19.6 RABY BAY REVETMENT WALL TRIAL AND REPORT

Objective Reference:

Authorising Officer: **Peter Best, General Manager Infrastructure & Operations**

Responsible Officer: **Rodney Powell, Senior Engineer Marine & Water Assets**

Report Author: **Toby Ehrsam, Coastal Infrastructure Adviser**

Attachments: **1. Raby Bay Repair Trial Assessment Report**

The Council is satisfied that, pursuant to Section 275(1) of the *Local Government Regulation 2012*, the information to be received, discussed or considered in relation to this agenda item is:

(c) the local government's budget

(h) other business for which a public discussion would be likely to prejudice the interests of the local government or someone else, or enable a person to gain a financial advantage.

PURPOSE

The purpose of this report is to request Redland City Council (Council) notes:

1. the recommendations of the Raby Bay Repair Trial Assessment Report (the Report); and
2. the implementation of Raby Bay Revetment Wall Stabilisation Program (Stabilisation Program)

BACKGROUND

Council engaged the consultant Arup to oversee a project to trial various new stabilisation methods to address the history of ongoing revetment wall movement, occurring in the Raby Bay Canal Estate.

Existing methods for canal stabilisation and full revetment wall reconstruction are implemented reactively (i.e. post-failure), and are considered robust and effective. However, due to ongoing rising construction costs, these methods are not financially sustainable into the future. This reactive approach also has other disadvantages, principally, significant stress on the revetment walls of adjoining properties which are not repaired, significant negative social impacts experienced by affected residents (eg: damage to private property, impacts on road and canal traffic, site access considerations and noise) and reputational damage to Council.

As such, Council requires a method that can be implemented proactively prior to failure and at a lower cost and lower social impact, than existing repair methods.

The Raby Bay Repair Trial Project (the Trial) consisted of three trial remediation areas. These trial areas are located at Masthead Drive, Sternlight Court, and at the south-western area of Foreshore Park. The trial areas underwent geotechnical investigations and monitoring to inform the potential failure mechanisms and rates of movement prior to construction works. Following construction, a 12-month monitoring phase commenced to gather data on post construction rates of movement.

The Trial comprised multiple stages as detailed below:

Stage 1: Geotechnical assessment of the Trial areas inclusive of surveying and monitoring of instrumentation.

Stage 2: Analysis of the results of Stage 1 and determination of Trial specification requirements for Stage 3.

Stage 3: Implementation of revetment wall remediation methods at a number of Trial sites.

Stage 4: A 12-month monitoring phase and a final assessment of the Trial remediation methods. Data from Stage 1 and Stage 2 are intended to be used to establish baseline measurements against which the Stage 4 monitoring is compared for effectiveness of the Trial methodologies.

ISSUES

The Stabilisation Program is a revetment wall renewal method that can be implemented proactively prior to the point where a full revetment wall reconstruction is required, and at a lower cost than the existing repair methods. The implementation of the Stabilisation Program is intended to reduce the requirements for full revetment wall reconstruction and associated high repair costs. The Stabilisation Program is not considered suitable for revetment walls that require full replacement.

As part of the Trial, trigger levels have been developed as thresholds for action as revetment walls deteriorate.

Thresholds for action are listed below:

Measured movement at wall	Proposed treatment
< 50mm	Monitoring
≥ 50mm and < 100mm	Monitoring and implementation of new repair methodology
≥ 100mm	Full reconstruction utilising previously employed methods, e.g. two rows of screw piles

Significant cost savings and stabilisation efficiencies are expected over time with the implementation of the Stabilisation Program. As outlined in the Report, a cost comparison between current revetment wall reconstruction costs and the most suitable Trial stabilisation method are outlined below:

Cost of work	Proposed treatment
[redacted]	Current revetment wall reconstruction (two rows of screw piles)
[redacted]	Most suitable trial stabilisation method (Mainmark Resin Injection)

Assessment of the Trial has been completed by Arup and the highest scoring repair solution is the resin injection method undertaken by Mainmark Pty Ltd with a score of 92% out of 100%.

The implementation of the Stabilisation Program is expected to result in a 195% increase in the number of revetment walls stabilised over the next 10 years without the need to increase annual capital budgets. The implementation of the stabilisation program over the next 10 years is projected to result in estimated savings of $15,000,000. In addition, significant social benefits to the community will be achieved by minimising disruption to residents from impacts on road and canal traffic, site access considerations and noise.

If the Stabilisation Program is not implemented, this will result in no change to the increasing costs of fully replacing revetment walls in the Raby Bay Canal Estate. In addition, not implementing the Stabilisation Program will result in ongoing social risks due to construction impacts on road and canal traffic, site access considerations and noise.

STRATEGIC IMPLICATIONS

Legislative Requirements

The recommendations presented in the Report have been developed to ensure conformance with "section 167 (5)(b) of the *Coastal Protection and Management Act 1995" (the Act)*.

For the Raby Bay canal estate, the Act specifies that works considered “accepted development” within the estate do not require specific permits or approvals and only require pre/post works notification to the Department of Environment and Science (DES) as outlined in the Code.

The budget for the implementation of the Stabilisation Program will be funded by a differential rate applied to specific properties in the Raby Bay Canal Estate. The ability to adopt a differential rate is dictated by the “Section 81 of the *Local Government Regulation 2012”* (Regulation). The adoption of an ongoing differential rate was approved by Council as part of FY2018/19 budget deliberations.

Risk Management

Non acceptance of the recommendations in the Report, will result in the deferral of the Stabilisation Program. This will result in a continuation of the reactive renewal of revetment walls with current full revetment wall reconstruction methods and associated costs.

Social risk to Council exists due to current renewal work typically being more disruptive to residents because of impacts on road and canal traffic, site access considerations and noise.

A financial opportunity has been identified, with an estimated $10,450 saving/metre of revetment wall stabilised.

Implementation of the Stabilisation Program will result in the proactive stabilisation of revetment walls before they reach total failure. Over time, this will reduce the incidence of revetment walls requiring full replacement and the associated cost and social impacts.

<u>Contractor risk</u>

All construction risks will be identified through the Council’s risk assessment process and managed by Project Delivery Group (PDG). Proposed construction methodology, site-based management plans, traffic management plans, environmental management plans and, any other evaluation criteria identified by PDG officers, will be requested prior to conclusion of the contract procurement process.

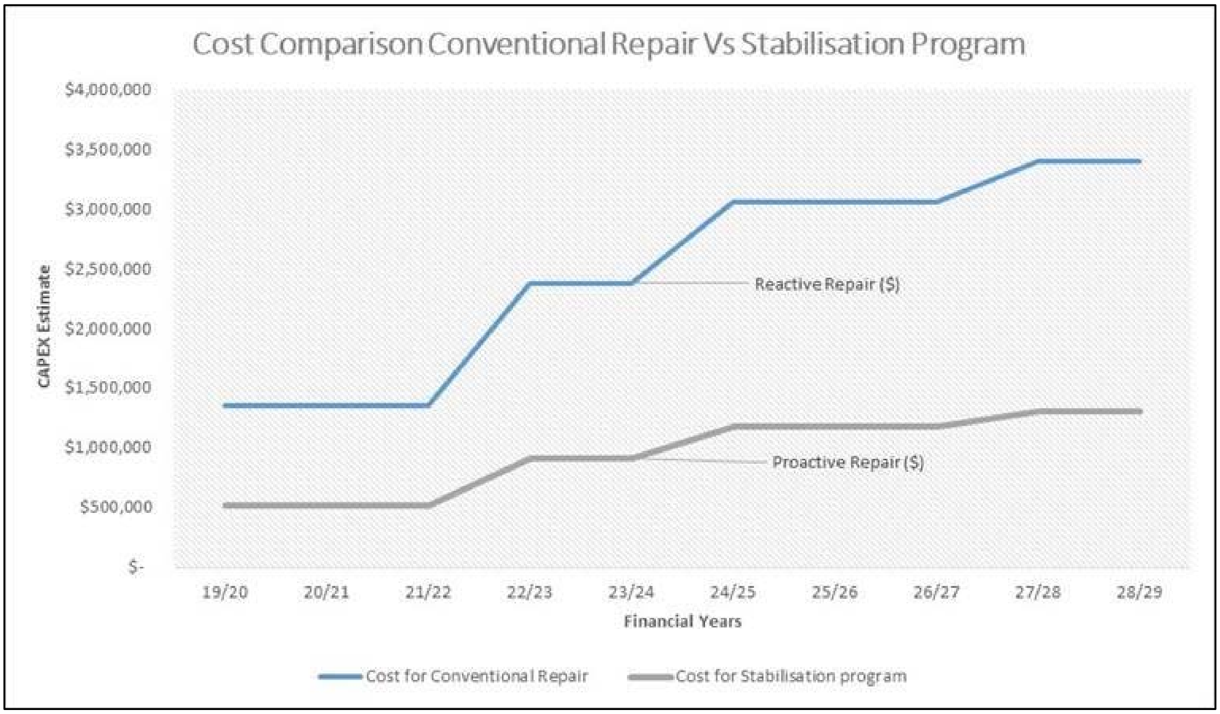
Financial

FY2018/19 budget implications – Nil.

Funding of $502,496 CAPEX is required in FY2019/20. This program of works is funded by the revetment wall differential rate and associated reserve.

Compared to existing methods, the reduced cost of implementing the proactive repair process is expected to allow for a 195% increase in the number of revetment walls to be stabilised without the need to increase annual capital budgets. It is estimated that an additional 965m of revetment walls will be stabilised in Raby Bay over the next 10 years.

The implementation of this program is expected to result in savings of approximately $15,000,000 CAPEX over a 10 year period, as shown in the graph below.



Projected 10 year program of works for the Stabilisation Program and Revetment Wall Program is outlined below:

Stabilisation Program 1 (Proactive Repair)										
	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29
Length of Revetment wall stabilised (m)	80	80	80	140	140	180	180	180	200	200
Raby Bay Revetment Wall Program 2 (Reactive Repair)										
	19/20	20/21	21/22	22/23	23/24	24/25	25/26	26/27	27/28	28/29
Length of Revetment wall replaced (m)	65	80	80	60	60	40	40	40	20	20

1. This program will be increased as the number of failures reduces
2. This program will reduce as the number of failures reduces

People

An internal panel of pre-qualified suppliers has been established and contractors can be engaged directly off this panel, removing the need for a tender process to occur for each project (savings of $15,000 - $35,000 per project). This procurement activity process is more efficient and delivery (construction) timeframes will be significantly reduced compared to current stabilisation projects.**Environmental**

There are no implications.

Social

During Stage 3 (Construction) of the Trial stabilisation methods were assessed and it was concluded that the resin injection method minimises disruption to residents, including impacts on road and canal traffic, site access considerations and noise.

Alignment with Council's Policy and Plans

This report is in line with Council’s Marine Estates Asset Management Plan.

The outcomes of recommendations in this report align with Council's Corporate Plan 2018-2023 vision outcome areas:

3. Embracing the Bay (3.3, 3.4 and 3.5);
5. Wise Planning and Design (5.4);
8. Inclusive and Ethical Governance (8.2, 8.3, 8.4, 8.5).

CONSULTATION

Consulted	Consultation Date	Comments/Actions
Raby Bay Technical Working Group Group Manager Project Delivery – PDG Service Manager Project & Contractor Management – PDG Project Coordinator Marine - PDG	May 2014	Risk assessment workshop held to assess the risks and develop an action plan associated with a planned trial of new repair practices for upper level failures in fill on Raby Bay Canal Estate.
General Meeting Resolution	August 2014	Item 16.2.4 of the General Meeting Minutes of 20 August 2014 - REDLAND CITY COUNCIL RABY BAY RISK ASSESSMENT WORKSHOP refers: That Council resolves to: 1. Note the report and agree to public release of the report; and 2. Approve allocation of the funds necessary (up to $250,000) from the Raby Bay Special Charge Reserve to carry out the Action Plan recommended in the report.
Raby Bay Ratepayers Association - Technical Working Group	Quarterly from Mid 2014 – current	Regular communication and updates have been provided to the Technical Working Group during quarterly meetings and identified milestone dates
Arup Project Manager and project team	Feb 2015 to July 2018	The Arup project manager and project team were tasked to design the trial, oversee the trial and assess the trial. Their involvement during this time was to oversee and manage all associated tasks to ensure the successful completion of the trial.
Project Coordinator Marine – PDG	January 2017 March 2017 June 2017	Technical review of contractor's performance and onsite activities during trial
Project Coordinator Marine – PDG Senior Tender & Contracts Officer - PDG	November 2017	Provided with trial assessment monitoring data
Division 2 Councillor	May 2018	Meeting with Councillor to provide update on Trial progress and outcomes
Division 2 Councillor	March 2019	Meeting with Councillor to provide update on Marine Project progress and outcomes

OPTIONS

Option One

That Council resolves to:

1. note the recommendations of the Raby Bay Repair Trial Assessment Report;
2. note the implementation of Raby Bay Revetment Wall Stabilisation Program; and
3. maintain this report and attachment as confidential until the contract is awarded, subject to maintaining the confidentiality of legally privileged, private and commercial in confidence information.

Option Two

That Council resolves to:

1. not note recommendations of the report; and
2. maintain this report as confidential, subject to maintaining the confidentiality of legally privileged, private and commercial in confidence information.

OFFICER'S RECOMMENDATION

That Council resolves to:

1. **note the recommendations of the Raby Bay Repair Trial Assessment Report;**
2. **note the implementation of Raby Bay Revetment Wall Stabilisation Program; and**
3. **maintain this report and attachment as confidential until the contract is awarded, subject to maintaining the confidentiality of legally privileged, private and commercial in confidence information.**

Redland City Council

Raby Bay Repair Trial

Raby Bay Repair Trial assessment report

240904-GEO-016

Issue 2 | 19 July 2018

Job number 240904

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Document Verification

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Plans and drawings

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Trial assessment

Executive summary

Redland City Council engaged Arup to facilitate a trial to identify possible repair methods as alternatives to those previously undertaken in order to proactively address canal revetment instability (i.e. repair prior to failure at sites with between 50mm and 100mm of wall movement) within Raby Bay canal estate.

Geotechnical monitoring undertaken at three trial sites indicated that where subsurface movement was occurring, it was relatively shallow (i.e. typically occurring within 2m to 3m depth).

Subsequently three new repair methods were trialled to address this shallow movement:

- Screw-in anchors below the retaining wall, undertaken by Ecospec at 7-11 Sternlight Court, originally constructed as part of Stage 12 the estate
- Resin injection, undertaken by Mainmark at 11-15 Sternlight Court, originally constructed as part of Stage 12 of the estate
- Jet grout columns, undertaken by Menard Oceania at 81-85 Masthead Drive, originally constructed as part of Stage 8 of the estate

An assessment of the trialled solutions was undertaken using several weighted criteria, including cost and impacts due to construction. Additionally, the performance of each trialled solution was assessed with available post-construction monitoring data.

The resin injection solution implemented by Mainmark was determined to be the most suitable repair solution of those trialled, based on the assessment criteria.

1 Introduction

Redland City Council (RCC) has commissioned a project to trial various stabilisation treatment methods to address the history of ongoing revetment wall movement observed within the Raby Bay Canal Estate (located in Cleveland, QLD).

Existing methods for canal stabilisation and wall repair are implemented reactively (i.e. post-failure), and are considered robust and effective, but too costly to continue implementing in the long term as the sole repair method given the current rates of failure throughout the canal estate. As such RCC require a method that can be implemented proactively prior to failure and at a lower cost than the existing repair methods.

As part of the Raby Bay Repair Trial project, three trial areas were selected for the trial remediation works. These trial areas are located along Masthead Drive, Sternlight Court, and at the south-western area of Foreshore Park. Trial areas underwent geotechnical investigations and monitoring to inform the potential failure mechanisms and rates of movement prior to construction works. Following construction, a 12 month monitoring phase commenced to gather data on post-construction rates of movement.

The purpose of this document is to summarise the Repair Trial process and detail the methodology and results of the Repair Trial assessment.

1.1 Project overview

The project comprised multiple stages as detailed below:

Stage 1: Geotechnical assessment of the trial areas inclusive of surveying and monitoring of instrumentation.

Stage 2: Analysis of the results of Stage 1 and determination of trial specification requirements for Stage 3.

Stage 3: Trialling of revetment wall remediation methods at a number of trials sites.

Stage 4: A 12 month monitoring phase and a final assessment of the Trial remediation methods. Data from Stage 1 and Stage 2 are intended be used to establish baseline measurements against which the Stage 4 monitoring can be compared to assess the effectiveness of the trialled methodologies.

1.2 Stage 4 Trial assessment phase

The Stage 4 phase of works comprises a 12 month post-construction monitoring phase, with monitoring undertaken by Golder Associates, and the Trial assessment. This report details the Trial assessment and its results.

Following construction, a preliminary report was produced based on available data, which included assessment of all criteria except for the performance of the trialled solutions (refer Section 4.3.1 for details on the assessment criteria). Following receipt of the post-construction monitoring data the assessment of the performance has been undertaken and the relevant sections of this report have been updated.

The process that has been undertaken for the Trial assessment is:

1. Collate all data for assessment, excluding the Stage 4 monitoring data
2. Review the information and undertake the Trial assessment (excepting performance of the methodologies)
3. Provide preliminary results and conclusions
4. Following the 12 month monitoring phase, receive Stage 4 monitoring data
5. Review the updated information and finalise the Trial assessment
6. Provide final results and conclusions

The Trial assessment process and results are detailed in Sections 4 and 5.

Conclusions and recommendations are provided in Sections 6 and 7.

2 Background

2.1 Site history

Development of Raby Bay Canal Estate began in the 1980s in what was previously tidal flats.

Construction was undertaken in 15 stages, by excavating material to form the canals and then it is believed that generally the cut material was used as fill to form the surrounding land. It is understood that construction began in the early 1980s, and historical aerial imagery [1] indicates that construction was largely complete by 1997 to 2002. The progress appears to have been as noted in Table 1.

Table 1: History of construction, inferred from historical aerial imagery [1]

Year	Notes
Mid-1983	Works largely do not appear to have started, some minor works near the shore may have started
Mid-1987	The earthworks for Stages 1 through 5 appear complete The earthworks for Stages 7 through 9 appear to be in progress
Mid-1990	The earthworks for Stages 1 through 9, 10 and 12 appear complete The earthworks for Stages 13 and 14 are in progress The earthworks for Stages 11 and 15 appear to be just commencing
Mid-1993	The earthworks for Stages 13 and 14 appear complete The earthworks for Stages 11 and 15 do not appear to have progressed
Late 1994	The earthworks for Stage 11 appears complete The earthworks for Stage 15 are in progress
Mid-1997	Construction appears largely complete for all stages

It is understood that canal revetments and walls have experienced various degrees of movement throughout the estate since its construction.

2.2 Typical sections

Canal sections are noted to typically comprise:

- A concrete retaining wall < 1m in total height, with or without a base slab and/or a shear key and a design top level of 1.60mAHD.
- Rock protection at the wall base and extending down the canal batter face to approximately -1.40mAHD.
- Canal batters at 1V:3H to a bed level of approximately -7.50mAHD.

Typical sections for the canal revetment for Sternlight Court (Stage 12) and Masthead Drive (Stage 8) are provided in Appendices A1 and A2 respectively.

2.3 Previous repair methods

It is understood that a variety of repair methods have been previously implemented. However the current methodology employed by RCC typically comprises:

- Both vertical and raked screw piles underpinning the concrete wall
- A second row of vertical screw piles further down the canal batter

This repair method is identified as costing approximately $17,000/linear metre [2] to implement.

2.4 Previous reports

A number of investigations and reports have been previously undertaken and it is understood that a variety of failure mechanisms and triggers were identified.

In 2012 RCC engaged Kellogg Brown & Root (KBR) to interpret recent geotechnical investigation data and provide recommendations towards the typical failure mechanisms and potential solutions for reducing the cost of ongoing repair works. KBR's conclusions in their 2013 report [2] included the following:

- A shallow slip failure was occurring in a wedge of uncompacted fill located under the rock armour, which has a maximum thickness of 3m (see Figure 1 below).
- Specifically, that the failure mode appears to be a failure in a wedge of uncompacted fill rather than a deeper circular slip extending into natural materials.
- Previous repair methods using long piles are therefore an overdesign, as such piles would be applied where a critical slip was present at depth, rather than for a shallow slide.

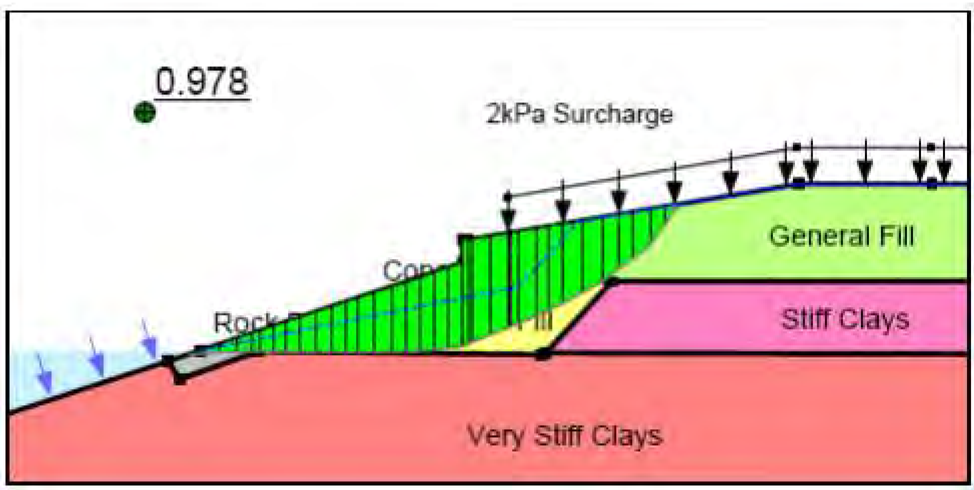


Figure 1: Shallow failure mechanism proposed by KBR [2]

A review of the first revision of KBR's report undertaken by GHD in 2013 [3] noted the following:

- Conversely to KBR's conclusion, GHD believe that, at the site at Piermont Place assessed, a translational slide is occurring in the fill and extending down the canal batter into the in situ material (see Figure 2 below), as the natural material is likely low strength due to fissuring and/or softening.
- The ground conditions at Raby Bay are variable and that, where failure planes and trigger mechanisms are not well understood or defined, it is reasonable to use more conservative and robust solutions that, to some degree, account for some uncertainty and the potential for lower strength natural materials.
- As failures occurring in the natural material are a significant risk, implementation of a "broad coverage fit and forget solution" is not recommended.

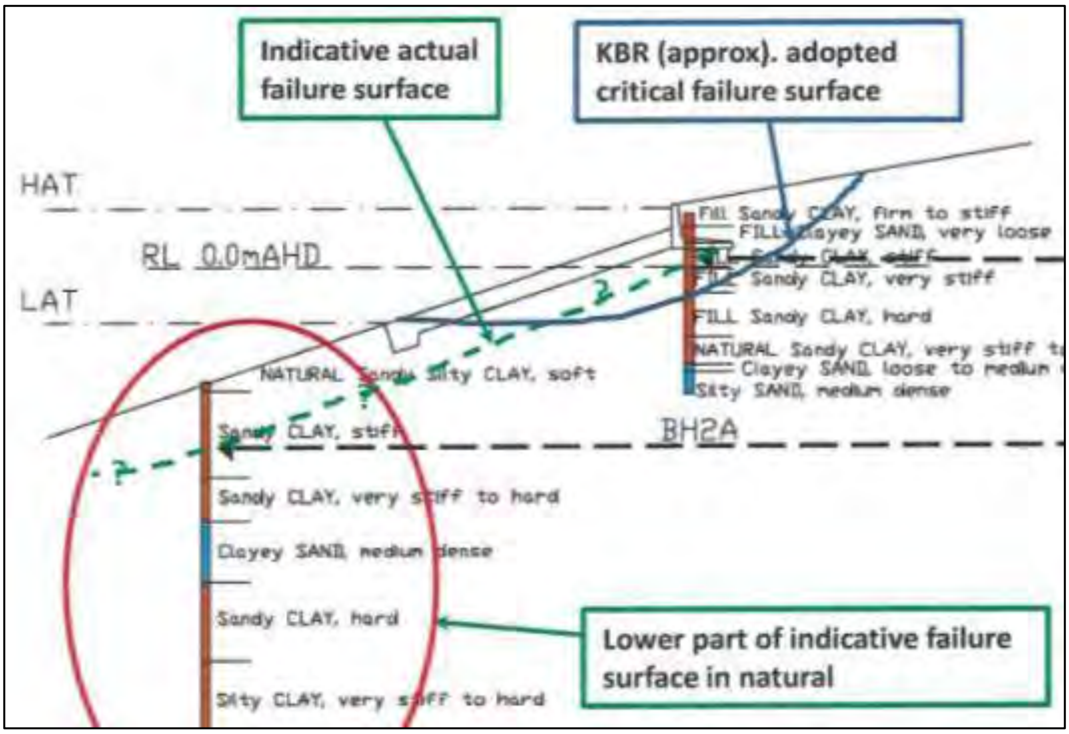


Figure 2: Shallow translational slide proposed by GHD [3]

3 Repair Trial project

3.1 Trial approach

It is understood that the overall aim of the Trial is to identify stabilisation methodologies that can be implemented cost effectively and proactively throughout Raby Bay.

