SPI - Asset Investigations and Repairs
Project ID 052

Critical Asset Overview Report

June 2023

Mott MacDonald
10 Temple Back
Bristol BS1 6FL
United Kingdom

T +44 (0)117 906 9500
mottmac.com

Bristol City Council
100 Temple Street
Bristol
BS1 9NE

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Executive summary

This report details priority group ratings and proposed actions for the assets within the scope of this project.

Asset Prioritisation

Within context of the critical asset ratings, the assets have been ranked into groups in order of repair priority, with Group 1 being the highest priority and Group 3 the lowest. The rankings are in Table 1.1 below. Further details can be found in Section 12.

Table 1.1: Asset priority summary

Priority Group	Assets
1	NCS21/23 and NCS28
2	NCN16, NCS18 and S28b
3	NCS06 and NCS13
N/A	N06

Asset Recommendations

A summary table of the recommended actions can be found below in Table 1.2. In addition to the listed recommendations, there are potential constraints from ecology, unexploded ordnance and contaminated land, see relevant sections for further details.

NCN16 has been omitted from this table as its repairs have been expediated expedited by Bristol City Council (BCC). Details of suggested repair options and recommended geotechnical investigations can be found in documents 100105143-MMD-NCN16-XX-TN-CV-001 [8] and 100105143-MMD-NCN16-XX-SP-GT-002 [10].

Table 1.2: Asset recommendations summary

Priority	Asset	Summary
1	**NCS21/23**	**Ground Investigations** • 2No. boreholes • Slit trench behind the top of the wall **Monitoring** • Visual – 1 month intervals **Reconstruction** • Deconstruct existing wall and replace with reinforced concrete retaining wall. • Reinstate footway and carriageway (if applicable) **Other Constraints** • Bedminster bridge listed status
	NCS28	**Ground Investigations** • 8No. boreholes • 2No. trial pit **Monitoring** • Visual – 1-month intervals • Real time monitoring – tilt meter and displacement sensor installation • Real time monitoring (potential tilt meter and displacement sensors) of bridge and abutment • CCTV survey of outfalls and functionality check of flap valves **Reconstruction***

Priority	Asset	Summary
		*It is not thought to be practical to repair the asset as there are concerns over the adequacy of the existing foundations. However, given the disruption of piling, a high level feasibility study should be undertaken to determine whether a wailing beam and anchor system (with miscellaneous masonry repairs) is appropriate. • Reconstruction is likely to consist of pile installation behind the existing masonry wall. Masonry wall can be rebuilt or allowed to deteriorate (risk of poor perception from public). **Other Constraints** • Langton Street Bridge listed status
2	**NCS18**	**Ground Investigations** • 4No. boreholes • 2No. hand dug trial pit • Slope stability analysis **Monitoring** • Visual – 2 month intervals • Real time monitoring – tilt meter installation **Repair – Slipway defects** • Repairs to collapsed sections in the vicinity of the slipway are considered to be a high priority if BCC find it important to retain the use of the slipway for access into the New Cut. Repairs here are to be of a combination of masonry (like for like) and reinforced concrete patch. **Repair – Slope wall defects** • Repair method to be evaluated following ground investigations and contractor engagement. • There is an anticipated high cost of siting plant and access to conduct patch repairs on the wall (concrete or masonry). Slope stabilisation works are a potential interim option
	S28b	**Ground Investigations** • 2No. boreholes • Dive survey **Monitoring** • Monitored for global movement – regular (3-4month intervals) photogrammetric model capture either from drone or boat, or automated monitoring **Repair** • To be determined following dive survey and ground investigations. • Likely piling or a concrete repair
3	**NCS06**	**Ground Investigations** • 4No. boreholes • 4No. hand dug trial pit • Slope stability analysis **Monitoring** • Visual – 2 month intervals **Repair** • Repair method to be evaluated following ground investigations and contractor engagement. • There is an anticipated high cost of siting plant and access to conduct like for like masonry repairs, or local demolition and rebuild. Slope stabilisation works are a potential interim option. **Other Constraints** Ground investigations to dictate whether priority group increases dependant on: • The building foundations are found to be dependent on the river wall and a concern develops over that section of the wall. • The condition of the bank retaining wall significantly deteriorates. • The slope stability assessment indicates there is a risk of collapse.

<table>
<tr><th>Priority</th><th>Asset</th><th>Summary</th></tr>
<tr><td></td><td>NCS13</td><td><u>Ground Investigations</u>
2No. boreholes
2No. hand dug trial pit
Slope stability analysis
<u>Monitoring</u>
Visual – 2 month intervals
<u>Repair</u>
Repair method for collapsed section to be evaluated following ground investigations and contractor engagement.
There is an anticipated high cost of siting plant and access to conduct like for like masonry repairs, or local demolition and rebuild. Slope stabilisation works are a potential interim option.
Sections of deformation to be repaired if movement is experienced.</td></tr>
<tr><td>N/A</td><td>N06</td><td><u>Follow-up actions</u>
Contact Edwards Diving Services (EDS) to seek and understand why the void behind Grain Barge was not mentioned in their report. Clarification should also be obtained with regards to accessibility of the arches, whether the arch barrels were inspected, and where the recorded spalls are located.
Potential follow up dive inspection to confirm condition and function of void.
No deformation found at any of the arch barrels.
Potential to de-risk asset from scope of this project following conversation/follow up dive survey with EDS relating to the void.</td></tr>
</table>

1 Introduction

1.1 Background

Across 2019 and 2020, Mott MacDonald were commissioned to undertake inspections of Bristol City Council (BCC) assets in the Bristol Floating Harbour, Feeder Canal, and the River Avon New Cut as part of the Harbour Condition Survey project. Overall, there are 194 retaining wall assets and the inspections found that there were 58 assets rated as being either in a serious or critical condition.

Mott MacDonald were then tasked with prioritising these 58 assets in terms of their consequence and likelihood of failure, and this resulted in 11 assets being identified as having both a high consequence and high likelihood of failure. Failure of these assets could potentially result in loss of life or serious injury, major flooding, adjacent property damage and immediate closure of the road network in the vicinity of the failure which are likely to have significant effects on the wider road network. Additionally, this will have financial, environmental and reputational damage to BCC and the local economy and South-West Region.

The 11 assets rated as having a high likelihood and high consequence of failure are:

- N06
- NCN03a*
- NCN16
- NCS06
- NCS13
- NCS18
- NCS21
- NCS23
- NCS28
- NCS30*
- S28b

Two of these assets, NCN03a and NCS30 have been removed from the scope of this project by BCC as they are undergoing further works within other schemes.

1.2 Scope of Works

Mott MacDonald have been commissioned by BCC to further investigate the highest priority assets, in an effort to fast-track necessary repairs and outline potential monitoring programmes. This report outlines findings and suggests monitoring options and recommends further investigations to be undertaken to inform repair options.

Within this project, BCC has further prioritised the investigation and remediation work for NCN16. This can be found in report 100105143-MML-NCN16-XX-TN-CV-001 [8].

1.3 Site Walkovers

Since the initial asset inspections, Mott MacDonald have completed site walkovers for geotechnical and structural purposes on the following dates:

  - 17th, 19th & 28th January 2021
  - 28th June 2022

– 27th September 2022

Observations and photos from these site walkovers and condition surveys are included in this report. Additional information is included from Bristol City Council archives.

The following surveys have been undertaken to collect data:

– Terra Drone (Skeye) in March 2019 – November 2019
– Glanville Geospatial Services – December 2019
– Glanville Geospatial Services – April 2019 to December 2019
– Skeye (drone survey) – October 2022

1.4 Asset Defect Sections

The following asset defect sections presented in this report, do not provide a complete summary of all defects identified for each asset. Instead, they highlight the critical defects being considered for repair and monitoring at this stage.

2 Monitoring

There are a variety of different monitoring techniques which can be used in the project to gather regular information on the deterioration of the assets. The primary options to consider include:

- Visual monitoring with photographic evidence.
- Visual monitoring with photogrammetric model (Drone survey).
- Laser scanning.
- Total station surveying.
- Installation of sensors.

To facilitate these monitoring options, vegetation removal in the vicinity of the assets should be conducted as required to enable the regular and unobstructed monitoring of them visually.

2.1 Visual Monitoring with Photographs

Mott MacDonald staff undertake a site walkover and capture photographs of an asset from safe available locations. Photographs are captured using a long lens camera to obtain the best images possible.

These photographs are then compared with the previously captured images to document visible changes and to compile a visual record of an asset.

Using this method in isolation and without further monitoring methods means that only significant changes to an asset are detected (e.g., additional loss of masonry), it may not be possible to detect minor movement.

There could also be issues with being able to capture photographs of certain assets during times when vegetation growth is at its peak, as a clear line of sight is required.

This option would be cheap as it would require approximately 3 days of staff time per walkover.

If additional close-up inspections are necessary, either boat or rope access would be required at a supplementary cost.

2.2 Visual Monitoring with Photogrammetric Model

A drone survey can be used to create a photogrammetric model. The model can be compared with previous models, such as the 2019 model and 2022 model to look for movement and any discreet changes to the masonry.

In the process of creating the model, hi-resolution images will be captured from numerous vantage points, which are unable to be reached by foot or boat (aerial/birds eye view). This allows for better coverage of the asset than would be possible if only taking images on foot.

Additionally, creating digital photogrammetric models of the New Cut assets contributes towards the initial investment outlaid in the digital twin, which was a key target of the 2019 project, and builds up the information on the assets.

While different models can be compared and overlaid, it may only be possible to detect larger movement events and loss of masonry, and minor movement may not be readily apparent. High accuracy surveys and models can improve the level of detection in combination with machine learning, but this will be at a higher cost.

This is considered to be an option as a biennial (every 2 years) practice to gain information over the long-term rather than a regular practice.

The cost of the drone survey can be estimated to be about £10,000 to £15,000 (excluding VAT) per survey depending on the number of assets to be surveyed. The cost comprises 2 to 4 days of drone survey and access provision to the New Cut by a specialist contractor. The drone survey can be also extended to the entire New Cut assets to obtain regular information about their condition.

2.3 Laser Scanning

Laser scanning of the walls would provide a point cloud model. Through this model, sections would be drafted to allow the comparison of readings allowing the detection of movement. The readings can be given in graphic form which will give a complex view of asset changes.

Specific sections will need to be selected meaning that there is the potential for new deformations to be initially missed. To avoid this occurrence, a site inspection should be undertaken prior to the confirmation of section positions.

A quote for laser scanning, processing scan data to a point cloud and the preparation of drafting sections from scan data has been provided by Anthony Brookes Surveys (ABS), an extract of this is provided in A.1.

The quoted cost to laser scan all 8 assets and have 20 sections drafted would be £7,260 (excluding VAT) per round of scanning.

The laser scan data would likely have some fuzz or noise, so the accuracy could be in the region of 6mm to 20mm depending on the surface and condition. ABS expects to get around 6mm accuracy across the New Cut sites.

Additionally, creating models of the New Cut assets continues contributing towards the initial investment outlaid in the digital twin approach and builds up the repository of information on the assets. To incorporate this data into the existing 3D model, it would require processing further than required for section drafting and this would be available to purchase from ABS at an additional cost.

To facilitate the laser scanning, there will need to be regular de-vegetation to ensure that the best possible coverage is obtained, and a clear line of sight is possible. This may be necessary on both sides of the river.

As laser scanning is a periodic survey method, there is the potential to miss signs of a sudden failure.

At the time that the quote was given (17/11/2022), ABS could attend site within 15 working days from receipt of a written instruction to proceed.

2.4 Total Station Survey

A total station survey scans targets installed onto the assets to detect changes in position between scan dates. Information will be complied in a spreadsheet for comparison. The accuracy of the surveying is approximately 3mm.

The targets require rope access for installation and be installed using an adhesive suitable for a marine environment. Over time, there is a risk that targets are lost which will lead to an incomplete data set.

A quote for surveying and processing the survey data into a comparison table has been provided by Anthony Brookes Surveys (ABS), an extract of this is provided in A.1.

The quoted cost to survey all 8 assets would be £3,860 (excluding VAT). There is also an initial additional cost for the installation of survey targets of £520 (excluding VAT) per day, it is anticipated that the installation process would require a minimum of 3 days, totalling £1,560 (excluding VAT).

Additionally, the quote has specified that targets will be installed at 1m intervals in two rows along an asset, the density of the targets could be increased or decreased as required which will vary cost.

To facilitate the surveying, there will need to be regular de-vegetation to ensure that the best possible coverage is obtained, and a clear line of sight is possible. This may be necessary on both sides of the river. Furthermore, prior to a survey taking place, targets will likely require cleaning to remove any sediment that may have been deposited on them, this will incur added costs.

As surveying is a periodic survey method, there is the potential to miss signs of a sudden failure.

At the time that the quote was given (17/11/2022), ABS could attend site within 15 working days from receipt of a written instruction to proceed.

There could also be issues with being able to undertake a survey of certain assets during times when vegetation growth is at its peak, as a clear line of sight is required.

2.5 Remote Sensor Installation

The installation of sensors would provide real-time (frequency adjustable) information on the movement of an asset and how an asset was being affected by different conditions e.g., tide, traffic, temperature, and other seasonal effects. There would also be signals relating to movement of an asset prior to a failure.

Sensor installation would come with a warning system that, if certain conditions are experienced, notifications will be sent out to critical individuals (BCC leadership team).

Remote tilt meters (Figure 2.1) can be installed on an asset wall and/or on the slope behind an asset. These would enable detection of deformations occurring on the wall or on the slope. Nodes can be fitted to beams to monitor global movement (Figure 2.2).

Figure 2.1: Wireless 3D tilt node fitted directly to concrete structure

Source: James Fisher Strainstall 2022

Figure 2.2: Wireless tilt nodes fitted to beams (for global movement)

Source: James Fisher Strainstall 2022

Additionally, displacement measurements (Figure 2.3) can be installed on a wall to detect whether cracks are propagating, or bulges are increasing in size.

Figure 2.3: Typical linear displacement sensor across crack

Source: James Fisher Strainstall 2022

For any particular asset, the installation of a series of sensors would be required, as well as a wireless gateway. The wireless gateway can be utilised by several different sensor locations provided that they are in range. A quote for the installation and running of the system has been provided by James Fisher Strainstall (JFS), an extract of this is provided in A.2.

The quoted upfront cost of installing remote monitoring sensors would be approximately £10,000 per installation location. This price includes the installation of 3No. tilt nodes, 2No. displacement measurements, and 2No. temperature measurements (with associated analogue node). The wireless gateway which can be shared over multiple assets costs circa £4,000 excluding VAT.

Monthly running costs of between £350-£500 would be incurred for remote transmission, storage, and display of the data. Note, the ultimate installation cost would be subject to final sensor specification (i.e., displacement sensors may not be required at some locations).

The JFS quotation also allows for monitoring to be implemented across a number of assets, with a total estimated price of £100,000 to be split over 8No. locations along with a £5000 yearly monitoring charge. This could be scaled up or down as required and allows for JFS design fees of £10,000 to £12,000 (excluding VAT).

JFS require a minimum of 6 weeks lead time to procure the equipment specific to the project.

It is also noted that this type of monitoring system may be of interest to BCC in relation to other assets outside of the scope of this project, and there are potential cost efficiencies to be had if wireless gateways are shared.

2.6 Monitoring Summary

A summary table with the advantages and disadvantages of monitoring options can be found in Table 2.1 below.

Table 2.1: Monitoring summary table

Survey Type	Advantages	Disadvantages
Visual monitoring	• Cheapest option	• Unable to accurately compare for small amounts of movement • Potential limitations due to vegetation growth – obscuring Line of Sight (LoS) across the watercourse and local to the asset in question • Boat or rope access would be required for close-up visual inspections – unknown lead time.
Drone survey	• Provides better coverage than on foot – reduced blockage to LoS from vegetation • Digital information can be integrated into BCC digital twin	• Photogrammetric model can only be compared visually through overlaying models • More expensive than visual monitoring on foot • Requires boat access to fly • Coordination required between access provider, drone company and BCC (Harbour Master) which could cause a long lead time • Potential obstruction from vegetation covering an asset • Data processing times
Total station surveying	• Accurate to 3mm • Results easily interpreted, results between surveys can be compared in excel spreadsheet	• Requires rope access installation of survey targets • Potential limitations due to vegetation growth – obscuring LoS across the watercourse and local to the asset in question • Targets would likely require a cleaning programme prior to a survey • 3 weeks lead time • Periodic surveying – potential to miss signs of a sudden failure • Targets may fall off the wall • Adhesive may be sensitive
Laser scanning	• Can build up a record of asset movement • Digital information can be integrated into BCC digital twin (for additional cost)	• Lower accuracy than total station (6mm-20mm) • Potential limitations due to vegetation growth – obscuring • LoS across the watercourse and local to the asset in question • 3 weeks lead time • Cost over an extended period of time will be expensive • Periodic surveying – potential to miss signs of a sudden failure

Survey Type	Advantages	Disadvantages
Installation of sensors	• Real time monitoring (hourly updates). • High accuracy (3/3600 of a degree) • Use of smart asset monitoring system. • Gateways can be used across multiple sites • Sensor battery life can extend into years depending on frequency of positioning updates (3 years at 1 hr updates)	• Expensive (£100k for installation of 8 locations, with £5k annual running costs) • 6 weeks lead time

3 Non-structural and Non-geotechnical Considerations

3.1 Ecology

An ecological constraints assessment has been undertaken for assets NCN16, NCS18, NCS28 and NCS13, this included a desk study and ecological walkover survey, and the findings are summarised within the respective section for each asset.

A desk based search of open access data was undertaken for assets S28b, NCS06 and NCS21/23. No ecological walkover survey has been undertaken for these assets. An ecological walkover survey will be required prior to any GI works, the results of this may recommend further protected species surveys.

An ecological assessment for asset N06 was not undertaken as part of this report as it will first need to be verified whether the asset can be de-scoped. In case further investigations or repairs will need to be carried then an ecological assessment should be undertaken prior to any such works.

3.2 Unexploded Ordnance (UXO)

A review of Zetica Risk Mapping [6] shows that Bristol is in a high-risk area. This is defined as an “area indicated as having a bombing density of 50 bombs per 1000acre or higher”. In addition, there are multiple Luftwaffe Targets around the River Avon New Cut. Any intrusive works will require further, more detailed research, risk assessments and applicable mitigation undertaken by the relevant party.

3.3 Contaminated Land

A contaminated land assessment will be required and undertaken as part of the ground investigations.

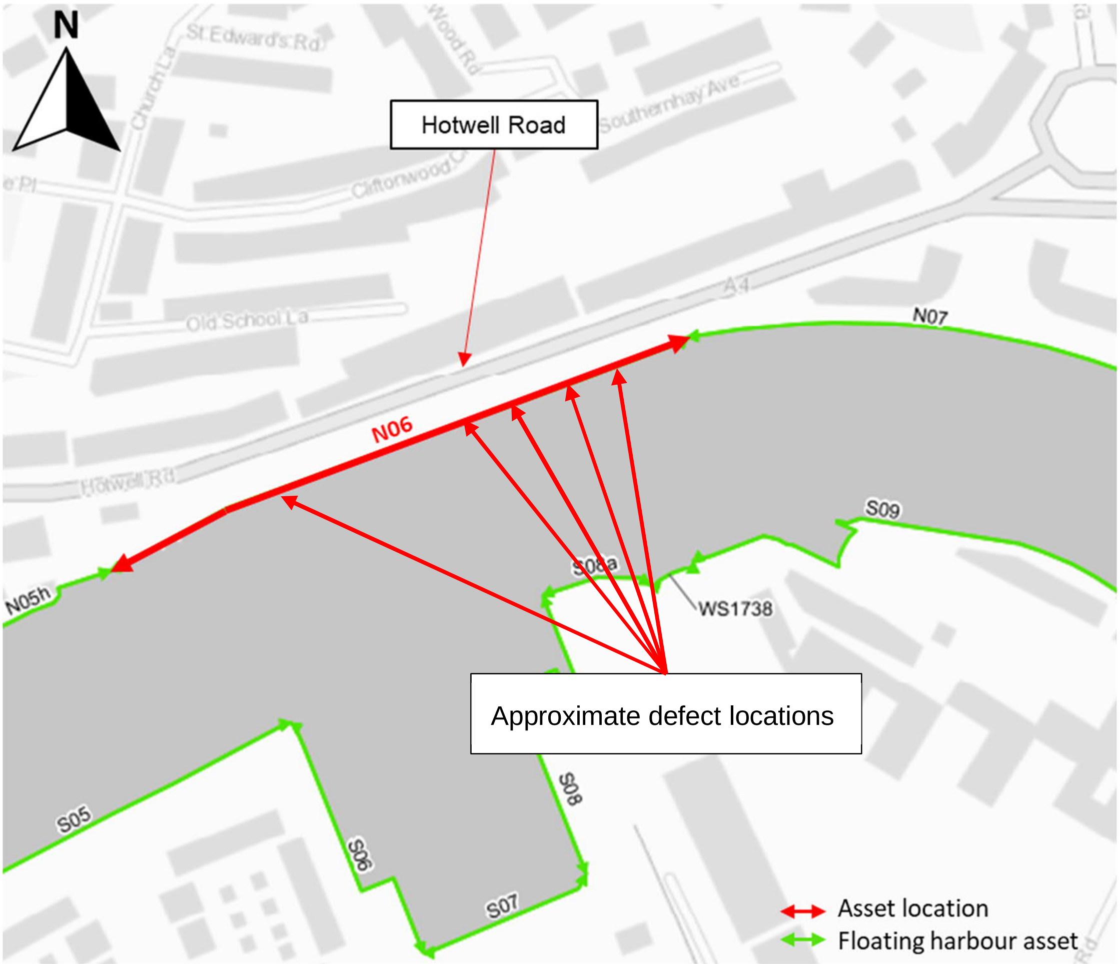
4 N06

4.1 Background Information

4.1.1 Asset Location

N06 is located within the Floating Harbour and is adjacent to the harbourside footpath which runs parallel to the A4, Hotwells Road. It is approximately 227m long and 7.8m high. The harbourside footpath lies at approximately 5mAOD and is generally level along the length of the asset. N06 lies at approximate National Grid Reference 357543, 172456 and a location plan is shown in Figure 4.1. A number of residential and retail properties are located to the north of the A4 Hotwells road and the land rises steeply to an area known as Clifton Wood.

Figure 4.1: N06 Location plan



Source: Mott MacDonald

4.1.2 Asset Description

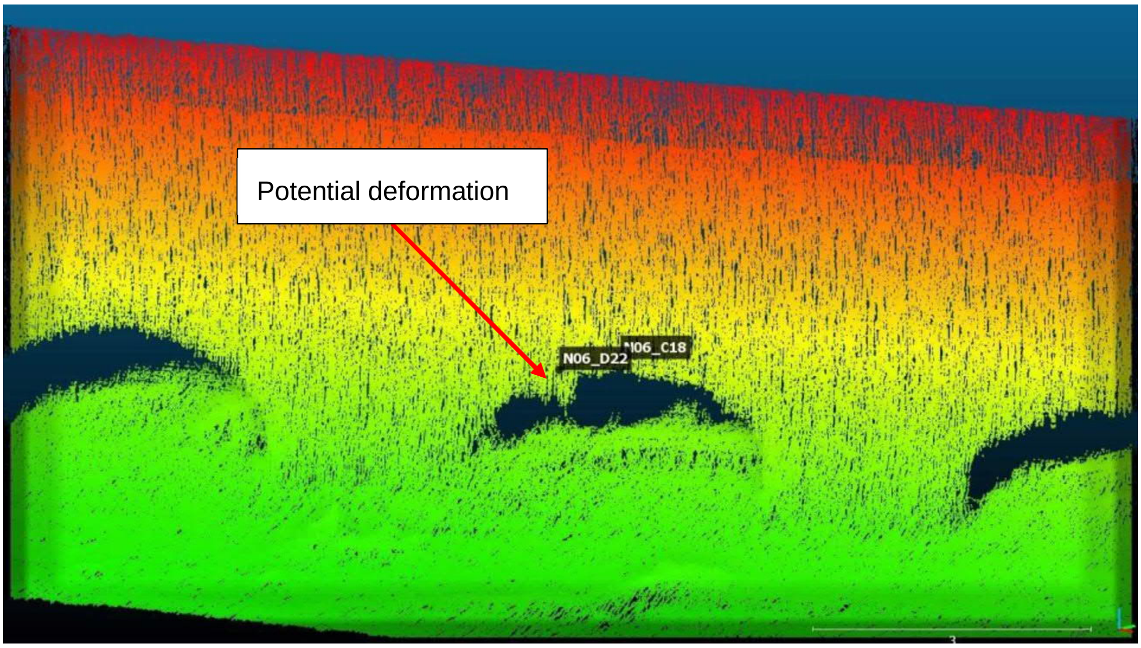
Asset N06 is predominantly constructed in masonry and has a series of 23 No. arches located underwater at the base of the harbour wall. The crowns of the arches are approximately 3m below the water level. The arches measure 1.5m high, 4m wide between springing points, and

600mm thick. There is a concrete apron below the arches measuring 700mm high, 200mm wide and spans the entire length of the wall.

4.1.3 Asset Defects

During the initial inspections, undertaken in 2019, potential deformations were detected in four separate arch barrels, Figure 4.2 shows an example of this. The potential deformations were all approximately 0.6m wide and drop 0.3m below the arch barrel. However, these defects were not identified during the dive survey (see section 4.1.8) and are now assumed to be anomalous readings in the sonar scan.

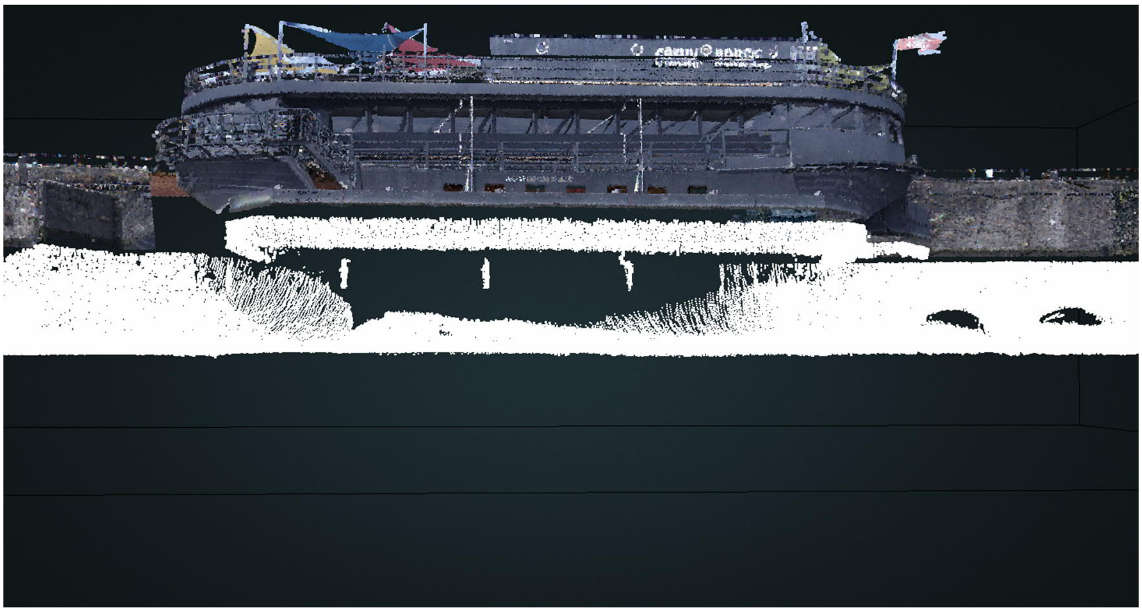
Figure 4.2: N06 Potential arch deformation of barrel (underwater)



Source: Mott MacDonald 2019

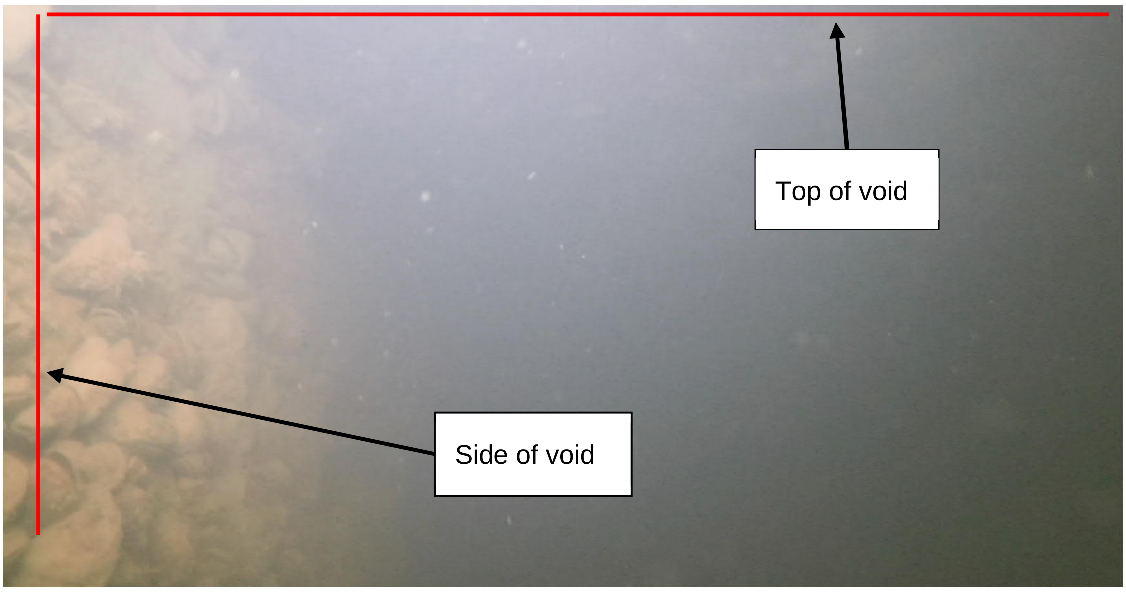
The Grain Barge blocks line of sight to a length of wall, and consequently this area could not be captured using Multi Beam Echo Sonar (MBES) scanning, as seen in Figure 4.3. An on-site inspection was undertaken for this area and a void in the harbour wall was detected below the waterline. An underwater video was subsequently taken using a camera on a long reach pole which confirm the presence of a void in this area, see Figure 4.3. The void is approximately 1.5m wide and of unknown height and depth.

Figure 4.3: N06 Data blackspot caused by Grain Barge



Source: Mott MacDonald 2019

Figure 4.4: N06 Void in harbour wall behind Grain Barge



Source: Mott MacDonald 2019

4.1.4 Consequence of Asset Failure

The failure of any of the arches or deterioration around the area of lost masonry would result in a loss of support to the masonry above the defects, to the footpath and potentially the carriageway.

4.1.5 Historic Mapping

A review of historic mapping was undertaken to assess the use and development of the asset and surrounding land, allowing for a more holistic understanding of the site. Table 4.1 presents a summary of history on site.

