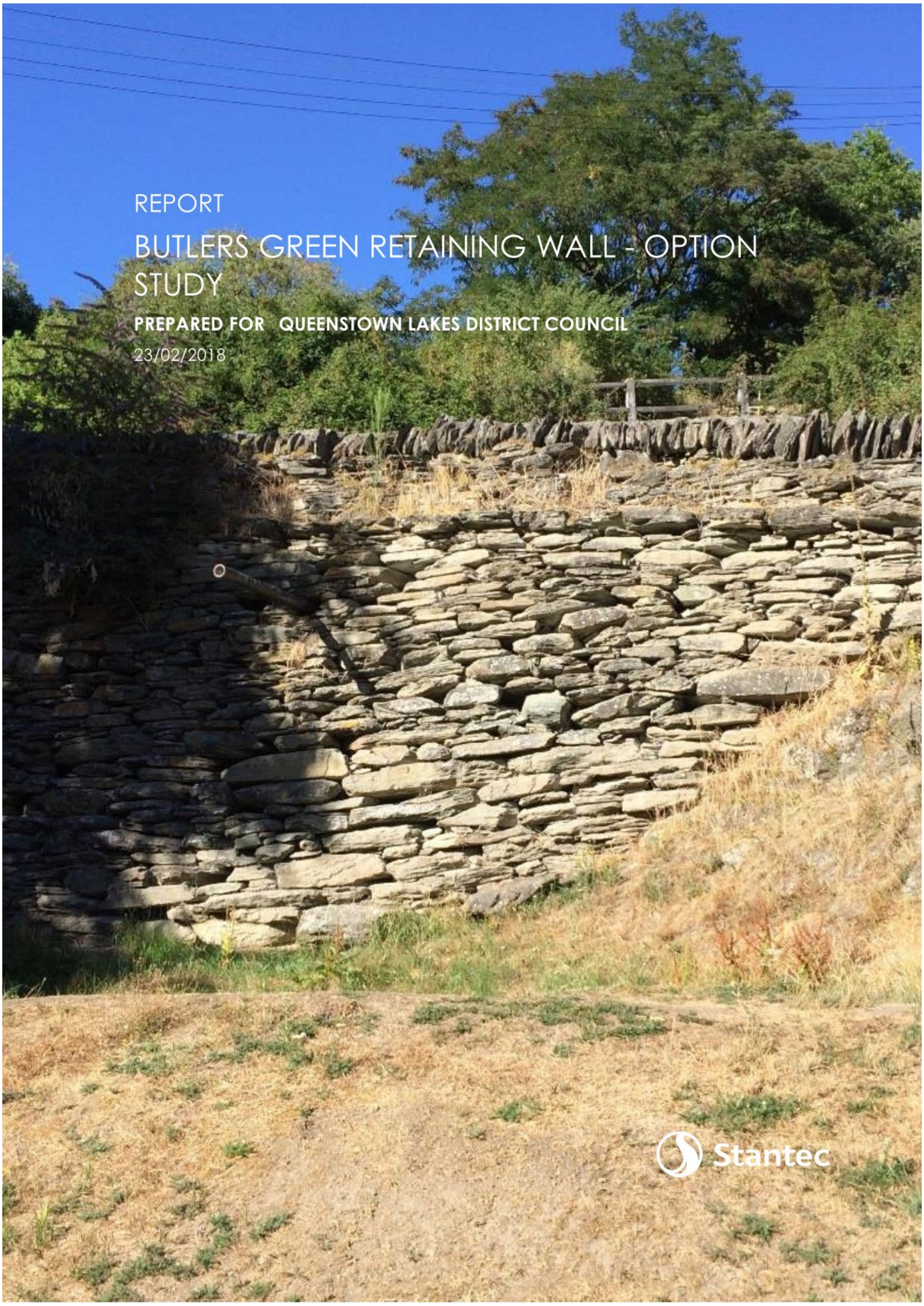
Attachment A - Option Study


REPORT

BUTLERS GREEN RETAINING WALL - OPTION STUDY

PREPARED FOR QUEENSTOWN LAKES DISTRICT COUNCIL

23/02/2018

Stantec

QUALITY STATEMENT

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REVISION SCHEDULE

Rev No.	Date	Description	Signature or Typed Name (documentation on file)			
			Prepared by	Checked by	Reviewed by	Approved by
1	23/02/2018	Final	EG	IB	DC	DC

