Understanding water and cliff failure at Sidestrand and Trimingham

Options Appraisal Report

November 2024

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Issue and Revision Record

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P01	01/11/24	C. Davis	G. Mason	A. Drake	DRAFT for client comment
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Contents

1 Introduction

Mott MacDonald has been commissioned by North Norfolk District Council (NNDC) to undertake a focused investigation into understanding water and cliff failure at Sidestrand and Trimingham.

The project is part of Coastwise, an initiative being delivered by NNDC, which is nationally funded scheme, through the Coastal Transition Acceleration Programme, funded by DEFRA and the Environment Agency (EA).

The study area is as per the client request for proposal document which states, "East of Sidestrand Hall School – to 100m east of Cliff Farm". The study area is further defined as the seaward side of the road running almost parallel to the cliffs and indicated in the image Figure 1-1.

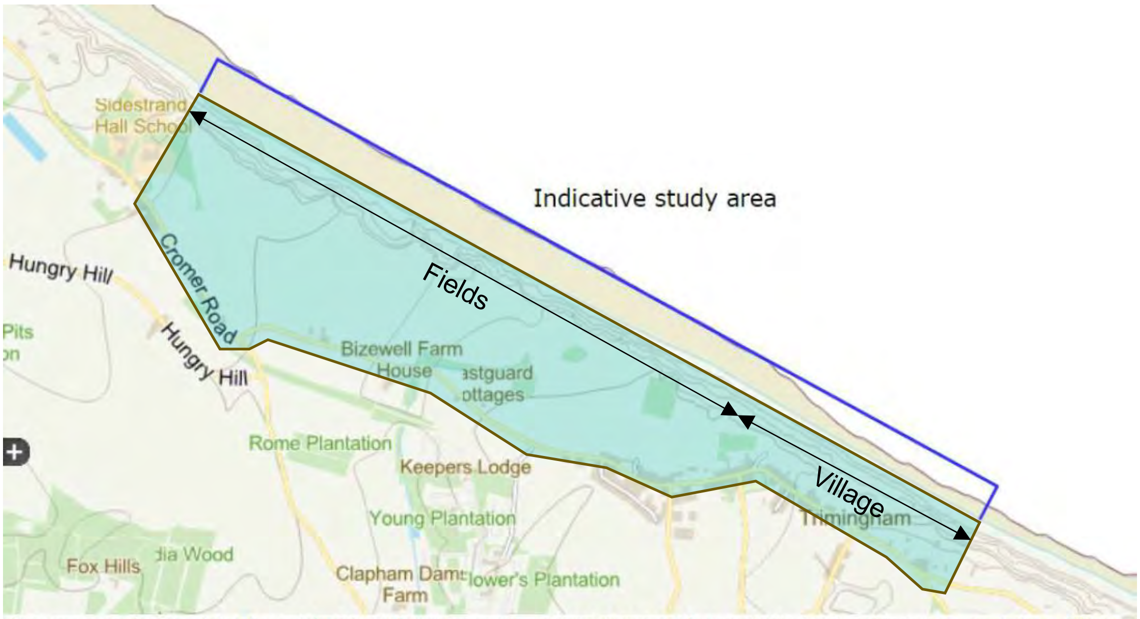
To assist with identifying areas where the options are potentially suitable for controlling water, the study area has been subdivided into the following sections:

- Fields
- Village

The splitting of the study area has been based solely on the land type near the edge of the cliff. Note that the village section does not represent the true area of the Trimingham village.

A visual representation of the sections is present in Figure 1-1.

Figure 1-1: Annotated study area map



This report should be read in conjunction with the "Understanding water and cliff failure at Sidestrand and Trimingham" report number 100120302-0002_P03 dated November 2024 by Mott MacDonald.

1.1 Objectives of the project

- To draw together existing technical knowledge alongside seeking local knowledge to better inform local understanding of the relationship between water and cliff failures between Sidestrand and Trimingham.
- To summarise and present this knowledge in a clear and accessible way.
- To identify realistic practical approaches that may assist with managing water locally in order to seek to potentially manage the rate of cliff failures.