Table 4.1: N06 Summary of site history

Year	On site	Off site
1881-1883	Mardyke Ferry crossing is shown as a dashed line running from the site location southwards to Chartham Wharf across the Floating Harbour	Mardyke Tramway runs north of the site, bounded by the harbour to the south and housing to the north
1901-1902	No change	Industrial School (Boys) is marked north of site
1913-1918	Mardyke Ferry crossing appears to have moved westwards of site	No significant change
1928	Mardyke Ferry moved back to the original position	No significant change
1930	No change	No significant change
1938	No change	No significant change
1938-1955	No change	Hotwell Road, A4 is marked adjacent north of site
1938-1963	No change	No significant change
Present day	No change	No significant change

4.1.6 Geology

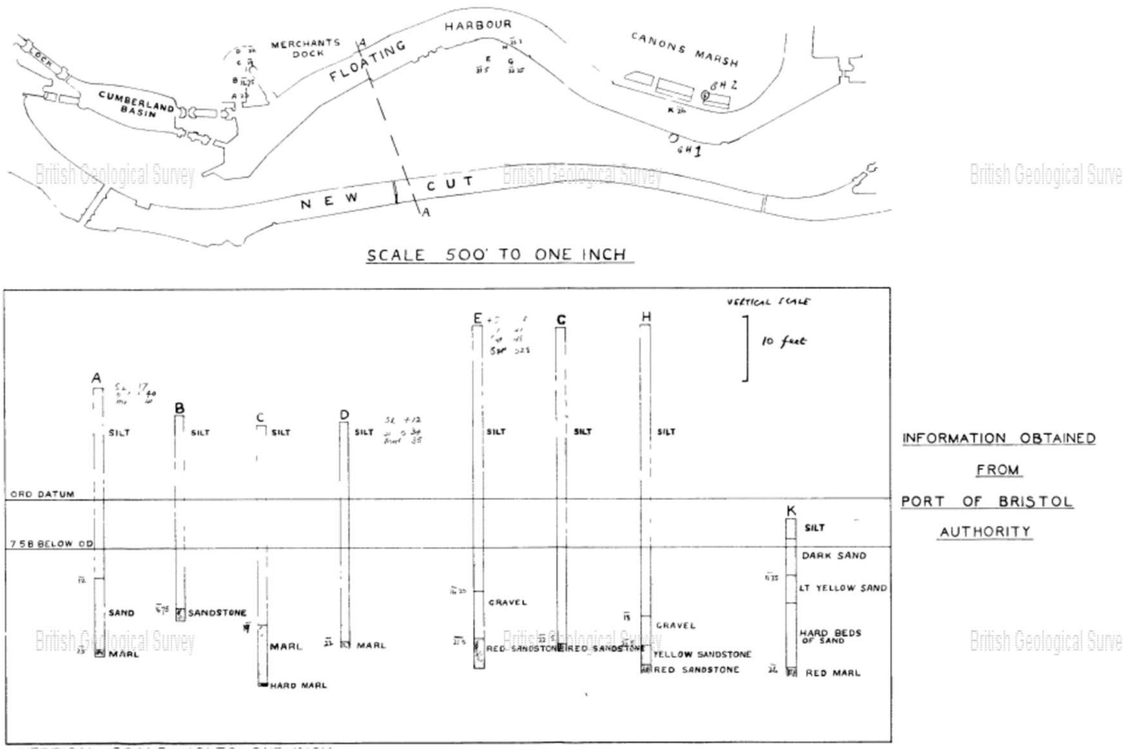
A review of geological mapping [1] shows the site to be overlain by Tidal Flat Deposits. These are described by BGS Lexicon as "*mud flat and sand flat deposits, deposited on extensive nearly horizontal marshy land in the intertidal zone that is alternately covered and uncovered by the rise and fall of the tide. They consist of unconsolidated sediment. Normally a consolidated soft silty clay, with layers of sand, gravel and peat.*"

The asset is located on the boundary of two bedrocks:

- Quartzitic Sandstone Formation is described by BGS Lexicon as "*Hard pale grey quartzitic sandstones with grey mudstones, seatearths and thin carbonaceous or coaly beds*"
- Redcliffe Sandstone Member is described by BGS Lexicon as "*Sandstone, distinctive fine- to medium-grained, deep red, calcareous and ferruginous. Commonly decalcified at shallow depths below the surface, giving rise to an uncemented sand*." There are no relevant exploratory hole records on the site to confirm deposits

There is one cross-section available from BGS which is undated, however, depths are described in feet which suggests the cross-section was developed pre. 1965. Generally, the boreholes given show between 20-40ft (6-12m) of silt over sandstone or marl. An extract is shown in Figure 4.5.

Figure 4.5: Geological cross-section at Asset N06 - BGS ID: 388598



4.1.7 Mining

A review of the Coal Authority Mapping [5] shows the asset is located in a Coal Outcrop area which means that ground workings associated with mining could have occurred in the past. Therefore, coal mining could affect the asset and a repair solution.

4.1.8 Dive Survey Summary

Following the 2019 inspection a dive survey was recommended to further investigate the void and the arches. This was undertaken by Edwards Diving Services (EDS) in June 2021.

EDS were tasked with providing information on the physical condition of all inspectable elements of the asset underwater, particularly the underwater arches where potential deformation was detected by the MBES scan. Site conditions on the day of inspection were fair and dry.

The overall condition of the arches was reported as good, with only minor defects noted, such as spalling, pointing loss and marine growth.

There were signs of timber planks or shutters which potentially covered the arch faces historically. The timbers have decayed and deteriorated which has caused them to fail and fill the area within the arches. Due to the presence of the timbers, it appears that EDS were unable to enter and fully inspect the arch barrels.

Pointing loss in the arches reaches a maximum of 20mm and the details of the spalling are in Table 4.2.

The position of the spalls has been interpreted as being to the face of the arch, rather than within the arch barrel. The survey has been interpreted in this way due to the survey reports defect table *"There were minor areas of spalling to the surface of the arches"* and because of the timbers restricting access into the arches.

Table 4.2: N06 Arch Spalling Details

Arch No.*	Spalling Details
4	12 o'clock position, 60mm deep, 60mm wide and 50mm high
5	Between 9 and 12 o'clock positions, up to 30mm wide
10	Between 12 and 2 o'clock positions, 65mm deep, 100mm wide and 90mm high
11	Between 11 and 12 o'clock positions, 70mm deep, 70mm wide and 30mm high
12	Between 9 and 10 o'clock positions, 110mm deep, 85mm wide and 40mm high
13	3 areas at 11, 12 and 2 o'clock positions, up to 170mm deep, 145mm wide and 125mm high
16	2 areas at 2 and 3 o'clock positions, up to 200mm deep, 90mm wide and 100mm high
21	Between 2 and 3 o'clock positions, up to 50mm deep, 65mm wide and 70mm high
23	12 o'clock position, 200mm deep, 70mm wide and 70mm high

* Arches are numbered from west to east (see also [11]). Arches with no reported spalling omitted from above list

EDS reported that the defects and areas of pointing loss stated in Table 4.2 were not considered significant enough to warrant immediate action; however, they are likely to get worse and be more expensive to repair if left.

It is noted that a recess identified during the on-site inspection in 2019 was not recorded during the EDS inspection. An image of the void can be seen in Figure 4.4.

The report can be found in document A8379 [11].

4.2 N06 Summary

The dive survey completed by EDS (June 2021) failed to identify any deformation in the 23 No. arches. Given this, it may be possible to de-risk this asset and remove it from the critical list.

However, prior to this, BCC should contact EDS to seek an understanding as to why the void in the harbour wall behind Grain Barge was not recorded in their dive survey report, and to confirm whether the area behind Grain Barge was inspected as part of that survey. The void was clearly visible in the underwater video captured on-site in 2019.

BCC should also seek clarification about the accessibility of the arches, whether the arch barrels were inspected, and where the recorded spalls are located.

Once confirmation has been sought, the void, and the arch barrels should either be inspected, or if already inspected and in a good condition, the asset could be de-risked from the critical asset shortlist.

As a visual inspection is not possible of the underwater elements, it is recommended that a follow-up principal inspection be undertaken within 72 months from June 2021 and should be conducted no later than June 2027, as set out in CS 450 Inspection of Highways Structures, The Inspection Manual for Highway Structures, 2007, unless a longer period is agreed with the overseeing organisation.

5 NCN16

Asset NCN16 has been expediated and a repair strategy formulated within a separate document as requested by BCC. The document reference for this report is 100105143-MMD-NCN16-XX-TN-CV-001 [8]. Ground investigations for this asset have been specified in 100105143-MMD-NCN16-XX-SP-GT-002 [10].

To the east of the asset, between NCN16 and NCN18, there is an apparent 30m failed section of wall. This area is not part of asset NCN16 as defined by BCC and therefore outside of the scope of this project.

5.1 Historic Mapping

The historic mapping section was omitted from the expediated report and has been included here for completeness.

A review of historic mapping was undertaken to assess the use and development of the asset and surrounding land, allowing for a more holistic understanding of the site. Table 5.1 presents a summary of history on site.

Table 5.1: NCN16 Summary of site history

Year	On site	Off site
1882	Coronation Ferry is present and marked with a dashed line from north to south, across the water Steps lead down to the water's edges from a slip way that extends east and west of the crossing on the northward side, and just west of the crossing on the south Brickwork is shown on the northern slope	Cumberland Road is present north of site, bounding the New Cut Bristol Harbour Branch Great Western Railway (GWR) is present north of site and north of the Redcliff Ward New Goal (Disused) is present adjacent northwards of site. Housing is present due south and southeast of site, south of the river Access to Coronation Ferry south bank appears to start from Southville Road, approx. 50m southwest of site, following an un-named road northward to the water's edge. This road appears to pass under Coronation Road where it is labelled Coronation Bridge. There is also stepped access directly from Coronation Road.
1883, Published 1886	No change	No significant change
1881-1883 Published 1887	No change	No significant change
1901-1902 Published 1904	No change	New Goal (Disused) is no longer labelled Tram tracks have been constructed to the north of site
1901-1902 Published 1905	Coronation Ferry is no longer marked	No significant change
1902	Coronation Ferry marked on map	Coronation Bridge is no longer labelled The slipway and access to the Coronation Ferry is no longer visible on mapping
1912	No change	No significant change
1913 Published 1918	No change	No significant change

Year	On site	Off site
1913 Published 1921	No change	No significant change
1930	Coronation Ferry is still labelled but there is no dashed line to indicate the direction of the ferry	No significant change
1938	No change	No significant change
1938-1955	Coronation Ferry is no longer labelled. There is now a bridge present which crosses the New Cut	No significant change
1938-1963	No change	Buildings are present on the land where New Goal (Disused) was previously labelled. No label to indicate building use
1938-1967	No change	No significant change
Present day	No change	No significant change

5.2 Ecological Constraints

An ecological walkover survey was undertaken on 29 June 2022 by Mott MacDonald ecologists. The survey consisted of a walkover of the asset and a 30m buffer, where access permitted. The purpose of the survey was to identify the ecological constraints and risks of works. A summary of the Ecological Constraints Assessment produced following this survey is provided below.

Listed below are the habitats that were identified within the survey buffer;

- Scattered scrub and introduced shrub, present along the masonry wall closest to Cumberland Road.
- Scattered broad-leaved trees, present along the top of the masonry wall edge closest to the river.
- Small patch of semi-improved grassland, with a varied sward length.
- Mudflats are present directly underneath the masonry wall along the river edge.

In line with policy and best practice, avoidance measures should be embedded into the design of the works. The following avoidance measures were identified;

- Works within the river and mudflat Habitats of Principal Importance should be avoided;
- Where possible trees and other vegetation should be retained;
- Artificial lighting should be avoided during the construction and operational phases of the development;
- Obstructions to the watercourse and riverbanks should be avoided during the construction and operational phase;
- Any retained trees should be assessed by an appropriately qualified arboriculturist to determine root protection areas and any exclusion zones required to mitigate for damage during demolition and construction; and
- If possible, the site compound should be situated at least 16m away from the river and riverbanks, if this is not possible, permission would be required from the Environment Agency.

The table below summarises the identified ecological constraints and the recommended mitigation for each feature.

Table 5.2: Ecological constraints and mitigation/compensation recommendations

Feature	Location description	Mitigation and/or compensation
Designated sites	Avon Gorge Woodlands Special Area of Conservation and Site of Special Scientific Interest, Horseshoe Bend Site of Special Scientific Interest, and Severn Estuary (Special Area of Conservation, Special Protection Area, RAMSAR and Site of Special Scientific Interest downstream of the Site. Avon New Cut Local Nature Reserve on site.	A Habitat Regulations Assessment is recommended. The county ecologist should be consulted regarding the proposed works within the Avon New Cut Local Nature Reserve.
Habitats of principal importance	River and mudflats within the site	The county ecologist should be consulted at the earliest opportunity if the habitats of principal importance are anticipated to be impacted to discuss the working methodology as well as any compensation, enhancement or restoration work.
Bats	A basal cavity on one of the trees on site offers moderate to high potential to support roosting bats	Night-time working should be avoided. An endoscope survey of the basal cavity of the tree on NCN16 should take place immediately prior to any vegetation clearance works commencing, in order to establish the suitability of the feature to support roosting bats, and the presence or likely absence of bats. A toolbox talk regarding bats should be given to all site personnel.
Reptiles	The scrub and grassland habitats within the riverbank offer suitable habitat for common reptiles	If any habitat removal affecting potential hibernacula (such as log piles or root systems) is required, this should occur during the reptile active season (April – October inclusive, depending on the weather) under supervision of an ecologist. Vegetation clearance should follow phased cuts in a directional manner to allow dispersal of active reptiles to neighbouring habitats. A toolbox talk regarding reptiles should be given to all site personnel.
Nesting birds	The scattered trees, scrub and rough grassland provide suitable habitat for nesting birds. A nest was also observed on one of the trees, although it was deemed inactive at the time of the survey	Vegetation clearance of habitat suitable for nesting birds should be undertaken outside of the nesting season (between March and August inclusive) in line with standing government guidance. If this is not possible, vegetation will need to be checked by an ecologist no more than 24 hours prior to removal. The feasibility of nesting bird checks will be subject to the judgement of a suitably qualified ecologist, who will determine whether the vegetation to be cleared can be safely and adequately searched.
Bony fish	The River Avon New Cut has potential to be used by different species of bony fish (including European eel) for commuting and foraging	Should the scope of works include significant disturbance that could impact fish, such as high noise and vibration levels, works may need to be timed to avoid fish migration periods. A toolbox talk regarding fish should be given to all site personnel.
Otters (*Lutra lutra*)	The River Avon New Cut has potential to be used by commuting and foraging otters	No mitigation or compensation measures specific to otters identified.

Source: Mott MacDonald, 2022.

Further ecological surveys are recommended due to the potential for protected and notable species in the area.] A full Preliminary Ecological Appraisal Report should be undertaken.

Habitats should be classified using the UK habitats classification system. The report should include a Preliminary Roost Assessment of all trees and structures within 20m of the proposed works (Collins, 2016), a Habitat Suitability Index assessment of all waterbodies within 250m of the Site for great crested newts, and a walkover survey for invasive non-native plant species. This process may identify further ecological constraints as well as the need for further survey and mitigation measures.

A detailed habitat mitigation strategy should be developed to replace any habitats permanently lost as a result of the proposed works. The strategy would, as a minimum, replace lost habitat with habitats of the same or higher value. A Biodiversity Net Gain assessment can be used to quantify habitat value and should be undertaken to identify opportunities for biodiversity enhancement.

A Construction Environmental Management Plan will likely be required to set out the methods to ensure the environmental impact of construction is minimised. Finally, subject to the results of the further surveys, measures to minimise impacts on bats, fish, otters and reptiles should be included in a Reasonable Avoidance Measures Method Statement this should include best practise measures and general construction safeguards.

6 NCS06

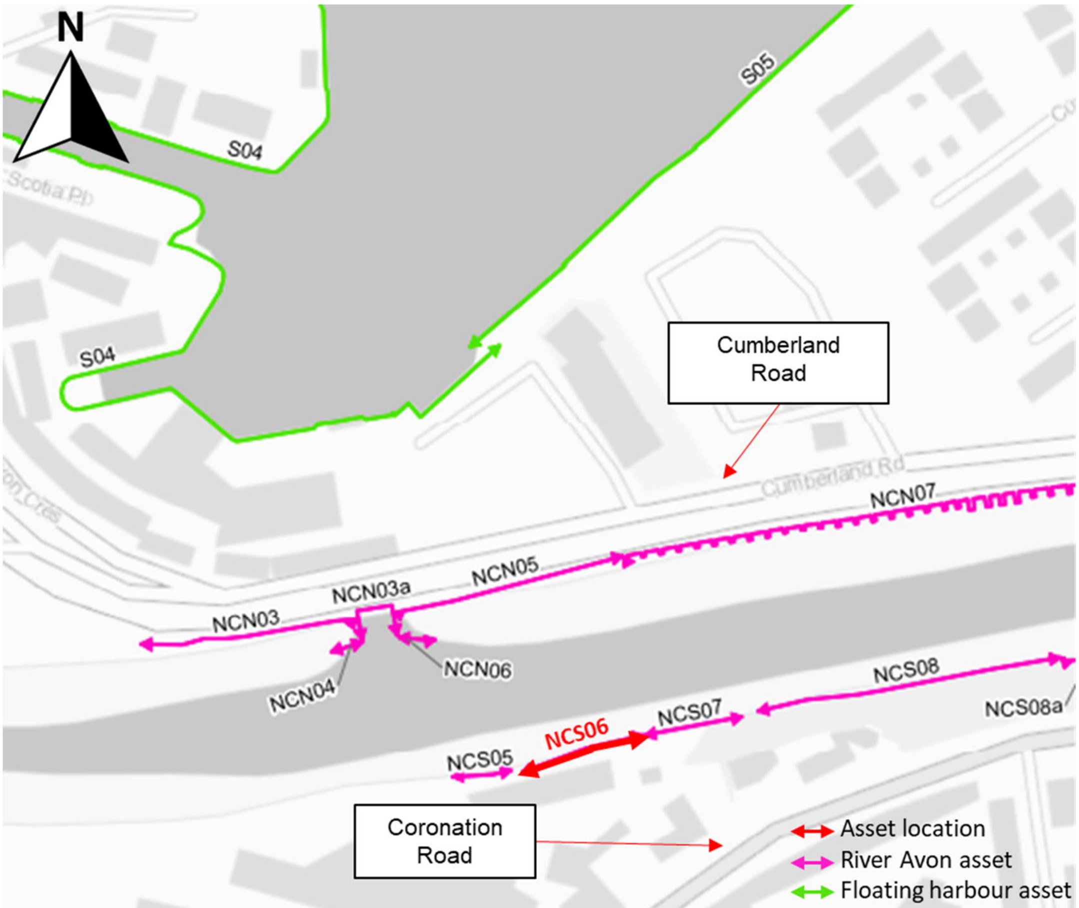
6.1 Background Information

6.1.1 Asset Location

Asset NCS06 is located directly south of the New Cut River and north of A370 that runs parallel to the river. NCS06 lies at approximate National Grid Reference 357283,172016. Figure 6.1 presents a location plan.

A petrol station, charging station and car repair station are located south of the asset. Bristol Metal Spraying & Protective Coatings Ltd (BMS) is located to the southwest of the asset. To the north of the asset, and across the river, a boathouse outbuilding, and other residential buildings have been identified.

Figure 6.1: NCS06 location plan



Source: Mott MacDonald

6.1.2 Asset Description

The asset is a masonry wall of apparent dry stone construction, it is approximately 44m long and 1.8m high. There are several sections of collapsed wall along the length of the asset. Behind the asset there is a steep vegetated slope containing several mature trees, the slope has an approximately gradient of 1:1.5. There is no obvious evidence of slope failure above. There is a significant sediment build-up and some vegetation in-front of the asset.

The original purpose of the wall is not clear, however, given the lack of any visible rock formations, it would appear likely that the function of the wall is to retain the slope or to provide scour protection to the slope.

There is potential evidence of a structure buried in sediment in front of NCS06 and a review of historical mapping indicates that there was previously a ferry crossing in this approximate location. It may also be a potential continuation of an apparent slipway located approximately 13m upstream. The feature is shown in Figure 6.2.

There are buildings located at the top of the slope behind the asset and, there is a building located above the western end of the asset.

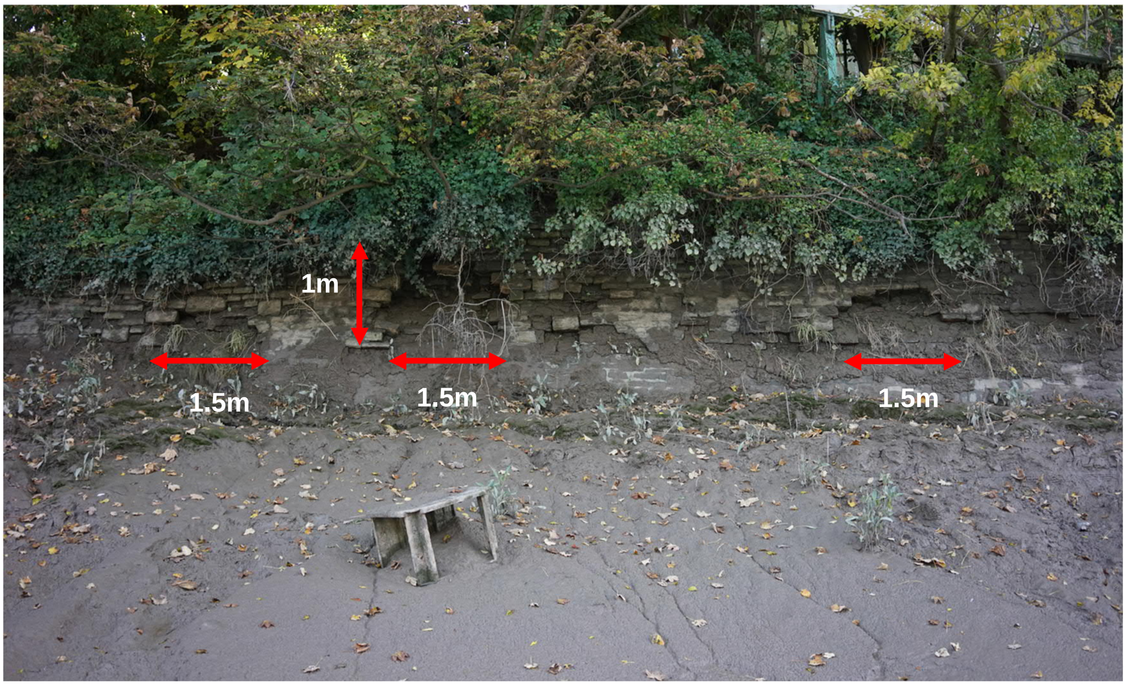
Figure 6.2: NCS06 Buried structure

Source: Mott MacDonald 2019

6.1.3 Asset Defects

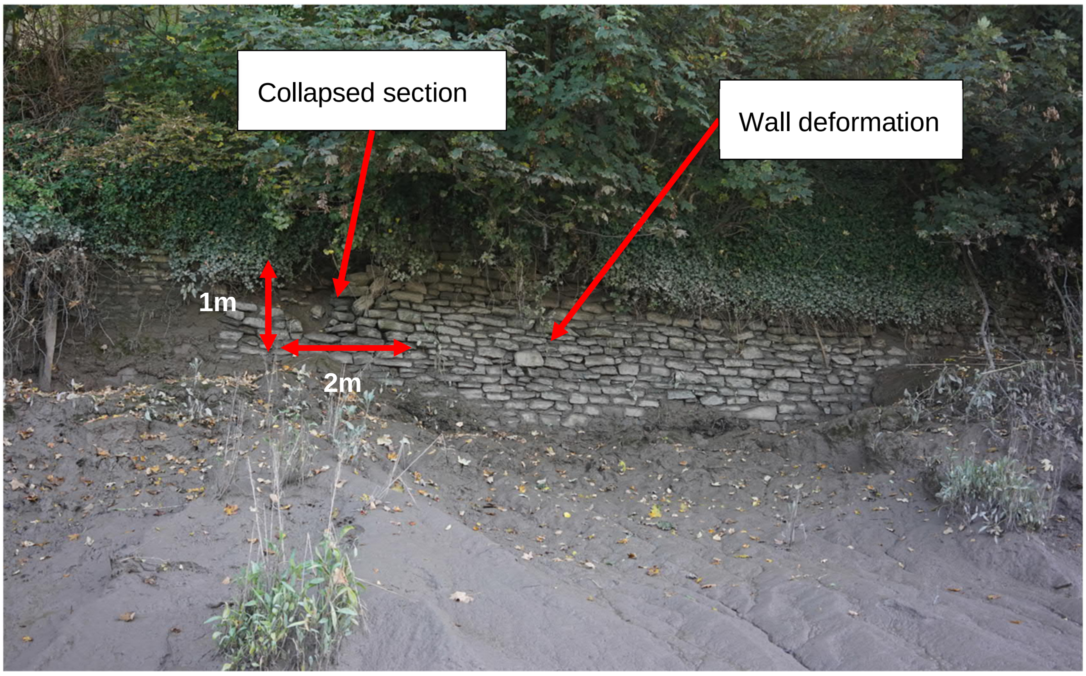
Localised collapsed sections of masonry are shown in Figure 6.3 and Figure 6.4. The approximate level at the bottom of the defects in Figure 6.3 is 6.36mAOD, and the toe of the wall in Figure 6.4 is 5.50mAOD. The typical range of the river in this location is between -0.7mAOD and 6.71mAOD.

Figure 6.3: NCS06 Collapsed sections



Source: Mott MacDonald October 2022

Figure 6.4: NCS06 Collapsed section and wall deformation



Source: Mott MacDonald October 2022

To the western end of the asset a building, part of the Bristol Metal Spraying & Protective Coatings site, is located above the wall. This is shown in Figure 6.5. This building is located approximately 8m from the wall deformation shown in Figure 6.4. It is unknown whether the wall is providing any support to the building but it is possible that the wall is retaining the material around the building's foundations. In addition, there are several buildings located at the top of the slope.

Figure 6.5: NSC06 Building part of Bristol Metal Spraying & Protective Coatings site

Source: Mott MacDonald 2019

6.1.4 Consequences of Asset Failure

As described in Section 6.1.2, the intended function of this wall is not clear. The immediate consequences of a failure differ depending on the asset function.

If the intended function is to be a retaining wall, then there is potential for a loss of support to the retained ground. Behind the asset, the nearest buildings are positioned approximately 8m from the wall. If there is a loss of support to the retained ground, then there is a risk of a loss of support to the building foundations.

At the western end, the building shown in Figure 6.5 is 8m from the nearest defect. If the defect continues to deteriorate and the wall collapsed, there is a risk of the defect propagating. The material retained in the vicinity of the building foundations could then lose support.

If the intended function of the wall is to provide scour protection, then there is a potential long-term risk of slope erosion and an increasing risk of slope failure. The consequences of a slope failure could be a loss of support to the various building foundations; however, this is anticipated to be a longer-term risk in comparison to if the asset is a retaining wall.

6.1.5 Historic Mapping

A review of historic mapping was undertaken to assess the use and development of the asset and surrounding land, allowing for a more holistic understanding of the asset. Table 6.1 presents a summary of history on site.

Table 6.1: NCS06 Summary of site history

Year	On site	Off site
1881 to 1882, published 1896 Or 1881 to 1883, Published 1887	Vauxhall Yard (Shipbuilding) is located south of site A wall or pathway leads from the road southwards of Vauxhall Yard to the Vauxhall Ferry, when the path meets the water's edge, follows the slope westward to meet Vauxhall Ferry.	Vauxhall Ferry is located adjacent east of site that cross the River Avon New Cut from north to site The River Avon New Cut is bounded by unmarked roads to the north and south There are man-made indent northwards of the Avon River New Cut. The indent is not labelled but the slope around the ident is labelled as 'Stones'. Northwards, in the Floating Harbour, there is a sluice labelled. This suggests that a This suggests that a culvert connects the River Avon New Cut and Floating Harbour at this point
1901 to 1902 Published 1904/1905	A wall has been constructed on the southern side of the slope of the River Avon New Cut.	Vauxhall Ferry is removed Sluice in the Floating Harbour is no longer labelled Great Western Railway (GWR) Harbour Railway is located on the northern slope of the River Avon New Cut. This follows the length of the island
1902 Published 1905	No change	No significant change
1912 to 1913	No change	No change
1913 Published 1918	The pathway leading to the Vauxhall Ferry (no longer exists) is labelled as slip	No significant change
1913 Published 1921 (two maps)	No change	The road that runs parallel to the New Cut is now labelled as Coronation Road
1930 Published 1933	No change	No significant change
Revised 1938 Published 1944	No change	No significant change
Revised 1938 Published 1945	No change	No significant change
Revised 1938 Published 1946	No change	No significant change
Revised 1938 Published 1947	No change	No significant change
Revised 1938 to 1955 Published 1955	No change	Great Western Railway (GWR) Harbour Railway is no longer present on mapping and has been replaced with Cumberland Road which runs parallel to the River Avon New Cut northern slope

Year	On site	Off site
1938 to 1963 Published 1964	No change	No significant change
Surveyed / Revised: 1938 to 1967, Published: 1967	No change	No significant change
Present day	No change	Multiple stages and slipways are now marked located in the Floating Harbour

6.1.6 Geology

Superficial Deposits on site are likely to be Tidal Flat Deposits. These are described by BGS Lexicon [4] as "mud flat and sand flat deposits, deposited on extensive nearly horizontal marshy land in the intertidal zone that is alternately covered and uncovered by the rise and fall of the tide. They consist of unconsolidated sediment. Normally a consolidated soft silty clay, with layers of sand, gravel and peat. Characteristically low relief".

Bedrock on site is likely Redcliffe Sandstone Member which is described by BGS Lexicon [4] as distinctive fine- to medium-grained, deep red, calcareous and ferruginous sandstone.

Two historical boreholes are available on BGS Geoindex [3] located approximately 200m due south of the asset at approximately 11mAOD. The boreholes are undated. One borehole was available from the 2015 Structural Soils Ground investigation approximately 70m due north of the asset. A summary of exploratory holes is presented Table 6.2.

Logs were also available for three boreholes located 200m northwest of the site. These borehole logs typically show a silty clay over gravel, becoming marl. Stratum depths were not included on the logs and the boreholes have therefore not been included in the summary table.

Table 6.2: NCS06 Existing exploratory hole summary

	Historic BGS Geoindex borehole records		2015 Structural Soils Ground Investigation
	ST57SE58	**ST57SE266**	**BH545**
Approx. distance from asset	**300m S**	**300m S**	**70m N**
Made Ground	0m BGL (description illegible)	0ft (0m BGL) concrete	0m BGL Dark brownish grey very sandy, fine to coarse subangular to angular GRAVEL 1m BGL Dark mottled grey reddish brown sandy slightly gravelly CLAY
Drift Deposits	-	4ft (1.45m BGL) Brown sandy loam	1.2m BGL Soft greyish brown slightly sandy slightly gravelly CLAY (Alluvium) 9.5m BGL Firm light bluish grey mottled brown silty CLAY 15m BGL Very dense dark greyish brown sandy GRAVEL
Keuper Trias	4.3m BGL (description illegible)	14ft (4.27m BGL) Brown sandy marl 20ft (6.1m BGL) Keuper Marl	17m BGL reddish brown mottled grey slightly sandy silty CLAY (MMG IVb) 18m BGL Extremely weak reddish brown medium bedded silty MUDSTONE 20m BGL Very weak locally extremely weak reddish brown SANDSTONE 21.8m BGL Weak very thinly to medium bedded reddish brown SILTSTONE
Middle Coal Measures	36m Hard brown shale	120ft (36.6m) Hard brown shale	Terminated at 23.40m BGL

6.1.7 Mining

A review of BGS Coal Authority Mapping [5] shows that the asset is located on an area of worked ground. Due to Bristol's history with Coal Mining, it is possible that the area of worked ground is related to coal mining. An out-crop of coal is located 100m south of the site.

6.1.8 Ecological Constraints

A desk study was undertaken in January 2023. This involved a search for designated sites and habitats to identify potentially important ecological constraints at the Site. Data to inform the desk study was obtained from the following sources:

- Multi Agency Geographical Information for the Countryside (MAGIC) website (http://www.natureonthemap.naturalengland.org.uk/MagicMap.aspx);
- Joint Nature Conservation Committee (http://jncc.defra.gov.uk);
- OS maps; and,
- Aerial imagery.

Based on aerial imagery and mapping the following habitats were identified within 30m of the asset:

- Developed land; sealed surface, present south of the asset;
- Buildings south of the asset;
- A line of trees along the southern edge of the asset; and,
- Mudflats, present along the northern edge of the asset.

Two Habitats of Principal Importance, river and mudflat habitats, were identified within 30m of the asset. The asset lies within Avon New Cut Local Nature Reserve. In addition, one site designated for its international importance and three for their national importance were identified within 2km of the Site. Three further designated sites are hydrologically linked downstream of the Site. Table 6.3 below summarises the designated sites within 2km of the site or that are hydrologically linked.

Table 6.3: Designated sites within 2km or hydrologically linked downstream of the asset

Designated site name	Designation	Orientation and distance from the site at the closest point
Avon New Cut	Local Nature Reserve	On site
Ashton Court	Site of Special Scientific Interest	0.9km west
Leigh Woods	National Nature Reserve	1.1km northwest
Avon Gorge Woodlands	Special Area of Conservation and Site of Special Scientific Interest	1.1km northwest and hydrologically linked
Horseshoe Bend	Site of Special Scientific Interest	5.4km northwest and hydrologically linked
Lamplighters Mash	Local Nature Reserve	6.2km northwest and hydrologically linked
Severn Estuary	Special Area of Conservation, Special Protection Area, Ramsar and Site of Special Scientific Interest	6.4km northwest and hydrologically linked

Source: MAGIC, 2023.

Based on the findings of the desk study, the following features have been identified as potential Important Ecological Features within the context of the site;

- Designated sites;
- Habitats of Principal Importance – river and mudflat habitat;
- Commuting, foraging and roosting bats;
- Nesting birds;
- Commuting otters;
- Bony fish; and
- Reptiles.

A full Preliminary Ecological Appraisal Report (PEAR) is recommended. Habitats should be classified using the UK habitats classification system. The report should include a Preliminary Roost Assessment (PRA) of all trees and structures within 20m of the proposed works (Collins, 2016), a Habitat Suitability Index (HSI) assessment of all waterbodies within 250m of the Site for great crested newts, and a walkover survey for invasive non-native plant species. This process may identify further ecological constraints as well as the need for further survey and mitigation measures.

A detailed habitat mitigation strategy should be developed to replace any habitats permanently lost as a result of the proposed works. The strategy would, as a minimum, replace lost habitat with habitats of the same or higher value. A Biodiversity Net Gain assessment can be used to quantify habitat value and should be undertaken to identify opportunities for biodiversity enhancement. .

A Habitat Regulations Assessment is recommended to advise on potential impacts of the proposed works on statutory designated sites downstream of the Site.

