Feasibility study of VCS VM0033

Methodology for Tidal Wetlands and Seagrass Restoration (v2.0) for use with restoration of UK saltmarsh habitat

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Acronyms

AFOLU	Agriculture Forestry and Other Land Use project
AOD	Above Ordnance Datum
ARR	Afforestation, Reforestation, and Revegetation
BNG	Biodiversity Net Gain
DCF	Discounted Cashflow
EA	Environment Agency
EF	Emission Factor
EWT	Essex Wildlife Trust
FE	Finance Earth
GHG	Greenhouse Gas
HAT	Highest Astronomical Tide
ICVCM	Integrity Council for the Voluntary Carbon Market
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
LOI	Loss on Ignition
LULUCF	Land Use, Land-Use Change and Forestry
MHWN	Mean High Water Neaps
MHWS	Mean High Water Springs
MLWN	Mean Low Water Neaps
MLWS	Mean Low Water Springs
MOD	Metres above Ordnance Datum
MR	Managed Realignment
MRV	Monitoring, Reporting and Verification
NFRM	Natural Flood Risk Management
NEIRF	Natural Environment Investment Readiness Fund
NPV	Net Present Value
PC	Peatland Code
PDT	Peat Depletion Time
PIU	Pending Issuing Unit
RSPB	Royal Society for the Protection of Birds
RTE	Regulated Tidal Exchange
SDT	Soil organic carbon Depletion Time
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
UKCEH	UK Centre for Ecology and Hydrology
UKGHGI	UK Greenhouse Gas Inventory
VAT	Value Added Tax
VCS	Verified Carbon Standard
VVB	Validation / Verification Bodies
WCC	Woodland Carbon Code
WWT	Wildfowl & Wetlands Trust

1. Glossary

Term	Definition
Accretion	Increase in land height / area from deposited sediments.
Additionality	A real increase in social or environmental value that would not have occurred in the absence of the intervention being appraised[1].
Biodiversity Net Gain (BNG)	A regulatory approach to development that leaves biodiversity in a better state than before. Where a development has an impact on biodiversity it requires developers to provide an increase in appropriate natural habitat and ecological features over and above that being affected in such a way it is hoped that the current loss of biodiversity through development will be halted and ecological networks can be restored[2]. BNG may be delivered onsite or offsite, in adherence to the mitigation hierarchy.
Buffer credits	A pool of carbon credits – contributed to by all projects – for the replacement of unintended release of CO_2e, to mitigate risk of non-permanence.
Bundling	A single buyer, or consortium of buyers, pays for the full package of ecosystem services that arise from the same parcel of land[3]. For example, the owner of a wetland habitat receives a single payment for its restoration that accounts for the multiple benefits delivered including biodiversity net gain, natural flood management and carbon sequestration.
Carbon Credit	A tradeable permit that corresponds to Greenhouse Gas (GHG) emissions reduction or sequestration of 1 tonne of CO_2 equivalent (tCO_2e) reduced / removed from the atmosphere.
CO_2e	Not all greenhouse gases warm the atmosphere equally, some gases (such as methane) have a greater global warming potential, or warming effect, than carbon dioxide. To account for this, the term CO_2e is used and means that greenhouse gases other than carbon dioxide can be converted, or normalized, to the equivalent amount of CO_2, based on their relative contribution to global warming. This provides for a single, uniform means of measuring emissions reductions for multiple greenhouse gases[4].

[1] HM Treasury. 2022. The Green Book.

[2] CIEEM. Biodiversity Net Gain.

[3] Department for Environment, Food & Rural Affairs (Defra). 2013. Payments for Ecosystem Services: A Best Practice Guide.

[4] Carbon Dioxide Equivalent (CO_2e) | UNREDD Programme (un-redd.org)

Term	Definition
Credit	All units/offsets/fungible tokens representing quantities of a real or deemed outcome across different ecosystem services.
Debt	Involves at least a Lender and a Borrower, bound by a legal contract during a limited period of time by which the Borrower(s) receive(s) a certain amount of money from the Lender(s) which will have to be repaid (in most cases) with interests. It can take the form of a Bond or a Loan.
Discounted Cash Flow ('DCF')	An approach that forecasts a project or a company's future cash flows and discounts them to the present in order to arrive at a present value.
Ecosystem	A complex of living organisms, their physical environment, and all their interrelationships within a particular geographic area.
Ecosystem Services	The diverse benefits that humans derive from the natural environment. Examples of these services include the supply of food, water and timber (provisioning services); the regulation of air quality, climate and flood risk (regulating services); opportunities for recreation, tourism and education (cultural services); and essential underlying functions such as soil formation and nutrient cycling (supporting services)[5].
Emission Factor (EF)	A coefficient which allows conversion of activity data into GHG emissions. It is the average emission rate of a given source, relative to units of activity or process/processes.
Equity	Defines the nominal value of all the shares of a company. The shareholders gain the ownership of a part of the company's assets (and incomes through the payment of dividends).
Essex Wildlife Trust ('EWT')	One of 46 wildlife trusts which cover the United Kingdom.
Ex-ante credit/unit	Expected carbon unit or credit calculated ahead of habitat restoration. See PIU below.
Finance Earth ('FE')	A mission-driven social enterprise, working in partnership with environmental organisations to protect and restore nature utilising market-based mechanisms and implementing bespoke financial tools.
Grant	Funding provided by public, private or philanthropic funders without any expectation or requirement for being repaid.
Internal Rate of Return ('IRR')	The internal rate of return (IRR) is a common metric used in financial analysis to estimate the profitability of potential investments and reflects the discount rate at which the Net Present Value (NPV) of all cash flows equal zero in a (DCF) analysis.

[5] Department for Environment, Food & Rural Affairs (Defra). 2013. Payments for Ecosystem Services: A Best Practice Guide.

Term	Definition
Managed Realignment ('MR')	Deliberate breaching of coastal defences and subsequent tidal inundation to restore intertidal habitat. This is the predominant method of saltmarsh restoration in the UK.
Nature-based Solutions ('NbS')	The actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits[6].
Net Present Value ('NPV')	The sum of the present value of a set of future cash inflows and outflows over a period, discounted at a certain rate.
Payments for Ecosystem Services ('PES')	The entire suite of economic arrangements used to reward the conservation of ecosystem services. This includes polluter pays 'offsetting' payments as well as 'beneficiary pays' arrangements.
Peatland Code ('PC')	A voluntary certification standard for UK peatland projects wishing to market the climate benefits of peatland restoration and provides assurances to voluntary carbon credit buyers that the climate benefits being sold are real, quantifiable, additional and permanent.
Peatland Carbon Unit ('PCU')	A tonne of carbon dioxide equivalent (CO_2e), which includes carbon dioxide, methane, nitrous oxide and aquatic carbon, of which the emission was avoided by a Peatland Code-verified peatland restoration project. It has been independently verified, which means that this emission reduction is guaranteed to have happened and can be used by companies to report against UK-based emissions or to use in claims of carbon neutrality or Net Zero emissions.
Pending Issuance Units ('PIU')	A unit that represents a contractual right to an anticipated delivery of an emission reduction offset. It is effectively a 'promise to deliver' a Carbon Unit in the future, based on predicted emission reductions. It is not 'guaranteed' and cannot be used to report against UK-based emissions until verified.
Proxy variable	A parameter that is monitored or measured to determine the value of a strongly correlated parameter that is not monitored or measured.
Sensitivity Analysis	A tool used in financial modelling to analyse how the different values of a set of independent variables affect a specific dependent variable under certain specific conditions.

[6] International Union for Conservation of Nature (IUCN), Commission on Ecosystem Management. Accessed in April 2022. Nature-based Solutions.

Term	Definition
Stacking	Multiple buyers pay separately for the ecosystem services that arise from the same parcel of land or body of water[7]. This is also referred to as layering. For example, selling carbon credits and BNG units from the same parcel of land for distinct outcomes and actions. There are different forms of stacking: • Horizontal stacking occurs when a project performs more than one distinct management practice on non-spatially overlapping areas and the project participant receives a single payment for each practice. For example, a landowner plants trees and receives nutrient credits for the forested buffer along a stream and carbon credits for the trees in the upland part of the property[8]. • Vertical stacking occurs when a project participant receives multiple payments for a single management activity on spatially overlapping areas (that is, on the same acre). For example, a landowner plants a forested riparian buffer to receive both water quality credits and carbon credits. • Sequential/temporal stacking occurs where the payments for one type of ecosystem service are received over non overlapping periods of time (e.g., carbon revenues for 30 years, then BNG revenues) or simultaneous where payments for various ecosystem services are received over the same period.
The Intergovernmental Panel on Climate Change ('IPCC')	The United Nations body for assessing the science related to climate change.
The Royal Society for the Protection of Birds ('RSPB')	A charitable organisation focused on conservation and registered in England and Wales and in Scotland.
UK Centre For Ecology & Hydrology ('UKCEH')	An independent, not-for-profit research institute, carrying out environmental science across water, land and air.
VM0033	Verified Carbon Standard (VCS) VM0033 Methodology for Tidal Wetlands and Seagrass Restoration (v2.0). Developed in the USA, applied globally.
Validation/verification bodies ('VVBs')	Qualified, independent third-party auditors who are approved by VCS.

[7] Department for Environment, Food & Rural Affairs (Defra). 2013. Payments for Ecosystem Services: A Best Practice Guide.

[8] Cooley, D. & Olander, L. 2012. Stacking Ecosystem Services Payments: Risks and Solutions.

Term	Definition
Woodland Carbon Code (‘WCC’)	The Woodland Carbon Code is a voluntary certification standard for UK woodland projects wishing to market the climate benefits of woodland creation and provides assurances to voluntary carbon market buyers that the climate benefits being sold are real, quantifiable, additional and permanent.
Wildfowl & Wetlands Trust (‘WWT’)	An international wildfowl and wetland conservation charity in the United Kingdom.

2. Summary

This report assesses the feasibility of using the Verified Carbon Standard (VCS) VM0033 Methodology for Tidal Wetland and Seagrass Restoration in a UK context. It is one of two final reports from the initial phase of the Saltmarsh Code project – the overall aim being to provide a Saltmarsh Code for use within the voluntary carbon market in the UK, thus providing the opportunity to generate incomes from carbon credits to support the delivery of accelerated saltmarsh restoration. Here we detail all key elements of VM0033 and comment on how applicable they are, and if they're compatible with, projects restoring saltmarsh in the UK via Managed Realignment (MR). We then present illustrative investment cases for two sites based on costs of VM0033 and a theoretical UK domestic Saltmarsh Code assuming similarities to the Woodland Carbon Code (WCC) and Peatland Code (PC). A sensitivity analysis is included to better understand variation in CO2e accumulation and restoration costs on returns on investment.

From the analysis presented here, we conclude VM0033 could be applied to saltmarsh restoration via MR in the UK, and that it allows for UK (or site/region) specific estimates of GHG reductions or removals by using the most appropriate method to match available data and current knowledge. However, the illustrative investment cases suggest VM0033 is not a commercially viable option. This is due to high upfront costs to projects compared to those estimated for a UK domestic Saltmarsh Code (assuming similarities to the WCC and PC).

We recommend development of a UK domestic Saltmarsh Code as the most favourable approach to developing the saltmarsh carbon market in the UK. The key reasons being:

- Greater commercial viability due to the decreased upfront costs to projects entering the code.
- Alignment of key aspects with the other UK domestic codes (WCC and PC), ensuring consistency within the market. This is particularly in regard to additionality rules.
- The ability to streamline methodology to address restoration of saltmarsh habitat via managed realignment (MR) in the UK only. This would result in an easier to follow process than VM0033 – developed for global applicability to a wide range of habitats.

Our recommendations for development of a UK domestic Saltmarsh Code are outlined in the accompanying report (Burden et al., 2023).

3. Introduction

The Saltmarsh Code project, started in 2021, aims to develop a UK domestic Saltmarsh Code to be available for projects in the UK, providing the opportunity to generate incomes from carbon credits to support the delivery of accelerated saltmarsh restoration. The goal is to create a rigorous and scientifically based voluntary certification standard, to be adopted within the voluntary carbon market, enabling saltmarsh carbon to be marketed and traded as carbon offsets, whilst providing assurances to buyers that the climate benefits being sold are real, quantifiable, additional, and permanent. The Saltmarsh Code will promote new habitat creation that would not otherwise be taking place. If designed so only UK companies – or UK arms of international companies – can invest; this additional restoration will contribute to the UK net-zero targets, providing more space for saltmarshes to trap and store carbon dioxide from the atmosphere – a nature-based solution to climate change mitigation.

The initial phase of the Saltmarsh Code project has been funded by the Natural Environment Investment Readiness Fund (NEIRF), an initiative designed by the Department for Environment, Food and Rural Affairs (Defra), the Environment Agency (EA), and Natural England which aims to stimulate private investment to improve and safeguard our natural environment. The fund is developing innovative nature projects that provide both environmental benefits and can attract private investment, helping them get ready for investment and therefore creating a pipeline between projects and the private sector. This initial 1-year project is the start of developing an operational Saltmarsh Code, with a focus on restoration of habitat through MR – the deliberate breaching of coastal defences and subsequent tidal inundation to restore intertidal habitat. This is the predominant method of saltmarsh restoration in the UK. It is a collaborative project between nine organisations, led by the UK Centre for Ecology & Hydrology (UKCEH). The diverse team includes scientific, conservation delivery, and investment finance experts across the charity, finance, and academic sectors.

The objectives of this initial phase were to:

1. Evaluate the current evidence about carbon sequestration rates in UK (or equivalent biogeographic zone) saltmarshes. This included reviewing what factors control and potentially predict carbon and greenhouse gas (GHG) fluxes, how sequestration and/or accumulation rates differ over time between

restored and natural saltmarsh, and identifying current common methods for monitoring saltmarsh carbon and GHG fluxes (Mason et al., 2022).

2. Review and analyse other international codes, standards, and protocols to gather information on how key elements of a code have been addressed for coastal habitats. Whilst analysing a subset of these codes in more detail, the Verified Carbon Standard (VCS) VM0033 Methodology for Tidal Wetland and Seagrass Restoration was identified as potentially useable in a UK context.
3. Analyse the implications of VM0033 vs. a UK code (this report) by:
   a) Assessing the applicability of key elements within VM0033 to a UK context
   b) Assessing project related validation- & verification-related costs of VM0033 vs a UK code based on existing domestic codes, i.e., Peatland Code and Woodland Carbon Code.
4. Develop illustrative investment cases at two sites to understand the business case for saltmarsh restoration using voluntary carbon unit generation as a revenue stream (this report).
5. Demonstrate whether a UK domestic Saltmarsh Code is needed and/or preferable and explain why.
6. Our recommendations for moving forward with the development of a UK domestic Saltmarsh Code are outlined within the accompanying report: Recommendations for development of a UK domestic Saltmarsh Code (Burden et al., 2023).

This report assesses if the VCS VM0033 Methodology for Tidal Wetlands and Seagrass Restoration (v2.0) is applicable and useable in enabling the climate benefits of UK saltmarsh habitat restoration to be traded within the voluntary carbon market. The report is in two halves. In the first (section 4) we detail all key elements of VM0033 and comment on how applicable they are to a UK context, and review which carbon pools and GHG sources are relevant to MR – the predominant method of saltmarsh restoration in the UK. All monitoring methods described within VM0033 are also reviewed in terms of applicability, and expertise level required for application.

The second half of this report (sections 5 and 6) presents and reviews illustrative investment cases for two sites based upon the methodology and assumed costs of the VM0033 methodology, and a theoretical UK domestic Saltmarsh Code assuming similarities to the Woodland Carbon Code and Peatland Code. We then discuss key financing considerations for developing a business case and answer two questions:

1. What role can private and public finance play in UK saltmarsh restoration projects, and

2. Is VCS VM0033 a commercially viable carbon credit verification regime for UK saltmarsh restoration projects.

The illustrative investment cases for the two sites do not follow all elements of VM0033, or include all steps outlined to quantify GHG emission reductions and/or removals. The two halves of this study were undertaken in tandem, and both serve to demonstrate if using VM0033 is feasible for the UK. The investment cases and financial modelling analysis are indicative, and we present a sensitivity analysis to better understand variation in CO_2e accumulation and restoration costs on returns on investment (Appendix 1 for detail). Appendix 2 presents a high-level assessment of a potential managed realignment scheme at Old Hall Marshes including the habitats to be formed, likely engineering works, programme, financial costs and carbon emissions.

