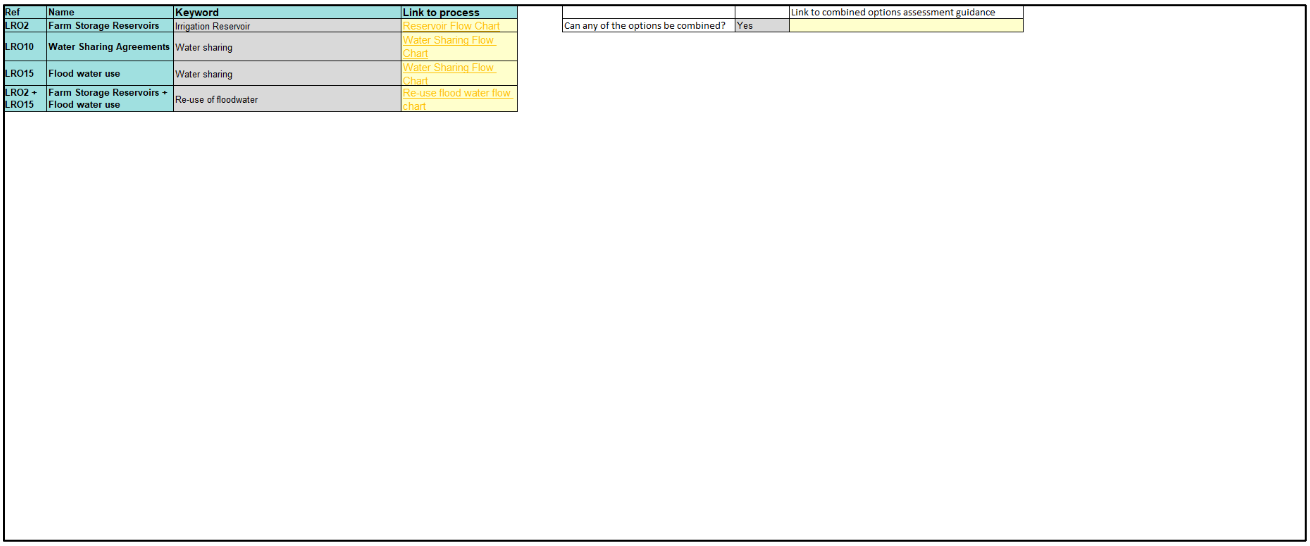
1 Scores, weighted scores, or a combination of scores and actual values- eg for cost and water resource benefit can be used. Scroll right to see options below
It is assumed that higher numbers are most desirable, which is true for scores. If costs or other metrics are to be used where the lower value is most desirable, "MO_MIN_" should preceed the heading title for that metric, as in the red highlighted column heading.
Save required data as a .csv file
2 go to polyvis website
https://www.polyvis.org/
Click on parallel plot
Uploadsaved csv file.
3 Click on columns, and select columns to be investigated. They will be numbered pvid 1-n
4 Click on the ?using polyvis button for a brief tutorial
This shows how to filter results, move axes, and colour lines according to different metrics.

		weighted scores										
pvid	LRO ID	Water resource benefit	Cost	Compliance with Water Licensing Regulations	Technical Feasibility	Environmental Impact	Community and Ecosystem Effects	Water Savings per Pound Invested	Time to Implement	Regulatory Compliance	Synergies with Other Initiatives	Effectiveness in Reducing License Strain
1	LRO1	0.835	0.152	0.363	0.408	0.212	0.273	0.304	0.122	0.18	0.12	0.06
2	LRO2	0	0	0	0	0	0	0	0	0	0	0
3	LRO3	0	0	0	0	0	0	0	0	0	0	0
4	LRO4	0	0	0	0	0	0	0	0	0	0	0
5	LRO5	0	0	0	0	0	0	0	0	0	0	0
6	LRO6	0	0	0	0	0	0	0	0	0	0	0
7	LRO7	0	0	0	0	0	0	0	0	0	0	0
8	LRO8	0	0	0	0	0	0	0	0	0	0	0
9	LRO9	0	0	0	0	0	0	0	0	0	0	0
10	LRO10	0	0	0	0	0	0	0	0	0	0	0
11	LRO11	0	0	0	0	0	0	0	0	0	0	0
12	LRO12	0	0	0	0	0	0	0	0	0	0	0
13	LRO13	0	0	0	0	0	0	0	0	0	0	0
14	LRO14	0	0	0	0	0	0	0	0	0	0	0
15	LRO15	0	0	0	0	0	0	0	0	0	0	0
16	LRO16	0	0	0	0	0	0	0	0	0	0	0
17	LRO17	0	0	0	0	0	0	0	0	0	0	0
18	LRO2 + LRO15	0	0	0	0	0	0	0	0	0	0	0

Figure 10-9: Spreadsheet tool – Ranking for Polyvis.

10.1.10 Prioritised options

Highlights the top ranked LROs, suggesting which options are most viable and promising for detailed assessment and potential implementation.



Ref	Name	Keyword	Link to process
LRO2	Farm Storage Reservoirs	Irrigation Reservoir	Reservoir Flow Chart
LRO10	Water Sharing Agreements	Water sharing	Water Sharing Flow Chart
LRO15	Flood water use	Water sharing	Water Sharing Flow Chart
LRO2 + LRO15	Farm Storage Reservoirs + Flood water use	Re-use of floodwater	Re-use flood water flow chart

		Link to combined options assessment guidance
Can any of the options be combined?	Yes	

Figure 10-10: Spreadsheet tool – Prioritised options.

10.1.11 Detailed assessment-charts

Provides a framework for a detailed assessment of various LRO options.

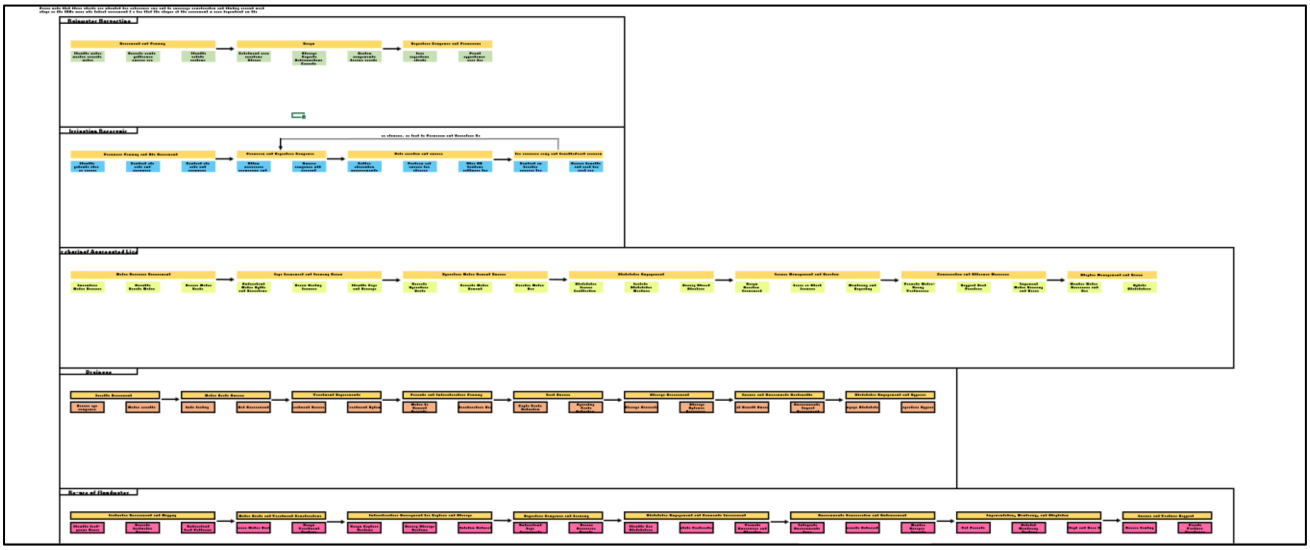


Figure 10-11: Spreadsheet tool – Detailed assessment charts.