A Construction Environmental Management Plan will likely be required to set out the methods to ensure the environmental impact of construction is minimised. Finally, subject to the results of the further surveys, measures to minimise impacts on protected species should be included in a Reasonable Avoidance Measures Method Statement this should also include best practise measures and general construction safeguards.

6.1.9 Site Walkover

Site walkovers were undertaken in June 2022 and September 2022, as well as the original drone survey in April 2019.

During the June 2022 site walkover, it was not possible to view the asset due to access constraints and new images were not obtained.

During the September 2022 site walkover, images were obtained, however, they were not of a similar quality to the 2019 inspection images. The asset appeared to be in a comparatively poor condition, but an accurate assessment of the asset condition could not be made.

6.1.10 Drone Survey

In October 2022, a drone survey was completed of the asset. The collapsed sections are all similar in appearance with no discernible changes to the masonry. There has potentially been some washout of fill, however, it is unknown whether this is retained or deposited material. Examples are shown in Figure 6.6, Figure 6.7, Figure 6.8 and Figure 6.9 below. The area of wall deformation is also similar in appearance and does not appear to have changed discernibly.

Figure 6.6: Defect example 1 2019

Source: Mott MacDonald 2019

Figure 6.7: Defect example 1 2022

Source: Mott MacDonald, October 2022

Figure 6.8: Defect example 2 2019

Source: Mott MacDonald 2019

Figure 6.9: Defect example 2 2022

Source: Mott MacDonald, October 2022

The drone survey has revealed further evidence that there is a buried structure as highlighted in Figure 6.2. This is shown in Figure 6.10, where it appears that there may potentially be buried steps.

Figure 6.10: NCS06 Buried structure 2022

Source: Mott MacDonald 2022

6.1.11 NCS06 Summary

It is considered likely that the asset provides support to the slope behind it. However, it is not understood how significant that role is, and whether, if the asset were allowed to deteriorate in the short-term, there would be a slope failure. The wall is providing toe protection against washout and if it were allowed to deteriorate, the risk of a slope failure would increase over time. Ground investigations are required to confirm the ground conditions and would confirm the function of the wall. A slope stability analysis would also provide information as to the risk to the slope in the absence of the wall. The ground investigations will also provide key geotechnical information parameters to be used for design remedial works.

It is unknown whether the wall is providing any support to the buildings, but it is likely that the wall is retaining material around the building's foundations. It is noted that there is significant sediment build-up in front of the wall in the location of the building.

As set out above, the short-term risk to these buildings is considered to be low, however, the long-term risk is higher due to the possibility of incremental wall failure and eventual slope failure.

Due to the level of sediment present on the face of the wall, it is difficult to determine some of the modes of failure which are present, however, there has likely been deformation in the wall caused by earth and tree root pressures from behind, followed by a collapse under self-weight and washout of loose masonry.

The 2019 drone data was compared to the 2022 drone data and the defects shown in previous figures do not appear to have significantly changed.

6.2 NCS06 Monitoring

There are several options for the monitoring of NCS06, these include:

- Regular visual monitoring with long lens photographs.
- Real-time monitoring with sensor system.
- Surveying with total station.
- Laser scanning.

Further details of these monitoring techniques can be found in Section 2.

In this instance, it is recommended that the asset is monitored visually at 2 month intervals.

Regular visual monitoring will enable a visual record of the asset to be collated and pick up any further changes to the wall structure, such as the loss of discreet masonry blocks.

The other listed options could be considered; however, they are not deemed to be essential for this asset.

6.3 NCS06 Ground Investigations

Ground investigations will determine ground properties and wall function. It is anticipated that the investigations for the asset will consist of:

- 4 No. Boreholes.
- 1 Nr Hand dug trial pit inside building at western end (Figure 6.5) to understand foundations of the building.
- 2 Nr. Hand dug trial pits to confirm ground conditions directly behind the wall.
- 1 Nr Hand dug trial pit to investigation of possible structure in-front of NCS06 (Figure 6.2).

Full and final details of ground investigation requirements can be found in 100105143-MMD-00-XX-SP-GT-004.

6.4 Slope Stability Analysis

A slope stability analysis could be undertaken for the areas local to defects which if allowed to deteriorate could potentially result in a slope failure.

The purpose of undertaking the analysis would be to determine whether, in the absence of the wall, the slope would fail. If the slope were found to have sufficient stability, the priority of some of the defects (Figure 6.3 and Figure 6.4) would be decreased, potentially leading to the asset being descoped from the scheme.

It should be noted that in the short term, while the slope may be stable in the absence of the wall, over a longer-term, following gradual washout from the river, that may change, and the slope may become unstable.

6.5 NCS06 Repair Options

It is likely that the current defects can be repaired in a like for like manner and repointed to secure them to adjacent masonry (if considered necessary following slope stability assessment). Note however, that restoring the existing wall with like for like patch repairs is unlikely to comply with modern design codes for a retaining structure.

Other options are available, such as the construction of reinforced concrete patch repairs to maintain stability of the adjacent masonry, the construction of a new (or replacement) retaining structure (e.g., reinforced concrete retaining wall, sheet piles, a gabion basket wall). or undertaking bank stabilisation works. These options would need to be informed by ground investigations.

Local construction of a reinforced concrete retaining wall would also be a possibility; however, a local retaining wall is considered to be of limited benefit and reconstructing the entire asset would be more appropriate.

Additionally, due to the steep slope and likely soft ground, undertaking remedial work will be challenging and contractor engagement will be important when evaluating a repair strategy. For a new retaining structure to be in-front of the existing asset there are a number of potential options including sheet piling, a precast concrete retaining wall or a gabion basket wall.

6.5.1 NCS06 Slope Stabilisation

This could be a feasible option if it is determined that in the absence of the wall, the slope would fail, and that targeted stabilisation works would be cheaper than repairing or reconstructing the wall. Ground investigations followed by a slope stability analysis would initially be required to understand this.

Bank stabilisation would require the installation of soil nails and a facing system into the bank. Prior to this being undertaken, widespread de-vegetation would be required in the area of installation. This is envisaged to be more extensive than de-vegetation requirements for the above patch or deformation repair methods.

It could be difficult to install a facing system due to the quantity of trees in the area and early contractor involvement should be undertaken to determine the site requirements. The removal of any trees from the bank could have a destabilising effect by changing the pore water pressure and potentially cause movement. In addition, tree removal would likely to be strongly objected to by local residents and the ecological concerns over removing potential habitats would need to be determined.

It should be noted that in the short term, while the slope may be stable following slope stabilisation works, over a longer-term, following gradual washout from the river, that may change, and the slope may become unstable.

6.6 NCS06 Recommendations

The asset has been ranked in Priority Group 3, see Section 12.

At this time, repairs for this asset are not considered to be as high a priority as repairs for other assets. In the meantime, the asset should be monitored to track movement and further deterioration.

It is recommended that regular visual monitoring is undertaken at 2 month intervals until the risk to the surrounding buildings is understood.

It is recommended that trees whose proximity to the wall is likely causing structural damage should be removed. Any tree removal should be done in consultation with an arboriculturist and ecologist and provision for replacement planting to retain habitats will need to be considered. Note, tree removal could result in a loss of stability of the slope and a suitably qualified geotechnical engineer should be engaged before any vegetation removal is undertaken.

There are no significant concerns over the condition of the wall immediately in front of the building to the western end. It is noted that there is significant sediment build up in front of the wall in this location.

It is recommended that ground investigations and a slope stability analysis are undertaken to confirm ground properties, wall function, slope stability, and the presence of a buried structure in-front of the asset (Figure 6.2).

Once investigations are completed, contractor engagement should be conducted to determine the costing for the different options outlined in Section 6.5. It is anticipated that there will be difficulty in siting the plant required for a like for like repair, or local demolition and rebuild. It may prove to be most cost effective to undertake slope stabilisation works and provide mitigations to slow the deterioration of the masonry wall. However, this would not protect the wall from progressive deterioration or washout of the bank material in the longer term (in the vicinity of wall failures).

If masonry repairs are to be undertaken, a touching distance visual inspection of the wall should also be undertaken, in order to confirm the location and extents of missing and loose masonry.

The Priority Group of this asset is likely to increase if:

- The building foundations are found to be dependent on the river wall and a concern develops over that section of the wall.
- The condition of the bank retaining wall significantly deteriorates.
- The slope stability assessment indicates there is a risk of collapse.

If any of these scenarios occur, repairs would become more urgent.

Available as-built records for the wall and adjacent buildings, including those at the top of the slope should be reviewed, if records show that foundations are sufficient to support the structures in the event of a slope failure, then the asset could potentially be descoped. However, there should be an awareness that progressive deterioration of the slope through washout could lead to future slope instability.

7 NCS13

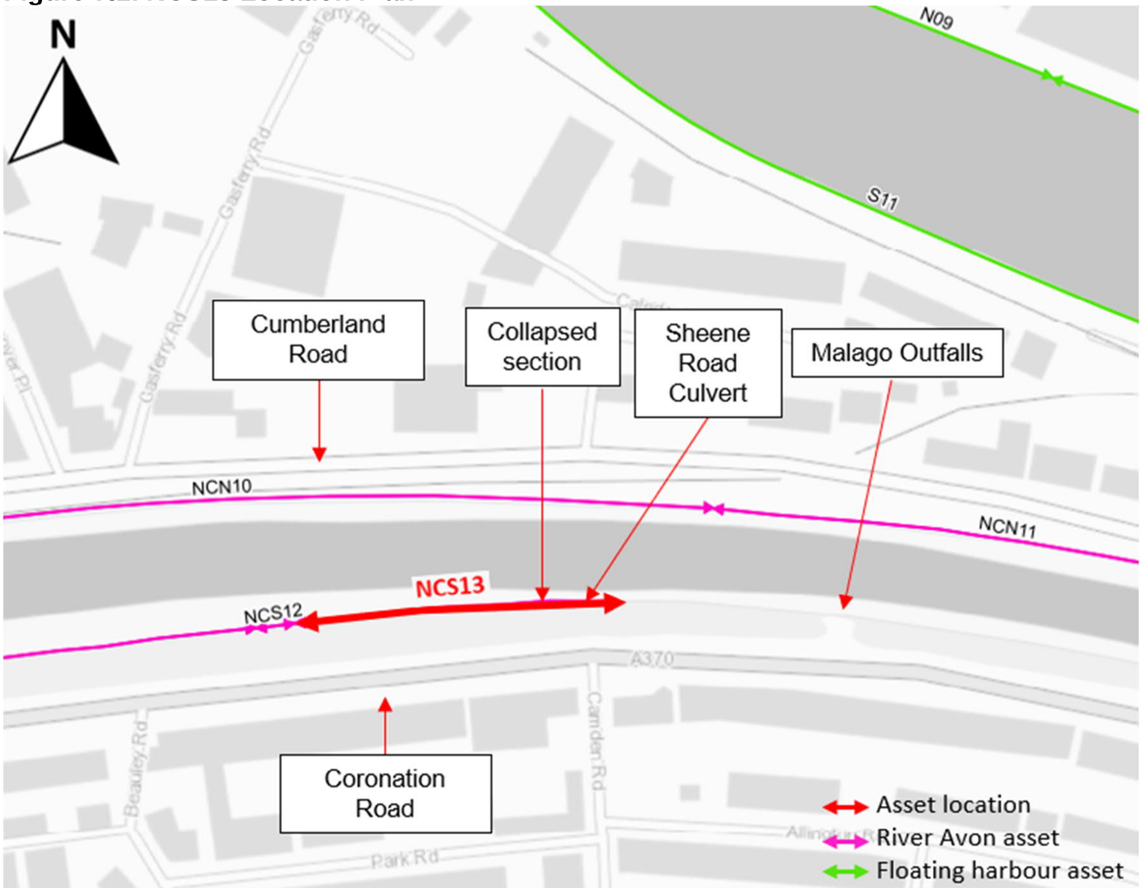
7.1 Background Information

7.1.1 Asset Location

The asset is located on the River Avon New Cut adjacent to the A370, Coronation Road. A Location plan is presented in Figure 7.1. The asset is located at approximate National Grid Reference 357305, 172026.

Coronation Road is located at the top of the slope and runs parallel to the New Cut River Avon, south of the asset. To the south of the asset is the residential area of Southville.

Figure 7.1: NCS13 Location Plan

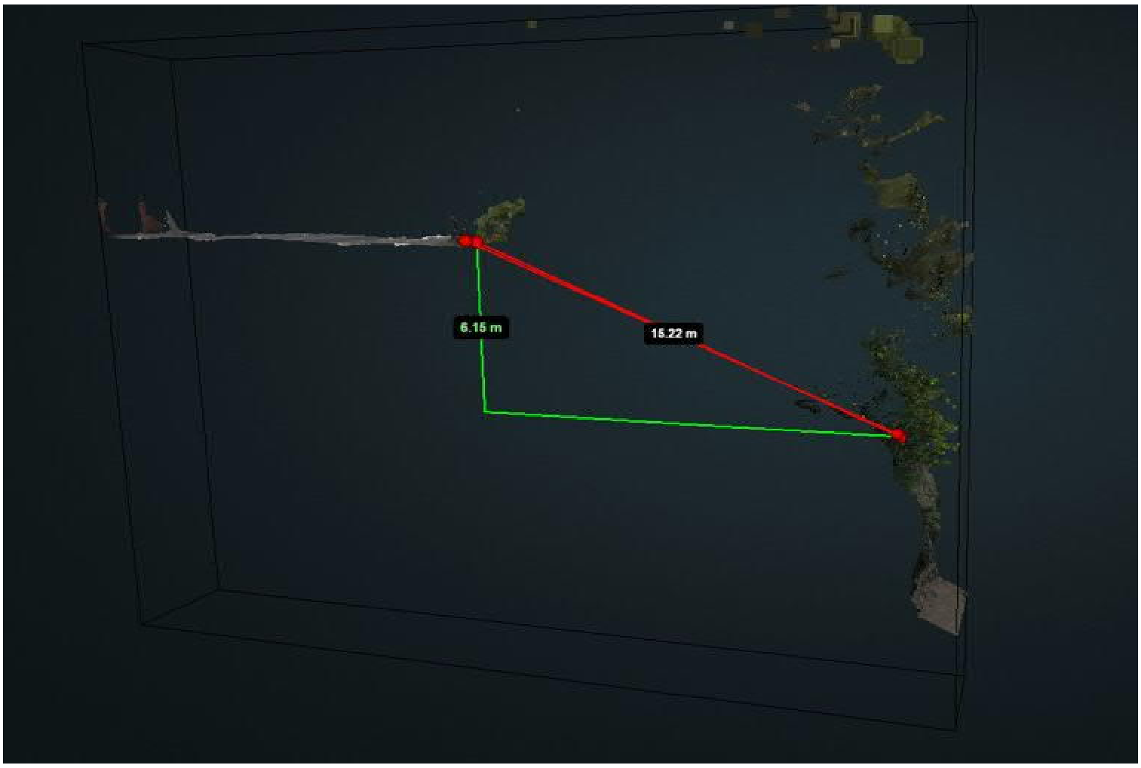


Source: Mott MacDonald

7.1.2 Asset Description

Asset NCS13 is a masonry wall which has been constructed upon rock outcrops. The asset is approximately 124m long and 2m high. The western section of the asset is retaining a steep vegetated slope set back up to 6m from the wall reducing towards the east. The eastern section (approx. 60m) of the asset, is believed to be directly supporting the steep vegetated slope. The slope behind the asset is approximately 1 in 3. A cross section showing the wall, slope and road positions is in Figure 7.2.

Figure 7.2: NCS13 Cross section

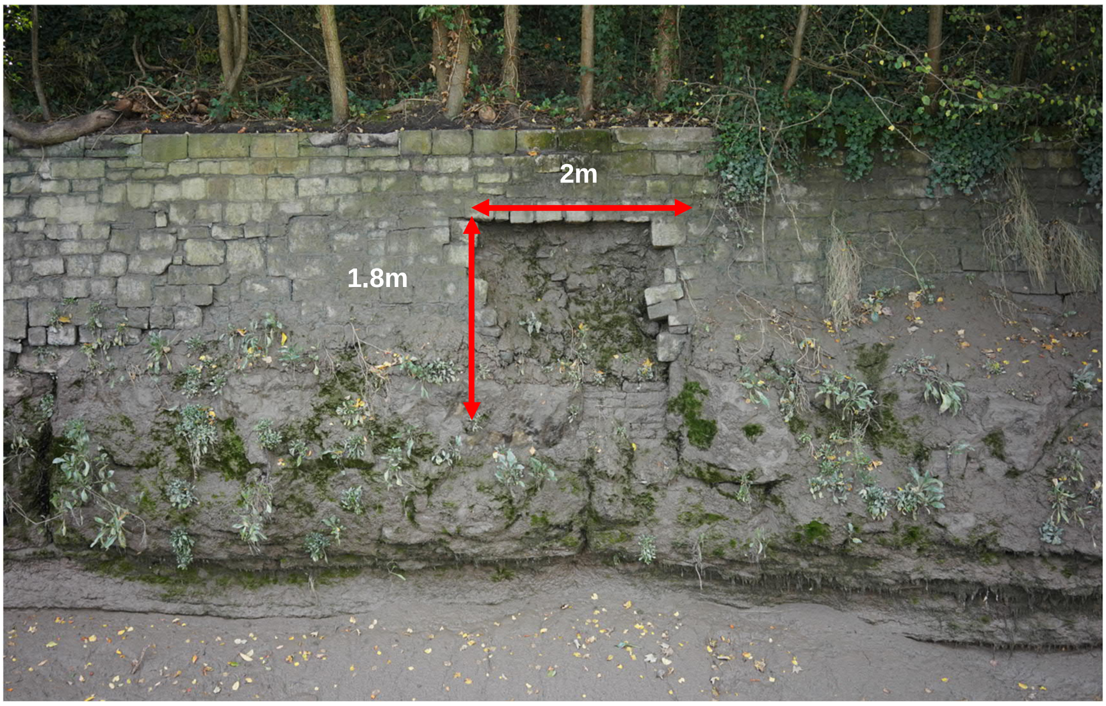


Source: Mott MacDonald 2019

7.1.3 Asset Defects

The main area of concern is the eastern section of the asset. There is a collapsed section of wall, approximately 2.5m x 2m, this is shown in Figure 7.3. Additionally, there are several areas of minor wall deformation, a typical example of this is shown in Figure 7.4. The level at the bottom of the collapsed wall section is 5.70mAOD. The river height in this area is not accurately known, but it is anticipated to regularly rise above the bottom of the defect.

Figure 7.3: NCS13 Collapsed section



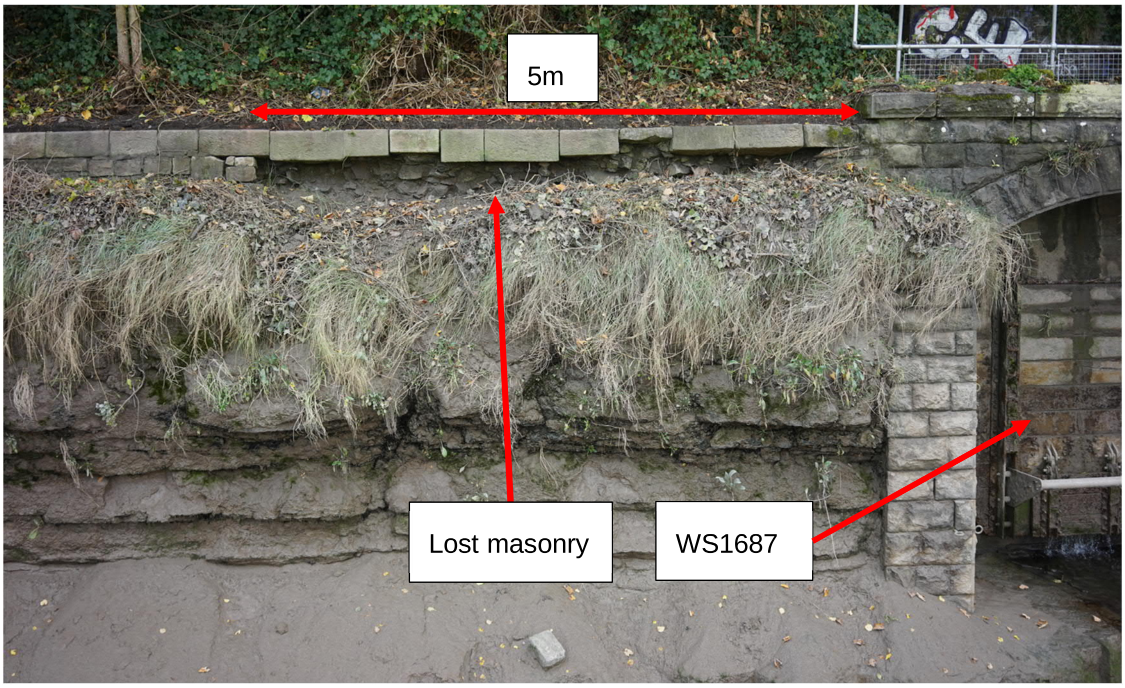
Source: Mott MacDonald October 2022

Figure 7.4: NCS13 Typical example of minor wall deformation

Source: Mott MacDonald October 2022

The gated outlet for Sheene Road Culvert (WS1687) is located along the asset's length. The outlet is owned by Wessex Water and is not part of this scope, but it appears to be in a fair condition. However, adjacent to the outlet, an approximate 5m length of wall is exhibiting lost masonry. This is shown in Figure 7.5.

Figure 7.5: NCS13 Missing masonry by Sheene Road Culvert



Source: Mott MacDonald October 2022

There is potentially scour happening to the bedrock that the wall has been constructed upon. The appearance of the rock is similar to other locations up and down the New Cut. This is shown in Figure 7.6. This is not considered a short-term concern.

Figure 7.6: NCS13 Scour

Source: Mott MacDonald October 2022

7.1.4 Consequences of Asset Failure

In the eastern section of the asset, where the defects shown in Figure 7.3 and Figure 7.4 are located, there is the potential for a failure to result in a loss of support to the slope behind and subsequently to Coronation Road which is located approximately 15m from the face of the wall (measured along the length of the slope, rather than on plan). If this were to occur, there would be major travel disruption as Coronation Road is a main distribution route.

7.1.5 Historic Mapping

A review of historic mapping was undertaken to assess the use and development of the asset and surrounding land, allowing for a more holistic understanding of the site. Table 7.1 presents a summary of history on site.

Table 7.1: NCS13 Summary of site history

Year	On site	Off site
1882 Published 1885	Retaining wall is labelled as stone	There is an unnamed road south of New Cut There is a row of 7 houses south of the road with open space adjacent to and south of the houses
1883 Published 1886	No change	No significant change
1901 to 1902 Published 1904	No change	Significant development in the area and is now known as Southville
Revised: 1901 to 1902, Published: 1905	No change	No significant change
Revised: 1902 Published 1905	No change	No significant change
Revised 1913 Published 1918	No change	No significant change
Revised 1912 to 1913 Published 1921	No change	No significant change
Revised 1913 Published 1921	No change	No significant change
Revised 1930 Published 1933	No change	No significant change
Revise 1938 Published 1944	No change	No significant change
Revised 1938 Published 1945	No change	No significant change
Revised 1938 Published 1946	No change	No significant change
Revised 1938 Published 1947	No change	No significant change
Revised 1938 to 1955 Published 1955	No change	No significant change
Revised 1938 to 1963 Published 1964	No change	No significant change
Revised 1938 to 1967 Published 1967	No change	No significant change
Present day	No change	No significant change

7.1.6 Geology

A review of BGS mapping [1] shows there are no superficial deposits on site and bedrock is found at ground level. Redcliffe Formation is described by BGS Lexicon [4] as "*sandstone, distinctive fine- to medium-grained, deep red, calcareous and ferruginous. Commonly decalcified at shallow depths below the surface, giving rise to an uncemented sand*".

NCS13 is not in a worked ground area but ground workings surround the site.

A review of the BGS Geoindex [2] shows that there are also no historical borehole logs available within 200m of the site. Three boreholes were available from the 2015 Structural Soils Ground Investigation [3]. A summary of the exploratory holes is included in Table 7.2 below.

Table 7.2: NCS13 Existing exploratory hole summary

	2015 Structural Soils Ground Investigation		
	BH547	**BH549**	**BH551**
Approx. distance from the site:	**70m N**	**80m N**	**90m NE**
Made Ground	0m BGL Asphalt 0.2m BGL Grey very sandy subangular to angular fine to coarse GRAVEL 0.4m BGL Brown fine to coarse gravelly SAND	0m BGL Asphalt 0.2m BGL Grey very sandy subangular to angular fine to coarse GRAVEL 0.6m BGL Reddish brown gravelly clayey fine to coarse SAND 1.2m BGL Firm low strength reddish brown sandy slightly gravelly CLAY 1.45m BGL firm low strength greenish brown ad brown slightly gravelly sandy CLAY 1.7m BGL Brown mottled grey very clayey fine to coarse SAND	0m BGL Asphalt 0.2m BGL Grey subangular limestone COBBLES 0.6m BGL Yellowish brown very gravelly slightly clayey fine to coarse SAND 0.8m BGL Stiff high strength greyish brown mottled red sandy slightly gravelly CLAY 1.3m BGL Stiff brownish grey mottled CLAY
Possible Made Ground	0.8m BGL Reddish brown gravelly clayey fine to coarse SAND 2.8m BGL Reddish brown mottled yellow brown very clayey SAND 3.2m BGL Firm becomes very soft brown mottled grey sandy CLAY 3.7m BGL Yellowish brown very clayey fine to carse SAND 4.1m BGL Grey very clayey fine SAND 4.2m BGL Very stiff very high strength reddish brown sand CLAY 4.9m BGL very soft reddish brown sandy CLAY	2.7m BGL Firm yellow low strength reddish brown mottled yellow brown and greenish grey sandy CLAY	1.8m BGL Brown mottled red brown very clayey fine to coarse SAND
Mercia Mudstone Group	-	3.4m BGL Very stiff reddish brown sandy CLAY	2.2m BGL Soft yellowish brown mottled reddish brown sandy CLAY 3.1m BGL Very stiff reddish brown sandy CLAY

	2015 Structural Soils Ground Investigation		
Redcliff Sandstone Formation	5.2m BGL Very weak becoming weak reddish brown conglomeratic SANDSTONE 9.05m BGL Weak thinly laminated to thinly bedded brown fine to medium grained SANDSTONE	4.5m BGL Weak becoming medium strong very thinly to thinly bedded reddish brown and brown fine to coarse SANDSTONE 5.75m BGL Weak thickly laminated to thinly bedded brown fine to medium SANDSTONE 6.2m BGL Very weakly thinly laminated to very thinly bedded reddish brown silty slightly weathered MUDSTONE 7.0m BGL Weak thinly laminated to very thinly bedded brown fine to medium slightly weathered SANDSTONE 7.3m BGL Very weak very thinly bedded reddish brown silty MUDSTONE 7.9m BGL Weak to medium strong thinly to medium bedded reddish brown fine to coarse conglomeritic SANDSTONE 8.8m BGL Very weak thinly bedded reddish brown slightly weathered silty MUDSTONE	4.0m BGL Weak to medium strong thinly laminated to thickly laminated orange brown and reddish brown fine to coarse SANDSTONE 5m BGL Very weak locally extremely weak brown and reddish brown very thinly to medium bedded fine to coarse SANDSTONE 5.9m BGL Extremely weak to very weak thinly to medium bedded reddish brown silty MUDSTONE 6.5m BGL Weak/very weak thinly laminated to thickly laminated brown fine to medium SANDSTONE 7.5m BGL Very weak becoming weak brown fine to coarse conglomeratic SANDSTONE 8.7m BGL Very weak reddish brown silty MUDSTONE
	Hole terminated at 11m depth	Hole terminated at 9.5m depth	Hole terminated at 8m depth

7.1.7 Mining

Bristol is known for it’s past as a Coal Mining area. A review of the Coal Authority interactive tool [5] shows map shows to site to not be within an area of known or probable coal mining.

7.1.8 Ecological Constraints

An ecological walkover survey was undertaken on 29 June 2022 by Mott MacDonald ecologists. The survey consisted of a walkover of the asset and a 30m buffer, where access permitted. The purpose of the survey was to identify the ecological constraints and risks of works. A summary of the Ecological Constraints Assessment produced following this survey is provided below.

Listed below are the habitats that were identified within the survey buffer;

- Semi-natural deciduous woodland, present in a 20m wide strip along the entire asset;
- Scattered scrub understory dominated by bramble (*Rubus fruticosus*) nettle (*Urtica dioica*) and ivy (*Hedera helix*);
- Patches of mixed dense scrub present along the eastern half of the asset;
- Semi-improved grassland growing on a 4m wide strip along the masonry wall edge closest to the river; and
- Mudflats are present directly underneath the masonry wall along the river edge.

In line with policy and best practice, avoidance measures should be embedded into the design of the works. The following avoidance measures were identified;

- Works within the river and mudflat Habitats of Principal Importance should be avoided;
- Where possible trees and other vegetation should be retained;

- Artificial lighting should be avoided during the construction and operational phases of the development;
- Obstructions to the watercourse and riverbanks should be avoided during the construction and operational phase;
- Any retained trees should be assessed by an appropriately qualified arboriculturist to determine root protection areas and any exclusion zones required to mitigate for damage during demolition and construction; and
- If possible, the site compound should be situated at least 16m away from the river and riverbanks, if this is not possible, permission would be required from the Environment Agency.

Table 7.3 below summarises the identified ecological constraints and the preliminary mitigation and/ or compensation recommendations.

Table 7.3: Ecological constraints and mitigation/compensation recommendations

Feature	Location description	Preliminary mitigation and/or compensation recommendations
Designated sites	Avon Gorge Woodlands Special Area of Conservation and Site of Special Scientific Interest, Horseshoe Bend Site of Special Scientific Interest, and Severn Estuary (Special Area of Conservation, Special Protection Area, RAMSAR and Site of Special Scientific Interest downstream of the Site. Avon New Cut Local Nature Reserve on site.	A Habitat Regulations Assessment is recommended. The county ecologist should be consulted regarding the proposed works within the Avon New Cut Local Nature Reserve.
Habitats of principal importance	River and mudflats within the site	The county ecologist should be consulted at the earliest opportunity if the habitats of principal importance are anticipated to be impacted to discuss the working methodology as well as any compensation, enhancement or restoration work.
Bats	Most trees on the asset offer low to moderate potential to support roosting bats due to the presence of potential roosting features and thick ivy cover	Night-time working should be avoided. A toolbox talk regarding bats should be given to all site personnel.
Reptiles	The scrub and grassland habitats within the riverbank offer suitable habitat for common reptiles	If any habitat removal affecting potential hibernacula (such as log piles or root systems) is required, this should occur during the reptile active season (April – October inclusive, depending on the weather) under supervision of an ecologist. Vegetation clearance should follow phased cuts in a directional manner to allow dispersal of active reptiles to neighbouring habitats. A toolbox talk regarding reptiles should be given to all site personnel.
Nesting birds	The scattered trees, scrub and rough grassland provide suitable habitat for nesting birds. A nest was also observed on one of the trees, although it was deemed unactive at the time of the survey	Vegetation clearance of habitat suitable for nesting birds should be undertaken outside of the nesting season (between March and August inclusive) in line with standing government guidance. If this is not possible, vegetation will need to be checked by an ecologist no more than 24 hours prior to removal. The feasibility of nesting bird checks will be subject to the judgement of a suitably qualified ecologist, who will

Feature	Location description	Preliminary mitigation and/or compensation recommendations
		determine whether the vegetation to be cleared can be safely and adequately searched.
Bony fish	The River Avon New Cut has potential to be used by different species of bony fish (including European eel) for commuting and foraging	Should the scope of works include significant disturbance that could impact fish, such as high noise and vibration levels, works may need to be timed to avoid fish migration periods. A toolbox talk regarding fish should be given to all site personnel.
Otters (*Lutra lutra*)	The River Avon New Cut has potential to be used by commuting and foraging otters.	No mitigation or compensation measures specific to otters identified.

Source: Mott MacDonald, 2022.

Further ecological surveys are recommended due to the potential for protected and notable species in the area. A full Preliminary Ecological Appraisal Report should be undertaken. Habitats should be classified using the UK habitats classification system. The report should include a Preliminary Roost Assessment of all trees and structures within 20m of the proposed works (Collins, 2016), a Habitat Suitability Index assessment of all waterbodies within 250m of the Site for great crested newts, and a walkover survey for invasive non-native plant species. This process may identify further ecological constraints as well as the need for further survey and mitigation measures.

A detailed habitat mitigation strategy should be developed to replace any habitats permanently lost as a result of the proposed works. The strategy would, as a minimum, replace lost habitat with habitats of the same or higher value. A Biodiversity Net Gain assessment can be used to quantify habitat value and should be undertaken to identify opportunities for biodiversity enhancement.

A Construction Environmental Management Plan will likely be required to set out the methods to ensure the environmental impact of construction is minimised. Finally, subject to the results of the further surveys, measures to minimise impacts on bats, fish, otters and reptiles should be included in a Reasonable Avoidance Measures Method Statement this should include best practise measures and general construction safeguards.