As such, the Trial was developed with the following goals:

- Understand how any successful trialled methods will be implemented by RCC. RCC already employed monitoring throughout Raby Bay prior to the Trial in areas of concern to identify areas that are moving and therefore more likely to fail. Their proposed thresholds for action are provided in Table 2.
- Determine the criteria important to RCC, which are primarily:
    1. Low cost to implement
    2. Low impact to implement e.g. low disruption to residents and existing features and structures
    3. Good performance, i.e. a complete or significant reduction in rate of movement
- Develop weighted assessment criteria that would realise the overall aim. The weighting of criteria needs to try and balance the criteria, particularly the conflicting nature of the three main criteria above.

Table 2: RCC proposed thresholds for action

Measured movement at wall	Proposed treatment
< 50mm	Monitoring
≥ 50mm and < 100mm	Monitoring and implementation of new repair methodology
≥ 100mm	Full reconstruction utilising previously employed methods, e.g. two rows of screw piles (refer Section 2.3)

The Trial process has been as follows:

- Stage 1
    - Review available information and select Trial Areas
    - Develop specifications for the geotechnical investigation and monitoring
    - Geotechnical investigation and monitoring installation undertaken by Golder Associates
    - Ongoing review of monitoring data to assess whether movements are occurring
    - Geotechnical assessment based on geotechnical investigation and monitoring results undertaken by Golder Associates

- Stage 2
  - Extend monitoring phase length (as a result of inconclusive measurements, refer Section 3.2.2.2)
  - Review results and reporting from the geotechnical assessment
  - Develop specifications for the Trial
  - Develop assessment criteria for the Trial
- Stage 3
  - Provision of technical advice during the tender phase
  - Contract supervision during the construction phase
- Stage 4
  - Post-construction monitoring phase
  - Trial assessment
    - Preliminary assessment following construction but prior to the completion of the monitoring phase
    - Final assessment following the completion of the monitoring phase

3.2 Trial areas and monitoring

3.2.1 Trial areas

Three trial areas were initially selected based on available information, primarily data showing a history of movement that had not subsequently and clearly ceased, and consideration of site access for the geotechnical investigation works. The trial areas could then later be split into smaller trial sites to trial multiple methodologies.

The three trial areas selected were as follows and shown in Figure 3:

- 7-9, 11, 13, 15, 17 Sternlight Court, part of Stage 12 of Raby Bay estate
- 77-79, 81, 83 Masthead Drive, part of Stage 8 of Raby Bay estate
- Foreshore Park, Raby Bay Boulevard, part of Stage 15 of Raby Bay estate

Figure 3: Raby Bay with the three trial areas [4]

3.2.2 Monitoring

3.2.2.1 Stage 1 investigation and monitoring

A geotechnical investigation and installation of monitoring equipment was undertaken by Golder Associates between May and August 2015.

The geotechnical investigation comprised:

- Site visit and visual inspection of trial areas
- 3No. test pits (one per trial area)
- Two geotechnical boreholes (one at Sternlight Court and one at Foreshore Park)

The monitoring equipment installed included:

- 11No. pairs of inclinometers (22No. in total) installed with one on- or near-land and one further into the canal
- 87No. survey pins and markers along and behind the revetment wall
- 1No. rain gauge to measure rainfall and
- 1No. water meter to monitor tidal fluctuation

Following the original 2 month monitoring phase undertaken as part of Stage 1, no definitive movement or movement trends had been identified. However, possible failure mechanisms and associated trigger mechanisms were identified from the available information. These are summarised in Table 3, and adapted from the Golder Associates report (ref. [5]).

Table 3: Trial area summary of conditions (adapted from ref. [5])

Location		Features identified	Failure mechanisms inferred	Possible trigger mechanisms
Sternlight Court	7-9	Shallow backscarp about 2 m behind wall. Wall has subsided and bowed. Corner of brick wall about 500 mm from line of concrete wall	Shallow rotational or sliding failure	Softening of poorly compacted basaltic fill
	7-9	Rock revetment has pulled away from base of concrete wall	Shallow flow slide	Softening of fill immediately beneath rock revetment
	9	Slight lean on mooring piles	Shallow flow slide	Softening of fill immediately beneath rock revetment
	9	Deformation in brick wall on boundary with 7, and deformation in fence along top of revetment	Shallow rotational or sliding failure	Softening of poorly compacted basaltic fill
	11-13	Gap between recent pavers and concrete wall & rock revetment settling against base of concrete wall	Shallow flow slide	Softening of poorly compacted basaltic fill
Masthead Drive	75-77	Significant lean of pontoon piles	Continuation of rotational failure or sliding failure (flow slide) at about 2 to 3 m depth	Softening of poorly compacted fill extending at least 10 m from behind property boundary
	79 - 81	Significant settlement behind revetment wall	Shallow rotational failure	Softening of poorly compacted fill
	81-83	Settlement of landscaping behind revetment wall and movement of wall outward and down	Shallow rotational failure	Softening of poorly compacted fill
Foreshore Park		Undercutting of steep bank. No significant deformations	Tidal erosion within softened fill, rapid drawdown failures in steep bank	Tidal movements and surface infiltration of rain

3.2.2.2 Stages 2 and 3 extension of monitoring

It was decided that the monitoring phase would be extended to try and capture clear results. Additionally, 11No. MEMS biaxial tiltmeters were installed on 18 April 2016 and which provided more frequent readings, although not to the depth of the inclinometers.

Monitoring continued throughout Stages 2 and 3. The monitoring results presented in the *Raby Bay Repair Trial - Proposed Implementation Plan* (RTIP) [6] which are current to 8 August 2016 are provided in Table 4. For instrumentation locations, refer to the *RTIP* [6].

It was noted in the *RTIP* [6] that due to the lack of ground movements observed at Foreshore Park, it would be excluded from the Trial Repair works. The Trial Repair works would go ahead at trial sites within the Sternlight and Masthead trial areas.

Table 4: Trial site monitoring results (to 8 August 2016), adapted from [6]

Location			Max movement, A-axis* [mm]	Average tilt, A-axis* [mm/m]	Approx base depth of movement [m]	Notes
Sternlight Court	7-9	SC1	35	-	2.5	Upslope and downslope movement
		SC2	50	-	2	
		SCT1	-	-1	-	Possible movements
	11-13	SC3	3	-	-	N/A
		SC4	3	-	-	-
		SCT2	-	0.5	-	-
	13	SC5	2	-	-	N/A
		SC6	-4	-	-	-
	13-15	SC7	4	-	3	N/A
		SC8	2	-	-	-
		SCT3	-	0	-	-
	15	SC9	2-3	-	5 and 2 resp.	N/A
		SC10	-1	-	1	-
		SCT4	-	0.5	-	Possible movements
Masthead Drive	77-79	MD1	6	-	2.5	Predominantly downslope movement
		MD2	15	-	2	
		MD3	5	-	2.5	Predominantly downslope movement
		MD4	10	-	2.5	
		MD5	13	-	3	Upslope and downslope movement
		MD6	16	-	2.5	
		MDT1	-	0.5	-	-
		MDT2	-	-4	-	Conclusive movements
	81	MD7	15	-	2	Upslope movement
		MD8	2	-	-	
		MDT3	-	0.5	-	Possible movements
	83-85	MDT4	-	-1.5	-	Conclusive movements

Location			Max movement, A-axis* [mm]	Average tilt, A-axis* [mm/m]	Approx base depth of movement [m]	Notes
Foreshore Park	West	FS1	-2	-	-	N/A
		FS2	2	-	-	-
		FST1	-	-1	-	-
	Mid	FST2	-	-0.5	-	-
	East	FS3	-1	-	-	N/A
		FS4	1	-	-	-
		FST3	-	0.5	-	-

*The A-axis is typically approximately aligned with the main expected direction of movement (i.e. downslope).

Note: SC = Sternlight Court, MD = Masthead Drive, FS = Foreshore Park, T = tiltmeter
E.g. SC1 = Inclinometer 1 at Sternlight Court, SCT1 = Tiltmeter 1 at Sternlight Court

3.3 Trialled methodologies

The developed assessment criteria were used at the tender assessment phase to assist with the technical ranking of potential methodologies. Four trial methodologies were subsequently selected, which are summarised in Table 5.

Table 5: Selected Trial methods

Trial method	Methodology	Contractor
1	Screw-in anchors	Ecospec
2	Resin injection	Mainmark
3	Jet grouted columns	Menard Oceania
4	Deep soil mixed columns	Geo Stabilise

During the construction phase Trial Method 4 was excluded from the Trial [redacted]. This methodology has therefore not been assessed further and is not detailed in this report as part of the Trial assessment.

3.3.1 Trial Method 1 – screw-in anchors

Ecospec originally proposed to undertake two rows of screw-in anchors below the wall and through the soil underlying the rock revetment. The first row was approximately 1m vertically below the concrete retaining wall toe, and the second was approximately 1.5m below that.

However, they undertook probe piles and test anchors prior to commencing their stabilisation works and assessment of the results allowed them to reduce the number of rows of anchors to one. The single row of anchors was installed as close as possible to the base of the concrete retaining wall toe, below the wall's shear key.

The Ecospec as-constructed drawings are provided in Appendix A3.

3.3.2 Trial Method 2 – resin injection

Mainmark proposed to stabilise the wall and rock revetment through resin injection at points both behind the wall and in front of it, through the rock revetment. Injections were undertaken starting at the base which was typically 3m to 4m depth (i.e. aiming to found in stiffer material), and with injection points arranged on a triangular grid.

The as-constructed design included four rows of injections with two rows in front of the wall, one at the wall base and one behind.

The Mainmark as-constructed drawings are provided in Appendix A4.

3.3.3 Trial Method 3 – jet grouted columns

Menard Oceania (Menard) proposed to install a row of jet grouted columns under the wall via a trench excavated behind the wall. These columns were 1.2m diameter at 1.5m centre spacing to a typical depth of 4m (i.e. aiming to found in stiffer material).

The as-constructed design was as detailed above.

The Menard as-constructed drawings are provided in Appendix A5.

3.4 Trial sites

Prior to works starting, the required extents for the remedial works was confirmed by undertaking an assessment of the available data, which included:

- RCC terrestrial survey data
- Trial monitoring data
- A visual assessment undertaken by an Arup engineer on 25 January 2017

The trial areas were split into four trial sites so that each contractor would undertake their Trial works on sites of relatively similar sizes. The results, which are detailed in the technical note *Assessment of trial works extents* [7], are briefly:

- Trial Site 1 to comprise 7-9 Sternlight Ct and approximately 5m of 11 Sternlight Ct (to the pontoon walkway)
- Trial Site 2 to comprise approximately 13m of 11 Sternlight Ct (from the pontoon walkway), 13 Sternlight Ct and 15 Sternlight Ct
- Trial Site 3 to comprise 75 Masthead Dr and 77-79 Masthead Dr
- Trial Site 4 to comprise 81 Masthead Dr, 83 Masthead Dr and 85 Masthead Dr

The contractors were made aware of the sites they were assigned prior to accepting the roles and finalising cost estimates for the works. The trial sites with trialled methodologies are summarised in Table 6.

Table 6: Trial sites

Trial Site	Approx. length	Addresses	Trial method	Methodology	Contractor
1	45m	7-11 Sternlight Ct	1	Screw-in anchors	Ecospec
2	53m	11-15 Sternlight Ct	2	Resin injection	Mainmark
3	60m	75-79 Masthead Dr	N/A		
4	60m	81-85 Masthead Dr	3	Jet grouted columns	Menard Oceania

The trial site locations are shown in Figure 4 and Figure 5.

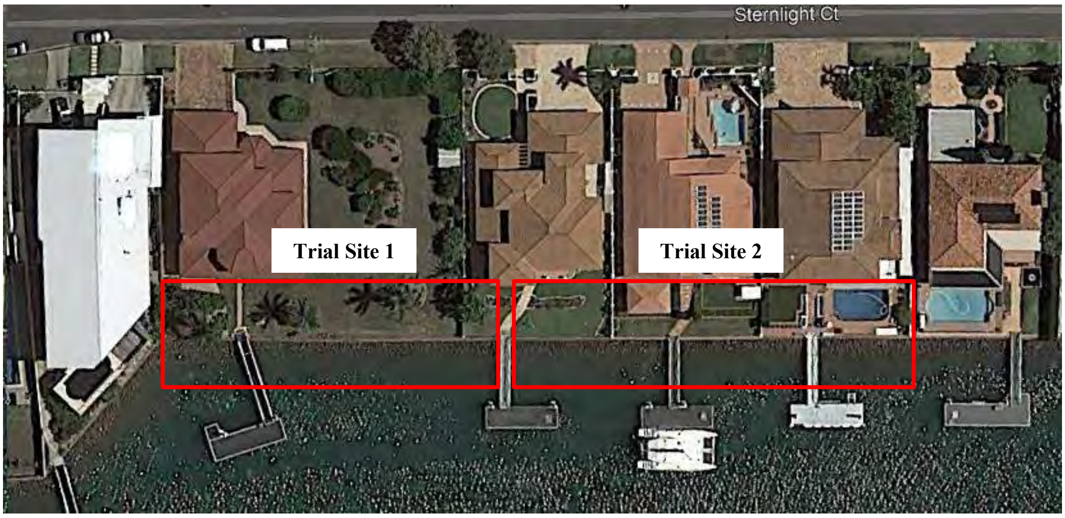


Figure 4: Location of Trial Sites 1 and 2 [4]

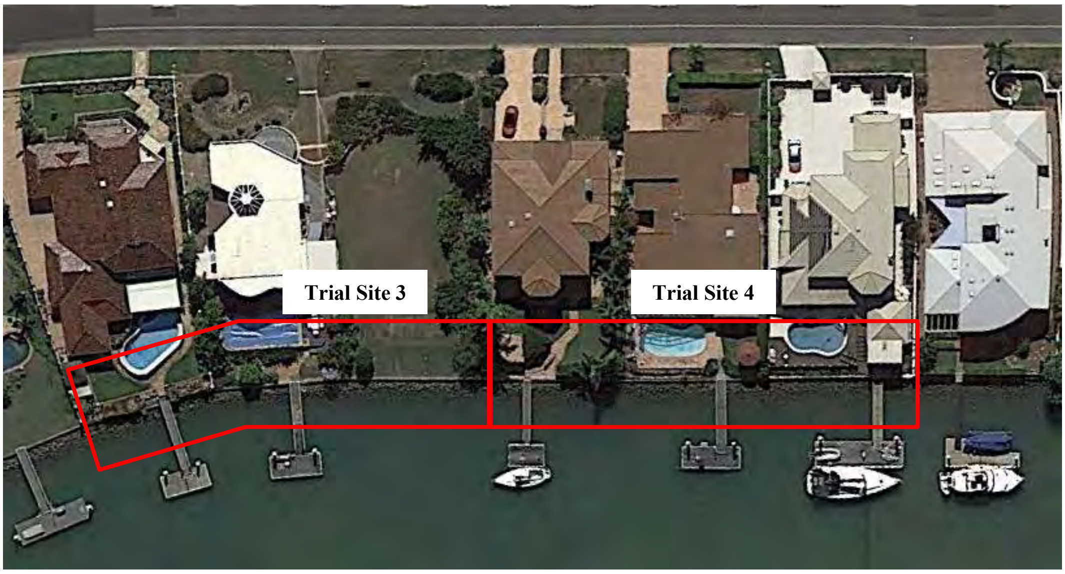


Figure 5: Location of Trial Sites 3 and 4 [4]

4 Trial assessment

4.1 Information for assessment

The Trial assessment addresses and includes information derived from the following, where applicable:

- Data from the geotechnical investigation
- Stage 1 and 2 monitoring data
- Stage 4 monitoring data
- Tender documents and information provided at tender phase
- Contractor documentation including construction plans, design reports and work lots
- Site visits and inspections

4.2 Constraints and exclusions

It is noted that while it was attempted to provide sites as equal in characteristics as one another to all contractors, this was not possible in reality. Characteristics include, but are not limited to, the following:

- Traffic management (if required) which can vary in intensity depending on the side of the road the works are located, amount of traffic and road geometry (e.g. through road with intersections versus cul-de-sac)
- Distance and location of site from laydown area (e.g. a laydown area requiring land versus barge access)
- Length of repair works
- Site history, including date of construction, specific construction methodology and geometry, specific ground conditions and loading history
- Landscaping requirements

The following were not assessed as part of the Trial:

- As noted in Section 3.3, works at Trial Site 3 were not undertaken as part of the Trial. The proposed methodology (deep soil mixed columns) has not been assessed, and so the viability, relative to the other methods, cannot be determined as part of this report.
- Similarly, the assessment considers only the three trialled methodologies, as undertaken by the contractors Ecospec, Mainmark and Menard, and does not cover any other methodologies, nor may it fully cover the same methodologies undertaken by other parties.
- Wall top-up to 1.6mAHD was a post-tender inclusion to the works, which is not considered crucial to aim of the Trial (to determine effective stabilisation

methods), nor was it required at all trial sites. Any works or issues related to the wall top-up works have not been included as part of the assessment.

4.3 Assessment criteria

4.3.1 Criteria

The assessment criteria, from the *Stage 3 Trial Remediation Assessment Criteria* [8], and weightings for all criteria are presented in Table 7.

However Criterion 8, which was considered at the tender stage, was not considered relevant to the Trial assessment and has not been assessed. Weightings have been adjusted using the following formula so that they remain proportional to the original weightings:

$$Updated\ weighting = \frac{Previous\ weighting}{Sum\ of\ previous\ weightings\ for\ Criteria\ 1\ to\ 7}$$

E.g. the weighting for Criteria 1 has been updated as follows:

$$\frac{20\%}{20\% + 20\% + 20\% + 10\% + 10\% + 10\% + 5\%} = \frac{20\%}{95\%} = 21.05\%$$

Table 7: Assessment criteria, adapted from [8]

Criterion		Considerations	Weighting	
			Previous	Updated
1	Cost	• Option minimises upfront construction cost (cost per metre of canal bank repair)	20%	21.05%
2	Impacts due to construction	• Option minimises impact on existing structures o Existing features do not have to be removed/replaced, or are not impacted or damaged by construction. o Option can be undertaken near sensitive features or structures such as gardens and pools. • Option minimises disruption to residents including impacts on road and canal traffic, site access considerations, noise, etc. o Construction can be undertaken quickly o Access can be easily gained (e.g. plant/materials access via the canal, foot traffic through properties rather than requiring cranes or traffic management) o Access can be achieved and construction can be completed with no or little moving of vessels from pontoons o Construction can be completed with minimal works and site footprints (e.g. minimising removal of or damage to existing features, materials are minimal or can be stored offsite easily, etc.) and sites are tidied and returned to a pre-construction condition. o Construction methods minimise noise or noise can be contained to certain times of day.	20%	21.05%
3	Performance	• Level of reduction of movement relative to baseline (if established) i.e. option reduces or eliminates the rate of movement at the site. • Reduction in signs of failure or distress i.e. option shows few signs of distress, or signs of distress are minor.	20%	21.05%

Criterion		Considerations	Weighting	
			Previous	Updated
4	Maintenance	• Option will maximise service life and durability • Option minimises future works/repairs or repairs are cost effective • Maintenance period (i.e. amount of time anticipated before maintenance or repairs, if required) • Option can easily accommodate/retrofit future adjustments or repairs, and the method does not impact future works by constricting access o Option allows safe and easy access for inspection/maintenance to all of its elements o Repair can be undertaken with minimal access requirements (e.g. foot access through properties, plant or materials by boat, does not require use of cranes or large plant, etc.) • Option is robust and minimises need for general maintenance, where needed simple repairs can be achieved easily o Maintenance is needed infrequently or is simple to undertake o Minimal labour and/or materials are required for maintenance	10%	10.53%
5	Constructability and programme	• Option can be constructed safely, construction methods can be undertaken using methods that minimise danger to personnel • Option minimises construction timeframes, construction can be undertaken quickly or at all times (e.g. at high or low tide) • Contractor can provide an expected programme of works • Ability to conduct, monitor and adjust repair based on varied site conditions such as existing canal bank stability and canal bank gradients, existing canal bank protection structures, existing amenity structures built on or adjacent to canal bank and ground movements during construction, varied ground conditions and loading including loading history • Ability to remove or replace option if required (for repair or at end of design life) is relatively simple (e.g. can be undertaken easily, has minimal access requirements, can be done with minimal disruptions, can be done without impacting nearby features, etc.)	10%	10.53%
6	Understanding of the project	• Contractor has demonstrated understanding of the project, inclusive of aim, scope, constraints in line with the *Technical Performance Specification for Trial Remediation Works* [9].	10%	10.53%
7	Quality control	• Contractor quality assurance and record keeping	5%	5.26%
8	Previous experience	• Contractor can demonstrate previous experience using their proposed methodology such as case studies • Contractor can provide contact details for a minimum of two referees able to substantiate their experience in undertaking similar works	5%	-

Note that Criterion 8 was assessed at the tender stage but is not considered relevant to the Trial assessment and has therefore not been assessed. Further the consideration "contractor can provide an expected programme of works" from Criterion 5 is also not considered relevant to the Trial assessment and has not been considering in the rating process.

4.3.2 Ratings and scores

Each trial method shall be scored against the assessment criteria. Scoring of the assessment criteria will be based on the following formula:

$$Score = \frac{Rating \times Weighting}{Maximum\ achievable\ rating}$$

The rating is a value given based on assessment (from 0 to 10) multiplied by the weighting for that criterion. Note that the *maximum achievable rating* value is therefore equal to 10 in all equations.

Further, a rating of 0 constitutes an outcome that was considered unacceptable to RCC, e.g. if considering damage to a structure, a rating of 1 might apply to an amount of damage that is undesirable but still within acceptable limits, while any damage that is unacceptable would attract a rating of 0. It is therefore possible that a rating of 0 could apply to numerous conditions, some of which are worse than others, but all of which are considered unacceptable to RCC.

Ratings for the cost criterion only shall be normalised using the following process:

$$Rating = \left(\frac{Lowest\ price}{Price}\right) \times Maximum\ achievable\ rating$$

The overall score for a trial method will be the sum of all scores.

The rating guide from the *Stage 3 Trial Remediation Assessment Criteria* [8] is provided in Table 13 (in Appendix B1.1). However, this rating guide has a tender focus, and has been adapted to suit the trial assessment criteria. This updated rating guide is presented in Table 14 (in Appendix B1.2), and provides guidance for ratings on a 0-10 spectrum by detailing examples for ratings of 0, 5 and 10. Ratings between these values shall be interpolated from the examples given.

4.4 Trial assessment

It is noted that the ratings that have been assigned as part of the Trial assessment are subjective but have been assigned based on Arup's observations throughout the works. The justifications supporting the assigned ratings are presented in the following sections.

4.4.1 Criterion 1 – Cost

Criterion:
Option minimises upfront construction cost (cost per metre of canal bank repair)

Cost has been assessed based on the amounts claimed during the Stage 3 works.

It is noted that the landscaping required is site dependent and can be highly variable. However, the jet grout column (Menard) works require excavation of a trench behind the retaining wall, while neither the screw-in anchor (Ecospec) nor the resin injection (Mainmark) methodologies require significant disturbance at surface behind the wall. As such, cost including landscaping has also been considered as it is expected that the jet grout column methodology would generally incur relatively higher landscaping costs.

Further the jet grout column works were undertaken using a land-based batching plant. However, it is recognised that most properties in Raby Bay would also require a barge-based batching plant. Values from Schedule B of Menard's contract have been used to provide an estimated equivalent cost had works been undertaken using a barge-based batching plant.

Costs for each contractor are summarised in Table 8.

Cost breakdowns for each contractor are summarised in Table 15 to Table 18 (in Appendix B2).

Table 8: Summary of contractor costs

Value	Screw-in anchors (Ecospec)	Resin injection (Mainmark)	Jet grout columns (Menard)	
			Land-based batching plant	Barge-based batching plant^
Wall repair only				
Total cost				
Repair length (m)				
Cost per metre ($)				
Wall repair with landscaping				
Total cost				
Repair length (m)				
Cost per metre ($)				

*At Menard's site 57m length of wall was stabilised. However, 60m length of wall top-up and landscaping was undertaken.

^Estimated equivalent cost had works been undertaken using a barge-based batching plant instead of a land-based batching plant.

4.4.2 Criterion 2 – Impacts due to construction

4.4.2.1 Impact on existing structures

Criteria:

Option minimises impact on existing structures

- Existing features do not have to be removed/replaced, or are not impacted or damaged by construction.
- Option can be undertaken near sensitive features or structures such as gardens and pools.

Screw-in anchors (Ecospec)

Works do not require removal or amendment of features behind the wall (test piles were undertaken but it is understood these would not typically be undertaken).

Anchors can be installed near sensitive features but shallow anchors have the potential to clash with pools or structure foundations. Anchors would need to be positioned lower, or may not be suitable at selected sites.

Resin injection (Mainmark)

To undertake injection behind the wall some minor impact may occur (e.g. remove and replace select tiles). This option was undertaken adjacent to a pool at 17 Masthead without obvious signs of impact to the integrity of the pool, however care would still need to be taken in similar future situations. The resin injection also caused some outward movement and rotation of the wall.

Jet grout columns (Menard)

A trench has to be constructed behind the revetment wall to allow jet grouting and collection of spoil. All features within approximately 0.5m of the back of the retaining wall must be removed and reinstated or replaced.

The retaining wall moved during construction. It is understood movements up to 200mm were experienced, and which is due in part due to the column diameter (1.2m) which then exerted pressures over a larger area than smaller diameter columns would. Smaller diameter columns may need to be pre-emptively used near sensitive features or structures. Care would need to be taken and the option may not be suitable if the sensitive features are near to the wall.