Executive Summary

An iconic historic stacked stone wall supports part of the Buckingham Street road formation around Butlers Green in Arrowtown. In two locations the face of the wall is bulging outward as a result of movement of the retained soil behind the wall. There is a risk of rapid failure of the wall, particularly following saturation of the soil or earthquake.

The purpose of this report is to investigate the risks, mitigation options and associated costs of repair options the wall. The options and associated costs investigated are summarised in the table below;

Table 1 - Options Summary

Options	Order of Magnitude Cost Estimate	Recommendation	Comments
Option 1 *- Support the front of the wall with imported soil*	$142,000 + GST	Worthy of consideration	• Lowest cost option to improve safety • Low disruption to Buckingham Street during construction • Technically effective • Relatively low risk option – the unsupported projection of wall still at risk • Potentially unappealing to the community and Heritage New Zealand
Option 2 *- Remove the existing stacked stone and replace with an engineered structure*	In the order of $500k – $1M	Rejected from further study as very costly historically unsensitve	• Technically the most effective • Only option that can achieve code compliance • Construction activity would disrupt Buckingham Street • Highest cost option considered • Highly likely to be unacceptable to Herigate New Zealand and the community • Lowest long term risk
Option 3 *- Improve the properties of the soil behind wall with concrete piles*	$306,000 + GST	Worthy of consideration but there remains a residual risk of the stacked stone facing collapsing in some circumstances	• Disruption to Buckingham street during constriction • There remains a risk of the stacked stone facing alone collapsing during an earthquake or following saturation of the backfill • Completed works would not cause a change in appearance of the wall
Option 4 *- Provide external support to the front of the wall with cantilevered counterfort columns*	-	Not investigated further because of the potential visual impact	• Minimal impact on Buckingham Street during construction • Visually intrusive and as a result unlikely to be acceptable to the community and Heritage New Zealand • Low cost • High impact

***Option 5** - Tie back facing with rock/soil anchors with "X" shaped fabricated washers*	$250,000 + GST	Considered the most technically practical solution	• Low disruption to Buckingham Street during construction • Scaleable solution • Straight forward construction with some manageable risk • There remains a risk of the stacked stone facing failing around the anchors/washers
Combination of options	Further assessment required	Suitable	• Flexibility • Potentially lowest costs
Do Nothing	nil	Not considered justifiable	• Risk of injury or death • Unplanned disruption to services, transport and business • Loss of the historic fabric of the wall

Queenstown Lakes District Council

Butlers Green Retaining Wall - Option Study

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1. Introduction

1.1 Purpose of this Report

Queenstown Lakes District Council (QLDC) have engaged Stantec to assess the stability of Arrowtown's Butlers Green retaining wall. Several sections of the wall have bulged outwards and prompted concerns that the wall may collaspe, and this may be without warning.

The purpose of this report is to investigate the risks, mitigation options and associated costs for the Butlers Green retaining wall in Arrowtown.

2. Background

The Butlers Green retaining wall is an old historical stacked stone structure constructed circa 1880. The height of the stacked stone varies up to approximately 5m retained depth. The wall appears to have been originally constructed with a parapet and subsequently this parapet has been backfilled against, which has resulted in an increase in retained soil depth.

Two notable sections of the wall are bulging outward significantly with a deflection of approximately 600 mm. This deflection has resulted in cracking of some stones and loss of stones in some areas.

Figure 1 – Location Plan (wall marked in red, bulging areas marked in yellow)

Figure 2 – The Retaining Wall viewed from Butlers Green, bulging areas marked in yellow

2.1 Geology and Ground Water

Bedrock is visible in outcrops in a number of areas at the toe of the wall and in a number of areas on the far side of Buckingham Street from the wall. Recent excavations adjacent to Dudley's cottage exposed bedrock varying between approximately 1 to 2m below the ground surface and with the surface shape dipping toward Buckingham Street.