7.1.9 Site Walkover

Site walkovers were undertaken in January 2022, June 2022 and September 2022, as well as the original drone survey in April 2019.

During the January 2022 site walkover, images of the asset were obtained. Due to extensive vegetation growth, it is difficult to compare the overall condition of the asset with the condition in 2019, however, the collapsed section shown in Figure 7.3 appears to be in a similar state.

During the June 2022 site walkover, no images were obtained.

During the September 2022 site walkover, due to access limitations, no images of a reasonable quality were obtained of the asset.

7.1.10 Drone Survey

In October 2022, a drone survey was completed of the asset. As shown in Figure 7.7 and Figure 7.8, the collapsed section is similar in appearance with no discernible changes to the masonry. The minor wall deformation shown in Figure 7.9 and Figure 7.10, is also similar in appearance, however, due to the vegetation removal, the size of the defect area is more apparent.

Figure 7.7: NCS13 Collapsed section 2019

Source: Mott MacDonald 2019

Figure 7.8: NCS13 Collapsed section 2022

Source: Mott MacDonald, October 2022

Figure 7.9: NCS13 Wall deformation 2019

Source: Mott MacDonald 2019

Figure 7.10: NCS13 Wall deformation 2022

Source: Mott MacDonald, October 2022

Due to the hit and miss devegetation approach, a number of the defects in the less critical western section are not visible for comparison, however, these are not considered to be within the scope of this project.

7.1.11 NCS13 Summary

It is considered likely that the asset primarily functions as a retaining wall, providing support to the slope behind it. In the area where the collapse has taken place (shown in Figure 7.3), no further deterioration of the wall (or slope failure) is evident between 2019 and 2022.

In the absence of the wall, there is a possibility that there is enough support within the slope from vegetation and soil compaction, that would stop a short-term slope failure. However, a secondary function of the wall is to provide washout protection and in the long-term gradual erosion would likely lead to a slope failure. This would need to be confirmed through ground investigations and a slope stability analysis.

The 2019 drone data was compared to the 2022 drone data and the critical defect (Figure 7.3, Figure 7.7) does not appear to have changed significantly. The areas of minor wall deformation are more apparent, due to vegetation clearance, but they are not considered critical in nature.

7.2 NCS13 Monitoring

There are several options for the monitoring of NCS13, these include:

- Regular visual monitoring with long lens photographs.
- Surveying with total station.
- Laser scanning.
- Real-time monitoring with sensor system.

Further details of these monitoring techniques can be found in Section 2.

In this instance, it is recommended that the asset is monitored visually at 2-month intervals.

Regular visual monitoring will enable a visual record of the asset to be collated and should help identify significant deterioration of the wall within a reasonable timeframe (i.e., further loss of masonry, fractures, large movements).

The other listed options could be considered; however, they are not deemed to be essential for this asset.

7.3 NCS13 Ground Investigations

Ground investigations will determine ground properties and wall function. It is anticipated that the investigations for the asset will consist of:

- 2No. Boreholes.
- 2 Nr. Hand dug trial pits to confirm ground conditions directly behind the wall.

7.3.1 Slope Stability Analysis

A slope stability analysis could be undertaken for the areas local to defects which if allowed to deteriorate could potentially result in a slope failure.

The purpose of undertaking the analysis would be to determine whether, in the absence of the wall, the slope would fail. If the slope were found to have sufficient stability, the priority of the defect (Figure 7.3) would be decreased.

It should be noted that in the short term, while the slope may be stable in the absence of the wall, over a longer-term, following gradual washout from the river, that may change, and the slope may become unstable.

7.4 NCS13 Repair Options

At this time, repairs are only recommended for the collapsed section shown in Figure 7.3. There are two primary repair methods which can be considered for the asset repair. These methods will stabilise the wall in the region local to the defect.

1. A like for like repair consisting of masonry blockwork.
2. In-situ concrete patch repair utilising rock fixings / ground anchors (subject to geotechnical investigations).

The repair methodology will need to consider the tidal nature of the New Cut and may need to be completed quickly within a short window of time.

It may be a requirement that the upper section of wall above the current defect needs to be taken down or stabilised prior to commencing work; this will be subject to the outcome of geotechnical investigations, the ability for plant to access the site, temporary works considerations; and the wall’s current condition at the time of the repair.

Alternatively, ground investigations and the slope stability assessment may find that the bank has sufficient capacity or can be strengthened such that the wall could be allowed to fail, although this would have negative aesthetic impact.

If there are any particular concerns over the scour of the bedrock the installation of reno-mattresses could be considered.

ECI discussions have informed that a cantilevered scaffold will likely be required to create a safe working environment to complete necessary repairs.

7.4.1 NCS13 Masonry Patch Repair

Where the collapse has occurred (Figure 7.3), it is anticipated that there would be a useable foundation as the rock shelf is still visible and there is masonry below the hole, however, this would need to be confirmed through ground investigations.

The collapsed section would be reconstructed using masonry blocks and to provide additional support, tie-bars into the adjacent masonry could also be used to provide better continuity (if required). As this wall is expected to be a retaining structure (subject to ground investigations), there is a risk that reconstructing in masonry would not adhere to current design standards.

There are also potential safety concerns over this methodology as the section of masonry which remains above the collapse is likely to be unstable and could potentially collapse when remedial work is being undertaken. The upper section of masonry may require temporary support or deconstruction prior to a repair being undertaken. However, deconstruction would potentially remove support for any retained material, increasing risk of a slope failure. The safety concern of upper wall stability is increased versus a concrete repair due to a longer working time.

7.4.2 NCS13 In-situ Concrete Patch Repair

Repairing the collapsed section (Figure 7.3) with this methodology would be sufficient to stabilise the wall local to the repair. It is unlikely that it would adhere to current design standards for a retaining structure.

This entails installing a series of fixings throughout the defect which will be used to anchor/support a reinforced concrete patch repair. The type of fixing (anchor/dowel) will be determined following ground investigations. Without sufficient rock anchors/dowels to support the vertical load, a useable foundation will be required.

It is likely that the final repair will sit proud of the existing masonry wall face and extend for a nominal distance beyond the maximum extents of the defect to obtain a rectangular repair (subject to ECI input on concreting).

7.4.3 NCS13 Deformation Repair

There are several areas of deformation throughout the asset. Where there are areas of deformation as shown in Figure 7.4, the current recommendation is to monitor these and track movement. If movement is experienced, the areas should be repaired with potential options as follows:

- The wall can be demolished local to that area and rebuilt (either a masonry repair, or concrete repair, subject to ground investigations) as outlined above.
- Pattress plates could also be installed in the area of deformation to stabilise the local area, the suitability of pattress plates would need to be determined through preliminary investigations to find the angle of misalignment and ground properties.

7.4.4 NCS13 Slope Stabilisation

This could be a feasible option if it is determined that in the absence of the wall, the slope would fail, and that targeted stabilisation works would be cheaper than repairing or reconstructing the wall. Ground investigations followed by a slope stability analysis would initially be required to understand this.

Bank stabilisation would require the installation of soil nails and a facing system into the bank. Prior to this being undertaken, widespread de-vegetation would be required in the area of installation. This is envisaged to be more extensive than de-vegetation requirements for the above patch or deformation repair methods.

It could be difficult to install a facing system due to the quantity of trees in the area and early contractor involvement should be undertaken to determine the site requirements. The removal of any trees from the bank could have a destabilising effect by changing the pore water pressure and potentially cause movement. In addition, tree removal would likely to be strongly objected to by local residents and the ecological concerns over removing potential habitats would need to be determined.

It should be noted that while the slope may be stable following slope stabilisation works, there is a longer-term risk of gradual washout and reduced bank stability. It's likely this approach will be favourable as an interim repair measure where the cost and practicalities of conducting smaller repairs is not considered to be an effective solution; potentially allowing for a larger scale repair/replacement to be undertaken in the future.

7.5 NCS13 Recommendations

The asset has been ranked in Priority Group 3, see Section 12.

It is recommended that regular visual monitoring is undertaken at 2 month intervals to note any further asset deterioration.

It is recommended that ground investigations and a slope stability analysis are undertaken to confirm ground properties, wall function, slope stability. Subject to slope stability findings, the asset could potentially be descoped from remedial works in the future, if there is no risk to the carriageway.

If the ground information and slope stability analysis support the need for repairs, a more informed decision can then be taken on an appropriate repair methodology. This is likely to be as follows:

- Concrete / masonry patch repairs for areas of missing masonry,
- Installation of localised pattress plates at areas of bulging

Note, that restoring the existing wall with like for like patch repairs is unlikely to comply with modern design codes for a retaining structure and would instead be focussed on providing a stabilising repair of the adjacent masonry.

As an alternative to the above, slope stabilisation works could potentially be undertaken as an interim measure, mitigating the risks to the bank and adjacent infrastructure in the event of a wall failure. However, this would not protect the wall from progressive deterioration or washout of the bank material in the longer term (in the vicinity of wall failures).

The areas of deformation could potentially be monitored using remote sensors to give accurate data on wall movement. It is not deemed to be essential in this location and could be considered in the event that the sensors would be within range of a monitoring Gateway (see Section 2.5) used for higher priority assets.

It is advised that the targeted removal of specific trees (whose proximity to the wall is likely to be causing structural damage) be considered. Any tree removal should be done in consultation with an arboriculturist and ecologist and provision for replacement planting to retain habitats will need to be considered. Note that there is a risk of loss of stability to the bank due to excessive vegetation removal, and a suitably qualified geotechnical engineer should be engaged before any vegetation removal is undertaken.

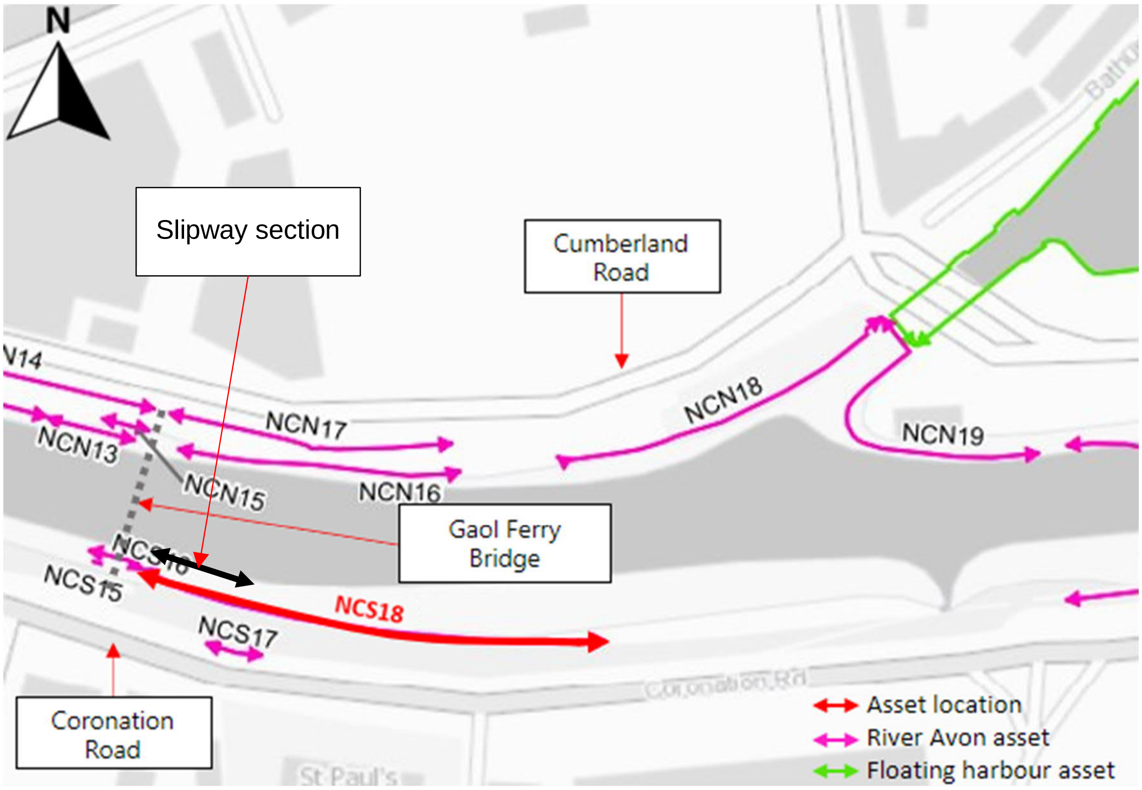
8 NCS18

8.1 Background Information

8.1.1 Asset Location

Asset NCS18 is located adjacent to the A370 Coronation Road, on the south bank of the River Avon at National Grid Reference 358424, 172018. Figure 8.1 shows the site location plan. it is located to the east of Gaol Ferry Bridge.

Figure 8.1: NCS18 Location plan



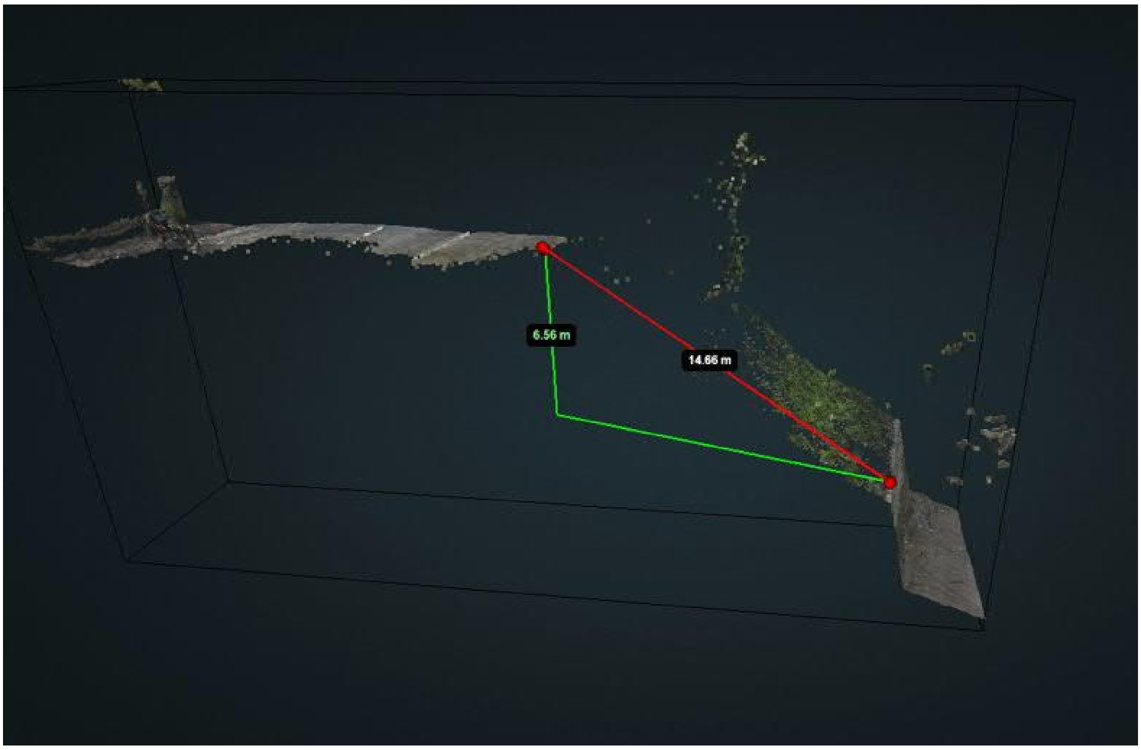
Source: Mott MacDonald

8.1.2 Asset Description

The asset is a masonry wall approximately 130m long, the height of the exposed wall varies due to sediment. It was constructed for the Gaol Ferry Crossing which was the connecting route between Southville and Gaol Ferry Steps across the River Avon. The ferry crossing has since been replaced by the Gaol Ferry footbridge. The asset partly forms a walkway down to the ferry slipway (30m) as well as acting as a retaining/facing wall for a length (100m) of the riverbank.

The exact role of the masonry wall is unknown throughout its length and may act as either a facing wall or a retaining structure, or as a mixture of the two. In the event that it is a retaining structure, it is likely supporting the steep bank below Coronation Road. The slope behind the asset is approximately 1 in 2 with Coronation Road located approximately 13m behind the wall. A cross section showing the wall, slope and road positions is in Figure 8.2.

Figure 8.2: NCS18 Cross section



8.1.3 Asset Defects

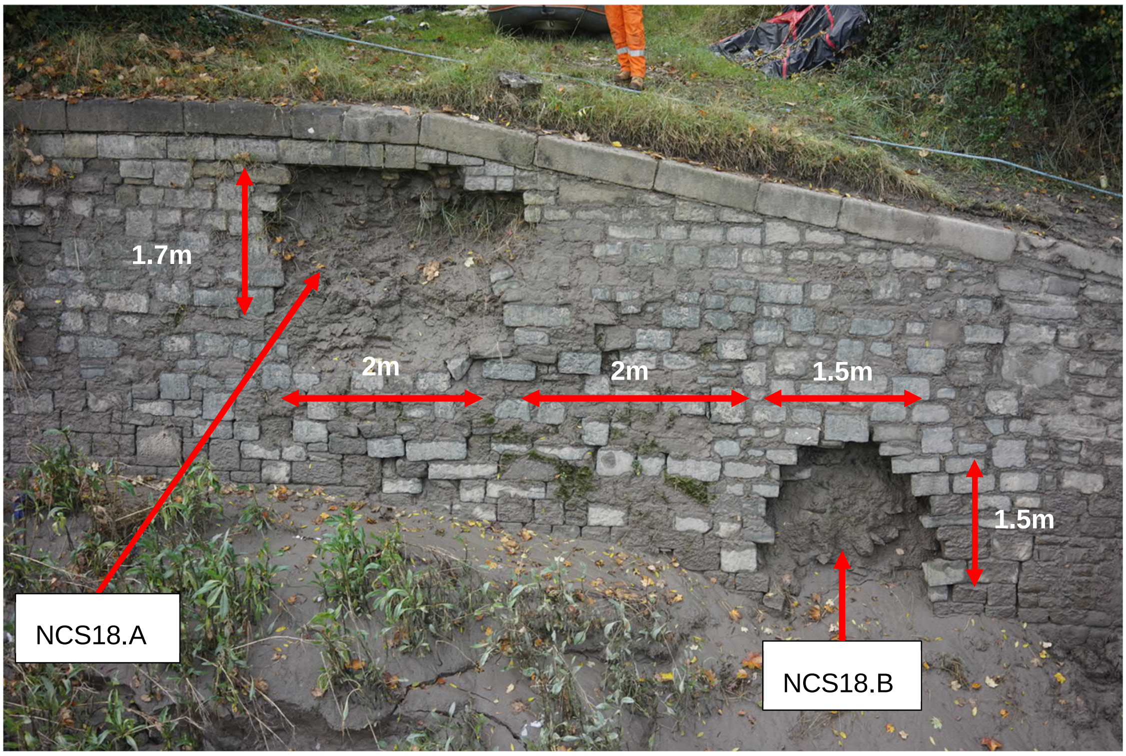
There are several collapsed sections of the wall and areas of deformation. The defects have been treated as two different sections depending on their location, slipway and slope wall.

Slipway defects are located below or within the immediate vicinity of the slipway to the River Avon. These are the defects shown in Figure 8.3 and Figure 8.7.

Slope wall defects are located in-front of the slope which rises to Coronation Road. These are the defects shown in Figure 8.4, Figure 8.5 and Figure 8.6. It is anticipated that tree roots are causing some of the deformations that are present.

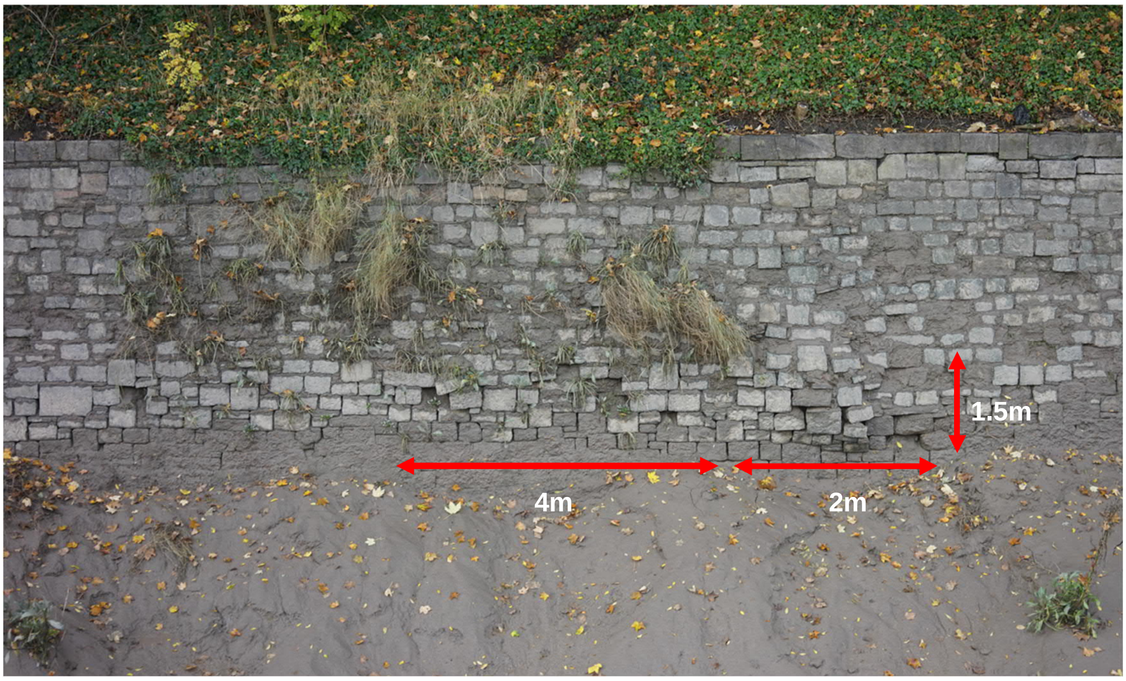
The level at the bottom of the defects in Figure 8.3 is 4.5mAOD and 6.2mAOD respectively. The level at the bottom of the defect in Figure 8.7 is 2.5mAOD. The approximate toe of wall height for the remaining defects (Figure 8.4, Figure 8.5 and Figure 8.6) is 5mAOD. The river level in these locations is anticipated to regularly rise above these levels.

Figure 8.3: NCS18 Collapsed sections (Slipway)



Source: Mott MacDonald, October 2022

Figure 8.4: NCS18 Wall deformation (Slope wall)

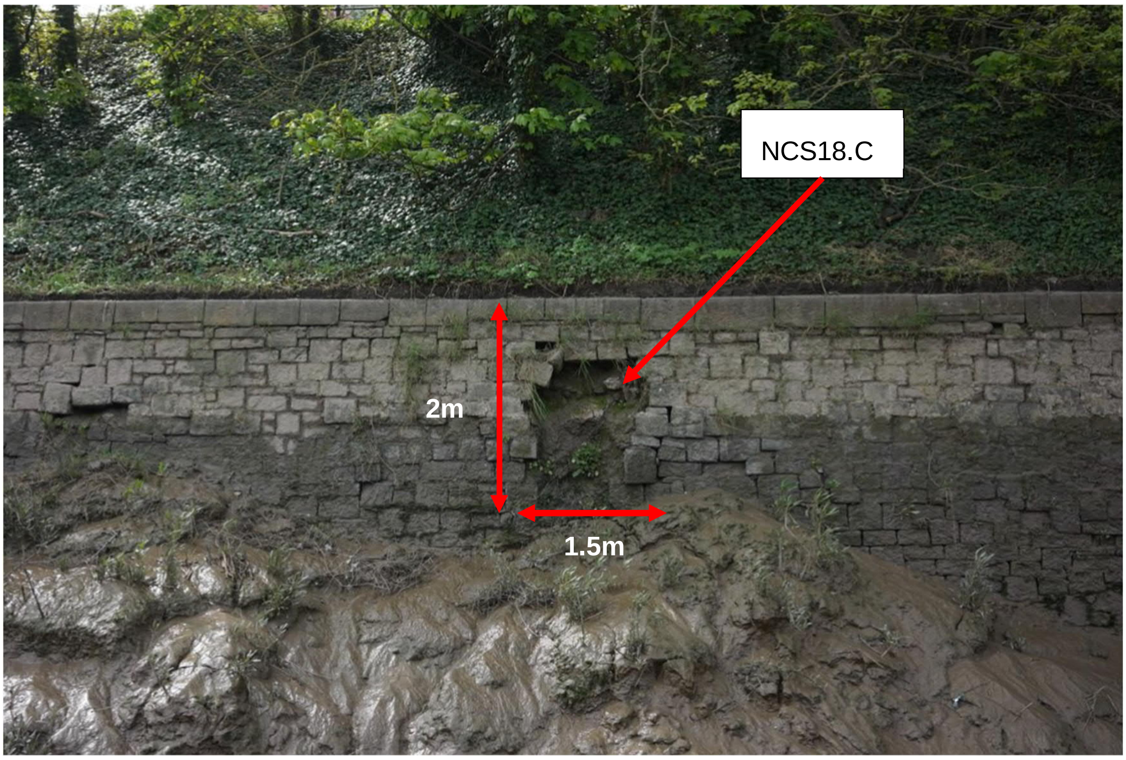


Source: Mott MacDonald, October 2022

Figure 8.5: NCS18 Wall deformation and lost masonry (Slope wall)

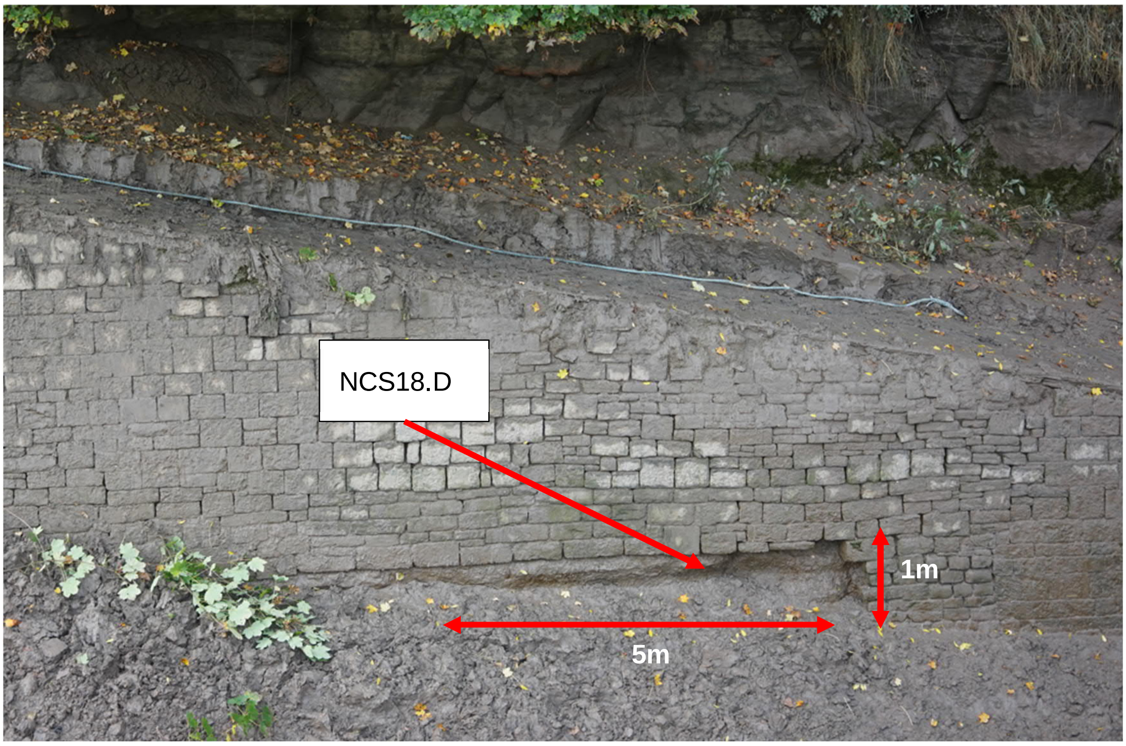
Source: Mott MacDonald, October 2022

Figure 8.6: NCS18 Collapsed section (Slope wall)



Source: Mott MacDonald 2019

Figure 8.7: NCS18 Lost masonry (Slipway)



Source: Mott MacDonald, October 2022

8.1.4 Consequences of Asset Failure

The consequence of further failure depends on the position along the asset as the supported features differ along its length.

Were it to occur where the slope is directly supported by the asset (Figure 8.4, Figure 8.5 and Figure 8.6), there is the potential for Coronation Road to be impacted. If this were to occur, there would be major travel disruption as Coronation Road is a main distribution route in central Bristol.

If a further failure happened in the vicinity of the slipway (Figure 8.3 and Figure 8.7), the slipway would potentially become unusable, limiting maintenance access to the bridge pier and access to the river.

8.1.5 Historical Mapping

A review of historic mapping was undertaken to assess the use and development of the asset and surrounding land, allowing for a more holistic understanding of the asset. Table 8.1 presents a summary of history on site.

Table 8.1: NCS18 Summary of site history

Year	On site	Off site
1882	Coronation Ferry is present and marked with a dashed line from north to south, across the water Steps lead down to the water's edges from a slip way that extends east and west of the crossing on the northward side, and just west of the crossing on the south The slope southwards of the asset is labelled as stone.	Access to Coronation Ferry appears to start from Southville Road, approx. 50m south west of site, following an un-named road northward to the water's edge. This road appears to pass under Coronation Road where it is labelled Coronation Bridge. There are stepped access directly from Coronation Road. New Goal (Disused) is present adjacent northwards of site across the New Cut. Housing is present due south and south east of site
1883, Published 1886	No change	No significant change
1881-1883 Published 1887	No change	No significant change
1901-1902 Published 1904	No change	New Goal (Disused) is no longer labelled Tram tracks have been constructed to the north of site
1901-1902 Published 1905	Coronation Ferry no longer marked	No significant change
1902	Coronation Ferry marked on map	Coronation Bridge is no longer labelled The slipway and access to the Coronation Ferry is no longer visible on mapping
1912	No change	No significant change
1913 Published 1918	No change	No significant change
1913 Published 1921	No change	No significant change
1930	Coronation Ferry is still labelled but there is no dashed line to indicate the direction of the ferry	No significant change
1938	No change	No significant change
1938-1955	Coronation Ferry is no longer labelled. There is now a bridge present which crosses the New Cut	No significant change

8.1.6 Geology

A review of the BGS geological mapping [1] shows the site to be underlain by the Redcliffe Sandstone Member formation. BGS Lexicon describes this as *"sandstone, distinctive fine- to medium-grained, deep red, calcareous and ferruginous. Commonly decalcified at shallow depths below the surface, giving rise to an uncemented sand"*. Superficial deposits are shown to not be present on the geological maps.

A review of BGS Geoindex [2], showed that no exploratory holes were available on site. Four trial pits were located approximately 200m to the north west of site. The trial pits were excavated in the 1980s and the logs are typed. One borehole was available from the 2015 Structural Soils Ground Investigation [3] approximately 200m north east of site. A summary of the exploratory holes is shown in the Table 8.2 below.

Table 8.2: NCS18 Existing exploratory hole summary

	Historic BGS Geoindex borehole records				2015 Structural Soils Ground Investigation
	ST57SE326 TP01	**ST57SE327 TP02**	**ST57SE328 TP03**	**ST57SE329 TP04**	**BH561**
Approx. distance from the site:	**200m W**	**200m W**	**200m W**	**200m W**	**200m NE**
Made Ground	0.1-0.2 m BGL Loose creamy grey sandstone chippings 0.2 - 0.7 m BGL Rubble in silt matrix	0 - 0.9 m BGL Rubble in sandy matrix	0 - 1.1 m BGL Rubble	0.0– 1.1 m BGL Silty matrix 1.2 m BGL Black cinder layer	0-0.2 m BGL Dark brown sandy SILT 0.2-0.35m BGL yellowish to orangish brown gravelly SAND
Weathered Zone (Assumed Redcliffe Sandstone)	0.7 - 2.6 m BGL Soft to stiff (increasing strength with depth) brown CLAY	0.9 - 2.4 m BGL Medium to coarse brown SAND	1.1 - 2.7 m BGL Medium to coarse red brown clay sand	1.2 - 2.3 m BGL Medium to coarse dark brown clayey SAND	0.4-0.7m BGL Light yellowish brown slightly gravelly SAND
Redcliffe Sandstone	> 2.6 m BGL Moderately strong calcareous SANDSTONE	>2.4 m BGL SANDSTONE	>2.7 m BGL Moderately strong calcareous SANDSTONE	>2.4 m BGL Moderately strong calcareous SANDSTONE	0.7-9.7m BGL Extremely weak to weak, SANDSTONE OR Very weak MUDSTONE
					9.7-38.8m BGL Extremely weak to very weak MUDSTONE OR Weak SANDSTONE
South Wales Middle Coal Measures Formation					>38.8m BGL Very weak CONGLOMERATE OR Weak to medium strong SILTSTONE

8.1.7 Mining

Bristol is known for it's past as a Coal Mining area. A review of the Coal Authority interactive tool [5] shows that the asset is located within the area of a Coal Outcrop. This indicates that a coal seam is present either at or close to the surface. However, the map shows to site to not be within an area of known or probable shallow coal workings

8.1.8 Ecological Constraints

An ecological walkover survey was undertaken on 29 June 2022 by Mott MacDonald ecologists. The survey consisted of a walkover of the asset and a 30m buffer, where access permitted. The purpose of the survey was to identify the ecological constraints and risks of works. A summary of the Ecological Constraints Assessment produced following this survey is provided below.