4.4.2.2 Impact to public and residents

Criteria:

Option minimises disruption to residents including impacts on road and canal traffic, site access considerations, noise, etc.

- Construction can be undertaken quickly
- Access can be easily gained (e.g. plant/materials access via the canal, foot traffic through properties rather than requiring cranes or traffic management)
- Access can be achieved and construction can be completed with no or little moving of vessels from pontoons
- Construction can be completed with minimal works and site footprints (e.g. minimising removal of or damage to existing features, materials are minimal or can be stored offsite easily, etc.) and sites are tidied and returned to a pre-construction condition.
- Construction methods minimise noise or noise can be contained to certain times of day.

Screw-in anchors (Ecospec)

The construction speed was limited by the tides, which must be low enough to allow installation of the anchors, and the need to retroactively move some boats and pontoons after originally deciding this would not be required. It is noted that towards the second half of the programme the installation of the anchors was undertaken more efficiently, as multiple anchors were installed and then all tensioned in one go, rather than installing and tensioning each anchor sequentially.

There was approximately 8.5 weeks from commencement of mobilisation (not including the probe pile installation and testing period) to completion of the stabilisation works, or a rate of approximately 3.75 weeks per 20m (where a typical property in the estate has 20m of retaining wall). Wall top-up and landscaping are not included in this time.

Works are undertaken from the water, and access and materials are typically gained from the water although some foot access may be gained through properties.

In order to undertake the works, boats needed to be moved from pontoons, and some pontoons also needed to be moved.

A site laydown area is need for anchors and facilities and some remediation of the area may be required following works (e.g. vehicle tracks, dead grass).

Barges and excavators are loud, but are used during the allowable work hours only.

Resin injection (Mainmark)

The injection into the rock revetment is limited by tides but other injection points are not. More efficiency in the injection process was achieved following the initial trial period.

There was approximately 6.5 weeks from commencement of pre-construction works (including service location and dynamic cone penetration (DCP) testing) to completion of the stabilisation works, or a rate of approximately 2.5 weeks per 20m. Landscaping is not included in this time.

The works required only foot access through properties. The resin injection rig is in the back of a truck which can be parked along the side of the road.

Boats and pontoons did not need to be moved.

Very minimal equipment was required, which was typically compact. The resin is stored in the rig.

When the rig is running it produces a noise of equivalent volume to a standing vehicle. DCP testing can produce loud sounds but a limited number of tests are typically undertaken and the duration of the testing is typically short.

Jet grout columns (Menard)

The construction speed was limited by the consistency of the spoil (which returned very thick), resulting in a slower than typical production time. As the spoil was so thick it could not be vacuum excavated or pumped and had to be collected by an excavator and transferred to a barge which further slowed progress. Additionally, a delay between the end of jet grouting works and backfilling of the trench occurred due to water ponding in the trench which was left to dry out before backfilling commenced. The speed of any future works is noted to be highly dependent upon whether the consistency of the spoil can be improved so that it can be pumped.

There was approximately 9.5 weeks from commencement of pre-construction works (including trenching) to completion of the stabilisation works (backfilling of the trench), or a rate of approximately 3.25 weeks per 20m. This time does not include landscaping, but does include wall top-up, which was undertaken between end of jet grouting and backfilling of the trench.

However, it is noted when ignoring the delay between end of jet grouting and backfilling of the trench, there was approximately 6 weeks of works, or a rate of approximately 2 weeks per 20m. Wall top-up and landscaping are not included in this time.

Works were undertaken from the canal using barges. The batching plant and site compound were located across the road, requiring traffic management due to the grout hoses crossing the road. It is generally expected that most properties will require the batching plant to be located on a barge as well which would improve the ease of access by removing the need for traffic management, and eliminating the need for the grout hoses to go through the properties. However, there could be issues with having enough space to locate the barges near the site, and may limit navigability of the canal, or impact adjacent properties' pontoons and boats. It is assumed that some equipment, materials and foot access would still be gained through properties.

In order to undertake the works, all boats and pontoons needed to be moved.

The batching plant was very large and backfill material for the trenches was stored on the properties, with both areas then requiring remediation following the works. However, if the batching plant is moved to a barge this would reduce the site footprint.

Barges and excavators are loud, but are used during the allowable work hours only.

4.4.3 Criterion 3 – Performance

The performance of trialled solutions has been assessed against the available monitoring and site inspection data included within the following:

- Golder technical memorandum *Raby Bay Inclinometer, Tiltmeter and Survey Readings February 2017*, dated 2 March 2017 (ref. 1529649-064-TM-Rev0) [10].
- Golder technical memorandum *Raby Bay Inclinometer, Tiltmeter and Survey Readings June 2018*, dated 14 June 2018 (ref. 1529649-084-TM-Rev0) [11].
- Available site photos taken pre-, during and post-construction by Arup engineers. Select photos are provided in Appendix B4.
- Site photos taken by RCC on 20 June 2018 [12]. Select photos are provided in Appendix B4.

Measurements that have been assessed are:

- Inclinometer movements from the June 2018 report [11]. Extracted plots are provided in Appendix B3.1.
- Tiltmeter measurements were obtained from the June 2018 report [11]. Measurements are plotted in Appendix B3.2.
- Survey marker measurements were obtained from the March 2017 [10] and June 2018 [11] reports. Measurements are plotted in Appendix B3.3.

Note that there is a gap in monitoring data when monitoring was halted prior to construction works commencing and then recommencing post-construction. When looking at the pre-construction movement, this gap (i.e. the gap between the last pre-construction measurement and the first post-construction measurement) is ignored as it cannot be discerned what magnitude of movement during this period is a result of ongoing slips or due to construction works.

As such, the pre-construction rate of movement considered is between the earliest available reading and the last reading prior to construction works which was in December 2016 to February 2017.

The post-construction rate of movement is considered to be between the first reading post-construction and the latest reading. Post-construction monitoring recommenced at different times depending on the timing of works at that particular site, but typically was:

- The first available reading in April 2017 or later at Trial Sites 1 and 2
- The first available reading in July 2017 or later at Trial Site 4

Some monitoring points were decommissioned prior to construction, or damaged during construction and have therefore not been monitored. Further, some survey points have not been able to be accessed consistently. In particular, no post-construction inclinometer or tiltmeter monitoring data is available for Trial Site 4.

The active and deactivated inclinometer and tiltmeter locations are summarised in Table 9.

Table 9: Active and decommissioned/damaged inclinometers and tiltmeters

Trial Site	Address	Inclinometers and tiltmeters	
		Active	Decommissioned/damaged
1	7-11 Sternlight Ct	SC1, SCT1	SC2
2	11-15 Sternlight Ct	SC5, SC8, SC9, SCT2, SCT3, SCT4	SC3, SC4, SC6, SC7, SC10
4	81-85 Masthead Dr	-	MD7, MD8, MDT3, MDT4

Regarding the accuracy of monitoring measures, note that:

- According to the 2016 Golder report, the estimated accuracy of the inclinometer readings is ±1.5mm to ±3mm [5]. As such, recorded movements deviating ≤3mm (either positive or negative) from the baseline reading cannot be definitively interpreted as movements.
- The stated accuracy of the tiltmeters is 2.5mm/m [10]. As such, recorded movements of less than 2.5mm/m cannot be definitively interpreted as movements.
- The stated accuracy of the surveying measurements is ±2mm, or up to 4mm variation [11]. As such, recorded movements deviating ≤2mm (either positive or negative) from the baseline reading cannot be definitively interpreted as movements.

4.4.3.1 Reduction of movement

Criterion:
Level of reduction of movement relative to baseline (if established) i.e. option reduces or eliminates the rate of movement at the site.

Screw-in anchors (Ecospec)

The inclinometer readings for SC1 (see Appendix B3.1) indicate that:

- The pre-construction movement appears to be approximately 41mm laterally over 65 weeks, correlating to a rate of 0.63mm/wk.
- The post-construction movement of approximately 5mm laterally over 58 weeks, or a rate of 0.09mm/wk.

The tiltmeter data for SCT1 (see Appendix B3.2) indicates that that:

- Prior to construction recorded movements are less than 2.5mm/m (within tolerance) and do not show any particular trend.
- Post-construction recorded movements are less than 2.5mm/m (within tolerance) but nevertheless appear to be gradually increasing over time with an overall increase of 1.3mm/m between June 2017 and June 2018 (over 49 weeks). However, there appears to have been a peak in tilt around March 2018, with a slight decrease since, comprising:
  - An increase in tilt of 1.65mm/m between June 2017 and March 2018.
  - A decrease in tilt of 0.35mm/m between March 2018 and June 2018.
- There appears to be a slight reversal of the plotted tilt (i.e. reduction in tilt) from approximately March 2018, however there has not been a sufficient duration of measurements from this appoint to assess whether this is a long-term change in the trend.

The survey data (see Appendix B3.3.1) indicates that:

- The pre-construction movement:
  - Maximum lateral and vertical movements occurred at the wall. Movements generally decreased further away from the centre of the site, and away from the canal.
  - Maximum 3D movement occurred at point MON003 and was approximately 62mm over 66 weeks (0.94mm/wk). The second largest movement was MON002 and was approximately 60mm over 66 weeks (0.91mm/wk).
- The post-construction movement:
  - Maximum lateral and vertical movements were typically at the wall and generally decreased further away from the canal.
  - Maximum 3D movement occurred at MON008 and was approximately 13mm over 40 weeks (0.32mm/wk). The second largest movement was at SP406 and was approximately 12mm over 51 weeks (0.24mm/wk).

- There appears to be a reduction in the rate of movement occurring around mid-March 2018, however there has not been a sufficient duration of measurements from this point to confirm whether this is a long-term change in the trend.

The available information indicates that a clear and significant reduction in the rate of movement has been realised post-construction. While no definitive movement has been picked up by the inclinometers, there does appear to have been movement occurring as picked up by the tiltmeter and survey markers, although the lack of movement within the inclinometer (which is adjacent to the tiltmeter) could suggest that this movement is occurring locally at shallow depths behind the wall.

Resin injection (Mainmark)

Inclinometer readings for SC5, SC8 and SC9 (see Appendix B3.1) indicate that pre- and post-construction movements are all within 2mm to 5mm of movement. Therefore, while some marginal movement may have occurred it does not appear that any definitive movement was occurring pre-construction, and has not occurred post-construction.

The tiltmeter data for SCT2, SCT3 and SCT4 (see Appendix B3.2) indicates that:

- Prior to construction recorded movements are less than 2.5mm/m (within tolerance) and do not show any particular trend.
- A spike in the tilt occurred at SCT2 between weeks 95 and 96 (late March/early April 2018) and at SCT4 between weeks 68 and 69 (late September 2017). It is interpreted that these spikes are likely due to contact between the tiltmeter installation and a person or object rather than a shift in the subsurface materials, but the cause is not definitively known.
- Post-construction recorded movements are:
    - 2.4mm/m at SCT2 (when ignoring the spike, otherwise 4.7mm/m due to the spike).
    - 2.95mm/m at SCT3.
    - 2.95mm/m at SCT4 (when ignoring the spike, otherwise 4.05mm/m due to the spike).
- The results for all three tiltmeters appear to be gradually increasing over time with an average increase of 2.8mm/m between June 2017 and June 2018 (over 49 weeks and when results are adjusted to exclude the spikes).
- There appears to be a flattening of the plotted tilt (i.e. no change in tilt) from approximately late February/early March 2018 at SCT3, however there has not been a sufficient duration of measurements from this appoint to assess whether this is a long-term change in the trend. There does not appear to be any change in the movement trends at SCT2 and SCT4.

The survey data (see Appendix B3.3.2) indicates that:

- The pre-construction movement:

  - Maximum lateral and vertical movements occurred towards the south (boundary with Trial Site 1). Movements generally decreased further away from the canal, but there was only marginally more movement (approximately 2mm movement) at the wall than further away.
  - Maximum movement (combining lateral and vertical readings) occurred at point MON009 and was approximately 15mm over 66 weeks (0.23mm/wk). The second largest movement occurred at MON015 and was approximately 9mm over 66 weeks (0.13mm/wk).
- The post-construction movement:
  - Maximum lateral and vertical movements were typically at the wall and generally decreased further away from the canal.
  - Maximum movements occurred at SP043 and MON009 and were approximately 9.1mm and 9.0mm respectively over 51 weeks (0.18mm/wk for both points). The third largest movement occurred at MON015 and was approximately 8mm over 51 weeks (0.17mm/wk).
  - There appears to be a reduction in the rate of movement occurring around mid-March 2018, however there has not been a sufficient duration of measurements from this point to confirm whether this is a long-term change in the trend.

Generally, there was only minimal, if any movement, at Trial Site 2 prior to construction, except at MON009 which is at the southern boundary shared with Trial Site 1. While no definitive movement has been picked up by the inclinometers, there does appear to have been movement occurring as picked up by the tiltmeters and survey markers. The pre- and post-construction rates of movement seem generally similar and may have marginally increased in some areas, however, given the small magnitudes of the movements (typically less than 10mm both pre- and post-construction) it is difficult to draw conclusions as the margin of error for measurements can have a disproportionately large effect on results at smaller magnitudes of measurements.

However, as the pre-construction rate of movement was generally minimal, no clear baseline rate of movement has been able to be determined. As a result, the post-construction rate of movement cannot be assessed relative to the baseline rate of movement.

Jet grout columns (Menard)

Inclinometer and tiltmeter data is not available for Trial Site 4.

The survey data (see Appendix B3.3.3) indicates that:

- The pre-construction movement:
  - Maximum lateral and vertical movements were typically at the wall and generally decreased further away from the canal.
  - Maximum movement occurred at point MON013 and was approximately 56mm over 76 weeks (0.74mm/wk). The second largest movement

occurred at MON014 and was approximately 56mm over 76 weeks (0.73mm/wk).

- The post-construction movement:
  - Maximum lateral and vertical movements were typically at the wall and generally decreased further away from the canal.
  - Maximum movement occurred at MON007 and was approximately 59mm over 27 weeks (2.23mm/wk), however, this point is on the boundary between Trial Site 3 and it is interpreted that this point has been influenced by movements at Trial Site 3 as the movement is reflective of other recorded movements in Trial Site 3 but not of those at Trial Site 4.
  - Ignoring MON007 the largest movement occurred at MON008 and was approximately 15mm over 27 weeks (0.58mm/wk). The second largest movement occurred at MON014 and was approximately 9mm over 27 weeks (0.34mm/wk).
  - The rate of movement appears relatively consistent over the monitored period, although it is noted that only 27 weeks of post-construction monitoring has been undertaken at Trial Site 4 compared to typically greater than 49 weeks for most of Trial Sites 1 and 2.

The available information indicates that a moderate reduction in the rate of movement has been realised post-construction. No inclinometer or tiltmeter data was available at Trial Site 4 post-construction, but there does appear to have been some movement occurring as picked up by the survey markers. However, it is noted that the post-construction monitoring period is shorter than available for the other Trial Sites. Further as the post-construction rates of movement are small in magnitude (typically less than 10mm) it is difficult to draw conclusions as the margin of error for measurements can have a disproportionately large effect on results at smaller magnitudes of measurements.

It is noted that the shorter duration of monitoring and reduced types of data gathered at Trial Site 3 necessarily reduces the certainty in the above conclusions relative to those at Trial Sites 1 and 2 where a greater duration and type of monitoring information is available.

4.4.3.2 Reduction in signs of distress

Criterion:
Reduction in signs of failure or distress i.e. option shows few signs of distress, or signs of distress are minor.

Screw-in anchors (Ecospec)

Pre-construction some cracking along the length of the wall and some spalling of concrete at construction joints were present. The wall had visibly bulged outwards. Soil behind the wall had washed out and been backfilled with gravel. The pontoon walkway concrete path and foundation had been undermined at the wall, and a gap between the foundation and the wall of approximately 150mm had opened up. A noticeable tension crack with scarp developed about 1.5 to 2m behind the wall. There is a noticeable drop in height of the soil and wall between the tension crack and the wall, particularly towards the northern end of the site. Water marks on the outside of wall show that the wall has dropped in height in the middle of the property and towards the northern boundary shared with 11 Sternlight Court. The concrete foundation for the fence at the boundary of 7-9 and 11 Sternlight Court had cracked and moved outward and downward with the wall.

During construction, in addition to the stabilisation works, the wall level was topped up and a facing coat was applied. Soil was backfilled behind the wall to the raised level. The concrete foundation for the fence at the boundary of 7-9 and 11 Sternlight Court was removed and replaced.

As of 20 June 2018 some cracks are present in the wall facing, but these seem to be pre-existing cracks in the concrete wall that have transferred through. As the wall was topped up and not replaced, the bulged shape remains but it does not visibly appear to have worsened. There does not appear to be any washout of material, and the pontoon walkway path and foundation have not been undermined. The tension crack does not appear to have reopened. The concrete foundation at the fence at the 7-9 and 11 Sternlight Court boundary has not appeared to have cracked.

Select photos demonstrating the pre- and post-construction site conditions are provided in Appendix B4.1.

The available information indicates that there are very few signs of distress that have developed following construction and completion of the Stage 4 monitoring period.

Resin injection (Mainmark)

Pre-construction some cracking along the length of the wall and some spalling of concrete at construction joints were present. Some gaps were present between the back of the wall and concrete foundations and slabs, pavers and bricks, indicating that the wall may have moved outwards and downwards at some stage following installation of the concrete. In some cases material had washed out of these gaps.

During construction, and as a result of the resin inject process, the wall was pushed outwards and experienced some rotation. In addition to the stabilisation works, pre-existing gaps between the back of the wall and concrete foundations, slabs, pavers and bricks (some of which were widened as a result of construction) were backfilled with gravel.

As of 20 June 2018 the revetment wall appears to be in a similar condition as it was following construction. Gaps between the wall and concrete foundations, slabs, pavers and bricks do not appear to have visibly widened since construction, and material does not appear to have washed out since being backfilled with gravel.

Select photos demonstrating the pre- and post-construction site conditions are provided in Appendix B4.2.

The available information indicates that there are very few signs of distress that have developed following construction and completion of the Stage 4 monitoring period. It is noted, however, that as per the assessment of the reduction of movement in Section 4.4.3.1, that monitoring data indicates that the site was not showing clear signs of movement prior to the construction works. As such it cannot be definitively concluded that the lack of signs of distress is as a result of the construction works.

Jet grout columns (Menard)

Pre-construction some cracking along the length of the wall and some spalling of concrete at construction joints were present.

At 81 Masthead Drive approximately 0.5m to 1m behind the back of the wall there was evidence of a tension crack underneath the pavers, where the bricks had pulled apart and rotated, indicatively as a result of outward and downward movement of the wall. A small brick retaining wall running along part of the length of the canal revetment wall had moved and rotated outwards. While the cinderblock fence base at the boundary of 77-79 masthead had cracked.

At 83 Masthead Drive the concrete slab abutting the back of the revetment wall had been undermined and had shifted and cracked as a result. In some places the wall had moved away from the slab, leaving a gap. The wall had visibly bulged outwards within this property.

At 85 Masthead Drive there were fewer signs of distress. There was some indicate that the wall had moved outwards nearer to the boundary with 83 and few signs of movement were evident at the boundary with 87.

During construction, and as a result of the jet grouting process, the wall was pushed outwards, which appeared to have largely occurred within 83 Masthead Drive. To facilitate the jet grouting works a trench was excavated behind the wall, resulting in the removal and replacement of features within approximately 0.5m of the back of the wall. In addition to the stabilisation works, the wall level was topped up.

As of 20 June 2018 the revetment wall appears to be in a similar condition as it was following construction.

At 81 Masthead Drive the brick pavers and walls do not show signs of movement, except near to the 77-79 boundary where a slight gap has opened up behind the wall and some of the brick pavers near to the westernmost pontoon anchor appear to have tilted downwards slightly. Based on available monitoring data, and as discussed in Section 4.4.3.1 is interpreted that the wall has moved at 77-79 which has resulted in these signs of distress at this localised area. These signs of movement do not exist elsewhere along the length of Trial Site 4.

At 83 Masthead Drive the concrete slab is flush with the top of the revetment wall, and no gap has opened up. As the wall was topped up and not replaced, the bulged shape remains but it does not visibly appear to have worsened.

At 85 Masthead Drive there are no signs of distress that are visibly apparent.

Select photos demonstrating the pre- and post-construction site conditions are provided in Appendix B4.3.

Excepting the movement near the boundary with 77-79 Masthead Drive, the available information indicates that there are very few signs of distress that have developed following construction and completion of the Stage 4 monitoring period.

4.4.4 Criterion 4 – Maintenance

4.4.4.1 Service life and durability

Criterion:
Option will maximise service life and durability

Screw-in anchors (Ecospec)

It was noted at the tender stage that the screw-in anchors had a 50 year design life.

Resin injection (Mainmark)

It was noted at the tender stage that the expected design life was in excess of 50 years. A design life of 50 years has been assumed.

Jet grout columns (Menard)

The design life of the jet grout columns is 50 years [13].

4.4.4.2 Future works and repairs

Criterion:
Option minimises future works/repairs or repairs are cost effective

Screw-in anchors (Ecospec)

Anchors do not need to be removed at end of design life. Additional anchors can be installed at that time.

Resin injection (Mainmark)

The resin would not be removed at the end of design life. Further stabilisation works could be undertaken at that time.

Jet grout columns (Menard)

Grout columns would not be removed at the end of design life. Further stabilisation works could be undertaken at that time.

4.4.4.3 Maintenance period

Criterion:
Maintenance period (i.e. amount of time anticipated before maintenance or repairs, if required)

Screw-in anchors (Ecospec)

Maintenance is not expected to be required. Most anchors were grouted following installation but some anchors were left un-grouted to allow monitoring of the force in the anchors. Corrosion protection can be provided to the un-grouted monitoring anchors using cardium compound if required [14].

Monitoring of screw-in anchors including the un-grouted monitoring anchors, is, however, recommended to be undertaken for a several years following construction, with measurements of revetment wall movements and anchor actions to be taken [14].

However, with regards to the assessment, the above recommended monitoring is not strictly equivalent to maintenance and is for a limited time following construction.

Resin injection (Mainmark)

Maintenance is not required.

Jet grout columns (Menard)

Maintenance is not required.

4.4.4.4 Accommodation of repairs

Criteria:

Option can easily accommodate/retrofit future adjustments or repairs, and the method does not impact future works by constricting access

- Option allows safe and easy access for inspection/maintenance to all of its elements
- Repair can be undertaken with minimal access requirements (e.g. foot access through properties, plant or materials by boat, does not require use of cranes or large plant, etc.)

Screw-in anchors (Ecospec)

As noted in Section 4.4.4.3 maintenance is not expected to be required although monitoring is recommended. Inspection of anchors would require locally removing the rock revetment. Anchors would not require removal or repair, and instead additional anchors can be installed if required.

Resin injection (Mainmark)

Inspection of this solution would not be undertaken as excavation of the resin could affect its integrity. Further resin injection, if required, could be undertaken.

Jet grout columns (Menard)

Inspection of this option would not be typically undertaken, however inspection would require excavation to expose the grout columns. Further installation of grout columns, if required, could be undertaken.

4.4.4.5 Robustness

Criteria: Option is robust and minimises need for general maintenance, where needed simple repairs can be achieved easily • Maintenance is needed infrequently or are simple to undertake • Minimal labour and/or materials are required for maintenance

Screw-in anchors (Ecospec)

Maintenance is not required.

Resin injection (Mainmark)

Maintenance is not required.

Jet grout columns (Menard)

Maintenance is not required.

4.4.5 Criterion 5 – Constructability and programme

4.4.5.1 Safety of construction

Criterion: Option can be constructed safely, construction methods can be undertaken using methods that minimise danger to personnel

Screw-in anchors (Ecospec)

Works over and adjacent to water are required as anchors are installed using an excavator on a barge. Tensioning of anchors is undertaken using a jack. There is limited environmental risk.

Resin injection (Mainmark)

Near water works are required to undertake injection works but no large plant is required, except for the resin rig which is located in a truck and is parked on the street out the front of the site. Environmental risk is low as the resin is inert when in a mixed form and there are controls in place to prevent un-mixed resin components from spilling.

Jet grout columns (Menard)

Works over and adjacent to water are required as jet grouting, trenching and spoil removal are undertaken from an excavator on a barge. Risk of grout spilling into waterway is managed through mitigation measures outlined in Menard's *Quality Safety and Environment Plan*.

4.4.5.2 Construction timeframes

Criterion:
Option minimises construction timeframes, construction can be undertaken quickly or at all times (e.g. at high or low tide)

Screw-in anchors (Ecospec)

This option is limited by the tides. Anchors cannot be installed at higher tides. The works were facilitated by utilising Kinsail Court Park immediately opposite the canal as a laydown area. In areas where land available for use as laydown areas is further away, construction times may be impacted.

Resin injection (Mainmark)

This option is somewhat limited by tides but on-land work can be undertaken during higher tides.

Jet grout columns (Menard)

This option is somewhat limited by tides as the barge needed to be near to the retaining wall to allow jet grouting or removal of spoil. Further, spoil from the jet grouting process had to be removed by barge which then had to transfer back to the boat ramp at Raby Bay Harbour.

4.4.5.3 Programme of works

Criterion:
Contractor can provide an expected programme of works

This has been excluded for the Trial Assessment, as noted in Section 4.3.1.

4.4.5.4 Adaptability of methodology

Criterion:
Ability to conduct, monitor and adjust repair based on varied site conditions such as existing canal bank stability and canal bank gradients, existing canal bank protection structures, existing amenity structures built on or adjacent to canal bank and ground movements during construction, varied ground conditions and loading including loading history

Screw-in anchors (Ecospec)

This option may not be able to be undertaken near pools or structures with foundations depending on embedment depth, or it will need to be adjusted.