3.1 VCS VM0033: Methodology for Tidal Wetland and Seagrass Restoration, v2.0

The VCS is a voluntary carbon markets program developing standards to estimate carbon gains from restoration activities, enabling these carbon credits to be traded. VM0033 Methodology for Tidal Wetland and Seagrass Restoration (v2.0) operates globally and is applicable to all tidal wetland systems: tidal forests (such as mangroves), tidal [salt] marshes and seagrass meadows. It outlines the requirements and methodologies to estimate GHG reductions and removals resulting from activities designed to restore these habitats – such as MR – and includes activities such as creating, restoring and/or managing sediment supply; salinity; water quality; and native plant communities. Emissions reductions and/or removals are estimated primarily based on the ecological changes that occur due to restoration activities.
Restoration projects using this methodology are expected to generate GHG emission reductions and removals through:

- Increased biomass
- Increased autochthonous soil organic carbon
- Reduced methane and/or nitrous oxide emissions due to increased salinity or changing land use
- Reduced carbon dioxide emissions due to avoided soil carbon loss

To date (as of November 2022), uptake of VCS VM0033 methodology has been limited since its launch in 2015, with four projects currently registered with VM0033, of which three are under development and one has been registered fully.

For the rest of this report the VCS VM0033 Methodology for Tidal Wetlands and Seagrass Restoration (v2.0) will be referred to simply as "VM0033"

4. Applicability of VM0033 methodology and feasibility in a UK context

The following section reviews the specific requirements of VM0033 and comments on how applicable they are to a UK context, given typical restoration activity through MR. The detail of each requirement is explained and summarised from the VM0033 text to provide an overview of the methodology, and additional guidelines (if recommended, or prescribed for use) are also included.

4.1 Applicability conditions

The VM0033 methodology states eight conditions under which the methodology can be applied to restoration activities. These are summarised in Table 1, with notes as to how these would apply in a UK context. In summary, UK saltmarsh restoration would meet these conditions. The predominant restoration method (MR) restores tidal wetlands by re-connecting land to tidal flow, allowing the revegetation and rewetting of new habitat to happen (meeting conditions 1, 2, and 8). Applicability condition 3 – the need to demonstrate that prior to the project, the area was free of land-use that could be displaced outside the project area – would need to be demonstrated for each project. However, most land restored to saltmarsh in the UK to date has either been flood plain, marginal agricultural land, or grazing land, none of which are intensive, and have therefore not posed a great displacement risk (also referred to as Leakage). Conditions 4-7 are either not relevant, or data could be collected to address them. The definition of tidal wetland restoration as used in VM0033 is:

Re-establishing or improving the hydrology, salinity, water quality, sediment supply and/or vegetation in degraded or converted tidal wetlands. For the purpose of this methodology, this definition also includes activities that create wetland ecological conditions on uplands under the influence of sea level rise or activities that convert one wetland type to another or activities that convert open water to wetland.

Table 1: Applicability conditions for VM0033 Methodology for Tidal Wetland and Seagrass Restoration, including notes on how these apply in a UK context.

	Applicability Condition	UK context
1	Project activities which restore tidal wetlands are eligible.	In line with the definition for tidal wetland restoration, UK projects re-establish tidal waters and therefore hydrology, salinity, and sediment supply in converted tidal wetlands.
2	Project activities may include any of the following, or combinations of: a) Creating, restoring and/or managing hydrological conditions (e.g., removing tidal barriers, improving hydrological connectivity, restoring tidal flow to wetlands or lowering water levels on impounded wetlands) b) Altering sediment supply (e.g., beneficial use of dredge material or diverting river sediments to sediment-starved areas) c) Changing salinity characteristics (e.g., restoring tidal flow to tidally restricted areas) d) Improving water quality (e.g., reducing nutrient loads leading to improved water clarity to expand seagrass meadows, recovering tidal and other hydrologic flushing and exchange, or reducing nutrient residence time) e) (Re-)introducing native plant communities (e.g., reseeding or replanting) f) Improving management practice(s) (e.g., removing invasive species, reduced grazing	The majority of saltmarsh restoration in the UK is via MR, which is the deliberate breaching of sea defences to allow tidal water to enter the project site - condition 2a. There is an increasing interest in the use of beneficial use of dredged material also which would fit under condition 2b also.
3	Prior to the project start date, the project area: a) Is free of any land use that could be displaced outside the project area, as demonstrated by at least one of the following, where relevant: i) The project area has been abandoned for two or more years prior to the project start date; or ii) Use of the project area for commercial purposes (i.e., trade) is not profitable as a result of salinity intrusion, market forces or other factors. In addition, timber harvesting in the baseline scenario within the project area does not occur; or iii) Degradation of additional wetlands for new agricultural sites within the country will not occur or is prohibited by enforced law. OR	Within the UK, land converted to saltmarsh habitat is usually either flood plain, marginal agricultural land, or grazing land. None of these prior land uses are intensive and are of low profitability. For this reason, we feel saltmarsh restoration in the UK would be able to demonstrate applicability under this condition, however, this will need to be demonstrated in each case.

	Applicability Condition	UK context
	b) Is under a land use that could be displaced outside the project area), although in such case baseline emissions from this land use must not be accounted for, and where degradation of additional wetlands for new agricultural/aquacultural sites within the country will not occur or is prohibited by enforced law. OR c) Is under a land use that will continue at a similar level of service or production during the project crediting period (e.g., reed or hay harvesting, collection of fuelwood, subsistence harvesting).	
4	Live tree vegetation may be present in the project area and may be subject to carbon stock changes (e.g., due to harvesting) in both the baseline and project scenarios.	Trees are generally not present within UK project areas. However, if they were, carbon stock changes could be taken account of.
5	The prescribed burning of herbaceous and shrub aboveground biomass (cover burns) as a project activity may occur.	Prescribed burning is not a practise used on saltmarsh in the UK.
6	Where the project proponent intends to claim emission reductions from reduced frequency of peat fires, project activities must include a combination of rewetting and fire management.	Peat fires do not generally happen on UK saltmarsh.
7	Where the project proponent intends to claim emission reductions from reduced frequency of peat fires, it must be demonstrated that a threat of frequent on-site fires exists, and the overwhelming cause of ignition of the organic soil is anthropogenic (e.g., drainage of the peat, arson).	Peat fires do not generally happen on UK saltmarsh.
8	In strata with organic soil, afforestation, reforestation, and revegetation (ARR) activities must be combined with rewetting.	Managed realignment is a rewetting activity, and revegetation of project areas happens naturally due to the re-establishment of tidal water

4.2 Additionality

VM0033 uses an activity method for the determination of additionality of tidal wetland restoration and conservation activities: Module VMD0052 *Demonstration of Additionality of Tidal Wetland Restoration and Conservation Project Activities* (VCS, 2021). It has two steps; if projects can demonstrate they meet both these requirements, they are considered additional:

Step 1: Regulatory surplus: The project is not mandated by any law, statute, or other regulatory framework.

Step 2: Positive list: The project meets the applicability conditions as set out in the module. These are the same as Table 1, condition 2, with the additional options:

- Protecting at-risk wetlands
- Improving water management on drained wetlands
- Maintaining or improving water quality for seagrass meadows
- Recharging sediment to avoid drowning of coastal wetlands
- Creating accommodation space for wetlands migrating with sea-level rise

This lenient approach to additionality is further explained to be due to global tidal wetland conservation activities being low compared to their "maximum adoption potential", and the calculations behind this are explained. From a UK perspective, these additionality tests are much weaker than the two UK domestic codes currently in operation (Peatland Code and Woodland Carbon Code), notably lacking an investment test to show the work would not have been possible without carbon finance. This is problematic for two reasons, the first being the range of additionality tests proposed for use across global carbon markets by The Integrity Council for the Voluntary Carbon Market (ICVCM). The second is the benefit to market confidence and project developers if all UK codes are seen as an aligned 'family' with consistency around key aspects, such as additionality. For these reasons, the additionality approach in VM0033 is not seen as robust enough for use in the UK and additional tests would need to be added. There is also no mention of the ability to stack or bundle other ecosystem benefits or income streams, however it is presumed this would be permitted given the lenient requirements.

4.3 Risk Analysis

Projects need to conduct a non-permanence risk analysis to determine its non-permanence risk rating. The analysis also determines the number of buffer credits needed to protect against risk of the carbon gain of projects being reversed. VM0033 uses the AFOLU Non-Permanence Risk Tool (where AFOLU stands for, Agriculture Forestry and Other Land Use projects). Projects need to clearly document and demonstrate the risk analysis covering each risk factor applicable to the project.

During validation and verification, the VVB needs to evaluate the risk assessment undertaken that supports the risk rating.

Risk factors are classified into three categories: internal, external, and natural risks, each with sub-categories (Table 2). Risk ratings are a sum of all parts and can be reduced if mitigation activities are to be applied. If a project fails any of the risk factors, it will fail the entire risk assessment and will not be eligible for crediting without changes to the project and a further compliant risk assessment.

Table 2: A summary of the risk factors within the AFOLU Non-Permanence Risk Tool for determination of the risk rating of projects.

Risk category	Sub-categories
Internal Risks	Project Management
	Financial Viability
	Opportunity Cost
	Project Longevity
External Risks	Land Tenure and Resource Access/Impacts
	Community Engagement
	Political Risk
Natural Risks	No further sub-categories. Based on likelihood and significance, expressed as an estimated percentage of average carbon stocks in the project area that would be lost in a single event

This risk assessment could be used in a UK context and provides a robust approach to determining a variable buffer size for individual projects. This is advantageous compared to the use of a uniform buffer contribution, or one which is more arbitrary assigned as it allows less risky projects to sell more credits, and therefore produce more revenue. For each project scenario, the risk assessment and therefore risk score will be different. However, this does increase project uncertainty vs a prescribed buffer and given the smaller scale of saltmarsh restoration in the UK, it is important that any tool, such as a risk assessment, is designed in a cost-effective way.

For the investment case presented here, a ‘precision buffer’ of 10% and a ‘risk buffer’ of 15% have been applied to the total number of marketable carbon credits, based on the approach and levels required in the Peatland Code. This is due to the uncertainty regarding the CO_2e accumulation rates as well as potential GHG emissions from undertaking saltmarsh restoration activities.

4.4 Leakage

Leakage is defined as any increase in GHG emissions that occur outside the project boundary and is measurable and attributable to the project activities. VM0033 splits leakage into two components:

- Activity-shifting leakage and market leakage:
  It is assumed that where the applicability conditions are met for this methodology, these types of leakage do not occur and can be assumed to be zero. Therefore, for the UK context, we can also assume these to be zero (see Table 1).
- Ecological leakage:
  It may be assumed that ecological leakage does not occur in projects meeting the applicability conditions of this methodology, as projects must be designed in a manner which ensures their hydrological connectivity with adjacent areas does not lead to a significant increase in GHG emissions outside the project area. However, projects must demonstrate their design meets these requirements, and to guide this assessment Table 3 outlines avoidance criteria related to a variety of processes. For typical UK restoration, changes to the water table outside the project boundary will not occur and will therefore pass this condition. There may be instances when raising of the water table happens – where new projects are not enclosed by new sea defences and a natural transition zone between saltmarsh and terrestrial habitat will develop – but this is not a common occurrence. However, if this does, and it results in an increase in CH_4 emissions or a decrease in vegetation production, a project would not pass this component of the leakage condition. The key here is if this leakage was <u>outside</u> of the project boundary, and how this is defined is further detailed in section 4.5. It could be the case that mapping a “buffer zone” (Table 4) would ensure any potential negative impacts would be mitigated.

Table 3: Processes associated with Ecological Leakage outside a project boundary, and related criteria for avoidance. Taken from VM0033. Comments added relevant to a UK context

Ecological leakage process outside project boundary	Avoidance criterion	UK relevant comments
Lowering water table that causes increased soil carbon oxidation	Maintain wetland conditions (e.g., converting from impounded water to a wetland does not cause soil oxidation)	Within UK MR, lowering of the water table outside the project boundary should not happen as the 'new' habitat will be connected directly to tidal ingress. The water moving into the project area will only come from the tide, and will not be draining another piece of land
Lowering water table that causes increased N_2O emissions	No conversion of non-seagrass wetland to open water	
Raising water table that causes increased CH_4 emissions	No conversion of non-wetland to wetland	Raising of the water table outside of the project boundary should also not happen with UK MR projects. This is because restoration sites are often enclosed by new sea defences, to protect land and assets adjacent to project sites. Where they are not enclosed, a natural transitional zone between saltmarsh and terrestrial habitat will develop. In this instance, an increase in CH_4 emissions or a decrease in vegetation production may happen outside of the project boundary.
Raising water table that causes decreased vegetation production that causes decreased new soil carbon sequestration	No causation of vegetated to non-vegetated (or poorly vegetated) conditions	

4.5 Project boundaries

Within the context of VM0033, the 'project boundary' includes the GHG sources, sinks and reservoirs that are relevant to the project and baseline scenarios. These need to be described – including justification for not including any relevant GHG source, sink, or reservoir – and are split into four main categories (temporal, geographical, carbon pools, and GHG sources). These are listed in the following Tables (4-6), with comments related to a UK context.

In summary, the advice here gives a sound basis on how to decide and describe the project boundary for UK projects. Some guidance is not relevant for restoration through MR (for example, the temporal considerations in Table 4), but can be omitted. Sea-level rise data and models exist for the UK, and geographical boundaries can be easily mapped and stratified. Stratification is already considered the preferred option for accounting for GHG emission reductions and/or removals in UK projects (as it allows for proxy values based on sound scientific understanding of specific characteristics or 'typology' of saltmarsh. This is the general approach the Peatland Code and Woodland Carbon Code use). As for carbon pools and sources of GHGs (Tables 5 and 6), the guidance covers everything UK projects would need to include. Soil will be the largest carbon pool in the project area for UK projects, and restoration is expected to generate an increase. As a general note, VM0033 suggests using the AR-Tool04 "Tool for testing significance of GHG emissions in A/R CDM project activities" to determine whether changes in other carbon pools are 'de minimis' (lacking significance or importance). This could result in above- and below-ground biomass being omitted from calculations.

Table 4: Project boundary categories and descriptions taken from VM0033. Comments added relevant to a UK context.

Project boundary	Sub-category	Description	UK relevant comments
Temporal boundary	Peat depletion time (PDT)	Drained peat is subject to oxidation and subsidence. Areas with peat at the commencement of a project may lose all peat before the end of the crediting period. The time at which all peat has disappeared, or at which the peat depth reaches a level where no further oxidation or other losses occur (e.g., at the average water table depth), is referred to as the PDT. Projects that do not quantify reductions of baseline emissions (i.e., those which limit their accounting to GHG removals in biomass and/or soil) need not estimate PDT.	These are not applicable to UK saltmarsh restoration at this time. Restoration is predominantly via MR (the deliberate breaching of sea defences to allow tidal water to enter a project site) which creates new habitat by rewetting land that has been historically drained, and continued vertical ‘growth’ of this habitat by continued deposition of sediment and organic matter. The risk of erosion due to sea-level rise is captured in the Geographical Boundary guidance.
	Soil organic carbon depletion time (SDT)	SDT in the baseline scenario limits the period during which the project is eligible to claim emission reductions from restoration, and is estimated at the project start date for each stratum (year elapsed since project start date). Projects that do not quantify reductions of baseline emissions (i.e., those which limit their accounting to GHG removals in biomass and/or soil) need not estimate SDT.	
Geographical boundary	General	Definition of the geographic boundaries of the project area at the beginning of project activities. The project must provide geographic coordinates of land included in the project area to facilitate accurate delineation of the project area. This can be achieved in various ways, such as by remote sensing, published topographic maps and data, land administration and tenure records, or other official documentation.	This data will either be available, or can easily be sought for UK projects.
	Stratification	Where the project area at the start date is not homogeneous, stratification may be carried out to	This approach is relevant to UK saltmarsh restoration, and its

Project boundary	Sub-category	Description	UK relevant comments
		improve the accuracy and precision of carbon stock and GHG flux estimates. Where stratification is employed, different stratifications may be required for the baseline and project scenarios in order to achieve optimal accuracy of the estimates of net GHG emission reductions and/or removals. Strata can be revised within the project scenario as habitats change with time since restoration. Strata may be defined based on variables such as soil type and depth, vegetation cover and/or vegetation composition, and salinity, or expected changes in these characteristics. There is further requirements and guidance with respect to stratification in certain scenarios: - Areas with organic soil must be stratified - In order to claim emission removals projects must provide evidence the project area was not cleared of native ecosystems to create GHG credits. Such proof is not required where such clearing took place prior to the 10-year period prior to the project start date. - Tidal wetlands may be stratified according to salinity for the purpose of estimating CH_4 emissions, with areas of water lacking tidal exchange stratified separately.	premise is the preferred option for accounting for GHG removal within project areas – proxy values based on specific saltmarsh characteristics. This approach to GHG removal estimation allows for cheaper monitoring and verification, and relies on stratification of the habitat.