10.1.12 References

A section dedicated to listing the sources of information, methodologies, and data used in developing the tool and conducting LRO assessments.

Reference/Link	Type	Description
Irmak et al. (2005)	Paper	Crop coefficient (Kc) values for different crops.
Water (2021)	Report	Main crop types in the UK and their water needs.
Environment Agency's estimates of water use	Link	Water use for general agriculture in the UK.
How much water crops need	Link	Guide on crop water requirements.
FAO guide on irrigation needs	Link	Calculating irrigation needs.
Calculating crop water use	Link	Guide on crop water use.
Cranfield University	Report	Efficient irrigation and water storage reservoirs guides.
Kent County Council (2015)	Guide	Design Guide for Irrigation Reservoirs in Kent.
Building or modifying a reservoir in the UK	Link	Requirements for building/modifying a reservoir.
UK Legislation	Link	Relevant to planning an irrigation reservoir.
Turner et al. (2015)	Paper	Abstraction licence application process and planning consent for reservoirs.
NFU Farm Energy Service	Link	Guidance on solar PV for farms.
Irrigation guide for new growers	Guide	Pete Dollimore's irrigation guide.
Guidance Rainwater harvesting: regulatory position statement	Link	UK Government's guidance on rainwater harvesting.
L.S. Pereira, I. Alves (2005)	Paper	Crop water requirements research.
UKIA – Irrigation Best Practice	Link	Water management for field vegetable crops.
AHDB DIY Full Water Audit Pack	Link	Full water audit pack for agriculture.
Water Requirements of Livestock	Link	Factors affecting livestock water requirements.
LandIS – Soilscapes	Link	England soil map and information.
Enduramaxx – Agricultural Rainwater Harvesting Systems	Link	Guide on agricultural rainwater harvesting systems.
D&H Group – Rainwater Harvesting	Link	Advice on agricultural rainwater harvesting.
Met Office – Historic Station Data	Link	Rainfall data for the UK.
EA Rainwater Harvesting: an on-farm guide	Link	Comprehensive guide on farm rainwater harvesting.
Building Regulations 2000 – Drainage and Waste Disposal	Link	UK Government legislation on drainage and waste disposal.
Benefits of Rainwater Harvesting Systems	Link	Insights on sustainability and BREEAM scoring for rainwater harvesting.

Figure 10-12: Spreadsheet tool – References.

Overall, this spreadsheet tool stands as an instrument designed to aid in the strategic selection of LROs. It is designed to be used together with user judgement and empower stakeholders to make informed, evidence-based decisions.

11 Concluding remarks

The report presents a methodological framework aimed at enhancing water resource management in agriculture. It delves into various Local Resource Options (LROs), presenting their potential benefits alongside the challenges associated with their implementation. The methodology presented offers a structured pathway for Water Abstractor Groups to navigate through the complex terrain of water resource management, advocating for an integrated approach that balances agricultural needs with ecological preservation and efficiency. It outlines a structured, scalable methodology for WAGs to identify and assess local resource options, emphasizing stakeholder engagement and pilot testing for refinement. Various LROs are explored, highlighting their potential benefits and implementation challenges, suggesting a diversified approach to addressing water scarcity.

Stakeholder Engagement is Crucial: The framework emphasizes the importance of engaging stakeholders throughout the process. This includes farmers, local communities, government agencies, and environmental groups. Early and ongoing engagement ensures the incorporation of diverse perspectives, builds trust, and fosters a sense of collective responsibility towards sustainable water management.

Key conclusions that can be drawn regarding the application of the framework:

- Flexibility and Adaptability: The methodology highlights the need for flexibility to adapt to changing conditions, including climate variability, regulatory changes, and evolving water demands. This adaptability is crucial for the long-term success of Local Resource Options (LROs), ensuring they remain effective under various scenarios.
- Integrated Approach: The framework advocates for an integrated approach to water resource management, combining various Local Resource Options to address water scarcity. This diversified strategy can optimize water use, enhance resilience, and ensure the sustainability of agricultural practices.
- Data-Driven Decision Making: Data analysis and modelling techniques are essential for informed decision-making. The framework suggests the use of tools and methodologies that consider water resources, economic, environmental, and social factors to evaluate and rank LROs.
- Continuous Learning and Sharing: Establishing a platform for sharing experiences, best practices, and lessons learned is vital for continuous improvement. Collaboration among Water Abstractor Groups, researchers, and other stakeholders can lead to innovation and the development of more effective water management strategies.
- Seeking Funding and Technical Support: Although outwith the scope of the current report, identifying funding opportunities and securing financial and technical support is necessary for the development and implementation of LROs. Government

subsidies, grants, and private investments can reduce the financial burden on agricultural stakeholders.

- Policy and Regulatory Alignment: The framework must align with existing legal and regulatory frameworks governing water use. Working closely with regulatory bodies can facilitate compliance, streamline the implementation of LROs, and contribute to the development of supportive policies. At the same time, these projects can form the evidence basis for needs to amendments to policy and regulation to more easily implement some of the more novel LRO approaches.

References

Aldrick, J., Bielby, S., Bishop, S., Blackburn, E., Critchley, R., Jepps, J., Stunnell, J. and Zaidman, M. (2014) *Handbook of Source Yield Methodologies.* London: UK Water Industry Research Limited.

Chengot, J., Knox, J.W., and Holman, I.P.. (2021) 'Evaluating the Feasibility of Water Sharing as a Drought Risk Management Tool for Irrigated Agriculture', *Sustainability,* 13(3), pp.1456.

Cranfield University (2014) *Water for agriculture: collaborative approaches and on-farm storage.* Cranfield University.

Cranfield University (nd) *Rainwater harvesting tool.* Available at: https://www.d-risk.eu/index.php?params=rwhtool [Accessed: 11/03/2024].

DEFRA (2023) *An update following the UK Farm to Fork summit held at 10 Downing Street on 16 May 2023.* Available at: https://www.gov.uk/government/publications/outcomes-from-the-uk-farm-to-fork-summit/an-update-following-the-uk-farm-to-fork-summit-held-at-10-downing-street-on-16-may-2023#water-security [Accessed: 11/03/2024].

Environment Agency (1999) *R&D Technical Summary WS149 - Assessment of the Potential for Aquifer Storage and Recovery in England and Wales.* Bristol: Environment Agency.

Environment Agency (2009) *Rainwater Harvesting: an on-farm guide.* Bristol: Environment Agency.