1.2 Scope of work

This report presents a summary of realistic practical measures that may be considered to help manage water locally to reduce the water driven failures of the cliff. These measures will be presented as options in Section 2 and each option will consider the following topics:

- Impact on groundwater
- Constructability
- Design life assessment
- Social value
- Impact on land users/owners
- Environmental impacts
- Sustainability (relative estimate of embodied carbon production)
- Relative cost (estimate)
- Future steps
- Likelihood of success

1.3 Limitations

Please note that the impact of coastal processes on the stability of the cliffs is not considered in this report as it is outside the scope of works for Mott MacDonald. Furthermore, the options presented do not consider any work to improve coastal protection or reinforce / stabilise the existing cliff slopes (i.e. with anchors or slope drains) as they are not considered to be realistic practical measures in the context of the site and Mott MacDonald's scope of works.

Additionally, some of the options presented may be outside of the scope of Coastwise's current funding remit and would require further discussion with DEFRA, EA and other funders.

1.4 Potential constraints

The study area in Trimingham and Sidestrand is within the vicinity or nearby several significant constraints. Each option has considered (at a high level) the environmental designations but consultation with the respective organisation has not been undertaken as it is outside the scope of work. This will need to be completed once the preferred option(s) have been identified.

The list below highlights some of the most significant constraints. Specialist input and further work is required to identify the full list of constraints and stakeholders once the preferred option(s) have been identified.

Significant site constraints include:

- Sites of special scientific interest (SSSI) – Natural England has designated the cliffs as a SSSI for biological and geological features and sites the importance of the mass movement processes https://designatedsites.naturalengland.org.uk/PDFsForWeb/Citation/1003919.pdf.

  - Natural England has previously stated (email to NNDC dated 9th April 2024) *"The Sidestrand to Trimingham cliffs is considered the best soft rock site for invertebrates in East Anglia and many of the rare species are associated with crevices and fallen debris generated by natural processes. The purple broomrape that grows in the grassland close to the cliff edge is a Red Data Book species (The International Union for Conservation of Nature (IUCN) Red List of Threatened Species) and as such the colonies present are of importance. The sediment generated by erosion of the soft cliffs here is considered a 'critical' supply that reduces erosion rates elsewhere along the coast and maintaining natural processes in this area is a key aim of the Shoreline Management Plan. It is unlikely that we (Natural England) would be able to consent an activity that could lead to a change in the delicate balance of these communities and also that would result in the condition of a SSSI becoming ecologically unfavourable. The site is already in unfavourable declining condition for geology and any management should seek to improve that status rather than potentially contribute to restrictions on the erosional processes necessary to maintain exposure of geological features."*
- This site is designated as a Geological Conservation Review (GCR) site by virtue of these features of geological interest, including the Pleistocene deposits of East Anglia, the vertebrate Palaeontology, and mass movement processes.
- River Mun – The study area is within the catchment of the River Mun and any influence on water quality, water flow, physical processes and ecosystem will need to be communicated with the Norfolk Rivers Trust and EA.
- Source Protection Zone (SPZ) – Approximately 2km south-east of the study area, the ground beneath Mundesley is designated a SPZ (Zone I to III) to safeguard drinking water quality through constraining the proximity of an activity that may impact upon a drinking water abstraction. The underlying chalk (at depth) in the study area is the source of the water extracted in Mundesley.
- Shoreline Management Plan (SMP) – The site is within the Environment Agency's SMP 6 (Overstrand to Mundesley 6.07) and the current approach is set as develop naturally with no active intervention.
- Areas of Outstanding Natural Beauty (AONB) – The site and surrounding area has been designated as AONB by Natural England for having such natural beauty that it is desirable it is conserved and enhanced.

2 Optioneering

The main factor impacting stability of the cliffs (apart from coastal processes) is the groundwater flow through the cliff and surface water running over the cliff.

This section presents a series of realistic practical measures that will help manage water locally to reduce the water driven failures of the cliff. The main criteria for each option proposed is to either:

- reduce infiltration of rainwater into the ground, and/or
- reduce groundwater flow towards the cliff, and/or
- lower groundwater levels at the cliff.

Based on information above and the key aspects described in Section 1.1, the following options have been proposed:

Improving drainage

Option 1 - Remediate existing highway drainage

Option 2 - Remediate existing field drainage

Option 3 - Upgrade / install new drainage

Option 4 - Create earthen banks)

Improving drainage and creating storage

Option 5 - Swales and small ponds

Option 6 - Wetland creation

Option 7 - Retention pond

Option 8 - Retention pond with discharge drainage

Strategic planting

Option 9 - Plant or increase buffer strips

Option 10 - Convert cropland to grassland

11 - Agroforestry (planting of specific flora)

Reducing groundwater levels

Option 12 - Vertical dewatering pipes

Each option is presented and assessed individually. It is envisaged that a combination of two or more options could be the optimum solution and the combination of options may vary for different sections (field and village sections – see Figure 1-1) of the study area.