Project boundary	Sub-category	Description	UK relevant comments
	Sea level rise	Expected relative sea level rise must be considered, and the potential for expanding the project area landward to account for wetland migration, inundation and erosion. The project area cannot be changed during the project crediting period. The project must provide a projection of relative sea level rise within the project area based on IPCC regional forecasts or peer-reviewed literature applicable to the region, global averages are not suitable. There must be an assessment of potential wetland migration, inundation, and erosion. In general, the most vulnerable tidal wetlands are those in areas with a small tidal range, those with elevations low in the tidal frame and those in locations with low suspended sediment loads. Projects can conservatively assume that part of the wetland within the project area erodes and does not migrate, and there includes guidance to estimate the CO_2 emissions from this. Guidance is also given for accounting for project area submergence due to relative sea level rise.	Within the UK there is robust data and models that predict anticipated sea-level rise over long time periods (next 100 years) for the UK specifically. There is also data available on suspended sediment loads, for all major estuaries, although potentially not for smaller areas. Most UK saltmarsh habitats are enclosed by sea defences to protect assets along the coast. When restoring habitat through MR, new sea defences are most often rebuilt further inland and, in these situations, prevent migration of habitat horizontally. Therefore, each project will need to consider the clause "project area cannot be changed during the project crediting period" and may not be able to meet it.
	Ineligible wetland areas	For projects quantifying CO_2 emission reductions, project areas which do not achieve a significant difference (≥ 5%) in cumulative carbon loss over a period of 100 years beyond the project start date are not eligible for crediting based on the reduction of baseline emissions, and these areas must be mapped.	These areas can easily be mapped as part of the stratification exercise described above and revised as habitats change.

Project boundary	Sub-category	Description	UK relevant comments
	Buffer zones	Buffer zones can be established to ensure potential negative impacts to the hydrology in the project area (such as causing water table to drop or otherwise negatively impacting the hydrology) are mitigated. The buffer zone may be inside or outside the geographic boundary of the project area and must be mapped.	Potentially applicable to UK saltmarsh restoration. The alteration of hydrology in surrounding land to the project is usually mitigated by existing, or creating new sea walls. However, there may be instances where this cannot or does not happen, and therefore a buffer could be established and mapped.
Carbon Pools, and Sources of GHGs	Further detail in Tables 5 and 6	Carbon pools and GHGs included and excluded from the project boundary are shown in Table 5 and 6. These do not need to be accounted for if together the omitted decrease in carbon stocks or increase in GHG emissions amounts to less than 5% of the total GHG benefit generated by the project. The AR-Tool04 “Tool for testing significance of GHG emissions in A/R CDM project activities” may be used to determine whether change in carbon pools are ‘de minimis’ (lacking significance or importance).	Comments in Tables 5 and 6

Table 5: Carbon pools to include or exclude from baseline and project scenario in a UK context.

Carbon Pool	Included in scenario		UK relevant comments
	Baseline	Project	
Aboveground tree biomass	Yes	No	Included in baseline in case trees are present and removed before restoration projects start. This isn't expected in the majority of cases
Aboveground non-tree biomass	Yes	Yes	Restoration will result in changes to this pool, the magnitude of which will be dependent on the previous land-use.
Below-ground biomass	Yes	Yes	Although may be omitted from project scenario as the increase in this pool is not expected to be as significant as soil carbon stock. It may be considered 'de minimis'.
Litter	Optional	Optional	Optional for wetland restoration and conservation projects. It may be indirectly included in the aboveground biomass pool
Dead wood	Optional	Optional	Optional for wetland restoration and conservation projects. Not expected to be a large pool, or increase significantly in UK saltmarsh restoration projects
Soil	Yes	Yes	Largest carbon pool in the project area and restoration is expected to generate an increase
Wood products	No	No	Not applicable for saltmarsh habitat restoration

Table 6: Sources of GHGs to include or exclude from baseline and project scenario in a UK context.

Sources of GHGs	GHG	Included in scenario		UK relevant comments
		Baseline	Project	
The production of methane by microbes	CH_4	Yes	Yes	Included in baseline to account for previous land-use. Potentially a source of emissions in the project scenario in low salinity areas.
Denitrification/ nitrification	N_2O	Yes	Yes	Included in baseline to account for previous land-use. Expected to increase as a result of restoration, so included here as a precautionary measure.
Burning of biomass and organic soil	CO_2 CH_4 N_2O	Yes	No	Burning of biomass and organic soil is not a common practice in the UK, however there could be instances in which this needs to be taken account of within the baseline scenario. It is not applicable for saltmarsh habitat restoration in the UK, so is not included for the project scenario
Fossil fuel use	CO_2	Yes	Yes	Included in baseline to account for management practices on previous land-use. Included in project scenario to account for engineering works to restore habitat (e.g., building new sea walls and excavation to initiate a creek system)
	CH_4 N_2O	No	No	Advice in VM0033 is to exclude these GHGs as they are not significant source of emissions in fuel use

4.6 Baseline scenario

To determine the most plausible baseline scenario (i.e., what would be happening in the absence of the restoration project), the VM0033 methodology uses AR-Tool02 “Combined tool to identify the baseline scenario and demonstrate additionality for A/R CDM project activities”, however the additionality elements must be disregarded as the methodology applies the activity method for demonstrating this (as outlined in section 4.2 Additionality of this report). The tool provides a stepwise approach to identify the baseline scenario so that an accurate comparison can be made between the GHG emissions that would have occurred under the baseline scenario, and the GHG emission reductions and/or removals that were achieved by project activities. In summary, the AR-Tool02 approach can be applied to typical UK restoration activity, and below, the steps are explained and commented on from a UK perspective.

Step 1. Identification of alternative scenarios to the proposed saltmarsh restoration project that could then be considered the baseline scenario (i.e., the baseline may not always be the current land-use). These all need to be credible and realistic alternative suggestions that could occur in the absence and time frame of the restoration project, drawing on sources such as land use records, field surveys, data and feedback from stakeholders, and information from other appropriate sources. Three alternative land-use scenarios for typical UK saltmarsh restoration are identified as the following, although this will need to be considered by each project specifically:

1. Continuation of the pre-project land use (this scenario needs to always be included)
2. Restoration is carried out without being registered with a voluntary carbon market code or standard. This may be the case where it is mandated by law, for example for compensatory habitat
3. Accidental breach of sea walls/defences, for example due to storm damage, and subsequent transition to saltmarsh habitat on land reconnected to the tide

Step 2. Barrier analysis to identify if any of the alternative land-use scenarios suggested could not occur due to a range of barriers. These are listed here, but the methodology does make a point of stating there could be others. Full details can be found in the AR-Tool02 guidance:

- Investment (other than insufficient financial returns)
- Institutional
- Technological
- Local tradition (cultural)
- Prevailing practice
- Local ecological conditions
- Social
- Land tenure, ownership, property rights

Of those listed, the most likely barriers for UK projects are due to, lack of investment or access to credit in the case of restoration going ahead without being registered with a voluntary carbon market code or standard; land ownership in the case of accidental breaches of sea walls allowing the natural development of saltmarsh habitat; and social conditions in the case of continuing the pre-project land use, especially if used commercially due to increased demand on land area in general.

Step 3. Investment analysis serves to determine which of the remaining land-use scenarios (after step 2) is the most economically or financially attractive within the boundary of the proposed project area. This involves determining an appropriate analysis method – examples used in the tool are cost analysis, investment comparison analysis, or benchmark analysis; calculating and comparing these financial indicators; and including a sensitivity analysis to assess robustness of conclusions.

Step 4. Common practice analysis of the extent to which saltmarsh restoration projects have already been undertaken in the proposed geographical area. Included here is analysis as to how similar projects have been implemented previously or are currently underway. A comparison between projects that have already happened, and the proposed project needs to determine if there are 'essential distinctions' between them, which may include the circumstances in which they were implemented. Within a UK context, the funding stream for restoration projects will be the most obvious distinction. The majority of saltmarsh restoration to date has been to create compensatory habitat for damage to designated sites, or flood risk management. Around half of the UK's MR schemes to date have been funded through developer contributions to compensate for damage (Armstrong et al., 2021). If a project has flood defence potential, it may be eligible for funding through Flood & Coastal Erosion Risk Management Grant in Aid partnership funding.

If within Step 4 similar activities can be observed and essential distinctions between the proposed project and similar activities can be made, then the proposed project cannot be considered the baseline scenario. All restoration projects in the UK to date have had different sources of funding, and no project has been registered under the VCS standard. Therefore, one of the alternative land-use scenarios identified which remains after barrier (step 2) and investment (step 3) analysis would be classed as the most appropriate baseline scenario.

4.7 Quantification of GHG emission reductions and removals

GHG emissions reductions and removals need to be quantified for both the baseline and project scenarios. VM0033 provides detailed guidance on how to quantify carbon stock changes, in biomass carbon pools, soil processes, and where relevant, fossil fuel use. The advice is summarised in Table 7. In both the baseline and project scenarios, there needs to be a deduction for allochthonous carbon when quantifying CO_2 emissions from soil (section 4.7.3), and sea level rise needs to be accounted for (section 4.7.2).

Methodologies for data and parameters needed at the point of project validation, and for continued monitoring are outlined within VM0033 section 9. As the guidance is designed to be applicable worldwide, and for a range of habitats, we have reviewed all methods presented to assess which are most applicable to saltmarsh restoration by MR in the UK (section 4.8) and commented on the level of expertise required for application.

The net GHG emission reduction or removal within the VM0033 methodology is calculated using the following equation:

$NER_{RWE} = GHG_{BSL} – GHG_{WPS} + FRP – GHG_{LK}$

Where:

NER_{RWE}	= Net CO_2e emission reductions from the project activity; t CO_2e
GHG_{BSL}	= Net CO_2e emissions in the baseline scenario; t CO_2e
GHG_{WPS}	= Net CO_2e emissions in the project scenario; t CO_2e
FRP	= Fire Reduction Premium (net CO_2e emission reductions from organic soil combustion due to rewetting and fire management); t CO_2e
GHG_{LK}	=Net CO_2e emissions due to leakage; t CO_2e

It should also be noted that for projects where sea level rise may cause a loss of saltmarsh area and associated biomass and/or soil organic carbon stocks, the maximum quantity of GHG emission reductions or removals that may be claimed from the biomass and soil organic carbon pool is limited to the net GHG benefit generated by the project 100 years after its start date.

The VM0033 methodology is flexible in its approach to data types, allowing the use of local published values, proxies (a parameter that is monitored or measured to determine the value of a strongly correlated parameter that is not monitored or measured), peer-reviewed models, and default emissions factors (a coefficient which allows conversion of activity data into GHG emissions. It is the average emission rate of a given source, relative to units of activity or process/processes). It is suggested data is sought in this order, and to use defaults as a last resort. This flexibility means the VM0033 methodology can be applied in the most accurate and relevant way for projects with varying levels of financial support, and in countries or areas with varying levels of knowledge and data resources. In the UK, the two current domestic codes (Peatland Code and Woodland Carbon Code) have developed proxies and emission factors to estimate carbon gain or loss. This has the benefit of making MRV cheaper, and removes a potential hurdle to projects entering the codes. The same approach could be used for saltmarsh restoration in the UK using the VM0033 methodology.

Both the baseline and project scenarios use the VCS module “VMD0019 Methods to Project Future Conditions” (The Earth Partners LLC, 2012) to assist in projecting the future GHG pools and emissions. It takes into account variables (either controlled, planned, or systemic) that have been identified as having a significant influence on the future GHG emissions, and guides the reader through a sequence of steps to project the future conditions of these variables, to then project future GHG emissions. There are other considerations that may also need future ‘values’ estimating as they may have an impact on GHG emissions. These include market factors to project future demand for a particular commodity (when assessing the rate at which production of that commodity would grow within the project area); human and cultural factors, for example what a particular farmer would do on a property in the future, based on that farmer's needs and desires; biological and related factors such as the impact of climate change related weather changes.

In addition to the summary in Table 7, the methodology outlines four main driving factors likely to affect the change in the baseline scenario over a 100-year time period that are relevant for GHG accounting, and gives advice as to how these should be accounted for:

- Initial land use and development patterns: Assumptions and trends about likely future development of the project area must be documented and considered. Current development patterns and plausible future land-use changes must be mapped. Particular attention must be paid to existing or future construction of barriers to tidal/river hydrology, sediment supply, and ability to migrate landwards with sea level rise.
- Initial infrastructure that impedes natural tidal hydrology: the baseline scenario must take into account and map the current and historic layout of any tidal barriers and drainage systems, covering at least the 20 years prior to the project start date. The effect of these on current hydrological functioning of the project area must be assessed.
- Natural plant succession for the physiographic region of the project: Based on the assessment of changes in water table depth, a time series of future vegetation composition must be derived
- Climate variables: Areas of inundation and erosion within the project area must be considered in relation to the above three factors

Table 7: Summary of GHG emissions to account for in the baseline and project scenarios. Taken from VM0033.

GHG emissions resulting from	Sub category	GHG emission estimates are based on
Accounting for sea level rise		Robust evidence for sea-level rise estimates themselves, then either proxies, or through the use of literature, data, default factors, or models for the estimation of GHG emission resulting from it (as in the case of emissions from eroded soil)
Net carbon stock change in biomass carbon pools	Trees and shrubs Herbaceous vegetation	Carbon stock changes
Net GHG emissions from soil	CO_2 emissions from soil – in situ (includes deductions for allochthonous carbon) CO_2 Emissions from Eroded Soil CO_2 Emissions from Soil Exposed to an Aerobic Environment Through Excavation CH_4 emissions from soil N_2O emissions from soil	Either proxies (e.g., carbon stock change, water table depth), or through the use of literature, data, default factors, or models. A note on CH_4 and N_2O emissions: These may be conservatively excluded where conditions in the baseline and project scenarios will not be different or will decline.
Net non-CO_2 emissions from prescribed burning (project scenario only)		Not applicable to UK saltmarsh restoration

Emissions from fossil fuel use	Direct method: assumes availability of data on the amount of fuel combusted Indirect method: Uses other data, such as total mass transported by vehicle type, total travel distance, fuel type used, etc, in an equation to estimate. Default values can be used to substitute some data requirements if they are unknown.

4.7.1 Emissions from fossil fuel use

The AR-Tool05 “Estimation of GHG emissions related to fossil fuel combustion in A/R CDM project activities” allows for estimations of increases in GHG emissions related to fossil fuel combustion in vehicles and mechanical equipment when restoring a habitat. The tool includes a direct method which assumes availability of data on the amount of fuel combusted, and an indirect method where fuel consumption cannot be monitored by the project, or when they need to be predicted ahead of time. The indirect method uses data such as total mass transported by vehicle type, total travel distance, fuel type used, and calorific value of fuel. Default values can be used to substitute some data requirements if they are unknown. For the UK, the EA has developed a Carbon Modelling Tool (Carbon Modelling Tool’ Lit 14605 v7.4. Environment Agency, 2022) to enable estimation of carbon emissions from embankment construction at the strategic outline business case/feasibility stage of developing MR projects. Further detail about this is available in Appendix 2.

For the development of the business case (section 5), carbon emissions from undertaking saltmarsh restoration have been assumed at 10% of gross emission reductions, as per the Peatland Code, and as outlined in section 5.3.1.

4.7.2 Accounting for sea-level rise

Sea-level rise needs to be taken account of (as explained in Table 4 when defining the project boundary) due to the risk of the restored habitat becomes submerged during the project lifetime, or up to 100 years after the project start date. The consequences of submergence included in the methodology are:

1. Oxidation of aboveground biomass, where it is assumed all carbon is immediately returned to the atmosphere.
2. The potential for carbon stock in the soil to be eroded and transported out of the project area. This will depend on the rate and how the habitat is submerged. For slower ‘drown out’ it can be assumed the soil carbon pool is left intact, or loss is insignificant, and will remain under water and not return to the atmosphere. However, in areas with wave action there could be erosion with carbon removed. In this case, estimation of resulting GHG emissions is the same as for eroding soil.

Calculations for both these considerations are given, and guidelines to consider how a restoration project may be designed in such a way to mitigate against the chance of submergence/erosion compared to the baseline. In the UK, the greatest rates of sea level rise will be experienced in the south of England, due to continued post-glacial rebound with Scotland rising and southern England sinking. Therefore, mitigation measures to reduce the risk of new habitat becoming submerged or eroding are of more import for the south of the UK then the North. Current estimates to 2100 (UKCP18 marine projections – Palmer et al. (2018)) are between 0.29m –

1.15m for southern England, and 0.08m – 0.9m for Scotland representative concentration pathways climate change scenarios of 2.6, 4.5, and 8.5).

4.7.3 Deductions for allochthonous carbon

Blue carbon is divided into two types: autochthonous – carbon originating from within the project area, and allochthonous – carbon originating from outside the project area and then deposited within. All autochthonous carbon is considered to be 'credit-worthy' for a project. Allochthonous carbon is only considered to be worthy of credits for a project if it can be demonstrated it would have been returned to the atmosphere in the absence of the project. There is further guidance for the adjustments needed to take account of allochthonous carbon in Coastal Blue Carbon in Practise: A Manual for Using the VCS Methodology for Tidal Wetland and Seagrass Restoration VM0033 (Emmer et al., 2015).