Environment Agency (2011) *Effluent re-use for potable water supply: Position Statement.*

Environment Agency (2018) *Spreading treated sewage effluent on land during prolonged dry weather: RPS 214.* Available at: https://www.gov.uk/government/publications/spreading-treated-sewage-effluent-on-land-during-prolonged-dry-weather-rps-214/spreading-treated-sewage-effluent-on-land-during-prolonged-dry-weather-rps-214 [Accessed: 28/03/2024].

Environment Agency (2021) *Rainwater harvesting: regulatory position statement.* Available at: https://www.gov.uk/government/publications/rainwater-harvesting-regulatory-position-statement/rainwater-harvesting-regulatory-position-statement [Accessed: 28/02/2024].

Environment Agency (2024) *Abstracting floodwater outside of licence conditions during flood events: RPS300.* Available at: https://www.gov.uk/government/publications/abstracting-floodwater-outside-of-licence-conditions-during-flood-events-rps-300/abstracting-floodwater-outside-of-licence-conditions-during-flood-events-rps-300 [Accessed: 11/03/2024].

Felixstowe Hydrocycle Ltd (2024) *Felixstowe Hydrocycle.* Available at: https://www.felixstowehydrocycle.com/ [Accessed: 11/03/2024].

Fresh4Cs. Available at: https://www.fresh4cs.eu/index.php?id=1 [Accessed: 28/03/24].

Haro-Monteagudo, D., Knox, J.W., & Holman, I.P. (2019). 'D-Risk: A decision-support webtool for improving drought risk management in irrigated agriculture', *Computers and Electronics in Agriculture*, 162, pp. 855-858.

Hatfield, J., Sauer, T. and Prueger, J. (2001) 'Managing Soils to Achieve Greater Water Use Efficiency', *Agronomy Journal*, 93, pp.271–280.

Iglesias, A. and Garrote, L., (2015) 'Adaptation strategies for agricultural water management under climate change in Europe', *Agricultural Water Management*, 155, pp.113–124.

Irmak, S., Payero, J.O. and Martin, D.L. (2005) *Using Modified Atmometers (ET_{gage}®) for Irrigation Management*. University of Nebraska – Lincoln Extension, Institute of Agriculture and Natural Resources.

JBA Consulting (2021) *Water Resource Benefits of Working With Natural Processes.* Available at: https://consult.environment-agency.gov.uk/water-resources/water-resources-priority-catchments/supporting_documents/CETJBAXXXXRPZ0019A6C02WRB_WWNP_final%2010catch.PDF

Jeffrey, P., Ryan, S. and Smith, H. (2014) *Establishing a Robust Case for Final Effluent Reuse – An Evidence Base.* London: UK Water Industry Research Limited.

Harris, S., Adams, M. and Jones, M. (2005) *NLARS: Evolution of an artificial recharge scheme*. Reading: Thames Water Utilities Ltd*.*

Knox, J. and Kay, M. (2008) *Save water and money – irrigate efficiently.* Peterborough: Environment Agency.

Lampayan, R., Rejesus, R., Singleton, G. and Bouman, B. (2015) 'Adoption and economics of alternate wetting and drying water management for irrigated lowland rice', *Field Crops Research*, 170, pp.95–108.

Larner, C. (2023) 'What is the Felixstowe Hydrocycle? And what does it do?', *Great British LIFE.* Available at: https://www.greatbritishlife.co.uk/lifestyle/23815513.felixstowe-hydrocycle/ [Accessed: 28/03/2024].
Leathes, W., Knox, J. W., Kay, M. G., Trawick, P., & A, R.-D. J. (2008) 'Developing UK farmers' institutional capacity to defend their water rights and effectively manage limited water resources'. *Irrigation and Drainage, 57, 322–331. https://doi.org/10.1002/ird.436*

Mashaly, A.F. and Fernald, A. (2020) 'Identifying Capabilities and Potentials of System Dynamics in Hydrology and Water Resources as a Promising Modeling Approach for Water Management', *Water*, 12(5), pp. 1432.

Mojid, M. and Mainuddin, M. (2021) 'Water-Saving Agricultural Technologies: Regional Hydrology Outcomes and Knowledge Gaps in the Eastern Gangetic Plains—A Review', *Water*, 13(5), pp. 636.

Singh, A.K. (2014) 'Simulation–optimization modeling for conjunctive water use management', *Agricultural Water Management*, 141, pp.23–29.

Snell, M. (1997). *Cost-benefit Analysis for Engineers and Planners*. Thomas Telford.

UKIA (nd). The Irrigators' Handbook. Available at:

www.ukia.org

UK Groundwater Forum (nd) *FAQs: Borehole on my Property.* Available at: http://www.groundwateruk.org/I-want-a-borehole.aspx [Accessed: 11/03/2024].

University of Manchester: Polyvis tool (nd), available at https://www.polyvis.org/ [Accessed: 11/03/2024].

Ware, T (2021) 'How Much Water Crops Need and Why'*, TWL Irrigation.* Available at: https://www.twl-irrigation.com/how-much-water-crops-need-and-why/ [Accessed: 04/01/2024].

Water for Tomorrow (2023) *Catchment Management System.* Available at: https://fe.cms.hydra.org.uk/?x=144824.20849&y=6915596.64755&z=8&r=0&l=11#/wft [Accessed: 11/03/2024].

Water for Tomorrow (2023) *Resources.* Available at: https://water-for-tomorrow.com/resources/ [Accessed: 11/03/2024].

Water for Tomorrow (2023) *Water for Tomorrow: Guidance Resource Pack.*

Weatherhead, K., Kay, M. and Knox, J. (2008) *Thinking about an irrigation reservoir? a guide to planning, designing, constructing and commissioning a water storage reservoir.* Solihull: Environment Agency.

Linked documents

https://www.gov.uk/guidance/publishing-accessible-documents#writing-accessible-documents

https://www.rgsjpa.org/what-is-an-accessible-document-and-why-is-accessibility-so-important/

A Stakeholder engagement plan

A.1 Stakeholder engagement

General

The stakeholder engagement process seeks to integrate a broad range of perspectives and expertise to ensure the effective development of the Local Water Resource Options (LRO) framework. Using focus groups is a strategic approach to efficiently gather information from various stakeholders simultaneously. Stakeholders have been categorized into different focus groups based on whether their insights and information are sought or if their active participation is crucial during the workshop sessions. This structured segmentation allows for a targeted and streamlined engagement strategy.

Objectives of the stakeholder engagement

- Gathering insights: Obtain a comprehensive understanding of the current water resource practices, challenges, and preferences.
- Foster collaboration and cooperation among diverse stakeholder groups, promoting a shared understanding of the project goals.
- Establish clear and transparent communication channels to keep stakeholders informed about project progress, decision-making processes, and the incorporation of their feedback.
- Identify and address potential risks related to stakeholder resistance, diverging expectations, or unforeseen challenges that could impact the successful development and testing of the water resource options framework.