Under normal circumstances no significant discharge of ground water is detectable in the area, either at the ground surface or through the wall face. We note that there appears to be an ongoing issue with leakage of water from the reticulated supply system. Recently a leak in the main in Villers Street resulted in a significant flow from the ground adjacent to Dudley's Cottage and currently there appears to be a leak from services in a private lane in Villers Street and water can be seen flowing from the ground and into the stormwater system. Because of the underlying rock it is considered likely that any ground water will flow on the horizon between the rock and the overlying soil.

2.2 Previous Monitoring of Movement

Movement of the wall has been an ongoing issue and concerns have been raised on a number of occasions.

- Approximately 8 years ago cracks appeared in the surface of Buckingham Street adjacent to Dudley's Cottage adjacent to a bulge in the highest section of the wall. The cracks were repaired with asphalt but no action was taken to stabilise the wall
- Approximately 3 years ago a bulge appeared in the wall adjacent to the Berkshire Street intersection (above the walking track at the toe of the wall). This movement appears to be continuing to occur. Parking was stopped at the top of the wall by the provision of timber barricades but the walking track remains open. Recently concern has been expressed about the stability of the parapet at the top of the wall and rock fall mesh has been recommended.

QLDC has previously engaged Aurum Survey Consultants to undertake survey monitoring of the wall movement in 2013/2014 via the use of survey targets mounted to various rocks. The data indicates inconclusive results, however anecdotal evidence suggests the wall has moved significantly over the past 20 years.

2.3 Existing Services

The existing services which are known are shown in Figure 10 later in this report. Adjacent to Dudley's Cottage there are no known services in Buckingham Street. There are known water supply and sewer services in Buckingham Street behind the retaining wall between Villers Street and Berkshire Street. There is also an overhead power line adjacent to the wall. At the toe of the wall there is an existing foul sewer.

A stormwater pipe is visible discharging through the wall but is not marked on Councils GIS.

3. Condition Assessment

The wall is currently moving in at least two locations and as a result under current conditions it has a factor of safety of 1 or less. Increased ground water or earthquake will reduce this factor of safety further and rapid failure is possible. In addition the area of the wall immediately above the walking track is now bulging to a vertical or over vertical face and further reducing the factor of safety of the face.

Some areas of the wall are not displaying detectable signs of movement. It is likely that variability in the rock surface and back fill material contribute to the variable nature of the deflection of the face of the wall