Anchor spacing, position, bearing and dip can be adjusted to suit site-specific requirements.

Resin injection (Mainmark)

This option may not suitable for sites with larger movements. It was noted in Mainmark’s tender submission that their proposal was intended for sites with less than 50mm of lateral movement, and that further, the intent of the works was to reduce the rate of movement rather than to stop the movement [15].

The option may not be able to be undertaken where structures abut the retaining wall, depending on the extents of the structure and whether the injection points can be appropriately adjusted to provide sufficient stabilisation. The option may need to be adjusted near pools or sensitive structures, including services.

The retaining wall at Trial Site 2 did not appear to have a base slab, which lead to resin injection causing rotation of the wall (which a base slab would have helped resist). As such, injections may need to be considered depending on the type of retaining wall present.

Jet grout columns (Menard)

This option may not be able to be undertaken near pools or sensitive structures, or it will need to be adjusted (e.g. column diameter or spacing). It will not be able to be undertaken where structures abut the retaining wall (or would be exorbitantly expensive).

4.4.5.5 Ease of end of life replacement

Criterion: Ability to remove or replace option if required (for repair or at end of design life) is relatively simple (e.g. can be undertaken easily, has minimal access requirements, can be done with minimal disruptions, can be done without impacting nearby features, etc.)

Screw-in anchors (Ecospec)

Anchors do not need to be removed at end of design life.

Resin injection (Mainmark)

The resin would not be removed at the end of design life.

Jet grout columns (Menard)

Grout columns would not be removed at the end of design life.

4.4.6 Criterion 6 – Understanding of the project

Criterion: Contractor has demonstrated understanding of the project, inclusive of aim, scope, constraints in line with the *Technical Performance Specification for Trial Remediation Works* [9]

Screw-in anchors (Ecospec)

[redacted] This option was the most expensive of the three trialled, but was reasonably low impact (e.g. landscaping was generally not impacted, traffic management was not required, however, some boats and pontoons had to be moved).

Resin injection (Mainmark)

[redacted]

This option was the least expensive all three trialled, and was very low impact (landscaping was generally not impacted, only a footpath crossing was required for the resin hoses, access was obtained through properties).

Jet grout columns (Menard)

[redacted] This option scored second against cost, but was a very high impact methodology (e.g. the jet grouting process caused significant wall movements, all boats and pontoons had to be moved, landscaping behind the wall was completely removed due to the trench and the grout hose crossing required considerable traffic management).

4.4.7 Criterion 7 – Quality control

Criterion:
Contractor quality assurance and record keeping

Screw-in anchors (Ecospec)

As-constructed drawings showed and provided records detailed the necessary information, including anchor layout, load test results, and anchor preloads.

Resin injection (Mainmark)

As-constructed drawings provided the necessary information, including resin injection points and volumes.

Jet grout columns (Menard)

As-constructed drawings showed and provided records detailed the necessary information, jet grout column locations, grout volumes and pressures at installation, and strength testing results.

4.4.8 Criterion 8 – Previous experience

Criteria:

- Contractor can demonstrate previous experience using their proposed methodology such as case studies
- Contractor can provide contact details for a minimum of two referees able to substantiate their experience in undertaking similar works

This has been excluded for the Trial Assessment, as noted in Section 4.3.1.

4.4.9 Other considerations

It is understood that all contractors were new to working within Raby Bay estate and were thus new to the site-specific combination of conditions and constraints. The assessment has been undertaken in order to assess not just the works undertaken during the Trial, but the potential learnings gained by the contractors.

Screw-in anchors (Ecospec)

- Undertook test piles and anchors to gain a better understanding of the site conditions.
- Following refinement of their understanding of the tidal fluctuations, and moving a boat and pontoon to allow proper access of their barge they were working more efficiently than initially.

Resin injection (Mainmark)

- Trialled their resin mix and overburden (i.e. loads applied at surface to limit ground heave).
- Once finalising their method, they increased their speed of works.

Jet grout columns (Menard)

- Experienced unforeseen issues with the consistency of the spoil material from jet grouting, which slowed works and had flow-on delays. It is understood that Menard believe that they can improve the spoil return, however this has not been realised and, therefore, the effect this could have on the speed of works is not known and has not been factored into the assessment.
- Undertook works using a land-based batching plant and site compound, however, it is recognised that most properties in Raby Bay would require a barge-based batching plant. As such the assessment has been undertaken assuming use of a barge-based batching plant.

5 Trial assessment results

Costs have been assumed to include landscaping, as per Table 8 and as summarised in Table 10.

Table 10: Costs assumed for the Trial assessment

Location	Sternlight Court		Masthead Drive
Trial Method	1	2	3
Trial Site	1	2	4
Methodology	Screw-in anchors	Resin injection	Jet grout columns
Contractor	Ecospec	Mainmark	Menard Oceania
Cost ($/m including landscaping)			

As noted in Section 4.4.3.1, Trial Site 2 did not appear to be moving prior to construction, and therefore the baseline rate of movement was not able to be determined at this trial site. However, the baseline rate of movement was able to be established at Trial Sites 1 and 4.

Thus, in order to provide as much as a like-for-like comparison as possible the performance criterion has been broken down into two separate sub-criteria for assessment and then assessed in two ways.

The sub-criteria are:

- Level of reduction in movement relative to the baseline
- Reduction in signs of distress

The following assessments were undertaken:

- Scenario 1: Level of reduction in movement has been assessed and included in the score
    - Both sub-criteria have a weighting of 10.53%, which is an equal division of the 21.05% weighting for the original performance criterion
    - Baseline rate of movement not established at Trial Site 2 and, as such, the rating for the level of reduction of movement has been assigned a rating of 0
    - Results presented in Table 11
- Scenario 2: Level of reduction in movement has been excluded
    - Reduction in signs of distress has a 21.05% weighting
    - Results presented in Table 12

The total scores for each methodology provided in Table 11 and Table 12 show that there is minimal variation for the screw-in anchors (Ecospec) and the jet grout columns (Menard). The resin injection (Mainmark) results show a 10% difference in scores (82% for Scenario 1 and 92% for Scenario 2) which provides an indicative range of potential scores, had the baseline rate of movement been established at Trial Site 2. It is noted that the maximum possible total score for the resin injection (Mainmark) method would be 93%, if it had been rated 10 for reduction in movement relative to the baseline in Option 1.

Table 11: Trial assessment results (Scenario 1, accounting for level of reduction of movement and reduction in signs of failure or distress)

Criteria	Weighting	Screw-in anchors (Ecospec)		Resin injection (Mainmark)		Jet grout columns (Menard)	
		Rating	Score	Rating	Score	Rating	Score
Cost	21.05%	[redacted]					
Impacts due to construction	21.05%						
Performance	21.05%						
Level of reduction of movement relative to baseline (if established)	10.53%						
Reduction in signs of failure or distress	10.53%						
Maintenance	10.53%						
Constructability and programme	10.53%						
Understanding of the project	10.53%						
Quality control	5.26%						
Previous experience	-						
	Total score	**68%**		**82%**		**59%**	

Table 12: Trial assessment results (Scenario 2, accounting for reduction in signs of failure or distress only)

Criteria	Weighting	Screw-in anchors (Ecospec)		Resin injection (Mainmark)		Jet grout columns (Menard)	
		Rating	Score	Rating	Score	Rating	Score
Cost	21.05%	[redacted]					
Impacts due to construction	21.05%						
Performance	21.05%						
Level of reduction of movement relative to baseline (if established)	N/A						
Reduction in signs of failure or distress	21.05%						
Maintenance	10.53%						
Constructability and programme	10.53%						
Understanding of the project	10.53%						
Quality control	5.26%						
Previous experience	-						
	Total score	**69%**		**92%**		**62%**	

6 Trial assessment conclusions

A previous assessment undertaken by KBR concluded that canal wall failures taking place within Raby Bay were generally triggered by a shallow failure mechanism occurring in a wedge of uncompacted fill located at the revetment wall and rock armour. GHD review of the KBR report indicated that there could potentially be deeper failures occurring. Golder Associate's report, produced as part of the Trial project, identified several possible failure mechanisms, including shallow rotational or sliding failures and shallow flow slides at the Sternlight Court and Masthead Drive Trial areas, although definitive movements had not been identified at that time.

Shallow failures limited to the wall location are broadly consistent with the failure mechanism identified by KBR. However, some movements recorded at shallow depths in the downslope inclinometers (e.g. inclinometers SC2, SC7, MD2, MD4 and MD6) indicate a separate or supplementary failure mechanism, such as a shallow translational slide. Leaning pontoon piles could also be indicative of shallow translational slides. At the time of writing, no movements recorded indicate deep seated failures, as was postulated to be a potential failure mechanism by GHD.

The three trialled repair methodologies all address slope instability at the upper part of the canal batter, i.e. at the wall location and as such, pending the results of the post-construction monitoring, are suitable for addressing shallow failure mechanisms in the upper part of the slope, where the largest impact due to movement are identified.

Based on the trial assessment, the resin injection solution implemented by Mainmark is the most suitable repair solution of those trialled. Further, the resin injection solution was the cheapest of those trialled, and significantly outperformed the other solutions in impacts due to construction.

It is noted that:

- The resin injection solution performed relatively well in all assessed criteria, particularly regarding cost and impacts due to construction. However, due to limitations of the Trial and the limitations of the resin injection solution it must be recognised that:
    - The resin injection site, Trial Site 2, did not have conclusive movements. As no or minimal movement was recorded during the Stage 4 monitoring period, it cannot be concluded that this is solely as a result of the resin injection works.
    - Further, while the solution showed few signs of distress this could be in part due to the little to no movement the site was experiencing prior to the construction works.
    - The resin injection solution, as trialled, is not considered suitable for sites with lateral movement in excess of 50mm [15].
- Different repairs methods may be more suitable for various sites, depending on the local conditions. While the resin injection method is considered relatively adaptable to various sites, some assessment of the suitability of a

repair method for the specific site conditions, constraints and likely failure mechanism, needs to be made prior to implementing repair works.

7 Further notes and recommendations

The following commentary should be considered by RCC prior to implementing any repair methodologies within Raby Bay.

7.1 Trial assessment

- Assessment of cost was not able to be undertaken in an absolutely equitable manner due to differences in the construction methodologies and sites. Namely the jet grout column (Menard) works inherently require some landscaping works during the reinstatement of their trench whereas the screw-in anchor (Ecospec) works do not impact behind the retaining wall at all, and impact due to the resin injection (Mainmark) works behind the wall is minimal.
    - Landscaping cost was included in the cost assessment to account for the fact the jet grout column (Menard) works will inevitably incur some landscaping costs, however their site encompassed properties that included heavy landscaping up to the back of the retaining wall which, while not uncommon, is not present at all properties within Raby Bay and may not be representative.
    - It is suggested that cost could be reassessed if contractors provided updated cost estimates, all for the same site, or several sites. However, such an assessment has not been undertaken as part of this report.
    - Similarly, if cost is updated, estimated programme/s could also be provided. However, estimated programmes should be based on the works and efficiencies achieved during the Trial, i.e. based on works and learnings achieved, and speculative (i.e. unproven) changes in methodology should not be considered.
- Weighting of criteria in future tenders (if required) could be adjusted to suit requirements. However weighting low cost over performance, for example, could result in less effective methods being implemented and which may result in additional costs in subsequent maintenance, repair or replacement.

7.2 Repair methods

- Of the methodologies trialled the resin injection (Mainmark) solution best fits the assessment criteria and RCC’s desire to limit, where possible, cost, and construction impacts while maximising performance. However, this solution, as trialled, is not considered suitable for sites with lateral movement in excess of 50mm [15].
    - Mainmark could be approached to see if the resin injection solution can be adjusted for sites with wall movements up to 100mm.
    - Thresholds for implementing repairs could be adjusted such that the resin injection solution is more applicable.

    - More robust methods such as screw-in anchors (Ecospec) or jet grout columns (Menard) could alternatively be utilised when existing lateral movements tend greater than 50mm, although jet grouting may not be suitable near sensitive structures as it could cause disturbance.
- Consideration of the site-specific conditions should be made prior to appointing a contractor or repair method. For example, it is worth noting, in addition to the above points, the following advantages and disadvantages of the trialled methods:
    - None of the methods, as installed, address instability/movement in the lower part of the batter slopes. It is possible that the solutions could be adjusted to address the downslope but it is expected that there would be an increased cost and as well as effects on the level of impact, constructability and programme.
    - While possible to implement, the jet grout column solution may not be suitable in sites that would require significant landscaping, when considering residential setting and the potential constructability and communication issues. This solution may also not be suitable near sensitive structures.
    - The screw-in anchor solution may not be able to be implemented where there are deep structures/foundations or pools, although anchors may be able to be installed at lower levels to avoid such structures.
- The screw-in anchor solution was beneficial from an access point of view given that all access and works could be undertaken from the water (limiting impact to the property and residents) but it required movement of some boats and pontoons. If smaller plant could have been used, or an excavator with a longer arm such that no or fewer boats and pontoons required moving, this would improve the construction impact.
- The jet grout column programme was heavily impacted by the thickness of the spoil returned from the jet grouting process. If spoil workability can be improved then the speed of construction may be improved considerably.

7.3 Information and data

- It is understood that contractors typically receive site-specific geotechnical investigation and monitoring data, and geotechnical reports. It is suggested that the following information could also be provided to contractors:
    - Raby Bay-wide historical information including a chronology of events (e.g. known dates and staging), past contractors and designers, employed construction methodologies, typical sections and as-built drawings, where available.
    - Site inspection reports and notes, photographs, etc.
    - Surveying data.
    - Pre-condition surveys, including cataloguing and measurement of defects, and covering the immediate site, adjacent areas and potential access

routes, undertaken as early as possible (e.g. when the decision is made to implement repair methods at that site). This could be compared to a contractor's pre-construction dilapidation report in the instance of any suspected movements or damage as a result of repair works.

- It is recommended that monitoring continues to target behind, at and downslope of the retaining wall to more confidently understand the extents and depths of any potential failure zones.
- Testing could also be undertaken to assess the reactivity of soils, as a repeated shrink-swell of soil could result in wall movements.
- It is understood geotechnical investigations and monitoring typically include boreholes and inclinometers in the rock revetment. RCC also undertake surveying along the retaining wall. However, it would be worth considering, where possible and cost effective, boreholes, test pits, hand augers or other sampling methods in the properties as well.
- Geotechnical sampling and laboratory testing should consider, where possible, any specific requirements for the potential repair methods to be implemented.

7.4 Construction

- Landscaping should be confirmed with contractors and owners/residents prior to commencement of construction to prevent potential misunderstandings and delays.
- The requirement for wall top-up or replacement should be assessed prior to the engagement of a contractor. It was understood during Stage 3 that RCC's existing requirements for wall top-up are:
  - Top of retaining wall to be at 1.6mAHD or higher.
  - Top-up of up to 400mm vertically is allowed. Where greater than 400mm vertical height exists between top of wall and 1.6mAHD, the wall should be replaced.
  - No quantitative limit on horizontal alignment, but walls should not be topped up if there are signs of significant distress, e.g. cracking or wide joints.
- It is recommended that RCC engage a RPEQ engineer to design a standard wall top-up. The design should include drawings that can be passed onto contractors and should also include at least the following:
  - Clearly defined thresholds for when wall top-up is allowed and when replacement is triggered.
  - Design and drawings covering the known wall types within Raby Bay.
  - Suitable material types (e.g. grout or concrete) and appropriate tie-in measures.
  - Aesthetic requirements or finishes.

8 References

[1] Queensland Department of Natural Resources and Water, 2007. Historical aerial images – Beenleigh Sheet 9542.

[2] Kellogg Brown & Root, 2013. *Raby Bay Canal Batter Stability Update – Geotechnical Investigation Analysis Report*, dated 24 June 2013 (ref. BEJ809.002-W-REP-003 Rev. 0).

[3] GHD, 2013. *Peer Review of Raby Bay Geotechnical Study*, dated 28 March 2013 (ref. 41/25756).

[4] Google, 2017. Google Earth Pro. Software, version 7.3.0.3832. Accessed 6 October 2017.

[5] Golder Associates, 2016. *Raby Bay – Geotechnical Investigation & Monitoring for Proposed Stabilisation Trial*, dated 25 February 2016 (ref. 1529649-035-REV1).

[6] Arup, 2016. *Raby Bay Repair Trial - Proposed Implementation Plan*, dated 1 November 2016 (ref. 240904-GEO-010, Issue 1)

[7] Arup, 2017. *Assessment of trial works extents*, dated 9 February 2017 (ref. 240904-GEO-014, Issue1)

[8] Arup, 2016. *Stage 3 Trial Remediation Assessment Criteria*, dated 18 March 2016 (ref. 240904-GEO-006, Issue 1).

[9] Arup, 2016. *Technical Performance Specification for Trial Remediation Works*, dated 1 June 2016 (ref. 240904-GEO-003, Issue 3).

[10] Golder Associates, 2017. *Raby Bay Inclinometer, Tiltmeter and Survey Readings February 2017*, dated 2 March 2017 (ref. 1529649-064-TM-Rev0).

[11] Golder Associates, 2018. *Raby Bay Inclinometer, Tiltmeter and Survey Readings June 2018*, dated 14 June 2018 (ref. 1529649-084-TM-Rev0).

[12] Redland City Council, 2018. Photos of Trial Sites 1 through 4, taken on 20 June 2018.

[13] Menard Oceania, 2017. *Geotechnical Assessment and Design of Jet Grouting for Slope Stabilisation Works*, dated 5 April 2017 (ref. 5040198-MB-Q-DRE-R-01, Revision 0).

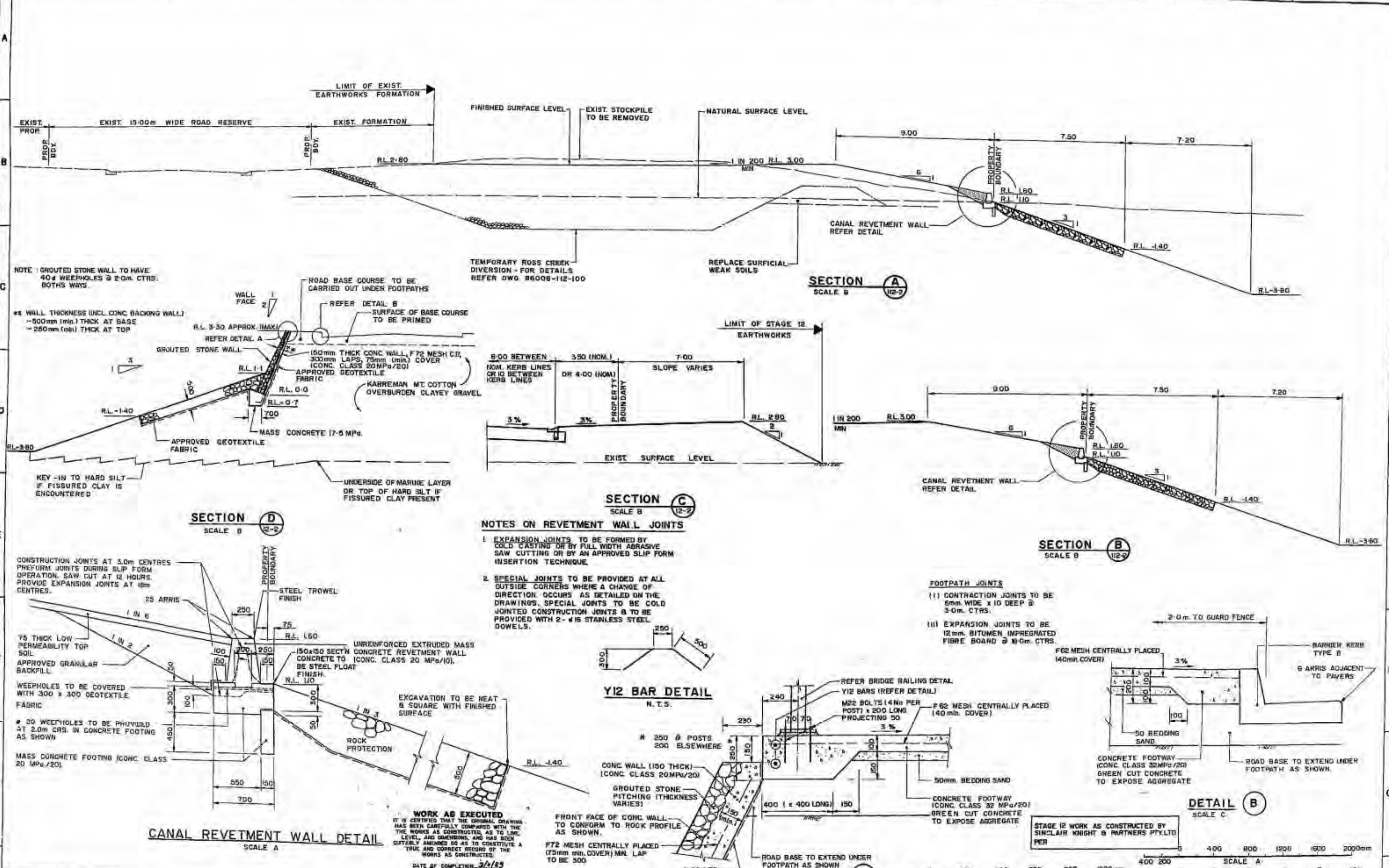
[14] P.J. Yttrup & Associates, 2017. *Canal Bank Stabilisation Trial at 7 Sternlight Court, Raby Bay*, dated 20 July 2017 (ref. 22473).

[15] Mainmark Civil and Mining Services, 2016. *Tender: T-1777-15/16-CIG –Tender In Respect of the Establishment of a Register of Pre-Qualified Suppliers for Raby Bay Repair Trial - URETEK RESIN Remediation of Poorly Compacted Fill Layer*, dated 7 August 2016.

Appendix A

Plans and drawings

A1 Sternlight Court revetment typical section



WORK AS EXECUTED

IT IS CERTIFIED THAT THE ORIGINAL DRAWING HAS BEEN CAREFULLY COMPARED WITH THE THE WORKS AS CONSTRUCTED, AS TO LINE, LEVEL, AND DIMENSIONS, AND HAS BEEN SUITABLY AMENDED SO AS TO CONSTITUTE A TRUE AND CORRECT RECORD OF THE WORKS AS CONSTRUCTED.

DATE OF COMPLETION 3/1/89

SINCLAIR KNIGHT AND PARTNERS SUPERVISING ENGINEER

STAGE 12 WORK AS CONSTRUCTED BY SINCLAIR KNIGHT & PARTNERS PTY.LTD PER

NO	DATE	APP'D	AMENDMENT
E	31.10.89	PMD.	AS CONSTRUCTED
D	2.11.88	J.A.E.	AMENDED TO COUNCIL REQUIREMENTS
C	21.10.88	J.A.E.	REDESIGNED TO NEW LOT LAYOUT
B	22.9.88	J.A.E.	REVETMENT WALL KEY AMENDED
A	9.6.88	J.A.E.	AMENDED TO COUNCIL REQUIREMENTS

SINCLAIR KNIGHT & PARTNERS
CONSULTING ENGINEERS
Sinclair Knight & Partners Pty Ltd
Incorporated in NSW
139 Leichhardt Street Brisbane
Qld 4000 Australia
Telephone (07) 835 1572
Telex AA41968

CLIENT: CIVIC PROJECTS (RABY BAY) PTY. LTD.

PROJECT: RABY BAY DEVELOPMENT - STAGE 12

DRAWN: M.G. TRACED: H.P. CHECKED: Q.P 9 /8/88 APPROVED: 3/8/88

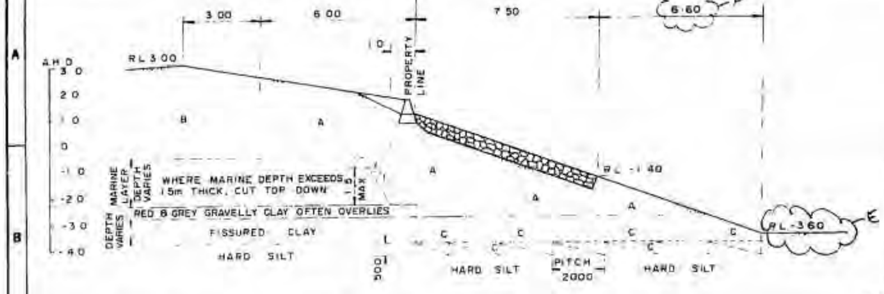
TITLE: SUBDIVISIONAL ROADWORKS AND DRAINAGE
TYPICAL CROSS SECTIONS
EARTHWORKS

SCALE: AS SHOWN
DRAWING No: 86006-112-04 AMDT: E

D006588

R1-7/46-4 A1

A2 Masthead Drive revetment typical section

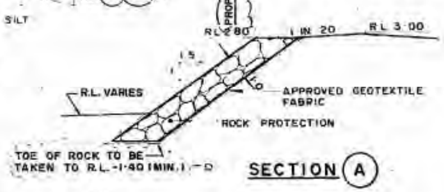


A - RED & GREY GRAVELLY CLAY FROM CANAL BOTTOMS COMPACT TO 100% STANDARD DENSITY
B - ALLOTMENT FILL - 95% STANDARD DENSITY
C - KARREMAN MT COTTON OVERBURDEN - CLAYEY GRAVEL REPLACE TO TOP OF FISSURED CLAY & KEY IN TO HARD SILT COMPACT TO 100% STANDARD DENSITY

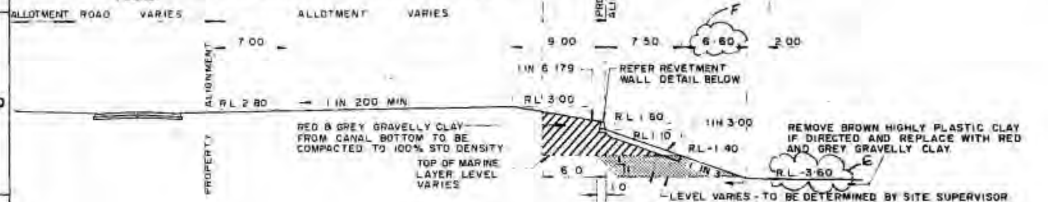
AMENDED CONSTRUCTION DETAILS - WHERE FISSURED CLAY IS ENCOUNTERED

N.T.S.