Key stakeholder groups

The first step is to identify a broad range of stakeholders which could include:

- Study WAG group and if relevant, other WAG groups
- Specific farmers/abstractors
- Regional WR groups

1. Drainage:
    - Association of Drainage Authorities (ADA)
    - IDBs (Internal Drainage Boards)
2. Water Supply:
    - Water companies
3. Regulation and government:

- Environment Agency (EA)
- Local EA representatives/hydrologists
- Regional/National Water Planning
- Defra
- Local authorities (Eng Norfolk and Suffolk that we know have an active interest)
- Environmental groups
- Rivers Trust
- Natural England

A.2 Stakeholder input

This process should be dynamic and iterative. Stakeholders should be categorised based on their level of interest and influence, assessing their attitudes and concerns, and determining strategies for engagement. The process will need to adapt to changes in project dynamics and stakeholders' interests.

Engagement strategies

Developing tailored engagement strategies for different stakeholder groups is essential. This includes:

- Workshops and Meetings: Facilitating discussions to gather inputs, share project information, and address concerns.
- Surveys and Questionnaires: Collecting data on stakeholder preferences, expectations, and suggestions.
- Focused interviews: To understand agricultural and regulatory landscape and explore the opportunities and barriers relating to local farm water supplies.

Tools and resources

- Digital platforms
- Semi-structure telephone or MS Teams conversations
- Engagement workshops and meetings

If any workshops are planned they should follow a rough structure to help maximise the relevant information gained from them.

Questions for semi-structured interview

Although the interview does not have to be fully structured, the following list of questions is likely to provide helpful information during the telephone interviews:

- Introduction
- Name and role
- How long have you been involved in agricultural practices in this region?
- Challenges and Concerns:
    - What are the primary challenges you face in terms of water availability?
    - Are there specific issues or concerns related to water availability, quality, or reliability that you would like to highlight?
- Current Practices:
    - What are the current water supply methods and sources used in your agricultural operations? Any experience with LROs specifically?
    - Are there any innovative or traditional methods that you have found to be particularly effective?
    - Have you experimented with any alternative water sources or conservation techniques?
- Water Requirements:
    - What are your specific water requirements for agricultural activities?
    - How do variations in water availability impact your operations?
- Collaboration:
    - How would you prefer to be involved in the development and implementation of water supply solutions?
    - What level of collaboration do you envision between local stakeholders, researchers, and policymakers?
- Expected Outcomes:
    - What specific outcomes or benefits would you hope to see from the implementation of improved water supply solutions?
    - How can the project best engage and involve the broader local community in addressing water supply challenges for agriculture?
    - Are there community-based initiatives or organizations that should be considered in the project?
- Barriers to Adoption:
    - What potential barriers or challenges do you foresee in the adoption of new water supply solutions within the local agricultural community?
    - How can these barriers be addressed to facilitate successful implementation?

Feedback mechanisms

Stakeholder feedback should be actively incorporated into project planning and decision-making. This involves:

- Engaging stakeholders early in the process will establish a channel for communication and build trust from the onset.
- Regularly reviewing and adjusting project plans based on stakeholder inputs.
- Developing mechanisms for ongoing communication and feedback throughout the project lifecycle.
- Addressing conflicts and concerns through transparent and participatory processes.

Stakeholder engagement is not a one-time activity but a continuous process that requires dedication and commitment. By prioritizing meaningful engagement, LRO projects can achieve sustainable outcomes that are supported by the community and stakeholders, ensuring long-term success and resource sustainability.

Timeline for engagement

- Recommend early engagement once stakeholders are mapped.
- Iterative process-input will be required at various stages of the project.

B Example process for developing specific LROs

B.1 Floodwater re-use

The reuse of floodwater for agricultural water supply, particularly during summer months, presents a sustainable solution to water scarcity and can also contribute to environmental benefits. A methodology to harness floodwater effectively requires comprehensive planning, infrastructure development, stakeholder engagement, and regulatory compliance. Additionally, considering the benefits for environmental flows adds a layer of ecological sustainability to the approach. This methodology would have to be considered in tandem with the steps described for new reservoirs. The key steps include:

1. Floodwater Assessment and Mapping
   - Identify Flood-prone Areas: Map out regions that frequently experience flooding, using historical data, climate models, and geographic information systems (GIS).
   - Evaluate Floodwater Volumes: Estimate the volume of water available during flood events and assess the quality of floodwater for agricultural use.
   - Understand Flood Patterns: Analyse the timing, frequency, and duration of floods to align floodwater capture strategies with agricultural needs.
2. Water Quality and Treatment Considerations
   - Assess water quality risk upstream through a desk-based exercise.
   - Test floodwaters for contaminants if needed, including agricultural runoff, industrial waste, and pathogens, to determine treatment requirements.
   - Design Treatment Solutions: Based on water quality assessments, develop appropriate treatment processes to make floodwater safe for agricultural use and environmental flows.
3. Infrastructure Development for Capture and Storage
   - Design Capture Systems: Plan for the construction of reservoirs, detention basins, or recharge ponds to capture floodwater efficiently.
   - Develop Storage Solutions: Invest in both surface and underground storage facilities if water quality means that water needs to be treated and held until it's needed for summer irrigation or to enhance environmental flows.
   - Distribution Networks: Design systems to distribute stored water to agricultural lands and areas requiring environmental flows.
4. Regulatory Compliance and Licencing
   - Understand Legal Frameworks: Liaise with the EA and Local Authority to secure licences and planning.

- Secure Necessary Abstraction Licences and Permits: Obtain all required permits and licences for water capture, treatment, storage, and distribution activities, ensuring compliance with local, regional, and national laws.

5. Stakeholder Engagement and Community Involvement
   - Identify Key Stakeholders: Engage with farmers, local communities, environmental groups, and government agencies involved in water management and agriculture.
   - Facilitate Collaboration: Create forums for discussion and collaboration among stakeholders to gain support and address concerns related to floodwater reuse.
   - Promote Awareness and Education: Educate the community about the benefits of floodwater reuse for agriculture and environmental conservation.
6. Environmental Conservation and Enhancement
   - Integrate Environmental Flows: Plan for the release of stored water to support aquatic ecosystems, especially during critical low-flow periods.
   - Promote Biodiversity: Use floodwater management practices that enhance habitat connectivity and biodiversity, such as creating wetlands or riparian buffers.
   - Monitor Ecological Impacts: Continuously assess the impact of floodwater reuse on local ecosystems and biodiversity, adjusting management practices as necessary to mitigate negative effects.
7. Implementation, Monitoring, and Adaptation
   - Pilot Projects: Implement pilot projects in selected areas to test the viability of floodwater capture, treatment, and reuse strategies.
   - Establish Monitoring Systems: Monitor the quality and quantity of captured floodwater, the effectiveness of storage and distribution systems, and the impact on agricultural productivity and ecosystems.
   - Adapt and Scale Up: Use the insights gained from pilot projects and monitoring activities to refine approaches, address challenges, and expand successful practices to other regions.
8. Financial and Technical Support
   - Secure Funding: Explore funding options from government grants, private investments, and international aid to support infrastructure development and operational costs.
   - Provide Technical Assistance: Offer technical support to farmers and land managers for the adoption of floodwater reuse practices, including irrigation technology and water management strategies.