3.1 Eastern Failure Area above Walkway

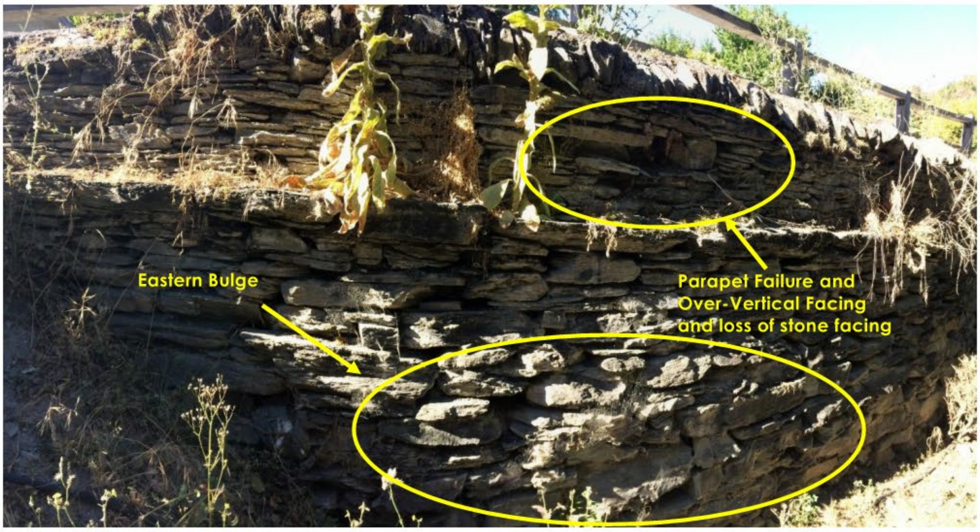

Figure 3 - Photograph of Eastern Wall Segment and Parapet Failure

The section of the wall above the walkway and adjacent to Berkshire Street is bulging by approximately 500mm. This movement appears to be ongoing and the condition if the wall is deteriorating. The top of the wall has deflected approximately 400 – 500mm and the wall in this area is over 2m high. The length of the bulge is approximately 10m. This segment is immediately above the existing pedestrian walkway. Action has been recommended by Stantec to place rock fall mesh to protect the walkway from the risk of the parapet falling.

The movement of the wall is resulting in fracturing of the stones and loss of some stones from the face.

Figure 4 - Stones Cracking in Facing Near Eastern Bulge

Figure 5 - Stones Cracking in Facing Near Eastern Bulge

A section of the parapet on the eastern end of the wall is currently over-vertical and it appears that stones are starting to be lost from the wall face. The segment of wall that is over-vertical appears to have deflected up to 500 -600mm from its original position (refer Figure 6).

Figure 6 - Parapet and Wall Deflection As Seen From Above

3.2 Western Failure Area Adjacent to Dudley's Cottage

The western wall segment is along the section of Buckingham Street leading to Dudley's Cottage. There is a significant bulge and this area exhibits a general global wall failure. The wall in this location is nearly 4 metres high and the bulge spans most of the lower half of the wall (see below).

Figure 7 – Photograph of Western Wall failure area

There is a storm water drainage pipeline extending out of the face of the wall that was flowing at the time of inspection despite no prior rainfall. We believe that this water originates from a break in the water supply reticulation in private property in Villers Street.

The road surface has been repaired above this area and an unsealed water channel has been formed which will direct surface water to the back of the wall and may allow direct ingress of water behind the wall facing. The presence of this unsealed water channel will reduce the factor of safety of the wall.

Figure 8 - Western Wall Failure From Above

4. Risk

4.1 General Risks

The failing of the wall may result in the following outcomes:

- Injury or death to people below the wall if the failure is rapid
- Damage to water supply and waste water services in Buckingham Street
- Disruption to traffic and access
- Resulting disruption to business
- Risk to road users immediately following any rapid collapse
- Loss of the iconic historic wall and loss of the amenity of the area
- Cost to repair any damage

5. Repair Options

Five options have been considered for repair of the wall.

It is important to note that most of the presented options identified in this report do not ensure reliable performance of the wall and thus compliance with the New Zealand Building Code. Option 2 (complete replacement) is the only solution that can provide code compliance and all other options are simply propping solutions to **increase** the factor of safety but not necessarily achieve full compliance with the New Zealand Building code. Accurate modelling and resulting calculation of the capacity of the proposed repair mechanisms identified in this report is not practically achievable. The options identified will reduce the risk of collapse, but only replacement and reconstruction (option 2) can reliably achieve compliance with the New Zealand Building Code .

The site is sensitive and we recommend that it should be considered an actively managed risk that requires assessment following any adverse events. Such events include; known heavy vehicle or machinery traffic on the adjacent road, heavy rain (say >15mm in one 24 hour period), and seismic events.

For options other than complete replacement of the wall, there remains a risk of loss of facing rock, particularly during earthquakes or heavy rain. To mitigate this risk Council may also wish to fence off an area around the base of the wall and/or erect signage to prevent pedestrians from standing under the structure.

5.1 Option 1 – Fill in Front of Wall, Leaving 1m Exposed

This option involves using bulk earthworks to fill part, or all, of the front of the wall to form a toe buttress of engineered fill to support part of the exposed face. This is shown in Figure 9 below;

Figure 9 - Option 1 Indicative Passive Fill Location on the Western Failure

For the eastern failure area filling against the wall would fill the area occupied by the pedestrian walkway at the toe of the wall. This would necessitate moving the existing pedestrian path past the front of the wall. Potentially steps could be constructed directly down to the green area and away from the wall.