The deduction for allochthonous carbon must only be applied to soil layers deposited or accumulated after the project start date. The methodology states there is one situation (applicable to saltmarsh habitat) where a project may assume that allochthonous carbon is zero: for organic soils (defined as having an organic surface layer that exceeds 10 cm). It is assumed that allochthonous carbon is very low because such soils receive little surface deposition of mineral-associated carbon. For projects with mineral soils the methodology explains the need to estimate a deduction for allochthonous carbon, and gives options for how to do this:

- Using default values (listed in methodology)
- Measured through analysis of field-collected surface soil cores and analysed for soil carbon or organic matter (the most straight-forward method of primary data collection)
- Sediment tiles to measure deposited sediment carbon or organic matter
- Collection of suspended sediments in tidal channels or sediments deposits in tidal flats, and analysed for sediment carbon or organic matter
- A quantitative model may be used if the modelled values are verified with direct measurements from a system with similar water table depth and dynamics, salinity, and plant community type as the project area. The model must be accepted by the scientific community as shown by publication in a peer-reviewed journal and repeated application to different wetland systems

If collecting primary data, equations are provided to estimate the deduction for allochthonous carbon from the measured values. The equation presented for marsh soils incorporates the equation in Craft et al. (1991), which describes the relationship between organic carbon and organic matter using the Loss on Ignition (LOI) technique, rather than elemental analysis. The LOI method has been widely used within the literature ever since, but the applicability of common conversion factors to UK marshes (Craft et al. (1991) is based on data from Southeast US marshes) has been questioned. There now exists a conversion factor based solely on data from UK saltmarshes (Austin et al., 2022). Therefore, this methodology for making deductions for allochthonous carbon could be made to be more specific, and therefore more relevant to a UK context.

For the illustrative investment case within the current project, we have aligned with IPCC guidelines for inclusion of tidal marsh in national GHG inventories (IPCC, 2014) and assumed no 'credit worthy' carbon accumulation until at least 10% of the project area is covered by saltmarsh vegetation (section 5.3.1). This, in part, takes account of the greater amount of allochthonous carbon accumulated within restoration sites whilst they are transitioning from their former land use into saltmarsh habitat, although it is likely this will result in an overestimation as sediment will continue to be imported with the tide. This rule is applied here in the absence of any more precise, or complete information.

4.7.4 Estimation of uncertainty

There is also guidance for calculating uncertainty, focussing on two sources: that associated with estimation of stocks in carbon pools and changes to these over time; and uncertainty associated with assessment of emissions. Uncertainty values can either be from default factors (the example given in the methodology being those given in IPCC guidelines), expert judgment, or estimates based of sound statistical sampling. Where an uncertainty value is not known or cannot be calculated, conservative estimates may also be used instead of uncertainties. A precision target of a 90% or 95% confidence interval equal to or less than 20% or 30%, respectively, of the recorded value must be targeted for all aspects of baseline and project scenarios, and monitoring methodologies.

It is good practise to plan to diminish uncertainty. Activities such as stratification of the project area (explained in section 4.5) will help reduce uncertainty by allowing more specific carbon removal estimates to be used for specific areas. Data sources (or strata) with the highest uncertainty can also be targeted with further work.

4.8 Monitoring methods review

The VM0033 methodology outlines monitoring procedures (section 9 of VM0033 document) to quantify net GHG emission reductions and removals resulting from project activities implemented to restore tidal wetlands anywhere in the world. Due to this global applicability to a wide range of habitats, there is redundancy in this monitoring guidance when considering UK saltmarsh restoration only. Here we have reviewed all monitoring methods presented to assess which are most applicable to the UK context (Table 8). This review relies on expert opinion and evaluates each according to its relevance to UK saltmarsh habitats (High/Medium/Low – for example, estimating aboveground tree biomass is highly relevant in a mangrove habitat, but is of less value in most UK saltmarsh settings and has therefore been scored as Low relevance), and in terms of the level of expertise required for implementation, where:

- HIGH = scientific competence needed to measure, analyse, model and interpret site-specific and secondary data sources
- MEDIUM = scientific competence needed to measure and interpret site-specific and secondary data sources (using external expert inputs to analyse and model data)
- LOW = competence needed only to make certain site-specific measurements (under direction from external experts). We have also linked these methods to the summary presented in Table 7 of GHG emissions categories that need to be accounted for both in the baseline and project scenarios.

We found many of the methods applicable to a UK context (especially due to the flexible approach to data types that can be used – as described in section 4.7). Of the 59 methods presented, we classed 34 of high relevance, 6 as medium, and 19 as low. The indicative level of expertise required to apply the method serves also as an indication of costs, especially where direct measurements are needed. Out of those methods of high and medium relevance to UK saltmarsh restoration, half require a high level of scientific competence to measure, analyse, and model data outcomes. A potential hurdle to projects entering a code is cost, so anything that can be done to reduce costs to projects is beneficial for code uptake. The level of expertise needed to deliver VM0033 highlights the benefits of developing lower cost proxy measures, or emission factors (EFs) to estimate carbon gain or loss – as is standard practice in the two current domestic codes. As more data and understanding of carbon processes in saltmarsh becomes available, the development of EFs will become more achievable. For calculating emissions from the identified baseline scenario, EFs used for the Land Use, Land-Use Change and Forestry (LULUCF) sector of the UK Greenhouse Gas Inventory (UKGHGI) could potentially be used. Investigating the potential of this approach would be a useful next step.

Table 8: Review of monitoring data and parameter needs outlined in VM0033 at a) validation, and b) during monitoring. Ordered by relevance to quantification of GHG emissions in a UK context. Please note, only methods reviewed to have high and medium relevance presented here (19 were considered of low relevance).

a) Data and Parameters Available at Validation	Page Number in VM0033	Relevance to UK context	Expertise Required	Table 7 Category
Average organic soil depth above the drainage limit in stratum i at the project start date.	65	HIGH	MEDIUM	Net GHG emissions from soil
Rate of organic soil loss due to subsidence and fire in the baseline scenario in stratum i; a conservative (high) value must be applied that remains constant over the time from t = 0 to PDT.	66	HIGH	HIGH	Net GHG emissions from soil
Rate of organic soil loss due to subsidence in the project scenario in stratum i in year t.	67	HIGH	HIGH	Net GHG emissions from soil
Rate of organic carbon loss in mineral soil due to oxidation in the baseline scenario in stratum i in year t.	68	HIGH	HIGH	Net GHG emissions from soil
Rate of organic carbon loss in mineral soil due to oxidation in the project scenario in stratum i in year t.	69	HIGH	HIGH	Net GHG emissions from soil
Rate of organic soil loss due to subsidence in the baseline scenario in stratum i.	70	HIGH	HIGH	Net GHG emissions from soil
Soil organic carbon stock in the baseline scenario in stratum i in year t.	72	HIGH	HIGH	Net GHG emissions from soil
Mineral soil depth in stratum i at the project start date.	72	HIGH	MEDIUM	Net GHG emissions from soil
Volumetric organic carbon content of organic or mineral soil.	73	HIGH	HIGH	Net GHG emissions from soil
Area of baseline stratum i (in year t).	73	HIGH	MEDIUM	
Carbon stock in herbaceous vegetation in the baseline scenario in stratum i in year t.	74	HIGH	MEDIUM	Net carbon stock change in biomass carbon pools

CO_2 emissions from the SOC pool of in-situ soils in the baseline scenario in stratum i in year t.	75	HIGH	HIGH	Net GHG emissions from soil
Organic carbon loss due to oxidation, as a percentage of C mass present in in-situ soil material in the baseline scenario in stratum i in year t.	75	HIGH	HIGH	Net GHG emissions from soil Accounting for sea-level rise
Organic carbon loss due to oxidation, as a percentage of C mass present in eroded soil material in the baseline scenario in stratum i in year t.	75	HIGH	HIGH	Net GHG emissions from soil Accounting for sea-level rise
Percentage of carbon of in-situ soil material in stratum i in year t.	76	HIGH	MEDIUM	Net GHG emissions from soil
Depth of in-situ exposed soil in the baseline scenario in stratum i in year t.	77	HIGH	MEDIUM	Net GHG emissions from soil
Proportion of an area covered by the herbaceous vegetation, shrubs, and/or the crowns of live trees.	77	HIGH	LOW	Net carbon stock change in biomass carbon pools
Percentage of soil organic C.	78	HIGH	HIGH	Net GHG emissions from soil
Dry bulk density.	79	HIGH	MEDIUM	Net GHG emissions from soil
CO_2 emissions from the eroded SOC pool in the baseline scenario in stratum i in year t.	81	HIGH	HIGH	Net GHG emissions from soil Accounting for sea-level rise
C mass present in eroded soil material in the baseline scenario in stratum i in year t.	82	HIGH	HIGH	Net GHG emissions from soil Accounting for sea-level rise
Percentage of carbon of soil material eroded in the baseline scenario.	82	HIGH	HIGH	Net GHG emissions from soil Accounting for sea-level rise
Depth of the eroded area from the surface to the surface prior to erosion in the baseline scenario in stratum i in year t.	83	HIGH	MEDIUM	Net GHG emissions from soil Accounting for sea-level rise

CO_2 emissions from the SOC pool of tidal wetland soil exposed to an aerobic environment in the baseline scenario in stratum i in year t.	83	HIGH	HIGH	Net GHG emissions from soil
Allowable uncertainty; 20% or 30% at a 90% or 95% confidence level, respectively.	86	HIGH	HIGH	N/A
Global Warming Potential of CH_4.	93	HIGH	MEDIUM	Net GHG emissions from soil
Global Warming Potential of N_2O.	94	HIGH	MEDIUM	Net GHG emissions from soil
Percentage of soil that is organic matter.	78	MEDIUM	MEDIUM	Net GHG emissions from soil
Percentage of deposited sediment that is organic matter.	79	MEDIUM	HIGH	Net GHG emissions from soil
Percentage of deposited sediment that is organic C; %. This is on sediment traps, not cores.	80	MEDIUM	HIGH	Net GHG emissions from soil
Average Surface Area (SA) of the sediment.	81	MEDIUM	MEDIUM	Net GHG emissions from soil

b) Data and Parameters Monitored	**Page Number in VM0033**	**Relevance to UK context**	**Expertise Required**	**Table 7 Category**
Area of project stratum i (in year t).	97	HIGH	MEDIUM	
Percentage of soil organic C.	98	HIGH	MEDIUM	Net GHG emissions from soil
Dry bulk density.	99	HIGH	MEDIUM	Net GHG emissions from soil
Proportion of an area covered by the herbaceous vegetation, shrubs, and/or the crowns of live trees.	99	HIGH	LOW	Net carbon stock change in biomass pools
Percentage of carbon in deposited sediment; %.	101	HIGH	MEDIUM	Net GHG emissions from soil
CO_2 emissions from fossil fuel combustion during the year y; t CO_2 yr^{-1}.	102	HIGH	MEDIUM	Emissions from fossil fuel use
Total uncertainty for project activity.	102	HIGH	HIGH	N/A
Percentage of soil that is organic matter.	97	MEDIUM	MEDIUM	Net GHG emissions from soil
Percentage of deposited sediment that is organic matter.	100	MEDIUM	MEDIUM	Net GHG emissions from soil

5. Financing Considerations for Developing a Business Case for Saltmarsh Restoration

This section aims to assess the commercial viability for saltmarsh restoration in the UK and to explore the role carbon revenues could play in supporting private investment to help fund the delivery of saltmarsh restoration. The analysis of VM0033 in section 4 shows this existing methodology could be applied to the UK. The confirmation that an existing global code could work provides evidence for broader support that carbon could be a suitable revenue stream from saltmarsh restoration projects.
Two sites were selected for which high-level business cases have been built in order to understand the commercial potential for carbon finance in the UK. Of these, one site has already been delivered (Steart Marshes) and provides an opportunity to look back at whether carbon finance could have raised enough funds for the restoration project. Including a site that has already been restored also has the benefit of known prices for the restoration phase, constraining some uncertainty with the finance modelling. The other site (Old Hall Marshes) represents a prospective investment and provides an opportunity to demonstrate how much of the total cost of restoration could be raised by carbon finance. This analysis assumes both sites are deemed eligible under the VM0033 criteria, and is focused on the potential revenues from the sale of saltmarsh carbon credits alongside costs for restoration, maintenance, validation and verification. These costs are based on general application of carbon codes and site-specific data, as well as several assumptions where no data is available yet.

With respect to VM0033, an options assessment was performed to understand the validation and verification-related costs (including preparation of project design documents, validation and ongoing verification), and the implications for projects between adopting VM0033 and developing a UK domestic Saltmarsh Code' (i.e., a saltmarsh equivalent of the Woodland Carbon Code and the Peatland Code, which both apply to the UK).

It is important to caveat the limited data availability and the uncertainty around CO_2e accumulation and sequestration rates from the pilot sites chosen, and the UK in general. As per the systematic review undertaken as part of this NEIRF project (Mason et al., 2022), data is scarce, and methodology and reporting is inconsistent across studies making it difficult to collate knowledge. Moreover, further work is required into the treatment and quantification of (i) allochthonous carbon, (ii) GHG emissions from undertaking saltmarsh restoration and (iii) risk buffer, a pool of 'unclaimed units' to cover unforeseeable losses that may occur over time as a result of restoration reversal. Hence, a range (high, medium and low) of CO_2e accumulation rates has been considered for both pilot sites in the financial analysis based on the historical data and Burden et al. (2019) model (further detail in section 5.1). In addition, since there have been no transactions of saltmarsh carbon credits in the UK, there is significant uncertainty around pricing. Publicly available data for transactions in UK woodland and peatland carbon credits have been used to inform price estimates for these potential saltmarsh carbon credits.

With respect to restoration costs, estimating these for large engineering schemes such as most MRs, requires extensive site-based data analysis and feasibility studies, including ground and hydrological investigation. Costs can vary due to unexpected ground conditions, heritage, or environmental issues, even when the restoration work has begun. To date, scheme costs have varied significantly due to multiple site-specific factors such as ground conditions, design complexity and requirement for secondary compensation. ABPmer (2015) quotes values of <£800/ha to over £123,000/ha (2014 prices) for schemes constructed between 1991 and 2015[9]. In recent years, restoration costs have risen significantly due to higher inflationary pressures meaning that earlier delivery costs/hectare are no longer appropriate for today's conditions.

5.1 Data used for estimation of emission reductions and removals in pilot sites

For the development of the business case, carbon sequestration estimates for the two pilot sites have been based on CO_2e accumulation rates using the Burden et al. (2019) model. This model estimates total carbon accumulation over time, and as such does not take account of inorganic, or allochthonous carbon. It is used here in the absence of more precise, complete information, and has also been used in an IUCN (2021) feasibility study for the preparation of Blue Carbon offsetting projects in Spain for the same reason. This model is based on data from the Essex coastline, with data taken from restored saltmarshes of different 'ages' (years since reconnection to tidal flow), natural sites, and pre-restoration land-use in close proximity to the restored sites. This range of data allows for predictions of saltmarsh development over time using a space for time proxy. The pre-restoration land-use and natural saltmarsh sites were used as 'start' and 'end' points to constrain the model, with the various age of marsh (16-114 years at time of sampling) presenting the trajectory of change in between. Accretion rates used in the model were also taken from an Essex saltmarsh, with 12 years' worth of data since restoration of the site (Garbutt, 2018). The model results in total carbon accumulation estimates over time up to 150 years after restoration (presented as average, and upper and lower

[9] Excluding the outlier for the 0.4ha urban managed realignment site at Barking Creek in London.

as an indication of uncertainty – where lowest and highest observations of %C and bulk density have been used to parameterise the model). This range of estimates forms the basis of lower, average and upper assumptions for the Old Hall Marshes pilot sites (Table 9). A similar approach was taken to estimate total carbon accumulation over time at Steart Marshes. Mossman et al. (2022) collected data at the sites for the first four years after restoration and here we have used the site-specific sedimentation rate, change in sediment depth, bulk density, and total carbon % in a similar model structure to estimate the total carbon accumulation rate. We then used a range of accretion rates (3.3 and 4.65mm: Allen and Duffy, 1998; 10.5mm: Allen and Rae, 1988) for the Severn estuary to extrapolate over time, as an indication of uncertainty (Table 9).

