REPORT

Assessment of the sea wall between Langstone Mill and Wade Lane

Technical Study

Client: Chichester Harbour Conservancy

Reference: PC5050-RHD-XX-XX-RP-X-0001

Status: S0/P03.01

Date: 18 October 2023

HASKONINGDHV UK LTD.

2 Abbey Gardens
Great College Street
London
SW1P 3NL
United Kingdom
Water & Maritime

+44 207 2222115 **T**
info@uk.rhdhv.com **E**
royalhaskoningdhv.com **W**

Document title:	Assessment of the sea wall between Langstone Mill and Wade Lane
Subtitle:	Technical Study
Reference:	PC5050-RHD-XX-XX-RP-X-0001
Your reference	
Status:	S0/P03.01
Date:	18 October 2023
Project name:	Langstone Technical Study
Project number:	PC5050
Author(s):	Royal HaskoningDHV

Drafted by:	CM, RB, CS, WS and MJ
Checked by:	CM
Date:	05/10/2023
Approved by:	DB
Date:	19/10/2023

Classification
Project related

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Glossary

Brackish	Water than has more salinity than freshwater, but not as much as seawater
Chainage	Distance along an elevation profile
Coastal and floodplain grazing marsh	Periodically inundated pasture or meadow
Coastal defence	Measures to protect the land from flooding or erosion
Coastal erosion	Wearing away or removing of land or structures due to coastal processes
Coastal squeeze	The loss of natural habitats or deterioration of their quality arising from human-made structures or actions, preventing the landward transgression of those habitats that would otherwise naturally occur in response to sea-level rise in conjunction with other coastal processes
Embankment	A raised bank made of earth or building material
Enforced embankment	An embankment that is enforced with masonry, concrete, or other building material
Estuary	The tidal mouth of a river
Floodplain	Generally flat area of land next to a body of water that is susceptible to flooding
Habitat	The preferred environment of a plant, animal, or organism
Habitat creation	Creating ecosystems in areas where that ecosystem doesn't currently exist
Highest astronomical tide	The highest level of water that can be predicted to occur under average meteorological and any combination of astronomical conditions
Intertidal	The area between high and low tides
Land reclamation	Creating new land from the sea
Managed realignment	Managed removal of coastal protection to allow coastal flooding to occur in a controlled manner
Mean high water neap	The average of the high water heights of two successive tides during the neap tide
Mean high water spring	The average of the high water heights of two successive tides during the spring tide
Mean low water neap	The average of the low water heights of two successive tides during the neap tide
Mean low water spring	The average of the low water heights of two successive tides during the spring tide
Mudflat	An area of mud in the intertidal zone
Natural flood and coastal erosion management	When natural processes are used to reduce the risk of flooding and coastal erosion
Nature based solutions	Solutions that are inspired and supported by nature, which are cost-effective, provide environmental, social, and economic benefits and help build resilience
Neap tide	A tide that occurs when there is the smallest height difference between high and low water

Ramsar	A wetland site designated to be of international importance under the Ramsar Convention
Reedbed	An area of water or marshland dominated by reeds
Return period	An average or estimated time between events of the same magnitude
Saltmarsh	A vegetated area of wetland that is flooded and drained by the tide
Seawall	A wall or embankment that prevents the sea flooding or eroding the land
Sediment supply	The amount of sediment that is supplied to a coastal environment by coastal processes
Spring tide	A tide that occurs when there is the greatest height difference between high and low water
Still Water Level	The average water level at any given time, excluding local variation due to waves
Tidal surge	A rise in water levels due to the combination of the astronomical tide and storm surges

Acronyms

AONB	Area of Outstanding Natural Beauty
BAP	UK Biodiversity Action Plan
CFBD	Coastal Flood Boundary Dataset
DEFRA	Department for Environment, Food and Rural Affairs
EA	Environment Agency
FCERM	Flood and Coastal Erosion Risk Management
HAT	Highest Astronomical Tide
LiDAR	Light detection and ranging
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
PV	Present Value
OD	Ordnance Datum
PLC	Permits, licences and consents
RCP	Representative Concentration Pathway
RHCP	Habitat Compensation and Restoration Programme
SAC	Special Area of Conservation
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
UKCP18	United Kingdom Climate Projections 2018

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Executive Summary

Royal HaskoningDHV (RHDHV) was commissioned by Chichester Harbour Conservancy to undertake a technical study in relation to the coastal defences and adjacent land between Langstone Mill and Wade Lane in Chichester Harbour. The objective of the study is to provide an independent assessment of the site, considering the condition of the coastal defences, local nature conservation, environmental and recreational interests and the regulatory and legislative frameworks governing future coastal management strategies. This technical study is intended to provide the evidence base to inform decision making.

The sea wall between Langstone Mill and Wade Lane is fronted by mudflat sporadically covered with saltmarsh habitat. Saltmarsh habitats are extremely important in coastal environments not just for their ecological value and the species they support, but also because they act as natural flood defence dissipating wave energy before it reaches inland. The saltmarsh across Chichester Harbour is in an unfavourable declining condition with a loss of up to 60% between 2008 and 2016. The presence of hard coastal defences is contributing to this decline may preventing the saltmarsh from moving inland with rising sea levels, which would occur in a natural coastal setting.

Human modification of the coast at Langstone has been ongoing since at least the Medeival period with significant landscape modification from the early 19th Century onwards associated with the construction of Langstone Mill and the sea wall which sheltered the land behind it making it suitable for agriculture. The sea wall dammed the lower reaches of Lymbourne Stream preventing it from flowing naturally into the sea and creating the mill pond whose outfall is managed artificially through a sluice gate. The damming of the stream and pond will have cut off sediment supply to the coast, which is important for sustaining healthy saltmarsh environments.

The land behind the sea wall comprises deciduous woodland, reedbeds and coastal and floodplain grazing marsh which are all priority habitats according to the UK Biodiversity Action Plan (BAP). The saltmarsh and intertidal mudflat in front of the sea wall are also BAP priority habitats. Lymbourne Stream is a chalk stream which are rare and have high conservation value. Each of these features has conservation value and must be considered in future management strategies.

In March 2022, an approximately 30m section of brick sea wall collapsed near Wade Lane following winter storms. Elsewhere, the sea wall fronting Langstone Mill Pond has been deteriorating with a significant loss of mortar and bricks that are creating voids and exposing bank material behind the sea wall that is more susceptible to erosion. This has localised sections of sea wall that are vulnerable to future failure. Attempts have been made to protect and repair the sea wall by the general public. This has been undertaken without the relevant consent and planning permissions.

This independent condition assessment, following relevant Environment Agency guidance, has concluded that large sections of the sea wall are in poor condition which means there are defects in the structure that will significantly reduce its performance. The life expectancy of this section of sea wall is predicted to be 5-10 years.

One particular section near Wade Lane is in poor/very poor condition and includes an area where the sea wall has failed completely. The footpath overlying this section of the sea wall is currently intact but erosion monitoring along this failed section (being undertaken by Coastal Partners) indicates rates of up to 0.13 m per month are occurring which would lead to complete removal of the footpath within the 2 to 2.5 years (from July 2023). The life expectancy of the sea wall at this location is predicted to be between 2 and 5 years.

Locally, there are sections of the sea wall that are in fair to good condition, these include the sluice gate in the central part of the sea wall, and a small section near Wade Lane that has been rebuilt (by professionals) in recent years. These sections are expected to last between 10 and 30 years but they represent a very small proportion of the structure in its entirety which will fail over shorter timescales.

Considering the deteriorating condition of the sea wall, intervention is required to manage the coast and habitats in the future. This requires an understanding of current and future water levels in relation to the height of the sea wall and the elevation of the land behind it. Using local tidal data and UK climate predictions and assessment of the current and future extent and frequency of coastal inundation was undertaken.

The results indicate that at an average create height of 2.7m, the sea wall currently allows water to overtop and flow into the mill pond and land behind it during high tide and typical winter storm events. There is ecological evidence of this with some brackish tolerant species present in the lower areas of the paddock adjacent to the pond, but also with the death of trees along the southern margin of the pond. The frequency of overtopping will increase in future until on average one overtopping event occurs once a week by 2055. At the same time water levels will rise and the extent of coastal inundation will become larger. However, due to relatively high land levels behind the sea wall, this inundation will not extend to properties along Wade Lane or further north within Langstone. Some properties along Langstone High Street will be affected by larger storm events but this is already the case despite the presence of the sea wall.

The increased frequency of overtopping will drive a slow transition within Langstone Mill Pond from a freshwater to intertidal habitat. This will happen even if the sea wall is maintained. From 2050 onwards water levels will become sufficient relative to land levels to allow saltmarsh to form landward of the sea wall. By 2075, saltmarsh could form within the low lying areas of the paddock and within Langstone Mill Pond. Depending on the base levels of Langstone Mill Pond, the freshwater habitat will adapt into a tidal lagoon or saltmarsh with transitional coastal habitats forming along the margins. However, if the sea wall fails earlier, as predicted based on its current condition, the habitat transition will occur sooner.

This technical study considers the site history, condition of the coastal defences and their life expectancy, and projections of future water levels to assess a range of options, and the opportunities and constraints they present. This is undertaken with consideration of coastal management strategies, policy and ambitions for the environment.

Maintain and *Improve* options are not considered viable due to high costs and planning considerations, especially considering that any investment will be offset by the fact that the sea wall will be overtopped more frequently in future leading to a habitat transition in the mill pond anyway. The improve option could delay this transition but it is not sustainable or environmentally responsible to create a “freshwater island” within a coastal zone. The *Do Nothing* option is a high risk strategy as there will be no control on the timing and location of breaching which would cut off the footpath and coastal access, but also shock the habitats by not allowing them the time to transition gradually.

Managed Realignment is an appropriate strategy, but this is not a straightforward solution and the preferred approach depends on when and where a specific element of the scheme is implemented. Here, a *Managed Adaptation* approach is recommended that considers management of the coast for the short-term (0-5 years), medium-term (5-20 years) and long-term (>20 years).

In the short-term, a managed breach near Wade Lane is proposed with the installation of a boardwalk or footbridge to maintain footpath access. Over the next 25 years, the paddock will only be inundated during the highest tides and storm events during which time the rest of the footpath is already inaccessible. A program of monitoring is recommended to track the ongoing deterioration of the sea wall and the salinity of the mill pond to provide a baseline dataset to improve prediction of the timing of future breaches and habitat transitions (due to overtopping) which will in turn provide a timeline for future interventions. In the short-term the management objective would be manage the sea wall failure and maintain footpath access.

In the medium-term, the sea wall is predicted to fail at other locations and information on the timing and location of these failures will be informed by the sea wall condition monitoring program. It is proposed additional breaches are created at the points of failure and the timing and location of these breaches will determine the impact on the habitats within Langstone Mill Pond. For example, if the failure occurs near the sluice gate, the pond will likely drain completely (depending on pond base levels and water levels at the time) but if the failure was near the reedbed where elevations are higher, the pond may not fully drain and any exchange between the freshwater and intertidal habitats may only occur on the highest tides. Due to uncertainty in the timing and implications of these steps, an adaptive approach is recommended with the overall objective of maintaining Langstone Mill Pond until the sea wall fails and then managing breaches to support habitat transition. The exiting footpath will be affected by future breaches and a phased setback of the footpath is proposed in the medium-term to maintain access to the coast.

In the long-term, Langstone Mill Pond will transition into an intertidal habitat with or without interventions due to rising sea levels which will increase the frequency of overtopping events. The objective in the long-term is to allow the coast to transition into a rich and diverse habitat and support this transition through localised restoration and enhancement. Recognising the inevitable loss of freshwater habitat due to rising sea-levels we have proposed an option to compensate for this habitat loss which sees construction of a freshwater pond within Langstone Meadows in an area of higher ground that will not be affected by sea-level rise in the next 75 years.

Adopting a managed adaptive approach comprising nature-based solutions will allow the coast at Langstone to adapt sustainably and naturally to rising sea levels and give it the space to adjust in a period of rapid change. This solution will allow nature to recover from centuries of human modification and increase biodiversity overall across Chichester Harbour. Building bigger and higher walls around an artificially created freshwater habitat directly adjacent to the sea would not be a sustainable or responsible solution.

The information and findings presented in this report are based on work undertaken by Royal HaskoningDHV.

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1 Introduction

Royal HaskoningDHV (RHDHV) was commissioned by Chichester Harbour Conservancy to undertake a technical study in relation to the coastal defences and adjacent land at Langstone, Chichester Harbour. The overall objective of this study is to provide an independent assessment of the site, considering the condition of the coastal defences, local nature conservation, environmental and recreational interests and the regulatory and legislative frameworks governing future coastal management strategies.

1.1 Background and context

1.1.1 Designated sites

Chichester Harbour is located on the south coast of England and is home to the following designated sites, demonstrating its importance both nationally and globally for its coastal ecosystems and the services they provide:

- Chichester Harbour Area of Outstanding Natural Beauty (AONB);
- Chichester Harbour Site of Special Scientific Interest (SSSI);
- Chichester and Langstone Harbours Special Protection Area (SPA);
- Chichester and Langstone Harbours Ramsar site;
- Solent Maritime Special Area of Conservation (SAC);
- Chichester Harbour Amenity Area – designated under the 1971 Chichester Harbour Conservancy Act;
- Nutbourne Marshes, Pilsey Island and Thorney Deeps Local Nature Reserves;
- West Wittering Bathing Water; and,
- Chichester Harbour Shellfish Waters (Chichester Channel, Thornham Channel and Emsworth Channel).

In February 2021, Natural England published its Condition Review of the Chichester Harbour SSSI (NERR090) (Bardsley et al. 2021) and through a combination of desk-based evidence reviews and field surveys, they assessed the condition of the harbour's special habitats and species (known as notified features). Overall, the main intertidal habitat features were assessed as being in 'unfavourable declining' condition largely due to the continued loss, and poor quality of saltmarsh and mudflat habitat. The Condition Review highlighted the need to remove barriers to coastal change caused by inappropriate coastal management which are resulting in saltmarsh erosion due to a process known as "coastal squeeze"[1].

1.1.2 Policy and guidance

At a national level, Defra have published a 25-year plan for the Environment (Defra 2018) that should be considered as part of any future coastal management strategies across Chichester Harbour. These include reducing risks from flooding and coastal erosion by expanding the use of natural flood management solutions, and nature recovery through protection, conservation and enhancing natural beauty.

[1] Coastal squeeze is defined as 'the loss of natural habitats or deterioration of their quality arising from anthropogenic structures or actions, preventing the landward transgression of those habitats that would otherwise naturally occur in response to sea level rise in conjunction with other coastal processes. Coastal squeeze affects habitat on the seaward side of existing structures." (Defra 2021)

At a local level, the National Character Area Profile for the South Coast Plain (including Chichester Harbour) (Natural England 2014) has also recognised the need to manage the effects of coastal change by allowing the operation of natural coastal processes and improving the sustainability of current management practices along the coast to successfully integrate the needs of the natural environment, landscape, local communities, agriculture, tourism, and recreation.

The North Solent Shoreline Management Plan covers the Chichester Harbour and the policy for the coast between Wade Lane and Southmoor Lane is “Hold the Line” (Environment Agency 2010) which means the continued provision of defences along the coast to protect coastal communities, agricultural land, environmentally important and designated coastal and freshwater grazing marsh habitats, roads, and heritage features. However, continued maintenance of these coastal defences will also result in continued loss of seaward intertidal habitats through coastal squeeze with sea-level rise into the future. Therefore, the SMP indicates that further detailed studies are undertaken to consider whether managed realignment at Southmoor is feasible.

In 2020, the Shoreline Management Plan Refresh project undertook a Health Check on the SMP to ensure its policies remained relevant. For the area of coast between Wade Lane and Southmoor Lane, the health check advice was to Remain Aware and Revisit the Policy (RHDHV & Jacobs 2020). The review recognised that a managed realignment scheme at Southmoor was unaffordable and that with no strategic guidance on the unsustainable defences, the expectation of the policy to Hold the Line is not met by the reality of funding requirements and the responsibility for the defences has fallen on to local landowners. The Remain Aware advice recognised there is a need to consider the viability of a long-term Hold the Line strategy given the funding constraints and unstainable condition of the defences.

Although not written in policy or guidance, locally, there are members of the public who would like to “save Langstone Mill Pond”. The public perception is that the deteriorating defences are putting Langstone Mill Pond at risk from salt water intrusion and that the sea walls should be repaired and rebuilt to protect the freshwater habitat. There is a perception that if the mill pond becomes saltmarsh this will be negative for the environment.

To summarise, the ambitions of statutory and non-statutory bodies is to work with nature to enhance nature in the face of climate change and rising sea levels and move away from coastal management practices that are unsustainable and do not allow the coast to adapt to change. This is juxtaposed against the SMP which is Hold the Line, although the recent health check of this policy recognised this is not sustainable in the future (both environmentally and economically). Furthermore, local communities would like to maintain the current habitats, sea wall and footpath as they are. These complexities and conflicting management policies and opinions will be considered in this Technical Study.

1.2 Study area

The study area covered by this Technical Study includes the coastal defences between Langstone Mill Pond and Wade Lane (**Figure 1**) and the adjacent land including Langstone Meadows, Langstone Mill Pond, Lymbourne stream and grazing paddocks to the east of Lymbourne stream. Note the study area boundary given in **Figure 1** is not definitive and in the context of this assessment, consideration has been given to the wider setting.

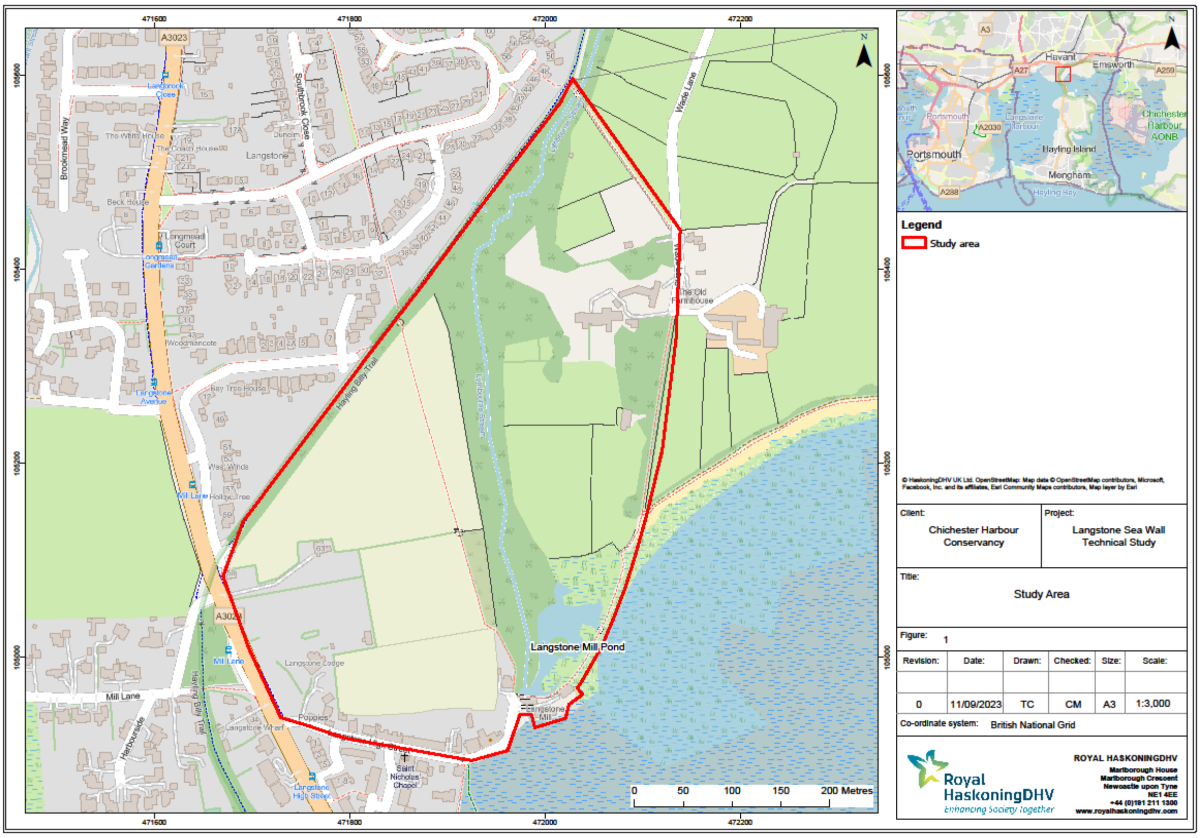

Figure 1 Location of study area

1.3 Scope

This Technical Study provides a condition assessment of the existing coastal defences within the study area and considers the life expectancy of the sea wall, Langstone Mill Pond and Footpath 108/56/2 assuming there is no active intervention. It also provides a high-level appraisal, including an indication of likely costs, of potential options for the future management of the sea wall, including potential for new freshwater and saltmarsh habitat creation. The suitability of different options depends on the physical, ecological, cultural, and socio-economic factors at the site. As such, a baseline environmental characterisation has been undertaken which forms the basis to assess the opportunities and constraints for each option. This includes an assessment of site history (including heritage assets), local infrastructure and frequency of sea wall overtopping at present and in the future (considering sea-level rise projections).