B.2 Drainage

1. Drainage Water Assessment and Mapping
   - Identify drainage areas with potential for water collection.
   - Evaluate volumes and quality of drainage water for agricultural use.
   - Understand seasonal and weather-related patterns affecting drainage water availability.
2. Water Quality and Treatment Considerations
   - Test drainage water for agricultural suitability.
   - Design treatment processes tailored to drainage water characteristics.
3. Infrastructure Development for Capture and Reuse
   - Develop systems for efficient capture and storage of drainage water.
   - Plan for treatment facilities as required.
   - Establish distribution networks for agricultural reuse.
4. Regulatory Compliance and Licencing
   - Work with IDBs, the Environment Agency, and local authorities for necessary permissions.
   - Ensure all activities comply with water management regulations.
5. Stakeholder Engagement and IDB Collaboration
   - Engage with IDBs, farmers, and other local stakeholders.
   - Facilitate collaborative planning and implementation.
6. Environmental Considerations
   - Plan for minimal impact on natural water courses and ecosystems.
   - Monitor ecological effects of drainage water reuse.
7. Implementation, Monitoring, and Adaptation
   - Initiate pilot projects to test the approach in controlled environments.
   - Monitor outcomes and adapt strategies based on results.
8. Financial and Technical Support
   - Identify funding sources for infrastructure and operation.
   - Provide technical guidance for system installation and maintenance.

B.3 Water sharing /Aggregated licences

1. Water Resource Assessment
   - Inventory Water Sources: Map out all available water sources in the area, including surface water (rivers, lakes) and groundwater (aquifers).
   - Quantify Available Water: Estimate the volume of water available from each source, considering seasonal variations and climate change projections.
   - Assess Water Quality: Determine the quality of water sources to ensure they meet agricultural needs without causing harm to crops or soils.

2. Legal Framework and Licencing Review
    - Understand Water Rights and Regulations: Familiarize yourself with local, regional, and national water laws, including water withdrawal limits and environmental protections.
    - Review Existing Licences: Analyse current water licences/permits, including their allocations, conditions, and expiration dates.
    - Identify Gaps and Overlaps: Look for areas where water rights may overlap or where unlicenced water use is occurring.
3. Agricultural Water Demand Analysis
    - Evaluate Agricultural Needs: Assess the water requirements of different crops and stages of growth, considering factors like soil type and climate.
    - Calculate Water Demand: Estimate the total water demand for agriculture within the jurisdiction, accounting for peak usage periods.
    - Prioritize Water Use: Determine critical water needs and prioritize allocations based on factors like food security, crop value, and sustainability practices.
4. Stakeholder Engagement
    - Early consultation with the EA and local authorities to identify any existing barriers and if these are negotiable.
    - Facilitate Stakeholder Meetings: Organize meetings to discuss water needs, concerns, and conservation strategies.
    - Develop Shared Objectives: Work with stakeholders to create common goals for water sustainability and equitable distribution.
5. Licence Management and Allocation
    - Design Allocation Framework: Develop a system for water allocation that considers legal requirements, water availability, agricultural needs, and sustainability goals.
    - Issue or Adjust Licences: Based on the framework, issue new licences or adjust existing ones to reflect current water realities and future projections.
    - Monitoring and Reporting: Set up systems for licensees to monitor their water use and report back. Include mechanisms for compliance checks and enforcement of rules.
6. Conservation and Efficiency Measures
    - Promote Water-Saving Technologies: Encourage the adoption of irrigation technologies that reduce water use if not already in place.
    - Support Best Practices: Facilitate workshops or training sessions on water-efficient farming practices.
    - Implement Water Recycling and Reuse: Advocate for systems that allow for the treatment and reuse of agricultural runoff or wastewater.

7. Adaptive Management and Review

- Monitor Water Resources and Use: Continuously assess water availability and agricultural demand, adjusting allocations as necessary.
- Update Stakeholders: Keep all parties informed about changes in water status, licencing, and regulations.

B.4 Reservoirs

1. Site Identification and Feasibility Study
    - Evaluate potential sites based on hydrological, geographical, and environmental criteria.
    - Conduct feasibility studies considering water demand, catchment area, and storage capacity.
2. Design and Planning
    - Plan reservoir design, including dam construction, spillways, and inlet/outlet structures, with attention to safety and environmental impacts.
    - Develop detailed plans for water distribution systems to agricultural areas.
3. Regulatory Compliance and Permissions
    - Secure all necessary environmental assessments and planning permissions.
    - Engage with EA, Local authority and other regulatory bodies for water abstraction and construction approvals.
4. Stakeholder Engagement
    - Consult with farmers, local communities, and environmental groups to address concerns and ensure support.
    - Work closely with agricultural and water management authorities for integrated planning.
5. Construction and Infrastructure Development
    - Follow best practices in reservoir construction, ensuring structural integrity and minimal environmental disruption.
    - Implement infrastructure for efficient water distribution to agricultural lands.
6. Monitoring and Management
    - Establish monitoring systems for water quality and reservoir levels.
    - Implement adaptive management practices to respond to changing water needs and climatic conditions.
7. Environmental and Ecological Enhancement
    - Integrate features to support local biodiversity, such as creating wetlands or fish passages.
    - Monitor and mitigate any negative impacts on local ecosystems.

C Yield estimation

C.1 Overview

To fully understand the water resources, benefit of a supply or group of supplies, yield analyses should be carried out. This appendix outlines methods that can be used for some different types of sources.

This appendix provides an overview of potential methods and is not intended as a step-by-step guide to the use of the techniques described, although such guides are referenced where available. It is assumed that users are familiar with yield estimation techniques and have the relevant knowledge and experience to undertake yield assessments.

There may be more than one suitable method of yield estimation for each source, and this report suggests which may be most suitable, but this does not mean that others should be discounted. The method used will depend on a number of factors including available data, resources (people and software) and time available, but also user preference. Where sources are grouped into an LRO, it may be most appropriate to build a model to calculate the system yield of the sources, which can be greater than the sum of the individual yields when operations are optimised, due to non-linear relationships between sources and supply and demand.

References are made to the Handbook of Source Yield Methodologies (Aldrick et al. 2014), for a more detailed, step by step description of the relevant methodologies, or to other reference sources where applicable. The Handbook is aimed at water resource yield analyses for water company WRMPs, but the same techniques are applicable to agricultural yield analyses.

C.2 Yield definitions

In this report we describe how to calculate the hydrological yield of sources. This is the amount that can be supplied under given design conditions. It is essentially the amount that can be abstracted in the worst historical drought, or during a drought of a specified return period.

The hydrological yield may be constrained by either physical limitations such as pump or pipe capacities, or by licence constraints. When this is the case, the hydrological yield, or “potential” yield, is higher than the “constrained” yield.

In water company and regional WRMPs, the deployable output is used to describe the system yield when the conjunctive use of all sources in a resource zone is taken into account, along with demand constraints such as the levels of service (frequency of demand restrictions or failures to meet demand). For LROs, which are smaller in scale, levels of service might not be a consideration, although WAGs may wish to define the required reliability of the LRO system, as well as the required yield.

C.3 Types of sources

In this guide the key methods for assessing the yield of the most likely LRO components are summarised and referenced. These are run of river abstractions, reservoirs, boreholes, and rainwater harvesting. Adjustments to the methods used for those sources can be made to estimate the yields of sources such as flood flow abstractions, drainage water use, treated effluent re-use, (all similar to run of river abstractions) and managed aquifer recovery (similar to reservoir storage).