THE TOP OF EACH COMPACTED LAYER, IN THIS AREA IS TO BE SCARIFIED TO ENSURE IT WILL MARRY IN TO THE SUCCEEDING LAYER TO PREVENT A HORIZONTAL SLIP PLANE DEVELOPING. THE VERTICAL FACE AT THE COMPACTION EXTENT LINE, 6m BACK FROM THE ROCK REVETMENT SHALL BE ROUGHENED TO PREVENT A VERTICAL SLIP PLANE.



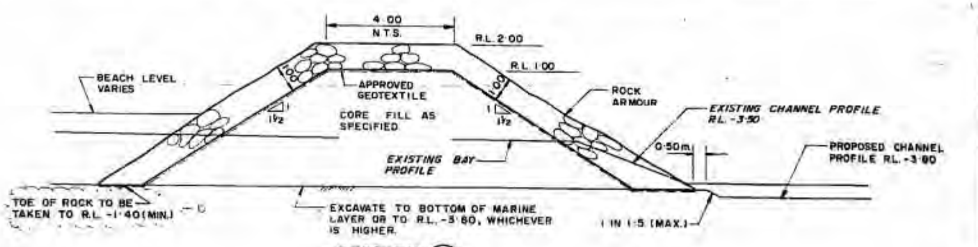
SECTION (A)



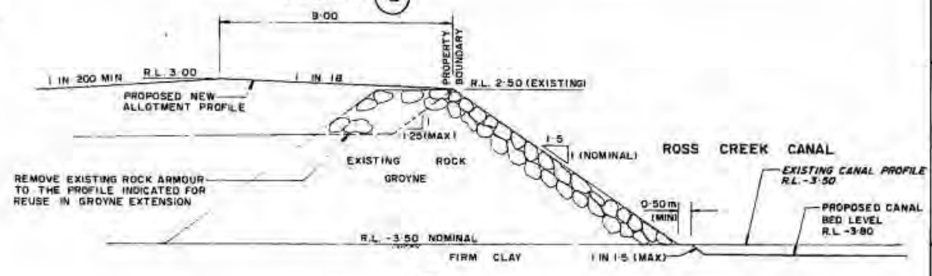
- REMOVE MARINE LAYER TO MAXIMUM DEPTH OF 1.5m TO EXTENT SHOWN & REPLACE WITH RED & GREY GRAVELLY CLAY FROM CANAL BOTTOM TO 100% STD. COMPACTION. EXCAVATION TO BE INSPECTED BY SUPERINTENDENT'S REPRESENTATIVE PRIOR TO BACKFILL. SHOULD THE LAYER OF EXISTING MARINE MATERIAL EXCEED 1.5m THE SUPERINTENDENT SHALL INSPECT THE EXCAVATION AND ADVISE OF THE REQUIRED CONSTRUCTION PROCEEDURE. SHOULD THE MARINE LAYER EXTEND BELOW R.L. -3.50, THE MATERIAL SHALL BE EXCAVATED TO 16.70m. BEYOND THE PROPERTY BOUNDARY (INTO THE CANAL)

TYPICAL ALLOTMENT DETAIL

N.T.S.



SECTION (E)



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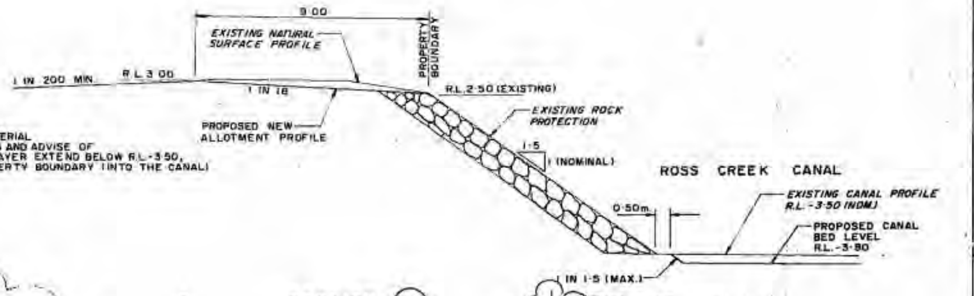

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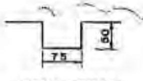
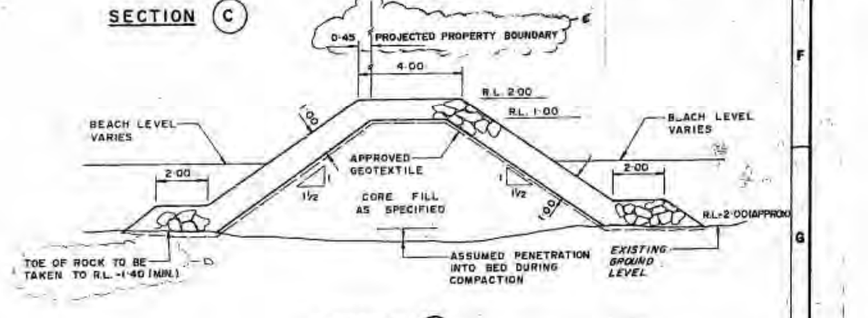


KEY DETAIL

NOTE: 1. EXPANSION JOINT (12mm. BITUMEN IMPREGNATED FIBRE BOARD) - TO BE PROVIDED AT 18.0m. CTRS. COINCIDENTLY IN FOOTING AND REVETMENT WALL.

2. CONTRACTION JOINT
a) FOOTING - JOINT TO BE FORMED BY PLACING 4.5mm. F.C. SHEET VERTICALLY AT 3.0m. CTRS.
b) REVETMENT WALL - 6mm. WIDE, 40mm. DEEP JOINT TO BE PROVIDED AT 3.0m. CTRS. COINCIDENTLY WITH FOOTING JOINTS PRIOR TO CONCRETE SET. BACK FACE OF WALL TO BE SAW CUT, AT PREFORMED JOINT, 100mm. DEEP WITHIN 24 HOURS OF PLACEMENT OF CONCRETE.

E



SECTION (B)

STAGE 8 WORK AS CONSTRUCTED BY SINCLAIR KNIGHT & PARTNERS PTY.LTD
PER 20/2/88

WORK AS EXECUTED
IT IS CERTIFIED THAT THE ORIGINAL DRAWING HAS BEEN CAREFULLY COMPARED WITH THE THE WORKS AS CONSTRUCTED, AS TO LINE, LEVEL, AND DIMENSIONS, AND HAS BEEN SUITABLY AMENDED SO AS TO CONSTITUTE A TRUE AND CORRECT RECORD OF THE WORKS AS CONSTRUCTED.

REVETMENT WALL DETAIL

D005740

No.	DATE	APP'D	AMENDMENT
E	20.11.87	C.P.R.	REVETMENT WALL, SECT. A & SECT. B REVISED
D	16.11.87	C.P.R.	REVISED TO COUNCIL REQUIREMENTS
C	2.10.87	R.P.L.	REVETMENT WALL DETAIL ALTERED
B	30.10.87	J.A.E.	TOE OF REVETMENT WALL LEVEL CORRECTED
A	20.10.87	C.P.R.	REDESIGN ISSUE
F	26.2.87	C.P.R.	TYPICAL ALLOTMENT PROFILE REVISED

SINCLAIR KNIGHT & PARTNERS
CONSULTING ENGINEERS
Sinclair Knight & Partners Pty Ltd
139 Leichhardt Street Brisbane
Qld 4000 Australia
Telephone (07) 839 1572
Telex AA41968

CLIENT: CIVIC PROJECTS (RABY BAY) PTY. LTD.
PROJECT: RABY BAY DEVELOPMENT - STAGE 8
DRAWN: C.P.R. TRACED: K.V. CHECKED: 20/10/87 APPROVED: 20/10/87

TITLE: TYPICAL CROSS SECTIONS
SHEET 2 OF 3
D005740
SCALE: AS SHOWN
DRAWING No: 86006-36
AMDT: F

R1-7/34-63 A1

A3 Ecospec as-constructed drawings

SCREW PILING NOTES

SS1 WORKMANSHIP AND MATERIALS

SS1.1 WORKMANSHIP/ MATERIALS ALL WORKMANSHIP AND MATERIALS SHALL BE IN ACCORDANCE WITH THE FOLLOWING STANDARDS:

AS 1163	STRUCTURAL STEEL HOLLOW SECTIONS
AS 1450	STEEL TUBES FOR MECHANICAL PURPOSES
AS/NZS 1554	STRUCTURAL STEEL WELDING – WELDING OF STEEL STRUCTURES
AS 1579	ARC WELDED PIPES & FITTINGS FOR WATER & WASTEWATER
AS 2159	PILING – DESIGN AND INSTALLATION
AS 3600	CONCRETE STRUCTURES
AS 3678	STRUCTURAL STEEL – HOT ROLLED PLATES, FLOOR PLATES AND SLAB
AS/NZS3679.1	STRUCTURAL STEEL – HOT ROLLED BARS & SECTIONS
AS/NZS3679.2	STRUCTURAL STEEL WELDED I SECTIONS
AS 4100	STEEL STRUCTURES
AS/NZS 4671	STEEL REINFORCING MATERIALS

SS1.2 CONSTRUCTION. SCREW PILES SHALL BE CONSTRUCTED TO THE TOLERANCES IN AS2159.
PILE INSTALLATION RATES SHALL BE SLOWED DOWN WHEN APPROACHING HARD GROUND CONDITIONS
AND PILES SHALL NOT BE ROTATED IN THE GROUND IF NO PILE ADVANCE IS OCCURRING.

SS2. WELDS AND BOLTS

B

WELDING SHALL BE PERFORMED BY AN EXPERIENCED OPERATOR IN ACCORDANCE WITH AS1554.

UNLESS STATED ELSEWHERE ALL WELDS CONNECTING THE HELIX TO THE PILE SHAFT SHALL BE AS FOLLOWS:

WELD METAL DESIGNATION E41XX, W40XX
WELD METAL STRENGTH 410MPa
WELD CATEGORY GP CATEGORY FILLET WELD

ALL BOLTS SHALL BE IN ACCORDANCE WITH AS1252. UNLESS STATED ELSEWHERE ALL BOLTS USED IN CONNECTIONS SHALL BE AS FOLLOWS:

BOLT DESIGNATION HIGH STRENGTH STRUCTURAL
BOLT CATEGORY 8.8/S
TENSILE STRENGTH 800MPa
YIELD STRENGTH 640MPa

SS3. DURABILITY

UNLESS STATED ELSEWHERE THE SCREW PILING DESIGN HAS BEEN BASED ON A TOTAL CORROSION ALLOWANCE OF 1.5mm BASED ON A CORROSION RATE OF 30 MICRONS PER YEAR OVER 50 YEARS.

SS4. LOCATION AND TOLERANCES

FOR FINAL PILE POSITIONS & LOCATIONS REFER PILE SET OUT PREPARED BY THE SUPERSTRUCTURE DESIGN ENGINEER.

UNLESS SHOWN OTHERWISE THE POSITION OF A PILE MEASURED AT THE CUTOFF LEVEL SHALL BE NOT MORE THAN 75mm MAX. AWAY FROM ITS DESIGN POSITION.

DURING AND AFTER INSTALLATION ANY PILE MORE THAN 75mm MAXIMUM AWAY FROM ITS FINAL DESIGN POSITION SHALL BE RE–APPRAISED BY THE SUPERSTRUCTURE DESIGN ENGINEER.

UNLESS STATED OTHERWISE PILES SHALL BE TRIMMED TO A CUT OFF LEVEL WITHIN ±25mm OF THE DESIGN CUTOFF LEVEL.

INSTALLED PILE LENGTH SHALL BE NO LESS THAN THE SPECIFIED DESIGN PILE LENGTH.

WHERE THE INSTALLED PILE LENGTH IS INCONSISTENT WITH THE DESIGN LENGTH A REAPPRAISAL OF THE GEOTECHNICAL CAPACITY MUST BE UNDERTAKEN.

THE TOLERANCES ON THE STRAIGHTNESS ON THE COMPLETED LENGTH OF STEEL PILES SHALL BE 1/250 OF THE LENGTH – UP TO A MAXIMUM DEVIATION OF 50mm.

THE MAXIMUM ANGULAR DEVIATION AT A PILE JOINT SHALL NOT EXCEED 1 in 100.

SS5. HANDLING & STORAGE

PILES SHALL BE HANDLED AND STORED SO THAT THEY ARE NOT OVERSTRESSED AND IN SUCH A WAY TO PREVENT ANY PERMANENT DISTORTION TO ANY PART.

SS6. INSTALLATION

PILE INSTALLATION SHALL BE CARRIED OUT TO ENSURE THAT THE MAXIMUM MEASURED INSTALLATION TORQUE DOES NOT EXCEED 0.9 TIMES THE YIELD STRENGTH OF THE PILE SHAFT.

PILE INSTALLATION TORQUE FOR ALL PILES SHALL BE MEASURED AND RECORDED AT 0.5m INTERVALS FOR THE FINAL 2.0m ABOVE THE DESIGN INSTALLATION DEPTH FOR EVERY PILE INSTALLED.

CONTINUOUS PILE TORQUE PROFILING WITH INSTALLATION TORQUE MEASUREMENTS AT 0.5m INTERVALS SHALL BE CONDUCTED FOR A MINIMUM OF 5% OF THE TOTAL NUMBER OF INSTALLED PILES AND NOT LESS THAT A TOTAL OF THREE (3) PILES PER SITE.

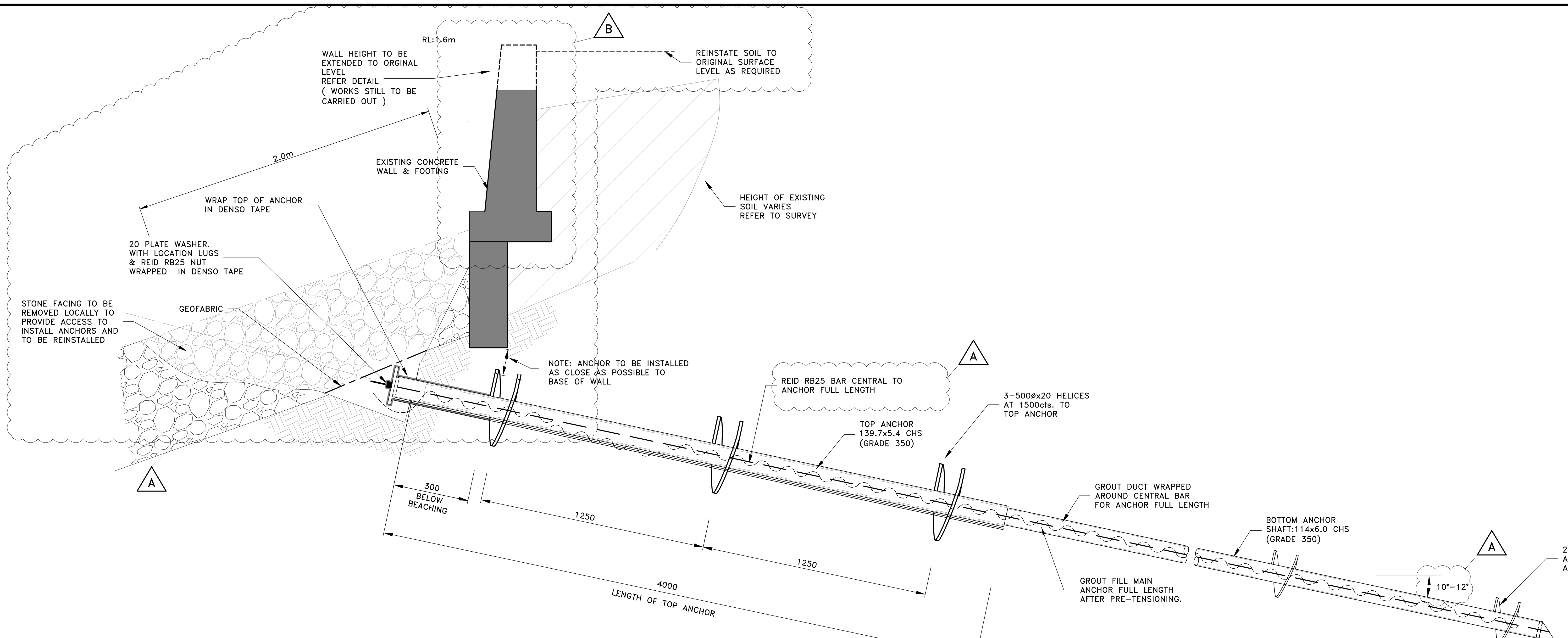
SS7. RECORDS OF DATA

THE FOLLOWING INFORMATION SHALL BE RECORDED FOR ALL SCREW PILES DURING INSTALLATION:
- DATE OF INSTALLATION
- LOCATION AND DIMENSION OF PILES
- INSTALLATION DEPTH
- INSTALLATION EQUIPMENT TYPE AND DESIGNATION
- FINAL SETTING TORQUE FOR EVERY PILE
- FULL INSTALLATION TORQUES OR SET FOR MINIMUM OF 5% OF PILES
- SEQUENCE OF INSTALLATION
- ANY APPARENT PILE DEVIATION FROM SPECIFIED LOCATION AND INCLINATION.

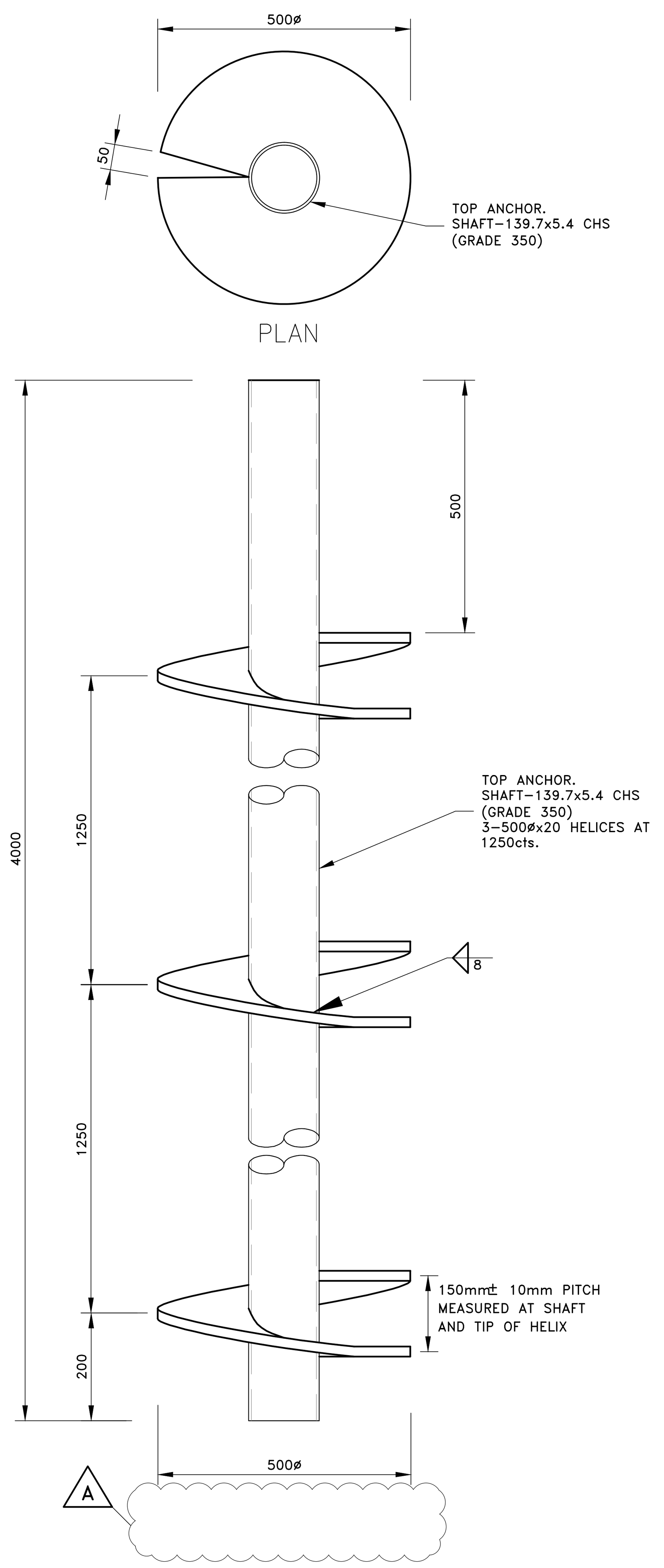
SS8. REINFORCEMENT & GROUTING

SS8.1 REINFORCEMENT. THE PILE REINFORCEMENT SHALL BE PLACED CENTRAL IN THE PILE WITH CENTRALISERS AT VERTICAL INTERVAL NOT EXCEEDING 4 METERS.

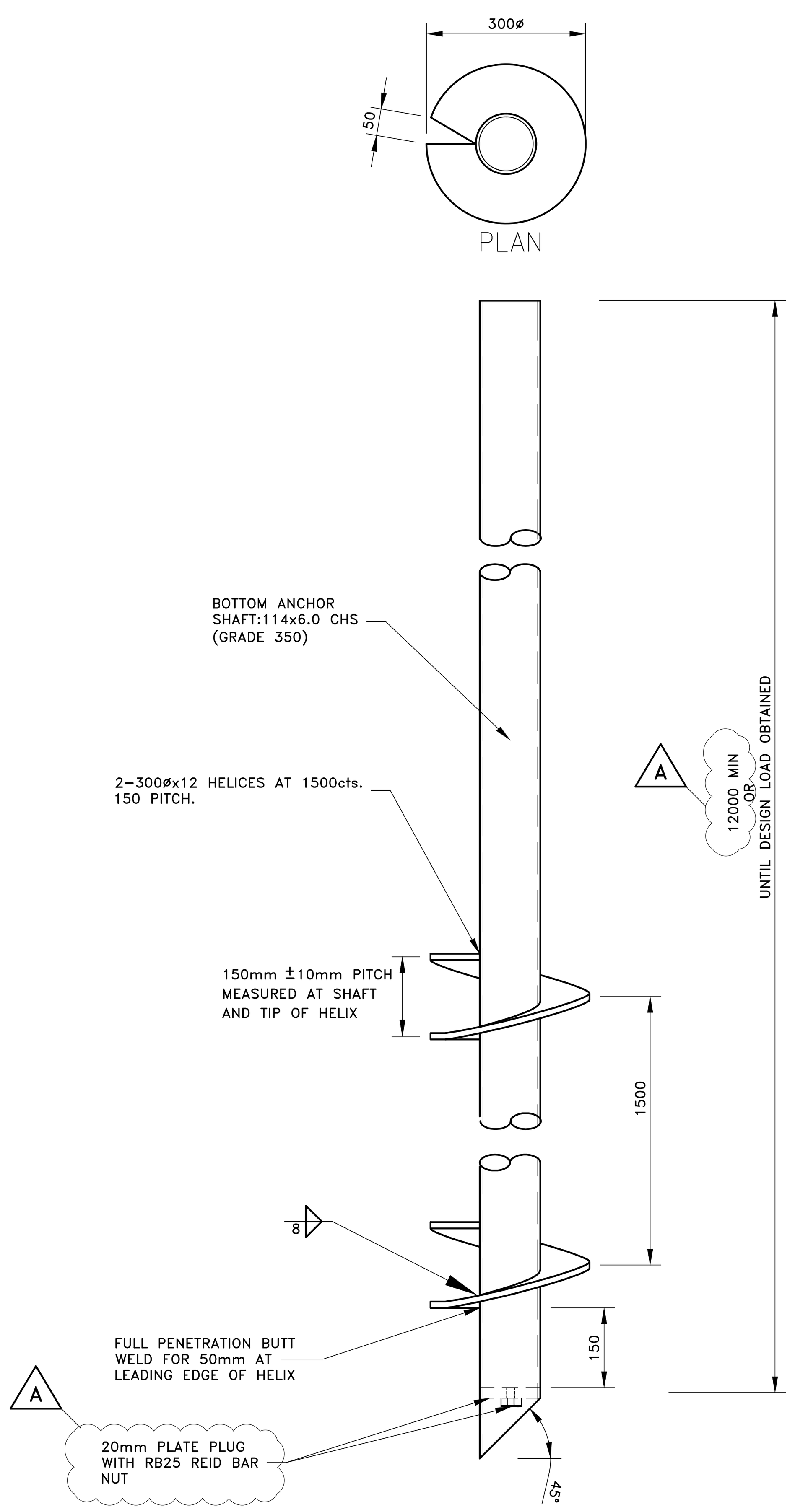
SS8.2 GROUTING. THE PILE SHAFT SHALL BE GROUT FILLED WITH A FLOWABLE GROUT PUMPED INTO THE PILE. THE GROUT SHALL HAVE A MINIMUM 28 DAY COMPRESSIVE STRENGTH OF 40MPa.