This Technical Study is intended to provide the evidence base to inform decision making. The options presented are subject to stakeholder consultation and are based on an initial assessment. The preferred option will require additional design and consideration in relation to planning and consent requirements (see Langstone Coastal Path Consenting Guide — Coastal Partners).

2 Coastal Defences Condition Assessment

2.1 Site walkover

A site walkover was undertaken by coastal scientists and engineers from Royal HaskoningDHV on 8th August 2023, to assess the condition of the sea wall and provide an overview of the environmental setting.

The site walkover covered the full section of sea wall from Langstone Mill to Wade Lane, the footpath running alongside Lymbourne stream and Langstone Meadows. Photographs and 360-degree videos were taken along the route to provide imagery to inform the assessment and an archive which could be used to monitor future deterioration of the sea wall and intertidal and terrestrial habitats. A series of observations were made during the site walkover that are relevant to this assessment. These are cited through the report where appropriate.

2.2 Overview of the coastal defences

During the site walkover a visual inspection of the coastal defences along the embankment was undertaken to assess the current condition, identify sections that have failed and sections that appear to be at risk of failing, potentially during the next large storm or through ongoing deterioration. A summary of the findings is presented below.

The coastal defences between Langstone Mill Pond and Wade Lane consist of an earth embankment with masonry covering its seaward face. Along the southern-most section of the mill pond, Langstone Mill is adjacent to Langstone Mill Pond, and the coastal path runs between the mill pond and the mill (**Figure 2**). The path continues over the top of the seawall towards Wade Lane, from where it continues onto the beach. As such, the coastal defences fulfil three functions: retention of fresh water in the mill pond, flood protection to the hinterland and preserving the coastal path.

Figure 2: Overview of the coastal defences around Langstone Mill, including condition assessment sections.

2.3 Failure Mechanisms

It should be noted that the different stages of failure of the coastal defences might hamper different functions. Generally, the seawall is likely to fail in the following sequence:

1 Initially, the masonry face will fail:

- 1.1 Mortar is lost from the masonry face, and ultimately bricks get dislodged, exposing small parts of the embankment, or;
- 1.2 The face lacks sufficient support and topples over, exposing the embankment over its full height.

2 The coastal path will fail:

- 2.1 If bricks have become dislodged: this can lead to loss of fill material. This will impact the coastal path through the formation of voids, which lead to failure of the path and unsafe conditions. If enough fill material is lost, the masonry face can fail altogether, in which case the sequence would continue with 2.2 below.
- 2.2 If the masonry wall has toppled over: the earth embankment behind the masonry face is likely to slump to a less steep angle after full failure of the masonry wall. It is now exposed to tidal and wave action and will progressively deteriorate, reducing its width. This will impact the coastal path, which will become unusable from a health and safety perspective before the full failure of the earth embankment.

3 The embankment will fail: the width of the earth embankment has reduced such that it breaches under the next storm, compromising its flood protection and freshwater retention function. Note that the embankment could also fail due to pressure from the retained fresh water.

Additionally, it should be considered that sections of the seawall can fail sequentially due to outflanking. Once part of the masonry face has failed, it is more likely for the adjacent sections to fail afterwards. Similarly, when the defence is breached, an accelerated failure of adjacent sections can be expected.

2.4 Historical Assessments

In March 2022, an approximately 30m section of brick sea wall collapsed near Wade Lane following winter storms (**Figure 3**) and a condition assessment was undertaken in which the sea wall was assigned a poor rating by AECOM (2019).

Figure 3 (Left) collapsed sea wall in spring 2022 (photograph coastal partners); (right) collapsed sea wall in January 2023 (photograph D. Brew, RHDHV 2023)

A high-level assessment of the Chichester Harbour seawalls was carried out in January 2023 by Royal HaskoningDHV (RHDHV 2023) and the same damage to the wall was highlighted. Attempts were made by locals from the community to repair/maintain the damaged areas with sandbags. However, these sand bags are a temporary solution and are already failing (see Langstone Coastal Path Local Initiatives — Coastal Partners). In the largest area of failure, Section F in **Figure 2**, there was a considerable amount of rubble in the initial photos (**Figure 3**). Some displacement of that material has taken place; it cannot be confirmed whether this was manually moved or reworked by the tides.

Figure 4 Damaged seawall at Langstone Mill. Photographs taken 4th January 2023 (RHDHV 2023).

Following these signs of wear and deterioration, Coastal Partners have been monitoring this sea wall closely and further information is available on their website (Langstone, Mill Pond to Wade Lane, Havant — Coastal Partners). Between December 2022 and July 2023 their monitoring indicated that some sections of the footpath are not eroding but are instead becoming wider by up to 0.3 m and other areas are eroding by up to 0.8 m. The areas of accretion may reflect sections where the embankment is slumping giving the impression that the footpath is stable here but with time it is expected these areas will erode. At the maximum observed rate of erosion (0.13 m per month), the full footpath width (average 3.5 m) would be removed within 2-2.5 years (from July 2023).

2.5 Visual inspection

The condition of the defences was assessed on 8th August 2023 in line with the Environment Agency Condition Assessment Manual (Environment Agency, 2012). The condition grading and descriptions are presented in **Table 1** which are the standards adopted by the Environment Agency for visual inspections of coastal defences. The condition grades range from 'very good' to 'very poor', and the descriptions reflect the condition according to flood defence performance. Representative photographs of the sea wall condition are given in **Table 3** with the locations shown in **Figure 5**.

Table 1: Visual Inspection Condition Grades, Environment Agency Condition Assessment Manual, 2012.

Grade	Rating	Description
1	Very Good	Cosmetic defects that will have no effect on performance.
2	Good	Minor defects that will not reduce the overall performance of the asset.
3	Fair	Defects that could reduce performance of the asset.
4	Poor	Defects that would significantly reduce the performance of the asset. Further investigation needed.
5	Very Poor	Severe defects resulting in complete performance failure.

Based on the findings of the visual inspection, the defences have been divided into seven sub-sections as indicated in **Figure 2**. A summary of the inspection is presented in **Table 2**.

Table 2: Summary of condition survey on 8th August 2023

Section	Description of defence and general observations	Defence condition
A	The weir is in good condition with an even flow over the width and some minor erosion at the weir walls. These defects do not seem to reduce the performance of the weir. The path in this area is in good condition. The masonry wall lining the mill pond looks to have been constructed recently. A clear tide line is visible on the landward walls of the mill buildings, at approximately 400mm above the path.	Weir: 2 – Good Pond wall: 1 – Very good
B	The path has collapsed over approximately 25m at the end closest to section A, with some debris remaining under the water in the pond. In northward direction from Langstone Mill, various repairs have been done to the seawall; these can be identified by the change in capping materials, i.e., different brick types and concrete instead of the older bricks. There is a significant loss of mortar joints throughout this section. Significant brick displacement is also visible along this section, which could have been caused by the loss of mortar joints. Some of the path has been damaged and a void can be seen showing the infill material behind. There is a large amount of the vegetation along the wall for approximately 25m before the Eastern Sluice. Although this is not initially an issue, this may lead to structural integrity issues as roots could damage the joints in the wall.	4 – Poor
C	The Eastern Sluice has a significant vegetation cover on the moving parts. Although the sluice is holding water, it cannot be confirmed that it functions correctly.	3 – Fair

Section	Description of defence and general observations	Defence condition
	The masonry structure has a loss of mortar in the joints and cracks along the eastern wing wall of the sluice. Undermining can be seen at the base of the southern wall (closest to Langstone Mill).	
D	The masonry wall shows signs of both long-term (parts of the wall were rebuilt) and temporary repairs (sandbags were placed to patch gaps). There is a significant loss of mortar on the seaward face.	4 - Poor
E	This recently constructed section of masonry wall is in good condition. The join to section D has failed, which has left a void. In future, this may increase in size and cause erosion and loss of material behind the newly constructed wall section.	2 - Good
F	Within this section, most of the masonry wall has failed. The eastern portion (approximately 12.5m) of the wall is still standing, however, there is a large crack in this section indicating that it may fail soon. Along sections where the wall is still standing, a concrete shelf is visible at its base, which is starting to be undermined. The western portion consists of a concrete wall which is in fair condition. From historic photos (Google Earth), the concrete wall was constructed following a failure in 2016. There is a historic wooden structure set seaward from the wall, which has failed; only short parts extend above the ground	Masonry wall: 5 – Very Poor / Failed Earth embankment: 4 – Poor Concrete wall: 3 - Fair

2.6 Photographs

Figure 5 Representative locations of photos taken during the inspection.

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Table 3 Photographs of sea wall and associated structures condition

Photo Number	Photo	Caption	Section
A		The weir at Langstone Mill Pond; this weir is in good condition, with an even flow over the crest.	A
B		The mill pond, showing the brick retaining wall in good condition, with the broken failing path in the foreground.	A
C		The Mill Pond and the failed path.	B

Photo Number	Photo	Caption	Section
D		This photo looks back at Langstone Mill along the seawall. The mixture of capping styles can clearly be seen.	B
E		The seawall, with 2 different capping styles. There is significant movement of the masonry capping. Vegetation can be seen coming through the masonry sections.	B
F		Development of a void behind the masonry seawall.	B

Photo Number	Photo	Caption	Section
G		Sluice gate with heavy vegetation growth. Gap at the top allowing for overflow.	C
H		Masonry strut in the sluice outfall structure showing mortar missing.	C

Photo Number	Photo	Caption	Section
I		Sluice outfall structure. The far strut is showing some undermining at the internal toe.	C
J		Masonry bricks missing, showing rock infill behind.	D
K		Masonry grouting missing at the bottom of the seawall	D

Photo Number	Photo	Caption	Section
L		Failed seawall, which was attempted to be repaired with sandbags. More bricks have been displaced since.	D
M		Loss of mortar. There also seems to be a difference in the batter angle between two sections of the masonry seawall.	D
N		A major failure of the masonry seawall which was attempted to be repaired with sandbags at least twice.	D

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Photo Number	Photo	Caption	Section
O		A recently constructed section of seawall.	E
P		Approximately 30m of failed wall section. Along some areas, repairs have been attempted.	F
Q		Remaining standing section of the failed wall.	F

Photo Number	Photo	Caption	Section
R		Masonry brick displacement and mortar grouting is missing.	F
S		Timber fence installed along the coast east of the seawall.	East of Seawall

2.7 Remaining Life of Defences

An assessment of the remaining life of the defences was performed using the Environment Agency's Guidance on Asset Deterioration (SC060078/R3; Environment Agency, 2013). For all the structures, a Maintenance Regime 1 (low / basic – do minimum repair and maintenance) was assumed. A summary of the results of the assessment is provided in **Table 4**. It should be noted that the results of this assessment only reflect the condition and deterioration of the individual sections. However, if one section were to fail, this could lead to accelerated failure of other sections. For example, if the masonry wall in section D were to fail close to where it joins section E, then section E could become outflanked, drastically reducing the expected lifetime in **Table 4**. It should also be noted that the Environment Agency's Guidance on Asset Deterioration is based on an assessment of a range of defences from different contexts providing a typical or average estimate. If site-specific monitoring or deterioration assessments have been undertaken, they are considered a more accurate representation of an assets remaining life, and these should replace the estimates given here. It should also be noted that no structural information is available on the configuration of the embankment behind the sea wall and these assessments are based on a visual inspection only.

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Table 4: Estimated Residual Life of the coastal defences based on Environment Agency guidance.

Section	Remaining Life	Comments
B	5-10 years	This section is a combination of an earth embankment and a masonry wall. The masonry wall is expected to fail over the next five years. The embankment is expected to be able to retain is function for a period up to five years after that.
C	10-20 years	Although the functioning of the sluice gate could not be confirmed, the structure surrounding the gate seems in fair condition. The masonry structure seems to be in Fair condition and is probably still robust compared to loading conditions.
D	5-10 years	This section is a combination of an earth embankment and a masonry wall. The masonry wall is expected to fail over the next five years. The embankment is expected to be able to retain is function for a period up to five years after that.
E	20-30 years	This section of wall was recently constructed and is in Good condition.
F	2-5 years	The masonry wall facing the embankment has failed along most of this section, and it is therefore the residual strength of the earth embankment that determines the residual life of the structure. It should be noted that the newly constructed concrete wall will have a considerably longer expected lifetime than this. Note that monitoring of erosion is being undertaken along Section F and the initial results suggest the embankment (and footpath) will fully erode in the next 2-2.5 years. These estimates may change with further monitoring.

2.8 Surrounding areas

To the west of Langstone Mill, there is a masonry wall extending towards the village of Langstone. This wall is in good condition. There does not seem to be any major issues with this section of defence. Additionally, at many properties along this section, as far inland as The Saltings, private flood protection equipment has been installed.

To the east of the defences that have been assessed is a timber wall that has been constructed with disused railway sleepers. This wall extends for approximately 350m and is in good condition. Sporadically, small sections (1-2 planks) are missing or in need of repair, but this does not threaten the integrity of the flood defence, as the timber wall is backed by a relatively high earth embankment.

The saltmarsh that is seaward of the defences acts as a defence itself according to the CIRIA condition assessment manual. The saltmarsh is patchy in its distribution and the intertidal area is largely mudflat (see **Section 6.4**). According to the Environment Agency Condition Assessment Manual (Environment Agency, 2012) the saltmarsh would be classified as in very poor condition.

2.9 Legal owners and maintainers of coastal defences

The legal responsibilities for the coastal defences around Chichester Harbour are difficult to define. The Environment Agency's Asset Information and Maintenance System (AIMS) (Environment Agency 2023a) provides partial coverage of the coastal defences around Chichester Harbour that are currently owned, managed or inspected by the Environment Agency and other organisations (JBA Consulting, 2022) (**Figure 6**). According to the AIMS dataset, the maintainers of the sea wall between Langstone Mil and Wade Lane are unknown.

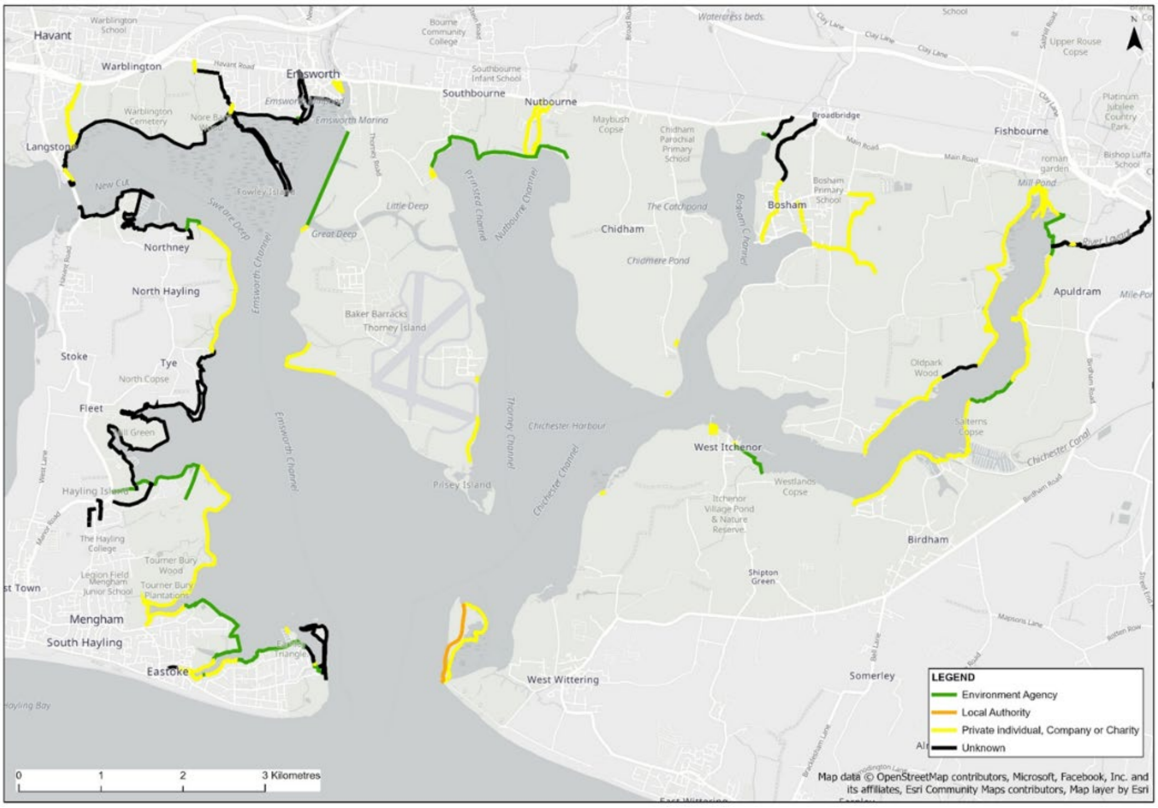

Figure 6 Asset maintainer as defined by the AIMS data around the Chichester Harbour coast (source: Environment Agency)

3 Site history and cultural heritage

3.1 Introduction

The history of the study area is in part related to the environmental history and the modification of this environment by human activity. This section of the Technical Study establishes the known archaeological, historic environment and built heritage features associated with the study area. Note, at this stage of the assessment this provides a high-level overview and should not be used in place of a detailed desk-based assessment which would likely be required to support any planning or consent applications (depending on the preferred option for future management). The Historic Environment Record for Hampshire has not been consulted for this study.

3.2 Heritage assets

Designated Heritage Assets within the study area include:

- **Langstone Conservation Area:** The conservation area encompasses the former historical hamlet of Langstone, which developed in proximity to the harbour. It shares a border with the Wade Court conservation area to the north and is adjacent to the Mill Lane Conservation Area to the west. The

Langstone Conservation Area spans coastal lowlands to the east and south, as well as the level expanse of verdant fields extending towards the north and west.

- **Wade Court Conservation Area:** The conservation area encompasses Wade Court House and its associated outbuildings it encompasses the water garden created from Lymbourne stream. The remains of an estate landscaped during the late 19th and early 20th centuries which contributes significantly to the rural appearance of the land bordering Chichester Harbour.
- **The Old Mill (Grade II Listed, NHLE 1340200):** A water mill (commonly known as a tide mill), a mill store (currently repurposed as a dwelling), and an adjoining windmill (integral to the dwelling structure). Erected during the early 19th century, this arrangement showcases remarkable cohesion. The water mill spans a creek and is intricately linked to a protective seawall featuring sluices.
- **59 and 61, Langstone Road (Grade II Listed, NHLE 1340206):** A matched set of residences dating from the late 18th century is characterised by their weather-boarded exteriors and tiled roofs. The front facade, facing west, provides a sense of symmetry, featuring two levels along with an attic, and two windows. The entrances to each residence are situated along the sides, accessible through modest porches on the southern aspect.
- **Wade Court (Grade II Listed, 1271906):** This country house, originally constructed in the early 18th century and later expanded in the late 19th century, has undergone various alterations over time. It is made of red brick with stone accents and features multiple sections. The original house, situated at the right (west) end, consisted of five bays. During the late 19th century, a seven-bay extension was added in a blend of Queen Anne and Jacobean architectural styles. Additionally, a substantial medieval-style tower was erected towards the east (left) end of the front.

There are several Designated Heritage Assets to the south of the study area within the residential area of Langstone, these include:

- The Royal Oak Public House (Grade II Listed, NHLE 1091597);
- 16, 17 and 18, High Street (Grade II Listed, NHLE 1091596);
- 8-14, High Street (Grade II Listed, NHLE 1091595);
- The Green Cottage (Grade II Listed, NHLE 1091604); and
- The Ship Inn (Grade II Listed, NHLE 1303563).

3.3 Site history

Langstone's extensive history of human settlement dates from the prehistoric to modern periods and is deeply intertwined with its coastal location and subsequent commercial activities.