5.1.1 Benefits

This is a relatively low risk solution for the western segment of wall and is also suitable for the eastern segment. The multiple benefits are:

- Relatively low risk (it reduces the risk of failure during an earthquake to only the segment of wall projecting above the fill line)

- Simple solution and relatively simple to implement without disruption to either traffic or services within the road
- Aesthetically pleasing when compared to other options (once shaped and grassed)

5.1.2 Risk

Although this is the support option with the lowest risk, some longer term risks and regulatory risks still exist.

- There remains a residual risk of failure of the section of the wall projecting above the fill
- There is a risk that HNZ may reject this option as it is a high impact solution.
- Risk of collapse from disturbance during earthworks.

5.1.3 Cost Estimate

The following cost estimate is for treatment of only the two main failing areas.

Table 2 - Option 1 Cost Estimate

Item	Cost Estimate excluding GST
Design, Procurement, MSQA, Project Management	$26,000
Consent/Archaeological Elements	$6,000
Construction	$110,000
TOTAL	$142,000

5.2 Option 2 – Remove and Replace Wall

Option two involves completely removing the wall facing stones and constructing an engineered retaining wall (or retained earth solution with gabions). To soften the visual impact, it might be possible to reconstruct a tied back facing for the wall using some old recycled stones.

5.2.1 Benefits

This option is the lowest risk of future failures as the wall will be engineered and the facing tied back to mitigate any risk of falling stones or rapid total collapse. This is the only option that could practically obtain code compliance.

5.2.2 Risk

Although this is a technically sound option, there are risks that render it impractical to implement:

- It is the highest impact option and HNZ would likely be opposed to removing the wall.
- Significant disruption to both traffic and services within the road.
- Services within the adjacent road would need to be relocated or reconstructed.
- The construction period would be long and would generate significant heavy vehicle traffic in the area.

5.2.3 Cost

This option has not been priced for the above reasons but it would involve significantly more costs than the other proposed options (potentially $500k - $1M).

5.3 Option 3 – Bored Concrete Piles behind Wall

Concrete piles could be used to improve the properties of the failing material behind the wall. This would involve bored concrete piles (nominally 450mm diameter) spaced at approximately 1m centres terminating in a rock socket. This would intersect the slip plane and prevent further movement of the driving material. Currently we are not certain of the rock profile under the roads. This option would not address the potential instability of the facing alone and it is possible that the facing rock could still topple outward following either heavy rain or earthquake.

5.3.1 Benefits

The benefits of this method are as follows:

- No impact on the existing wall post construction (risks during construction as discussed below)
- Can be used in conjunction with other methods, such as small tie backs to the facing in some areas

5.3.2 Risk

This is the most technically challenging and highest risk method of construction. The construction methodology would need to address the risk of collapse due to vibration, striking larger facing rocks, and the temporary increase in hydrostatic load as a result of the wet concrete.

Another common risk between all options is the risk of facing failure during an earthquake. Other options involve some tying back or filling over potential loose facing material and subsequently reducing the risk of large scale facing collapse. This option leaves the full height of facing vulnerable to collapse, although this may be mitigated by supplementing with facing ties.

The potential cost of this option varies greatly depending on the location and depth of rock and as such, a geotechnical investigation could be undertaken to refine the scope.

5.3.3 Cost

This proposed cost estimate below cannot be accurate without more knowledge of the location of the underlying rock. The cost of construction may vary if significant portions of the retained material is rock and/or if some areas are identified to not require treatment.

Table 3 - Option 3 Cost Estimate

Item	Cost Estimate excluding GST
Design, Procurement, MSQA, Project Management	$50,000
Consent/Archaeological Elements	$6,000
Construction	$250,000
TOTAL	$306,000

5.4 Option 4 – Cantilevered Counterfort Posts

Cantilevered counterfort posts at the base of the wall with walers spanning horizontally between the counterforts .