C.4 Yield Estimation techniques

C.4.1 Data requirements

To estimate the yield of river abstractions, or reservoir, a reliable flow record is required. The Handbook of source yield Methodologies incudes yield estimation for impounding reservoirs, assuming the inflows to the reservoir are impounded river flows, but the techniques are equally applicable to the water taken from a river abstraction, from drainage water re-use, or from flood flows. In each case, the time series of "reservoir inflows" would need to represent the water available to supply the reservoir. This is illustrated for the case of a flood flows licence in the River Thet case study, where the available inflows are flows above a certain threshold.

Most methods of yield estimation require hydrological data, which may be either gauged or modelled data. The Handbook of Source Yield Methodologies describes the ways that flow records can be produced for use in yield analyses.

If gauged data is available, this can be used. If there is no gauged data, but there is a gauge on a nearby catchment, translocation methods can be used to produce a synthetic record of gauges flows for the proposed site. Rainfall runoff modelling can be used to develop a synthetic flow series if translocation methods aren't suitable for the catchment, although these will need to be calibrated and validated. The Handbook of Source Yield Methodologies suggests that Catchmod and Hysim are most frequently used, but in recent years PDM and GR6J have been increasingly used by water Companies for such modelling.

C.4.2 Irrigation reservoir

The Handbook of Source Yield Methodologies details how to use gauged or modelled inflows to calculate the potential yield of a reservoir. In the case of irrigation reservoirs, the process may be simpler, and often a reservoir is sized so that it is large enough to supply the crop demands for a single season, assuming no inflows during that period.

Example of steps required for calculating irrigation reservoir yield

- Identify potential reservoir site.
- Calculate potential sizes of impoundment.
- Obtain inflow records- use nearby gauged data, use rainfall runoff modelling.

- Calculate yield for each potential reservoir size, assuming modelled inflows (or abstractions)

C.4.3 Boreholes

The reliable yield approach (Handbook of Source Yield Methodologies, chapter 15) is simple to apply, and can be applied to most groundwater sources, and gives the yield that can be supplied in the worst historical drought. It does not give an indication of the reliability of this yield estimate, and because it is the yield in the worst historic drought, the source can supply larger volumes in most years, and will supply a lower volume when a worse drought occurs.

C.4.4 River Abstraction

The yield of river abstractions, drainage water use, or flood abstractions can be calculated from gauged flows, or using rainfall runoff modelling or translocation techniques to estimate gauged flows. The Handbook of Source Yield Methodologies (chapter 9) details how to use gauged or modelled inflows to calculate the potential yield of a run of river abstraction. The available abstraction will depend on the licence hands off flow conditions, and these should be discussed with the Environment Agency to understand what likely conditions will be. Different abstractions may be allowed at different flow thresholds, which will depend on the resource availability in the Abstraction Licensing Strategy,

C.4.5 Water resources simulation modelling

Water Resource Modelling can be used to calculate the yield of a combination of resource options that make up an LRO. Water resource behavioural models such as Aquator or PyWR can be used to model the combined yield of summer river abstractions, a winter river abstraction, drainage water use and a storage reservoir with the seasonal profile of forecast demands. This can aid understanding of the best combination of LRO components. This is exemplified in the case study of the Thet catchment, where an Aquator model has been used to show the yields that can be supplied for various sizes of reservoir in a system with several irrigation demands, and several boreholes, as well as a new farm storage reservoir.

Behavioural modelling may be particularly suited to testing the operation of LRO schemes over several seasons and can help to develop the best operating regime to optimise the conjunctive use of the different demands and supplies of the WAG.

Table C-1: Summary of yield estimation methodologies.

Method	Description	Applicability	Strengths	Limitations	Notes
Transposition Techniques	Transfers inflow sequences from a donor site to an ungauged site with adjustments.	Ungauged watercourses, extending records.	Flexible, uses observed data, quick.	Depends on donor site quality and may not capture unique characteristics of the target site.	Discussed widely in hydrological textbooks including Aldrick et al. (2012); Beven (2012); Shaw et al. (2011); Maidment (1993).
Rainfall-Runoff Modelling	Simulates river flow sequences based on rainfall and evapotranspiration data. Models most frequently used now are PDM and GR6J.	Any catchment, especially ungauged ones.	Can handle various conditions and scenarios, including climate change.	Complex and requires extensive data and calibration.	
Reservoir Mass Balance	Calculates inflows, outflows, and storage changes to estimate yield.	Reservoir systems.	Directly accounts for physical water movements and storages.	Requires accurate measurement, complex for systems with many inputs and outputs.	
Source Constraints	Identifies and assesses limitations on yield due to physical, operational, environmental, and quality constraints.	Surface water and conjunctive use systems.	Provides a comprehensive overview of factors limiting water source yield.	Complex analysis that requires detailed data on various constraints.	See Aldrick et al. (2012)
Mass Curve Analysis	Plots cumulative inflow and demand over time to determine required storage.	Reservoirs and groundwater systems.	Simple, visual tool for storage requirement estimation.	Depends on historical data	See Aldrick et al. (2012); Shaw et al. (2011)
Stochastic Simulation	Uses statistical models to generate synthetic hydrological data for system simulation under various scenarios.	Surface water and groundwater systems, especially under climate variability.	Can evaluate a wide range of scenarios including rare events and climate change impacts.	Requires statistical expertise; synthetic data may not capture all hydrological processes.	See Aldrick et al. (2012)
Soil Water Balance Models	Estimates groundwater recharge and runoff considering precipitation, evapotranspiration, and soil processes.	Ungauged catchments and groundwater recharge estimation.	Useful in areas lacking detailed hydrological measurements.	accuracy depends on model calibration	Rarely used in UK in an applied science context. See Pereira et al. (2020) for review of FAO56 soil water balance model approach to determining crop irrigation requirements and irrigation scheduling.
Analytical Models	Uses mathematical equations to describe groundwater flow and surface water interactions.	Groundwater systems.	Provides insights into aquifer dynamics and pumping impacts.	May oversimplify complex hydrological systems; requires understanding of aquifer properties.	groundwater system modelling, see Aldrick et al. (2012)
Empirical Methods	Relies on observed data to establish relationships between hydrological variables.	Preliminary assessments and when data are limited.	Quick and easy to apply with limited data.	May not accurately represent physical processes; limited by the quality and range of historical data.	See Aldrick et al. (2012)
Behavioural Modelling	Detailed simulation of the physical and operational characteristics of a water supply system to assess behaviour under various conditions. Simulates reservoir operation over time using historical/modelled streamflow.	Reservoir yield studies. Complex systems with multiple sources and uses.	Incorporates actual operation rules and losses; assesses supply reliability. Captures interactions within the system; suitable for conjunctive use analysis.	Extensive data requirements such as detailed historical streamflow records and possibly sophisticated modelling capabilities such as rainfall runoff modelling. Computationally intensive.	Widely used in water companies and regional planning. See Aldrick et al. (2012); Morley and Savić (2020); Tomlinson et al. (2020); Staszek et al. (2018)
Climate Change Impact Models	Incorporate future climate projections to assess impacts on water resource availability and yield.	Long-term planning and management considering climate change.	Allows for adaptation planning by assessing future water availability risks.	Relies on climate projections that may have uncertainties; requires climate modelling expertise.	See Aldrick et al. (2012)
Statistical Analysis	Utilizes long-term historical data to identify trends, variability, and extreme events through statistical techniques.	Systems with extensive historical data records.	Can uncover trends and patterns not immediately evident. Offers insight into natural variability.	Limited by the quality and completeness of the data record. May not capture future changes or anomalies.	used typically for groundwater sources DO assessment, see Aldrick et al. (2012)

C.5 Additional references

Aldrick, J., Bielby, S., Bishop, S., Blackburn, E., Critchley, R., Jepps, J., Stunnell, J. and Zaidman, M. (2014) *Handbook of Source Yield Methodologies.* London: UK Water Industry Research Limited.