Human occupation and use of the area is first evidenced in the Prehistoric where Bronze Age roadhouses, a timber feature and an axe hoard were identified during excavations to the north of Hayling Island (Williams and Soffe 1987; Lawson 1999). A middle Bronze Age cinerary urn, an oval pit, and a fragment of hearth was also uncovered 200m to the west of the Site (NGR SU 71510 05000) dating to the mid-1st century AD (Allen & Gardiner 2000).

The lowest reaches of the valley to the west of the study area contain estuarine alluvium indicating that the area known as South Moor (or Mere) was formerly subject to tidal flooding and for much of the prehistoric period the area was low-lying coastal plain bisected by the Langstone and Broom Channels (Allen and Gardiner 2000, 109).

The remnants of a Roman Villa were located to the north of the existing village of Langstone 250m northwest of the study area. The building sequence began in the mid-late 1st century AD and continuing into the 4th century (Gilkes 1998). Similarly, on Hayling Island excavations in the 1970s uncovered a Roman temple on the site of two successive late Iron Age timber shrines. The shrines dated from the early/mid-1st century BC and continued up to and beyond the Roman conquest in AD 43, being replaced on the same site by the large stone-built temple in the 60s/70s AD, which mirrors the plan of the earlier shrine (King and Soffe 2013).

Recent archaeological assessments of Langstone Harbour suggested that the current intertidal zones such as Emsworth Harbour to the east of the study area and the area on which the Wadeway (The Wadeway | Hayling History | Hayling Island Site) was constructed was saltmarsh in the Romano-British period and is therefore likely to have been waterlogged (Allen and Gardiner 2000).

The first documentary evidence which suggest a settlement at Langstone and the existence of a crossing point to Hayling Island comes from the Domesday Book which refers to the settlement of Wade (https://opendomesday.org/). Reference to the village of Wade is repeated in the 1260s during the reign of King John (Page 1908) and the village of West Wade is mentioned in a lease of the lands to the Duke of Arundel (Morley 1987, 9). Heritage Gateway records a possible deserted medieval village (Wade DMV) to the southeast of the study area centred on the current mill pond.

During the later medieval period Langstone thrived as Havant's significant port. Its role as a bustling commercial centre involved the import of wood, coal, locally sourced sand, and gravel, while exporting grains. Substantial vessels, some capable of carrying three to four hundred tons, unloaded their cargo at quays located alongside the causeway near the bridge (Havent Borough Council 2011).

In 1817 Langstone is recorded as being strategically situated at the ingress of the ford or wadeway and as containing three mills, twelve houses and a public house (Havant Borough Council 2011). In 1824, the initial road bridge to Hayling Island was constructed along with the elongation of Langstone Road leading southward from Langstone High Street. Preceding the bridge's inception, crossing the water was confined to boats or the visible Wadeway during low tide. This connection subsequently diverted through-traffic away from the village, thereby providing a protective buffer against intensifying vehicular flow and developmental pressures (Havant Borough Council 2011).

The mid-19th century brought notable progress to Langstone. The Admiralty responded to maritime activities in Chichester Harbour by erecting a coastguard station in 1860, complete with a watchtower, a row of coastguard cottages, and the Chief Officer's residence. Concurrently, commercial endeavours led to the establishment of a railway line linking Langstone to Havant in 1865, facilitating the transportation of goods from ships to London. The railway was subsequently extended to South Hayling in 1867, necessitating the construction of a new railway bridge over the water.

The OS 6” to 1 mile Map published in 1870 depicts most of the Site as agricultural farmland, bordered on the west by the Hayling Railway and Langstone Station and the east by the mill race and dam associated with the Old Mill (NHLE 1340200). The Royal Oak public house (NHLE 1091597) and Wade Court (NHLE 1271906) are also shown.

The OS 6” to 1 mile Map published in 1910 and 1939 shows incremental westward development on the outskirts of Langstone with the addition of residential properties along Langstone High Street. The decline of coastal trade in the 20th century, combined with the deteriorating Langstone Harbour bridge, led to the railway line's closure in 1962. The section between Langstone and Havant is now a combined footpath, cycleway, and bridle path.

The early 20th century marked the construction of a limited number of detached and semi-detached villas along Langstone High Street, primarily associated with Langstone Lodge. The period also witnessed the creation of flint boundary walls.

4 Coastal erosion and sea-level rise assessment

The land fringing Chichester Harbour has been reclaimed over the years, resulting in low-lying land with significant areas at risk of tidal flooding from tidal surges. Typically, coastal flooding can be caused by either Still Water Level flooding, wave overtopping, or a combination of the two. In the context of coastal management, given its relatively sheltered location from the open sea, the dominant source of coastal flooding around Chichester Harbour is due to Still Water Level flooding, which is the average water level at any given time, excluding local variation due to waves.

An understanding of the elevation and topography of the study area relative to water levels is important for estimating the potential extent of flooding considering the condition assessment of the existing sea wall. It is also important to understand changes in water levels resulting from climate change and extreme storm events with up to 1 m of sea-level rise predicted over the next 100 years. This section considers existing tidal data and sea-level rise projections to estimate the frequency and extent of flooding within the study area.

4.1 Water levels

Baseline extreme water levels were obtained from the Environment Agency (EA) Coastal Flood Boundary Dataset (CFBD) (Environment Agency, 2018). This dataset provides extreme water levels for a variety of return periods along the coast of England and Wales and within estuaries and harbours (**Figure 7**) for reference year 2017. More specifically, baseline extreme water levels have been obtained from the estuary dataset, where the closest data point to Langstone Harbour is located south-west of Hayling island (chainage 4604_1).

Sea-level rise projections have been taken from the closest available data cell, situated south-east of Hayling Island (**Figure 7**, right) using UK Climate Projections 18 (UKCP18) Representation Concentration Pathway (RCP) 8.5 (70th percentile) projections in line with Environment Agency guidance (Environment Agency 2020). This climate change scenario represents the higher end of climate change predictions and predicts that sea levels within the area of study will rise by approximately 0.8m over the next 100 years. Sea-level rise projections have been applied to the Environment Agency CFBD water levels to derive future extreme water levels for present day (taken as 2025) and year 2050 (+25 years), 2075 (+50 years) and 2100 (+75 years). **Table 5** summarises the extreme water levels for a variety of return period events and water levels are quoted in metres relative to Ordnance Datum (mOD).

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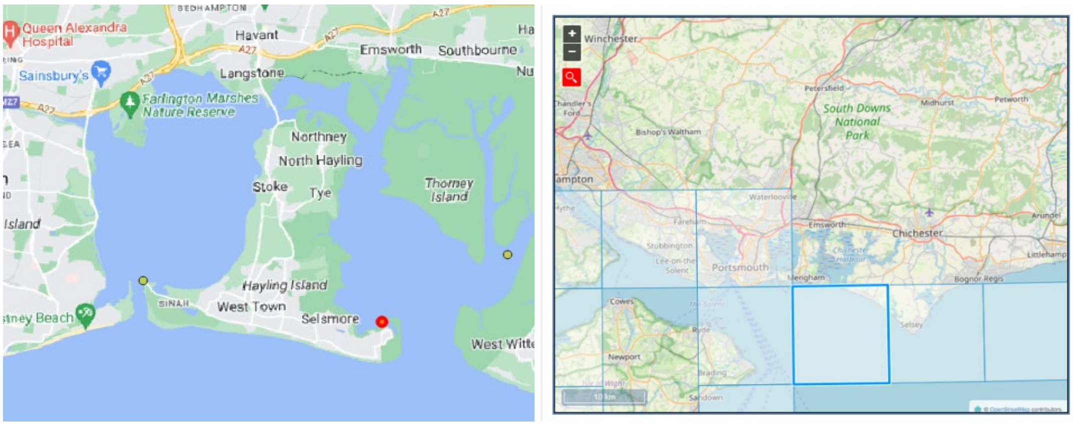

Figure 7: Environment Agency CFBD output point (left, in red) and UKCP18 sea-level rise output area (right, enclosed by the blue polygon).

Table 5: Extreme water levels (Environment Agency CFBD chainage 4604_1) in future years including sea-level rise (RCP 8.5 70th percentile). Note extreme water levels are higher than tide levels as they include any effects from storm surges.

Return period (1 in x)	Base water Levels 2017 (mOD)	2025 (mOD)	2050 (mOD)	2075 (mOD)	2100 (mOD)
1	2.70	2.75	2.93	3.18	3.49
10	2.94	2.99	3.17	3.42	3.73
20	3.01	3.06	3.24	3.49	3.80
50	3.10	3.15	3.33	3.58	3.89
75	3.14	3.19	3.37	3.62	3.93
100	3.17	3.22	3.40	3.65	3.96
200	3.24	3.29	3.47	3.72	4.03
1000	3.65	3.70	3.88	4.13	4.44

4.2 Tidal levels and tidal range

Baseline tidal levels were extracted from the Admiralty Tide Tables (UK Hydrographic Office, 2022) for the Langstone Harbour entrance. Similar to the water level assessment, sea-level predictions were derived from the UKCP 18 dataset (employing the RCP 8.5 70th percentile scenario) and have been applied to the baseline tidal levels to understand future water levels. The results obtained from this analysis are presented in **Table 6**.

Table 6: Changes to tidal levels at Langstone Harbour over time due to sea-level rise (RCP 8.5 70th percentile).

Langstone Harbour entrance	2022 (mOD)	2025 (mOD)	2050 (mOD)	2075 (mOD)	2100 (mOD)
HAT	2.66	2.68	2.86	3.11	3.42
MHWS	2.06	2.08	2.26	2.51	2.82
MHWN	1.16	1.18	1.36	1.61	1.92
MLWN	-0.84	-0.82	-0.64	-0.39	-0.08

Langstone Harbour entrance	2022 (mOD)	2025 (mOD)	2050 (mOD)	2075 (mOD)	2100 (mOD)
MLWS	-1.94	-1.92	-1.74	-1.49	-1.18

4.3 Existing ground levels

LiDAR data (2022) was used to determine the existing ground levels (**Figure 8**). In addition, multiple cross sections along the sea wall were analysed to establish the representative crest level of the coastal defences. It is concluded that a crest level of 2.7 mOD represents the entirety of the wall section. It is important to note that the LiDAR data's resolution is not sufficient to confidently capture the shape of the defences and, to a certain degree, the crest level accurately. To obtain more accurate levels, a topographic survey would be required. The lowest lying area behind the defences is Langstone Mill Pond (although it should be noted that the levels in the LiDAR data reflect the water surface, not the bottom of the pond which is estimated to be between 1.0 and 1.4 mOD) and Lymbourne stream and its floodplains. The surrounding land rises rapidly to higher levels.

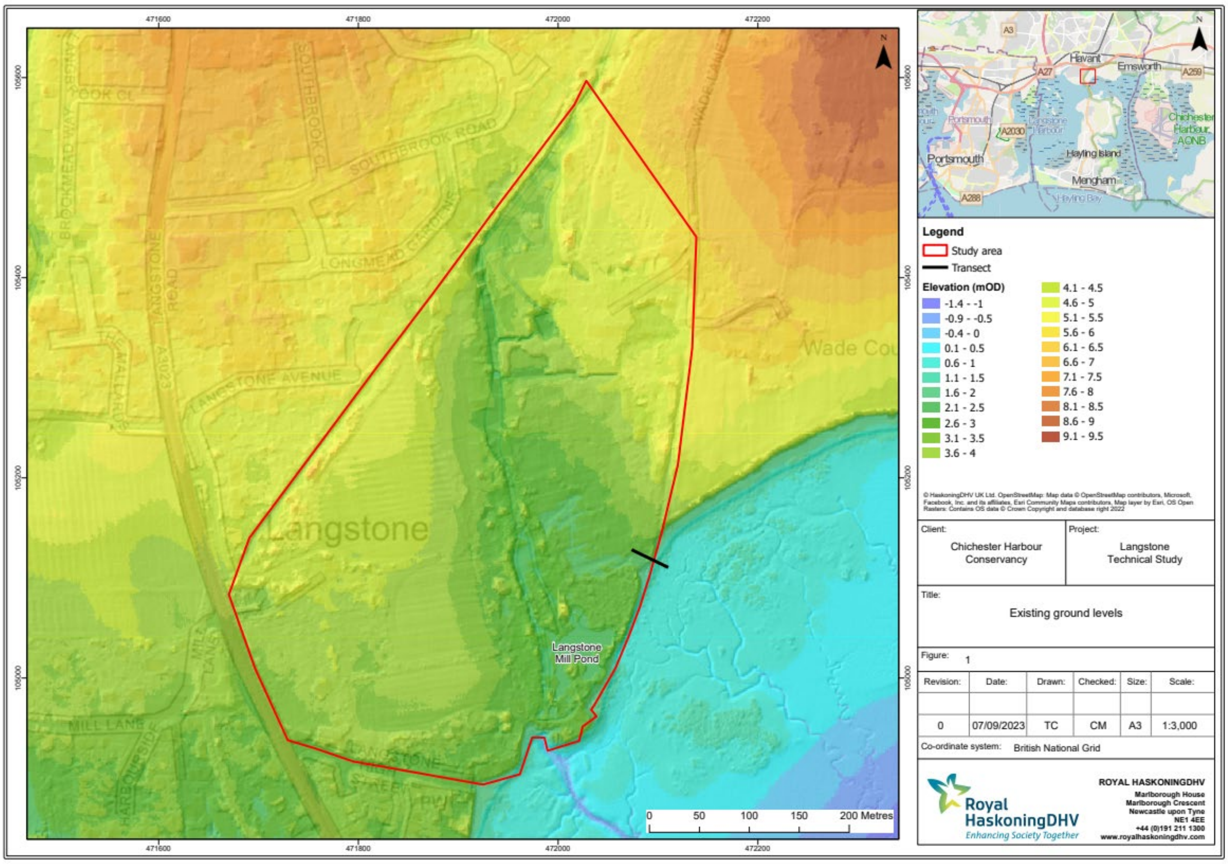

Figure 8: Existing ground levels at Langstone.

Figure 9 displays a cross section of the coastal defence alongside the projected tide levels for 2025 and estimates of future extreme sea levels (refer to Figure 8 for location of cross section). At present, the sea wall is prone to Still Water Level overtopping in the event of a 1-in-1-year storm and also during the Highest Astronomical Tide (HAT). It is important to note that HAT is the expected maximum astronomical tidal level under average meteorological conditions and does not account for extreme variations caused by specific weather conditions, which can result in both higher and lower water levels. Given that in 2025, Mean High Water Spring (MHWS; the average of the two high waters with the highest tidal range in each tidal cycle) is only 62cm under the crest, the sea wall is also considered to have a high chance of overtopping during spring tides. Note, these levels do not account for additional water level induced by waves, which would raise the levels further.

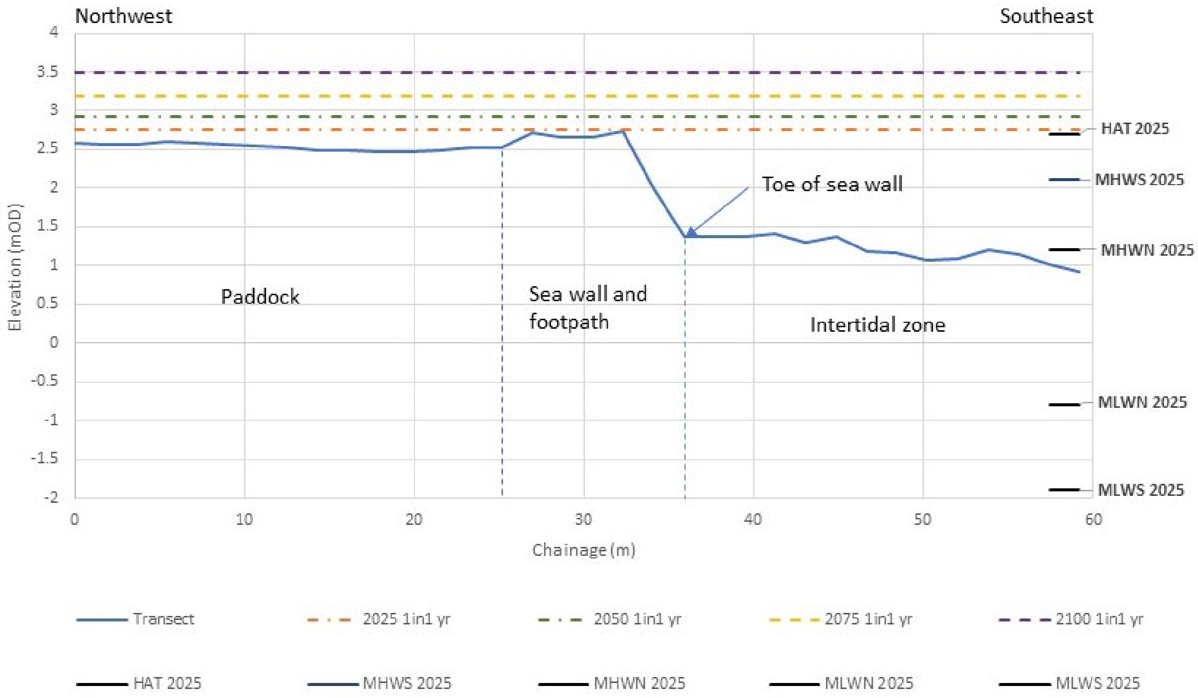

Figure 9: Transect showing elevations of the site relative to predicted tide levels in 2025 and extreme water levels until 2100. The location of this transect is shown on Figure 8.

4.4 Coastal flooding

4.4.1 Introduction

A high-level assessment of the extent of coastal flooding was undertaken by comparing the elevation of the land behind the sea wall to the present-day tidal levels but also the water levels during storm events with different return periods. This assessment can also be projected into the future by considering predictions of sea-level rise. At a high-level, this approach does not include barriers to coastal flooding, such as existing coastal defences, and the images shown in **Figure 10** to **Figure 12** describe the situation if the entire sea wall between Langstone Mill Pond and Wade Lane is removed. In its current state, the sea wall is still functioning as a defence but as it deteriorates with time, breaches in the defence will create pathways for tidal waters to ingress landwards. These pathways will depend on the location and size of any breaches in the sea wall, which will in turn determine the extent of flooding. Therefore, the images in **Figure 10** to **Figure 12** should be interpreted carefully as they show the worst-case scenario if the entire defence is removed. However, they are useful in understanding what assets, including habitats, could be affected if the sea wall is breached (naturally or deliberately).

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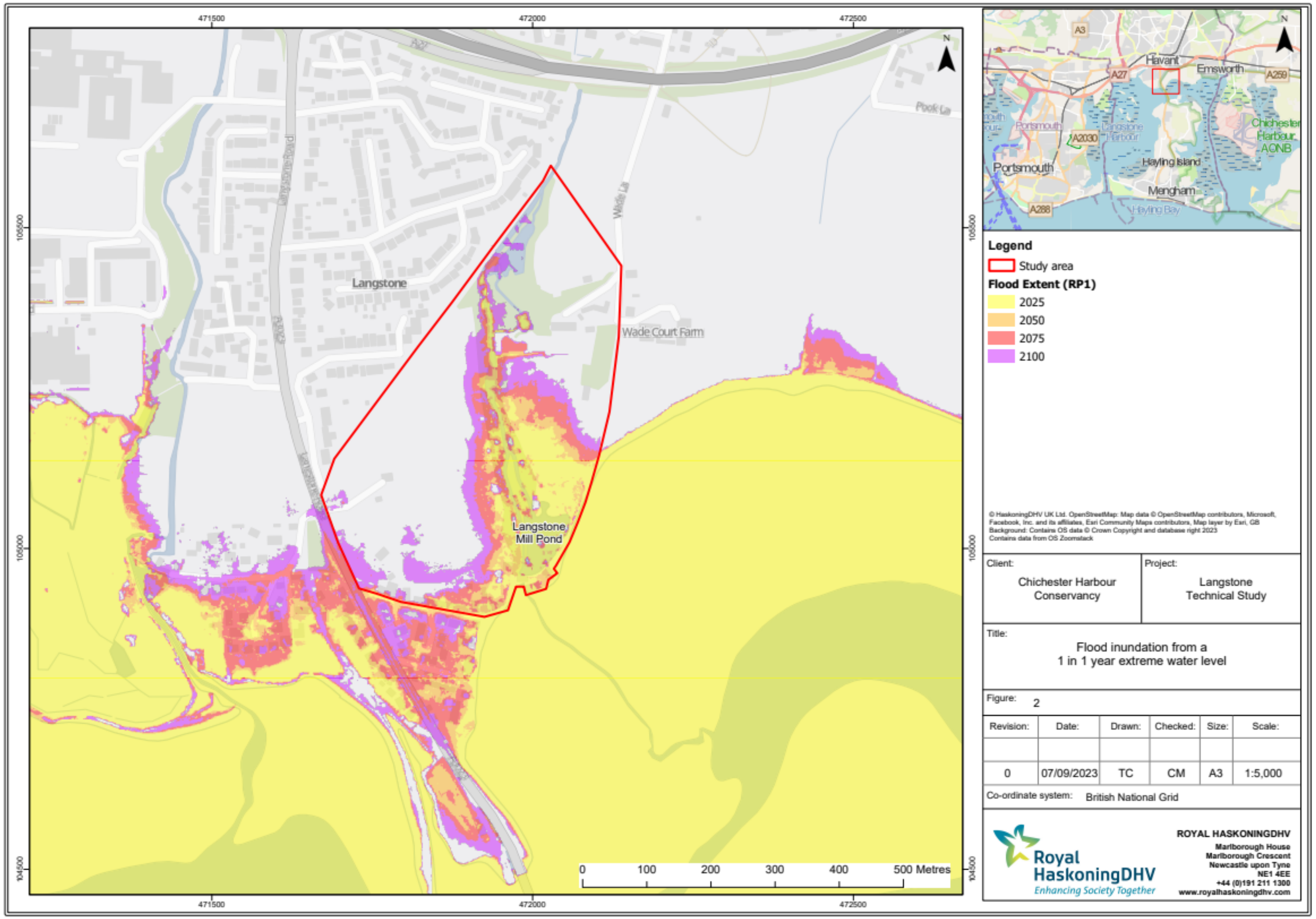

Figure 10: Flood inundation from a 1 in 1-year extreme water level.