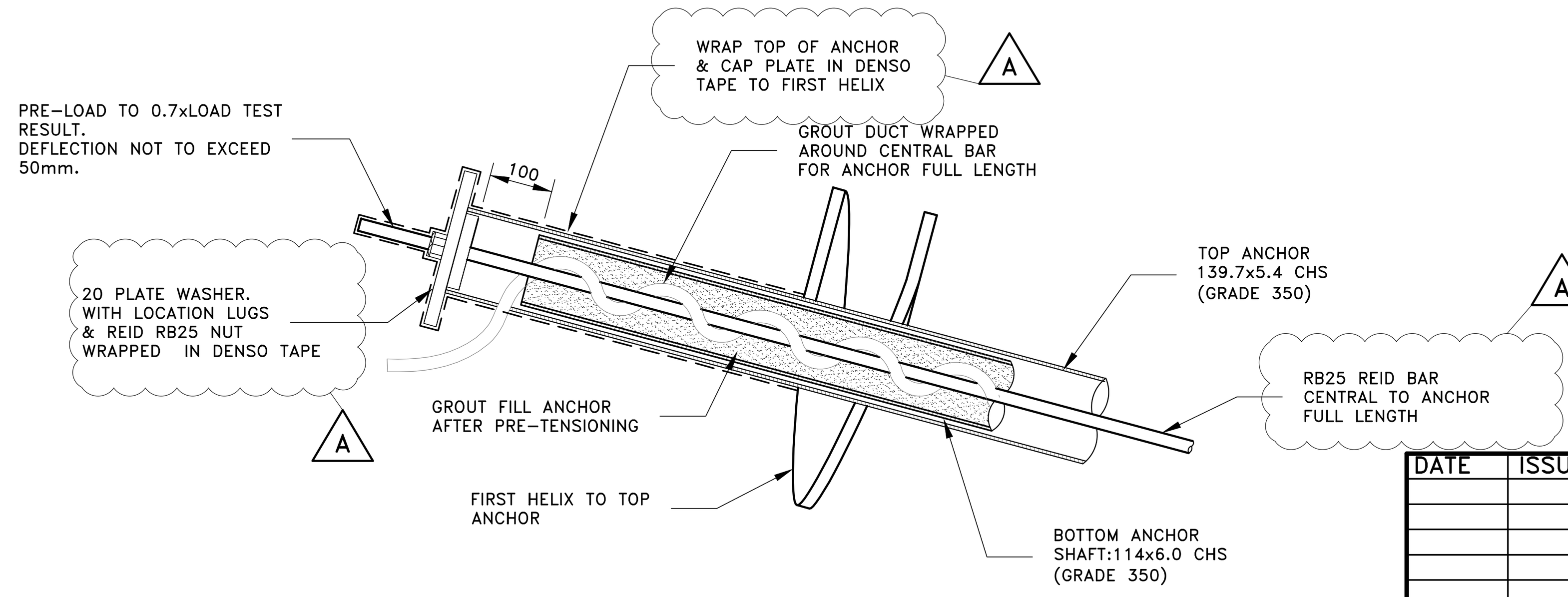
TYPICAL ANCHOR DETAIL 1:20



TOP ANCHOR DETAIL 1:10



BOTTOM ANCHOR DETAIL 1:10



TOP OF ANCHOR DETAIL 1:10

DATE	ISSUED TO	NO	DATE	ISSUED TO	NO

DATE	REVISION	BY
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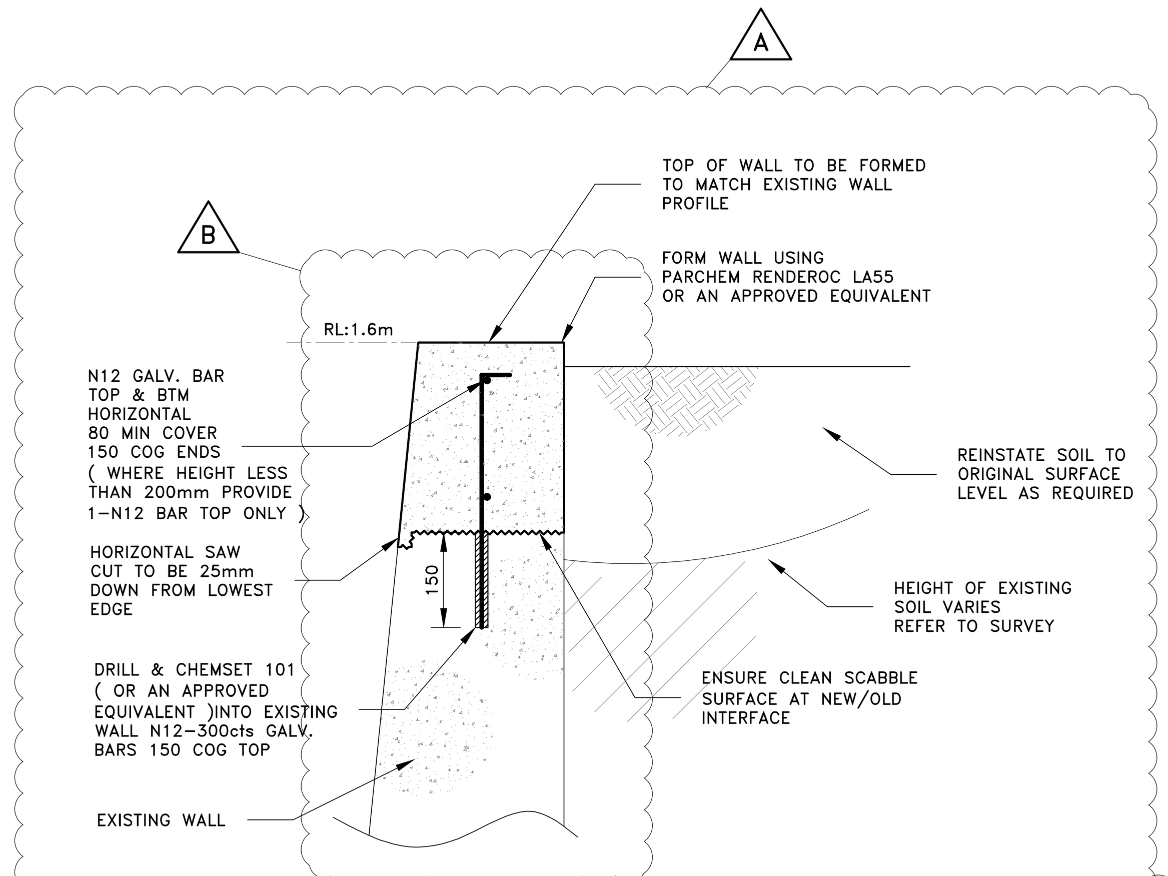
27.07.17	REV B CLOUDED	RH



WALL EXTENSION DETAIL 1:10
(WORKS STILL TO BE CARRIED OUT)

B

ISSUE: AS CONSTRUCTED

P.J.YTTRUP & ASSOCIATES PTY.LTD
CONSULTING ENGINEERS
A.C.N. 005 909 919 A.B.N. 71 687 799 203
33 ROBERTS ROAD
BELMONT 3216
Email: admin@yttrup.com
PH: (03) 5243 3388 FAX: (03) 5244 3023

CLIENT
ECOSPEC AUSTRALIA

PROJECT
7 STERNLIGHT COURT
RABY BAY
CANAL QLD

DRAWING
TRIAL ANCHOR INSTALLATION

ENGINEER	DRAWN	JOB No
PJY	JK	22473
CHECKED NM RPEQ 09940	SHEET No S1 of 2	
SCALE 1:150 1:20	DATE 03.03.17	REV No B — A1

ANCHOR LAYOUT PLAN 1:100

DATE	ISSUED TO	NO	DATE	ISSUED TO	NO

DATE	REVISION	BY
19.05.17	ADDED SHEET S2	RH
27.07.17	REV B CLOUDED	RH

ISSUE AS CONSTRUCTED

P.J.YTTRUP & ASSOCIATES PTY.LTD
CONSULTING ENGINEERS
A.C.N. 005 909 919 A.B.N. 71 687 799 203
33 ROBERTS ROAD
BELMONT 3216
Email: admin@yttrup.com
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CLIENT
ECOSPEC AUSTRALIA

PROJECT
7 STERNLIGHT COURT
RABY BAY
CANAL QLD

DRAWING
ANCHOR INSTALLATION PLAN

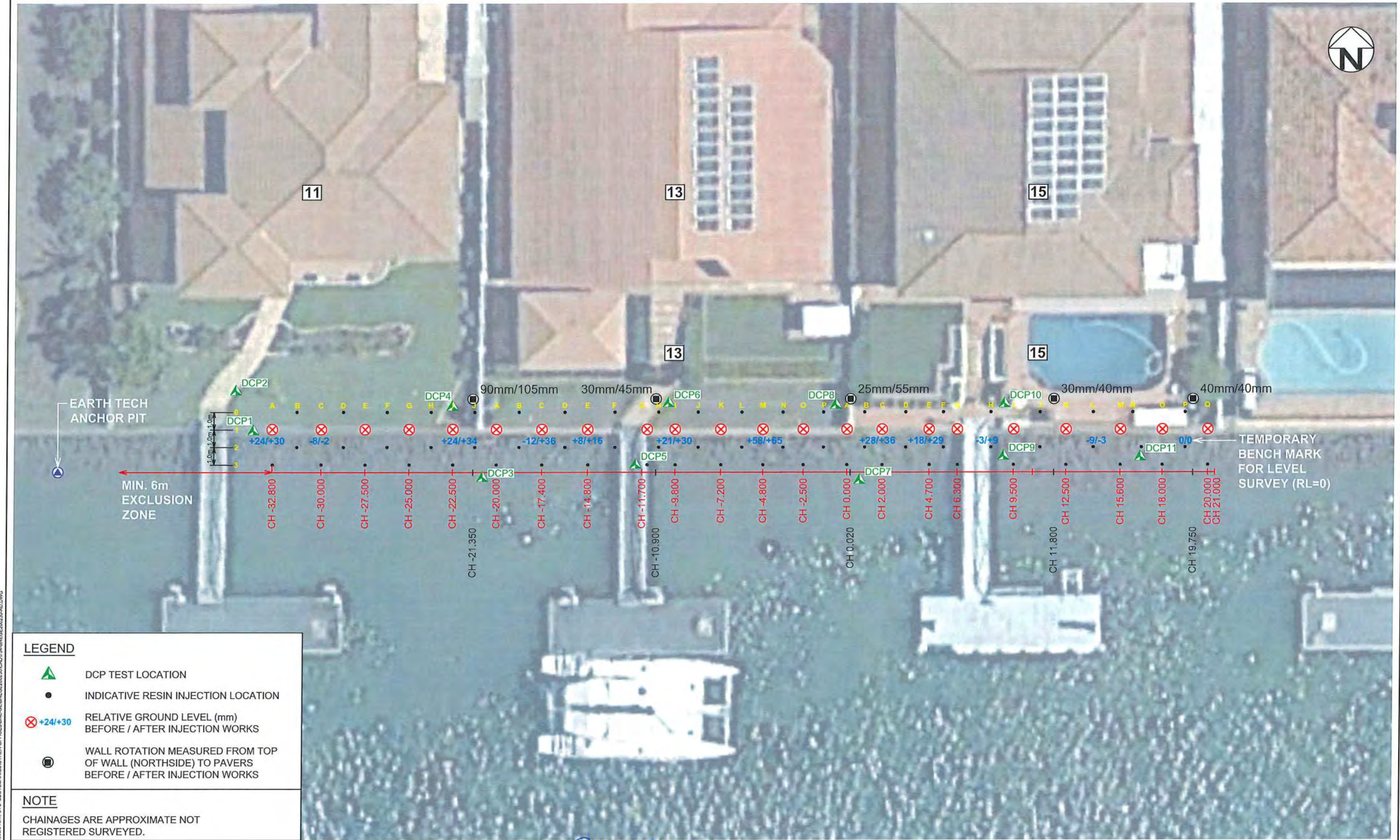
ENGINEER	DRAWN	JOB No
PJY	JK	22473
CHECKED NM RPEQ 09940	SHEET No S2 of 2	
SCALE 1:100	DATE 03.03.17	REV No B

B

A1

U:\22473\22473 170303 Trial Anchor Installation REV B.dwg, 27/07/2017 3:46:24 PM, DWG To PDF.pc3

A4 Mainmark as-constructed drawings



LEGEND

- DCP TEST LOCATION
- INDICATIVE RESIN INJECTION LOCATION
- +24/+30 RELATIVE GROUND LEVEL (mm) BEFORE / AFTER INJECTION WORKS
- WALL ROTATION MEASURED FROM TOP OF WALL (NORTHSIDE) TO PAVERS BEFORE / AFTER INJECTION WORKS

NOTE

CHAINAGES ARE APPROXIMATE NOT REGISTERED SURVEYED.

revision no.	description	drawn	approved	date
A	ORIGINAL ISSUE	NA	NA/SB	14/06/17

Patrick Gibbons RPEQ 11846

2.5 0 2.5 5 7.5 10

Scale (metres) 1:200

AERIAL IMAGE SOURCE: GOOGLE EARTH PRO 7.1.2
AERIAL IMAGE ©: 2017 AEROMETREX

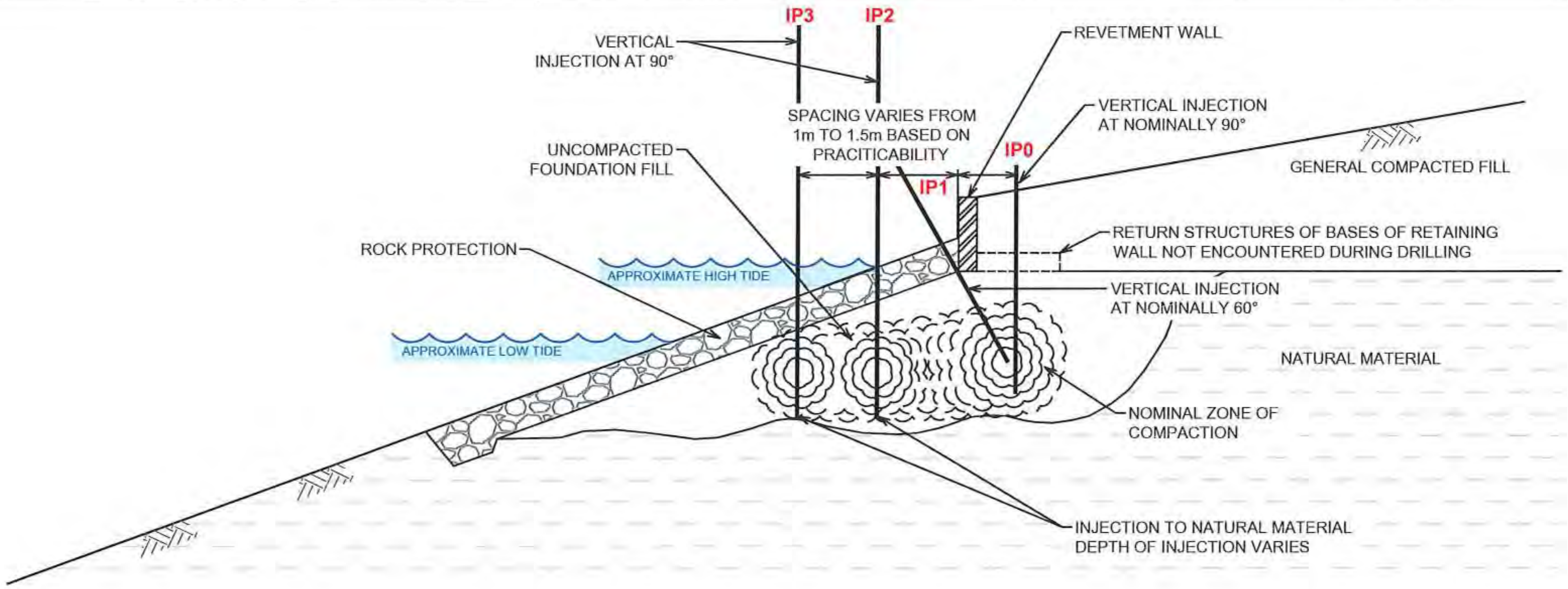
drawn	NA / AW
approved	NA / SB
date	14 / 06 / 17
scale	AS SHOWN
original size	A3

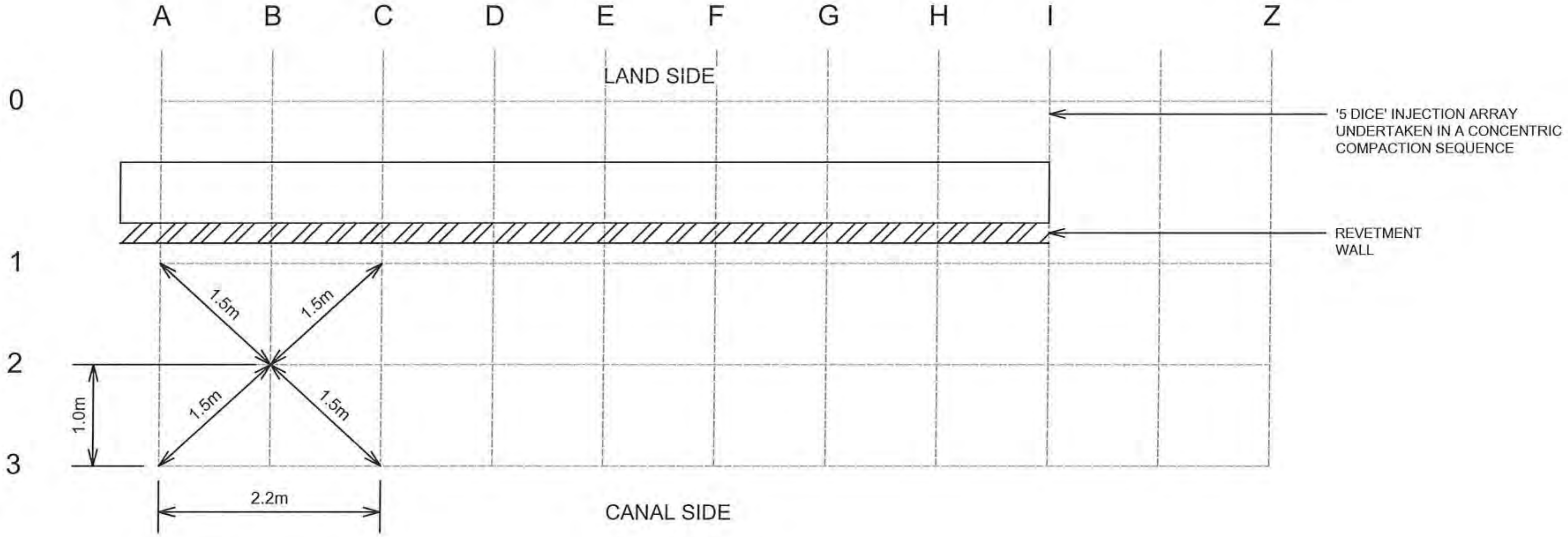
mainmark

coffey A TETRA TECH COMPANY

client:	MAINMARK CIVIL AND MINING SERVICES PTY LTD
project:	RABY BAY TRIAL REMEDIATION WORKS 11-15 STERNLIGHT CRT, CLEVELAND, QLD
title:	BEFORE AND AFTER WORKS
project no:	754-BNEGE200230-AD
figure no:	FIGURE 1
rev:	A

PLOT DATE: 14/06/2017 2:29:35 PM DWG FILE: F:\1. PROJECTS\4. SYD-GEOTECHNICS\OTHER OFFICES\BNE-GE\BNEGE200230\CAD\754-BNEGE200230-AD.DWG





SCALE 1:50

no.	description	drawn	approved	date
A	ORIGINAL ISSUE	NA	NA/SB	4/07/17

revision

0.5 0 0.5 1.5 2.5

Scale (metres) 1:50

Patrick Gibbes
RPEQ 11846

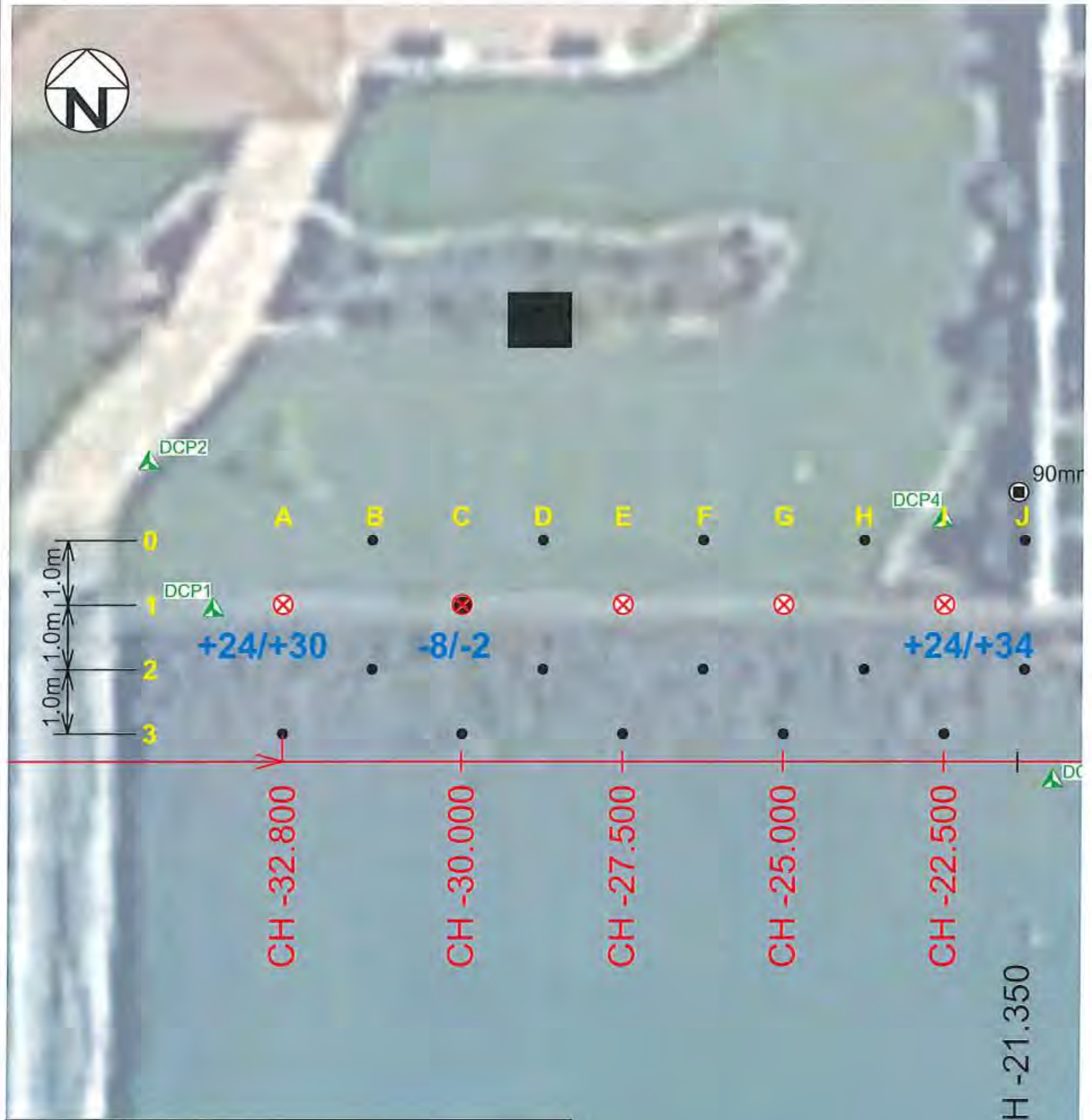
drawn	NA / AW
approved	NA / SB
date	14 / 06 / 17
scale	AS SHOWN
original size	A3

mainmark

coffey
A TETRA TECH COMPANY

client:	MAINMARK CIVIL AND MINING SERVICES PTY LTD
project:	RABY BAY TRIAL REMEDIATION WORKS 11-15 STERNLIGHT CRT, CLEVELAND, QLD
title:	TYPICAL SECTION INJECTION LAYOUT

project no: 754-BNEGE200230-AD	figure no: FIGURE 2	rev: A	



LEGEND

- DCP TEST LOCATION
- INDICATIVE RESIN INJECTION LOCATION
- INDICATIVE INJECTION LOCATION (SURVEYED)
- +24/+30 RELATIVE GROUND LEVEL (mm) BEFORE / AFTER INJECTION WORKS
- WALL ROTATION MEASURED FROM TOP OF WALL (NORTHSIDE) TO PAVERS BEFORE / AFTER INJECTION WORKS

NOTE

CHAINAGES ARE APPROXIMATE NOT REGISTERED SURVEYED.