Table 9: CO_2e accumulation range for pilot sites based on the Burden et al. (2019) model. Old Hall Marshes includes lower, average, and upper modelled estimates of total carbon accumulation. Steart Marshes includes estimates based on 3 accretion rates (mm per year), to provide an indication of uncertainty. Orange shading = Selected for business case

Old Hall Marshes				Steart Marshes			
CO_2e accumulation range (tCO_2e/ha/yr)				CO_2e accumulation range (tCO_2e/ha/yr)			
Time Period	**LOWER**	**AVERAGE**	**UPPER**	**Time Period**	**3.3mm**	**4.65mm**	**10.5mm**
0-20 years	2.6	3.8	5.2	**0-20 years**	30.8	32.7	41.2
20-50 years	1.3	2.4	3.8	**20-50 years**	6.4	9.0	20.2
50-years	1.3	2.4	3.8	**50-years**	6.4	9.0	20.2

5.2 Key Project Characteristics

To analyse the commercial viability of sites, a set of base case assumptions have been made based on historical data (where available), and sensitivity tables have been run on the key variables to project various scenarios. In the next sections, key assumptions for revenues, cost and financing are discussed.

Figure 1 provides a summary of the two pilot sites.

Figure 1: Summary of pilot site characteristics

5.3 Revenues

Saltmarsh restoration generates a range of environmental and social benefits, including regulating ecosystem services (e.g., flood mitigation, carbon accumulation, water quality), provisioning ecosystem services (e.g., higher fish stocks due to the creation of breeding and fish nursery grounds) and cultural ecosystem services (e.g., health and well-being and tourism from recreational public access) (Hudson et al., 2021). In this project, the carbon sequestration revenue potential for saltmarsh MR was analysed in order to understand the potential role and significance of carbon income in attracting private investment.

5.3.1 CO_2e Accumulation Range

The systematic review undertaken as part of the NEIRF project (Mason et al., 2022) did not provide evidence to determine proxy measures to allow the development of easy metrics and/or emission factors to determine carbon sequestration rates at UK restoration sites (as is used in the Peatland Code and Woodland Carbon Code). As a result, a model (Burden et al., 2019) has been used to estimate total CO_2e accumulation rates over time at both pilot sites. This model is further explained in

section 5.1. The model has previously been used in the IUCN (2021) “Feasibility Study for the preparation of blue carbon offsetting projects in Andalucia, Spain”.

The typical ‘carbon curve’ for saltmarsh sites includes higher rates of accumulation in the first 20 years post-restoration before reducing to a lower, stable level. For some sites, this reduction in annual accumulation rate will happen even sooner, depending on site specific conditions. A 100-year project period has been assumed including maintenance and management activities being undertaken throughout, as a reasonable long term time frame over which site performance and management costs can be reasonably estimated. Creditable CO_2e accumulation on the sites has been assumed to commence from when plant cover extends over at least 10% of the overall area, in line with IPCC guidelines for inclusion of tidal marsh in national GHG inventories (IPCC, 2014). This is, in part, to take account of the greater amount of allochthonous carbon accumulated within restoration sites whilst they are transitioning from their former land use into saltmarsh habitat. For the illustrative investment cases presented here, it has been assumed this will take approximately two years following completion of restoration.

Given the uncertainty regarding CO_2e accumulation rates for different saltmarsh sites, the financial model includes a range of potential accumulation rates. Under the base case scenario for Old Hall Marshes, the modelled upper CO_2e accumulation range (5.2t CO_2e/ha/yr until year 20, 3.8tCO_2e/ha/yr from year 21 to year 100) has been used for the purposes of the assessment to represent a site with maximum commercial potential in a region with relatively lower overall accumulation rates (Blackwater estuary, Essex).

For Steart Marshes where accumulation rates are estimated to be significantly higher, the average range (32.7t CO_2e/ha/yr until year 20, 9.0tCO_2e/ha/yr from year 21 to year 100) is assumed as the base case for the assessment, based on annual accretion rates of 4.65mm, slightly above sea level rise of 3.3mm.[10]

Table 10 details CO_2e accumulation estimates across all ranges. Given the uncertainty regarding the accuracy of CO_2e accumulation rates as well as GHG emissions from undertaking saltmarsh restoration activities, contingencies have been applied to the total number of marketable carbon credits in the model in the form of a 10% ‘Precision Buffer’ followed by a 15% ‘Risk Buffer’, based on the approach and levels required in the Peatland Code.

Further thought is required into what the appropriate calculation method should be for the estimation of GHG emissions from saltmarsh restoration. For example, the EA

[10] Accretion rates below sea level are deemed unlikely as this would imply that the saltmarsh is inundated, whilst significantly higher accretion rates are also unlikely as saltmarshes are typically not significantly higher than the average sea level.

has developed a Carbon Modelling Tool, however the current version does not allow for the determination of GHG emissions from ground works when locally sourced material is used in the construction phase. With respect to the risk buffer, VM0033 stipulates a variable risk buffer based on the AFOLU Non-Permanence Risk Tool. Within this project a flat 15% buffer has been assumed based on the Peatland Code to simplify the illustrative business model developed here. In the next phase of the development of the UK Saltmarsh Code, further guidance will need to be developed both for accounting for emissions from the restoration activities and on how to measure the risk buffer.

5.3.2 Carbon Pricing and Sale Strategy

For the purposes of the assessment, saltmarsh carbon credits have been priced towards the upper range based on estimates from the peatland and woodland markets in the UK, taking into consideration the wider benefits beyond carbon that are generated from saltmarsh restoration projects. Based on anecdotal evidence of “premium” pricing for ‘charismatic carbon’ projects (e.g., Trees for Life sales at £50 for a Pending Issuing Unit (PIU), Wilder Carbon demand at £75/PIU, Wildland demand at £60/PIU), a price of £60 per saltmarsh carbon credit rising at 1% real growth and a nominal price cap of £150 per saltmarsh carbon credit has been assumed in the model. It is worth noting that this price cap is considered by Finance Earth to be a conservative assumption, given the recent significant increases in voluntary carbon prices in the UK and globally, and the long-term demand drivers. The cap is reached around 2050, by which time, applying a 2% discount rate to reflect NPV, a £150 carbon credit is worth £84 in today’s money. By 2120, towards the final years of the project’s lifetime, a £150 credit is worth just over £20 today applying the same (low) discount rate. The sale of credits is assumed to incur a 3% fee at every sale point representing transaction brokerage fees.

The assumed sale strategy comprises selling only verified carbon units (ex-post) and not PIUs (ex-ante, i.e., in advance of saltmarsh restoration) given risks to market integrity and sustainability identified with selling ex-ante units, which include:

1. Increased risk to long-term project viability as by selling ex-ante units at the start of a project, a project reduces or removes the means by which it can raise additional income to cover unforeseen costs (e.g., high inflation) in the (potentially very distant) future;
2. Increased risk of greenwashing, since selling ex-ante units reduces or removes the means by which projects can assert control over the end retiree of the underlying credits, should the buyer become an irresponsible off-setter between the time of purchasing a PIU and the PIU converting to a verified unit; and

3. Reduced/eliminated ability of projects to receive benefits from future increases in carbon prices that could otherwise be used to enhance social and/or environmental benefits generated by the site.

It should also be noted that international voluntary carbon markets do not currently allow for the sale of ex-ante credits.

5.3.3 Overview – Revenue Base Case Assumptions

Table 10: Overview – Carbon Revenues Base Case Assumptions

Assumptions	Old Hall Marshes	Steart Marshes	Sources
Size	72 ha	255 ha	RSPB & WWT
Start of creditable carbon accumulation*	Year 3	Year 4	IPCC [WWT & Jacobs]
Project duration	100 years		Finance Earth
CO_2e accumulation range	Upper	Average	UKCEH Model (based on Burden et al., 2019)
CO_2e accumulation (0-20 yrs)	5.2 tC0$_2$e/ha/yr	32.7 tCO_2e/ha/yr	
CO_2e accumulation (20-100 yrs)	3.8 tCO_2e/ha/yr	9.0 tCO_2e/ha/yr	
Source Emissions	10% Precision Buffer		Peatland Code
Risk Buffer	15% Risk Buffer		Peatland Code
Verified UK Carbon pricing	£60/tCO_2e rising at 3.5% (nominal rate, 1% real + 2.5% inflation) with a nominal cap of £150/tCO_2e		FE
Selling strategy	Verified units only (no PIUs)		FE
Cost of Sales	3% of sales		FE

* Start of creditable carbon accumulation presumed to be when 10% of the area is vegetated, which has been estimated her to be two years after restoration activities have been completed. Restoration is assumed to take place in year 1 for Old Hall Marshes, and years 1 and 2 for Steart Marshes. Creditable carbon accumulation therefore starts in year 3 for Old Hall marshes and year 4 for Steart Marshes.

5.4 Costs

The costs of a typical saltmarsh restoration project have been mapped against the key project phases, which are described by the EA in its Saltmarsh Restoration Handbook 2021, chapter 2 (Armstrong et al., 2021) and outlined in Figure 2. The restoration period for both sites varies as per the timelines provided by Jacobs, and they have been rounded up to calendar years to organise them into an annualised financial model.

5.4.1 Excluded Costs

Pre-restoration development costs, such as feasibility and impact assessments, project design considerations, stakeholder consultation and planning permissions have been excluded. It is unlikely that project developers will be able to raise private finance to fund these phases of the project at this very early stage of the saltmarsh carbon market's evolution. Projects at this initial stage of development, i.e., pre-"shovel-ready", have a much higher and different set of risks and thus would typically require a different type or set of investors, and in practice are likely to rely heavily or entirely on public and philanthropic sources. In line with project finance markets such as in renewable energy and other infrastructure markets, repayable finance has been modelled as being received at the point at which the project is "investment-ready", i.e., after development has been completed, the site is ready to be restored and only capital funding is required to commence restoration.

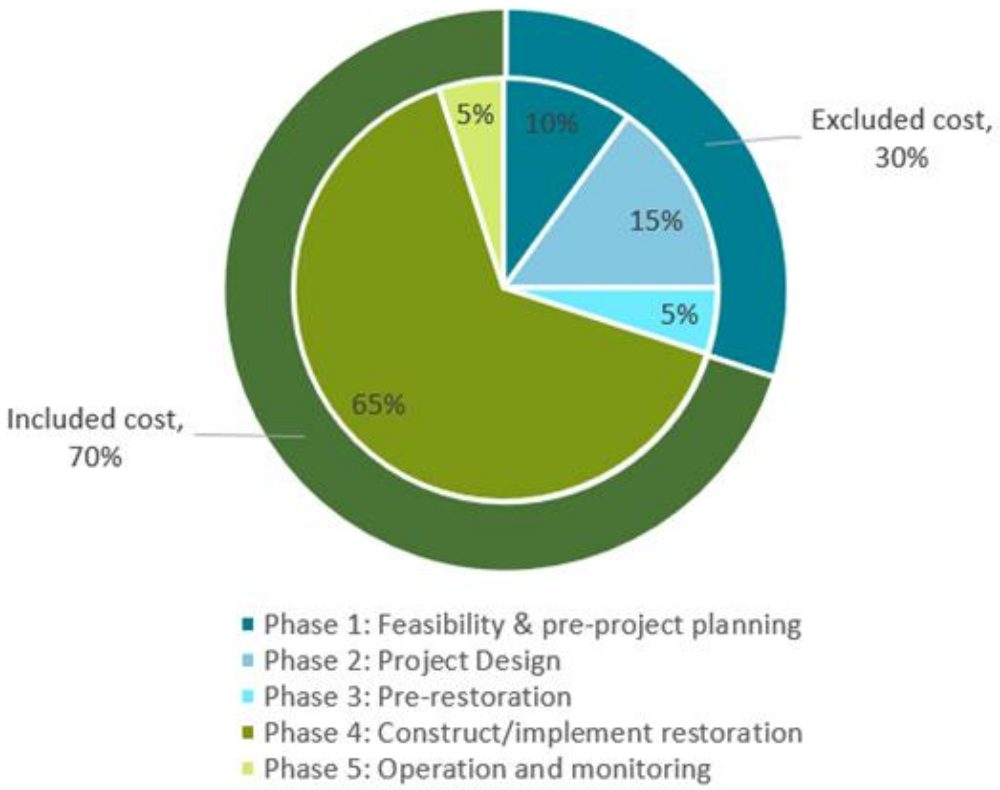

Figure 2: Lifetime cost estimates based on phases for Saltmarsh Restoration Jacobs (2022).

Land acquisition and lease payment costs have also been excluded from the financial model at this stage to ensure the exercise is relevant for sites where land has been donated or is already owned by the developer, such as at Old Hall Marshes. In practice, land-related costs can represent a significant proportion of lifetime costs.

Value Added Tax (VAT) has also been excluded from the calculations under the assumption that it can be recovered by the project or the project developer. If this is not the case, including VAT would add up to 20% to the modelled costs (for eligible items only).

5.4.2 Restoration and Maintenance Costs

For Old Hall Marshes, Jacobs assessed the potential options for undertaking MR on the site and presented two possible options as part of a high level, desktop-based feasibility study (Appendix 2):

- Option 1 – Build on top of the old embankment – To raise the internal bank to around 4.2 metres above Ordnance Datum (m AOD) from its current level of around 2.75 m AOD maintaining the 1 in 4 slope (and with a crest width of 4 metres) would require around 75,000 m^3 of fill.
- Option 2 – Build from scratch – To completely rebuild the internal embankment to 4.2 m AOD with 1 in 16 slope (and with a crest width of 4 metres) would require around 300,000m^3 of fill assuming a base level of 0 m AOD.

Total scheme costs are expected to be in the range of £60,000-£100,000/ha, of which 70% can be attributed to restoration, supervision, operation and monitoring. As described in section 5.4.1, the remaining 30% of costs relate to pre-restoration and have been excluded. Option 1 has been assumed as part of the base case scenario, with the lower end of the cost range (i.e., 70% of £60,000/ha = £42,000/ha) being used for the analysis to understand if the restoration is financially viable at this level. This assumes that in practice, costs may be reduced through further design refinement as well as engagement and negotiation with a range of suitably qualified contractors. Appendix 1 includes a sensitivity analysis and demonstrates the impact of a 30% increase in restoration costs.

For Steart Marshes, the total cost for the whole site (477ha) was approximately £11 million (excluding land-related costs)[11]. The MR accounts for 255ha of the site, and it is assumed to have proportional costs[12]. Additionally, it is important to note that the Steart Marshes restoration costs include some development costs that it has not been possible to identify and remove to make fully comparable to the Old Hall Marshes restoration cost. Based on interviews with project developers (RSPB, EWT and WWT) it is assumed that long-term maintenance costs of restored saltmarsh sites following a MR are £100/ha/yr from years 2-20 and £50/ha/yr for the remainder of the project period (both in 2022 prices and inflation-linked).

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[11] These figures have been inflated by 141%, as per the Office for Budget Responsibility March 2022 forecast between 1Q'12-3Q'22.

[12] 255ha/477ha * £11m * 141% (adjustment for inflation between Q1'12 - Q3'22) / 255ha = c. £33,000/ha

5.4.3 Validation and Verification Costs

A future UK Saltmarsh Code could either form part of an existing international standard or be developed independently as a UK-only and UK-specific code. The financial implications for projects based on the verification route chosen have been analysed by comparing the estimated costs of adhering to VM0033 (an existing methodology), with the costs of adhering to a UK domestic Saltmarsh Code (based on actual costs involved in the Peatland Code). Under the base case scenario, costs of adhering to a UK domestic Saltmarsh Code have been modelled to assess project viability, as these costs are significantly lower when compared to VM0033. An analysis of the financial implications for a project to adhere to VM0033 is provided in the section 6.3.

Based on costs associated with the Peatland Code, it is assumed that the project will incur total costs of £9,000 to develop a Project Design Document and independently validate the project. This will be followed by a cost of £2,000 (inflation-linked) at every verification point (assumed to be annual in the base case scenario). Detailed base case cost assumptions have been described in Table 11.

Table 11: Overview – Cost Base Case Assumptions.

Assumptions	Old Hall Marshes	Steart Marshes
Restoration period	Year 1	Years 1 to 2
Restoration cost option	Managed realignment	
Restoration cost (inc. construction)	42,000 £/ha	33,000 £/ha
Maintenance cost (2-20 yrs)	100 £/ha/yr	
Maintenance cost (21-100 yrs)	50 £/ha/yr	
Verification agency	UK domestic Saltmarsh Code	
Project Design document	£5,000 (one-off)	
Initial Validation Fee	£4,000 (one-off)	
Verification cost (by VVB)	£2,000 per verification	
Verification frequency	Annual	
Land	Land purchase or rental excluded	
Development	Pre-validation costs excluded	

Sources: Jacobs, WWT (MR only restoration cost data); Finance Earth. Other cost estimates based on Finance Earth advisory work relating to Peatland Code and other eNGO-led natural capital projects in the UK.