Beven, K.J. (2012) *Rainfall Runoff Modelling: The Primer. 2nd Edition.* Wiley-Blackwell.

Maidment, D.R. (1993) *Handbook of Hydrology.* MaGraw-Hill.

Morely, M. and Savić, D. (2020) 'Water Resource Systems Analysis for Water Scarcity Management: The Thames Water Case Study', *Water,* 12 (6), pp. 1761.

Pereira, L.S., Paredes, P. and Jovanovic, N. (2020) 'Soil water balance models for determining crop water and irrigation requirements and irrigation scheduling focusing on the FAO56 method and the dual K_c approach', *Agricultural Water Management,* 241 (1), pp. 106357.

Shaw, E.M., Beven, K.J., Chappell, N.A. and Lamb, R. (2011) *Hydrology in Practice 4th Edition.* London: CRC Press.

Staszek, D., Savic, D. and Fu, G. (2018) 'Decision making methods for water resources planning in England and Wales', *EPiC Series in Engineering,* 3, pp. 2011-2018.

Tomlinson, J.E., Arnott, J.H. and Harou, J.J. (2020) 'A water resource simulator in Python', *Environmental Modelling and Software,* 126, pp. 104635.

Weatherhead, K., Kay, M. and Knox, J. (2008) *Thinking about an irrigation reservoir? a guide to planning, designing, constructing and commissioning a water storage reservoir.* Solihull: Environment Agency.

D Cost assessment LROs

D.1 General

Estimating costs for agricultural water resource management solutions involves a blend of first principles, empirical data, modelling, and established methodologies. The approach depends on the specific solution being implemented, the scale of the project, local conditions (such as labour costs, climate, and soil type), and available technology. It can be a complex but essential process. It ensures that investments are made wisely, resources are used efficiently, and the chosen solutions are sustainable in the long term. A general overview of how costs can be estimated is provided below, followed by sections on specific approaches. Approaches can also be combined depending on the option, the specific desired outcome, and if options need to be compared some methods are preferable than others.

- First Principles Estimation: This approach involves breaking down the system into its fundamental components (materials, labour, energy, etc.) and estimating the cost of each component. For instance, in a drip irrigation system, you would estimate the costs of piping, emitters, filters, pumps, installation labour, and any required control systems. This method requires a good understanding of the technology and the operational context.
- Empirical Data and Case Studies: Looking at similar projects and their costs can provide valuable benchmarks. Government agencies, agricultural extension services, and industry associations often publish case studies and cost data for various water management practices. This information can help estimate costs for new projects, adjusted for differences in scale, location, and technology.
- Established Methodologies: Several established methodologies can guide cost estimation such as those discussed in section D5.
- Expert Consultation: Consulting with experts in agricultural engineering, water resource management, and agronomy can provide insights into the most cost-effective solutions and potential pitfalls. These specialists can also offer advice on available subsidies, grants, and other financial incentives that can offset costs.

D.2 Tailoring to local conditions

It's crucial to adjust cost estimates based on local conditions, especially to assess availability and cost of materials and labour and embed costs of local regulations and permits. In addition to initial setup costs, ongoing operational, maintenance, and replacement costs should be factored into the total cost of ownership. These can significantly impact the long-term sustainability and viability of water management solutions.

D.3 Key cost elements

Irrespective of the methodology employed there is a need to establish basic costs of specific elements, such as presented in the table below:

Table D-1: Costing of key elements

Cost element	Description
Enabling costs	Costs associated with preparing the site for construction, such as access roads, site clearing, and utility rerouting.
Capital costs	The cost of materials, labour, and equipment for the construction of the LRO
Operation and maintenance costs	Yearly costs to maintain the LRO, including inspections, minor repairs, and vegetation control. Also, costs associated with operation (e.g. utilities, expenses, salaries, insurance etc)
Other costs	e.g. Costs for larger maintenance tasks that might happen less frequently
Replacement	Cost of replacing major components of the LRO.

D.4 Unit costs

There is not much established literature in the UK on cost for agricultural infrastructure. There are several sources of information for flooding and NFM measures that could be used as guidance, however, this is why it is very important to seek local input and information pertinent to the study region to get a more tailored result. A possible source of information for costs of implementation includes the following comprehensive study (2021):

- Long-term costing tool for flood and coastal risk management - GOV.UK (www.gov.uk) (see relevant evidence summaries)

D.5 Methods

Each of the methods presented has its strengths and applications, depending on the project goals, the availability of data, and the decision-making context. Combining multiple methods can provide a more rounded and robust analysis, helping stakeholders make informed decisions about project implementation.

- Life Cycle Cost Analysis (LCCA): LCCA considers all costs associated with the project from initial investment to disposal, including construction, operation, maintenance, and decommissioning costs. Unlike Present Value (PV) analysis, which discounts future costs to present value, LCCA can provide a more straightforward comparison of total costs over time without necessarily adjusting for the time value of money.

- Cost-Benefit Analysis (CBA): CBA extends beyond cost assessment to compare the costs and benefits of a project, translating all impacts into monetary terms. It's broader than PV analysis in that it includes intangible benefits and costs, providing a comprehensive view of a project's net value or net social benefit.
- Net Present Value (NPV) is a financial metric that calculates the difference between the present value of cash inflows and the present value of cash outflows over a project's lifetime. It's used to assess the profitability and financial feasibility of investments or projects. The NPV method discounts future cash flows to their present value using a specific discount rate, which typically reflects the cost of capital or opportunity cost of investment. In the context of a project like an irrigation reservoir, NPV helps determine the overall financial viability by considering all expected costs (including initial construction costs, operation, maintenance, and any future cash flows related to the project) and benefits (such as increased agricultural yields, water savings, and any additional revenue streams). A positive NPV indicates that the project's returns exceed its costs, considering the time value of money, making it a financially worthwhile endeavour.
- Cost-Effectiveness Analysis (CEA): CEA is used when benefits are difficult to quantify in monetary terms. It evaluates the cost per unit of outcome achieved (e.g., cost per cubic meter of water supplied) and is useful for comparing the efficiency of different projects or options in achieving a specific objective.
- Return on Investment (ROI): ROI measures the efficiency of an investment by comparing the expected gains to the cost of the project. It's a straightforward metric that provides insight into the financial return provided by the project, expressed as a percentage.
- Total Cost of Ownership (TCO): TCO assesses the total economic value of an investment by considering all direct and indirect costs associated with owning and operating the project over its lifespan. It's similar to LCCA but often includes broader factors such as opportunity costs and indirect financial impacts.