Listed below are the habitats that were identified within the survey buffer;

- Line of semi-mature deciduous trees growing along the southern edge of the asset;
- A stone wall is present on the middle section (underneath Gaol Ferry Bridge) separating the asset from Coronation Road. Parts of the wall showed gaps and cracks on the stonework;
- Dense patches of mixed scrub and introduced shrub present along the edge of the asset closest to Coronation Road;
- Scattered scrub understory dominated by bramble, nettle and ivy. A 5m wide strip of less dense scrub is also growing along the masonry wall edge closest to the river;
- Semi-improved grassland growing on a central patch immediately east of the bridge; and
- Mudflats are present directly underneath the masonry wall along the river edge.

In line with policy and best practice, avoidance measures should be embedded into the design of the works. The following avoidance measures were identified;

- Works within the river and mudflat Habitats of Principal Importance should be avoided;
- Where possible trees and other vegetation should be retained;
- Artificial lighting should be avoided during the construction and operational phases of the development;
- Obstructions to the watercourse and riverbanks should be avoided during the construction and operational phase;
- Any retained trees should be assessed by an appropriately qualified arboriculturist to determine root protection areas and any exclusion zones required to mitigate for damage during demolition and construction; and
- If possible, the site compound should be situated at least 16m away from the river and riverbanks, if this is not possible, permission would be required from the Environment Agency.

Table 8.3 below summarises the identified ecological constraints and the preliminary mitigation and/ or compensation recommendations.

Table 8.3: Ecological constraints and mitigation/compensation recommendations

Feature	Location description	Preliminary mitigation and/or compensation recommendations
Designated sites	Avon Gorge Woodlands Special Area of Conservation and Site of Special Scientific Interest, Horseshoe Bend Site of Special Scientific Interest, and Severn Estuary (Special Area of Conservation, Special Protection Area, RAMSAR and Site of Special Scientific Interest downstream of the Site. Avon New Cut Local Nature Reserve on site.	A Habitat Regulations Assessment is recommended. The county ecologist should be consulted regarding the proposed works within the Avon New Cut Local Nature Reserve.
Habitats of principal importance	River and mudflats within the site	The county ecologist should be consulted at the earliest opportunity if the habitats of principal importance are anticipated to be impacted to discuss the working methodology as well as any compensation, enhancement or restoration work.
Bats	Most trees on the asset offer low to moderate potential to support roosting bats due to the presence of potential roosting features and thick ivy cover	Night-time working should be avoided. A toolbox talk regarding bats should be given to all site personnel.
Reptiles	The scrub and grassland habitats within the riverbank offer suitable habitat for common reptiles	If any habitat removal affecting potential hibernacula (such as log piles or root systems) is required, this should occur during the reptile active season (April – October inclusive, depending on the weather) under supervision of an ecologist. Vegetation clearance should follow phased cuts in a directional manner to allow dispersal of active reptiles to neighbouring habitats. A toolbox talk regarding reptiles should be given to all site personnel.
Nesting birds	The scattered trees, scrub and rough grassland provide suitable habitat for nesting birds. A nest was also observed on one of the trees, although it was deemed unactive at the time of the survey	Vegetation clearance of habitat suitable for nesting birds should be undertaken outside of the nesting season (between March and August inclusive) in line with standing government guidance. If this is not possible, vegetation will need to be checked by an ecologist no more than 24 hours prior to removal. The feasibility of nesting bird checks will be subject to the judgement of a suitably qualified ecologist, who will determine whether the vegetation to be cleared can be safely and adequately searched.
Bony fish	The River Avon New Cut has potential to be used by different species of bony fish (including European eel) for commuting and foraging	Should the scope of works include significant disturbance that could impact fish, such as high noise and vibration levels, works may need to be timed to avoid fish migration periods. A toolbox talk regarding fish should be given to all site personnel.
Otters (*Lutra lutra*)	The River Avon New Cut has potential to be used by commuting and foraging otters	No mitigation or compensation measures specific to otters identified.

Source: Mott MacDonald, 2022.

Further ecological surveys are recommended due to the potential for protected and notable species in the area. A full Preliminary Ecological Appraisal Report should be undertaken. Habitats should be classified using the UK habitats classification system. The report should include a Preliminary Roost Assessment of all trees and structures within 20m of the proposed works (Collins, 2016), a Habitat Suitability Index assessment of all waterbodies within 250m of the Site for great crested newts, and a walkover survey for invasive non-native plant species. This process may identify further ecological constraints as well as the need for further survey and mitigation measures.

A detailed habitat mitigation strategy should be developed to replace any habitats permanently lost as a result of the proposed works. The strategy would, as a minimum, replace lost habitat with habitats of the same or higher value. A Biodiversity Net Gain assessment can be used to quantify habitat value and should be undertaken to identify opportunities for biodiversity enhancement.

A Construction Environmental Management Plan will likely be required to set out the methods to ensure the environmental impact of construction is minimised. Finally, subject to the results of the further surveys, measures to minimise impacts on bats, fish, otters, eels and reptiles should be included in a Reasonable Avoidance Measures Method Statement this should include best practise measures and general construction safeguards.

8.1.9 Site Walkover

Site walkovers were undertaken in January 2022, June 2022 and September 2022, as well as the original drone survey in 2019.

During the January 2022 site walkover, images were obtained from the opposite bank. Not all of the critical defects were visible due to vegetation growth.

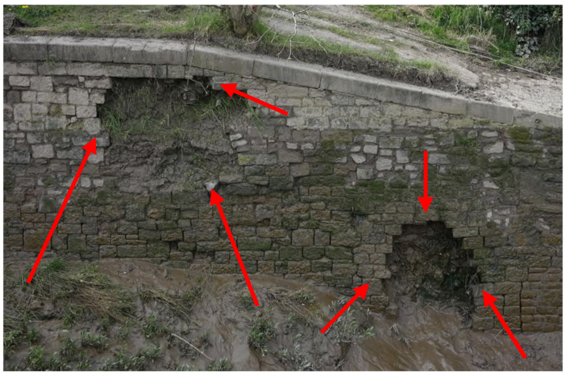
During the June 2022 site walkover, no images were obtained.

During the September 2022 site walkover, images were obtained but were not of comparable quality with the 2019 images.

8.1.10 Drone Survey

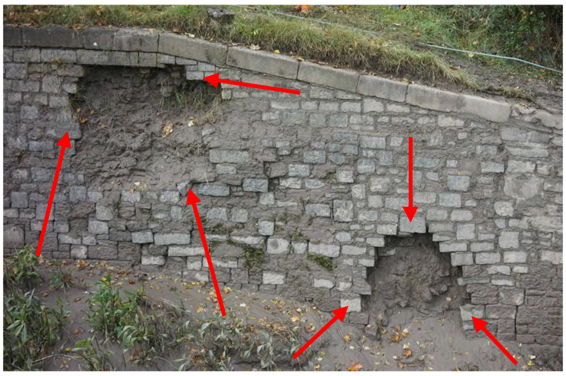
In October 2022, a drone survey was completed of the asset. As shown in Figure 8.8, Figure 8.9, Figure 8.10 and Figure 8.11 the defects are similar in appearance with no discernible changes to the masonry. The other defects highlighted previous for NCS18 have not been shown as their 2022 appearance is similar to 2019.

Figure 8.8: NCS18 Defect A and B 2019



Source: Mott MacDonald 2019

Figure 8.9: NCS18 Defect A and B 2022



Source: Mott MacDonald, October 2022

Figure 8.10: NCS18 Wall deformation 2019

Source: Mott MacDonald 2019

Figure 8.11: NCS18 Wall deformation 2022

Source: Mott MacDonald, October 2022

8.1.11 NCS18 Summary

It is considered likely that the asset primarily functions as a retaining wall, providing support to the bank behind it. However, this is not confirmed, and in the areas where collapses have taken place, there has not been a progression of the defect or slope failure in the immediate vicinity between 2019 and 2022.

A secondary function of the wall is to provide washout protection and in the long-term gradual erosion would likely lead to worsening wall condition and eventual slope failures.

The cause of the defects is not known; however, it is anticipated that several of the deformed areas are being caused by tree roots.

Comparison of 2019 and 2022 drone data shows that the defects identified do not appear to have deteriorated significantly in the time between the two surveys.

8.2 NCS18 Monitoring Options

There are several options for the monitoring of NCS18, these include:

- Regular visual monitoring with long lens photographs.
- Real-time monitoring with sensor system.
- Surveying with total station.
- Laser scanning.

Further details of these monitoring techniques can be found in Section 2.

In this instance, it is recommended that the asset is monitored using a combination of regular visual monitoring at 2 month intervals and real-time monitoring.

Regular visual monitoring will enable a visual record of the asset to be collated and pick up any further significant changes to the wall structure, such as the loss of discreet masonry blocks. Visual monitoring will not pick up gradual movement or subtle changes.

Localised real-time monitoring with a sensor system could be installed, this will provide accurate monitoring of any slope or wall movement. It will also provide information on a potential failure that may occur and be able to trigger a warning system, alerting necessary individuals (BCC Leadership team). The system may be able to detect whether the tide, temperature, or other seasonal events are affecting the wall.

The other listed options could be considered; however, they are not deemed to be essential for this asset.

8.3 NCS18 Ground Investigations

Ground investigations will determine ground properties and wall function. It is anticipated that the investigations for the asset will consist of:

- 4 No. Boreholes.
- 2 No. Hand dug trial pits to confirm ground conditions directly behind the wall.

8.3.1 Slope Stability Analysis

A slope stability analysis could be undertaken for the areas local to defects which if allowed to deteriorate could potentially result in a slope failure.

The purpose of undertaking the analysis would be to determine whether, in the absence of the wall, the slope would fail. If the slope were found to have sufficient stability, the priority of some of the defects (Figure 8.4, Figure 8.5 and Figure 8.6) could be decreased.

It should be noted that in the short term, while the slope may be stable in the absence of the wall, over a longer-term, following gradual washout from the river, that may change, and the slope may become unstable.

8.4 NCS18 Repair Options

Prior to a repair, ground investigations will be required to confirm the ground properties and wall function (i.e., retaining or facing), as well as the stability of the slope and constraints on construction access / temporary works etc.; all of which will help determine a recommended design option.

There are currently two repair methods which are considered likely for the asset. These methods will stabilise the wall in the region local to the applicable defects.

- A like for like repair consisting of masonry blockwork.
- In-situ concrete repair utilising rock fixings / ground anchors (subject to geotechnical investigations).

In order to facilitate the repair, it may be necessary to local demolish a local section of masonry (i.e., where the top of the wall is unstable or where there is excessive deformation – see Figure 8.4 and Figure 8.5). It is thought that either a masonry or concrete repair could be used in these instances dependant on the results of ground investigations and the specific location of the failure in question (see below). If sediment removal is required local to defects, eel rescue may be necessary depending on the proximity to water level.

Note, concrete and masonry patch repairs will act to stabilise the adjacent masonry and restore wall continuity, however they are unlikely to meet modern design standards for earth retaining structures. An alternative to this would be the localised full demolition of failed areas and construction of a replacement retaining structure. This has not been considered due to the cost, sits outside of the critical repair scope for this package of works, and because it will not strengthen the adjacent sections of wall.

8.4.1 NCS18 Masonry Patch Repair

This option is considered to be most appropriate for the following defect:

- NCS18.A (Figure 8.3)

Where the collapse has occurred, it is not known whether there would be a useable foundation as the rock shelf is not visible. The function of the wall at this location is also unknown, and a masonry repair would not be suitable if the wall were found to be retaining rather than facing. These would need to be confirmed through ground investigations.

Where a rock shelf/useable foundation is not immediately apparent, material would need to be excavated down to a level such that one is found, or a new foundation would need to be cast so that it can be built upon.

The collapsed section would be reconstructed using masonry blocks and to provide additional support, tie-bars into the adjacent masonry could also be used to provide better continuity (if required). Instead of masonry blocks dry-bags may be utilised for small repairs where aesthetics are less important.

Subject to contractor engagement, a cantilevered gantry scaffold could be lowered into place to enable as safe working environment.

8.4.2 NCS18 In-situ Concrete Patch Repair

This option is considered to be most appropriate for the following defects, due to their positioning low down on the wall which would necessitate a quicker repair:

- NCS18.B (Figure 8.3)
- NCS18.C (Figure 8.6)
- NCS18.D (Figure 8.7)

The repair would entail installing ground fixings throughout the defect which will be used to support a reinforced concrete patch repair. The type of fixing (anchor/dowel/bolt) will be determined following ground investigations.

It is likely that the final repair will sit proud of the existing masonry wall face and extend for a nominal distance beyond the maximum extents of the defect to obtain a rectangular repair (subject to ECI input on concreting).

8.4.3 NCS18 Slope Stabilisation

This could be a feasible option if it is determined that in the absence of the wall, the slope would fail, and that targeted stabilisation works would be cheaper than repairing or reconstructing the wall. Ground investigations followed by a slope stability analysis would initially be required to understand this.

Bank stabilisation would require the installation of soil nails and a facing system into the bank. Prior to this being undertaken, widespread de-vegetation would be required in the area of installation. This is envisaged to be more extensive than de-vegetation requirements for the above patch or deformation repair methods.

It could be difficult to install a facing system due to the quantity of trees in the area and early contractor involvement should be undertaken to determine the site requirements. The removal of any trees from the bank could have a destabilising effect by changing the pore water pressure and potentially cause movement. In addition, tree removal would likely to be strongly objected to by local residents and the ecological concerns over removing potential habitats would need to be determined.

It should be noted that while the slope may be stable following slope stabilisation works, there is a longer-term risk of gradual washout and reduced bank stability. It is likely this approach will be favourable as an interim repair measure where the cost and practicalities of conducting smaller repairs is not considered to be an effective solution; potentially allowing for a larger scale repair/replacement to be undertaken in the future.

8.5 NCS18 Recommendations

The asset has been ranked in Priority Group 2, see Section 12.

It is recommended that the areas of wall deformation and slope above are monitored using remote sensors and that regular visual monitoring is undertaken at 2 month intervals to note any further asset deterioration.

It is recommended that ground investigations and a slope stability analysis are undertaken to confirm ground properties, wall function, slope stability. The slope stability analysis should be conducted to confirm the overall stability of the bank (both local to the defects and throughout the length of the asset), and therefore whether the asset can potentially be de-risked.

Following these investigations, a decision can be made on the type of repairs to be conducted, as well as on access provisions, temporary works selection, and risk of a carriageway collapse.

When assessing potential design solutions for deformed sections of wall, special consideration should be given to the presence of tree roots in the immediate area of the defect. These roots may provide additional component of overall stability to the ground conditions, however, their growth and development may also exacerbate deformation of the structures present. It is advised that targeted tree removal, whose proximity to the wall is likely to be causing structural damage, should be undertaken provided that it does not result in a loss of stability of the slope. Any tree removal should be done in consultation with an arboriculturist and ecologist and provision for replacement planting to retain habitats will need to be considered.

8.5.1 Slipway Recommendations

If the client wishes to maintain access into the River Avon, it is recommended that the collapsed sections in the vicinity of the slipway be repaired (NCS18.A, NCS18.B and NCS18.D) before they deteriorate to a position that the slipway cannot be used safely. The recommended repair for these sections would be a potential combination of like for like masonry patch repairs and/or reinforced concrete patch repairs to stabilise the masonry. Appropriate ground fixings (subject to ground investigations) would be required to secure the concrete to the ground behind as the wall in these locations.

8.5.2 Slope Wall Recommendations

The repairs to the slope abutting wall are likely to consist of concrete patch repairs or the local demolition and reconstruction of the wall in concrete or masonry.

Note, that restoring the existing wall with like for like patch repairs is unlikely to comply with modern design codes for a retaining structure.

As an alternative to the above, slope stabilisation works could potentially be undertaken as an interim measure, mitigating the risks to the bank and adjacent infrastructure in the event of a wall failure. However, this would not protect the wall from progressive deterioration or washout of the bank material in the longer term (in the vicinity of wall failures).

9 NCS21 & NCS23

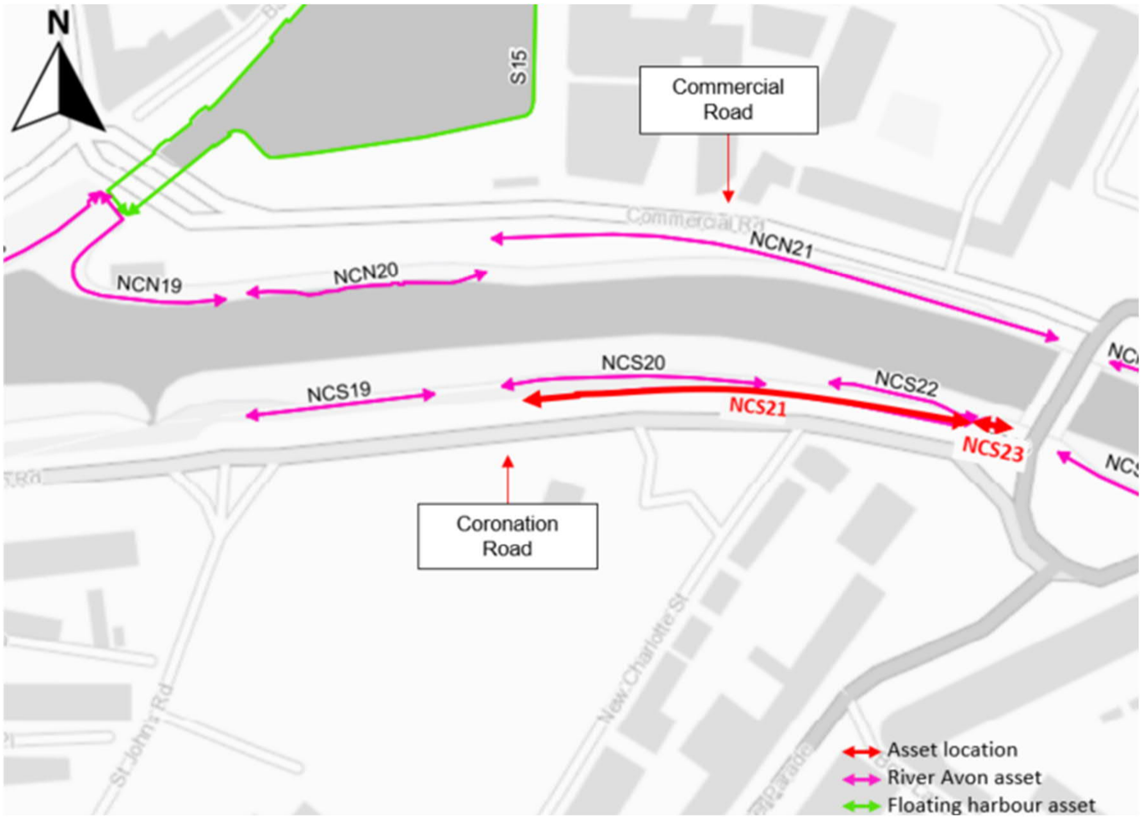
Due to the proximity of the assets NCS21 and NCS23, they have been reviewed together.

9.1 Background information

9.1.1 Asset Location

Assets NCS21 and NCS23 are located on the southern slope of the Avon River New Cut at National Grid reference, 358841, 172032. The assets are bound to the south by the A370, Coronation Road, which runs from east to west where it reaches Bedminster Bridge. A superstore is located approximately 50m south of the assets. The assets are surrounded by roads and buildings. Figure 9.1 shows the site location plan.

Figure 9.1: NCS21 & NCS23 Location plan



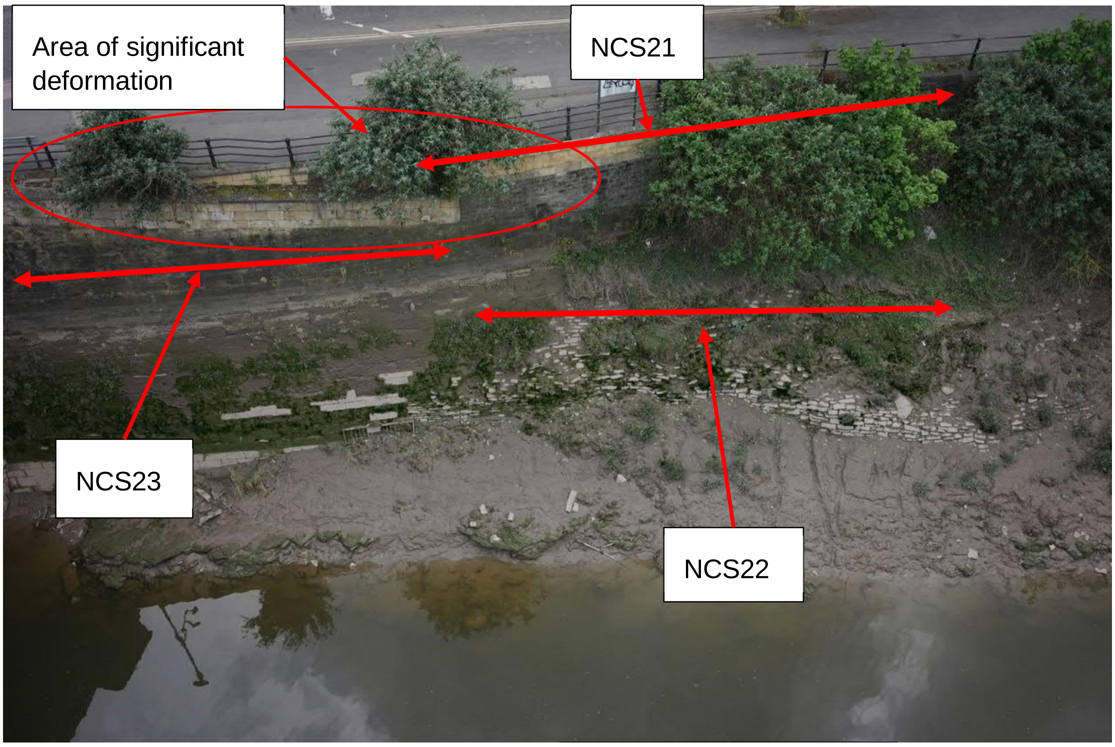
Source: Mott MacDonald

9.1.2 Asset Description

Assets NCS21 and NCS23 are masonry walls which are situated above the adjacent bridge wing walls and retain the bank to support the adjacent carriageway and pedestrian parapet. In the vicinity of the defects, the assets appear to be constructed in single leaf blockwork.

Located below these two assets is NCS22. It is in a critical condition and is providing an unknown level of support to NCS21 & NCS23. The arrangement of the three assets is shown in Figure 9.2.

Figure 9.2: NCS21, NCS22 & NCS23 Arrangement



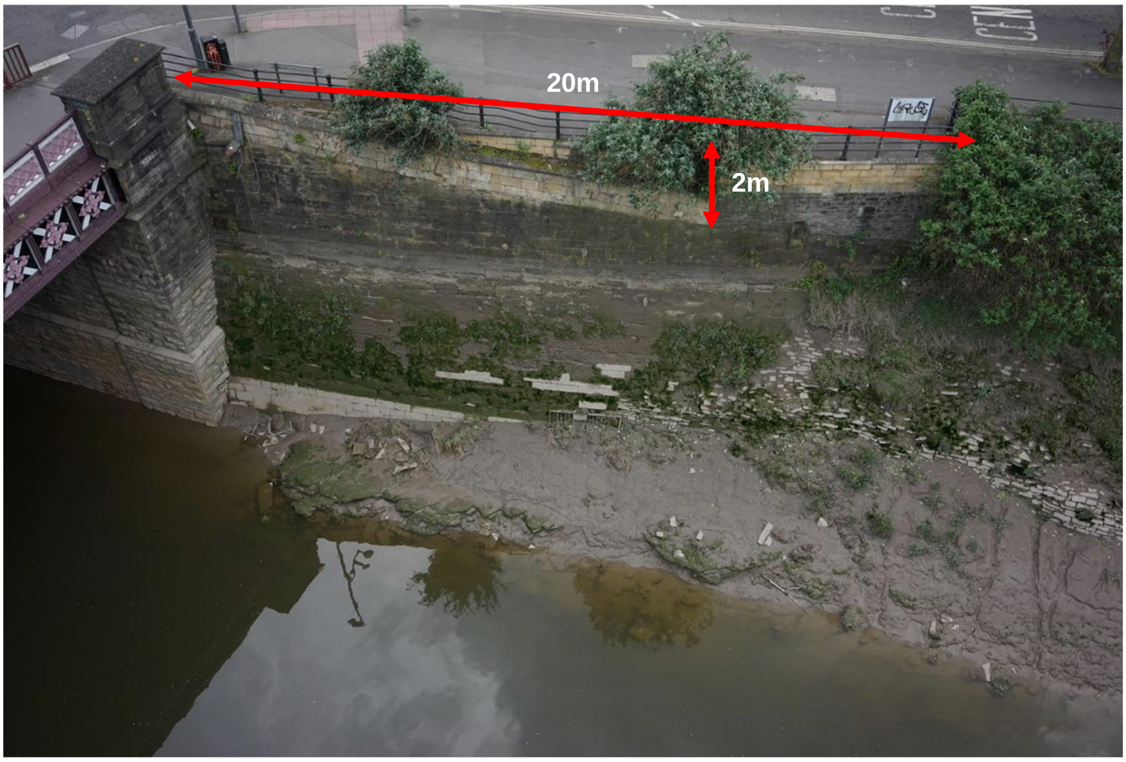
Source: Mott MacDonald 2019

9.1.3 Asset Defects

The critical sections are the deformed areas over a 20m length, situated along the top of the wall, shown in Figure 9.3. There is evidence of significant buddleia growth potentially causing the damage. These sections would be unlikely to resist a vehicle or concentrated pedestrian loading and sections of the wall are unstable. The defects can be seen in Figure 9.4, Figure 9.5 and Figure 9.6. Cracks are visible in the blockwork where the wall is leaning.

The footway is immediately behind the asset and Coronation Road is a 3m behind at its closest point. The level at the lowest point of the defect area is 9.2mAOD, the river is not anticipated to regularly rise to this level.

Figure 9.3: NCS21 & NCS23 Dimensions

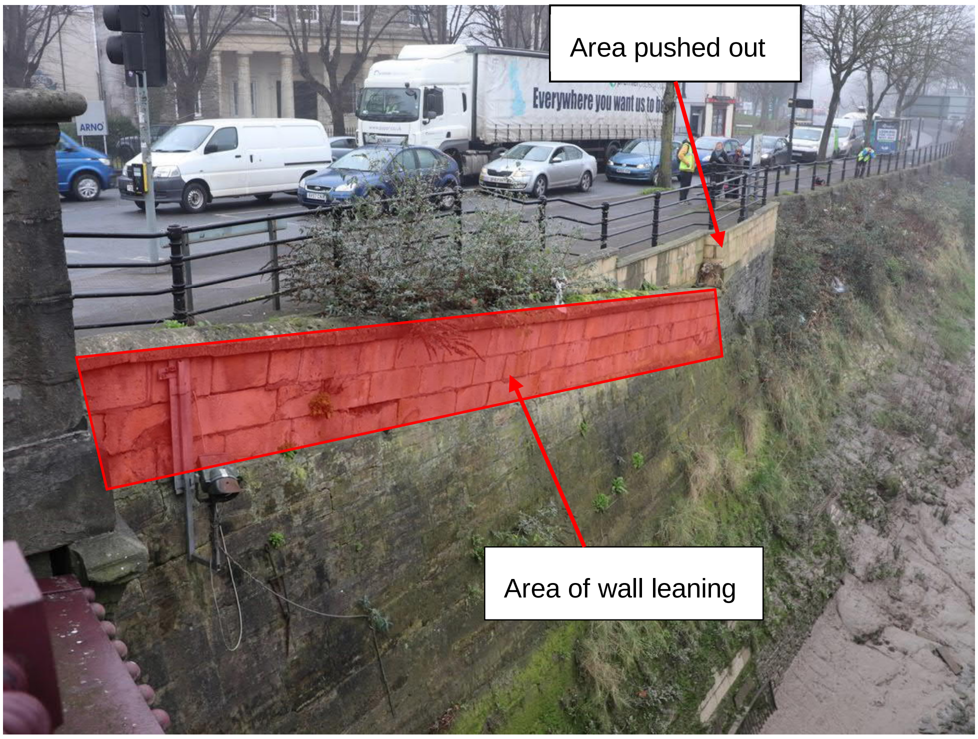


Source: Mott MacDonald 2019

Figure 9.4: NCS21 & NCS23 Wall deformation

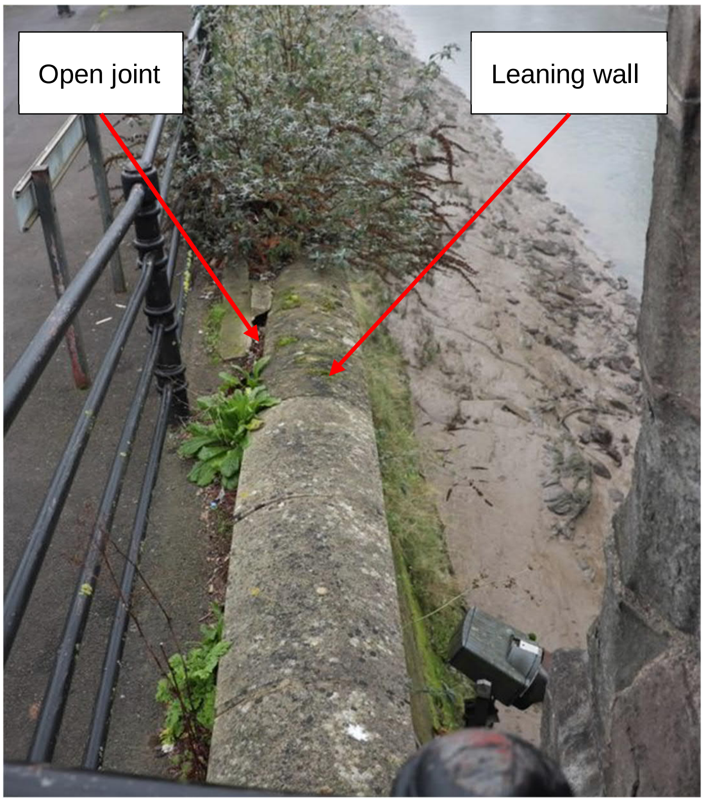
Source: Mott MacDonald, January 2022

Figure 9.5: NCS21 & NCS23 Defect area



Source: Mott MacDonald, January 2022

Figure 9.6: NCS21 Leaning wall



Source: Mott MacDonald, January 2022

9.1.4 Consequences of Asset Failure

In the event of a failure, there is likely to be a loss of support/collapse of the footway. As the critical area is at the top of the asset, and the footway is wide (minimum distance to carriageway is 3m), Coronation Road is unlikely to collapse because of the defect progressing, however buried highways infrastructure in the footway may be impacted.

The safety of the road users and load carrying capacity of the road would likely be reduced as a result, and load restrictions or a partial closure of Coronation Road may be necessary. There is likely to be significant travel disruption as Coronation Road is a main distribution route.

9.1.5 Historic Mapping

A review of historic mapping as undertaken to assess the use and development of the asset and surrounding land, allowing for a more holistic understanding of the asset. Table 9.1 presents a summary of history on site.

Table 9.1: NCS21 and NCS23 Summary of site history

Year	On site	Off site
1882	Asset is located on the south slope of the River Avon New Cut. Hatching indicative of brickwork is present 'Mud & Shingle' are labelled in the river	Bedminster Bridge is present, directly perpendicular to site, crossing the River Avon New Cut A tramway is marked that runs north to south, over Bedminster Bridge The area is dense with buildings north and south of the river The river is bound to the north and the south by unmarked roads
1883	No change	Commercial Road and York Road are now marked to the north and south of the river respectively
1881 to 1883 Published: 1887	No change	No significant change
1901 to 1902 Published 1905	No change	No significant change
1902 Published 1905	No change	No significant change
1912 to 1913 Published 1921	No change	The tramway is no longer marked on mapping
1913 Published 1921	No change	No significant change
1930, Published: 1933	No change	No significant change
1938 Published 1945	No change	No significant change
1938 Published 1947	No change	No significant change
1938 to 1955 Published 1955	No change	No significant change
1938-1963 Published 1964	No change	No significant change
1938-1967 Published 1967	No change	Bristol Bridge has been converted to a roundabout consisting of two bridges across the River Avon New Cut.

9.1.6 Geology

A review of BGS mapping [1] shows that Tidal Flat Deposits are likely to be present on site. BGS Lexicon [4] describes Tidal Flat Deposits as *"mud flat and sand flat deposits, [that] are deposited on extensive nearly horizontal marshy land in the intertidal zone that is alternately covered and uncovered by the rise and fall of the tide. They consist of unconsolidated sediment. Normally a consolidated soft silty clay, with layers of sand, gravel and peat"*.