We anticipate that this structure would consist of cantilevered UC posts cast into bored holes at the toe of the wall. Walers may be either structural steel or concrete. We do not anticipate that this would be an attractive option to look at.

5.4.1 Benefits

This option is scalable and construction of this option would avoid interference with services behind the wall.

5.4.2 Risk

Risks involved with this option include:

- Risk of increasing instability by drilling at the toe of the existing wall
- Likely to be unattractive and not supported by either the community or Heritage New Zealand.

As with other options, this does not eliminate the risk that parts of the facing between the counterforts and walers may shed in an earthquake.

5.4.3 Cost

This options has not been priced.

5.5 Option 5 – Tie Back with Self Drilling Anchors and Washers

This option involves the use of self-drilling anchors drilled through the wall facing and anchored behind the moving soil block. To capture the facing, steel "X" shaped washers (likely fabricated from universal channels welded in a cruciform shape) would be placed over the ends of the anchors. Welded steel washers will have a rustic appearance and may be considered sympathetic to the structure. We anticipate that the anchors would be placed in one or two rows at approximately 2m spacing horizontally

5.5.1 Benefits

This option is considered structurally reliable and a practical solution. This option is scalable and can be used as a whole or partial solution. The construction process is relatively simple and fast and can be carried out from the front of the wall without disruption to the road above.

5.5.2 Risk

The risk of global failure and/or failure of the facing in an earthquake still remains, however implementing additional anchors will reduce this risk. The extent to which additional anchors will be effective is dependent on multiple assumptions and is thus it is not meaningful to attempt to accurately identify increase in the factor of safety by adding anchors.

The construction process of installing self-drilling ground anchors introduces some risks. The drilling process involves flushing out the cuttings with a large amount of grout and a heaving effect occurs on the surrounding ground. These risks will must be closely managed when developing in the construction methodology and during construction.

Obtaining HNZ approval is a risk as the stand alone option involves approximately 40 anchors with washers. Although the washer materials and design can be made to sympathise to other mining structures there is still a significant visual impact.

It is anticipated that it will be possible to anchor the ground anchors into rock. However we are not certain of the rock profile and there is a risk that anchors may have to extend beyond the road reserve.

Service strike on the eastern section of wall is a risk with self-drilling anchors. There are both sewer and wastewater mains (potentially more unknown services) buried within the adjacent road which will need to be managed during construction. The existing underground services will need to be located to ensure that there is no clash.

5.5.3 Cost

The cost estimate below is indicative of a whole solution to treat the two main segments of failing wall. If this option is implemented as a supplement to other options, each self-drilling anchor and washer installation will cost approximately $2,500.00 plus establishment/disestablishment costs for the specialised machinery.

Table 4 - Option 5 Cost estimate

Item	Cost Estimate excluding GST
Design, Procurement, MSQA, Project Management	$44,000
Consent/Archaeological Elements	$6,000
Construction	$210,000
TOTAL	$260,000

6. Accuracy and Purpose of Cost Estimates

The cost estimates included in this report are preliminary only and are intended to provide an indication of the order of magnitude budget cost and to be used for option ranking purposes. These estimates are not detailed and are based on assumptions of both conditions and quantities of materials which we are not able to confirm at this time.

We have included an estimate of design costs in each of the estimates where appropriate. We recommend that the cost of any option that Council wishes to pursue is refined by working through the estimate with an appropriate Contractor.

7. Considerations

7.1 Geotechnical Investigation

Geotechnical uncertainty is a risk to the cost and scope of this project. A detailed geotechnical investigation would be useful in assessing the viability of the options presented above and will also provide refinement of scope, design and cost.

Option 1 and 4 would not require a detailed geotechnical investigation as they are purely a "bolt on" solution which does not depend on the in-situ material behind the wall. Option 3 and 5 both would benefit from an understanding of the location of rock and backfill material for design and cost estimating purposes. The cost implications of a varying ground profile for these options could also be mitigated through the schedule of works (i.e. including provisional rates for additional anchor or pile lengths, etc.).