At this stage, the options are based on engineering judgement and experience. If an option is selected then further work will be required, if it is beyond normal maintenance of water management systems or normal land management practices, to prove the viability of the proposals which will include design, calculations and drawings. In particular, because these options seek to change the flow/level of water in the ground over a large area, the impacts on adjacent infrastructure and environment would need to be considered as part of the design. This design may require hydrology and hydrogeological studies to assess impacts.

Optioneering on the cliff face

As mentioned in Section 1.4, the cliff face is designated as SSSI by Natural England. A previous enquiry by NNDC for drone seeding (CropAngel) along the cliff face was rejected by Natural England as the option could be damaging to the ecology of the SSSI. Therefore, given the likelihood of further rejection by Natural England for any works on the cliff face, no design option (such as: seeding, soil nailing, regrading, drainage pipes) has been presented for this study area. Please also refer to the limitations of this report in Section 1.3.

Although cliff slope stabilisation and coastal protection measures have not been excluded from our studies for this site, they are acknowledged to be extremely beneficial to the stability of cliff slopes and should be considered for other sites where possible.

Improving drainage

2.1 Option 1 - Remediate existing highway drainage

Description of the option

Clean the existing road gullies and pipework to remove any blockages. An additional review the road drainage design by drainage engineers. Further investigate the condition of the existing highways drainage network with a CCTV survey and prove the location of the drainage outlet and/or soakaway. This will allow a drainage engineer to assess drainage flow direction and condition of the asset.

This solution will reduce surface water run-off from the highway network running onto and infiltrating the surrounding ground.

Section of the study area effected	Village section only
Constructability	Easy and routine work which will have an immediate impact.
Design life	The high percentage of “silting up” recorded in the gullies and pipework indicate that regular cleaning and maintenance should be undertaken.
Social value impacts	Positive social impact due to less surface water flooding.
Land user impacts	• Positive impact on landowners and road users. • The maintenance work will require traffic management such as temporary road works or closure.
Environmental impacts	• Cleaning road gullies can have a positive impact by reducing the risk of flooding and surface water runoff. • Material arising from road drainage emptying and cleaning has potential implications for pollution and should be disposed of correctly in accordance with waste management procedures.
Sustainability (embodied carbon production)	Low impact • Limited embodied carbon produced from the works. • However, if gullies require regular cleaning, then the embodied carbon impact would increase.
Relative cost (estimate)	Low (but recurring maintenance cost). • Norfolk County Council anticipated an investigation survey would cost several thousand pounds with a specialist supplier and traffic management.
Likelihood of success	• The survey should identify the outlet or soakaway for the road drainage but there is potential it could be inconclusive. • This option will only impact sections of the study area where the road is near the cliff edge. • The overall impact of clean gullies and pipework will not stop water infiltration across the full study area. • The cleaning of gullies and pipework will likely need to be a regular task and may not be undertaken consistently by Norfolk County Council.
Future steps	The proposal for the remedial works and investigation survey will need to be undertaken in cooperation with Norfolk County Council.

2.2 Option 2 - Remediate existing field drainage

Description of the option

Clear any existing blocked drainage channels and pipes that are restricting water flow towards the River Mun. Vegetation clearance along the drainage or water course may be required.

The solution will direct rain and surface water into the River Mun rather than infiltrating ground and potentially heading towards the cliffs.

Section of the study area effected	Fields section only
Constructability	Easy and routine work which will have an immediate impact.
Design life	Regular cleaning and maintenance should be undertaken
Social value impacts	Neutral social impact.
Land user impacts	• Works will require landowner permission. • The option only considers existing field drainage systems, where known.
Environmental impacts	• The works would need to be approved by the EA and other respective organisations, to ensure no pollution enters the water course and the remedial works do not impact the River Mun (i.e. increase water flow, increase in nitrates in water with reduced vegetation).
Sustainability (embodied carbon production)	Low impact • Limited embodied carbon produced from the works.
Relative cost (estimate)	Likely to be low (but potential recurring cost). • The work would only require a small team and equipment. • Costs could increase if the works need to happen regularly.
Likelihood of success	• From the site walkover and research there are blocked drains in the north-west of the site and this blockage could be contributing to reduced rainfall runoff and a higher groundwater. • The works should be routine works but only limited to the section of fields
Future steps	• Investigation to determine existing drainage network. • Calculations will need to be undertaken to estimate how much benefit this proposal would have on the groundwater conditions. • Approval required from landowners, EA and others.