Injection Reference Number	Property Address	Depth of Injection	Time	Date	Volume
D0	NO.11	4	11:20	14-Mar-17	32.01
D0	NO.11	2	11:28	14-Mar-17	19.80
D0	NO.11	1	11:37	14-Mar-17	8.14
D0	NO.11	1.5	11:46	14-Mar-17	13.20
B0	NO.11	1	11:52	14-Mar-17	9.97
B0	NO.11	1.5	11:59	14-Mar-17	14.32
B0	NO.11	2	12:05	14-Mar-17	19.66
B0	NO.11	4	12:31	14-Mar-17	18.81
A1	NO.11	4	12:40	14-Mar-17	22.88
C1	NO.11	4	13:15	14-Mar-17	9.97
E1	NO.11	4	13:42	14-Mar-17	13.48
G1	NO.11	4	14:11	14-Mar-17	21.48
I1	NO.11	4	15:31	14-Mar-17	18.25
H0	NO.11	1	11:20	14-Mar-17	13.20
H0	NO.11	1.5	11:28	14-Mar-17	10.11
H0	NO.11	2	11:37	14-Mar-17	8.28
H0	NO.11	4	11:46	14-Mar-17	41.14
F0	NO.11	1	11:52	14-Mar-17	10.67
F0	NO.11	1.5	11:59	14-Mar-17	13.20
F0	NO.11	2	12:05	14-Mar-17	15.72
F0	NO.11	4	12:31	14-Mar-17	30.47
J0	NO.11	1	12:40	14-Mar-17	4.77
J0	NO.11	1.5	13:15	14-Mar-17	15.72
J0	NO.11	2	13:42	14-Mar-17	51.95
J0	NO.11	4	14:11	14-Mar-17	5.90
B2	NO.11	1	13:37	15-Mar-17	48.44
B2	NO.11	1.5	13:46	15-Mar-17	22.18
B2	NO.11	2	14:01	15-Mar-17	36.78
D2	NO.11	1	14:22	15-Mar-17	26.11
D2	NO.11	1.5	14:44	15-Mar-17	29.34
D2	NO.11	2	14:59	15-Mar-17	38.75
A3	NO.11	1	14:56	15-Mar-17	1.40
A3	NO.11	1.5	15:10	15-Mar-17	10.81
A3	NO.11	2	15:29	15-Mar-17	12.21
C3	NO.11	1	15:41	15-Mar-17	3.51
C3	NO.11	1.5	16:02	15-Mar-17	7.44
J2	NO.11	1	13:39	15-Mar-17	52.79
J2	NO.11	1.5	13:50	15-Mar-17	17.13
J2	NO.11	2	14:01	15-Mar-17	13.06
H2	NO.11	1	14:16	15-Mar-17	26.96
H2	NO.11	1.5	14:29	15-Mar-17	11.79
H2	NO.11	2	14:36	15-Mar-17	4.77
F2	NO.11	1	14:43	15-Mar-17	21.62
F2	NO.11	1.5	14:50	15-Mar-17	12.92
F2	NO.11	2	14:57	15-Mar-17	1.40
E3	NO.11	1	8:14	16-Mar-17	35.94
E3	NO.11	1.5	8:31	16-Mar-17	24.57
E3	NO.11	2	8:48	16-Mar-17	12.78
G3	NO.11	1	8:59	16-Mar-17	26.53
G3	NO.11	1.5	9:09	16-Mar-17	34.68
G3	NO.11	2	9:28	16-Mar-17	29.62
I3	NO.11	1	9:41	16-Mar-17	36.64
I3	NO.11	1.5	10:02	16-Mar-17	12.78
I3	NO.11	2	10:11	16-Mar-17	16.57
B0	NO.11	1	10:29	16-Mar-17	5.62
B0	NO.11	1.5	10:33	16-Mar-17	15.44
D0	NO.11	1	10:39	16-Mar-17	8.84
D0	NO.11	1.5	10:44	16-Mar-17	8.42
F0	NO.11	1	10:49	16-Mar-17	12.50
F0	NO.11	1.5	11:02	16-Mar-17	10.81
H0	NO.11	1	11:08	16-Mar-17	7.44
H0	NO.11	1.5	11:15	16-Mar-17	7.16
J0	NO.11	1	11:23	16-Mar-17	10.11
J0	NO.11	1.5	11:29	16-Mar-17	162.44
A1	NO.11	1	7:16	17-Mar-17	15.72
C1	NO.11	1	7:29	17-Mar-17	17.27
E1	NO.11	1	7:49	17-Mar-17	19.94
G1	NO.11	1	8:11	17-Mar-17	6.32
I1	NO.11	1	8:28	17-Mar-17	24.71
A1	NO.11	1.5	9:01	17-Mar-17	28.78
C1	NO.11	1.5	9:28	17-Mar-17	29.06
E1	NO.11	1.5	10:11	17-Mar-17	15.16
G1	NO.11	1.5	10:31	17-Mar-17	23.31
I1	NO.11	1.5	12:01	17-Mar-17	29.34
B2	NO.11	1	7:16	17-Mar-17	17.97
D2	NO.11	1	7:29	17-Mar-17	16.43
F2	NO.11	1	7:49	17-Mar-17	21.20
H2	NO.11	1	8:11	17-Mar-17	5.05
J2	NO.11	1	8:28	17-Mar-17	24.85
B2	NO.11	1.5	9:01	17-Mar-17	33.55
D2	NO.11	1.5	9:28	17-Mar-17	26.25
F2	NO.11	1.5	10:11	17-Mar-17	15.58
H2	NO.11	1.5	10:31	17-Mar-17	22.04
J2	NO.11	1.5	12:01	17-Mar-17	29.20

no.	description	drawn	approved	date
A	ORIGINAL ISSUE	NA	NA/SB	14/06/17

revision

1 0 1 3 5

Scale (metres) 1:100

Patrick Gibbons RPEQ 11846

AERIAL IMAGE SOURCE: GOOGLE EARTH PRO 7.1.2
AERIAL IMAGE ©: 2017 AEROMETREX

drawn	NA / AW
approved	NA / SB
date	14 / 06 / 17
scale	AS SHOWN
original size	A3

mainmark

coffey
A TETRA TECH COMPANY

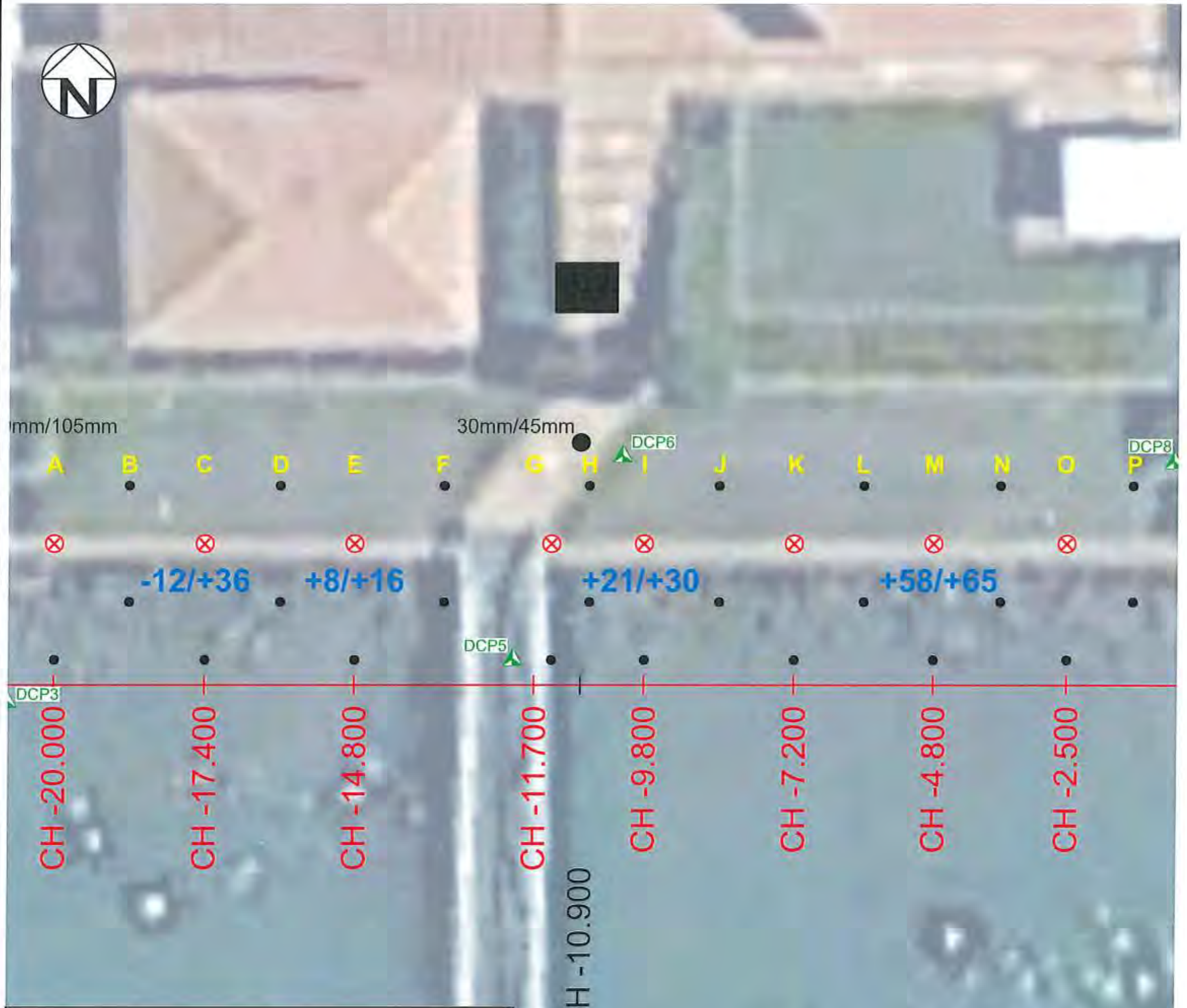
client: MAINMARK CIVIL AND MINING SERVICES PTY LTD

project: RABY BAY TRIAL REMEDIATION WORKS
11-15 STERNLIGHT CRT, CLEVELAND, QLD

title: BEFORE AND AFTER WORKS - HOUSE 11

project no: 754-BNEGE200230-AD | figure no: FIGURE 3 | rev: A

PLOT DATE: 14/06/2017 2:41:46 PM DWG FILE: F:\1. PROJECTS\04. SYD-GEOTECHNICS\OTHER OFFICES\BNE-GE\BNEGE200230\CAD\754-BNEGE200230-AD.DWG



LEGEND

- DCP TEST LOCATION
- INDICATIVE RESIN INJECTION LOCATION
- INDICATIVE INJECTION LOCATION (SURVEYED)
- +24/+30 RELATIVE GROUND LEVEL (mm) BEFORE / AFTER INJECTION WORKS
- WALL ROTATION MEASURED FROM TOP OF WALL (NORTHSIDE) TO PAVERS BEFORE / AFTER INJECTION WORKS

NOTE

CHAINAGES ARE APPROXIMATE NOT REGISTERED SURVEYED.

Injection Reference Number	Property Address	Depth of Injection	Time	Date	Volume
P0	NO.13	1	10.31	9-Mar-17	15.02
P0	NO.13	1.5	10:46	9-Mar-17	2.81
P0	NO.13	2	11:00	9-Mar-17	3.65
N0	NO.13	1	11:10	9-Mar-17	9.55
N0	NO.13	1.5	11:21	9-Mar-17	12.50
N0	NO.13	2	11:32	9-Mar-17	11.79
H0	NO.13	1	11:43	9-Mar-17	8.00
H0	NO.13	1.4	11:46	9-Mar-17	6.88
H0	NO.13	2	11:50	9-Mar-17	8.42
F0	NO.13	1	11:54	9-Mar-17	14.60
F0	NO.13	1.4	12:01	9-Mar-17	1.54
F0	NO.13	2	12:05	9-Mar-17	3.51
A3	NO.13	1	13:09	9-Mar-17	3.93
E3	NO.13	1	13:16	9-Mar-17	4.07
B2	NO.13	1	13:20	9-Mar-17	3.37
D2	NO.13	1	13:29	9-Mar-17	21.62
A1	NO.13	1	13:38	9-Mar-17	6.04
E1	NO.13	1	13:41	9-Mar-17	3.93
M1	NO.13	1	13:59	9-Mar-17	21.20
N1	NO.13	1	15:01	9-Mar-17	17.69
L0	NO.13	1	10:31	9-Mar-17	22.18
L0	NO.13	1.5	11:10	9-Mar-17	22.04
L0	NO.13	2	11:17	9-Mar-17	12.21
J0	NO.13	1	11:20	9-Mar-17	9.97
J0	NO.13	1.5	11:33	9-Mar-17	9.55
J0	NO.13	2	11:38	9-Mar-17	12.07
D0	NO.13	1	11:43	9-Mar-17	11.37
D0	NO.13	1.5	11:44	9-Mar-17	6.04
D0	NO.13	2	11:48	9-Mar-17	4.63
B0	NO.13	1	11:54	9-Mar-17	33.98
B0	NO.13	1.4	12:01	9-Mar-17	13.06
B0	NO.13	2	12:05	9-Mar-17	13.20
C3	NO.13	1	13:09	9-Mar-17	10.67
G3	NO.13	1	13:16	9-Mar-17	4.21
F2	NO.13	1	13:20	9-Mar-17	6.04
C1	NO.13	1	13:29	9-Mar-17	13.90
G1	NO.13	1	13:38	9-Mar-17	8.28
I1	NO.13	1	13:59	9-Mar-17	15.44
K1	NO.13	1	15:01	9-Mar-17	5.90
A1	NO.13	1	9:18	10-Mar-17	3.37
E1	NO.13	1	9:21	10-Mar-17	3.09
B2	NO.13	1	9:29	10-Mar-17	4.49
D2	NO.13	1	9:58	10-Mar-17	4.77
F2	NO.13	1	10:10	10-Mar-17	5.05
H2	NO.13	1	10:21	10-Mar-17	3.23
J2	NO.13	1	12:12	10-Mar-17	5.90
L2	NO.13	1	12:33	10-Mar-17	6.74
N2	NO.13	1	12:58	10-Mar-17	5.34
P2	NO.13	1	13:51	10-Mar-17	4.77
G3	NO.13	1	14:22	10-Mar-17	6.32
K3	NO.13	1	14:36	10-Mar-17	4.63
C1	NO.13	1	9:18	10-Mar-17	5.48
G1	NO.13	1	9:21	10-Mar-17	5.48
A3	NO.13	1	9:29	10-Mar-17	4.63
C3	NO.13	1	9:58	10-Mar-17	6.46
E3	NO.13	1	10:10	10-Mar-17	5.90
G3	NO.13	1	10:21	10-Mar-17	9.55
I1	NO.13	1	12:12	10-Mar-17	6.46
K1	NO.13	1	12:33	10-Mar-17	10.53
M1	NO.13	1	12:58	10-Mar-17	6.04
O1	NO.13	1	13:51	10-Mar-17	9.55
I3	NO.13	1	14:22	10-Mar-17	9.55
M3	NO.13	1	14:36	10-Mar-17	7.30
O3	NO.13	1	14:48	10-Mar-17	11.79
A3	NO.13	2	8:56	7-Mar-17	36.22
C3	NO.13	2	9:12	7-Mar-17	36.22
E3	NO.13	2	9:44	7-Mar-17	31.45
F2	NO.13	2	10:12	7-Mar-17	30.19
D2	NO.13	2	10:39	7-Mar-17	41.28
B2	NO.13	2	10:58	7-Mar-17	31.73
A1	NO.13	4	11:31	7-Mar-17	40.86
C1	NO.13	4	11:50	7-Mar-17	37.49
E1	NO.13	4	12:23	7-Mar-17	31.17
F0	NO.13	4	13:38	7-Mar-17	35.66
D0	NO.13	4	14:41	7-Mar-17	28.36
B0	NO.13	4	15:16	7-Mar-17	40.71
O3	NO.13	1.5	10:38	8-Mar-17	6.46
M3	NO.13	1.5	10:48	8-Mar-17	9.83
K3	NO.13	1.5	10:57	8-Mar-17	9.69
I3	NO.13	1.5	11:05	8-Mar-17	7.16
G3	NO.13	1.5	11:13	8-Mar-17	12.50
H2	NO.13	1.5	11:24	8-Mar-17	24.29
J2	NO.13	1.5	11:29	8-Mar-17	4.49
L2	NO.13	1.5	11:33	8-Mar-17	7.30
N2	NO.13	1.5	11:40	8-Mar-17	11.37
O1	NO.13	1.5	11:48	8-Mar-17	12.21
M1	NO.13	1.5	11:58	8-Mar-17	11.51
K1	NO.13	1.5	12:08	8-Mar-17	6.32
I1	NO.13	1.5	12:16	8-Mar-17	30.33
G1	NO.13	1.5	12:26	8-Mar-17	14.18
P2	NO.13	2	12:34	8-Mar-17	9.41
P2	NO.13	1.5	12:40	8-Mar-17	7.72
G3	NO.13	1.5	12:45	8-Mar-17	7.16
E3	NO.13	1.5	12:49	8-Mar-17	8.00
C3	NO.13	1.5	12:54	8-Mar-17	6.60
A3	NO.13	1.5	13:00	8-Mar-17	24.85
B2	NO.13	1.5	13:15	8-Mar-17	21.76
D2	NO.13	1.5	13:22	8-Mar-17	19.52
F2	NO.13	1.5	13:31	8-Mar-17	21.20
G1	NO.13	1.5	13:40	8-Mar-17	15.86
E1	NO.13	1.5	13:50	8-Mar-17	13.06
C1	NO.13	1.5	13:53	8-Mar-17	9.27
A1	NO.13	1.5	14:11	8-Mar-17	6.46

revision no.	description	drawn	approved	date
A	ORIGINAL ISSUE	NA	NA/SB	14/06/17

1 0 1 3 5

Scale (metres) 1:100

Patrick Gibbons
RPEQ 11846

AERIAL IMAGE SOURCE: GOOGLE EARTH PRO 7.1.2
AERIAL IMAGE ©: 2017 AEROMETREX

drawn	NA / AW
approved	NA / SB
date	14 / 06 / 17
scale	AS SHOWN
original size	A3

mainmark

coffey
A TETRA TECH COMPANY

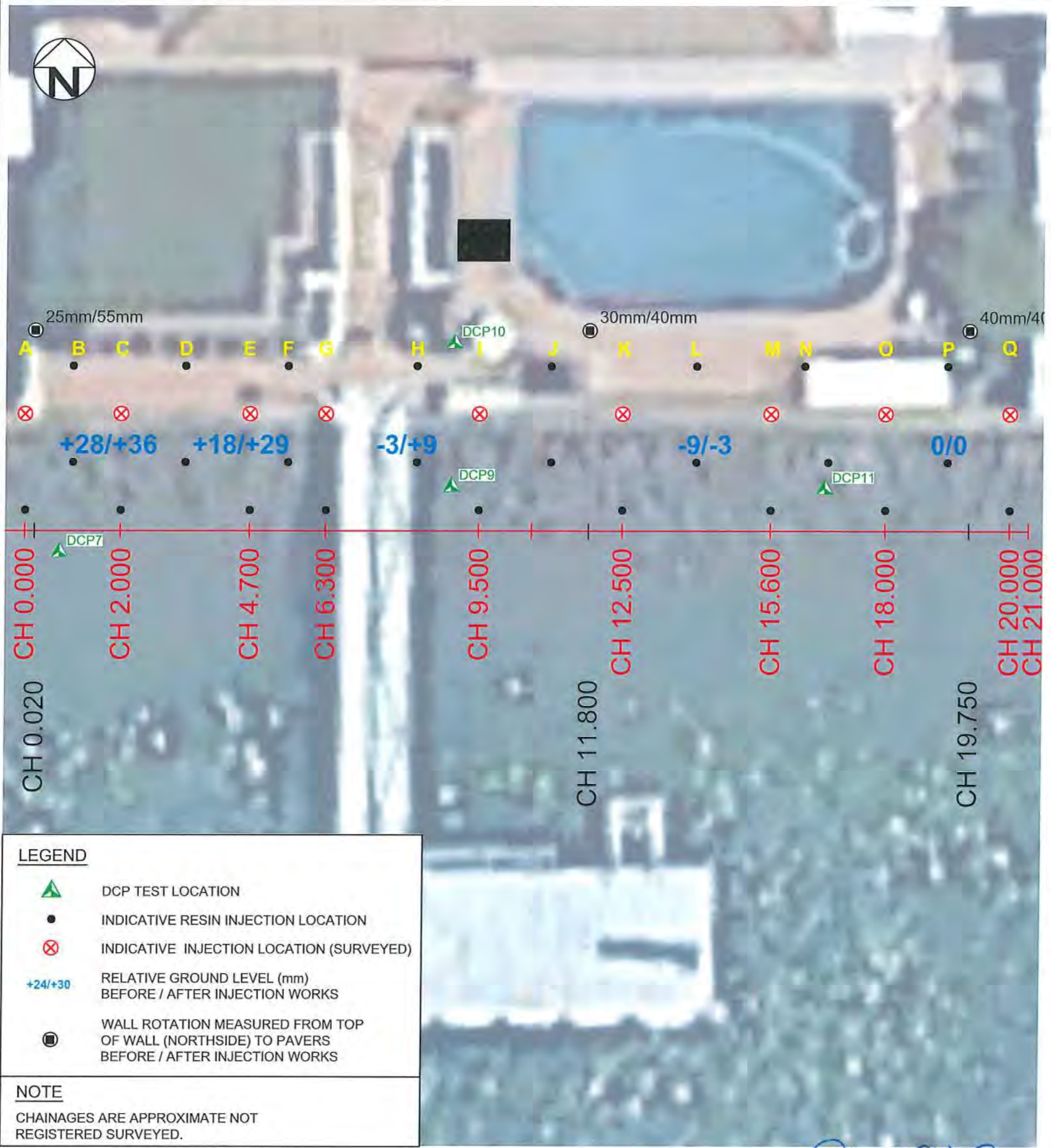
client: MAINMARK CIVIL AND MINING SERVICES PTY LTD

project: RABY BAY TRIAL REMEDIATION WORKS
11-15 STERNLIGHT CRT, CLEVELAND, QLD

title: BEFORE AND AFTER WORKS - HOUSE 13

project no: 754-BNEGE200230-AD | figure no: FIGURE 4 | rev: A

PLOT DATE: 14/06/2017 2:42:02 PM DWG FILE: F:\1. PROJECTS\4. SYD-GEOTECHNICS\OTHER OFFICES\BNE-GE\BNEGE200230\CAD\754-BNEGE200230-AD.DWG



LEGEND

- DCP TEST LOCATION
- INDICATIVE RESIN INJECTION LOCATION
- INDICATIVE INJECTION LOCATION (SURVEYED)
- +24/+30 RELATIVE GROUND LEVEL (mm) BEFORE / AFTER INJECTION WORKS
- WALL ROTATION MEASURED FROM TOP OF WALL (NORTHSIDE) TO PAVERS BEFORE / AFTER INJECTION WORKS

NOTE

CHAINAGES ARE APPROXIMATE NOT REGISTERED SURVEYED.