Table D-2: Summary of proposed methodologies for cost estimation

Methodology	Description	Application in Project Analysis	Benefits	Limitations	Main Equations
LCCA	Assesses all costs from acquisition to disposal.	Evaluates long-term financial obligations and savings for projects.	Provides a complete view over a project's life span.	Predicting future costs can be challenging.	Total Cost = ∑ (Cost at Year n / (1 + r)^n)
CBA	Compares total expected costs to total expected benefits.	Evaluates economic, social, and environmental benefits against project costs.	Offers a holistic assessment of a project's value.	Quantifying intangible benefits and costs is challenging.	CBA Ratio = ∑ (Benefits at Year n / (1 + r)^n) / ∑ (Costs at Year n / (1 + r)^n)
ROI	Measures the efficiency or profitability of an investment.	Analyses financial returns against the investment in a project.	Simple and intuitive; allows for comparability.	Does not account for the time value of money.	ROI = (Net Profit / Cost of Investment) x 100
NPV	Calculates the difference between the present value of cash inflows and outflows.	Determines the financial viability by discounting future cash flows.	Accounts for the time value of money.	Appropriate discount rate can be challenging to determine.	NPV = ∑ (Cash Inflow at Year n / (1 + r)^n) - ∑ (Cash Outflow at Year n / (1 + r)^n)

Methodology	Description	Application in Project Analysis	Benefits	Limitations	Main Equations
CEA	Evaluates the cost per unit of outcome achieved.	Compares the efficiency of different projects or options in achieving a specific objective.	Useful for comparing efficiency when benefits are difficult to quantify in monetary terms.	Does not provide information on the total or net value of a project's benefits.	CEA Ratio = Total Cost / Health Outcome Achieved
TCO	Considers all direct and indirect costs associated with owning and operating a project over its lifespan.	Identifies the total economic value of an investment, including construction, operation, maintenance, and indirect financial impacts.	Highlights the broader financial impacts beyond initial purchase or construction costs.	Can be complex to calculate accurately due to the need to forecast future costs and potential indirect impacts.	TCO = Initial Cost + ∑ (Operating and Maintenance Costs + Replacement Costs - Residual Value) / (1 + r)^n

- Notes: n is the year number (where n = 0 represents the current year, n = 1 the next year, and so on).
- r represents the discount rate or the rate of return that could be earned on an investment in the financial markets with similar risk.
- ∑ denotes the sum over the years for which the costs and benefits occur.
- For CEA, "Health Outcome Achieved" could be any measurable outcome the project aims for, such as litres of water saved, hectares of land irrigated, etc., depending on the project's objectives.
- For TCO, "Initial Cost" includes acquisition or construction costs, while "Operating and Maintenance Costs" cover the expenses of running the project annually. "Replacement Costs" consider the costs of major repairs or replacements over the project's life, and "Residual Value" accounts for any salvage value at the end of the project lifespan.

D.6 Assessing benefits

Assessing benefits is useful for informed decision-making, strategic alignment, and justifying investments in projects not only based on costs but also potential benefits. Demonstrating the benefits of a project can secure buy-in from stakeholders, including investors, policymakers, and the community, by showing the tangible and intangible returns on investment. A few methods that could be used for assessing benefits are shown below:

- Quantitative/Monetized Benefit Analysis: Like CBA, this approach attempts to quantify all benefits in monetary terms, including direct financial gains, environmental improvements, and social impacts. It is challenging but provides a comprehensive view of a project's positive contributions.
- Qualitative Benefit Analysis: When benefits cannot be easily quantified, a qualitative approach can be employed to describe the potential impacts of a project. This can include narrative descriptions, case studies, or expert judgments about environmental, social, and community benefits. Link
- Social Return on Investment (SROI): SROI extends ROI analysis to include social, environmental, and economic costs and benefits. It provides a ratio of benefits to costs, incorporating values that are not traditionally accounted for in financial statements. Link:
- Multi-Criteria Decision Analysis (MCDA): MCDA is used to assess and compare the performance of projects across various criteria, including but not limited to financial metrics. Benefits are evaluated based on a set of criteria reflecting stakeholders' values and priorities, allowing for a balanced assessment of options. Link:
- Environmental Impact Assessment (EIA): While traditionally used to assess negative impacts, EIA can also highlight positive environmental contributions of a project, such as biodiversity enhancement, water quality improvements, and contributions to climate resilience.

D.7 Additional references

Cost Estimation Methodologies:

Snell, M. (1997). *Cost-benefit Analysis for Engineers and Planners*. Thomas Telford.

Newman, D.G., Eschenbach T.G., Lavelle, J.P. (2012), *Engineering Economic Analysis, 11th Edition*. Oxford University Press.

Tools for calculating benefits (not specific to agricultural water but could be repurposed):

- B£ST is based on robust research evidence and provides a structured approach to evaluating a wide range of benefits. Where feasible, it enables benefits to be quantified and monetised. Summary tables present results under the Ecosystem

Services (ESS) framework and in terms of natural, social and other capitals. A series of graphs are automatically generated for use in reports. Link: https://ecosystemsknowledge.net/resources/tool-assessor/best-benefits-estimation-tool/

- Ciriabest (CIRIA's Benefits EStimation Tool) makes assessing the benefits of blue-green infrastructure quicker and easier, without the need for full-scale economic inputs. ciriabest is an online, spatial tool which guides the user through the benefits estimation process. It provides a structured way to estimate the value of the multiple benefits of blue-green projects. It provides a robust method to estimate the monetary value of a range of benefits that are not normally quantified. Link: https://www.susdrain.org/resources/best.html

E Template of Proposed Context of Report

1. Introduction

2. Applying the LRO Framework

2.1 General

2.2 Stage 1: Define scope and objectives

2.3 Background and context

2.4 Water Quantity

2.5 Engagement with the WAG

2.6 Other stakeholder engagement

2.7 Stage 2: Data analysis Current water situation

2.8 Baseline water balance

2.9 Stage 3: Screening

2.10 Stage 4: Ranking

3. Stage 5: Detailed Evaluation of LROs

3.1 General

3.2 Prioritised options

3.3 Yield analysis

3.4 Cost analysis

3.5 Environmental and social considerations

3.6 Climate Change

4. Discussions

4.1 Key Findings

4.2 Further Steps

Offices at

Bristol
Coleshill
Doncaster
Dublin
Edinburgh
Exeter
Glasgow
Haywards Heath
Isle of Man
Leeds
Limerick
Newcastle upon Tyne
Newport
Peterborough
Portsmouth
Saltaire
Skipton
Tadcaster
Thirsk
Wallingford
Warrington

Registered Office
1 Broughton Park
Old Lane North
Broughton
SKIPTON
North Yorkshire
BD23 3FD
United Kingdom

+44(0)1756 799919
info@jbaconsulting.com
www.jbaconsulting.com
Follow us:

Jeremy Benn
Associates Limited

Registered in England
3246693

JBA Group Ltd is
certified to:
ISO 9001:2015
ISO 14001:2015
ISO 27001:2013
ISO 45001:2018