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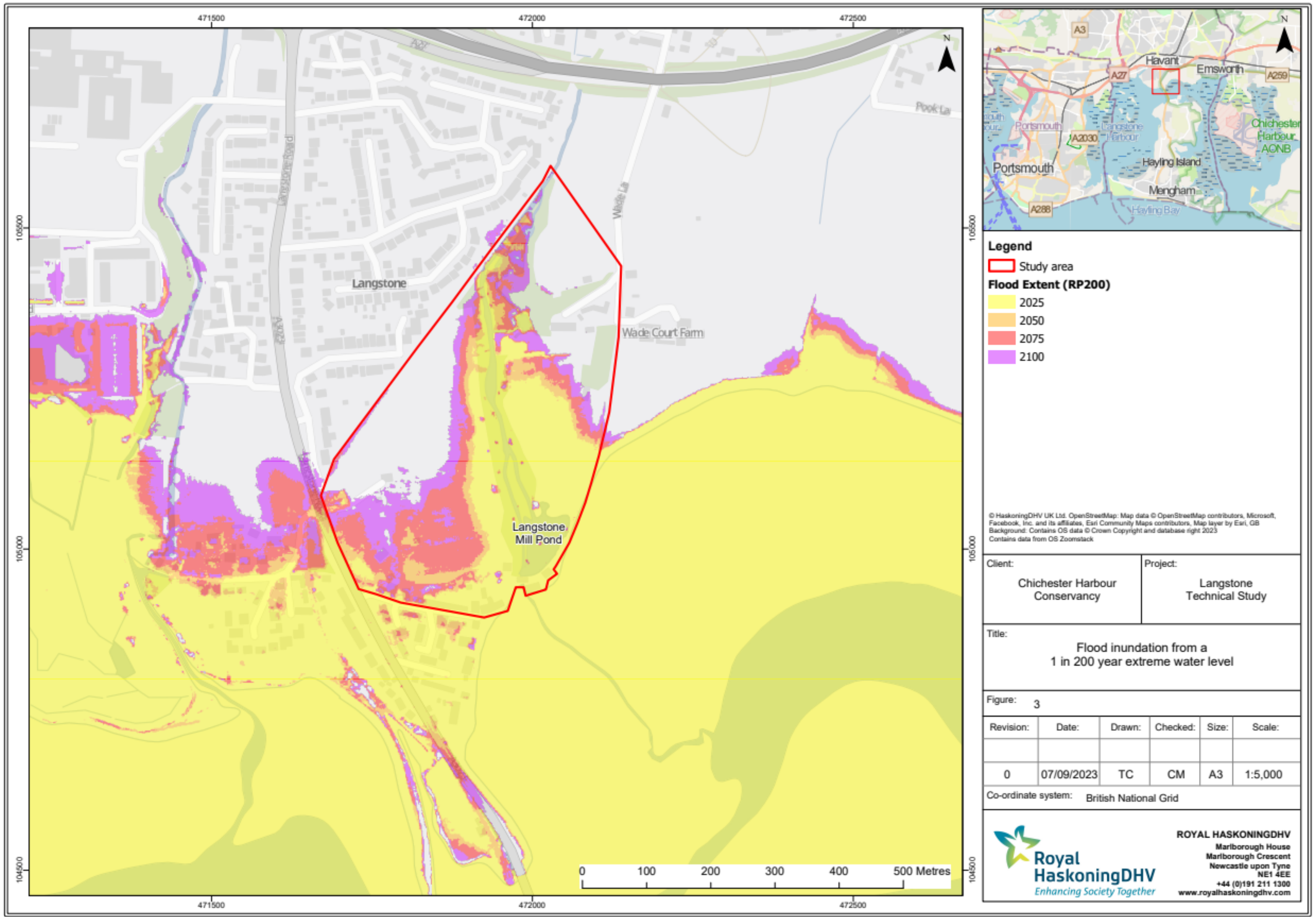

Figure 11: Flood inundation from a 1 in 200-year extreme water level.

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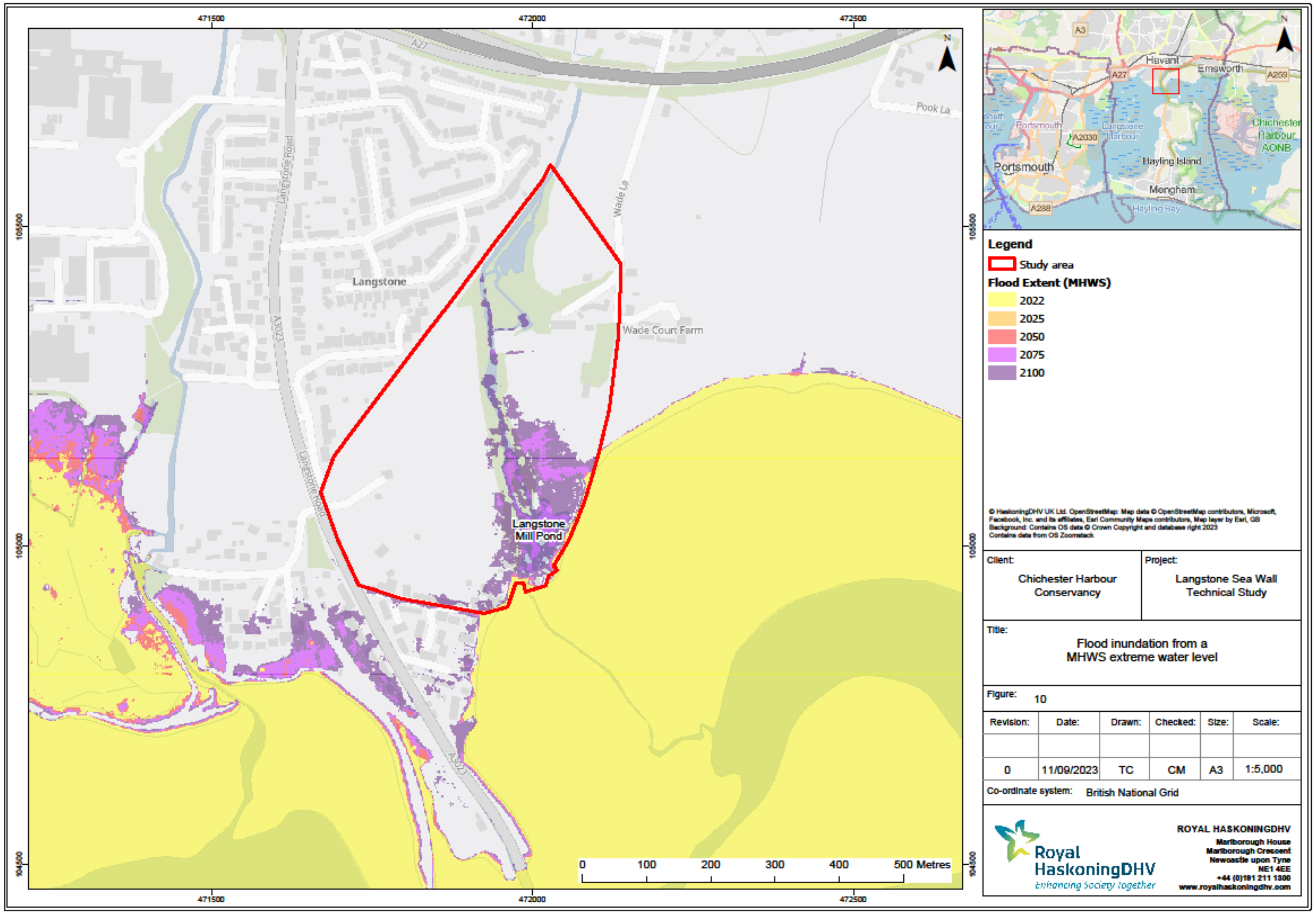

Figure 12; Flood inundation from MHWS tides.

4.4.2 Mechanisms of coastal flooding

In this study, the terms inundation, coastal flooding and tidal ingress are used to describe situations where saline (brackish) water flows into the land behind the sea wall. This study considers the impact of coastal flooding via two main mechanisms:

- Overtopping: where water levels are high enough to flow over the top of the sea wall (and sluice gates); and,
- Breaching: where the sea wall is compromised creating a gap that is permanently open and low enough in elevation to allow tidal waters to flow through under typical tidal conditions.

A distinction between these two mechanisms has been made as the frequency, duration and extent of coastal flooding will differ between the two. Their dominance will also change with time in relation to sea-level rise and the condition of the sea wall. Where possible, when referring to coastal flooding, this study defines which mechanism is being referred to.

4.4.3 Extent of coastal flooding

With the existing sea-wall crest levels, present day water levels, and an extreme water level event with a 1 in 1-year return period (likely to occur once a year), inundation of Langstone Mill Pond, Lymbourne stream and nearby Victorian gardens near Wade Court is expected. The paddock between Langstone Mill Pond and Wade Lane is also likely to be inundated, as illustrated in **Figure 10**. Over time due to sea-level rise, the area affected by inundation during such events will expand further inland. However, it does not reach properties to the north or east of Langstone Mill Pond or the A27 within the next 75 years (time frame of these predictions). It is important to note that under this scenario, the inundation is expected to be short-lived, i.e. for the duration of a storm or high tide event after which conditions would return to normal after the event passed. The effect of tidal waters on Lymbourne stream will depend on the hydrology of the stream at the time. For example, if the event occurs during or after a period of high rainfall, the stream may be discharging large volumes of freshwater that would limit how far upstream the tidal waters could influence.

The extent of inundation has also been estimated for a 1 in 200-year return period event, as shown in **Figure 11**. In this scenario, the extent of the inundated area is greater but no additional assets are effected when compared with the 1 in 1-year scenario. The infrastructure at risk of inundation from coastal flooding is presented in **Section 6**.

Figure 12 shows the extent of inundation under typical tidal conditions rather than storm events. The extent of coastal flooding during a MHWS tide is much lower when compared to storm events. Langstone Mill Pond, Lymbourne stream and the adjacent paddock will not be frequently inundated during spring tides until sometime between 2050 and 2075. This suggests that if the sea wall was breached, tidal inundation of these assets would only occur during extreme events over the next 25 years and it is only after 2050, when sea levels are high enough relative to land elevations, that a more permanent shift to an intertidal environment would occur.

4.4.4 Frequency of coastal flooding

Overtopping of the seawall can either occur due to the Still Water Level (SWL) or due to waves. In the case of SWL overtopping, the still water level is higher than the crest of the seawall, and therefore, water flows over the top of the wall. In the case of wave overtopping, the SWL is below the crest of the defence, but the interaction between waves and the seawall causes water to flow over the defence. For this study, the analysis in this section focusses on SWL overtopping (as no data is available on local wind or waves, and a full wave overtopping study is outside of the scope of this report). However, some allowance has been made to account for wave overtopping and the effects of local wave and wind set-up on the SWL. The number of occurrences of overtopping presented in this section assume wave conditions that are conservative and therefore should indicate an order of magnitude and provide an indication of the occurrence of overtopping into the future. It should be noted that in future, SWL flooding will become increasingly important compared to wave overtopping with rising sea levels.

Water level data between 1991 and 2023 was obtained from the Portsmouth tide gauge (acquired from British Oceanographic Data Centre) as an estimate of the water level at Langstone over that period. Although this does not capture local effects of wind and waves on water level set-up, or the effects of the shape of the harbour, it does capture larger scale meteorological influences on water levels. The effects of historic sea level rise were removed from the data before selecting all tidal cycles during which the SWL could have been higher than the crest of the seawall (2.7m OD). The total count was converted into an average per year. To assess the effect of future sea-level rise, the water level data was increased with sea-level rise predictions following the UKCP RCP 8.5 70th percentile before re-running the event selection. The results are presented in **Figure 13** by the green line. Between 2023 and 2100 a significant increase in the number of overtopping events per year is to be expected. By 2060, SWL overtopping into Langstone Mill Pond can be expected on average once per month. As noted above, this does not include the effect of waves.

To pragmatically account for local set-up and potential wave overtopping, it was assumed that a freeboard of at least 25cm would be required to mitigate any overtopping caused by these additional effects (acknowledging that for extreme storm events this is unlikely to be sufficient). These numbers should thus be interpreted with care. Performing the same analysis but comparing the water levels with a 2.45 mOD threshold (2.7mOD minus 0.25m freeboard), generates the blue line in **Figure 13**. Clearly, the added effect of local wave influences is likely to be significant. In 2023, on average, ten overtopping events are expected to occur (approximately one per month on average, but more likely a higher number of events will occur in winter when compared to summer), with this count increasing to nearly one event a day by 2100.

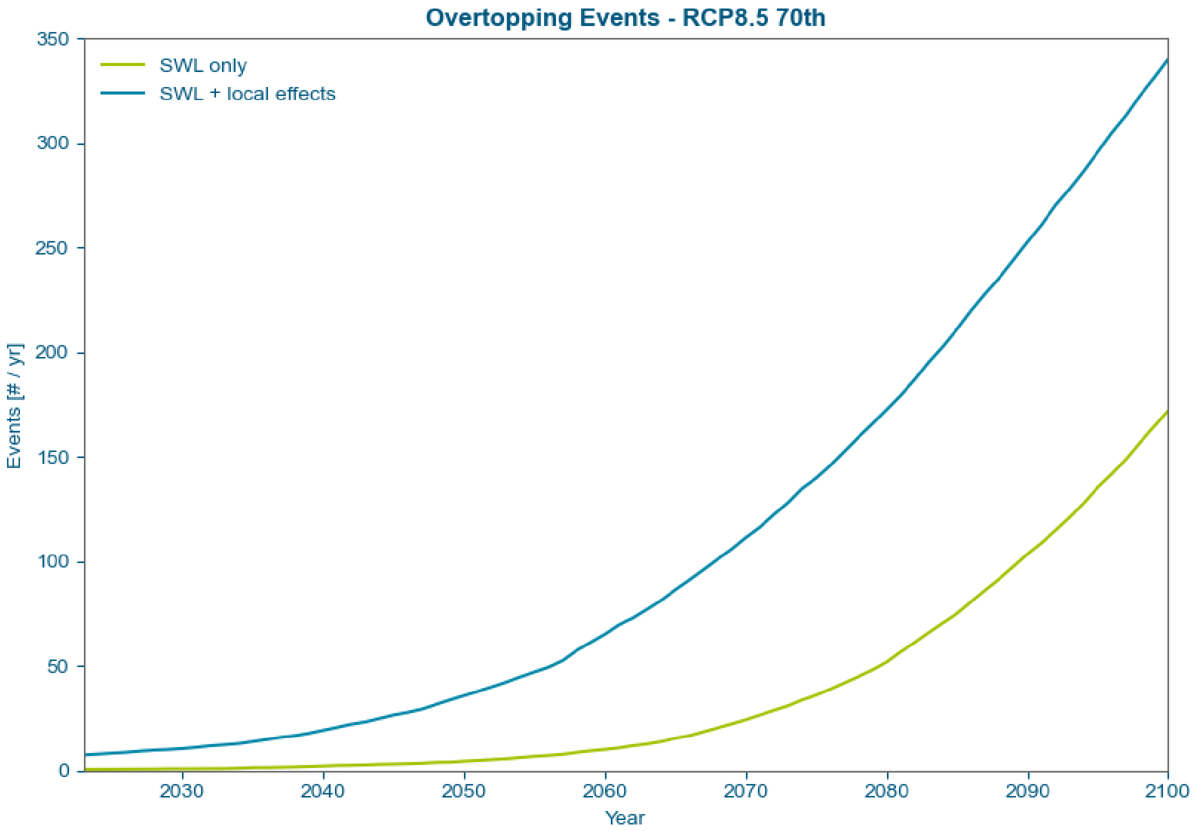

Figure 13: Estimated expected overtopping events under climate change scenario RCP8.5 70th percentile.

5 Land use and habitats

5.1 Priority habitats

According to the UK Biodiversity Action Plan (BAP) Priority Habitat Descriptions (**Figure 14**) the habitats within the study area are classified as:

- Reedbed (located directly to the east of Langstone Mill Pond);
- Deciduous woodland (located to the north and west of Langstone Mill Pond);
- Coastal and floodplain grazing marsh (located to the north and east of Langstone Mill Pond);
- Saltmarsh (within the intertidal area in front of the sea wall);
- Mudflat (within the intertidal area in front of the sea wall); and,
- No main habitat but additional habitats present (Langstone Mill Pond).

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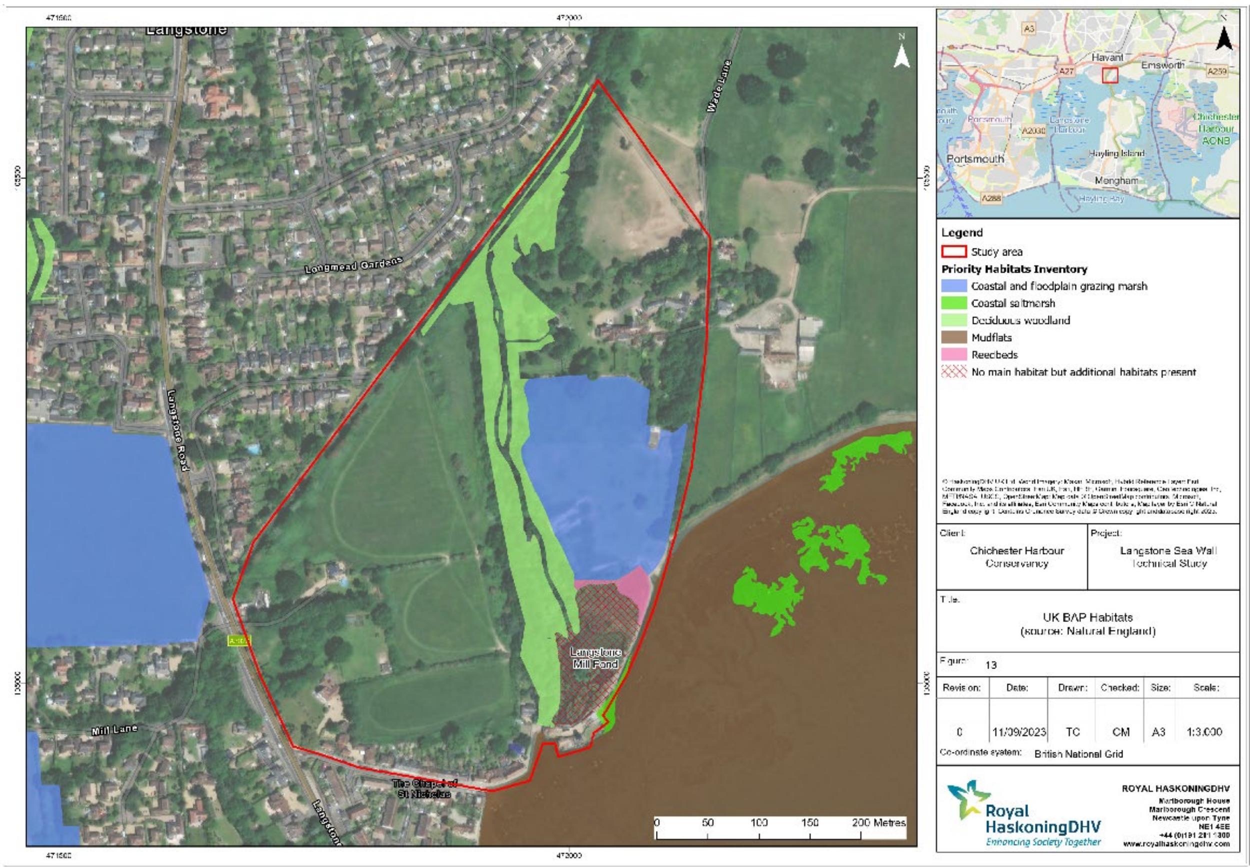

Figure 14 UK BAP Habitats within the study area

5.2 Langstone Mill Pond

Langstone Mill Pond is documented on historical maps from as early as 1888 (**Figure 15**). Langstone Mill was constructed in phases between 1720 and 1832 and it is likely the early sea wall or dam was constructed at the same time, cutting Lymbourne stream off from the harbour and allowing water to pond creating what is now Langstone Mill Pond.