2.3 Option 3 - Upgrade / install new drainage

Description of the option

Upgrade/install new field drainage to catch and direct surface water to the River Mun. The drainage system would need to be designed to be suitable for the intended land use. The option will likely require the excavation of trenches to install the new drainage network.

The solution will reduce standing water, direct rain and surface water into the River Mun or another outlet rather than infiltrating into the ground and towards the cliff.

Section of the study area effected	Fields section only
Constructability	Easy and routine work which will have an immediate impact.
Design life	The design life of field drains can be at least 20 years with regular cleaning and maintenance.
Social value impacts	Neutral social impact.
Land user impacts	• Works will require landowner permission. • The option only considers existing fields and not gardens.
Environmental impacts	The outlet for the field drainage will need approval from the EA and other organisations.
Sustainability (embodied carbon production)	Low impact • Low embodied carbon produced from the works.
Relative cost (estimate)	Moderate to high • The cost to install field drainage varies depending on the scale and intensity of the system and can range from £1,400 - £3,500 per hectare (source: Agriculture and Horticulture Development Board). • Costs associated with new drainage and the excavation works. • Potential cost for loss of land or crops.
Likelihood of success	• A network of field drains will help to intercept water infiltrating into the ground and lower groundwater. • Likely limited to the fields section and would not impact the village section.
Future steps	• Detailed design of the new drainage network would be required to ensure the long-term future of the pipes in relation to potential cliff failures. • Calculations will need to be undertaken to estimate how much benefit this proposal would have on the groundwater conditions. • Approval required from landowners.

2.4 Option 4 - Create earthen banks

Description of the option

Construct raised banks of earth parallel to the cliff edge at locations where topography means surface water flows towards the sea. Drainage will need to be installed in conjunction with the banks to prevent surface water ponding and infiltration. Hedgerows could be planted on the earthen banks to increase amenity value.

The bank will function as a barrier to prevent surface water flow over the cliff edge.

Section of the study area effected	Fields section only
Constructability	Relatively easy and routine work which will have an immediate impact to prevent surface water flow towards the cliff.
Design life	● Long design life for the banks. ● The design life of field drains can be at least 20 years with regular cleaning and maintenance.
Social value impacts	This option only impacts the north-west of the area and not Trimingham village.
Land user impacts	Change of land use for the landowner currently using it as agricultural land.
Environmental impacts	Increased biodiversity.
Sustainability (embodied carbon production)	Low or positive impact ● Limited embodied carbon from construction. ● Long-term benefits from increased vegetation.
Relative cost (estimate)	Low to moderate (construction) ● Potential earthworks to create earth banks for the hedgerows. High (potential land use change) ● There could be a cost to secure land use change from landowners. Environmental Land Management Schemes may provide funding.
Likelihood of success	Consider acceptability and interest from landowners alongside compatibility with farming practices.
Future steps	Surface water runoff calculations and catchment areas will need to be assessed so the hedgerows and earth banks can be designed.

Improving drainage and storage

2.5 Option 5 - Swales and small ponds

Description of the option

Excavate swales (V-shaped lined shallow channels) that will collect and redirect rainwater away from the cliff towards existing and new lined ponds.

This option will reduce infiltration and downstream flooding and promote evaporation and rainwater storage.