We estimate that a geotechnical investigation would cost in the order of $10,000 and would involve several test pits to identify depths and locations of rock and the location of underground services.

7.2 Partial Implementation or Combining Options

Partial implementation of one option or a combination of multiple options may be worthwhile. It may be effective to implement rock anchors to the western failure area and place fill on the eastern failure, while leaving the remaining areas untouched at this time.

Each of the cost estimates provided in this report are for the treatment of only the 2 unstable areas. Depending on councils appetite for risk, partial implementation of ground anchors in the relatively stable areas is worth consideration.

7.3 Above and Below Ground Services

Both sewer and water bulk mains exist within the road alignment adjacent to the wall and a sewer main within Butlers Green runs parallel with the base of the wall. Figure 10 indicates the general location of these services.

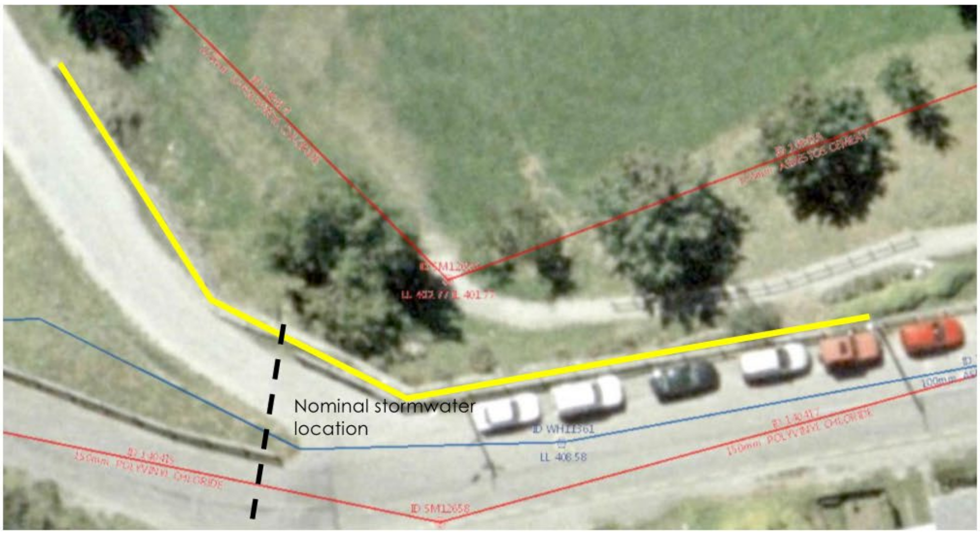

Figure 10 – Water and Wastewater Service Location

It is possible that other underground services exist within the road reserve. Appropriate service location including both 'before you dig' and potholing using a vacuum truck are considered necessary.

Overhead power is located directly adjacent to and above the wall and will restrict the use of excavators from above. The service must be managed during construction by isolation, temporary relocation or permanent relocated for some options, especially for the implementation of bored piles. Figure 11 shows the locations of above ground power services.

Figure 11 - Power Location

There is approximately 14 metres of road reserve between the wall and the nearest property boundary. Property boundaries were a potential risk for the remediation option involving anchors however we do not expect that 14m anchors will be necessary and 15m is the maximum practical length that self-drilling anchors can be used.

Figure 12 - Property Boundaries

7.4 Archaeological Considerations

We have visited http://www.archsite.org.nz/ and their interactive map, which displays NZAA's archaeological site recording scheme. The Butlers green retaining wall is identified as a structure of historical significance and will require an archaeological assessment and an archaeological authority before works are able to be carried out.

HNZ will be a part of the decision process and require that the site and remediation solution be assessed for suitability and impact to the structure. They also requested that a stonemason is involved in the construction process. Although this is an engineering design and construction project, it is possible that some of the stones in the facing could be damaged and require a stonemason to repair.

We have estimated a price of $3000 for the completion of an archaeological assessment on the wall and an additional $3000 to obtain an archaeological authority to undertake the works.

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Attachment B - mIMP_Butlers Green Retaining Wall Remediation