The asset is likely found on bedrock of Redcliffe Sandstone Member. BGS Lexicon describes this as *"sandstone, distinctive fine- to medium-grained, deep red, calcareous and ferruginous. Commonly decalcified at shallow depths below the surface, giving rise to an uncemented sand".*

According to Geology of Bristol district: A brief explanation of the geological map 264 'Redcliffe Sandstone Formation' was deposited in an elongate depression between Bedminster and Winterbourne, and locally exceed 50m in thickness. The Redcliffe Sandstone passes laterally into red mudstones and is locally interdigitated with Mercia Mudstone Marginal Facies'. Redcliffe Sandstone Formation is exposed in the New Cut along Coronation Road, Southville.

A review of BGS Geoindex [2] shows that there are no locally availably boreholes to confirm ground conditions.

9.1.7 Mining

Bristol is known for it's past as a Coal Mining area. A review of the Coal Authority interactive tool [5] shows the site to not be located within an area of known or probable coal mining.

9.1.8 Ecological Constraints

A desk study was undertaken in January 2023. This involved a search for designated sites and habitats to identify potentially important ecological constraints at the Site. Data to inform the desk study was obtained from the following sources:

- Multi Agency Geographical Information for the Countryside (MAGIC) website (http://www.natureonthemap.naturalengland.org.uk/MagicMap.aspx);
- Joint Nature Conservation Committee (http://jncc.defra.gov.uk);
- OS maps; and
- Aerial imagery.

Based on aerial imagery and mapping the following habitats were identified within 30m of the asset:

- Coronation Road and pavement (developed land; sealed surface) present along the entire asset;
- Scattered deciduous trees within 30m of the asset;
- Scattered scrub growing from and against the asset; and
- Mudflats along the northern edge of the asset.

Two Habitats of Principal Importance, river and mudflat habitats, were identified within 30m of the asset. The asset lies within Avon New Cut Local Nature Reserve. Northern Slopes Local Nature Reserve was also identified within 2km of the Site. No sites designated for their international or national importance were identified within 2km of the site Four designated sites are hydrologically linked downstream of the Site. Table 9.2 below summarises the designated sites within 2km of the site or that are hydrologically linked.

Table 9.2: Designated sites within 2km or hydrologically linked downstream of the asset

Designated site name	Designation	Orientation and distance from the site at the closest point
Avon New Cut	Local Nature Reserve	On site
Northern Slopes	Local Nature Reserve	1.4km south
Avon Gorge Woodlands	Special Area of Conservation and Site of Special Scientific Interest	2.5km northwest and hydrologically linked

Designated site name	Designation	Orientation and distance from the site at the closest point
Horseshoe Bend	Site of Special Scientific Interest	6.5km northwest and hydrologically linked
Lamplighters Mash	Local Nature Reserve	7.5km northwest and hydrologically linked
Severn Estuary	Special Area of Conservation, Special Protection Area, Ramsar and Site of Special Scientific Interest	7.7km northwest and hydrologically linked

Source: MAGIC, 2023.

Based on the findings of the desk study, the following features have been identified as potential Important Ecological Features within the context of the site;

- Designated sites;
- Habitats of principal importance – river and mudflat habitat;
- Commuting, foraging and roosting bats;
- Nesting birds;
- Commuting otters; and
- Bony fish.

A full Preliminary Ecological Appraisal Report should be undertaken. Habitats should be classified using the UK habitats classification system. The report should include a Preliminary Roost Assessment of all trees and structures within 20m of the proposed works (Collins, 2016), a Habitat Suitability Index assessment of all waterbodies within 250m of the Site for great crested newts, and a walkover survey for invasive non-native plant species. This process may identify further ecological constraints as well as the need for further survey and mitigation measures.

A detailed habitat mitigation strategy should be developed to replace any habitats permanently lost as a result of the proposed works. The strategy would, as a minimum, replace lost habitat with habitats of the same or higher value. A Biodiversity Net Gain assessment can be used to quantify habitat value and should be undertaken to identify opportunities for biodiversity enhancement. .

A Habitat Regulations Assessment is recommended to advise on potential impacts of the proposed works on statutory designated sites downstream of the asset.

A Construction Environmental Management Plan will likely be required to set out the methods to ensure the environmental impact of construction is minimised. Finally, subject to the results of the further surveys, measures to minimise impacts on protected species should be included in a Reasonable Avoidance Measures Method Statement this should also include best practise measures and general construction safeguards.

9.1.9 Site Walkover

Site walkovers were completed in January 2022, June 2022 and September 2022, as well as the original drone survey in 2019.

During the January 2022 site walkover, it was clear that de-vegetation had been undertaken and tree stump plugs had been inserted into some of the buddleia. Images of the wall were obtained, and the wall appeared to be in a similar condition to 2019 where the upstream section was leaning forwards and the wall is being displaced.

During the June 2022 site walkover, no images were obtained. It was observed that at the base of the wall, weathered rock was visible which suggests the wall is founded on the rock.

There were areas of cracking along the wall and displacement of blockwork at the top. There is shrubbery growing in some of the cracks along the wall and vegetation growing out the top, in between the assets. The growth at the top of the asset was causing asset NCS21 to bow forwards.

During the September 2022 site walkover, some of the vegetation had regrown. Part of the wall shown in Figure 9.4 where the coping stones are missing was unstable. Images were obtained, and the wall appeared to be in a similar condition to the previous walkovers.

9.1.10 Drone Survey

In October 2022, a drone survey was completed of the asset. As shown in Figure 9.7, Figure 9.8, Figure 9.9 and Figure 9.10 the asset appears to be in a similar condition with no discernible changes to the face of the wall. There has been a loss of the copings shown in Figure 9.11 which occurred between the site walkover in January 2022 and the drone survey. The cause of this is unknown but given the condition appears similar across the remaining wall it is likely to have been as a result of vandalism.

Figure 9.7: NCS21 & NCS23 Wall deformation 2019

Source: Mott MacDonald 2019

Figure 9.8: NCS21 & NCS23 Wall deformation 2022

Source: Mott MacDonald, October 2022

Figure 9.9: NCS21 & NCS23 Leaning wall 2019

Source: Mott MacDonald 2019

Figure 9.10: NCS21 & NCS23 Leaning wall 2022

Source: Mott MacDonald, October 2022

Figure 9.11: NCS21 & NCS23 Lost copings

Source: Mott MacDonald, January 2022

9.1.11 NCS21 and NCS23 Summary

From the site visits, it is clear that the deformation of the wall and local masonry failure will require remediation. This is anticipated to be through the removal and reconstruction of asset throughout the entire area highlighted in Figure 9.5 and potentially to a greater extent. It is unlikely that the existing wall meets current design standards and as such it is not recommended to replace like for like unless additional mitigations (to reduce potential surcharge loads etc.) are considered. The failed length (that is leaning outwards) is a safety risk and warrants demolition and rebuild, by which point the entire asset should likely be replaced.

Vegetation removal will be required to complete works and an ecologist should be consulted prior to removal being undertaken. Care should be taken to not remove disturb the wall and facilitate a collapse.

Due to the nature of the defects and potential causes of sudden failure modes (e.g., vehicle loading, concentrated pedestrian loading, or a significant saturation event in the carriageway), it is recommended that the area in the vicinity is closed off and that the wall is repaired at earliest convenience.

A failure of the asset would require the closure of the footway and potentially Coronation Road while the extent of damage was being assessed, with potential long-term closures to follow.

9.2 NCS21 and NCS23 Monitoring

The defect area as highlighted in Figure 9.5 is significantly deformed and should be regularly monitored for additional movement.

There are several options for the monitoring of NCS13, these include:

- Regular visual monitoring with long lens photographs.
- Surveying with total station.
- Laser scanning.
- Real-time monitoring with sensor system.

Further details of these monitoring techniques can be found in Section 2.

In this instance, it is recommended that the asset is monitored visually at monthly intervals.

Regular visual monitoring will enable a visual record of the asset to be collated and pick up any further changes to the wall structure.

The other listed options could be considered; however, they are not deemed to be essential for this asset.

9.3 NCS21 and NCS23 Ground Investigations

Ground investigations will determine ground properties and wall function. It is anticipated that the investigations for the asset will consist of:

- 2No. Boreholes.
- Slit trench behind and perpendicular to the top of the wall to understand wall construction methodology.

9.4 NCS21 and NCS23 Repair Options

There is one primary repair method which should be considered for the asset repair. This method will stabilise the wall and footpath in the region local to the defect.

- Demolish failed section and replace with reinforced concrete retaining wall.

There would also be the possibility of demolishing the failed section of wall and reconstructing in masonry, however, this is unlikely to meet current design standards and would not be the recommended approach, particularly if the pavement above remains open to vehicles.

9.4.1 Safety Concerns

There are concerns over the stability of the wall and the parapet foundations, it is unknown whether they would be able to resist a vehicle loading, concentrated pedestrian loading, or a significant saturation event in carriageway (e.g., burst water main). Steps should be taken to prevent vehicle and pedestrian access to the pavement above the asset to reduce the risk of triggering a collapse.

Previous concerns have been raised to BCC regarding this section of wall, it was raised during the initial project through the reporting of assets in a serious or critical condition. Additionally, advise was given to cordon off the area in the Asset Prioritisation Report.

If the wall were allowed to continue to fail, there is also a risk to the parapet foundations.

9.4.2 Demolish Failed Section and Replace with Reinforced Concrete Retaining Wall

To repair the deformation in a way which would meet current design standards, the failed section should be demolished and be replaced with a reinforced concrete retaining wall. This would require excavations into the footpath and possibly beyond into the carriageway, which would require reinstatement.

To aid with construction times and to reduce disruption to the public, a precast solution could be sought, this would be subject to contractor engagement.

The lower section of wall would need to be assessed to determine whether it would be able to support the weight of the new structure constructed above.

An additional consideration is the appearance of the new wall. The adjacent bridge (Bedminster Bridge) is Grade II listed and the new wall would be subject to planning permissions. As a potential solution, the original masonry once removed, could be clad onto the concrete wall to restore the appearance. Alternatively, masonry cladding, more in keeping with the stonework below could be clad onto the wall.

9.4.3 Deconstruct Failed Section and Like For Like Reconstruction

This method would entail the removal of vegetation, wall deconstruction, and reinstatement like for like in masonry blockwork.

As a like for like reinstatement is unlikely to adhere to modern design standards and loading, additional mitigations to reduce potential surcharge loadings would be necessary, such as bollards and/or barriers to prevent vehicular access. However, this would not address concentrated pedestrian loading.

The benefits of this methodology would come from a reduced requirement for ground investigations, reduced material costs, the ability to undertake the repair within BCC, and reduced design input in comparison to a new reinforced concrete retaining wall.

This is not the option recommended by Mott MacDonald as it is unlikely to meet design standards or be as robust as a new reinforced concrete retaining wall. However, due to potential cost and time savings, it is understood that it may be considered by BCC and therefore the associated risks should be considered.

9.5 NCS21 and NCS23 Recommendations

The asset has been ranked in Priority Group 1, see Section 12.

It is recommended that the existing failed length of wall is demolished and replaced with a new reinforced concrete retaining wall structure as a priority. The following actions should be enacted while a repair strategy is being finalised:

- Prior to remedial works, steps should be taken to prevent vehicle and pedestrian access – such as fencing, bollards, barriers, etc.
- Regular visual monitoring at monthly intervals should be undertaken to watch for any further changes to the asset.
- Regular vegetation clearance should be maintained in the vicinity of the defect with advice from an ecologist and landscape architect sought regarding a suitable management regime. Care should be given not to cause excessive movement of the wall, risking a collapse.

Note, there is potential for bat roosting and an ecologist should be consulted prior to any work being undertaken.

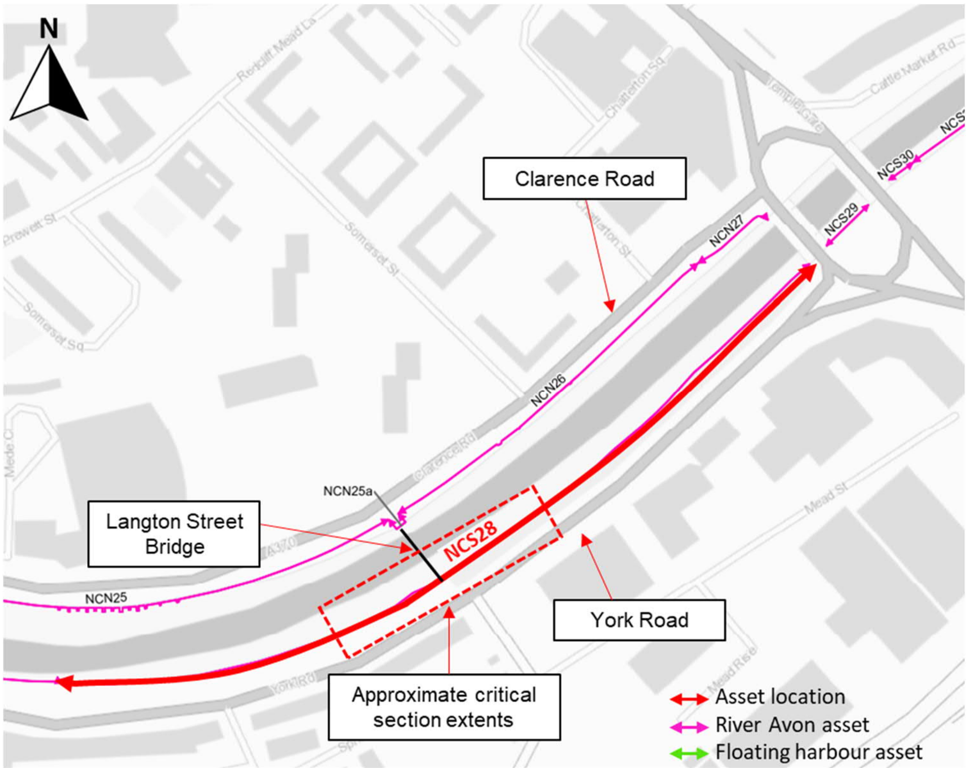
10 NCS28

10.1 Background information

10.1.1 Asset Location

Asset NCS28 is a masonry wall located on the south slope of the River Avon New Cut at approximate Eastings and Northings 359631, 172150.The asset is adjacent to the Bath Bridge roundabout that joins the A370, which bounds the asset and the A4. The A4 leads to Temple Meads station which is approximately 300m northeast of the asset. A train line runs from Temple Meads Station and follows a similar alignment to the A370 road, offset 200m due south, before moving behind the area of Bedminster. South of the A370 lies a petrol garage and a motor bike garage.

Figure 10.1: NCS28 Location plan



Source: Mott MacDonald

10.1.2 Asset Description

The exact makeup of the asset is unknown due to a lack of record information; however, it is believed to generally be a dry-stone wall that acts as both a retaining wall and a facing wall throughout its length. The asset is 485m long, however, the area of concern with regards to this project is a 100m section adjacent to Langton Street Bridge. This section is fronted by significant sediment build up in front of the wall. There are 13 No. buttresses over the critical 100m length.

There are several areas of substantial masonry loss and extensive globally deformed sections, particularly in the vicinity of Langton Street Bridge. The asset is generally in a poor condition along the entire length with extensive mortar loss. It is noted that there is a failure of a Wessex Water outfall pipe slightly upstream of the Langton Street Bridge which may have been caused by displacement of the wall. Langton Street Bridge is approximately in the middle of the asset and crosses the River Avon. The bridge is a Grade II listed structure which requires protections and permission to remediate.

Figure 10.2: NCS28 Aerial image (c.1930)

Source: Bristol Archives catalogue

10.1.3 Asset Defects

The critical area of the asset is an approximate 100m section centred at the Langton Street Bridge, see Figure 10.3. There are numerous areas of deformation, with open joints and pointing loss. These areas can be seen in Figure 10.4 and Figure 10.9.

Using historic google street view images (not available for a commercial report), it appears that the foundation of the buttress marked in Figure 10.9 has failed and that this section of wall has deteriorated / deterioration has accelerated over the last 10-15years. However, it is unclear whether the buttress failure is causing the global deformation in this section of wall, or because of the deformation.

There are depressions in the fill located behind the wall. These are likely as of a result of sediment washing through the wall after the river overtopping the wall or rainfall events.

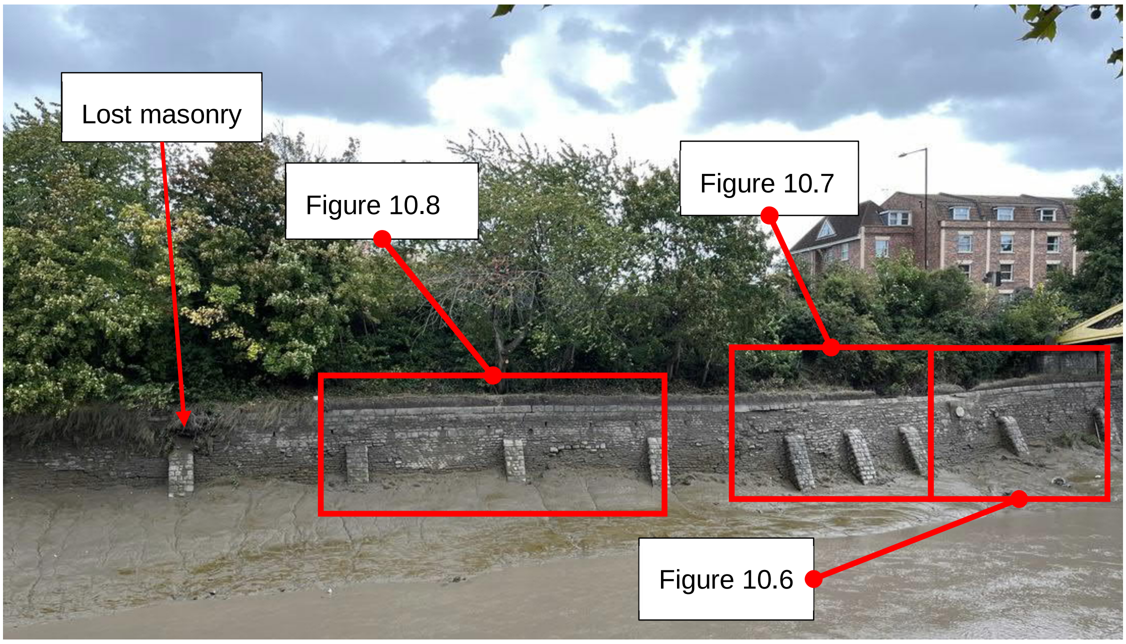
Below the upstream outfall, there has been a failure at the toe of the wall where masonry has been lost. There is an open joint rising up the wall originating in the vicinity of the lost masonry and extending approximately halfway to the outfall pipe, this is shown in Figure 10.13. It is not known whether the displacement of the wall caused the outfall pipe failure or vice versa.

The toe of the wall in the area shown in Figure 10.3 varies but is approximately 3.5mAOD. The river level is anticipated to regularly rise above this level.

Figure 10.3: NCS28 Area of concern

Source: Mott MacDonald, September 2022

Figure 10.4: NCS28 Upstream area of deformation

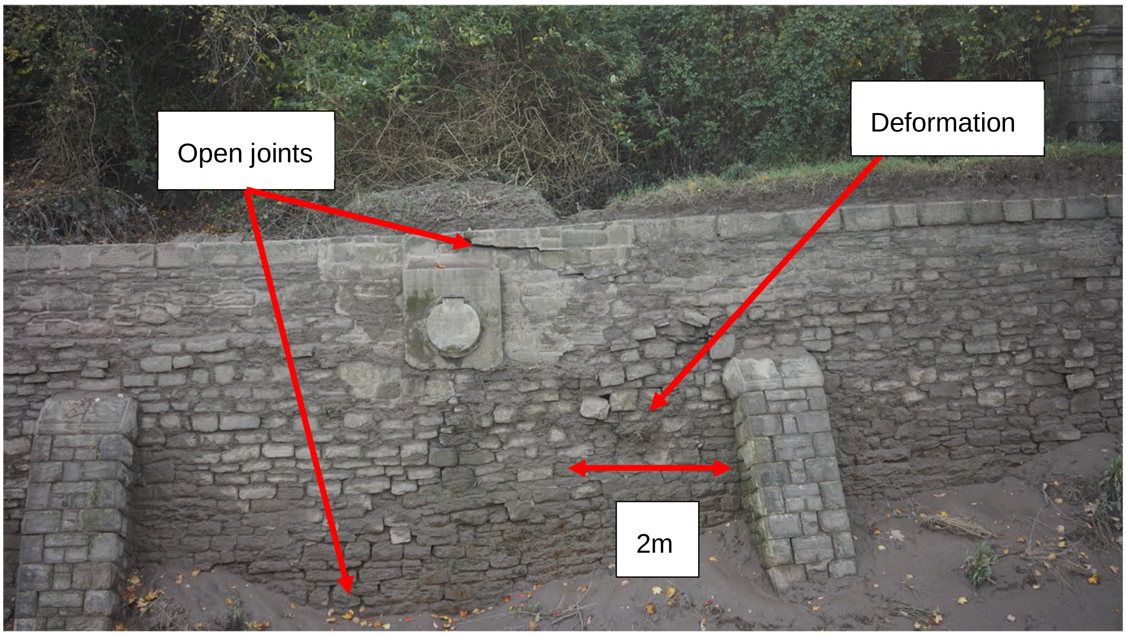


Source: Mott MacDonald, September 2022

Figure 10.5: NCS28 Upstream area of deformation view from bridge

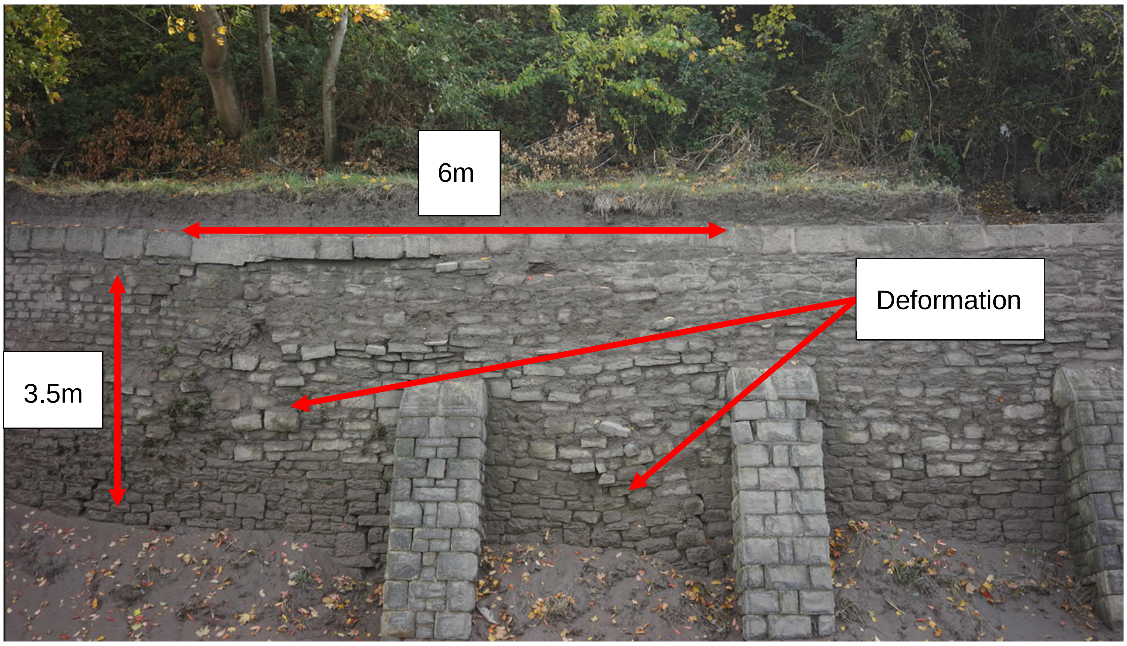
Source: Mott MacDonald, September 2022

Figure 10.6: NCS28 Upstream defects 1



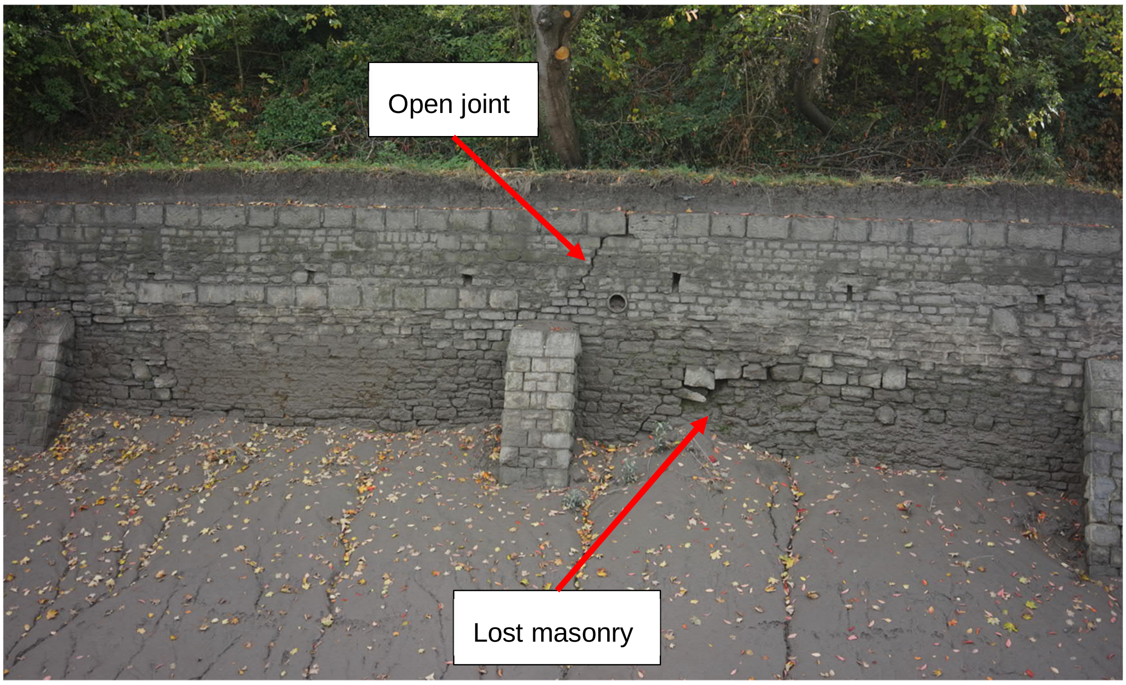
Source: Mott MacDonald, October 2022

Figure 10.7: NCS28 Upstream defects 2



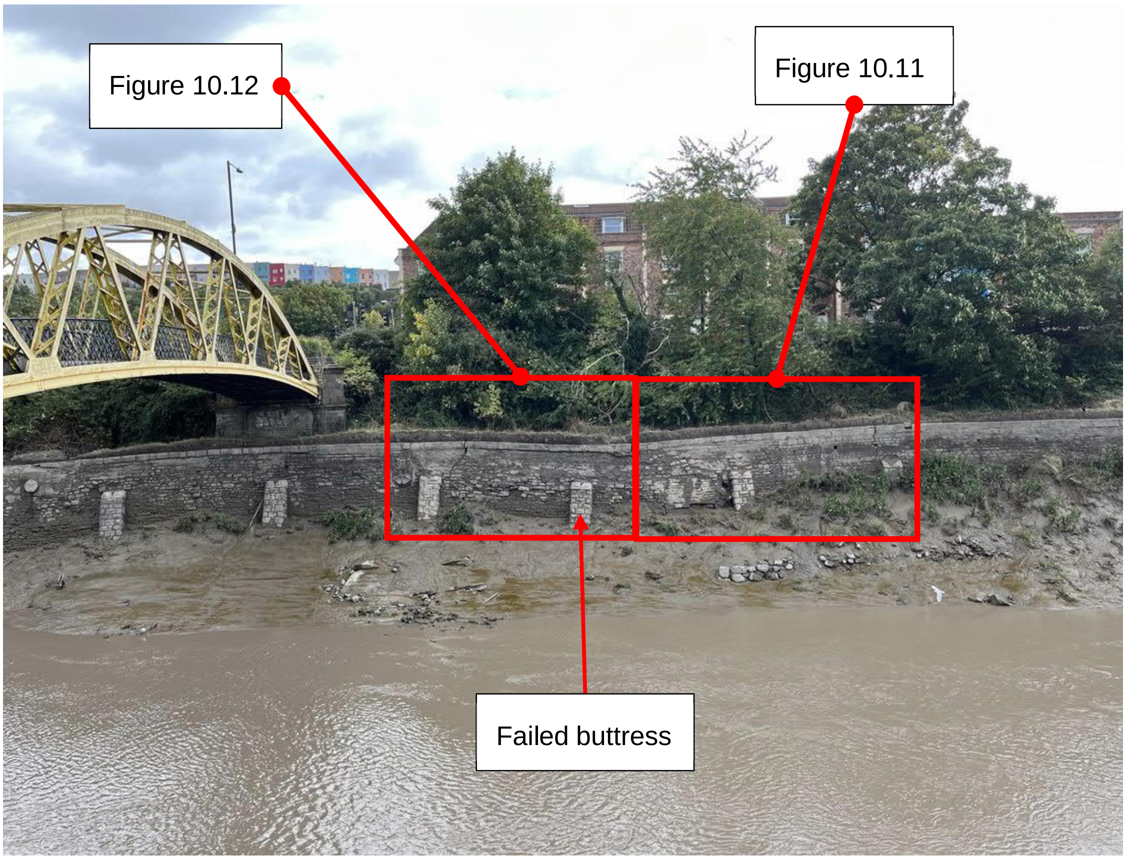
Source: Mott MacDonald, October 2022

Figure 10.8: NCS28 Upstream defects 3



Source: Mott MacDonald, October 2022

Figure 10.9: NCS28 Downstream area of deformation



Source: Mott MacDonald, September 2022

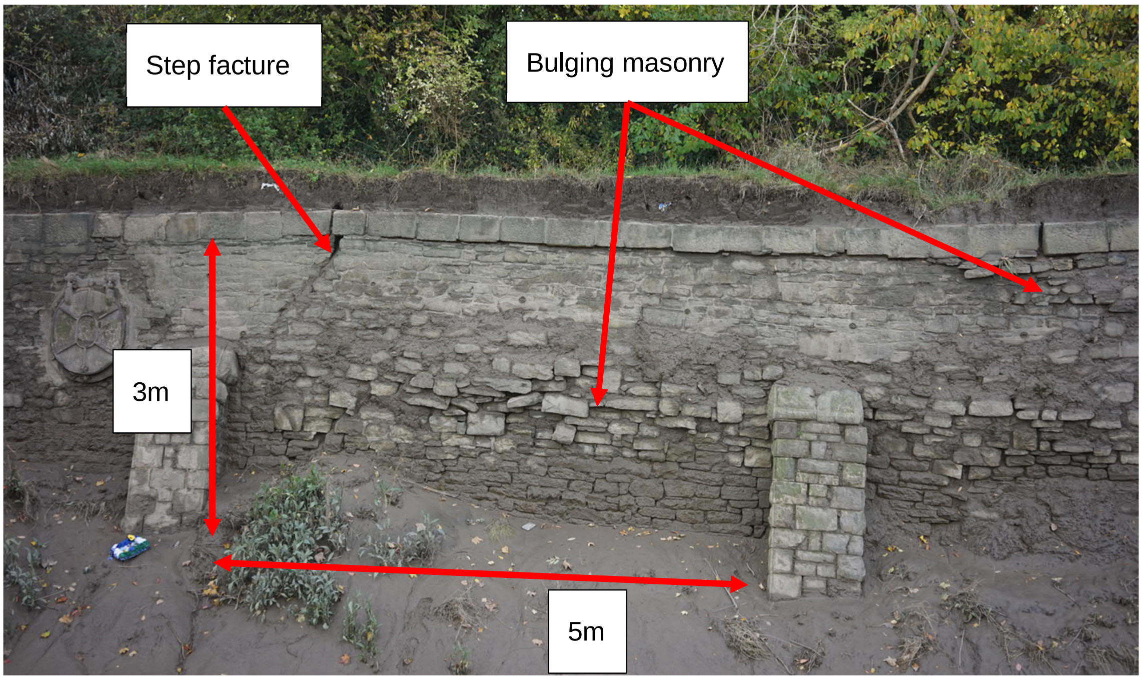
Figure 10.10: NCS28 Downstream area of deformation view from the bridge

Source: Mott MacDonald, September 2022

Figure 10.11: NCS28 Downstream defects 1

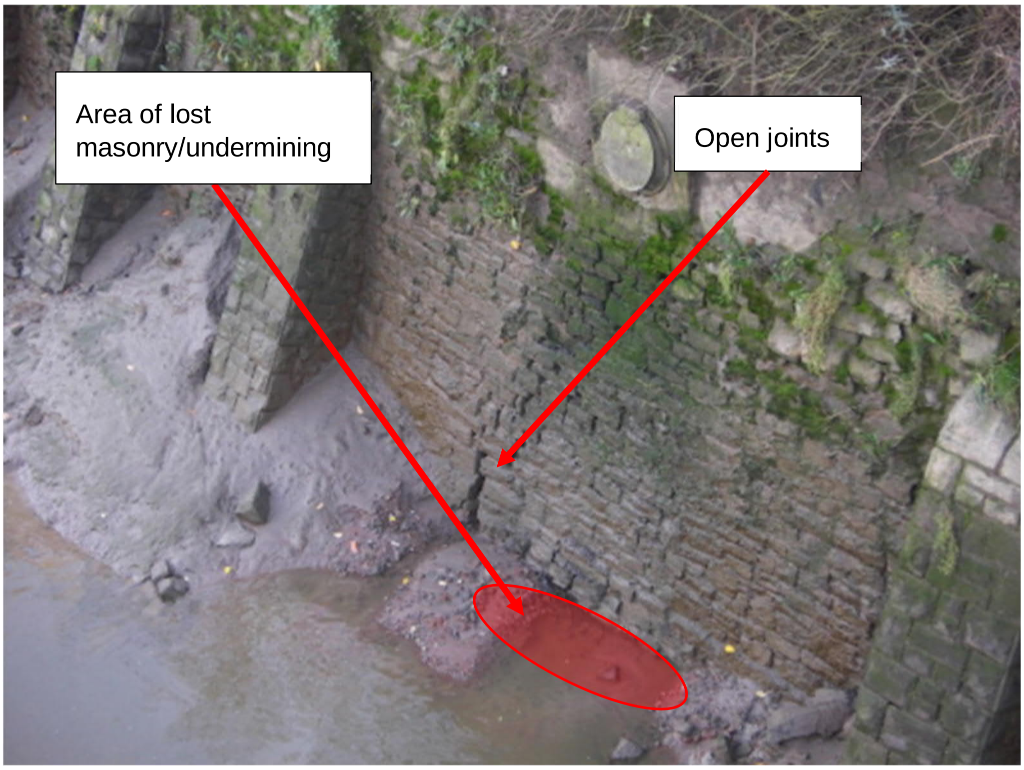
Source: Mott MacDonald, October 2022

Figure 10.12: NCS28 Upstream defects 2



Source: Mott MacDonald, October 2022

Figure 10.13: NCS28 Failure below outfall



Source: Bristol City Council

10.1.4 Historic Drawings

Contained within the Langton Street Bridge Conservation Statement [912] are historic drawings of the bridge. These drawings are not as-built drawings, and there are differences between the drawing and the approach parapets, so the accuracy of them cannot be relied upon. Based on scaling the drawings, which is also not reliable, the bottom of the abutment foundation could be at a depth of 16m from the top of the capping stone, this implies that the foundation could be approximately 6.5m below the current sediment level against the wall. The depth of the wall and wall foundation is not shown in the drawings.