The mill pond covers an area of approximately 0.9ha and is separated from the adjacent intertidal area by the sea wall, an outfall and sluice gates that limit the ingress of tidal waters (**Figure 16**)**.** The sluice gate is manually controlled, and its purpose is to allow freshwater to drain from the mill pond although there is a gap between the top of the sluice and the overlying bridge which would create a path for tidal ingress during high tides or storm surges. Anecdotal evidence suggests the pond is inundated by brackish water up to four times a winter during high tides or storm surges when brackish water overtops the seawall (Chichester Harbour Conservancy 2022). This may be the reason why some of the trees along the south-east edge of Langstone Mill Pond have died (**Figure 17**).

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Figure 15 Ordnance Survey map 1888-1913 (source: National Library of Scotland)

Figure 16 (Left) outfall/weir from the mill pond; (Right) sluice controlling fresh and brackish water outlet/inlet (Photographs taken during site visit 9th August 2023)

Figure 17 Alder and willow trees have died within the reedbed next to Langstone Mill Pond

An assessment of the ecology of Langstone Mill Pond was undertaken by Chichester Harbour Conservancy (2022). The mill pond is fringed by reedbeds (common reed *Phragmites*) and an area of woodland fringes Lymbourne stream to the north that appears largely unmanaged. Both are classified as BAP priority habitats (see **Section 5.1**) To the east of the pond is an area of paddock that is grazed by horses. The area is seasonally flooded from Lymbourne stream to the east and from the harbour to the south. This flooding creates good habitat for wetland birds. The paddock is classified as coastal and floodplain grazing marsh which is also a BAP priority habitat.

5.3 Lymbourne stream

Lymbourne stream is a chalk stream that feeds Langstone Mill Pond from the north. Chalk streams are rare and have high conservation value for wildlife, water supply, recreation, and culture (WWF 2014). The chalk streams around Chichester Harbour have been recognised as a Biodiversity Opportunity Area which is a priority area for the delivery of BAP targets with opportunities for wetland habitat management, restoration, and creation (Sussex Biodiversity Partnership 2008).

5.4 Saltmarsh and mudflat

The intertidal area fronting the study area is classified as mudflat and saltmarsh (**Figure 18**) which are BAP priority habitats. The saltmarsh habitat across Chichester Harbour is declining and over the period 1946 to 2018, the extent of saltmarsh habitat has reduced by 60.6% (Lockwood and Drakeford 2021). The Environment Agency has mapped the extent of saltmarsh between 2008 and 2016 and the data suggests the area of saltmarsh directly adjacent to the study area has increased over this period (Environment Agency 2023b) (**Table 7**; **Figure 19**). During the site visit, the intertidal area was characterised as a mudflat with sporadic patches of saltmarsh and the aerial imagery shows a general pattern of an increase in the area of mudflat and decrease in the area of saltmarsh from 1995 to 2022 (**Figure 20**). Historic photographs of Langstone show the saltmarsh thrived in the area in the past (**Figure 21**). It is likely the overall trend is one of saltmarsh decline but that localised fluctuations in saltmarsh extent occur over shorter timescales.

Figure 18 Photograph showing sparse saltmarsh fronting the sea wall at Langstone (taken during the site visit on 8th August 2023)

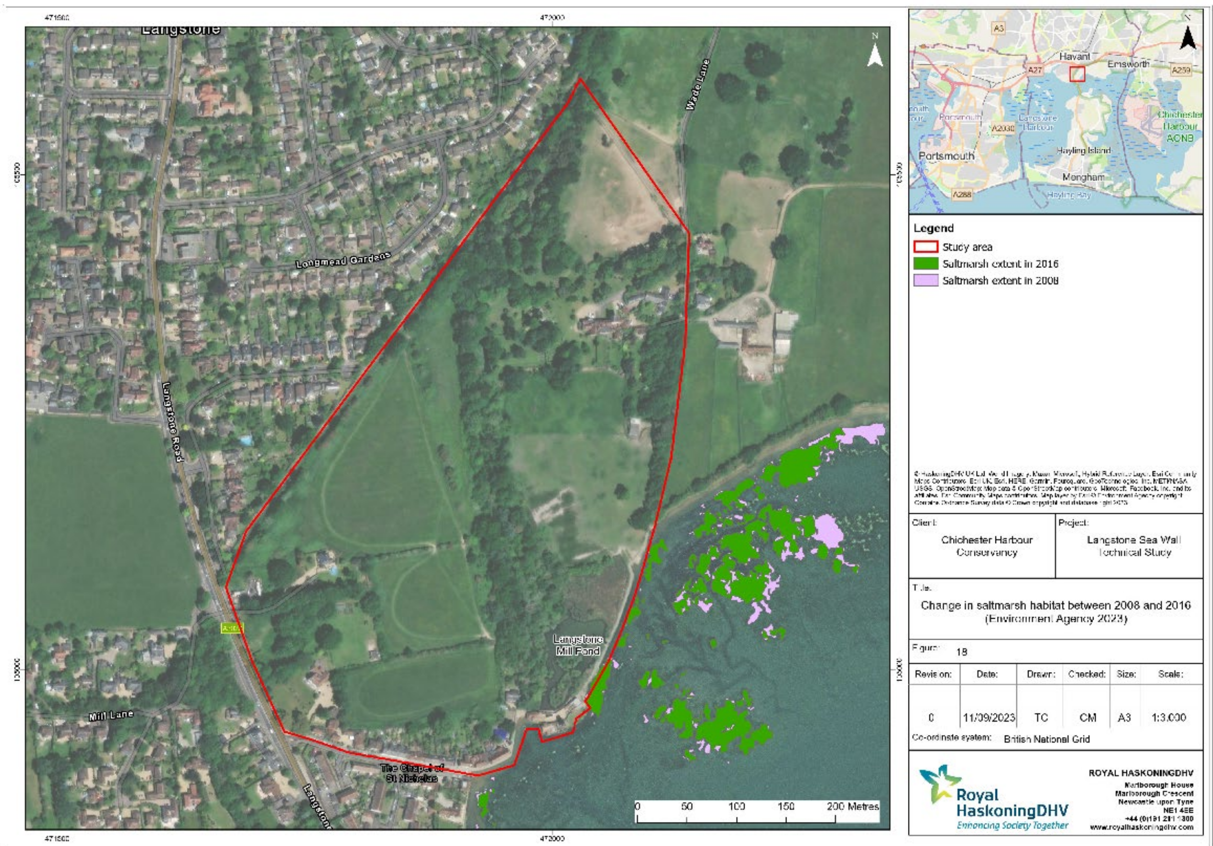

Figure 19 Change in saltmarsh habitat between 2008 and 2016 (Environment Agency 2023)

Figure 20 Changes in saltmarsh extent from 1995 to 2022 (source: Google Earth historical imagery)

Table 7 Area of saltmarsh adjacent to the study area

Year	Saltmarsh Area (m^2)
2008	3,684
2016	5,898

Figure 21 Saltmarsh thriving at Langstone (source: local resident Ann Griffiths reported in AECOM 2022) no date but expected to have been taken in the early 1900s (G.Holder Coastal Partners pers comm.)

5.5 Habitat creation

5.5.1 Introduction

The observed decline in the extent of saltmarsh and the Condition Review of the Chichester Harbour SSSI (NERR090) undertaken by Natural England (Bardsley et al. 2021), which outlined the saltmarsh and mudflat habitat were in an overall ‘unfavourable declining’ condition, means that habitat creation is an important aspect of any future coastal management strategy across Chichester Harbour. This section reviews the potential for habitat creation in the intertidal zone fronting the existing sea wall, but also within the area located landward of the sea wall.

5.5.2 Habitat types

The extent and type of coastal habitat that exists is closely tied to tidal levels. In the UK (and elsewhere), saltmarsh initially colonises areas between approximately MHWN tide and MHWS tide, with areas lower than this down to mean low water spring (MLWS) tide forming mudflat (Allen, 2000) (**Figure 22**). Another important aspect is the availability of suitable plant species for colonisation; different plants can colonise at lower levels than others. However, in general terms, the elevation of a site relative to the varying tidal range is used as an initial indicator of the habitats that could evolve (**Table 8**). Hence, the topography of the site and the tidal heights adjacent to it are one of the principal issues to be considered at the planning stage of a habitat creation scheme (Leggett et al., 2004).

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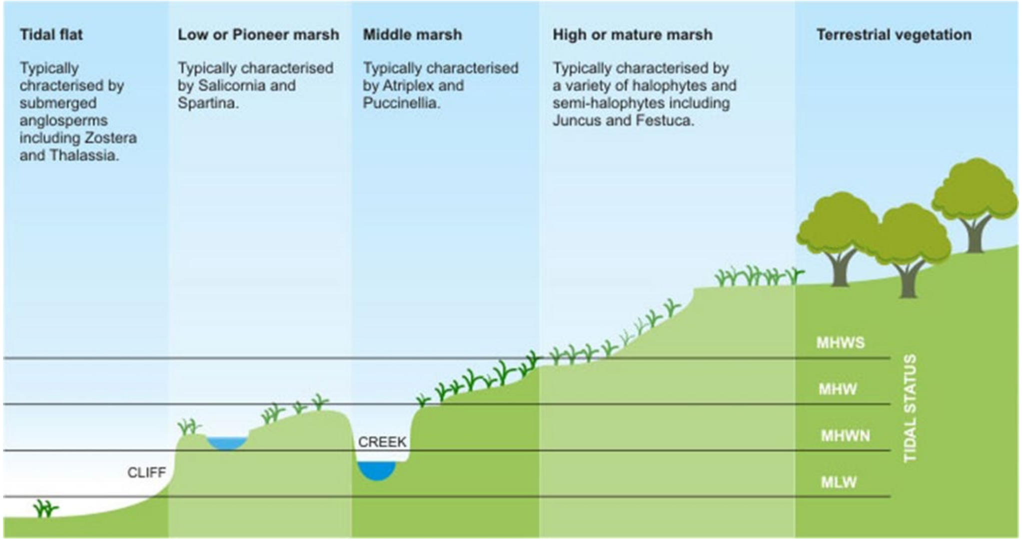

Figure 22 Approximate relationship between habitat and tidal datums

Table 8 Indicative coastal habitat types

From	To	Primary habitat
MLWS	MLWN	Intertidal mudflats and sandflats
MLWN	MHWN	Pioneer saltmarsh
MHWN	MHWS	Saltmarsh
MHWS	HAT	Transitional saltmarsh (high marsh transitioning to fresh marsh)

5.5.3 Habitat creation within the existing intertidal area

A Feasibility Study was undertaken within the intertidal area in front of Langstone village to assess if saltmarsh restoration methods were practical at this location (AECOM 2022). The suitability of different saltmarsh restoration techniques is related to the elevation of the site relative to the tidal frame (saltmarsh typically forms between MHWN tides and HAT level), but also due to sediment supply which allows the saltmarsh to accrete vertically. There is a net sediment deficit in Langstone Harbour (SCOPAC, 2012). Therefore, the restoration techniques at Langstone need to promote sediment accretion to restore elevation to a level where saltmarsh species can grow. Considering the conservation objectives of the Chichester Harbour AONB, any techniques used must conserve and enhance natural beauty.

Many of the methods available to improve sedimentation require installation of hard structures to create breakwaters or barriers and these are not aligned with the conservation objectives of the AONB. These are therefore not considered suitable. However, there are techniques that use a combination of natural brush material and wooden fences that can be used to create a ponded or sheltered areas that will support saltmarsh restoration. These can be enhanced with localised channel creation or sediment recharge (for example from material dredged elsewhere) to increase sediment supply. There is potential for these techniques to be implemented on the intertidal zone fronting Langstone village.

The feasibility study also included an assessment of the suitability of managed realignment in the intertidal zone in front of Langstone village and it concluded that this was not an option due to a lack of suitable area or space. This assessment was specific to the area in front of Langstone village where there is no space landward to realign the coast. However, this is not the case for the area to the east of the village where the land directly behind the existing sea wall does not comprise residential and commercial properties.

The AECOM (2022) study concluded that the saltmarsh at Langstone no longer represents a typical and healthy habitat and would require highly invasive restoration techniques to restore the intertidal habitat in its current location. The environment is constrained by existing infrastructure, including the sea wall and the freshwater habitats fringing the land behind it, and that macroalgal smothering due to the nutrient regime may limit the success of a saltmarsh creation scheme within the current intertidal zone.

5.5.4 Habitat creation landward of the sea wall

Given coastal habitat type is closely linked to water levels it is possible to predict what habitats would naturally form in the study area if the sea wall was not present. Also, considering projections of sea-level rise it is possible to predict how these habitats would change in extent in the future. Using LiDAR data as a topographic base map, and an assessment of future water levels (**Section 4**), predicted habitat type maps were created for 2022, 2050 and 2075 and 2100 as shown in **Figure 23** to **Figure 26**. The area represented by each habitat for each of the time periods is presented in **Table 9**.

Note, these maps show the extent of habitats if the entire sea wall was not present (which is not the case at present), but they can be used to show what areas could be affected if brackish water enters the study area (through overtopping of the seawall or via the damaged section of sea wall). Another important aspect to consider is that if the water level inundates an area, it doesn't mean that a particular habitat will form as there are other controlling factors that would influence what habitat is present. For example, in **Figure 23**, the maps show that water levels higher than MHWS would enter Langstone Mill Pond which would imply that saltmarsh could develop there. However, the input of freshwater from Lymbourne stream is greater than the ingress of brackish water which would limit saltmarsh from forming. Therefore, these maps must be interpreted with consideration of the other factors controlling habitat formation.

Table 9 Predictions of the type and area of habitat that would be created

Year	Transitional habitat (ha) (MHWS to HAT)	Saltmarsh (ha) (MHWN to MHWS)	Pioneer saltmarsh (ha) (MLWN to MHWN)	Intertidal mudflats and sandflats (ha) (MLWS to MLWN)	Total saltmarsh created (ha)
2025	2.05	0.15	0.03	0.00	0.18
2050	3.41	0.16	0.06	0.00	0.22
2075	4.20	0.96	0.11	0.00	1.07

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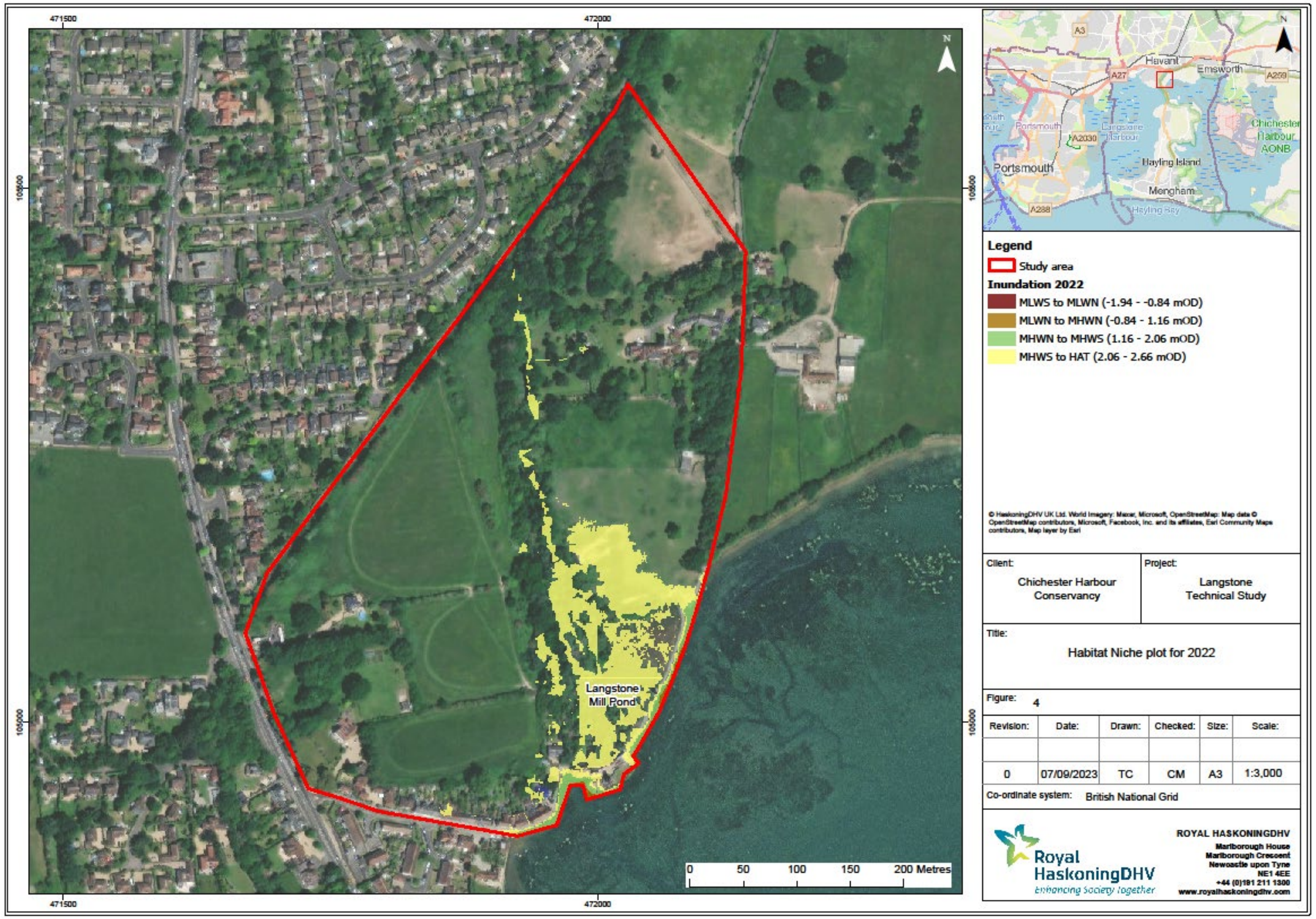