Section of the study area effected	Fields section only and potentially south-west of the village section
Constructability	• Excavation is required to create the new swales and ponds and/or enhance the use of existing ponds. • The swales and ponds will likely need to be lined (e.g. puddle clay) to prevent infiltration.
Design life	If maintained, the swales and ponds should last for decades.
Social value impacts	• This option is potentially difficult to replicate in Trimingham village with limited land available. • Potentially wetland creation could be constructed in the low lying ground to the south-west of Trimingham in the River Mun catchment.
Land user impacts	The excavation works will require land from landowners. This will reduce arable land.
Environmental impacts	• The introduction of swales and ponds can help with the biodiversity in the area. • If the rainwater can be effectively retained and stored in the swales and ponds, it is unlikely to impact the River Mun flooding and require further consents.
Sustainability (embodied carbon production)	Moderate impact to becoming positive impact • Construction will require earthworks and landscaping. • Long-term benefits to the environment from increased vegetation.
Relative cost (estimate)	Moderate to high (construction) • The construction of swales and ponds will be moderate, with costs increasing as lining clay is likely needed to be imported. High (potential land use change) • There could be a cost to secure land use change from landowners. Possibility for grants to assist with costs.
Likelihood of success	• Likely an effective way of collecting and redirecting rainwater. • Potential uncertainty if the rate of evaporation will be an effective method to remove water.
Future steps	• The location of the swales and ponds will require design, including a flood risk assessment. • Rate of evaporation will need to be calculated to ensure it is a suitable method to improve groundwater conditions.

2.6 Option 6 - Wetland creation

Description of the option

Change of land use to a semi-aquatic ecosystem within the River Mun flood plain and away from the cliff edge. The land is covered by water, either permanently or seasonally.

This would direct surface water away from the land closest to the cliff.

Section of the study area effected	Fields section and potentially south-west of the village section
Constructability	This option potentially requires large-scale landscaping and drainage to create an area suitable for a wetland.
Design life	If maintained, the wetland creation should last for decades.
Social value impacts	● This option is potentially difficult to replicate in Trimingham village with limited land available. ● Potentially wetland creation could be constructed in the low lying ground to the south-west of Trimingham in the River Mun catchment.
Land user impacts	The excavation works will require land from landowners. This will reduce or remove arable land.
Environmental impacts	● The introduction of wetland can help with the biodiversity in the area. ● If the water is retained on the land and not entering the water system, it is unlikely to impact the River Mun and the EA.
Sustainability (embodied carbon production)	Moderate impact to becoming positive impact ● Construction will require earthworks and landscaping. ● Additional impact from importing lining (puddle) clay from a different location. ● Long-term benefits to the environment from increased vegetation.
Relative cost (estimate)	High (construction) ● The excavation and landscaping will likely have a high cost, with costs increasing as lining clay is likely needed to be imported. High (potential land use change) ● There could be a cost to secure land use change from landowners. Possibility for grants to assist with costs.
Likelihood of success	● Likely an effective way of collecting rainwater. ● Potential uncertainty if the rate of evaporation will be an effective method to remove water.
Future steps	● The design of a wetland would need consider that it will not cause increases in groundwater levels at the cliffs. ● Drainage calculations and rate of evaporation will need to be calculated to ensure it is a suitable method to manage water.

2.7 Option 7 - Retention pond

Description of the option

Larger scale ponds located in specific areas to hold excess water and allow for evaporation and storage. Ponds would need to be designed with a lining to prevent infiltration.

Section of the study area effected	Fields and village sections
Constructability	This will require excavation of a deep pond or use of an existing pit/quarry. The pond will need to be lined to prevent infiltration.
Design life	Retention ponds and other storage and treatment systems typically have a lifespan of greater than 20 years.
Social value impacts	The excavation works would require a large area(s) of land or reuse of existing pits.
Land user impacts	Potential for change of land use.
Environmental impacts	The introduction of a pond can help with the biodiversity in the area.
Sustainability (embodied carbon production)	Moderate impact to becoming environmental beneficial ● Construction will require earthworks and landscaping. ● Additional impact from importing lining (e.g. puddle clay). ● Long-term benefits to the environment from increased vegetation.
Relative cost (estimate)	High (construction) ● The excavation and landscaping will likely have a high cost, with costs increasing as lining clay is likely needed to be imported. High (potential land use change) ● There could be a cost to secure land use change from landowners. Possibility for grants to assist with costs.
Likelihood of success	● Likely an effective way of collecting rainwater. ● Evaporation would be limited, especially in winter. ● Overflow pipes or swales would need to be designed.
Future steps	● Design and calculations are required to locate areas for the pond and ensure evaporation works. ● Calculations will need to be undertaken to estimate how much benefit this proposal would have on the groundwater conditions.

2.8 Option 8 - Retention pond with discharge drainage

Description of the option

Construct ponds to hold excess rainwater and allow for evaporation but with added discharge chambers or overflow structures to remove water quickly if high rainfall is predicted. Ponds would need to be designed with a clay lining.

This option will reduce infiltration and downstream flooding and promote evaporation and rainwater storage.