5.5 Financing

Given the nascent stage of the saltmarsh carbon market in the UK and the lack of comprehensive data on CO_2e accumulation rates, it is expected that impact and mission-aligned investors are more likely to be interested in investing in these projects than more mainstream, commercial investors and banks. Impact investors are those who make decisions on their investments based on the intention of generating both financial returns and positive environmental and/or social impact as opposed to commercial investors who make their investment decisions solely or predominantly based on the expectation of receiving a financial return. Given the relatively high-risk profile and volatile cashflow profile of these projects, repayable investment is more likely to take the form of equity rather than debt, which typically requires more stable, predictable cashflows.

The IRR is a common metric used in financial analysis to estimate the profitability of potential investments and reflects the discount rate at which the NPV of all cash flows equal zero in a DCF analysis. Investors typically compare a potential investee project's IRR against their internal cost of capital to assess whether a project is investable. We have used a benchmark IRR level of 10% for illustrative purposes in the following analysis to represent a minimum return level required to attract equity investment, although in practice the actual return requirement from equity investors will range from investor to investor and project to project, and may be much higher in many cases.

A 15-year investment period has been assumed in the model, which is much shorter than the project period of 100 years; as a purely ex-post selling strategy for carbon credits has been assumed to ensure market integrity (i.e., no PIUs are sold). As a result, at the point of the initial investor's exit in year 15, the project will have several decades of revenue potential remaining (as well as costs such as maintenance and verification). Therefore, to estimate the 'exit value' for the initial investor, a discount rate of 5% has been applied to all remaining (positive and negative) cashflows in the underlying project at the point of exit to calculate an NPV at year 15, which is then used in the IRR calculation. Detailed base case financing assumptions have been outlined in Table 12.

Table 12: Overview – Financing Base Case Assumptions.

Assumptions	Old Hall Marshes	Steart Marshes
Capital type	100% equity	
Target IRR	10%	
Expected investor exit	15 years	
Discount rate for cashflows post exit	5%	

Source: Finance Earth

6. Outputs of Financial Modelling and Analysis

Based on the base case assumptions laid out in the previous section as well as the expected investor criteria, this section presents the outputs of the financial modelling exercise to address the following key questions:

- **What role can private and public finance play in UK saltmarsh restoration projects** if saltmarsh carbon credits could be sold in the market on an ex-post basis and based on the latest available science for expected rates of carbon sequestration?
- **Is VM0033 a commercially viable carbon credit verification regime for UK saltmarsh restoration projects**, based on validation and verification cost estimates, and how does it compare in terms of affordability to a UK domestic Saltmarsh Code based on the Woodland Carbon Code and Peatland Code?

6.1 Timelines of Key Costs and Revenues

Both projects are assumed to have a 100-year time period starting at the point of restoration. Given the nascency of the UK saltmarsh carbon market, it is assumed that pre-restoration costs (including feasibility and technical designs, stakeholder consultations and planning approval processes) and land-related costs (including lease payments and acquisitions) are funded through grants and donations.

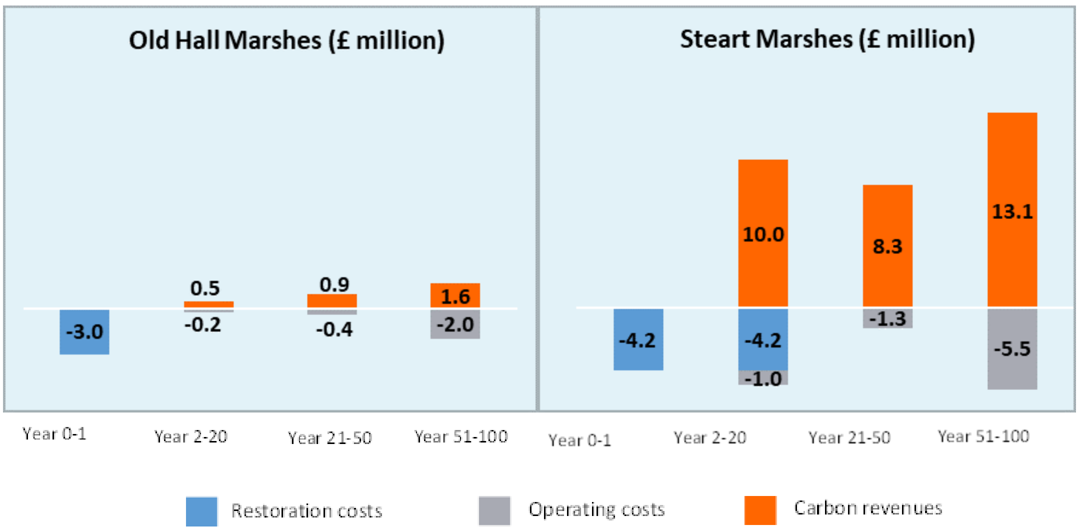

Figure 3: Timelines of key cost and revenues for Old Hall Marshes and Steart Marshes *(Note: figures are presented on an undiscounted basis. Source: Finance Earth)*

As shown in figure 3, carbon revenues may be able to cover ongoing maintenance costs for saltmarsh restoration projects. However, the timing of carbon revenues do not align with the upfront restoration costs, resulting in an upfront capital need that could potentially be met by private repayable finance.

6.2 What Role can Private and Public Finance Play?

To be investable, saltmarsh projects need to generate sufficient revenues to cover lifetime costs and meet the minimum return requirements of investors. Considering a scenario in which only carbon income is available, figure 4 implies neither Old Hall Marshes nor Steart Marshes are investable projects as their respective IRRs are significantly below the 10% threshold.

Scenario 1: Only Carbon Income with No Public Grant Funding

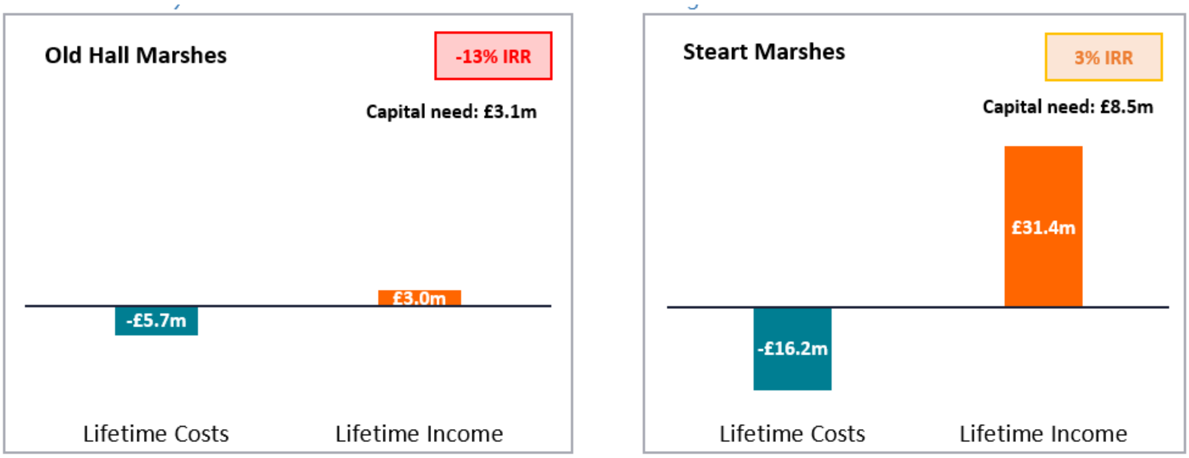

Figure 4: Scenario 1: Only Carbon Income with No Public Grant Funding *(Note: figures are presented on an undiscounted basis. Source: Finance Earth).*

Scenario 1 implies, in order to make the projects investable, carbon income needs to be supplemented with additional income streams such as grant funding. When an operational grant, modelled at £400/ha/yr for 15 years is included within the financial model, returns on investment increase but are still not sufficient to make either site investable (scenario 2, figure 5).

Scenario 2: Carbon Income with an Operational Grant

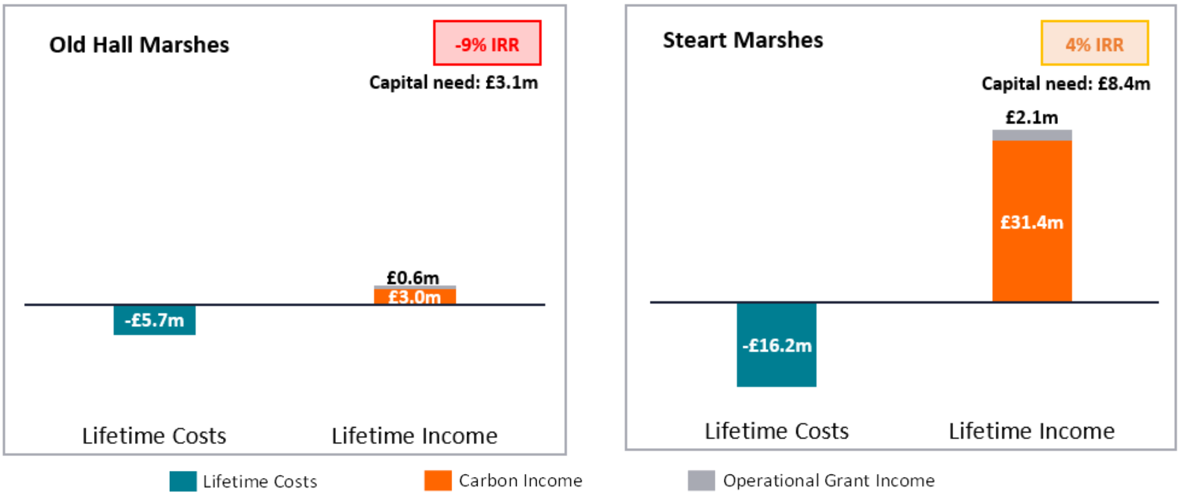

Figure 5: Scenario 2: Carbon Income with an Operational Grant. *(Note: figures are presented on an undiscounted basis. Source: Finance Earth.)*

Further supplementing income from selling carbon credits and the operational grant with an upfront, non-repayable capital contribution of £15,000/ha (scenario 3, figure 6) enables Steart Marshes to generate a 10% IRR. It also significantly reduces the capital requirement as the non-repayable capital contribution funds 45% of Steart Marshes' total restoration costs. The same non-repayable upfront capital contribution funds 36% of Old Hall Marshes' total restoration costs, but overall, the project is still loss-making for a private investor, despite the lower capital requirement of £2 million.

Scenario 3: Carbon Income with an Operational and an Upfront Grant

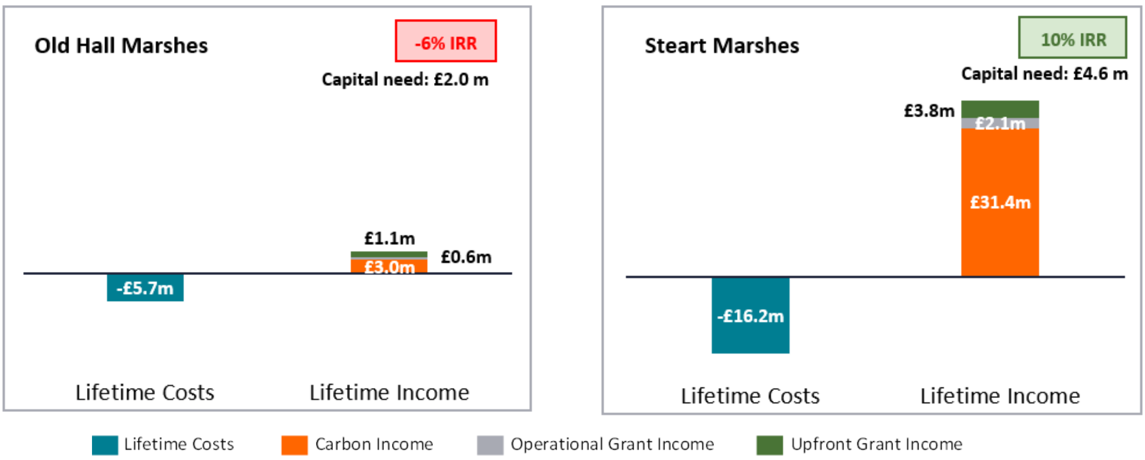

Figure 6: Scenario 3: Carbon Income with an Operational and an Upfront Grant *(Note: figures are presented on an undiscounted basis. Source: Finance Earth.)*

Based on this analysis and as highlighted in Figure 7, Old Hall Marshes is not attractive for private sector investment based on carbon income, even with blended capital and operational grants. Steart Marshes, on the other hand, is potentially attractive to an equity investor requiring 'double digit' returns, assuming that its carbon sequestration can be monetised and blended with capital and operational grants at the levels described. This implies that public funding to cover both capital and maintenance costs, which is allowed to be 'blended' with carbon income, is likely to be essential for the development of a UK saltmarsh carbon market.

The financial model outputs are sensitive to the base case assumptions, which are subject to change as a result of further evidence into carbon sequestration, additional restoration cost, further development of the UK Saltmarsh Code and changes in market demand for carbon credits. To understand the impact of CO_2e accumulation levels and restoration cost on the project returns on investment, please refer to Appendix 1 for detailed sensitivity analyses.

While the only ecosystem services revenues considered in the financial model were from carbon sales, in the next phases of development, the UK Saltmarsh Code may consider in more detail the potential to stack or bundle carbon with other ecosystem services such as BNG and Natural Flood Risk Management (NFRM) benefits. These additional income streams could potentially play a significant role in improving the viability and inevitability of saltmarsh restoration projects.

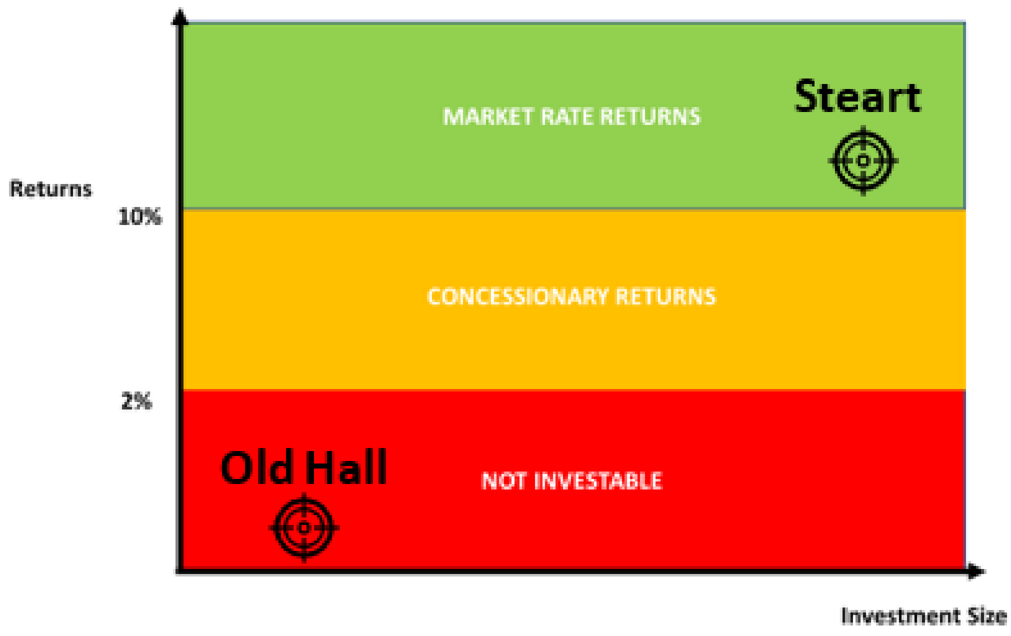

Figure 7: Potential of Old Hall Marshes and Steart Marshes to attract Private Finance. *(Source: Finance Earth.)*

6.3 Is VM0033 a Viable Option for UK Projects?

This report assessed the applicability of VM0333 methodology and feasibility in a UK context. This section analyses the financial and commercial implications for adopting VM0033 to validate and verify saltmarsh carbon credits in the UK.

VM0033 is significantly more costly than a UK domestic Saltmarsh Code (if it were to have similar verification costs to the Peatland Code and Woodland Carbon Code) for individual projects given the complexity of the methodology and the monitoring, reporting and verification processes as well as the higher fixed costs (e.g., creating Project Design Documents). Table 13 shows estimated costs under VM0033 and a theoretical UK domestic Saltmarsh Code based on the existing Woodland Carbon and Peatland Codes (however, we do recognise we have focussed on costs to the project here and – in contrast to VM0033 – the WCC and PC have costs borne by the administrator of the code that are not passed on to projects). VM0033 costs are based on stakeholder engagement with three VCS VVBs and two specialist consultants. Validation costs include account opening fees, registration fees/levy and initial validation costs. Verification fees under VM0033 exclude the costs for undertaking mandatory field visits, which may be high in the near term as (at the time of writing) there are no VVBs in the UK that can verify projects under VM0033, so overseas VVBs would be required. In addition, VM0033 requires a project to rotate their VVB at least once every six years (UK domestic codes have no such requirement).