Figure 23 Predicted habitats in 2022

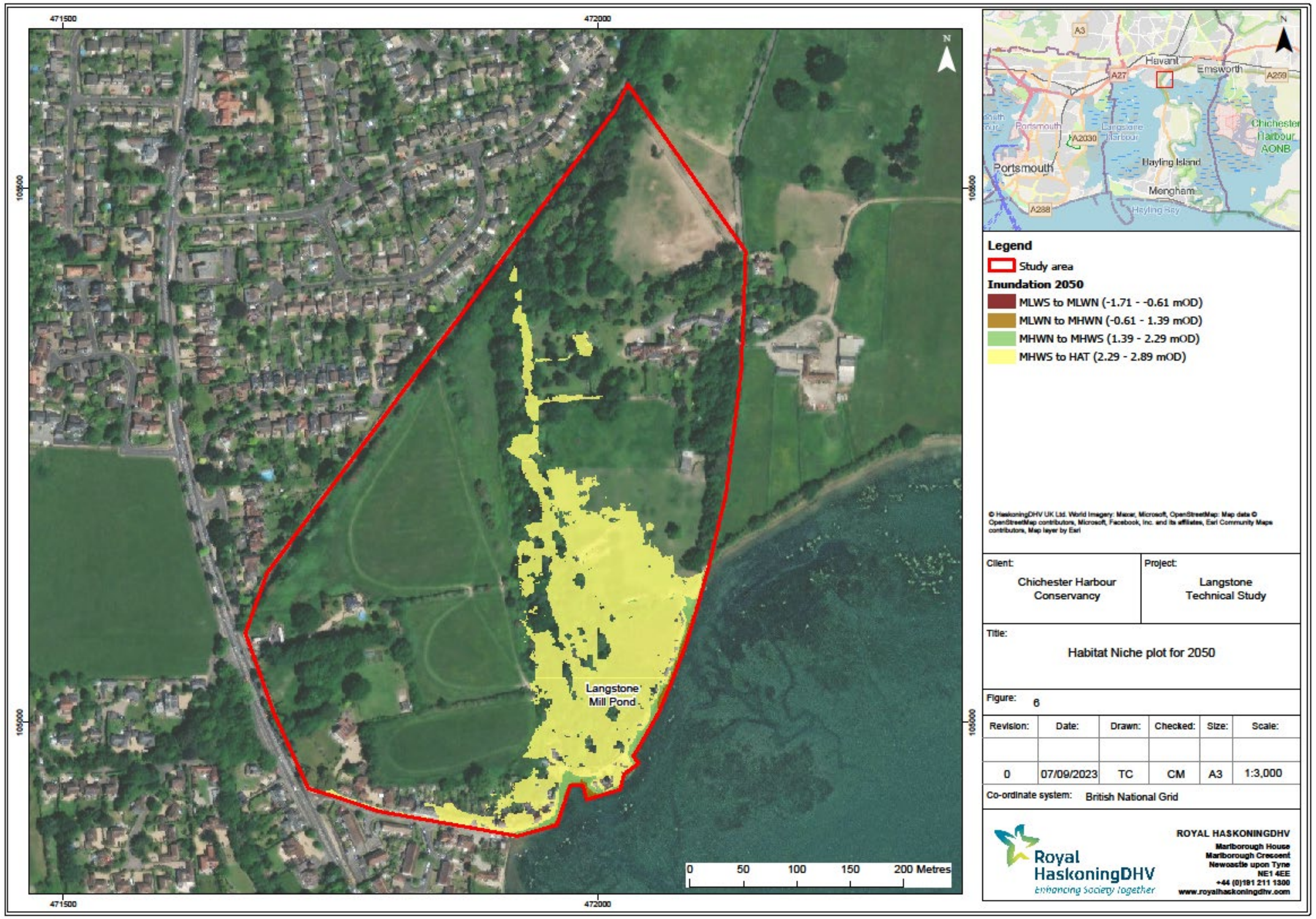

Figure 24 Predicted habitat in 2050

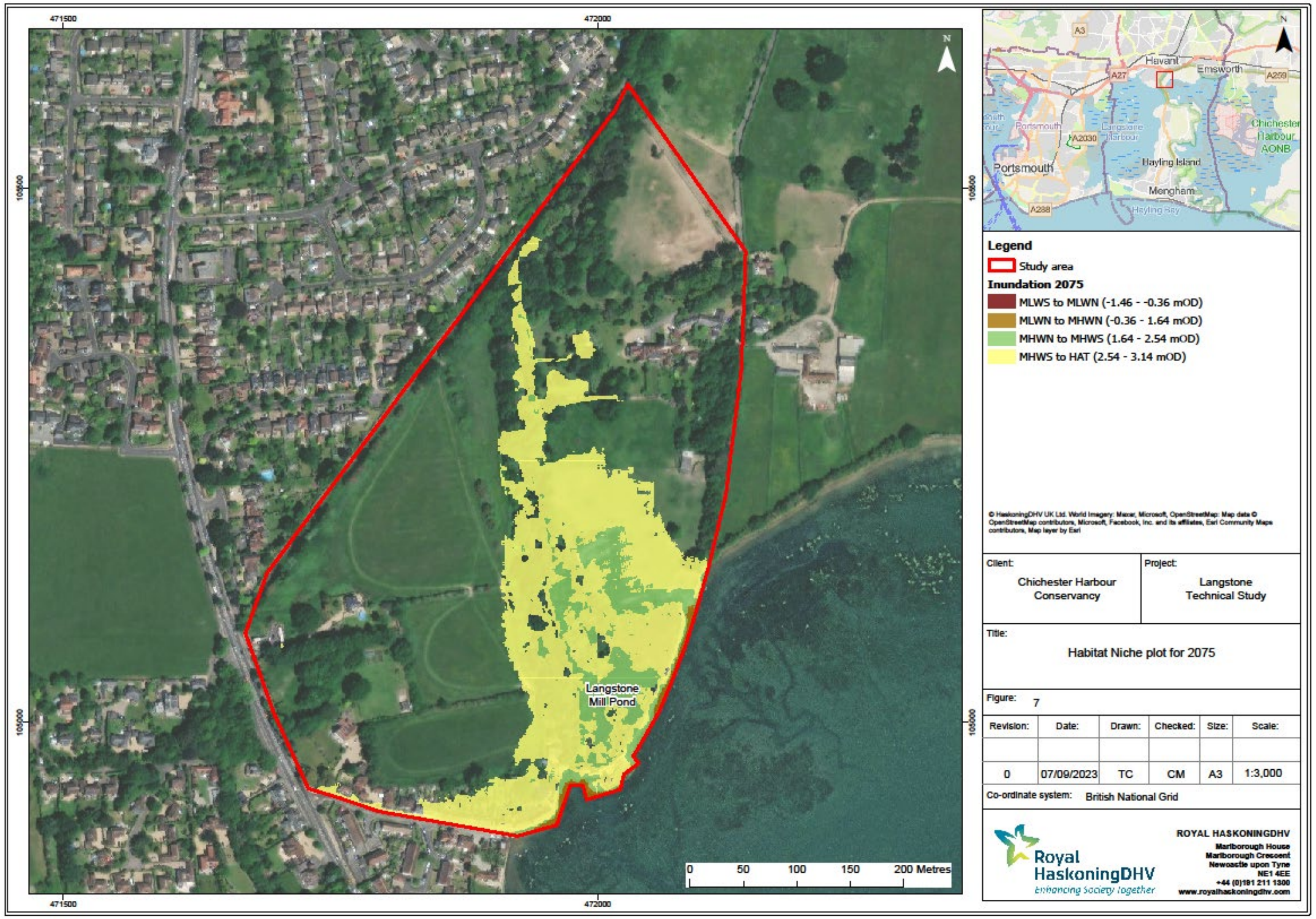

Figure 25 Predicted habitat in 2075

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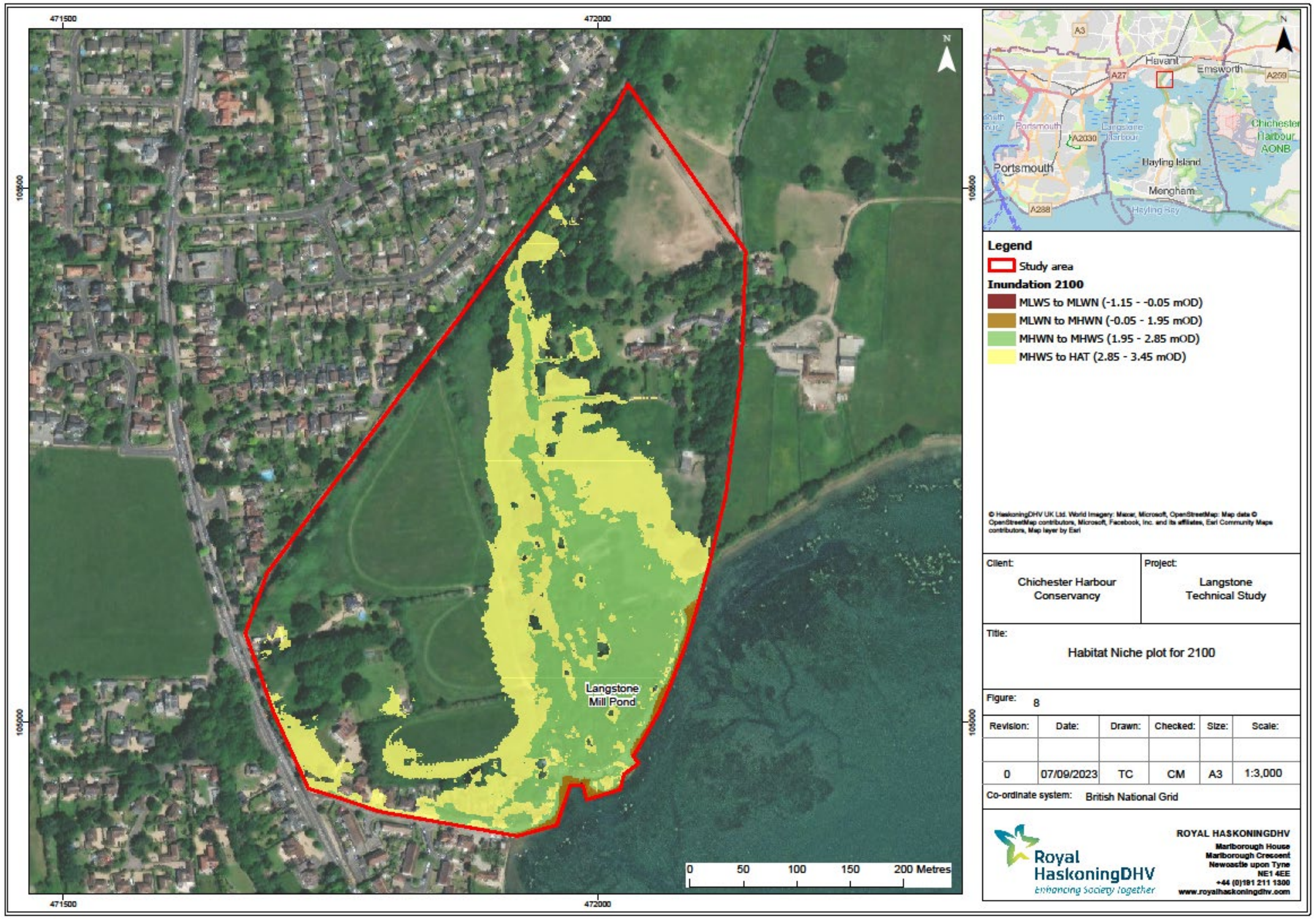

Figure 26 Predicted habitat in 2100

Using 2022 as a baseline for the present day (**Figure 23**), the habitat maps show that saltmarsh (forming between MHWN and MHWS) is only present in the area in front of the sea wall. The area behind the seawall would only be inundated by brackish water when water levels are between MHWS and HAT and would be characterised by transitional freshwater to brackish habitats. Despite this overtopping, the freshwater input from Lymbourne stream would dominate and brackish species would only be present at the southern end of the paddock which is the lowest-lying area that is inundated more frequently.

By 2050, rising sea levels would lead to a small loss of saltmarsh in front of the seawall which would be expected due to coastal squeeze. However, there is potential for a small area of saltmarsh to start forming at the southern margins of the paddock (**Figure 24**). Behind the sea wall, the land elevations remain high enough to support transitional habitats and while the extent of these habitats would increase slightly as the higher water levels reach further inland, there is little change when compared to 2022. However, the frequency of inundation would be higher so any species not tolerant to higher salinities would likely not survive. Considering the input of freshwater from Lymbourne stream, the study area would still be dominated by freshwater habitats.

By 2075, water levels are high enough to allow saltmarsh to develop within the paddock (**Figure 25**), although the health of this saltmarsh will depend on other variables such as sediment supply and water quality. The area surrounding this saltmarsh would be transitional habitat gradually changing from brackish to freshwater as land elevations rise. Given the mill pond and Lymbourne stream occupy lower elevations, the habitat map indicates saltmarsh could form within these low points, but this wouldn’t necessarily be the case. The freshwater stream is a water course which will contain water even at low tide. The lower reaches of the stream may be brackish, but this will depend on the supply of freshwater. If the sea wall is breached close to the mill pond (through ongoing deterioration or deliberately), the pond may drain creating an area that would be suitable for saltmarsh development.

By 2100, the potential area of saltmarsh would be increased to cover most of the paddock, the area of Langstone Mill Pond and the margins of Lymbourne stream (**Figure 26**). The increase in saltmarsh habitat would result in a reduction in area of transitional habitat but the land levels are such that much of the land around Wade Court and Langstone Meadows is not influenced by brackish water and will be dominated by freshwater habitats. This is important as it means there are areas near to the existing mill pond that could be used to create a new freshwater habitat to compensate for the inundation of the mill pond.

6 Existing infrastructure

Any changes to future management of the study area may potentially affect local infrastructure. The following key assets are located within the study area:

- Footpath 108/56/2 located on top of the seawall and along the timber fence: the footpath’s existence is linked to the residual lifetime of the seawall and will potentially be a risk at an earlier stage due to health and safety considerations. Although the footpath is currently overtopped only a few times a year, this will increase significantly in future due to sea-level rise, resulting in frequent closure of the footpath due to dangerous conditions.
- Langstone Mill: flood risk to the mill is similar to the risk of overtopping of the sea wall, as the floor levels of the mill and the crest level of the defence are similar. The mill is already at a present day 1 in 1-year flood risk.
- Langstone Road, Langstone High Street and Wade Lane (and associated residential properties located along these roads): most of the properties along the former two roads are already at significant flood risk due to their open connection to the harbour. However, a breach in the coastal defences along the mill pond could mean that there is flood risk to these properties from the north as well, including

properties that are currently not at risk. Properties along Wade Lane are not likely to be at risk, even if the coastal defences were to be breached.

- Langstone Mill Pond: already shows evidence of brackish water inundation, most likely due to overtopping of the existing sea wall. Full breaching (naturally or artificially) of the sea wall near Wade Lane will allow brackish water to enter the paddock to the east of the mill pond potentially creating a pathway for tidal waters to flow into the pond. Continued deterioration of the sea wall in front of the mill pond may lead to future failure or breaches which would drain the pond and allow brackish water to enter the pond.

7 Options Appraisal

Considering the condition of the sea wall outlined in **Section 2** and the potential the site offers to create new intertidal habitat, this section provides a high-level assessment of the potential engineering design options in relation to the site characteristics, local infrastructure, and future flood risk scenarios.

The costs associated with these options are high-level estimates only for the purpose of comparing the options to each other. These are based on relevant industry guidance (Environment Agency's Flood Risk Management Estimation Guide, Cost Estimation for Control Assets and SPON's Civil Engineering and Highway Works Price Book) and RHDHV's in-house experience on previous projects. The costs are presented as whole life costs (including maintenance and future replacement of structures following their deterioration) in accordance with relevant Environment Agency guidance, and the costs are thus presented at Present Value (PV). However, they are not detailed, accurate cost estimates, and shouldn't be interpreted as such, as they do not fully consider local conditions and the particulars of the outline / detailed design of any of these options. Note that these costs do not include any design, survey, or consenting fees, but do include a 60% optimism bias. Deterioration of assets has been estimated using the same approach and assumptions as in section 2.7.

7.1 Do Nothing

In the Do Nothing scenario, no maintenance would be performed to the sea wall and structures between Langstone Mill and Wade Lane. The Do Nothing scenario is represented schematically in **Figure 27**. The occurrence of tidal overtopping would become more frequent, creating an increasingly brackish environment in the mill pond. In future, it is likely that the seawall would breach in an uncontrolled manner, most likely in a period of 5-10 years (i.e. 2030 – 2035).

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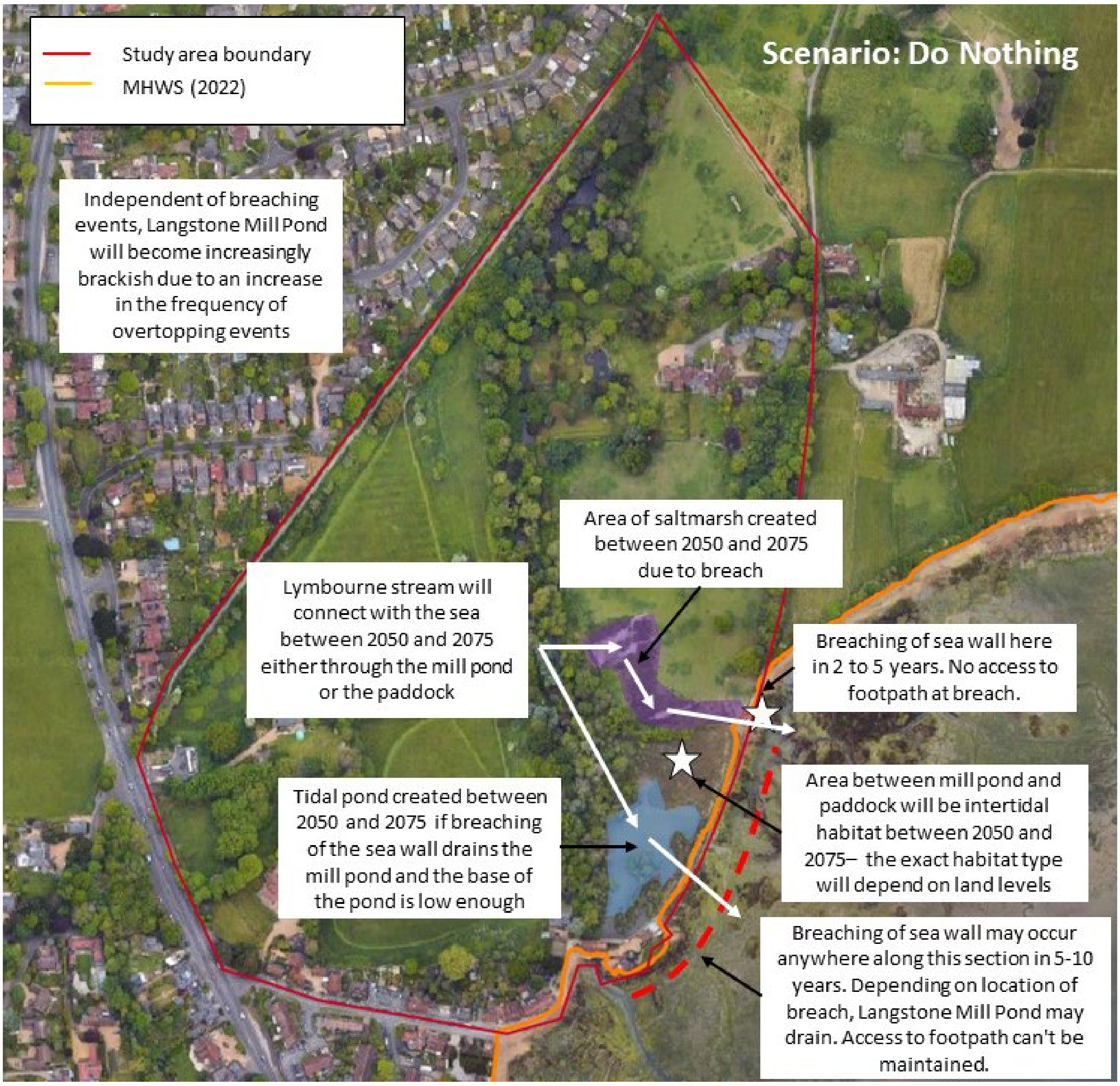

Figure 27 Schematic showing the key changes expected in the Do Nothing scenario

The consequences of a breach will differ depending on the location of the breach, and based on current information, it is likely that breaching will occur in phases:

- Phase 1 (2-5 years): The section at the highest risk is Section F, where the masonry wall has already failed. If a breach was to occur along this section, the grassland paddock behind it would flood regularly to a large extent, with salt water potentially reaching the mill pond and Lymbourne stream. The level of the paddock is slightly lower than the crest of the defences (2.5m OD) meaning that after a breach, the area would be inundated during extreme tidal events only. However, by 2075 an average spring tide could cause the area to be fully flooded.
- Phase 2 (5-10 years): Other sections where a potential breach could occur are sections B and D which are a considerable length of the sea wall (see **Figure 2**). If a breach were to occur here, it is likely that the mill pond would (at least partially) empty (which could scour the breach out further). The mill pond (and Lymbourne stream and its floodplains) would then be in direct connection with the tidal system. Although the bottom levels of the pond are not known, these are likely to be in the range of 1.0-1.4m OD, which means the mill pond would be subject to inflow and outflow of salt water during the highest

tides. It is challenging to predict if the mill pond will drain completely (which is needed for any saltmarsh formation) and with Lymbourne stream still flowing into the mill pond, the salinity and water levels in the pond will depend on the interactions between the coastal waters and freshwater discharging from the stream. It is also difficult to predict where the breach will occur. If it occurs at the edges of the mill pond (e.g. near the reedbeds) the pond may drain more slowly when compared to a breach near the eastern sluice gate, for example. The window of tidal exchange would increase with sea-level rise, with the pond being exposed to most high waters by 2100.