Section of the study area effected	Fields and village sections
Constructability	• This will require excavation of a deep pond or use of an existing pit. • Discharge drainage will require considerable excavation and infrastructure.
Design life	Retention ponds and other storage and treatment systems typically have a lifespan of greater than 20 years.
Social value impacts	The excavation works would require a large area(s) of land or reuse of existing pits.
Land user impacts	Potential for change of land use.
Environmental impacts	• The introduction of a pond can help with the biodiversity in the area. • Any water discharge will need to be considered on the influence on the River Mun and the EA will need to be notified.
Sustainability (embodied carbon production)	Moderate to high impact to becoming environmental beneficial • Construction will require earthworks and landscaping. • Added impact from importing lining (puddle) clay from a different location. • Significant works to excavate and install discharge drainage. • Long-term benefits to the environment from increased vegetation.
Relative cost (estimate)	High to very high (construction) • The excavation and landscaping will likely have a high cost, with costs increasing as lining clay is likely needed to be imported. • Adding drainage will require significant works. High (potential land use change) • There could be a cost to secure land use change from landowners. Possibility for grants to assist with costs.
Likelihood of success	• Likely an effective way of collecting rainwater. • Discharge drainage allows water to be removed before incoming rainfall. • Discharging water into the River Mun catchment might not be accepted.
Future steps	• Design and calculations are required to locate areas for the pond and the discharge pipes. • Calculations will need to be undertaken to estimate how much benefit this proposal would have on the groundwater conditions.

Strategic planting

2.9 Option 9 - Plant or increase buffer strips

Description of the option

Buffer strips of selected vegetation bordering fields can be added to any cropped open field areas.

Vegetation will reduce infiltration of rainwater and promote evapotranspiration.

Section of the study area effected	Fields and village sections
Constructability	• Easy and routine work which will take a few years (<2) to establish benefits. • Limited construction is required for planting the buffer strips.
Design life	This option will have a long life if properly maintained.
Social value impacts	Positive social impact due to adding green space in the fields.
Land user impacts	• Currently there is a buffer strip placed in the fields by a landowner. • More difficult to assess impact if this is proposed for private gardens.
Environmental impacts	• Natural England will likely need to be informed given the proximity to the SSSI. • Increased biodiversity.
Sustainability (embodied carbon production)	Low impact to becoming environmental beneficial • Limited construction is required. • Long-term benefits to the environment from increased vegetation.
Relative cost (estimate)	Low (construction) • Planting of the buffer strip will be low. High (potential land use change) • There could be a cost to secure land use change from landowners. Environmental Land Management Schemes may provide funding.
Likelihood of success	• The buffer strip will help absorb surface runoff and shallow water but potential not impacting deeper water. • Consider acceptability and interest from landowners alongside compatibility with farming practices.
Future steps	• Consultation with specialists would be required to ensure the correct flora is planted. • Width of the buffer strip will need to be calculated. • Calculations will need to be undertaken to estimate how much benefit this proposal would have on the groundwater conditions.

2.10 Option 10 - Convert cropland to grassland

Description of the option

Convert existing cropland to grassland through suitable land management measures and activities.

Grassland will reduce infiltration of rainwater and promote evaporation and transpiration compared to cropland.

Section of the study area effected	Fields section only
Constructability	Easy and routine work which will take a few years (<2) to fully establish benefits.
Design life	This option will have a long life if properly maintained.
Social value impacts	This option only impacts the north-west of the area and not Trimingham village.
Land user impacts	Change of land use for the landowner currently using it as cropland.
Environmental impacts	Increased biodiversity.
Sustainability (embodied carbon production)	Low or positive impact ● Low embodied carbon production from construction. ● Long-term benefits to the environment from increased vegetation.
Relative cost (estimate)	Low to moderate (construction) ● The process of changing the land to grassland will be relatively low. High (potential land use change) ● There could be a cost to secure land use change from landowners. Environmental Land Management Schemes may provide funding.
Likelihood of success	There will likely only be a limited improvement to the reduction in infiltration from changing land use from cropland to grassland.
Future steps	● Landowner interests would need to be met. ● Consultation with specialists would be required to ensure the correct flora is planted. ● Calculations will need to be undertaken to estimate how much benefit this proposal would have on the groundwater conditions.

2.11 Option 11 - Agroforestry (planting of specific flora)

Description of the option

Plant specific trees and vegetation to reduce rainwater infiltration and promote interception, evaporation and transpiration.