As shown in Table 13, typical costs for projects under VM0033 are significantly higher than those under a UK domestic Code. VM0033 may only be commercially viable for very large sites such as Steart Marshes that can absorb such costs through greater revenue generation potential.

Table 13: Validation and Verification Costs under VM0033 and a UK domestic Saltmarsh Code.

	PDD *	Validation	Registration	Verification **	Old Hall	Steart
					Total Costs	
UK domestic Saltmarsh Code	£5k	£4k	£0.05/unit	£2k	£12k/ha	£3k/ha
VM0033	c. £150k	c. £18k	$0.10/unit	c. £18k	£107k/ha	£30k/ha
Cost increase					**c. 9x**	**c. 9x**

** Project Design Document preparation and submission.*

*** Cost per verification.*

Source: Finance Earth

As per the sensitivity analysis (Table 14), VM0033 would not be a viable option for Old Hall Marshes even if CO_2e accumulation rates increased significantly. Using VM0033 for Steart Marshes under base case assumptions and including the capital and operational grants described above, reduces the return on investment by 1%, meaning that it may only be attractive for concessionary investors.

Table 14: Carbon accumulation / Carbon Code Sensitivity.

Carbon accumulation / Carbon code Sensitivity						
	Old Hall Marshes			Steart Marshes		
Carbon accumulation sensitivity	0%	+50%	+100%	0%	+50%	+100%
tCO_2e/yr (up to Y20)	5	8	10	33	49	65
tCO_2e/yr (Y20 onwards)	4	6	8	9	13	18
VM0033	n/a	n/a	n/a	9.2%	13.3%	16.5%
UK domestic Saltmarsh Code	(5.6)%	(2.6)%	(0.4)%	10.2%	14.1%	17.2%

Source: Finance Earth

This analysis implies that VM0033 is not likely to be a financially viable verification regime option for many UK projects as Steart is considered by Finance Earth to be a relatively large project.

7. Discussion and Conclusions

To develop a market for saltmarsh carbon, the UK can either adopt an existing code or standard, or develop one for use in the UK specifically. Within the Saltmarsh Code project, we reviewed several international codes which include saltmarsh habitat and identified VM0033 as potentially useable in a UK context. We therefore analysed all elements of the methodology to inform if they were applicable to a UK context. To understand the commercial viability for saltmarsh restoration in the UK, we also developed illustrative investment cases for two sites based on costs associated with VM0033, and those of a theoretical UK domestic Saltmarsh Code

From the further detailed analysis within this report of all elements of VM0033, it can be concluded that the methodology could be applied to saltmarsh restoration via managed realignment in the UK.

From a scientific point of view, the flexibility in the use of different data types for emissions estimates (local published values, proxies, peer-reviewed models, and default emissions factors) is key to this conclusion, making it easy to produce UK specific estimates by using the most appropriate method to match available data and current knowledge. We have commented on the difficulty in estimating emissions from fossil fuel use, the lack of data to enable the adjustments needed to account for allochthonous carbon, and the uncertainty around GHG emissions or reductions over time, and we recognise the need for more research and understanding in these areas. However, the VM0033 methodology would still be viable, with advice included as to how to calculate uncertainty values, or when to use conservative estimates.

More broadly, the conditions that need to be met for all elements of VM0033 are either applicable to UK saltmarsh restoration or can be justifiably omitted. However, the additionality tests are much weaker than those used in the two UK domestic code currently in operation (PC and WCC). This is problematic both due to the range of additionality tests that are proposed for use across global carbon markets by The Integrity Council for the Voluntary Carbon Market (ICVCM), and the inconsistency this would lead to in the UK market.

The conclusions from the illustrative investment cases are that VM0033 is likely not a commercially viable option for use in the UK. The analysis indicated a less than 10% return on investment for Steart Marshes – the larger of the two pilot sites, with a higher estimated carbon accumulation rate – even with the inclusion of a capital and operational grant, which would make it suitable only for concessionary investors. The costs to projects of validation, verification, and completing the Project Design Document (PDD) associated with VM0033 are simply too high compared to those estimated for a UK domestic Saltmarsh Code (assuming similarities to the WCC and PC). The same analysis was performed using the estimated costs of a UK domestic Saltmarsh Code. Again, carbon income alone did not result in investable projects. However, with the addition of a capital and operational grant, Steart Marshes met the 10% threshold return on investment, indicating it could generate market rate returns.

We recommend the development of a UK domestic Saltmarsh Code, with the main reason being the increased commercial viability compared to adopting the VM0033 methodology (this, along with other aspects considered when reaching this conclusion are given in Table 15). Validation and verification represent upfront and annual costs that are too high, and so may only be absorbed by very large and highly carbon-sequestering sites that can generate larger revenue streams. However, given that to date the vast majority of restoration sites in the UK have been small (average of 40ha when excluding the three largest projects – Medmerry, Steart and Wallasea Island (Hudson et al 2021)), opting to lower the costs projects would have to cover to enter the code is preferable. In addition, developing a UK domestic Saltmarsh Code would allow: additionality rules to be in line with the other UK domestic codes in operation; streamlining of the methodology resulting in a more straightforward, easy to follow process; and greater flexibility to update the guidance as new evidence becomes available.

Table 15: Comparative Analysis of VM0033 and a UK domestic Saltmarsh Code. Green = One route is viewed to be more preferable, Both Grey = Both routes are viewed similarly.

		Adopt VM0033	**Develop a UK domestic Saltmarsh Code**
Scientific viability	Applicable to UK context	- Global application to multiple intertidal habitats - Methodology allows for the use of a range of data types therefore estimation of site/region/country-specific emissions is achievable	- UK-specific, and saltmarsh only to start - Ability to update the guidance as new evidence becomes available
Commercial viability	Carbon curve certainty	Detailed methodology included to estimate GHG emission reductions or removals	- Develop EFs and a Carbon Calculator
		- Precisions and risk buffers not prescribed	Prescribed precision & risk buffer, in line with PC and WCC
	Cost efficiency of code	High fixed cost due to complex methodology, Monitoring, Reporting and Verification (MRV) requirements, and high fixed costs.	Cost efficient based on fee estimates from PC and WCC
	Allowance for stacking & bundling	Not mentioned but presumed yes due to weaker additionality tests. See section 4.2	- Domestic Code recommended to allow for stacking and bundling to increase role of private finance - If similar additionality criteria to Peatland Code and Woodland Carbon Code adopted then stacking only likely to be available for most expensive to restore sites
	Threshold for financial additionality	No financial additionality test	Domestic Code recommended to allow for substantial public / philanthropic funding given high restoration cost

Enabling factors	Viability of ownership & operation	VCS established organisation and is expected to operate VM0033	Funding and resource required to develop and manage the domestic Code
	Availability of accredited VVB	- VVBs accredited but none active in UK - VVB required to be rotated at least every 6 years	VVB required. Existing PC and WCC VVB include Soil Association and Organic Farmers and Growers
	Allowance for insetting	Yes	Yes (in line with PC and WCC)
	Timelines for Code development	Methodology in place, but uptake low to date	Domestic Code development expected to take c. 2 years

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Appendix 1 – Sensitivity Analysis

A1.1 Sensitivity Tables – Restoration Cost and CO_2e Accumulation

The IRR for Old Hall Marshes and Steart Marshes is sensitive to the various assumptions made in the financial model. In order to understand the CO_2e accumulation rate at which a project becomes investable and the impact of changes in restoration costs, sensitivity analyses have been conducted. The numbers in the sensitivity tables represent the IRR, with >10% denoting potential for private finance, between 2-10% denoting potential for concessionary capital and <2% denoting that the project is unviable. The sensitivity tables state ‘n/a’ where the restoration grant is higher than the restoration cost, and therefore the need for private funding is removed.

A1.2 Sensitivity - CO_2e Accumulation and Restoration Grant

As per the sensitivity analysis in Table A1-1, Old Hall Marshes becomes a viable and investable site only if the upfront restoration grant is increased to £37,500/ha. If CO_2e accumulation increases by +50% or +100%, the project still requires an increase in restoration grant (£/ha) versus the base case assumption of £15,000/ha, which reflects the relatively low CO_2e accumulation potential of Old Hall Marshes compared to Steart Marshes. For Steart Marshes, if CO_2e accumulation rates are higher, the IRR increases, which will make the site more attractive for private finance. Table A1-1 demonstrates the importance of the UK Saltmarsh Code providing emission factors or a “carbon calculator” as the changes in the CO_2e accumulation rates have a significant impact on the IRR, whilst keeping all other assumptions the same.

Table A1-1: CO_2e accumulation / restoration grant sensitivity.

CO_2e accumulation / restoration grant sensitivity							
		Old Hall Marshes			**Steart Marshes**		
CO_2e accumulation sensitivity		0%	+50%	+100%	0%	+50%	+100%
tCO_2e/yr (up to Y20)		5	8	10	33	49	65
tCO_2e/yr (Y20 onwards)		4	6	8	9	13	18
Restoration grant (£/ha)	**15,000**	(5.6)%	(2.6)%	(0.4%)	10.2%	14.1%	17.2%
	25,000	(1.9)%	1.2%	3.5%	19.6%	24.4%	28.2%
	37,500	10.7%	14.2%	16.9%	n/a	n/a	n/a

A1.3 Sensitivity - Restoration Cost and Restoration Grant

As per Table A1-2, if the restoration costs for Old Hall Marshes are reduced by 50%, it still does not reach the 10% IRR threshold at a restoration grant level of £15,000/ha, although it may attract concessionary forms of investment. For Steart Marshes a reduction in restoration costs will improve the IRR, which will make the financing more attractive and potentially decrease the required restoration grant amount.

Table A1-2: Restoration cost reduction / grant sensitivity.

Restoration cost / grant sensitivity							
		Old Hall Marshes			**Steart Marshes**		
Restoration cost sensitivity		**0%**	**-25%**	**-50%**	**0%**	**-25%**	**-50%**
Restoration grant (£/ha)	**15,000**	(5.6)%	(1.7)%	7.6%	10.2%	17.0%	48.4%
	25,000	(1.9)%	6.9%	n/a	19.6%	n/a	n/a
	37,500	10.7%	n/a	n/a	n/a	n/a	n/a

In the scenario where restoration costs are higher than assumed (Table A1-3), Steart Marshes would require a higher restoration grant (£/ha) to meet the IRR threshold of 10%. For Old Hall Marshes given the site only meets the threshold IRR of 10% at a restoration grant of £37,500/ha, further increases in restoration cost would require an even higher restoration grant.

Table A1-3: Restoration cost increase / grant sensitivity.

Restoration cost / grant sensitivity							
		Old Hall Marshes			**Steart Marshes**		
Restoration cost sensitivity		**0%**	**+20%**	**+30%**	**0%**	**+20%**	**+30%**
Restoration grant (£/ha)	**15,000**	(5.6)%	(7.7)%	(8.5)%	10.2%	7.1%	5.9%
	25,000	(1.9)%	(5.2)%	(6.3)%	19.6%	12.4%	10.2%
	37,500	10.7%	0.4%	(2.0)%	n/a	42.2%	24.8%

Restoration costs account for the majority of the lifetime cost for saltmarsh restoration. Based on existing project information and studies, saltmarsh restoration cost vary widely. The sensitivity tables reflect the high potential impact of cost increases / decreases on IRR and the levels of restoration grant required. There is therefore a need to streamline restoration projects to provide higher certainty in overall estimates and to understand the scenarios under which restoration may be most cost effective. Examples may include focusing on areas which do not require the need to build new embankments to protect assets or conducting trainings to ensure more local contractors are equipped to deliver such projects.

Appendix 2 – Old Hall Feasibility Study

A2.1 Introduction

This appendix presents a high-level assessment of several key features to be associated with a potential MR scheme at Old Hall Marshes in Essex (Figure A2-1). The note is intended to feed into a broader UK trial of an existing saltmarsh carbon code (VM0033) which requires information on scheme costs and programme and carbon emissions. The trial is being undertaken under the UK Saltmarsh Code project funded through the NEIRF – see https://www.ceh.ac.uk/our-science/projects/uk-saltmarsh-code.

The note covers:

- A brief outline of the study site.
- A new analysis of the intertidal habitats that could be created from breaching the current defences under present day sea levels.
- Approximate dimensions for a retired flood embankment and a breach.
- Approximate costs.
- Approximation of carbon costs associated with these engineering works.

The detail presented is suitable for use in an early-stage viability assessment only.

This note does not:

- Allow for costs or effort associated with additional monitoring, reporting and validation of carbon capture performance.
- Identify the potential carbon capture of the site.
- Assess the requirement for additional compensatory habitat that might result from changes to the existing site.

Figure A2-1. Location of study area within the wider setting of the Blackwater Estuary.

A2.2 Study Site

The proposed site is approximately 72 ha and located on the southern tip of the peninsula in the Blackwater Estuary (Figure A2-2). It appears to be currently used for freshwater nature conservation (National Nature Reserve) and is protected under National (SSSI) and International (SPA, Ramsar) designations. The peninsula is currently protected from tidal flooding by an embankment running its perimeter. Lower internal embankments separate the site from other freshwater compartments on the peninsula.

The RSPB, in discussion with the EA are considering options for the site, including MR and regulated tidal exchange, for the restoration of a range of coastal habitats over the entire area of Old Hall Marshes.

This note is only concerned with the south easter corner (72ha) of the Old Hall Marshes. This note has been created as part of the UK saltmarsh carbon code project and should not be construed as the identification of a preferred option for site management or a detail engineering design.

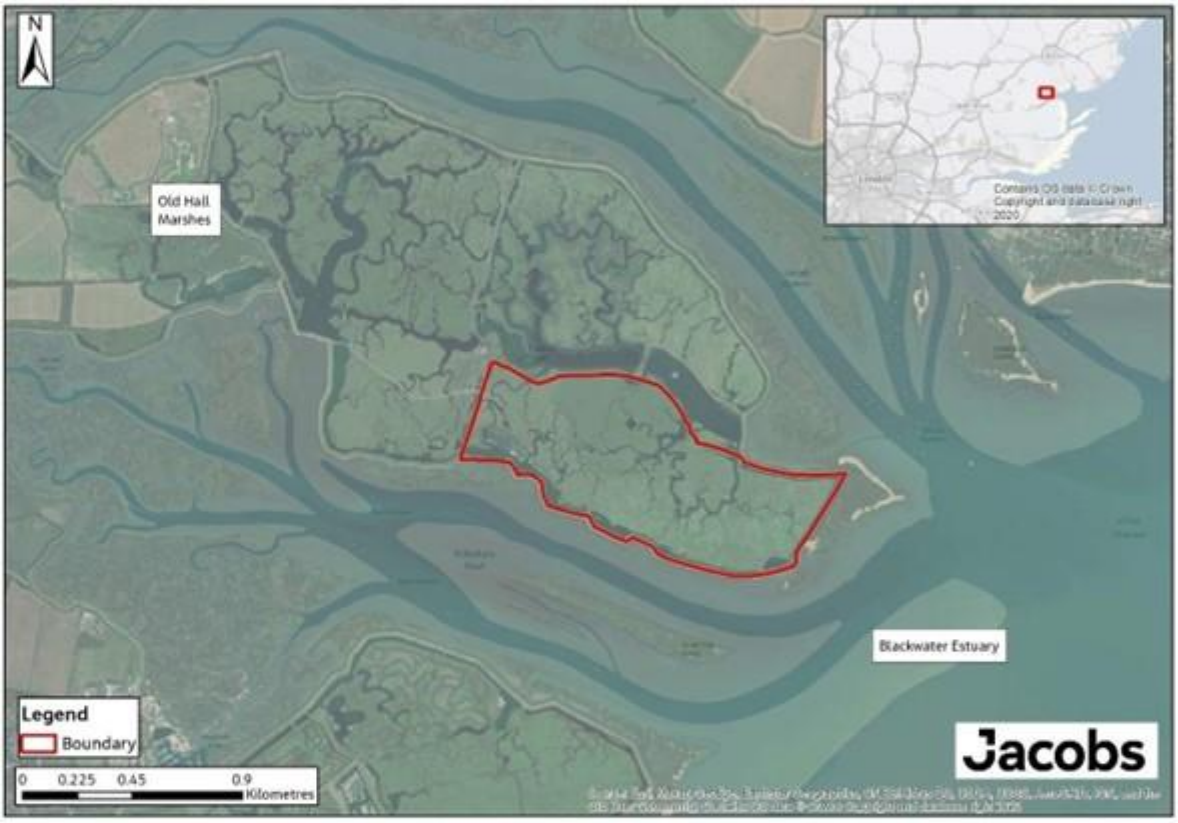

Figure A2-2. The position of the study area within Old Hall Marshes.