In both phases, the footpath is likely to be affected by 2030; although the coastal defence does not necessarily have to have failed by then, the coastal path may be closed due to health and safety considerations. This will require rerouting of the footpath (see Section **7.4.7**).

If an uncontrolled breach occurs, this may increase the rate of erosion of the adjacent sections of sea wall and footpath, removing a larger section of defence than could be maintained with a managed breach. At present, there is blockwork present in the intertidal zone which gives an impression of neglect. The public perception of an unmanaged breach is poor based on experience from the adjacent Southmoor site. An independent assessment undertaken by AECOM (2019) indicated that allowing an unmanaged realignment to take place over time would be a high-risk strategy from a Flood and Coastal Erosion Risk Management (FCERM) perspective, given the proximity of Langstone Mill Pond to the damaged areas of wall.

7.2 Maintain

The visual inspection showed that there are areas of the wall that are in need of major repairs and other areas where minor repairs are necessary. For this option, the coastal defences would be maintained to the same current standard of protection to prolong the life of the seawall (noting that the standard of protection would decrease with time due to sea-level rise), meaning that the wall would not be increased in height or width. The repairs would require five activities:

1. Removing vegetation along the length of the wall to ensure roots do not affect the structural stability of the wall.
2. Repointing the mortar joints along the entire length of the wall and secure any loose bricks.
3. Rebuilding sections of the wall that have failed (Photos J, L, N, P and Q, Table 3).
4. Repairing the path at the southern end and rebuilding the pondside retaining wall.
5. Ensuring the functionality of the sluice gate.

This option will still affect the freshwater habitats in the mill pond due to the low crest level of the existing wall. The maintenance works are expected to be recurrent; with the mortar in the joints being vulnerable to erosion in the tidal area, the maintenance works may have to be carried out every five to ten years.

The limited accessibility of the site, the current state of the path and the position of the wall within the tidal frame, will make these maintenance works more lengthy and costly than under normal conditions. The cost for repairing the wall, following steps 1-5 above, is estimated at £144,000. This includes repointing the mortar in the seawall over its full length, and fully replacing the wall over 20% of its length. Note this is an initial cost and it is anticipated that as the sea wall continues to deteriorate, a similar level of investment would be repeatedly required to maintain the wall, with eventually the wall having to be replaced fully. This results in a Present Value whole life cost of **£863,000**.

Following extensive option, environmental and economic appraisal, AECOM (2019) argued that replacement of the wall fronting the mill pond would not be financially viable. Also, repairing the wall would be insufficient to mitigate the health and safety risks associated with potential future localised structural failure considering the current standard of protection is relatively low.

7.3 Improve

This option considers ways to strengthen the sea wall with future sea-level rise and an assessment of likely timescale and frequency of overtopping. Essentially, this option seeks to increase the current standard of defence, and to maintain this at a sustainable level into the future. To achieve this, three possible options have been developed, which are described below. The recommended present-day standard of protection of 20% Annal Exceedance Probability (i.e. a 1 in 5-year storm event) is adopted in this scenario:

1 Replace the masonry wall with a concrete seawall structure.

2 Repair the masonry wall and install an upstand wall to reach the required height.

3 Replace the wall with an earth embankment.

With all these options, a solution will also need to be installed between the eastern end of the mill buildings and the mill pond to limit the ingress of salt water to the same degree as the improved seawall. These could be temporary structures that are installed during expected high waters only.

7.3.1 Option 1 – Replace the masonry structures with a concrete seawall

This option would fully replace the existing masonry wall and earth embankment with a concrete seawall. This wall could be constructed to the required height to protect the mill pond against frequent overtopping. The option is a hard engineering technique which has been used widely (**Figure 28**). The structure would be effective and last up to 50 years with maintenance. Vegetation management will be required to maintain the structure over its lifetime. However, there are opportunities for enhancement of biodiversity through the inclusion of elements that promote growth of intertidal flora and through the use of eco-concrete. The sluice gate that is currently in place would have to be replaced to fit with the new seawall.

The initial costs for this option are significant, as are the carbon emissions related to the production of concrete. However, the latter impact could be reduced by specifying a low-cement concrete. Gaining planning permission for this option will be challenging, as it does not align with the environmental and conservation objectives of the regulatory bodies.

Estimated costs for constructing the seawall and a new sluice gate are **£4.2M** for a structure that will last approximately 50 years. The PV whole cost of this option is **£5.2M**.

Figure 28: Example of a concrete seawall at Torcross, Devon, where the path is on top of the seawall crest.

7.3.2 Option 2 – Masonry wall with upstand wall

This option seeks to retain and repair the current masonry wall (similar to **Section 7.2** above) with an upstand glass wall on the seaward edge of the crest (**Figure 29**). This option would maintain the existing footpath and would be in keeping with the area, preserving the look and feel of the mill pond. Implementation would not have to be immediate but could be phased: repairs to the seawall within the next five years with addition of the upstand wall when overtopping becomes unacceptable.

The cost for this option will be that outlined in **Section 7.2** above plus the cost of the upstand wall. The sea wall will still require ongoing maintenance (expected every 5-10 years). Gaining planning permission for this option will be challenging, as it does not align with the environmental and conservation objectives of the regulatory bodies.

The total cost for this option, including repairs to the existing seawall, is estimated at **£386,000**. The PV whole life cost is estimated at **£1.3M**.

Figure 29: Example of glass and masonry seawall in Wells on the sea, Norfolk.

7.3.3 Option 3 – Embankment and realignment of path

This option considers replacing the existing wall with an enlarged embankment. This embankment would protect the hinterland against a suitable Standard of Protection, considering future sea-level rise. Typically, these embankments are trapezoidal in shape: two sloping sides and a crest wide enough to accommodate the footpath (Figure 30). It would allow vegetation to grow naturally on the slopes and add stability to those slopes against erosion.

This option has a much larger footprint than other options, which will take away some area from the saltmarsh fronting the embankment, or the mill pond to the rear. To save space, the embankment would encapsulate the existing embankment. This option is costly due to the earth works required, especially as clay would need to be sourced from elsewhere. The cost of this option is estimated at **£711,000**. The option is relatively low maintenance compared to other options, and is adaptable, i.e. if required, the embankment could be further heightened in the future, if the base was constructed initially to accommodate this change. There is also an opportunity for phasing the works to spread the relatively high initial costs, although this has not been explored further as part of this report. The whole life cost (approximately 60 years) is estimated at **£933,000**.

Alternatively, the seaward slope could be replaced by a new masonry wall. This would resemble the current situation more closely and would reduce the footprint. It would, however, not be possible to phase the works and it would require more maintenance works in future.

The sluice gate that is currently in place would have to be replaced to fit in with the new embankment. This would add additional initial costs to this option. Gaining planning permission for this option could be challenging as it will require significant construction in the intertidal zone.

Figure 30: Embankment at Lymington, Hampshire.

7.4 Managed realignment

7.4.1 Introduction

Managed realignment is the process of relocating the maintained defence to a new position inland of the original line, preferably on higher ground. This approach aims to facilitate the creation of new habitat in the area between the old and new defences (or higher ground). The removal of the primary defence line typically occurs in either of two ways: bank realignment, where the defence is completely removed, or breach realignment, where a portion of the defence is either lowered or removed. Subsequently, during each tidal cycle, the incoming tide inundates the exposed land, allowing the floodplain to gradually expand until it reaches the new inland line. Depending on many factors, the flooded land will over time be occupied by intertidal habitats including mudflat and saltmarsh.

The managed realignment option for Langstone outlined here considers both the removal of a section of a sea wall (the damaged section of the wall – see **Figure 31**) and the re-routing of Footpath 108/56/2. It also considers the life expectancy of the sea wall and Langstone Mill Pond and outlines a phased approach with different options to manage or compensate for the inevitable loss of freshwater habitat.

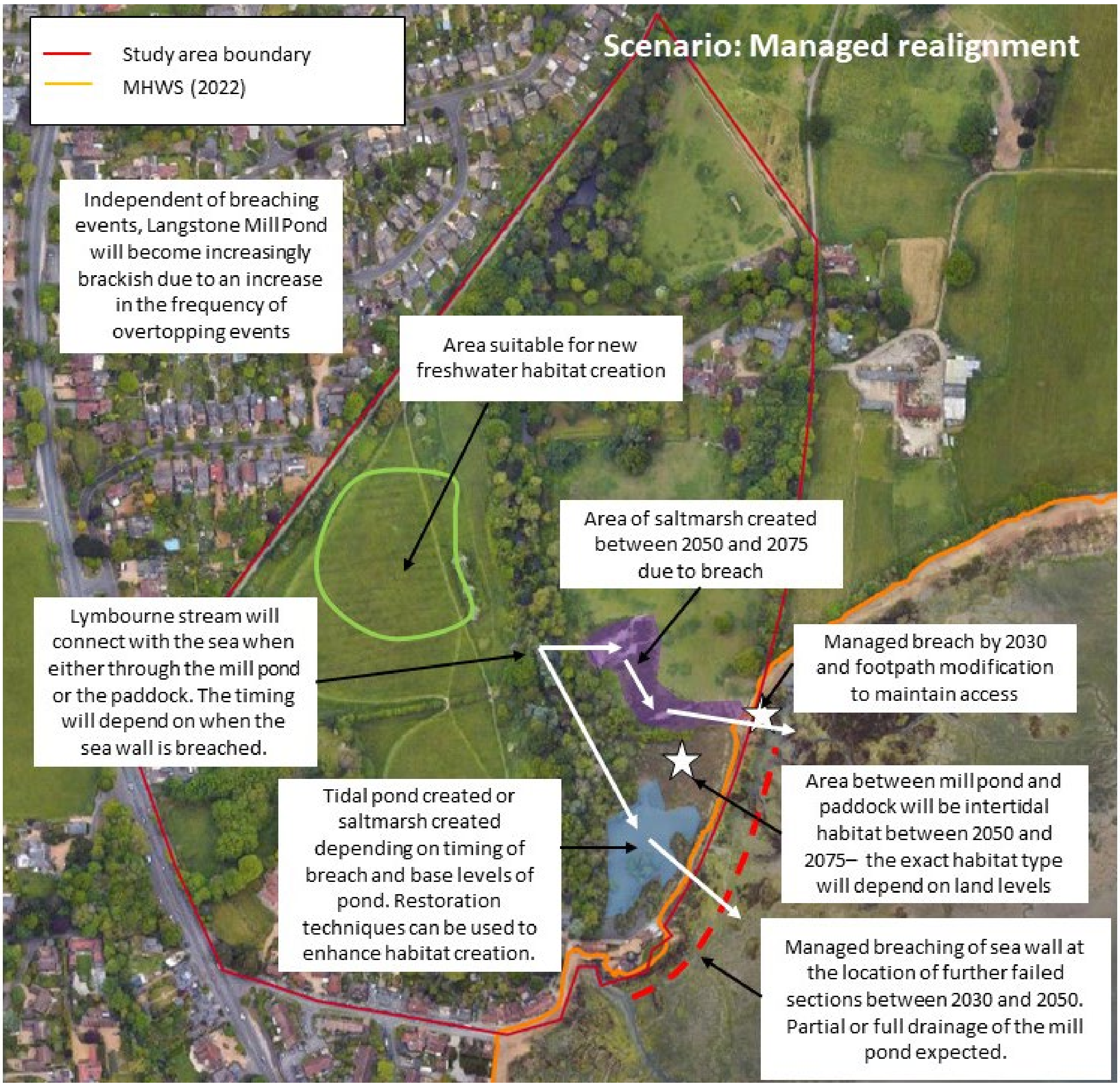

Figure 31: Proposed section of the sea wall to be breached – dashed red line.

7.4.2 Breaching of sea wall near Wade Lane

The sea wall has failed near Wade Lane (see **Section 2**) creating an area that is vulnerable to unmanaged realignment in the next two to five years. By intervening and creating a managed breach at the location of the failed sea wall (**Figure 31**), a managed realignment site could be created within the paddock behind the sea wall.

If the sea wall is breached (deliberately or naturally) the existing footpath will become inaccessible, and rerouting would be required. This can be achieved by relocating the footpath at the breach inland, in the southern area of the paddock, or perhaps introducing a wooden boardwalk elevated above the ground, considering the paddock is already susceptible to flooding from the freshwater stream. Alternatively, a bridge could be constructed over the breach to maintain access. Both options would allow for the gradual transition to a saltmarsh environment whilst not disrupting public access. The feasibility of rerouting the footpath through the paddock will depend on the land ownership and access rights. The cost for this option, if implemented between 2025 and 2030, based on a controlled breach and the inclusion of a bridge, is estimated at **£111,000-132,000 (PV)**, and a controlled breach with the inclusion of a boardwalk at **£117,000-140,000 (PV)**.

Managed realignment would result in a net loss of coastal grazing marsh within the paddock with time (at some time between 2050 and 2075). However, this loss would not be immediate and coastal grazing marsh habitats can be sustained with periodic ingress of brackish water (this is actually one of their defining features). Any loss would also be offset by an increase in saltmarsh habitat. There are a number of mature trees within the paddock that would be affected by the brackish water, but any long-term damage to them could be offset through new habitat creation.

7.4.3 Saltmarsh habitat creation within the paddock

A primary goal of managed realignment is to create a new habitat, specifically a saltmarsh habitat, inland of the sea wall. A preliminary assessment of the feasibility of this option has been outlined in **Section 5.5**. It was determined that there will be limited saltmarsh formation until between 2050 and 2075 due to tidal levels being lower than the ground levels inland of the sea wall and the health of any saltmarsh will depend on other factors such as sediment supply and water quality.

The transition from a freshwater environment to a saltmarsh may affect Langstone Mill Pond if the brackish waters flow into the pond via the reedbeds that are currently located between the pond and the paddock. However, given the relative high land levels relative to the existing tidal frame, brackish water would initially only inundate the paddock on the highest tides or during storms. The frequency, duration and extent of this inundation will increase with time from 2050 onwards. This option would allow the habitats, including those in Langstone Mill Pond to transition gradually over the next 25-75 years.

With time, the area of potential saltmarsh will increase with rising sea levels. However, in the short-term it would be possible to undertake preparation works within the realigned area to modify the land profile and encourage saltmarsh to establish more quickly. This could include excavating a creek to maximise the flooding and draining of the site while mimicking the channel and network properties of natural marshes (Hudson et al., 2021). Alternatively natural saltmarsh restoration techniques could be used (e.g. adding brush material and/or wooden fences to help trap sediment) once the defences have been breached. The cost for these works is estimated to be about **£54,000-64,000 PV** if executed between 2025 and 2030.

7.4.4 Temporarily maintain Langstone Mill Pond as a freshwater habitat

Langstone Mill Pond is a freshwater habitat that is periodically influenced by brackish water. At present, the salinity of the pond is not being monitoring to understand how much the brackish water is influencing the habitat, but there are signs some species are declining with the death of some trees fringing the southern side of the pond. The current habitat is therefore not exclusively “fresh” but it is dominated by freshwater species.

There are options to slow or limit the ingress of brackish water into Langstone Mill Pond, but these will only be effective up to when water levels persistently overtop the sea wall that retains the pond. Based on the assessment of overtopping outlined in **Section 4.5**, the sea wall at its current elevation is likely to be overtopped on average once a week by 2060 (considering the effects of tides and local waves). Based on its current condition, the sea wall in front of the mill pond is at risk of failing in the next 5-10 years. Therefore, it may only be possible to maintain a freshwater habitat in the short-term and any interventions to support this option should consider this by balancing the cost/time required to implement a solution against its lifespan.

With the above in mind, a simple and relatively low-cost solution could be local earth works to raise the land between the paddock and the reedbed to the east of the mill pond to cut off any pathways for salt water to inundate the pond (although salt water will still enter via overtopping). This new earth embankment would not be reinforced with hard structures but could include a clay core to prevent seepage and be vegetated with salt tolerant species to help reinforce it. However, the feasibility of this option will depend on how much salt water is entering the mill pond via overtopping and/or groundwater intrusion. There is potential for a new footpath to be routed along the top of these earth works but this would require construction of a more significant structure with a larger footprint that would increase the costs associated with import of soil. Such an embankment, designed to deliver protection against a 1 in 5-year storm, is estimated to cost about **£33,000-40,000 PV** (without footpath relocation) if works are executed between 2025 and 2030.

This solution is not sustainable in the long-term because with rising sea levels and the likely deterioration of other parts of the sea wall, the mill pond will be increasingly influenced by salt water regardless of any interventions in the paddock.

7.4.5 Creating a new freshwater habitat

If Langstone Mill Pond transitions to a brackish habitat in the longer term (over the next 25-75 years) measures could be taken to compensate for this loss by creating a new freshwater habitat landward of the existing sea wall. The land at Langstone Meadows is high enough so that it will not be influenced by brackish water within the next 75 years. This recreational ground could be enhanced with a new freshwater pond that would provide a comparable and nearby habitat for the birds and other species that use Langstone Mill Pond.

Creation of a new freshwater pond would require localised excavation in Langstone Meadows and diversion of Lymbourne stream to feed the pond. An outlet would be required to drain the pond, and this could be achieved by creating a new channel that connects the new pond with the weir at Langstone Mill. However, it is important to consider that with rising sea levels, Langstone Mill and the outfall/weir will be increasingly susceptible to flooding so it is anticipated the lower reaches of the stream will be tidally influenced; this is part of the natural functioning of a chalk stream when it reaches the sea.

The feasibility of creating a new pond within Langstone Meadows will incur high costs, estimated at approximately **£1M** (PV; assuming construction will take place in the early 2030s), and depend on the land ownership, which is currently unknown. A land agent can be appointed to determine the ownership.

7.4.6 Future breaches and saltmarsh creation in Langstone Mill Pond

Given the ongoing deterioration of the sea wall fronting the mill pond, it is anticipated that sections of this structure will fail in the next 5-10 years. Predicting the location of these points of failure is difficult but ongoing monitoring of the condition of the sea wall would allow deterioration to be tracked and vulnerable points identified prior to failure. This could be incorporated into a coastal management strategy which sets out the appropriate intervention depending on the location, severity and timing of the breach. If additional breaches occur, they will require formalization to ensure they are managed and the costs of this management will depend on the location, timing, and type of breach. In this study, it is assumed that one additional breach will occur and that the costs will be similar to those estimated for the breach near Wade Lane (see **Section 7.4.2**). These cost can be updated once more information is available through a monitoring program. Considering that this breach might occur further into the future than at Wade Lane, the estimated cost is about **£16,000-32,000 PV**.

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If a breach is required at a location directly in front of the mill pond, this will change its hydrology, potentially allowing it to drain partially, or fully. The subsequent impact on the freshwater habitat and the potential for intertidal habitat creation following a breach of this nature will depend on the base levels of the pond and the timing of the breach in relation to predictions of sea level. Local earth works or restoration techniques can be adopted to enhance the habitat transition, potentially creating a tidal pond fringed by saltmarsh habitat. As part of this transition, the lower reaches of Lymbourne stream will become tidally influenced creating a more natural functioning coastal system. This could potentially provide an additional sediment input to the intertidal zone which would support development of saltmarsh habitat.

7.4.7 Footpath diversion

Damage to the sea wall near Wade Lane means the footpath is at risk of erosion and the current rate suggests that it may disappear over the next 2-3 years. Maintaining safe public access to the coast is an important consideration and the loss of footpath (without intervention) would require rerouting.

In this study, future MHWS levels have been assessed relative to land elevation to understand potential reroute options for the coastal footpath if the sea wall near Wade Lane is breached. Using MHWS levels means that access will be maintained during most of the tidal cycles apart from the highest tides or storm events. During these events, overtopping would occur along the rest of the footpath fronting the mill pond making it inaccessible. Therefore, the restrictions caused by using MHWS levels to route the footpath will not limit access further as large parts of the coastal footpath will already be inaccessible during this time. Note the footpaths presented below are representative options and their feasibility will depend on access constraints and land ownership and further work would be required with relevant stakeholders to explore options to connect and manage future access to this coastline.

A summary of the footpath options is presented in **Table 10** and **Figure 32**.