10.1.5 Consequences of Asset Failure

If the asset fails in the critical area shown in Figure 10.3, there is the potential for a loss of support to the bridge abutment and the potential destabilisation/collapse of the bridge. There is also a risk of a loss of support to the area behind the asset resulting in a potential collapse of the footway and York Road.

If this were to occur, there would be significant reputation damage at the loss of Grade II listed Langton Street Bridge, and there would be major travel disruption as York Road is a main distribution route.

10.1.6 Historic Mapping

A review of historic mapping was undertaken to assess the use and development of the asset and surrounding land, allowing for a more holistic understanding of the site. Table 10.1 presents a summary of history on site.

Table 10.1:NCS28 Summary of site history

Year	On site	Off site
1881-1882, published 1885	River Avon (New Cut) present York Road bounds the New Cut southern slope Clarence Road bounds the New Cut northern slope	Bath Bridge adjacent west of site Temple Tramway present over Bath Bridge running north to south of site Temple Gate Works north east of site Temple station north of site Housing developments around site Unnamed depot south of site, later named Pylle Hill Goods Depot
1902	No change	Temple Station now labelled as Temple Meads Joint Station
1912 Published 1918	No change	No significant change
1930 Published 1933	No change	No significant change
1938 Published 1945	No change	No significant change
1938 Published 1946	No change	No significant change
1938 Published 1947	No change	No significant change
1938 Published 1955	No change	Temple Meads Joint Station now labelled as Temple Meads Station
1938-1963 Published 1964	No change	Bath Bridge has been converted into a roundabout
Present day	No change	St Mary Redcliffe and Temple School replaced buildings and located directly north west of the asset

10.1.7 Geology

A review of BGS mapping [1] shows that Tidal Flat Deposits are likely to be present in the area. BGS Lexicon [4] describes Tidal Flat Deposits as *"mud flat and sand flat deposits, [that] are deposited on extensive nearly horizontal marshy land in the intertidal zone that is alternately covered and uncovered by the rise and fall of the tide. They consist of unconsolidated sediment. Normally a consolidated soft silty clay, with layers of sand, gravel and peat"*.

The asset lies on the boundary between Mercia Mudstone *Group and Redcliffe Sandstone Member. BGS Lexicon describes Mercia Mudstone Group as "dominantly red, less commonly green-grey, mudstones and subordinate siltstones with thick halite-bearing units in some basinal areas. Thin beds of gypsum/anhydrite widespread; sandstones are also present"*. Redcliffe Sandstone Member is described as *"distinctive fine- to medium-grained, deep red, calcareous and ferruginous [SANDSTONE]"*.

According to Geology of Bristol district: A brief explanation of the geological map 264 [2] 'Redcliffe Sandstone Formation' was deposited in an elongate depression between Bedminster and Winterbourne, and locally exceed 50m in thickness. The Redcliffe Sandstone passes laterally into red mudstones and is locally interdigitated with Mercia Mudstone Marginal facies'. Redcliffe Sandstone Formation is exposed in the New Cut along Coronation Road, Southville.

A review of BGS Geoindex [2] shows that there are no locally availably boreholes to confirm ground conditions.

10.1.8 Mining

Bristol is known for it's past as a Coal Mining area. A review of the Coal Authority interactive tool [5] shows that the asset is located in a general coal mining area, however, it is not within an area of known or probable shallow coal workings, nor is there a coal stream nearby. Therefore, Coal Mining is unlikely to affect the asset or asset repairs.

10.1.9 Ecological Constraints

An ecological walkover survey was undertaken on 29 June 2022 by Mott MacDonald ecologists. The survey consisted of a walkover of the asset and a 30m buffer, where access permitted. The purpose of the survey was to identify the ecological constraints and risks of works. A summary of the Ecological Constraints Assessment produced following this survey is provided below.

Listed below are the habitats that were identified within the survey buffer;

- Semi-natural deciduous woodland, present in a 20m wide strip along the entire asset;
- Dense patches of mixed scrub and introduced shrub present along the edge of the asset closest to Coronation Road;
- Semi-improved grassland growing on a 2m wide strip along the masonry wall edge closest to the river; and
- Mudflats are present directly underneath the masonry wall along the river edge.

In line with policy and best practice, avoidance measures should be embedded into the design of the works. The following avoidance measures were identified;

- Works within the river and mudflat Habitats of Principal Importance should be avoided;
- Where possible trees and other vegetation should be retained;
- Artificial lighting should be avoided during the construction and operational phases of the development;
- Obstructions to the watercourse and riverbanks should be avoided during the construction and operational phase;
- Any retained trees should be assessed by an appropriately qualified arboriculturist to determine root protection areas and any exclusion zones required to mitigate for damage during demolition and construction; and
- If possible, the site compound should be situated at least 16m away from the river and riverbanks, if this is not possible, permission would be required from the Environment Agency.;

Table 10.2 below summarises the identified ecological constraints and the preliminary mitigation and/ or compensation recommendations.

Table 10.2: Ecological constraints and mitigation/compensation recommendations

Feature	Location description	Preliminary mitigation and/or compensation recommendations
Designated sites	Avon Gorge Woodlands Special Area of Conservation and Site of Special Scientific Interest, Horseshoe Bend Site of Special Scientific Interest, and Severn Estuary (Special Area of Conservation, Special Protection Area, RAMSAR and Site of Special Scientific Interest downstream of the Site. Avon New Cut Local Nature Reserve on site.	A Habitat Regulations Assessment is recommended. The county ecologist should be consulted regarding the proposed works within the Avon New Cut Local Nature Reserve.

Feature	Location description	Preliminary mitigation and/or compensation recommendations
Habitats of principal importance	River and mudflats within the site	The county ecologist should be consulted at the earliest opportunity if the habitats of principal importance are anticipated to be impacted to discuss the working methodology as well as any compensation, enhancement or restoration work.
Bats	Most trees on the asset offer low to moderate potential to support roosting bats due to the presence of potential roosting features and thick ivy cover	Night-time working should be avoided. A toolbox talk regarding bats should be given to all site personnel.
Reptiles	The scrub and grassland habitats within the riverbank offer suitable habitat for common reptiles	If any habitat removal affecting potential hibernacula (such as log piles or root systems) is required, this should occur during the reptile active season (April – October inclusive, depending on the weather) under supervision of an ecologist. Vegetation clearance should follow phased cuts in a directional manner to allow dispersal of active reptiles to neighbouring habitats. A toolbox talk regarding reptiles should be given to all site personnel.
Nesting birds	The scattered trees, scrub and rough grassland provide suitable habitat for nesting birds. A nest was also observed on one of the trees, although it was deemed unactive at the time of the survey	Vegetation clearance of habitat suitable for nesting birds should be undertaken outside of the nesting season (between March and August inclusive) in line with standing government guidance. If this is not possible, vegetation will need to be checked by an ecologist no more than 24 hours prior to removal. The feasibility of nesting bird checks will be subject to the judgement of a suitably qualified ecologist, who will determine whether the vegetation to be cleared can be safely and adequately searched.
Bony fish	The River Avon New Cut has potential to be used by different species of bony fish (including European eel) for commuting and foraging	Should the scope of works include significant disturbance that could impact fish, such as high noise and vibration levels, works may need to be timed to avoid fish migration periods. A toolbox talk regarding fish should be given to all site personnel.
Otters (*Lutra lutra*)	The River Avon New Cut has potential to be used by commuting and foraging otters	No mitigation or compensation measures specific to otters identified.

Source: Mott MacDonald, 2022.

Further ecological surveys are recommended due to the potential for protected and notable species in the area. A full Preliminary Ecological Appraisal Report should be undertaken. Habitats should be classified using the UK habitats classification system. The report should include a Preliminary Roost Assessment of all trees and structures within 20m of the proposed works (Collins, 2016), a Habitat Suitability Index assessment of all waterbodies within 250m of the Site for great crested newts, and a walkover survey for invasive non-native plant species. This process may identify further ecological constraints as well as the need for further survey and mitigation measures.

A detailed habitat mitigation strategy should be developed to replace any habitats permanently lost as a result of the proposed works. The strategy would, as a minimum, replace lost habitat with habitats of the same or higher value. A Biodiversity Net Gain assessment can be used to quantify habitat value and should be undertaken to identify opportunities for biodiversity enhancement.

A Construction Environmental Management Plan will likely be required to set out the methods to ensure the environmental impact of construction is minimised. Finally, subject to the results of the further surveys, measures to minimise impacts on bats, fish, otters and reptiles should be included in a Reasonable Avoidance Measures Method Statement this should include best practise measures and general construction safeguards.

10.1.10 Site Walkover

Site walkovers were completed in January 2022, June 2022 and September 2022, as well as the original drone survey in 2019.

During the January 2022 site walkover, there was extensive vegetation coverage at the top of the wall. Images were captured at this time and the asset appeared in a similar condition to 2019.

During the June 2022 site walkover, due to vegetation and foliage coverage, no site observations were made.

During the September 2022 site walkover, vegetation clearance had taken place, and this enabled a full view of the wall. The wall looked to be in a worse condition than 2019, however, this could have been due to better coverage (full vegetation clearance had not taken place in 2019). Open joints were more exposed and visible, areas of deformation were less hidden behind vegetation. There were depressions visible behind the wall, both upstream and downstream of the bridge. There was pooled water visible in the depressions upstream of the bridge, see Figure 10.14. Water was seen discharging from the outfall.

Figure 10.14: NCS28 Upstream depressions behind wall

Source: Mott MacDonald, September 2022

10.1.11 Drone Survey

In October 2022, a drone survey was completed of the asset. Changes between Figure 10.15 and Figure 10.16 show a small amount of masonry loss adjacent to a buttress. There are minor changes between Figure 10.21 and Figure 10.22, the joint between blocks on one buttress appears to have widened and there is a new crack through a block on another buttress. The remaining length of wall within the critical area appears to be in a similar condition to how it was in 2019. There does not appear to have been any further loss of masonry, opening of joints, and the deformed sections appear in similar positions. However, it is difficult to determine changes as there was extensive vegetation growth covering sections of masonry during the 2019 survey as shown in the images. Deterioration appears to be ongoing but at a slow rate between 2019 and 2022.

Figure 10.15: NCS28 Wall deformation 2019

Source: Mott MacDonald 2019

Figure 10.16: NCS28 Wall deformation 2022

Source: Mott MacDonald, October 2022

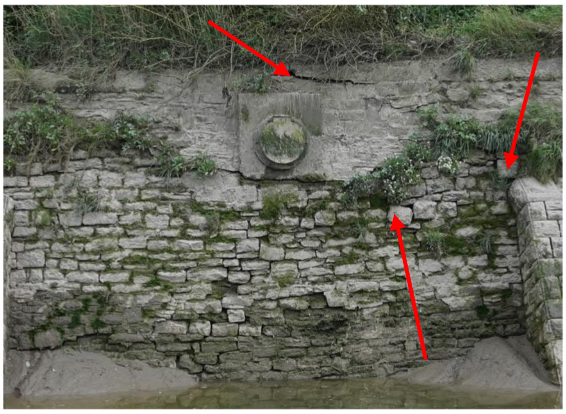
Figure 10.17: NCS28 Open joint 2019

Source: Mott MacDonald 2019

Figure 10.18: NCS28 Open joint 2022

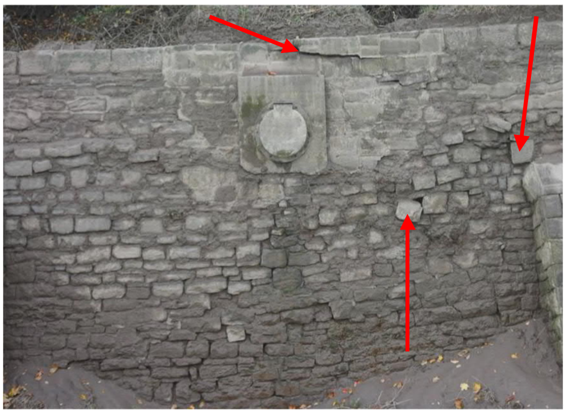
Source: Mott MacDonald, October 2022

Figure 10.19: NCS28 Outfall area 2019



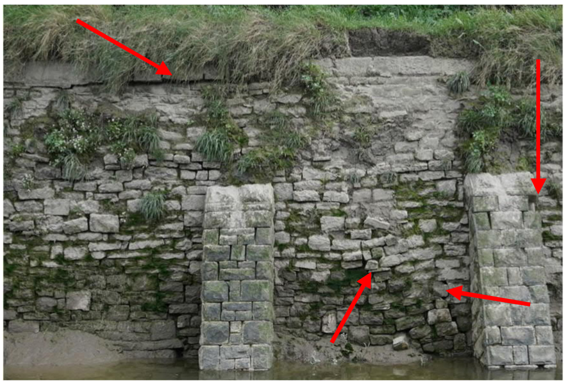
Source: Mott MacDonald 2019

Figure 10.20: NCS28 Outfall area 2022



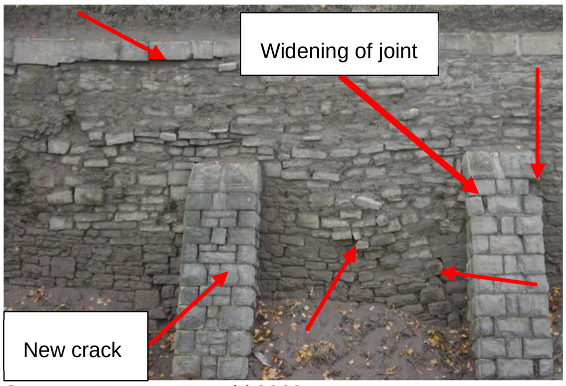
Source: Mott MacDonald, October 2022

Figure 10.21: NCS28 Wall deformation 2 2019



Source: Mott MacDonald 2019

Figure 10.22: NCS28 Wall deformation 2 2022



Source: Mott MacDonald 2022

10.1.12 NCS28 Summary

Within the critical area, NCS28 has significant areas of global and local deformation. There are several step factures/open joints, as well as lost masonry, and pointing loss. The buttress marked in Figure 10.9 has apparently failed, potentially of inadequate foundations, this means the other buttresses in the area may also have inadequate foundations.

Without an understanding of the outfall pipe failure and the volume of water it carries, it is difficult to determine whether it will contribute towards a wider asset collapse. This should be further investigated using a CCTV survey. There is the potential for a build-up of water pressure behind the wall leading to a sudden failure.

There is a risk that the wall is providing lateral restraint in front of the southern bridge abutment and that a failure would destabilise the abutment.

The ground conditions in the vicinity of the asset are currently unknown, but it is anticipated that the asset is a retaining wall and is providing a supporting function to the fill behind it.

10.2 NCS28 Monitoring

In the vicinity of Langton Street Bridge, the asset exhibits several large open joints, fractures, and significant areas of deformation.

There are several options for the monitoring of NCS28, these include:

- Regular visual monitoring with long lens photographs.
- Surveying with total station.
- Laser scanning.
- Real-time monitoring with sensor system.

Further details of these monitoring techniques can be found in Section 2.

In this instance, it is recommended that the asset is monitored using a combination of regular visual monitoring at monthly intervals and real-time monitoring.

Regular visual monitoring will enable a visual record of the asset to be collated and pick up any further significant changes to the wall structure, such as the loss of discreet masonry blocks. Visual monitoring will not pick up gradual movement or subtle changes.

Real-time monitoring with a sensor system could be installed as this will be unimpacted by any environmental conditions and will provide accurate monitoring of any slope or wall movement. Real-time monitoring is expected to be of most use as it will give a picture of how the structure behaves under different conditions.

It would also be advised that Langton Street Bridge is monitored for movement using sensors, this would allow the correlation of data and to help understand the relationship between the bridge, the wall/bank, and any impact of differing real time conditions.

The other listed options could be considered; however, they are not deemed to be essential for this asset.

In addition to monitoring the wall, CCTV surveys of the two outfalls, and a functionality check of the flap valves should be undertaken.

10.3 NCS28 Ground Investigations

Ground investigations will determine ground properties and wall function. It is anticipated that the investigations for the asset will consist of:

- 8No. Boreholes (2No. required to confirm ground behind and around the footbridge area).
- 2No. Hand Pits

There is possibly scope for a trial pit adjacent to the bridge abutment to confirm foundation depth. However, this is likely to require significant temporary works and may be unnecessary depending on repair/reconstruction choice.

10.4 NCS28 Repair and Reconstruction Options

Due to the condition of the asset, the apparent modes of failure, and the significant degree of deformation, the reconstruction or replacement of the wall is recommended rather than a repair.

At the present moment, only a high-level option can be evaluated due to a lack of knowledge about the original modes of failure. From images gathered and outlined in the previous sections it appears that there are several modes of failure with the vicinity of the bridge.

The working environment presents a challenge, as the structure is still retaining a significant amount of fill and the deconstruction of the wall could cause a slope failure, leading to a collapse of the York Road footpath or carriageway. As such, ground investigations should inform the requirements for plant access (e.g., piling to create a working environment)

These considerations leave a few options such as:

- Piling behind the existing wall and allow the masonry wall to deteriorate.
- Piling behind the existing wall and undertake like for like masonry repairs of damaged sections.
- Construction of a replacement concrete retaining wall structure (likely on piled foundations).
- Wailing beam and anchors system, with repairs to open joints and missing masonry.

Ground investigation and stability assessment would be required to confirm ground properties for design, bank stability assessments, and temporary works and access constraints.

We have discounted the construction of significant structural works in front of the existing river wall on the basis that it will require EA approval for narrowing the channel width which is undesirable.

10.4.1 NCS28 Piling

Piles could be installed to create a new retaining structure and make the existing masonry wall redundant. Due to concerns over bank stability, additional piling may need to be carried out to support the carriageway/slope and create a safe working environment for plant to access down to the existing wall. Ground investigations would be needed to determine the type of piling that would be suitable for the ground conditions.

During pile design/installation, consideration should be given to the risk of vibrations causing the existing wall to collapse, leading to a bank failure.

There is likely to be a significant impact on the local community and road congestion. This would be due to plant and material use/storage. There would also be noise and visual impacts on local residents during piling works.

Once piles were installed and the risk to the carriageway mitigated, there would be the option to try and restore the existing masonry through local demolition and reconstruction. This would maintain the appearance of the original masonry walls, protecting the aesthetics of the section of river. Alternatively, as the masonry would no longer be performing a retaining function, the masonry could be allowed to deteriorate but there is a risk of poor perception from the public.

It is anticipated that the repair would require closure of Langton Street footbridge for some of the works.

Note, it is thought that it would not be possible to install piles beneath the bridge. The wall in this area may need localised repairs, or it may be possible to construct a tie-beam behind the wall if required.

A new piled retaining wall behind the existing river wall could also facilitate the construction of at grade access to the adjacent footbridge. This is understood this is a long-term strategic goal for BCC.

10.4.2 NCS28 Concrete or Masonry Retaining Wall and Demolition of Existing Wall

To demolish and replace the existing wall it is likely that significant construction plant would need to access the site area. This is likely to prove challenging due to concerns over wall/bank stability, and piling may still be needed in order to support the carriageway/bank during demolition works and to create a stable working area. This is likely to come with significant cost and disruption to the local transport infrastructure. Alternatively, access could potentially be achieved from the river itself, although there would still be significant cost and access difficulties due to the large tidal range and headroom clearances under the adjacent bridges.

Any new replacement wall will likely require a piled foundation. Construction in front of the existing wall would intrude into the river channel and would have additional complications due to the tidal ranges of the River Avon. Construction behind, or in place of, the existing wall would require the excavation of the currently retained material, which would in turn impact on bank stability and potentially the adjacent bridge foundations; this would likely require significant temporary works to support the bank and would ultimately likely favour piling behind the wall to make it redundant (as detailed above). In either case, ECI discussions are recommended in order to consider construction constraints and sequencing early on in the design.

Once the piled foundations are in place, a new concrete retaining wall would be constructed. To speed up the construction, the use of in-situ or preferably precast concrete panels should be investigated.

It would technically be possible to construct a masonry retaining wall (similar to the adjacent wall sections), however this would require a significantly longer construction period and more extensive temporary works.

During the installation of the piled foundations, there is a risk that vibrations could cause the existing wall to collapse, leading to a bank failure. This will need to be further investigated if this option is being pursued. There is likely to be a significant impact on the local community due to plant and material use/storage, as well as noise and a visual impact on local residents.

It is anticipated that the repair would require the closure of Langton Street Bridge for some of the works. A partial closure of York Road is also likely (subject to access for plant and construction vehicles/material).

10.4.3 Wailing Beam and Ground Anchors

Due to the cost and disruption that piling is anticipated to have, an alternative/temporary repair solution could be to install a wailing beam and anchor system to restrain the wall. In conjunction, local repairs would be undertaken to open joints and areas of lost masonry. Stand-alone pattress plates could be installed to discrete areas of deformation.

Ground investigations will be required to determine the feasibility and longevity of this option, as it would be unlikely to provide appropriate support if there has been a foundation failure.

10.5 NCS28 Recommendations

The asset has been ranked in Priority Group 1, see Section 12.

It is recommended that ground investigations and a desk study are undertaken to understand the ground properties and behaviour in the vicinity of the asset. This will provide the necessary information to develop a recommended design solution. Ground investigations will also provide information on the requirements for temporary works / plant access.

It is recommended that monthly visual inspections should be carried out and remote monitoring is conducted with tilt-meters installed within the area of concern to provide real time information. Displacement sensors could be installed across some of the areas of bulging masonry to detect deterioration. Final survey requirements should be determined with the monitoring contractor.

The installation of sensors to the bridge, and bridge abutment should also be considered so that the relationship between the bridge, the abutment, and the wall can be understood.

If movement is experienced, York Road footway and Langton Street Bridge may need to be closed in case of wall collapse.

The installation of sensors to the bridge should also be considered so that the relationship between the bridge and the wall can be understood.

While a repair solution is being evaluated, research should be conducted into the Langton Street Bridge abutment. A review of As-Built information should be performed.

There are two primary areas of defects, upstream and downstream of the bridge. It is considered likely that piling behind the wall to make the existing structure redundant will be the most suitable option to fully repair the asset. However, the disruption caused by piling may warrant an investigation into the practicalities of a waling beam and anchor system (with miscellaneous masonry repair) as an interim measure. It is therefore advisable to undertake a high-level feasibility study investigating these options following completion of the ground investigations.

Note, there is potential for bat roosting and an ecologist should be consulted prior to any work being undertaken.

The failure of the outfall pipe needs to be investigated using CCTV and then addressed when remediation is undertaken, or it could present future difficulties to any actioned repair solution. The functionality of the flap valves should also be assessed.

11 S28b

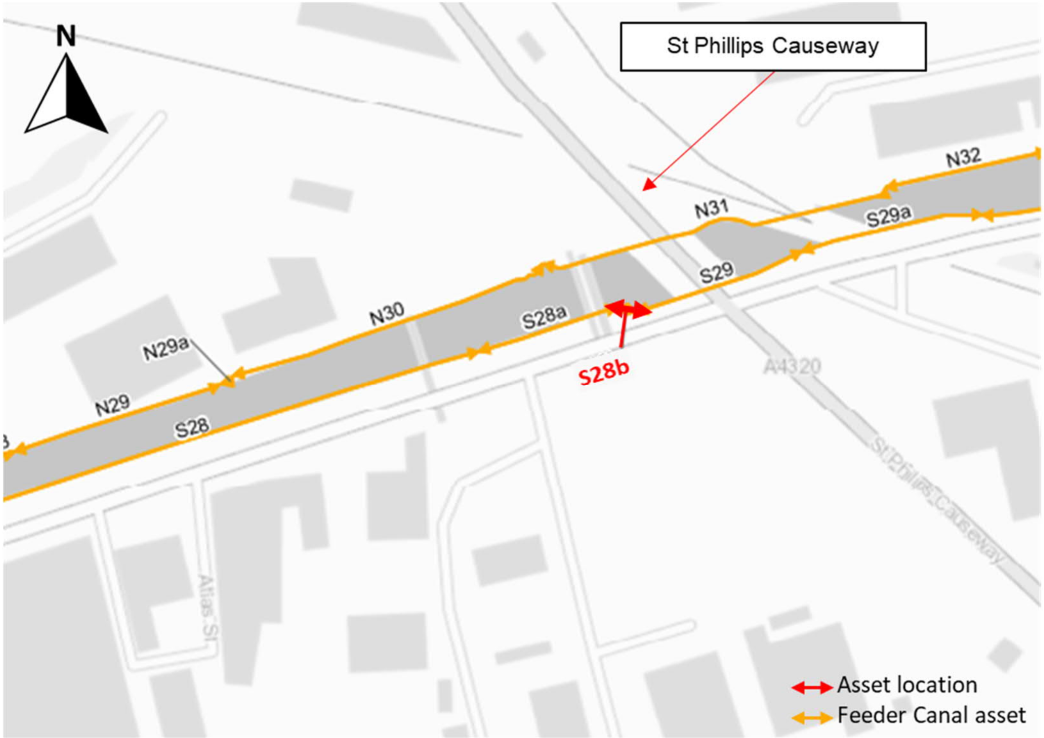
11.1 Background information

11.1.1 Asset Location

Asset S28b is located adjacent to Feeder Road, on the south bank of the Feeder Canal, at approximate Eastings and Northings 360750, 172561. Figure 11.1 shows the site location plan.

St Philips Causeway, A4320, is an overpass road located adjacent east of the asset. There are two covered bridges not publicly accessible adjacent west of the asset and another public footbridge approximately 160m west of the asset. There is a railway line that passes over Feeder Canal and underneath St Philips Causeway approximately 50m north of the asset.

Figure 11.1: S28b Location plan



Source: Mott MacDonald

11.1.2 Asset Description

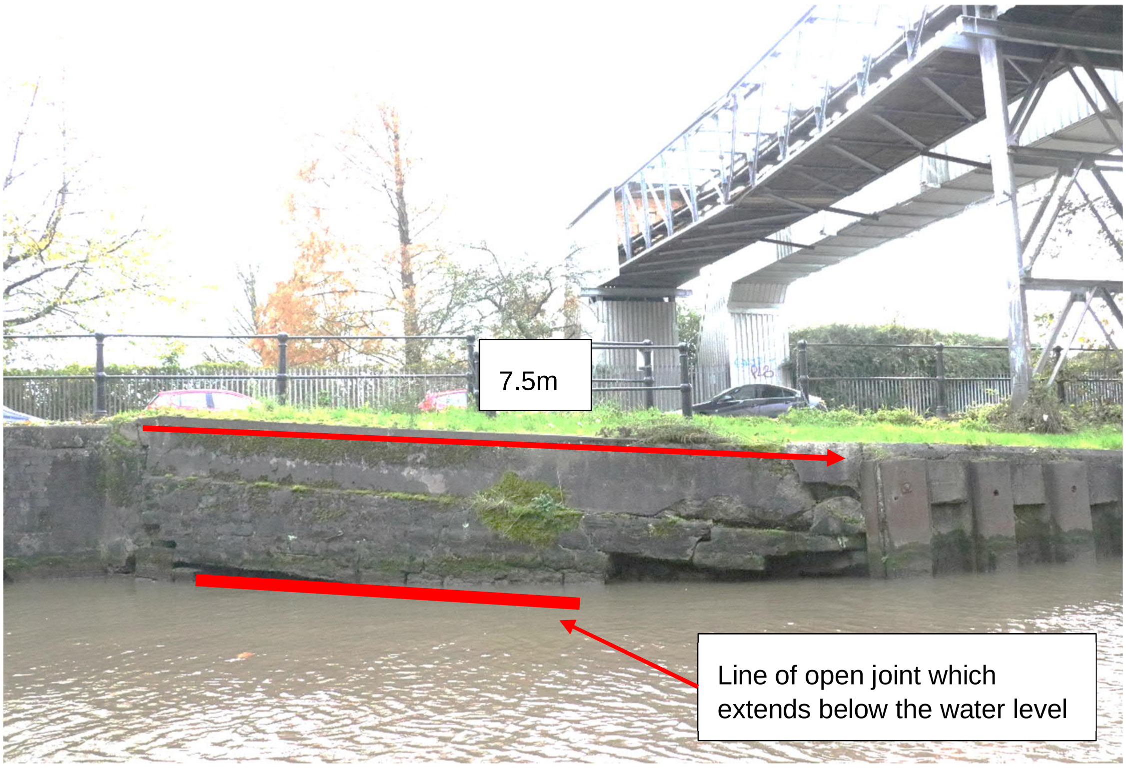
The asset is a masonry wall, fronting an area of gently sloping public land and a carriageway, on the Feeder Canal. It is likely that the asset is a retaining wall due to the ground conditions in the area as discussed in Section 11.1.6 below.

11.1.3 Asset Defects

There is an open joint across the whole asset length, approximately 7.5m, due to the separation between the upper and lower sections. An image of the asset is shown in Figure 11.2 below. There is also an area of potential washout at the base of the wall where it abuts the adjacent sheet piles, see Figure 11.3.

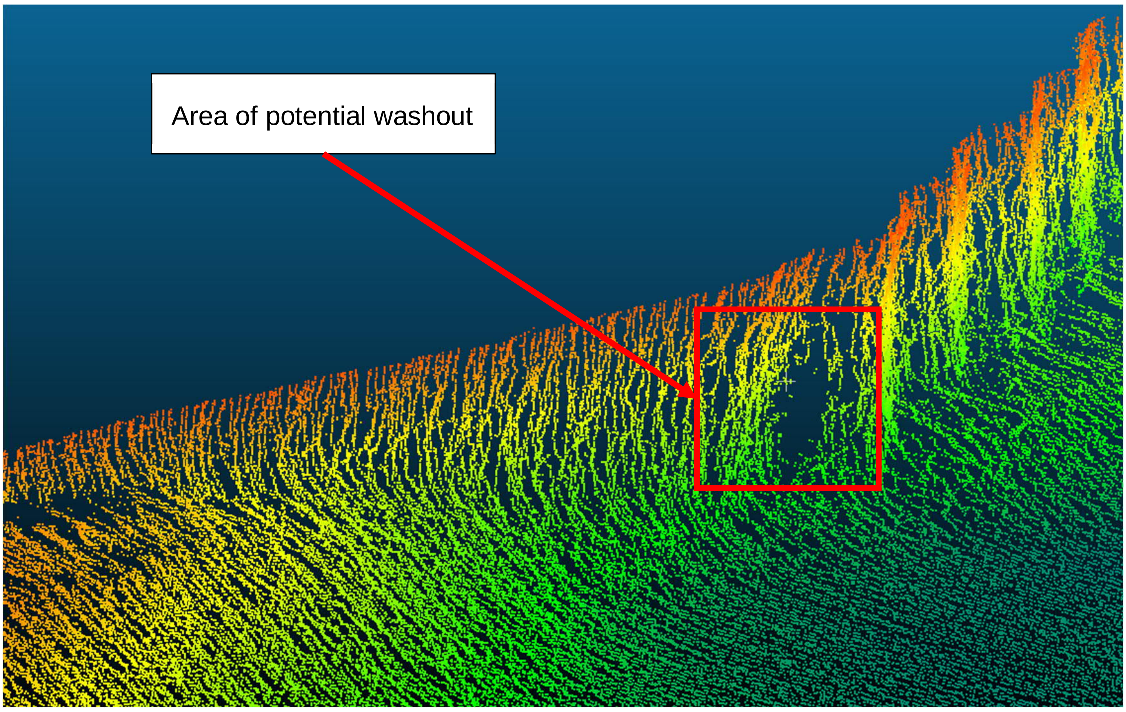
The footway is approximately 0.5m behind the asset and Feeder Road is approximately 3m behind the asset.