Section of the study area effected	Fields section only
Constructability	• Easy and routine work • Will take many years for the trees to establish and the benefits to be fully realised.
Design life	This option will have a long life if properly maintained.
Social value impacts	• This option only impacts the north-west of the area and not Trimingham village. • Increase in trees and vegetation to the area.
Land user impacts	Change of land use for the landowner currently using it as agricultural land.
Environmental impacts	Planting of trees has the potential to block views or conversely provide landscape enhancements and might impact on AONB.
Sustainability (embodied carbon production)	Low impact to becoming positive impact • Low embodied carbon production from construction. • Long-term benefits to the environment from increased vegetation
Relative cost (estimate)	Moderate (construction) • The cost of buying trees and hedgerows will varying based on the type and maturity. High (potential land use change) • There could be a cost to secure land use change from landowners. Possibility for grants to assist with costs.
Likelihood of success	• Agroforestry will help absorb surface runoff and shallow water but potential not impacting deeper water • Only limited to the fields section along the cliff edge.
Future steps	• Consultation with specialists would be required to ensure the correct flora is planted. • Calculations will need to be undertaken to estimate how much benefit this proposal would have on the groundwater conditions.

Reducing groundwater levels

2.12 Option 12 - Vertical dewatering pipes

Description of the option

Drill a series of deep (up to 70m) vertical boreholes along the study area and install slotted pipe drains. This will allow higher perched groundwater to drain into the lower geological layers. This will lower the groundwater level adjacent to the cliff. This option has been proposed based on no design or modelling and significant work would be required to determine the suitability of this method for lowering groundwater levels.

Section of the study area effected	Fields and village sections
Constructability	Specialist plant to drill deep boreholes will be required.
Design life	• Inspection and removal of silt in pipes will be required. • Previous attempts for vertical boreholes failed from "silting up" or breaking when located on/near an active landslide. Full construction details are unknown. • Maintenance and monitoring will be required.
Social value impacts	The locations of the pipes would need to be carefully considered.
Land user impacts	• Works may need to be undertaken on privately owned land. • Groundwater lowering can cause settlement of nearby buildings.
Environmental impacts	Deeper drains may locally increase water flow into the underlying chalk aquifer. This and other aspects of the proposal would need approval from the EA as the nearby area is a groundwater source protection zone.
Sustainability (embodied carbon production)	Moderate to high • Requires specialist equipment and numerous drilling locations.
Relative cost (estimate)	High to very high (construction) • The cost of vertical boreholes and dewatering pipes can vary depending on several factors like pipe length, thickness, material and ground conditions. • The dewatering pipes may need to be at least 70m long to achieve an effective depth. High (potential land use change) • There could be a cost to secure land use change from landowners depending on the dewatering pipe locations. Possibility for grants to assist with costs. Medium (ongoing maintenance) • Regular inspections, cleaning and monitoring will be required to maintain the effectiveness of the pipes.
Likelihood of success	• This method would likely be successful in lowering the groundwater but potentially too expensive and environmentally may not be feasible. • The drains need to be designed to allow maintenance and cleaning to prevent becoming blocked with silt which would reduce effectiveness.
Future steps	• Geotechnical and hydrogeological design. • Further design and investigation required to ensure the system can be effective at permanently lowering the groundwater or by a significant amount.

3 Future steps

The following steps are recommended:

- High level assessments prior to the workshop to aid understanding
  - Drainage – provide initial drainage considerations for surface water of existing infrastructure and proposed works.
  - Environmental – Consideration and recommendations for future works on the following environment topics such as: ecology, landscape and visual impact, materials and waste.
  - Hydrogeology – Further consideration of relevant precipitation data, hydrogeological model and parameters. Undertake hydrogeological 2D modelling to assess relative change in groundwater surface.
- Undertake a workshop to discuss and assess each option based on multi-criteria assessments (MCA).
- Discussions and input from stakeholders and landowners.
- Selection of the preferred option(s) following the scoring workshop and stakeholder / landowner input.
- Develop the preferred option(s) with further consultation with specialist engineers (drainage/environmental/hydrogeological/geotechnical) and town planning to support funding and/or consents.
- Progress with the hydrology and hydrogeological model to ensure the option(s) are effective in reducing water entering the cliff.
- Consider the percentage of landslide failures governed by groundwater in the cliff and failures from toe erosion.

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