Table 10 Summary of footpath options

Option	Location	Footpath length	Life expectancy	PV Cost
A	Footpath located slightly landward of existing footpath and routed to cross a breach in the sea wall. Boardwalk installed to provide stable footing which will be flooded periodically during the highest tides and storm events. Boardwalk is a low cost and adaptable solution. Slope angles along margins of breach can be designed to provide a shallow slope	0.03 km (30 m)	Will depend on the evolution of the tidal creek network in front and behind the breach. If the breach incises deeper and walls become steeper, the footpath will become unsafe. Could potentially be maintained until 2050.	£7,600-£9,100
B	Reroute footpath within paddock following an elevation contour of approximately 2.5 m. The footpath will run along the	0.30 km (300 m)	Will depend on the evolution of the new tidal creek network within the managed realignment area and	£38,400-£76,400

Option	Location	Footpath length	Life expectancy	PV Cost
	margins of the managed realignment site so will be running along the new coastline. A boardwalk can be used to maintain access in boggy ground or a footbridge can be installed to maintain access all tidal conditions (excluding storms).		changes to the mill pond (potentially induced by further breaches to the sea wall). Will also depend on the discharge and flooding history of the freshwater stream as any flooding from the stream could make the ground unsuitable for a footpath. Could potentially be maintained until 2075.	
C	Reroute the footpath to the north of Langstone Mill Pond, across Lymbourne Stream and the paddocks to the east of Langstone Mill Pond, emerging at Wade Lane. This would be required when the existing footpath becomes inaccessible due to frequency of overtopping or breaching of the sea wall.	0.6 km (600 m)	Will depend on the condition of the sea wall and the timing of future breaches in front of Langstone Mill Pond.	£59,500-120,000
D	Reroute the footpath through Langstone Meadows, along the lane that runs by Lymbourne stream and down Wade Lane. This will be required when the entire coastal footpath becomes inaccessible due to frequency of overtopping or breaching of the sea wall. At this point, the coastline will be located further inland.	1.2 km	Will depend on the condition of the sea wall and the timing of future breaches in front of Langstone Mill Pond.	No cost – uses existing footpaths

Figure 32 Location of potential footpath options

The footpath to the east of Wade Lane currently runs along the intertidal mudflat until it reaches a hard standing footpath near Pook Lane and Warblington Cemetery. With rising sea levels this footpath will become inaccessible at high tides and there is no scope for the footpath to move landward due to the presence of timber piles fronting an embankment which act as the coastal defence along this stretch of the coast. The timber piles are in relatively good condition and while some show signs of wear, they can be individually replaced at relatively low cost when required. These have been in place since at least the 1960s (according to anecdotal local knowledge) and are effective in their current condition given existing water levels. As sea levels rise these may wear more quickly but the relatively high embankment behind them will maintain the defence protecting the land behind.

An option to reroute the footpath along the top of this embankment was explored to increase the life expectancy of this section of footpath. Installing a footpath here would require removal of a mature and unmanaged row of trees and hedgerow whose root systems when sea levels become high enough and the area becomes exposed to the open sea. If the timber piles were removed to increase access to the intertidal area from the top of the footpath, this would also lead to destabilization of the embankment which would in turn make the footpath vulnerable to erosion. If the existing intertidal area becomes increasingly inaccessible due to rising water levels, an alternative could be to reroute the footpath behind the embankment in the fields (assuming access is granted).

7.5 Appraisal

The options presented in the previous section outline what is possible for the sea wall between Langstone Mill Pond and Wade Lane. In this section, each option is reviewed to outline a preferred approach based on the information available at the time of writing. Any changes to local or national coastal management strategies, funding streams or the condition of the coastal defences would influence the feasibility of this option. Furthermore, this is a high-level assessment, and the option is subject to change following further design stages and/or stakeholder feedback.

Table 11 presents a summary of this analysis and provides an overview of the opportunities and constraints linked to these options, along with associated costs. **Figure 33** presents the PV cost associated with each of these options over their lifetime. It should be noted that most of the cost of the managed realignment option is associated with development of the new freshwater habitat.

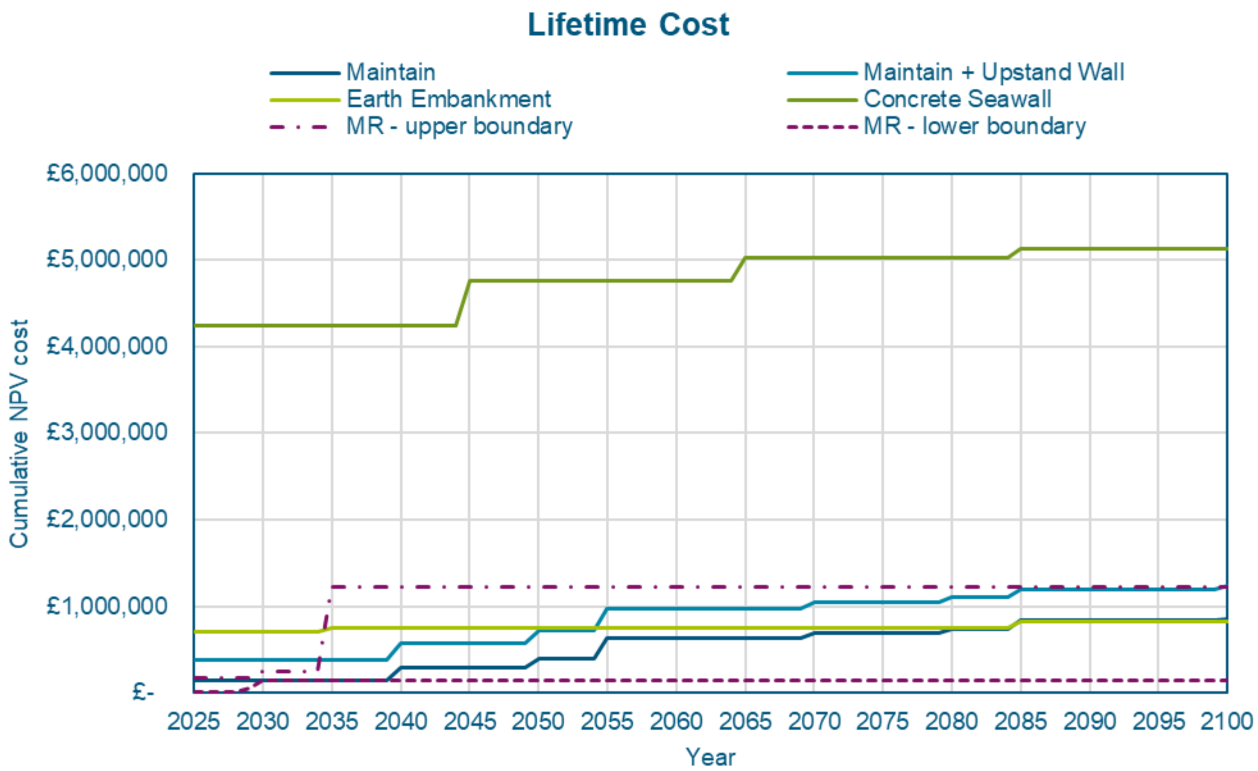

Figure 33: Estimate of the whole life PV cost of the different options. The boundaries on the cost of management realignment (MR) give a range within which the whole life costs can be expected to sit based on different investment timescales and the in- and exclusion of the creation of new freshwater habitat.

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Table 11 Summary of options

Option	Opportunities	Constraints	PV Cost (Present Day / Whole Life
Do Nothing	• No capital cost. • No planning and consent requirements • Allows the coast to retreat supporting intertidal habitat creation in future	• No control over timing of breach / failure of defences. • No control over location(s) of breach / failure. • No control over inland consequences (flooding) of breach / failure. • No control over foreshore consequence of breach / failure (i.e. spill of material including blockwork armouring). • Eventual loss of footpath.	No costs in terms of interventions
Maintain	• No adverse effects on inland receptors (other than through ongoing sea-level rise) • Maintains existing footpath.	• Unlikely to attain Natural England support due to its stance on works within SSSI • Repeated damage returning to present day situation in relatively short timescale (5-10 years). • May require planning and consent applications. • Lose ability to sustain standard of service due to sea-level rise, increased overtopping and storm damage expected. • Continued loss of intertidal habitat	£144k / £863k
Improve			
Option 1	• No adverse effects on inland receptors (ongoing sea-level rise managed through improved defences) • Maintains existing footpath.	• Unlikely to attain Natural England support in light of its stance on works within SSSI. • Will require planning and consent applications. • High carbon footprint • Continued loss of intertidal habitat	£4.3M / £5.2M
Option 2			£386k / £1.2k
Option 3			£711k / £932k
Managed Realignment			
Breach with boardwalk	• Likely to attain Natural England support due to its stance on works within SSSI. • Increase sediment supply by connecting stream with sea. • Control over timing of breaching • Control over location(s) of breaching • From 2050 to 2075: natural salt marsh formation. However, preparation of the site could speed up this process. • Maintains footpath via new diversion.	• Requires diversion of existing footpath. • Requires control over foreshore consequences of breaching (removal of waste and formation of external creek). • Requires planning and consent applications. • Transitional habitat (which form initially after a breach) is not appreciated in the local setting. • A bridge would form a permanent structure that would require maintenance of sections B and D of the seawall.	£117-140k / NA
Breach with bridge			£111-132k / NA
Saltmarsh enhancement			£54-64k / NA
Earth bund			£33-40k / NA
Rerouting footpath			£38-86k / NA

Project related

<table>
<tr><th>Option</th><th>Opportunities</th><th>Constraints</th><th>PV Cost (Present Day / Whole Life</th></tr>
<tr><td>Creating a new freshwater habitat</td><td rowspan="2">• Board walks are adaptable and can be removed and reused easier than a bridge.
• An earth bund could preserve the freshwater habitat over a longer period.
• Freshwater habitat loss could be compensated locally through the creation of a new mill pond.</td><td rowspan="2">• The earth bund is only effective until salt water intrudes persistently through overtopping (predicted to be from 2050 onwards).
• There is a high initial cost to the creation of the new freshwater pond, which would also require the rerouting of chalk stream. Landownership of Langstone Meadows unclear.</td><td>£1M / NA</td></tr>
<tr><td>Future breach management</td><td>£16-32k / NA</td></tr>
</table>

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The Managed Realignment approach would create a wide range of benefits for the Langstone area. Protecting, enhancing, and restoring the features of the saltmarsh system are relatively low-cost ways to build resilience against current and future flooding and erosion risks compared to more traditional hard engineering solutions. Natural features also have additional benefits, supporting biodiversity and carbon sequestration, and through tourism and recreation, supporting local communities and the economy.

Historically, saltmarshes have successfully adjusted to past sea-level rise by migrating inland where space has been available. Through the Managed Realignment options above, space can be created to allow the saltmarsh to adapt naturally to changing environmental pressures reducing the effect of coastal squeeze.

New saltmarsh habitat creation would support Government strategies and ambitions by:

- Improving the condition of the Chichester Harbour SSSI by slowing the net loss of saltmarsh habitat;
- Improving Biodiversity Action Plan targets supporting Biodiversity Net Gain;
- Achieving the statutory requirement to reach “net-zero” by 2050 through carbon sequestration;
- Expanding the use of natural flood management solutions, and nature recovery through protection, conservation and enhancing natural beauty as defined in Defra’s 25-year plan; and
- Managing the effects of coastal change by allowing the operation of natural coastal processes and improving the sustainability of current management practices according to the South Coast Plain National Character Area Profile.

Due to the topography of the site and the presence of the chalk stream, the Managed Realignment approach would create a mix of intertidal, transitional, and freshwater habitat types. The intertidal habitats could be targeted with ecological enhancements, such as natural transitions to the edges of the site as well as micro-topographic variations within the site itself, providing (in theory) an ideal ecological solution. Ultimately, in the long-term this could create a mosaic of habitats.

This contrasts with the Maintain and Improve options, where only the freshwater habitat of Langstone Mill Pond is preserved for a limited amount of time and the limited remaining amount of saltmarsh habitat at Langstone will be permanently lost. It should be noted that loss of the mill pond could result in the need for compensation of freshwater habitat elsewhere; either in the form of a new mill pond as suggested in this study (noting that this is a high-cost measure) or through a habitat compensation scheme elsewhere. It is important to keep in mind that this is not a constraint that is exclusive to the Management Realignment approach. With the increased salt intrusion into the mill pond which will occur in the Do Nothing, Maintain and (to lesser extent) the Improve options, over time the freshwater habitat is expected to become increasing saline as a result of sea-level rise.

In both the Do Nothing and Maintain scenarios, there is no intention of improving the standard of defence. This will result in increasing overtopping (and salt intrusion) into the mill pond, and the footpath having to be closed for longer periods of time. In the worst case, the reduced level of protection would result in an uncontrolled breach of the wall around the mill pond, which would likely cause the mill pond to drain in an uncontrolled manner. An immediate loss of the freshwater habitat would be the direct consequence, without the opportunity for a gradual transition to a more brackish habitat. This is only partially mitigated by the upgrade in the standard of defence in the Improve option. In all three options, the continued loss of fronting saltmarsh would mean a greater amount of wave energy would impinge on the defence, and as such it may deteriorate at a faster rate than currently anticipated.

Another constraint with the Do Nothing option is that as the existing embankment continues to deteriorate, blockwork and other masonry and fill material will become abandoned in the intertidal zone impacting the landscape value of Langstone Harbour with a possible perceived lack of management or consideration for the environment. Both the Maintain and Improve Option 2 options would be in keeping with the current look and feel of the mill pond and surrounding area. Improve Option 1 would not be in keeping with the overall area, whereas Option 3 could enhance the current landscape values by reconnecting the area with nature. The Managed Realignment option would go further than that in restoring the natural dynamics of the coast and over time letting the coast adjust to its natural position.

Finding funding will be challenging for the traditional engineering options. As there is no significant increase in the flood risk to properties if the sea wall fails (or is deliberately breached), the available Grant in Aid funding (GiA) will be limited. Adopting a Managed Realignment approach could potentially attract funding through the Habitat Compensation and Restoration Programme.

Gaining consent for the hard engineering options will face similar difficulties, as these are not aligned with local and national strategies and ambitions. Especially Improve Option 1 and Option 3 will likely prove difficult; either through the material use (concrete) or the extended footprint (in the case of the embankment).

In conclusion, the hard engineering options, despite being effective in the short-term, are not likely to maintain the freshwater habitat of the mill pond in the long-term and will result in the loss of the remaining saltmarsh habitat (in addition to losing the opportunity to create new saltmarsh). These solutions also come at a significant cost over their lifetime, which will likely prove to be unaffordable and not consentable. The Managed Realignment approach is more cost effective (without the creation of a new freshwater habitat), and promotes biodiversity net gain in the long-term. It is a flexible approach that can be suited to the timescales of the habitat transitions that are already in motion at the mill pond.

8 Recommended option

8.1 Introduction

The options appraisal outlined above indicates that managed realignment would provide a solution that maximises biodiversity over the lifetime of the scheme (up to 2100 considered here), is economically viable, and aligns with Government and other stakeholder groups' ambitions for the environment. At Langstone, management realignment could include a number of components that can be adopted at different times depending on the condition of the the existing seawall, predicted water levels (considering future sea-level rise), and the ecological and morphological evolution of the coast in response to individual events (e.g. storms) and interventions (e.g. managed breaching).

For example, brackish water is already entering the pond and the paddock, and the vegetation is adapting to this transition, which is natural behaviour. The freshwater stream has already been heavily modified and is not functioning as a natural system; a natural chalk stream would be brackish at the point it enters the sea, and it would also supply sediment to the coast which would support intertidal habitats. Even if the sea wall is repaired like for like, the frequency of inundation through overtopping would increase with rising sea-levels, and the pond would slowly adapt, becoming increasingly brackish. By 2060, the sea wall would be overtopped on a weekly basis. It is not sustainable to create a "freshwater island" within an intertidal zone and it is inevitable that Langstone Mill Pond will become brackish over time. However, understanding when this will occur and creating a coastal adaptation plan that considers the most suitable strategy for the short-term, medium-term and long-term would be an appropriate and sustainable solution.

A phased approach has been developed as the preferred option for delivering managed realignment at Langstone. This approach considers the immediate issues regarding footpath access, intermediate issues relating to the ongoing deterioration of the sea wall and longer-term effects of sea-level rise and habitat transition. A schematic of this approach is presented in **Figure 33**. Note, the option presented below is based on available information at the time of writing based on current policy guidance and financial markets, and the current assessment of sea wall condition. As further information becomes available, this approach will be subject to review and refinement.

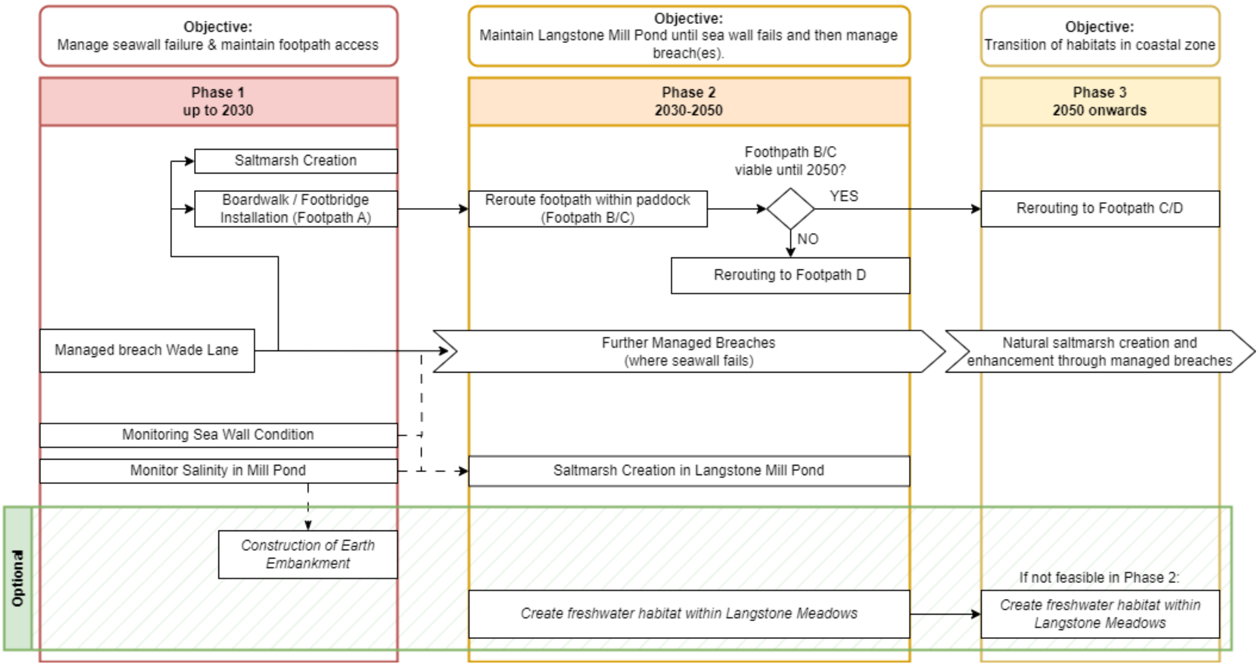

Figure 34 Schematic flow diagram outlining phases of implementation for managed realignment at Langstone

8.2 Phase 1 (up to 2030)

Objective: Manage sea wall failure and maintain footpath access

Recommended

- Managed breach of the sea wall near the point of failure near Wade Lane;
- Installation of a boardwalk or footbridge at the breach to maintain access to the coastal footpath (Footpath A);
- Monitoring of the condition of the sea wall between Langstone Mill and Wade Lane to identify sections that are vulnerable to failure (and unmanaged breaching) in future; and
- Monitoring of the salinity in Langstone Mill Pond.

Optional

- Construction of an earth bund/embankment within the paddock to create higher ground between the managed realignment site in the paddock and the reedbed next to the mill pond;
  - **Caveat** - feasibility of this will depend on ongoing condition monitoring of the sea wall and the salinity of the mill pond.
- Restoration within the managed realignment site to enhance saltmarsh development.

8.3 Phase 2 (2030-2050)

Objective: Maintain Langstone Mill Pond until the sea wall fails and then formalise breach(es).

Recommended

- Reroute the footpath within the paddock (Footpath B or Footpath C) when the frequency of high-water levels increases making the footpath or footbridge within the breach inaccessible;
- Manage failed sections of the sea wall with deliberate breaches, if/when needed;
- Potential rerouting of the footpath between Wade Lane and Langstone Mill (Footpath D) if Footpath B/C is no longer viable due to increased coastal and or river flooding; and
- Saltmarsh habitat creation within Langstone Mill Pond.

Optional

- Create new freshwater habitat within Langstone Meadows.

8.4 Phase 3 (2050 onwards)

Objective: Transition of habitats in coastal zone.

Recommended

- Saltmarsh creation and enhancement through managed breaches; and
- Reroute the footpath between Wade Lane and Langstone Mill (Footpath D) (unless this occurred during Phase 2).
- Create new freshwater habitat within Langstone Meadows.

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