Figure 11.2: Asset S28b



Source: Mott MacDonald 2019

Figure 11.3: S28b Potential washout



Source: Mott MacDonald 2019

11.1.4 Consequences of Asset Failure

There will be a loss of support to the retained material resulting in a collapse of the footway and potentially a partial collapse of Feeder Road. There is the risk of travel disruption as Feeder Road is a link road.

11.1.5 Historic Mapping

A review of historic mapping was undertaken to assess the use and development of the asset and surrounding land, allowing for a more holistic understanding of the asset. Table 11.1 presents a summary of history on and off site.

Table 11.1: S28b Summary of site history

Year	On site	Off site
1881	Feeder Canal, Feeder Road and railway line present	Housing located north of site approximately 100m of the asset Avonside Tannery is located approximately 100m east of the asset, southside of the canal. Great Western Works is located approximately 100m east of the asset, northside of the canal
1881 to 1884	No change	Manure Works, Clay Pit, Glue Size & Hair Works located directly south of the asset, below Feeder Road
1902	No change	Bristol Loop Line added to the Great West Railway Allotment gardens located north of site Crane located south of the asset on Feeder Road Avonbank Electric Light works located directly south of Feeder Road Clay Pit, Glue Size & Hair Works no longer labelled
1912, published 1918	No change	Avonbank Electric Light Works no longer labelled
1912 to 1913 published 1920	No change	Avonside Glue Works labelled Great Western Railway Bristol Relief Line labelled south of site, connected to the Bristol Loop Line
1912 to 1913 published 1921	No change	No significant change
1938	No change	No significant change
1947 to 1963	No change	No significant change
Present day	No change	No significant change

11.1.6 Geology

A review of geological mapping [1] for the area shows that the site is likely underlain by superficial deposits of Tidal Flat Deposits. BGS Lexicon [4] describes Tidal Flat Deposits as *"mud flat and sand flat deposits, deposited on extensive nearly horizontal marshy land in the intertidal zone that is alternately covered and uncovered by the rise and fall of the tide. They consist of unconsolidated sediment, mainly mud and/or sand. They may form the top surface of a deltaic deposit. Normally a consolidated soft silty clay, with layers of sand, gravel and peat".*

As Tidal Flat Deposits area typically very low strength, the asset is likely found on bedrock of Redcliffe Sandstone Member. BGS Lexicon [4] describes this as *"sandstone, distinctive fine- to medium-grained, deep red, calcareous and ferruginous. Commonly decalcified at shallow depths below the surface, giving rise to an uncemented sand".*

A review of BGS Geoindex [2] shows that there are 12 boreholes available within 250m of site. The exploratory holes presented are anticipated to be sunk at ground level of the Feeder Canal and therefore most relevant for this asset. The exploratory holes are presented in Table 11.2.

Table 11.2: S28b Existing exploratory hole summary

	Historic BGS Geoindex borehole records			
	ST67SW234	**ST67SW235**	**ST67SW237**	**ST67SW236**
Approx. distance from the site:	**20m N**	**20m N**	**20m SW**	**50m NE**
Made Ground		0m BGL Loose dark grey slightly clayey very ashy SILT	0m BGL Brown clayey topsoil with brick fragments, rootlets and occasional gravel, rootlets and occasional gravel 1m BGL Medium dense red brown silty clay with much brick fragments and peat	0m BGL Tarmac 0.1m BGL Reddish sandy stone fill 0.3m BGL Tarmac 0.3m BGL Concrete 0.6m BGL Reddish sandy stone fill 0.6m BGL Concrete 1.1m BGL Reddish sandy stone fill 1.2m BGL Concrete 1.4m BGL Reddish sandstone fill 1.5m BGL Concrete
Superficial deposits	0m BGL Soft grey clayey SILT 1.8m BGL Soft dark brown fibrous PEAT 2.8m BGL Soft grey slightly silty CLAY 4.2m BGL Brown mottled grey very clayey silty fine SAND 5m BGL Medium dense yellowish brown medium to coarse SAND 6.5m BGL Reddish brown mottled occasionally green very clayey slightly fine sandy SILT	3m BGL Medium dense dark grey very clayey ash and coarse SAND 6.3 Soft grey silty CLAY with occasional fine gravel and dark brown pseudo-amorphous PEAT 6.8m BGL Firm dark brown/black pseudo-amorphous PEAT 8.9m BGL Soft orangish brown very fine sandy silty CLAY 9.7m BGL Medium dense orangish brown SAND	2.3 m BGL dark brownish black PEAT 5.0m BGL Soft becoming firm grey occasionally mottled orange brown very silty CLAY with rootlets 6.5m BGL Dense greyish brown clayey silty SANDSAND 7.0m BGL Dense yellow brown fine to medium angular GRAVEL	-
Weathered Zone (Assumed Redcliffe Sandstone)	-		9.0m BGL Very stiff reddish brown occasionally mottled green clayey SILT with some rounded fine gravel	-
Redcliffe Sandstone Formation	6.5m BGL Reddish brown mottled occasionally green partially decomposed argillaceous slightly fine sand SILSTONE		-	-

11.1.7 Mining

Bristol is known for it's past as a Coal Mining area. A review of the Coal Authority interactive tool [5], shows that the asset is located within the 'Abandoned Mine Catalogue' and is located approximately 200m northwest of a mine entry point. A mine entry point indicates the entrance into a mine working, for which there are two types: shafts and adits. Mine shafts are vertical or near vertical entrances to a mine whereas adits are a walkable entrance to a mine. It is unknown whether the mine entrance close to the asset is a shaft of adit.

11.1.8 Ecological Constraints

A desk study was undertaken in January 2023. This involved a search for designated sites and habitats to identify potentially important ecological constraints at the Site. Data to inform the desk study was obtained from the following sources:

- Multi Agency Geographical Information for the Countryside (MAGIC) website (http://www.natureonthemap.naturalengland.org.uk/MagicMap.aspx);
- Joint Nature Conservation Committee (http://jncc.defra.gov.uk);
- OS maps; and
- Aerial imagery.

Based on aerial imagery and mapping the following habitats were identified within 30m of the asset:

- Feeder Road (developed land; sealed surface) , present along the entire asset;
- Semi-improved grassland growing on the river bank;
- Scattered deciduous trees within 30m of the asset; and
- River along the northern edge of the asset.

One Habitat of Principal Importance, river habitat, was identified within 30m of the asset. The asset does not lie within or adjacent to a site designated for conservation. No sites designated for their international or national importance were identified within 2km of the site. Avon New Cut Local Nature Reserve lies 1.km west of the site and is also hydrologically linked downstream. Four designated sites are hydrologically linked downstream to the site. Table 11.3 below summarises the designated sites within 2km of the site or that are hydrologically linked.

Table 11.3: Designated sites within 2km or hydrologically linked downstream of the asset

Designated site name	Designation	Orientation and distance from the site at the closest point
Avon New Cut	Local Nature Reserve	1.2km west and hydrologically linked
Avon Gorge Woodlands	Special Area of Conservation and Site of Special Scientific Interest	4.2km west and hydrologically linked
Horseshoe Bend	Site of Special Scientific Interest	7.6km northwest and hydrologically linked
Lamplighters Mash	Local Nature Reserve	8.9km northwest and hydrologically linked
Severn Estuary	Special Area of Conservation, Special Protection Area, Ramsar and Site of Special Scientific Interest	9.3km northwest and hydrologically linked

Source: MAGIC, 2023.

Based on the findings of the desk study, the following features have been identified as potential Important Ecological Features within the context of the site;

- Designated sites;
- Habitat of principal importance – river habitat;
- Commuting, foraging and roosting bats;
- Nesting birds;
- Commuting otters;
- Bony fish; and

- Reptiles.

A full Preliminary Ecological Appraisal Report (PEAR) should be undertaken. Habitats should be classified using the UK habitats classification system. The report should include a Preliminary Roost Assessment (PRA) of all trees and structures within 20m of the proposed works (Collins, 2016), a Habitat Suitability Index (HSI) assessment of all waterbodies within 250m of the Site for great crested newts, and a walkover survey for invasive non-native plant species. This process may identify further ecological constraints as well as the need for further survey and mitigation measures.

A detailed habitat mitigation strategy should be developed to replace any habitats permanently lost as a result of the proposed works. The strategy would, as a minimum, replace lost habitat with habitats of the same or higher value. A Biodiversity Net Gain assessment can be used to quantify habitat value and should be undertaken to identify opportunities for biodiversity enhancement.

A Habitat Regulations Assessment is recommended to advise on potential impacts of the proposed works on statutory designated sites downstream of the Site.

A Construction Environmental Management Plan will likely be required to set out the methods to ensure the environmental impact of construction is minimised. Finally, subject to the results of the further surveys, measures to minimise impacts on protected species should be included in a Reasonable Avoidance Measures Method Statement this should also include best practise measures and general construction safeguards.

11.1.9 Site Walkover

Along with the original survey in 2019, a site walkover was conducted in June 2022.

During the walkover in June 2022, the defect was below the water line.

11.1.10 S28b Summary

The asset’s function is not fully understood, although it is certainly providing some support to the adjacent bank and protects against washout. It is a reasonable assumption that it is also supporting the adjacent carriageway and public footway.

There is an open joint across the whole asset length 1.4m below the top of the wall, approximately 7.5m at an apparent separation of the upper and lower sections of wall. It is not understood whether this is due to an open joint / material loss, or possibly due to a loss of support for the wall due to settlement. There is also an area of potential washout at the base of the wall where in abuts the adjacent sheet piles.

It would be advisable to commission a dive survey and ground investigations for this asset in order to establish the nature and cause of the defect.

11.2 S28b Monitoring

Access limitations will restrict viewing angles for taking photograph from above the asset, which will limit information on global movement. Additionally, there is a perceived difficulty in accessing the opposite bank (steep and requiring access through Network Rail land), which increases the difficulty of traditional laser scanning and total station surveying.

It is recommended that the asset is monitored for global movement. This could be done in a number of ways, either through regular (3-4 month intervals) photogrammetric scanning completed by drone or from boat, or automatic monitoring.

11.3 S28b Ground Investigations

Ground investigations will determine ground properties and wall function. It is anticipated that the investigations for the asset will consist of:

- 2No. Boreholes.
- Dive survey to confirm defect extents.

11.4 S28b Repair Options

There are two primary repair options for the asset. These options are to be confirmed following a dive survey to determine the extent and severity of defects located below the waterline. The options would also be subject to the results of ground investigations.

- Shutter the defects and pump in concrete.
- Pile in-front or behind of the existing wall.

11.4.1 S28b Concrete Patch Repair

The concrete repair would be conducted using underwater concrete with anti washout properties or dry-bags for underwater installation. As concrete would be pumped into a watercourse, discussions with the EA would be necessary and any mitigations they require actioned.

To conduct the repair, the face of the asset would be shuttered to create the best seal possible and then suitable concrete would be pumped in to fill the void.

There are numerous different concrete construction methods within this area of Feeder Canal, and most of the repair would be below the waterline so the visual impact of this repair would be negligible. Additionally, there is no public access to the opposite bank.

It is possible that the current defects have been caused by settlement, and a concrete repair is likely to also be affected by settlement, rending the repair inappropriate. Whether settlement is a risk should be confirmed through regular monitoring, the recommended dive survey and ground investigations.

11.4.2 S28b Sheet Piling

Sheet piles could be installed in-front or behind of the asset, this would provide a comprehensive repair solution enabling the existing asset to deteriorate.

Piling is unlikely to be cost efficient for such a discrete length of wall as it would require extensive design and mobilisation. It would also have a larger impact on the local community due to increased plant, materials use/storage and likely lane closures on Feeder Road and take longer to complete than a concrete repair. If settlement has caused the defects in the asset, a concrete repair is unlikely to be appropriate and sheet piling will be necessary.

11.5 S28b Recommendations

The asset has been ranked in Priority Group 2, see Section 12.

It is recommended that the asset is monitored for global movement, either through regular (3-4 month intervals) photogrammetric scanning completed by drone or from boat, or automatic monitoring.

It is recommended that ground investigations and a dive survey should be conducted. This will allow the extent and severity of the underwater defects to be understood and inform on the ground properties and whether there is an ongoing risk of settlement.

Following these investigations, the asset should be repaired to mitigate any ongoing risk to the carriageway.

12 Asset Prioritisation

The assets within scope of this project have been ranked in priority groups for repair, with Priority Group 1 being most urgently requiring repairs, see for Table 12.1.

Before repairs are undertaken, further investigations, such as ground investigations, slope stability analysis, and as-built drawing review should be conducted. These further investigations will facilitate repair design and provide information on ground properties, wall function, plant access suitability, slope stability, and the properties of adjacent structures.

Furthermore, monitoring programmes should be setup for all assets to track movement and watch for additional deterioration. Appropriate monitoring contractors should be contacted as soon as is practicable to begin discussions relating to monitoring requirements.

Table 12.1: Asset priority

Priority Group	Assets
1	NCS21/23 and NCS28
2	NCN16, NCS18 and S28b
3	NCS06 and NCS13
N/A	N06

The assets have been ranked in these groups order for the reasons outlined in the following sections.

12.1 Priority Group 1

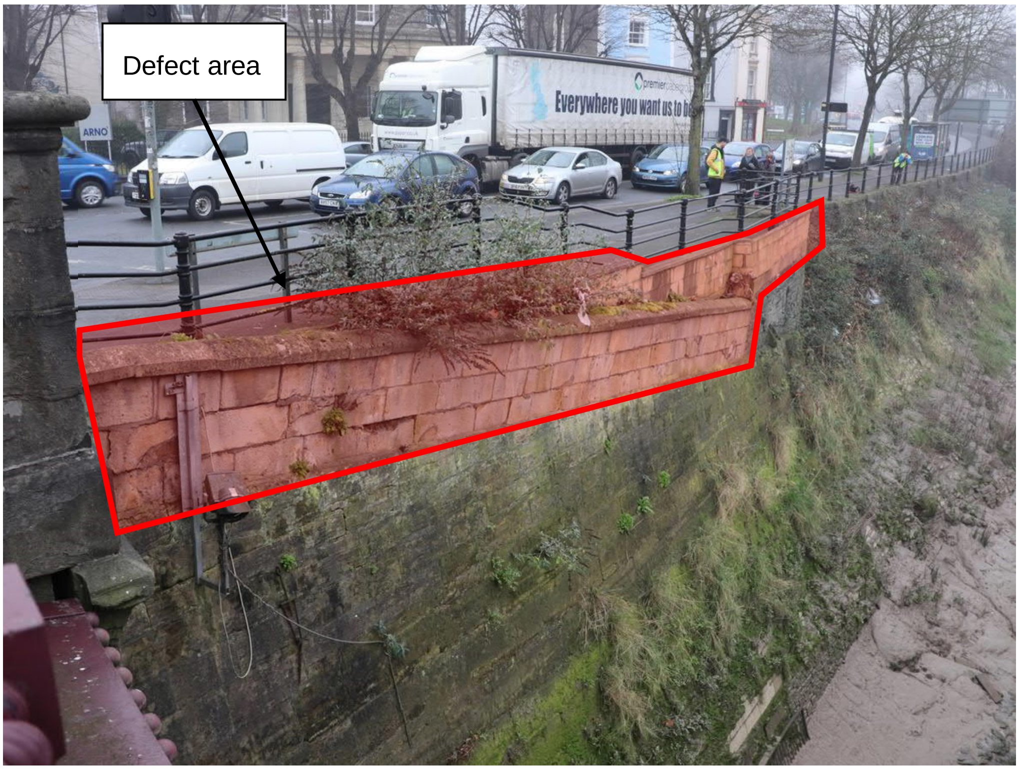
These are considered the most urgent assets for repair.

12.1.1 NCS21 & NCS23

There are significant concerns over the stability of the wall where it is supporting the adjacent footway (as highlighted in Figure 12.1). There is a clear risk that the wall is unlikely to resist vehicle loading, concentrated pedestrian loading, or a significant saturation event (e.g., burst water main). These modes of failure cannot be predicted and would come about as a sudden event with no prior indication of happening. Given the asset’s well trafficked location (and therefore inherent risk to members of the public), it is considered as being in the highest priority group for repair.

A failure of the asset would also require the closure of the footway (and potentially York Road) while the extent of damage was being assessed, with potential long-term closures to follow affecting the wider road network whilst repair activities are undertaken. Failure could also result in potential loss of life or serious injury and have financial, environmental and reputational damage to BCC and the local economy and South-West Region.

Figure 12.1: NCS21 & NCS23 Defect area



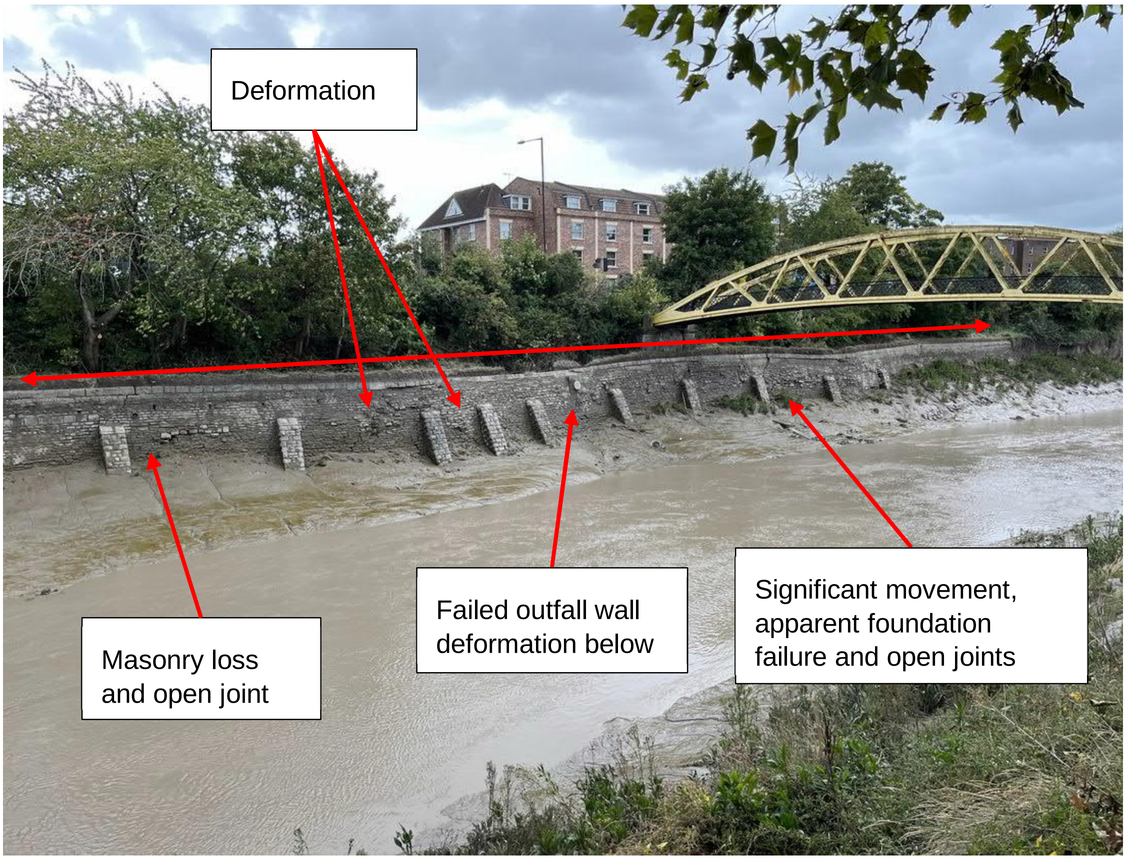
Source: Mott MacDonald 2022

12.1.2 NCS28

The asset likely functions as a retaining wall for the area of fill and slope behind. There are areas of significant global and local deformation across the area shown in Figure 12.2. Any further such deformation could result in a loss of support to the fill behind the asset. There is the potential for a sudden collapse of the asset, causing a loss of support to the slope, the footway and potentially the bridge. This may lead to potential long-term road closures affecting the wider road network whilst repair activities are undertaken. Failure could also result in potential loss of life or serious injury and have significant financial, environmental and reputational damage to BCC and the full local economy and South-West Region.

Due to the extent of movement which has already taken place, the apparent deterioration over the last 10-15 years (Section 10.1.3) and the risk of damage to the surrounding infrastructure, the asset is rated in the highest priority group to repair.

Figure 12.2: NCS28 Area of concern



Source: Mott MacDonald 2022

12.2 Priority Group 2

Repair strategies should be evaluated for these assets once Priority Group 1 asset repair programmes have begun.

NCN16 has been omitted from this section as it will likely be the first asset repaired due to BCC's desire to address this issue and a suitable contractor working adjacent to the site.

12.2.1 NCS18

The asset likely functions as a retaining wall, providing support to the bank behind, the slipway, and the landing stage area.

In the vicinity of the slipway, there are three collapsed sections (NCS18.A, NCS18.B and NCS18.D). If these are allowed to deteriorate further, the slipway may become too dangerous to use, limiting access to the bridge pier and the river and cause injury and potential death to the public.

There are several areas of lost masonry and deformation where the wall appears to retain the bank behind. These defects are considered to be a lower priority than slipway defects as it is thought that a slope failure, resulting in a loss of support to Coronation Road is unlikely in the short-term. However, if these wall failures are allowed to deteriorate, the washout of the slope will increase the long-term risk of a slope failure affecting the road network and potentially causing injury or death to the public. The overall risk of this occurring is lower as there should be signs of failure over a longer period of time that allows timely repairs.

Figure 12.3: NCS18 View from Gaol Ferry Bridge looking upstream

Source: Mott MacDonald 2022

12.2.2 S28b

The asset is likely retaining the footway and potentially the carriageway. If allowed to deteriorate further, there is a risk of the footway collapsing and a road closure affecting the road network in that area. Injury to the public may also potentially occur. There is a horizontal open joint across the face of the asset and a recess at the toe of the wall.

Figure 12.4: Asset S28b

Source: Mott MacDonald 2019

12.3 Priority Group 3

These are considered the assets with the lowest priority to repair.

12.3.1 NCS13

The asset likely functions at least partially as a retaining wall, providing support to the slope behind. The single collapsed section and areas of minor deformation in the region where the slope is directly supported by the wall do not appear to have deteriorated between 2019 and 2022. The slope also appears to have remained stable in the vicinity of these defects.

Figure 12.5: NCS13 Collapsed section

Source: Mott MacDonald 2022

12.3.2 NCS06

It is anticipated that the buildings in the vicinity of the wall have independent foundations and are not at immediate risk of collapse in the event of further short-term wall deterioration.

However, the Priority Group of this asset is likely to increase if:

- The building foundations are found to be dependent on the river wall and a concern develops over that section of the wall.
- The condition of the bank retaining wall significantly deteriorates.
- The slope stability assessment indicates there is a risk of collapse.

If any of these scenarios occur, repairs would become more urgent.

There are other masonry defects along the wall (as summarised in Section 6.1.3), however their significance to the asset are unlikely to have qualified NCS06 within the critical asset project scope.

12.4 N06

Following review of the dive inspection report by Edwards Diving Services (EDS), it was noted that the void detected on a MM site visit was not recorded, and that the report was unclear in relation to the arch defect locations.

It is recommended that BCC confirm with EDS that the entire asset was inspected and if so, clarify why no reference to this void was within the report. BCC should also seek clarification about the accessibility of the arches, whether the arch barrels were inspected, and where the recorded spalls are located.

Once confirmation has been sought, the void and the arch barrels should either be inspected or (if already inspected and in a good condition) the asset could be de-risked from the critical asset shortlist.

References

1. British Geological Survey, Bristol: Solid and Drift, Sheet 264, 2006
2. British Geological Survey Onshore Geoindex: GeoIndex - British Geological Survey (bgs.ac.uk) Access: October 2022
3. Structural Soils, 2015. AVTM Bathurst Basin Bridges Ground Investigation
4. British Geological Survey, Lexicon of Named Rock Units BGS Lexicon of Named Rock Units - British Geological Survey Accessed: October 2022
5. Coal Authority Interactive Mapping tool Interactive Map Viewer | Coal Authority (bgs.ac.uk) Accessed: October 2022
6. Zetica, UXB risk map, https://zeticauxo.com/downloads-and-resources/risk-maps Accessed November 2022
7. Multi-Agency Geographic Information for the Countryside (MAGIC) defra.gov.uk Accessed July 2022
8. Mott MacDonald (2022). SPI Asset Investigations and Repairs Asset NCN16. Doc.Ref.: 100105143-MMD-NCN16-XX-TN-CV-001, dated 23 November 2022
9. Architecton Limited (2014). Langton Street Bridge Conservation Statement for Bristol City Council.
10. Mott MacDonald (2022). BCC SPI Asset Investigations and Repairs – NCN16. Ground Investigation Specification and Bill of Quantities.
11. Edwards Diving Services (2021) A8379 Bristol Harbour Retaining Wall Diving Inspection.

Appendix A. Survey Quotations

A.1 Laser scanning and total station survey quote

Prices for laser scanning and total station surveys were provided by Anthony Brookes Surveys. These can be seen in Figure A.1 below.

Figure A.1: Anthony Brookes Surveys quote

Thank you for the invitation to tender.
Our prices to undertake a monitoring survey works at the above sites would be:

- **Setup site control and direct target installations (by provided rope access personnel)** **£ 520.00 per day**
- **Surveying and processing retro targets into a comparison table**
    - **Assets S28b, NCS06, NCS13** **£ 440.00 per site**
    - **Assets NCS18, NCS21 combined with NCS23** **£ 600.00 per site**
    - **Asset NCS28** **£ 1340.00**
- **Laser scanning and scans processing to point cloud**
    - **Assets S28b, NCS06, NCS13** **£ 720.00 per site**
    - **Assets NCS18, NCS21 combined with NCS23** **£ 1020.00 per site**
    - **Asset NCS28** **£ 2420.00**
- **Preparing and drafting sections from scan data to provide comparison** **£ 640.00 per 20 sections**

Value Added Tax at the standard rate of 20% would be added to these figures.

Within directing of the target installations we have allowed to advise on site where to install targets with the supplied rope access team and including provision of the targets and adhesive. It is planned to place targets at 1m intervals along the feature in two rows (low / high).

Surveying and processing the retro targets will include survey and compare results (in excel spread sheet) to the initial and previous readings.

Laser Scanning includes for site observations and control and processing the data to a pointcloud but without further analysis.

Sections drafted from scan data will allow us to compare them to the initial and previous readings in graphic form which will give you more complex view of asset changes. The tracing/comparing is quite time consuming so sections need to be chosen at key locations to avoid excessive time and cost.

Source: Anthony Brookes Surveys email extract, 17/11/2022

A.2 Real-time monitoring quote

A quote for sensor installation to provide real-time monitoring was obtained from James Fisher Strainstall, this can be seen in Figure A.2

Figure A.2: James Fisher Strainstall quote

Budgetary financial proposal

In order to provide an indication of possible pricing, we have considered the costs of sensors and nodes that may be required at a typical wall location.

Sensors and Wireless Nodes for one wall location:

We have assumed that each location may requre 3 nr tilt nodes, 2 nr displacement measurements and 2 nr temperature measurements (with 1 associated analogue node).

This is estimated to be installed in one shift at site, with cost including installation in the order of £10,000 + VAT per wall location

Wireless Gateway

The price for one wireless gateway, installed at a nearby Bristol City Council location, is approximately £4,000 + VAT.

(Note that we expect 2 nr to be required if the monitoring locations are widely distributed along the New Cut).

System Design, Preparation, RAMS, Software Configuration, Project Management etc.

We have assumed that the effort required for this will be similar, regardless of the number of monitoring locations and estimate it to be in the range £10,000 to £12,000 + VAT

Ongoing Monitoring

The monthly charge for data transmission, storage and display on the SAMS platform will be in the order of £350- £500 per month.

Summary

If we assume that there are 8 river wall locations to be monitored simultaneously, we would expect the overall price to be in the order of £100,000 plus £5,000 per year.

(Note: quantity discounts would be availabel from the suppliers – these have not been included in the summary estimate).

Source: James Fisher Strainstall email extract, dated 01/11/2022

Appendix B. Geotechnical Risk Register

A geotechnical risk register has been compiled in **Table B.5**. Impact index, likelihood index, risk matrix and designer's actions are presented in Table B.1, Table B.2, Table B.3 and Table B.4 respectively.

Table B.1: Impact index

Impact			Cost (C)	Time (T)	Reputation (R)	Health & Safety (H&S)	Environment (E)
1	Very low	Negligible	Negligible	Negligible effect on programme	Negligible	Negligible	Negligible
2	Low	Significant	>1 % budget	>5 % effect on programme	Minor effect on local company image/business relationship mildly affected	Minor injury	Minor environmental incident
3	Medium	Serious	>10 % budget	>12 % effect on programme	local media exposure/ business relationship affected	Major injury	Environmental incident requiring management input
4	High	Threat to future work and client relations	>20 % budget	>25 % effect on programme	nationwide media exposure / business relationship greatly affected	Fatality	Environmental incident leading to prosecution or protestor action
5	Very High	Threat to business survival and credibility	>50 % budget	>50 % effect on programme	Permanent nationwide effect on company image/ significant impact on business relationship	Multiple fatalities	Major environmental incident with irreversible effects and threat to public health or protected natural resource

Table B.2: Likelihood index

Likelihood	Probability
Negligible / improbable	<1%
Unlikely / remote	>1%
Likely / possible	>10%
Probable	>50%
Very likely / almost certain	>90%

Table B.3: Risk matrix

		Impact				
Likelihood		1	2	3	4	5
	1	N	N	N	N	A
	2	N	N	A	A	H
	3	N	A	A	H	S

Impact						
	4	N	A	H	S	S
	5	A	H	S	S	S

Table B.4: Designer actions

Risk Level	Description	Action by Designer
N	Negligible	None
A	Acceptable	Check that risks cannot be further reduced by simple design changes
H	High	Amend design to reduce risk or seek alternative option. Only accept option if justifiable on other grounds
S	Severe	

Table B.5: Geotechnical risk register

Ref.	Hazard	Consequence	Impact	Likelihood	Risk	Risk type	Risk control measure	Impact	Likelihood	Residual risk
01	Rock instability and erosion of rock across site	Potential rock slope failure leading to wall collapse	4	2	H	H&S, C, T	Ground Investigation to determine rock joint strength and joint orientation to enable slope stability analysis and erodibility assessment	3	2	A
02	Wall foundation instability across site	Potential failure of wall foundation leading to wall collapse	4	2	H	H&S, C, T	Ground Investigation to confirm presence of and expose foundation	3	2	A
03	Uncertainty whether walls are retaining or facing and related forces on wall	Potential failure of wall leading to wall collapse	4	2	H	H&S, C, T	Ground Investigation to confirm thickness and nature of material behind wall	2	2	A
04	Chemically aggressive ground conditions	Chemical attack of buried concrete and steel. Degradation of buried structures and weakening after installation. Design does not meet design life or performance criteria.	4	2	H	H&S, C, T	Appropriate DS Class and ACEC Class designation using Ground Investigation information. Sediment Estuary water sample Subsequent incorporation into design	4	1	N
05	Failure of drainage system through and behind walls	Groundwater pressures build up behind the wall leading to collapse	4	2	H	H&S, C, T	Ground Investigation to confirm groundwater levels at various tide levels Structural inspection presence and condition of existing drainage	3	2	A
06	Long term impact of vegetation on slope and masonry walls	Presence of or removal of vegetation on slope behind wall, leading to wall collapse	4	2	A	H&S, C, T	Ground Investigation to confirm groundwater conditions on site and presence of shrink swell material Maintenance of vegetation	2	1	N

Ref.	Hazard	Consequence	Impact	Likelihood	Risk	Risk type	Risk control measure	Impact	Likelihood	Residual risk
07	Slope failure	Slope collapse leading to wall collapse or road collapse	4	2	H	H&S, C, T	Ground investigation to determine slope properties to enable slope stability analysis	3	2	A

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