A2.3 Future habitats

The main determinant on the type of intertidal habitats that form is the degree of tidal inundation. Data on the existing land levels and tidal levels can therefore be used to approximate the habitats that would be expected to form within approximately 5 years. Over longer timescales sedimentation and sea level rise would be expected to change the distribution of vegetation.

Tidal levels at Bradwell Waterside, approximately 4 km to the south in the Blackwater Estuary (UKHO, 2021) are presented in Table A2-1.

Table A2-1. Tidal levels for Bradwell Waterside (UKHO, 2021)

Tidal Levels	CD (m)	OD (m)
HAT	5.6	2.92
MHWS	5.2	2.52
MHWN	4.2	1.52
MLWN	1.3	-1.38
MLWS	0.4	-2.28

Using these water levels and the land elevations acquired from LiDAR (Environment Agency, 2021), we anticipate that approximately 88% of the site will form mudflat, with the remainder largely comprising of saltmarsh (11%), refer to Table A2-2 for further detail. Other transitional and terrestrial habitats could occur in isolated and relatively small and fringing locations such as higher on the embankments (Figure A2-3).

Table A2-2. Potential habitats that could be created based on current elevations and sea levels.

Habitat	Area (ha)	Area (%)	Tidal Levels
Subtidal / Mudflat	63	88	< MHWN
Saltmarsh	8	11	MHWN – MHWS
Upper saltmarsh / Transitional	< 1	< 1	MHWS – HAT
Terrestrial	< 1	< 1	> HAT

A2.4 Required engineering works

Introduction

For the purposes of this assessment, it is assumed that the required engineering works are limited to building a new flood embankment to limit inland flooding and a breach to allow the site to experience tidal inundation. The position of these works allowed for in this note are shown in Figure A2-3. This assessment assumes that the banks forming the existing seaward perimeter of the proposed project site are abandoned and not maintained once the scheme is opened.

No consideration has been given to any other elements such as:

- Rerouting of freshwater drainage from the peninsular that drains through the site and installation of new outfall structures.
- Use of control structures to create lagoons.
- Excavation of pools or channels within the site or channel into the estuary.
- Creation of new footpaths, car parks, bird hides etc.

Embankment construction

The external banks which separate the site from the Blackwater estuary have around a 1 in 4 slope and have a crest level of around 4.2 metres above ordnance datum (mOD). The internal banks are around 1.5 m lower, with a crest level of approximately 2.75 mOD and similar slopes of around a 1 in 4 grade. The length of the required internal bank is around 1600 m. According to JBA modelling (JBA, 2018) the existing external embankments only provide a standard of protection up to a 1.3 – 5 % annual exceedance probability (AEP) event (equivalent to around a 1 in 20 – 1 in 70-year event).

For the present assessment it has been assumed that any retired embankments would be built to the same standard as the banks that currently separate the site from the estuary, i.e., with a crest height of 4.2m. This would need to be revisited in consultation with the EA before any works were to be undertaken.

There are two possible options for building the embankment:

Option 1 – Build on top of old embankment - To raise the internal bank to around 4.2 mOD from its current level of around 2.75 mOD maintaining the 1 in 4 slope (and with a crest width of 4 m) would require around 75,000 m^3 of fill.

Option 2 – Build from scratch - To completely rebuild the internal embankment to 4.2 mOD with 1 in 16 slope (and with a crest width of 4 m) would require around 300,000 m^3 of fill assuming a base level of 0 mOD. The exact defence and fill requirements would require further investigation at a later stage.

Breach size

For this assessment we assumed a preliminary breach size of approximately 250 m wide. This is similar to the size of other accidentally breached marshes (e.g., Northey Island, Fingringhoe) and nearby managed realignment sites (e.g., Orplands, Tollesbury) reported in Townend (2008). The exact breach dimensions would need to be investigated at a later design stage.

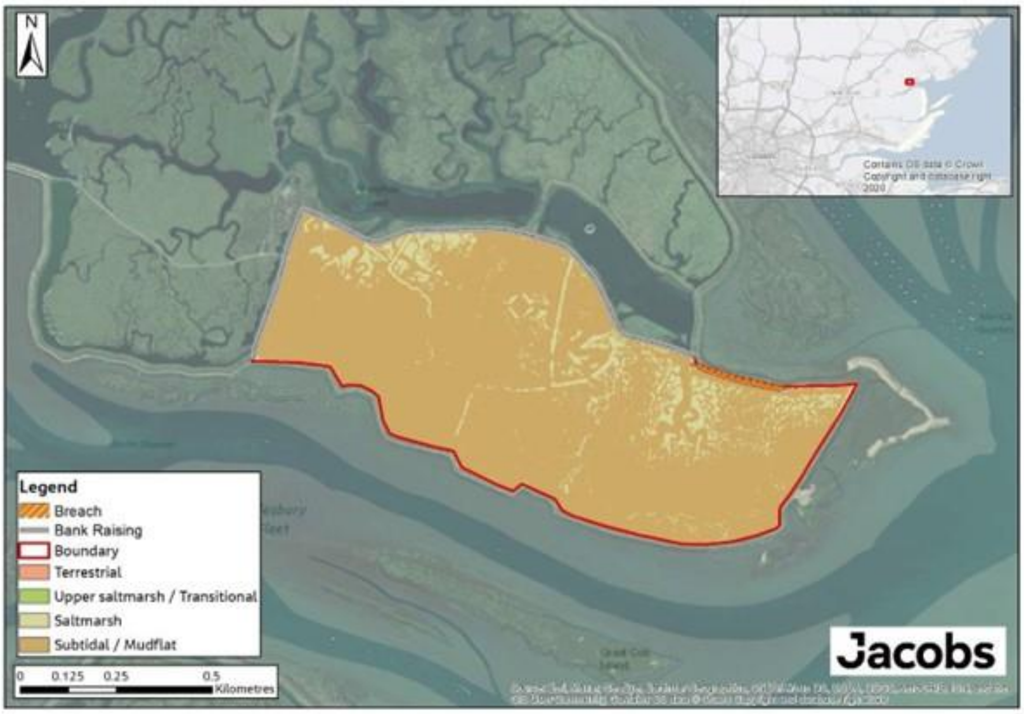

Figure A2-3. Alignment of Discussed Engineering Works.

A2.5 Realignment Scheme Costs and Programme

Background

The engineering works and resulting costs required to deliver managed realignment projects vary by site. Variations in total scheme cost arise from multiple factors including size of scheme, land purchase cost (if applicable), scheme complexity (e.g., infrastructure and access requirements) and ground conditions.

For convenience, scheme costs are often quoted as a cost/hectare. ABPmer (2017) quote values per hectare of <£2000/ha to over £900,000/ha for schemes constructed between 1991 and 2015. The large variation in costs and the fact that some types of cost have increased over time, mean that past delivery costs do not provide a simple guide for future delivery costs.

For this reason, the EA recently evaluated the costs for the delivery of recent managed realignment projects (Jenny Connell pers. comm.) and suggested 3 cost ranges:

Low	£25,000/ha
Medium	£60,000/ha
High	£100,000/ha

These values were based on recent EA led schemes, but in our view these rates reflect the lower end of the costs that can be associated with MR schemes, especially where ground conditions are challenging, or where sites contain or lie close to existing utilities. For future schemes the in-house capability of promoter (and thus required consultancy and construction services) may also influence delivery costs.

Future project costs may vary due to:

- Increasing competition for realignment sites and increased land prices.
- Fluctuating market costs of basic commodities like fuel.

Projects are delivered over phases of activity that are commonly characterised by concept and design maturity, organisational approvals and stakeholder engagement. Figure A2-4 and Figure A2-5 present the typical stages of saltmarsh restoration projects and distribution of activity within typical project durations.

Figure A2-4. Typical project stages for saltmarsh restoration (from Hudson et al., 2021).

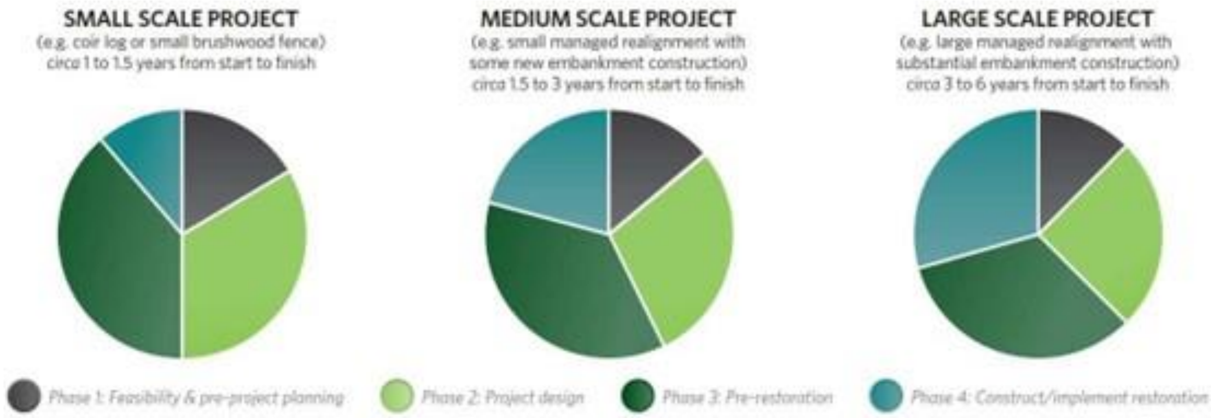

Figure A2-5. Saltmarsh restoration project timelines for different sized projects (from Hudson et al., 2021).

Old Hall Marshes

For a scheme at a site like Old Hall Marshes we anticipate that the scheme costs will be in the range of £60,000/ha to £100,000/ha, and that the scheme would take between 3 to 5 years to deliver.

This is based on a number of simplifying assumptions:

- No land purchase cost.
- No major knock-on compensatory requirements.
- No existing infrastructure to relocate.
- Material for raising the interior embankments is obtained from within the site.

- Scheme design is confined to raising of the interior embankment and a single breach.
- Hydrodynamic modelling requirements are limited.

Using the rates indicated above, we estimate that this Old Hall Marshes 72ha scheme will cost between £4,320,000 and £7,200,000. Assuming a delivery time frame of 5 years we anticipate a breakdown of activities and costs broadly as presented in Table A2-3.

Table A2-3. Project Delivery Indicative Activity Costs.

Activity	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
Feasibility & pre-project planning (including outline design)	10%					
Project design (inc. surveys & detailed design)		15%				
Pre-restoration (consents, approvals & planning etc.)			5%			
Construction & Supervision				65%		
Operation & monitoring					5%	
Indicative Cost Distribution for £60k - £100k/ha scheme rate	**£432k – £720k**	**£432k – £720k**	**£432k – £720k**	**£2,880k – £3,336k**	**£1,620k – £1,860k**	**£108k – £180k**

A2.6. Estimated carbon emissions

Table A2-4 shows the results from the EA's the 'Carbon Modelling Tool' Lit 14605 v7.4 (Environment Agency, 2022). The EA describe the Carbon Modelling Tool as *'[a] top-down whole life carbon assessment and optioneering tool, used during the project appraisal phase to enable quick and simple carbon assessment to inform the solution selection process'*. This tool is typically used at strategic outline business case/feasibility stage, before outline design has been developed. For Old Hall Marshes the tool gives the whole life (100 year) carbon emissions of between and 28,157 (Option 1) and 50,456 (Option 2) (tCO_2e). We believe that these values assume that the new embankments are constructed from material imported to the site (see note below).

Table A2-4. Carbon emission estimates for embankment construction at Old Hall Marshes based on the Environment Agency's the 'carbon modelling tool' Lit 14605 v7.4 (Environment Agency, 2022)

Stage	Option 2 300,000m^3 new embankment	Option 1 75,000m^3 modified embankment
Capital carbon (A1-A5) (tCO_2e) * *see Note below for alternative value*	20,290	9,701
Operational carbon (B1-B3) (tCO_2e) – 100 years	8,166	2,789
Replacement carbon (B4) (tCO_2e) – 100 years	19,907	9,025
Refurbishment carbon (B5) (tCO_2e) – 100 years	0	2,337
Demolition carbon (C) (tCO_2e) – 100 years	2,092	4,305
Whole Life carbon (tCO_2e) – 100 years	50,456	28,157
Whole Life carbon - slope uncertainty (%)	31	26

Note: A comparison of the carbon emissions associated with construction activities ('capital' in Table A2-4) with the more detailed assessments made at Steart Marshes MR by Mossman et al. (2022) shows that the values in Table A2-4 are substantial higher. Mossman et al. (2022) used the EA carbon calculator tool (version 3.1.2) for Steart, but modified the construction carbon estimate (see next paragraph). For Old Hall Marshes – emissions of between 9,701 tCO_2e and 20,290 tCO_2e arising from earth movements of 75,000m^3 and 300,000m^3 (corresponding to an average emission of between 0.0678 tCO_2e/m^3 and 0.1293 tCO_2e/m^3) as opposed to at 2,762 t/CO_2e from earth movements of 489,422 m^3 (corresponding to an average emission of between 0.0056 tCO_2e/m^3) i.e., emissions in Table A2-4 are around 10 to 20 times higher than at Steart.

At Steart, Mossman et al. (2022) used the EA carbon calculator tool (version 3.1.2). The EA describe the Carbon Calculator tool as *'[a] detailed bottom-up whole life carbon assessment tool, incrementally built up during the delivery phase, following selection of a preferred project solution option. The final Carbon Calculator assessment is used to create data points in the carbon models within the Carbon Modelling Tool.'* Mossman et al. (in press) note that the EA carbon calculator tool (version 3.1.2) cannot be adjusted to deal with locally won embankment material, and thus assigned much high embodied carbon values for earthwork than would be expected for locally won material. Mossman et al (in press) therefore derived a new carbon emission value based on fuel used. We suspect version 7.4 also has higher embodied carbon values than would be expected for locally won material and this explains why capital carbon costs in Table A2-4 are so much higher than values derived at Steart.

Recalculating the values for Old Hall Marshes based on the average emissions per m^3 found at Steart gives values of between 423 t/CO_2e and 1,693 t/CO_2e for 75,000 m^3 and 300,000 m^3 respectively. These values assume that material for the new embankment can be won from within the site and no import of material is required. This would need to be confirmed during the design process.

A2.7. Summary and conclusion

Scheme Concept and Habitat Creation

- The site is expected to initially form mainly mudflat (~88% of site area). Approximately 11% of the site would be suitable for saltmarsh development initially. We estimate that saltmarsh colonisation might take 2-5 years in these areas. Over the lower parts of the site saltmarsh would not be likely to develop until elevations had risen to at least MHWN.
- Sea level rise may impact the rates of accretion and creation of habitat.
- A check will be required that the presented scheme arrangement is consistent with the locals plans and strategies.

Carbon associated with Construction

The volumes of material required for the new embankment depend on whether it is constructed alongside or atop of the old embankment. We used Version 7.4 of the EA modelling tool to assess the capital, operational, replacement, refurbishment, demolition, residual and Whole Life Carbon for the Old Hall Marshes site. We suspect the EA carbon calculator tool has higher embodied carbon values than would be expected for locally won material. Recalculating the values for Old Hall Marshes based on the average emissions per m^3 found at Steart (which used locally won material) gives values of between 423 t/CO_2e and 1,693 t/CO_2e for 75,000 m^3 and 300,000 m^3 respectively. These values assume that material for the new embankment can be won from within the site and no import of material is required. This would need to be confirmed during the design process.

Cost Estimates

- Based on an estimated delivery cost per hectare of £60,000 to £100,000 the projected total costs to construction are £4.3M to £7.2M, excluding land cost. Assuming a delivery period of 5 years, annual spend is likely to result in an annual spend of between £432k and £3.3M depending on the stage of work.
- The broad range of costs reflects the need for further concept development to better understand the risks and uncertainties of a scheme. Costs could be significantly reduced if the requirement for a new embankment were to be removed, perhaps as part of a larger scheme for the entire peninsula.
- Whilst there is a broad range of costs, the values do assume a low complexity scheme design, particularly in relation to:
    - Geomorphological risks (navigation etc)
    - Flood risk
    - Existing infrastructure
    - Site access
- Additionally, no allowance has been made for additional work/costs associated with:
    - Knock-on compensatory / mitigation requirements.
    - Stakeholder engagement activities.
    - Land purchase

Programme Estimates

- Projects of this scale are likely to take at least 5 years to progress from concept development to the completion of site works.
- The programme and cost estimates assume that very limited or no work has commenced on development of a concept for this site area.

Conclusion

- The broad range of costs are difficult to narrow down without further concept development to establish the extent of engineering works and volumes of material required for bank improvements etc. The overall cost and carbon emissions of the scheme would be reduced significantly if the requirement to build a new embankment was removed. This option has not been considered here since it would increase the flood risks to the other parts of the peninsula. The requirements of secondary compensation is also a critical aspect, which has the potential to double the rates applied to this example.

A2.8 References

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