Injection Reference Number	Property Address	Depth of Injection	Time	Date	Volume
G3	NO.13	2	9:22	6-Mar-17	24.57
I3	NO.13	2	9:39	6-Mar-17	27.52
K3	NO.13	2	10:01	6-Mar-17	27.38
M3	NO.13	2	10:28	6-Mar-17	24.01
O3	NO.13	2	10:43	6-Mar-17	26.25
N2	NO.13	2	11:05	6-Mar-17	24.57
L2	NO.13	2	11:32	6-Mar-17	24.43
J2	NO.13	2	11:58	6-Mar-17	27.52
H2	NO.13	2	13:33	6-Mar-17	26.53
G1	NO.13	4	13:44	6-Mar-17	26.82
I1	NO.13	4	13:56	6-Mar-17	22.46
K1	NO.13	4	14:21	6-Mar-17	28.78
M1	NO.13	4	14:44	6-Mar-17	28.50
O1	NO.13	4	15:02	6-Mar-17	22.74
N0	NO.13	4	15:14	6-Mar-17	25.83
L0	NO.13	4	15:29	6-Mar-17	22.60
J0	NO.13	4	15:41	6-Mar-17	30.19
H0	NO.13	4	16:02	6-Mar-17	29.06
M3	NO.15	1.5	8:08	2-Mar-17	42.68
K3	NO.15	1.5	8:21	2-Mar-17	24.57
O3	NO.15	1.5	8:35	2-Mar-17	53.07
I3	NO.15	1.5	8:47	2-Mar-17	56.44
G3	NO.15	1.5	8:59	2-Mar-17	45.21
H2	NO.15	1.5	9:16	2-Mar-17	33.55
J2	NO.15	1.5	9:36	2-Mar-17	32.85
L2	NO.15	1.5	9:42	2-Mar-17	23.17
N2	NO.15	1.5	9:55	2-Mar-17	20.22
P2	NO.15	1.5	10:01	2-Mar-17	22.46
O1	NO.15	3	10:15	2-Mar-17	22.46
Q1	NO.15	3	10:36	2-Mar-17	15.86
Q3	NO.15	1.5	8:08	2-Mar-17	35.52
O3	NO.15	1.5	8:19	2-Mar-17	0.00
Q1	NO.15	1.5	13:43	1-Mar-17	19.80
O1	NO.15	1.5	14:11	1-Mar-17	37.91
I1	NO.15	1.5	14:59	1-Mar-17	4.49
G1	NO.15	1.5	15:21	1-Mar-17	21.62
K1	NO.15	3	15:50	1-Mar-17	41.56
H5	NO.15	4	11:01	28-Feb-17	93.92
J2	NO.15	4	11:31	28-Feb-17	33.69
H2	NO.15	2	12:33	28-Feb-17	49.98
J2	NO.15	2	12:45	28-Feb-17	27.52
H2	NO.15	1.5	13:03	28-Feb-17	26.39
J2	NO.15	1.5	13:31	28-Feb-17	31.45
O1	NO.15	1.5	14:08	28-Feb-17	9.69
Q1	NO.15	1	16:58	28-Feb-17	4.63
O1	NO.15	1.5	17:35	28-Feb-17	8.14
Q1	NO.15	1	18:01	28-Feb-17	14.60
L2	NO.15	4	11:01	28-Feb-17	79.32
N2	NO.15	4	11:31	28-Feb-17	50.54
P2	NO.15	4	12:33	28-Feb-17	46.61
L2	NO.15	2	12:45	28-Feb-17	27.94
N2	NO.15	2	13:03	28-Feb-17	16.01
P2	NO.15	2	13:31	28-Feb-17	40.86
L2	NO.15	1.5	14:08	28-Feb-17	4.21
N2	NO.15	1.5	16:58	28-Feb-17	12.07
P2	NO.15	1.5	17:35	28-Feb-17	12.07
M1	NO.15	1.5	13:43	1-Mar-17	108.81
K1	NO.15	1.5	14:11	1-Mar-17	58.40
E1	NO.15	1.5	14:45	1-Mar-17	21.62
C1	NO.15	1.5	14:59	1-Mar-17	62.90
A1	NO.15	1.5	15:10	1-Mar-17	27.66
B1	NO.15	1.5	15:18	1-Mar-17	30.47
G1	NO.15	3	15:50	1-Mar-17	13.76
G1	NO.15	1	8:11	3-Mar-17	19.80
I1	NO.15	1	8:22	3-Mar-17	19.37
K1	NO.15	1	8:38	3-Mar-17	16.71
M1	NO.15	1	8:54	3-Mar-17	15.58
O1	NO.15	1	9:31	3-Mar-17	18.53
Q1	NO.15	1	10:11	3-Mar-17	20.64
B0	NO.15	2	11:42	3-Mar-17	8.14
D0	NO.15	2	11:59	3-Mar-17	21.48
F0	NO.15	2	12:11	3-Mar-17	27.94
H0	NO.15	2	12:22	3-Mar-17	20.64
J0	NO.15	2	12:41	3-Mar-17	21.20
L0	NO.15	2	12:58	3-Mar-17	27.66
N0	NO.15	2	13:11	3-Mar-17	13.34
P0	NO.15	2	13:21	3-Mar-17	18.67
H2	NO.15	1	8:11	3-Mar-17	19.23
J2	NO.15	1	8:22	3-Mar-17	19.80
L2	NO.15	1	8:38	3-Mar-17	15.02
N2	NO.15	1	8:54	3-Mar-17	18.67
P2	NO.15	1	9:31	3-Mar-17	17.83
K1	NO.15	4	13:34	27-Feb-17	24.43
M1	NO.15	4	14:03	27-Feb-17	58.97
K1	NO.15	2	14:09	27-Feb-17	22.46
M1	NO.15	2	14:21	27-Feb-17	19.37
K1	NO.15	1.5	14:56	27-Feb-17	81.01
M1	NO.15	1.5	15:31	27-Feb-17	76.09
A1	NO.15	2	13:25	25-Feb-17	23.17
C1	NO.15	2	13:35	25-Feb-17	91.96
A1	NO.15	2	13:50	25-Feb-17	27.38
E1	NO.15	2	14:20	25-Feb-17	90.84
A1	NO.15	1.5	14:27	25-Feb-17	11.93
C1	NO.15	1.5	14:34	25-Feb-17	8.70
E1	NO.15	1.5	14:37	25-Feb-17	7.58
A1	NO.15	1	14:43	25-Feb-17	5.19
C1	NO.15	1	15:01	25-Feb-17	7.16
E1	NO.15	1	15:21	25-Feb-17	5.19
B2	NO.15	1	11:19	24-Feb-17	14.46
B2	NO.15	1.5	11:32	24-Feb-17	10.11
D2	NO.15	1.5	12:05	24-Feb-17	59.25
D2	NO.15	1	12:21	24-Feb-17	5.19
F2	NO.15	1.5	12:50	24-Feb-17	9.27
F2	NO.15	1	12:59	24-Feb-17	8.28
E3	NO.15	1.5	13:12	24-Feb-17	17.13
C3	NO.15	1.5	13:31	24-Feb-17	57.28
A3	NO.15	1.5	13:51	24-Feb-17	71.74
B2	NO.15	2	10:30	23-Feb-17	16.85
B2	NO.15	1.5	11:00	23-Feb-17	32.29
F2	NO.15	2	11:20	23-Feb-17	23.87
F2	NO.15	1.5	11:45	23-Feb-17	15.44
D2	NO.15	2	11:55	23-Feb-17	7.02
D2	NO.15	1.5	12:10	23-Feb-17	16.85
A3	NO.15	2	12:45	23-Feb-17	19.66
A3	NO.15	1.5	12:55	23-Feb-17	14.04
C3	NO.15	2	13:05	23-Feb-17	29.48
C3	NO.15	1.5	13:15	23-Feb-17	14.04
E3	NO.15	2	12:20	23-Feb-17	5.62
E3	NO.15	1.5	13:30	23-Feb-17	15.44
E1	NO.15	2	13:40	23-Feb-17	18.25
C1	NO.15	2	13:45	23-Feb-17	16.85
A1	NO.15	2	13:50	23-Feb-17	14.04
A1	NO.15	3	9:00	22-Feb-17	35.10
C1	NO.15	3	9:20	22-Feb-17	29.48
E1	NO.15	3	9:40	22-Feb-17	21.06
B2	NO.15	3	10:20	22-Feb-17	22.46
D2	NO.15	3	10:40	22-Feb-17	23.87
F2	NO.15	3	11:15	22-Feb-17	36.50
A3	NO.15	3	12:00	22-Feb-17	63.18
C3	NO.15	3	12:30	22-Feb-17	57.56
A1	NO.15	3	12:50	21-Feb-17	47.73
B2	NO.15	1.5	13:10	21-Feb-17	47.73
C1	NO.15	3	13:20	21-Feb-17	49.14
D2	NO.15	1.5	13:40	21-Feb-17	5.62
E1	NO.15	3	13:50	21-Feb-17	33.69

revision no.	description	drawn	approved	date
A	ORIGINAL ISSUE	NA	NA/SB	14/06/17

1 0 1 3 5

Scale (metres) 1:100

AERIAL IMAGE SOURCE: GOOGLE EARTH PRO 7.1.2
AERIAL IMAGE ©: 2017 AEROMETREX

RPEQ 11846

drawn	NA / AW
approved	NA / SB
date	14 / 06 / 17
scale	AS SHOWN
original size	A3

mainmark

coffey
A TETRA TECH COMPANY

client: MAINMARK CIVIL AND MINING SERVICES PTY LTD

project: RABY BAY TRIAL REMEDIATION WORKS
11-15 STERNLIGHT CRT, CLEVELAND, QLD

title: BEFORE AND AFTER WORKS - HOUSE 15

project no: 754-BNEGE200230-AD | figure no: FIGURE 5 | rev: A

PLOT DATE: 14/06/2017 2:49:37 PM DWG FILE: F:\1. PROJECTS\4. SYD-GEOTECHNICS\OTHER OFFICES\BNE-GEN\BNEGE200230\CAD\754-BNEGE200230-AD.DWG

A5 Menard as-constructed drawings

GENERAL NOTES

1. IN THESE DRAWINGS AND NOTES, THE FOLLOWING ABBREVIATIONS ARE USED:

   MO MENARD OCEANIA PTY LTD UNLESS NOTED OTHERWISE

   RCC REDLAND CITY COUNCIL UNLESS NOTED OTHERWISE

2. THESE DRAWINGS SHALL BE READ IN CONJUNCTION WITH MO DESIGN REPORT (REFERENCED 5040198-MB-Q-DRE-R-01), THE SINCLAIR KNIGHT & PARTNERS DRAWINGS (REFERENCED 86006-36 REV F), ARUP TECHNICAL SPECIFICATION (REFERENCED 240904-GEO-003), EXISTING SERVICES DRAWINGS, SURVEYS AND WITH SUCH OTHER WRITTEN INSTRUCTIONS AS MAY BE ISSUED DURING THE COURSE OF THE CONTRACT BY RCC.
3. UNLESS OTHERWISE NOTED, ALL LEVELS ARE GIVEN IN METERS AND ALL DIMENSIONS ARE IN MILLIMETERS. REDUCED LEVELS (RL'S) ARE REFERENCED TO AUSTRALIAN HEIGHT DATUM.
4. ALL MATERIALS, WORKMANSHIP AND TOLERANCES SHALL BE IN ACCORDANCE WITH AUSTRALIAN STANDARDS AND CODES OF PRACTICE UNLESS STATED OTHERWISE ON THE DRAWINGS.
5. MO SHALL CARRIED OUT INVESTIGATION OF ALL UNDERGROUND SERVICES AND THAT ALL EXISTING STRUCTURES, SERVICES (INCLUDING REDUNDANT SERVICES) AND UTILITIES ARE MAPPED, MARKED UP AND/OR DIVERTED AND REMOVED (IF IN CONFLICT WITH MO'S WORKS) PRIOR TO THE COMMENCEMENT OF MO'S WORKS ON SITE.
6. ANY DISCREPANCY AND / OR NON-COMPLIANCE WITH THE MO'S DRAWINGS SHALL BE CONVEYED TO MO'S DESIGNER FOR CLARIFICATION.
7. MO HAS RELIED ON THE ACCURACY OF THE FOLLOWING DOCUMENT IN ORDER TO DETERMINE SUBSURFACE GROUND CONDITIONS AN DESPISING REQUIREMENT:
   - RABY BAY - GEOTECHNICAL INVESTIGATION & MONITORING FOR PROPOSED STABILISATION TRIAL BY GOLDER ASSOCIATES, DATED 25 FEBRUARY 2016 (REF. NO. 1529649-035-REV1)
   - RABY BAY CANAL BATTER STABILITY UPDATE - GEOTECHNICAL INVESTIGATION ANALYSIS REPORT BY KELLOGG BROWN & ROOT, DATED 24 JUNE 2013 (REF. NO. BEJ809.002- W-REP-003 REV. 0)
   - MASTHEAD DRIVE TRIAL AREA - STAGE 8 - TYPICAL CROSS SECTIONS REFERENCED 86006-36 REV F
8. MO DESIGNER SHALL BE NOTIFIED BY SITE PERSONNEL (EITHER FROM RCC OR MO) IF SUBSURFACE GROUND CONDITIONS ENCOUNTERED ON SITE DIFFER FROM THE GEOTECHNICAL INVESTIGATION.

JET GROUTING WORKS:

1. JET GROUTING COLUMN UNCONFINED COMPRESSIVE STRENGTH TO BE 3.0MPa AT 28 DAYS.
2. JET GROUTING COLUMNS SHALL BE LOCATED AS PER DRAWING.
   - THE DEVIATION OF THE DRILLING STARTING POINT FROM THE THEORETICAL POSITION SHALL BE LESS THAN 100mm
   - THE VERTICAL DEVIATION OF DRILLING FROM THEORETICAL AXIS SHALL BE 1% OR LESS.
   - JG COLUMNS CUT OFF LEVEL +/- 75mm
3. MEASURES SHALL BE TAKEN TO ENSURE THAT A FINAL INTIMATE CONTACT IS FORMED BETWEEN THE TOP SURFACE OF THE JET GROUTED COLUMN AND THE REVETMENT WALL.
4. WHERE UNEXPECTED UNDERGROUND OBSTRUCTION ARE ENCOUNTERED, THE COLUMNS SHALL BE RELOCATED WITHIN ±150mm FROM THE DESIGN POSITION. SHALL OBSTRUCTION CANNOT BE AVOIDED, ADDITIONAL JG COLUMNS SHALL BE INSTALLED AROUND THE OBSTRUCTION.
5. DESIGN OF JET GROUTING WORKS COMPLIANT WITH THE FOLLOWING STANDARDS:
   - AS4678.2 EARTH RETAINING STRUCTURES
   - BS EN 12716-2001 EXECUTION OF SPECIAL GEOTECHNICAL WORKS - JET GROUTING
6. DURING JET GROUTING A VISUAL OBSERVATION OF THE FLOW AND FEATURES OF THE SPOIL RETURN AT THE COLLAR SHALL BE MAINTAINED.
7. IF DURING THE JET GROUTING UNEXPECTED BEHAVIOUR OF THE SPOIL RETURN IS OBSERVED, THE JG GROUTING PARAMETERS AND/OR METHOD SHOULD BE REVIEWED.
8. AN UNEXPECTED REDUCTION IN SPOIL RETURN SHALL BE INVESTIGATED AND DEALT WITH IMMEDIATELY. IT CAN BE CAUSE BY CLOGGING OF THE ANNULUS OF THE JETTING BOREHOLE.

QUALITY CONTROL:

1. JET GROUTING TESTING TO BE IN ACCORDANCE WITH WORK METHOD STATEMENT AND INSPECTION AND TESTING PLAN.
2. PRELIMINARY FIELD TEST SHALL BE DESIGNED & PERFORMED IN ORDER TO:
   - SHOW THE INTEGRITY OF THE COLUMNS.
   - PROVE MINIMUM UCS REQUIREMENT ARE MET.
   - MEASURE THE DIAMETER CONSTRUCTED.
3. TESTING OF TRIAL COLUMNS SHALL BE CARRIED OUT BY MEANS OF DENSITY AND VISCOSITY TESTING OF THE BATCHED GROUT UNCONFINED COMPRESSIVE STRENGTH TESTING OF SPOIL RETURN AND CORE SAMPLE AND CORING OF SELECTED COLUMNS FOR DIAMETER CONFIRMATION.

WORK SEQUENCE:

1. THE REVETMENT WALL SHALL BE USED AS REFERENCE LINE (BASELINE). JET GROUT COLUMNS SHALL BE SET OUT FROM THE BASELINE BY OFFSETTING USING TAPES AS PER DESIGN DRAWINGS. THE COLUMNS SHALL BE SET OUT AT RIGHT ANGLE TO THE REVETMENT WALL BASELINE POSITION.
2. SPOIL COLLECTION TRENCH AND SPOIL CONTAINMENT MEASURED SHALL BE INSTALLED PRIOR TO THE JET GROUTING WORKS.
3. THE INSTALLATION SEQUENCE SHALL BE SUCH THAT THE COLUMNS ARE INSTALLED ONE ROW AT A TIME AND WORK PROGRESSES AWAY FROM THE INSTALLED ROWS IN ONE DIRECTION ONLY.

WORKING PLATFORM NOTES

1. WORKING PLATFORM TO BE DESIGNED TO MEET MINIMUM STABILITY AND BEARING REQUIREMENTS AS PROVIDED BY MO.

MONITORING:

1. THE REVETMENT WALL TO BE UNDERPINNED SHALL BE MONITORED BY REPEATED LEVELING OR BY AUTOMATIC SETTLEMENT SENSORS USING ALARM SYSTEMS DURING JET GROUTING BY MO.
2. POST-CONSTRUCTION MONITORING TO BE OPERATED BY OTHERS AS PER MONITORING INSTRUMENTATION SET-UP BY RCC.
3. THE FREQUENCY OF MONITORING IS ESSENTIAL TO DETECT ANY UNEXPECTED GROUND BEHAVIOUR. THE MINIMUM EXPECTED MONITORING FREQUENCY IS GIVEN IN TABLE 1 BELOW.

TABLE 1: FREQUENCY OF MONITORING OF INSTRUMENTS

INSTRUMENT	DURING JET GROUTING WORKS
MONITORING POINT (BOLT IN CONCRETE)	EVERY DAY FOR THE FIRST WEEK AND 2 PER WEEK AFTERWARDS
MONITORING POINT (STAR PICKET)	EVERY DAY FOR THE FIRST WEEK AND 2 PER WEEK AFTERWARDS
INCLINOMETER	-
TILTMETER	-

4. MONITORING REVIEW LIMIT VALUES WILL BE USED TO ASSESS THE POTENTIAL IMPACTS OF THE MEASURED DATA AND TO IDENTIFY POTENTIAL PROBLEMS. THE LIMIT VALUES TO BE USED ARE DEFINED BELOW:

TABLE 2 - DEFLECTION CRITERIA

INSTRUMENT	GREEN ALERT DEFLECTION	AMBER ALERT DEFLECTION	RED ALERT DEFLECTION
MONITORING POINT (BOLD IN CONCRETE)	<20mm	20–30mm	>30mm
MONITORING POINT (STAR PICKET)	<20mm	20–30mm	>30mm
INCLINOMETER	–	–	–
TILTMETER	–	–	–

5. CONTINGENCY MEASURES SHALL BE TAKEN WHEN EXCEEDING TRIGGER, DESIGN AND ALARM VALUES. THE TABLE BELOW PROVIDES RECOMMENDATIONS ON ACTIONS TO BE EMPLOYED FOR EACH PARTICULAR ALERT:

TABLE 3- ALERT ACTION PLAN

ALERT TYPE	RESPONSE ACTION
GREEN	DEFLECTIONS WELL WITHIN ACCEPTABLE LIMITS. SURVEY REPORT TO BE FORWARDED TO MO DESIGN TEAM FOR REVIEW. WORKS MAY PROCEED TO THE NEXT STAGE.
AMBER	DEFLECTIONS CLOSE TO DESIGN LIMIT YET WITHIN ACCEPTABLE VALUES. ADDITIONAL CAUTION TO BE EXERCISED WITH REGARD TO OVER EXCAVATION. WALL DEFLECTION MONITORING FREQUENCY TO BE INCREASED TO EVERY 8 HOURS. WORKS MAY PROCEED TO THE NEXT STAGE PROVIDED THAT THE WALL MOVEMENT HAS STOPPED AND IS NOT IN RED ZONE. SURVEY REPORT TO BE FORWARDED TO MO DESIGN TEAM FOR REVIEW.
RED	DEFLECTIONS EXCEEDING DESIGN EXPECTATION. EXCAVATION TO BE STOPPED IMMEDIATELY. MINIMUM 1.5M HIGH AND 3M WIDE BERM IN FRONT OF THE NON-CONFORMING WALL TO BE CONSTRUCTED IMMEDIATELY TO STOP FURTHER MOVEMENT. MO DESIGN TEAM TO BE NOTIFIED IMMEDIATELY. IF NECESSARY, REMEDIATION PLAN TO BE DEVELOPED FOLLOWING SITE INSPECTION BY MO AND IN CONSULTATION BETWEEN THE CLIENT, MO AND OTHER RELEVANT PARTIES.

AS BUILT

REV	DATE	DRAWN	REV'D	APP'D	REVISION
2	24-10-17	H.W.	D.R.	A.H.	AS BUILT
1	27-04-17	H.W.	A.H.	A.H.	ISSUED FOR CONSTRUCTION - AMENDED AS MARKED
0	23-03-17	H.W.	A.H.	A.H.	ISSUED FOR CONSTRUCTION
A	17-01-17	H.W.	M.K.	M.K.	ISSUED FOR APPROVAL

menard

CLIENT REDLAND CITY COUNCIL
PROJECT RABY BAY TRIAL
TRIAL SITE 4: 81-83 MASTHEAD DRIVE

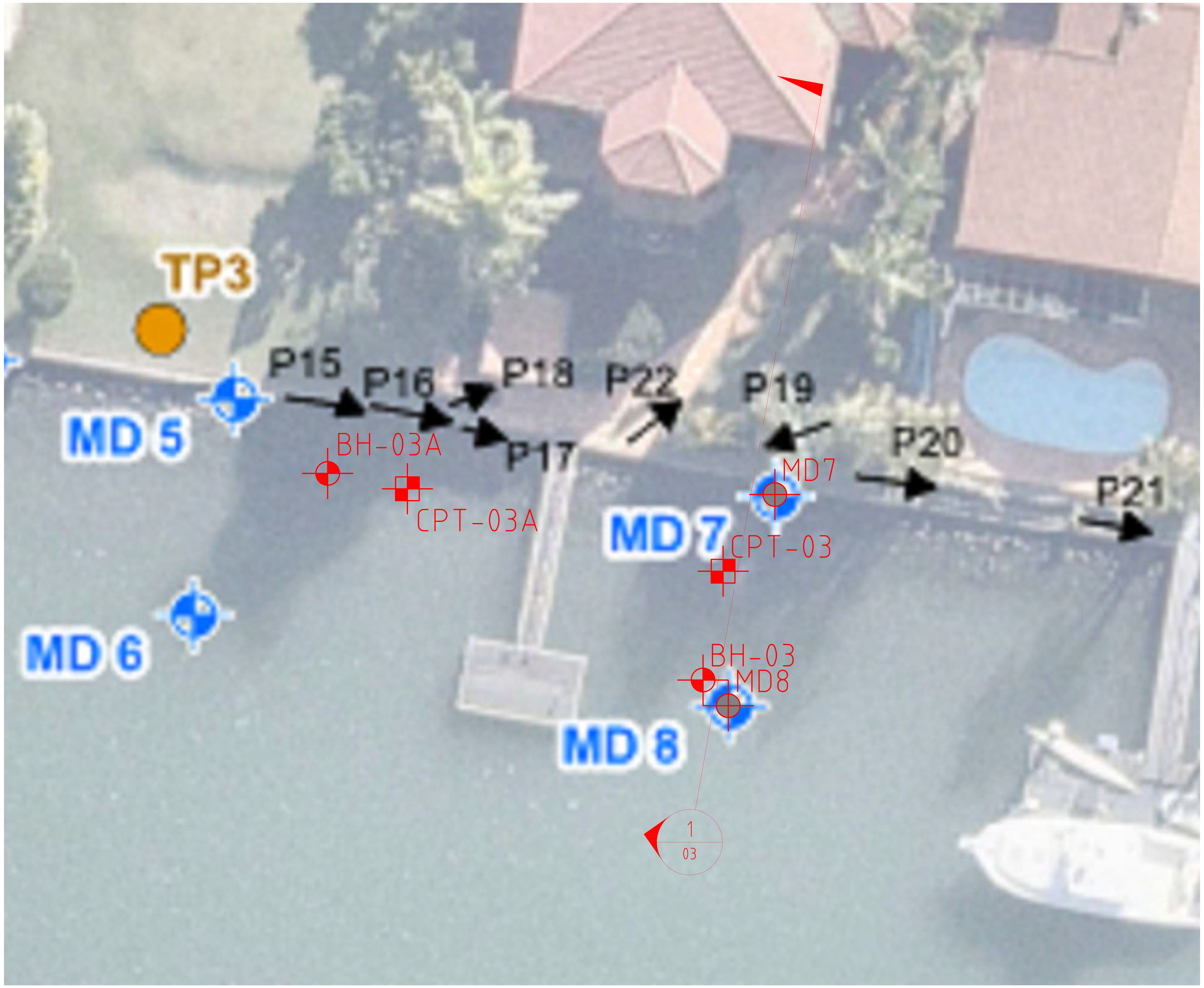
DRAWN H.W. | DRAWING CHECK H.W. | REVIEWED D.R. DATE 24-10-17 | APPROVED A.H. DATE 24-10-17
DESIGNED A.H. | DESIGN REVIEW A.H.

TITLE JET GROUTING STABILISATION WORKS
GENERAL NOTES

SCALE NTS | DRAWING No 5040198-DD-01 | REV 2

A1

DATE: 10/24/2017 10:01 AM LOGIN NAME: HALWIN WINATA – MENARD BACHY
LOCATION: \\AUSTRESS-NAS-01\Zeus\Employees\Halwin Winata\2017\2017-QLD-16672 Raby Bay Trial\MO Dwgs\5040198-DD-01[2] – RBT-JG Work – General Notes – A8.dwg



PLAN VIEW
SCALE 1:100

NOTES:

1. ALL DIMENSION ARE IN mm UNLESS SPECIFIED OTHERWISE;
2. ALL LEVELS ARE IN m AHD, UNLESS SPECIFIED OTHERWISE;
3. THIS DRAWING TO BE READ IN CONJUNCTION WITH:
   - MENARD'S GEOTECHNICAL ASSESSMENT AND DESIGN OF JET GROUTING COLUMNS FOR SLOPE STABILISATION WORKS.

LEGEND

- CPT — CPT LOCATION (SOIL SURVEYS) - 2012
- BH — BOREHOLE LOCATION (SOIL SURVEYS) - 2012
- MD — BOREHOLE LOCATION (GOLDER) - 2016

REFERENCES:

1. RABY BAY - GEOTECHNICAL INVESTIGATION & MONITORING FOR PROPOSED STABILISATION TRIAL BY GOLDER ASSOCIATES, DATED 25 FEBRUARY 2016 (REF. NO. 1529649-035-REV1);
2. RABY BAY CANAL BATTER STABILITY UPDATE - GEOTECHNICAL INVESTIGATION ANALYSIS REPORT BY KELLOGG BROWN & ROOT, DATED 24 JUNE 2013 (REF. NO. BEJ809.002- W-REP-003 REV. 0);
3. MASTHEAD DRIVE TRIAL AREA - STAGE 8 - TYPICAL CROSS SECTIONS REFERENCED 86006-36 REV F.

KEY MAP
SCALE 1:1000

AS BUILT

REV	DATE	DRAWN	REV'D	APP'D	REVISION
1	24-10-17	H.W.	D.R.	A.H.	AS BUILT
0	23-03-17	H.W.	A.H.	A.H.	ISSUED FOR CONSTRUCTION
A	17-01-17	H.W.	M.K.	M.K.	ISSUED FOR APPROVAL

REV	DATE	DRAWN	REV'D	APP'D	REVISION

menard

CLIENT: REDLAND CITY COUNCIL
PROJECT: RABY BAY TRIAL
TRIAL SITE 4: 81-83 MASTHEAD DRIVE

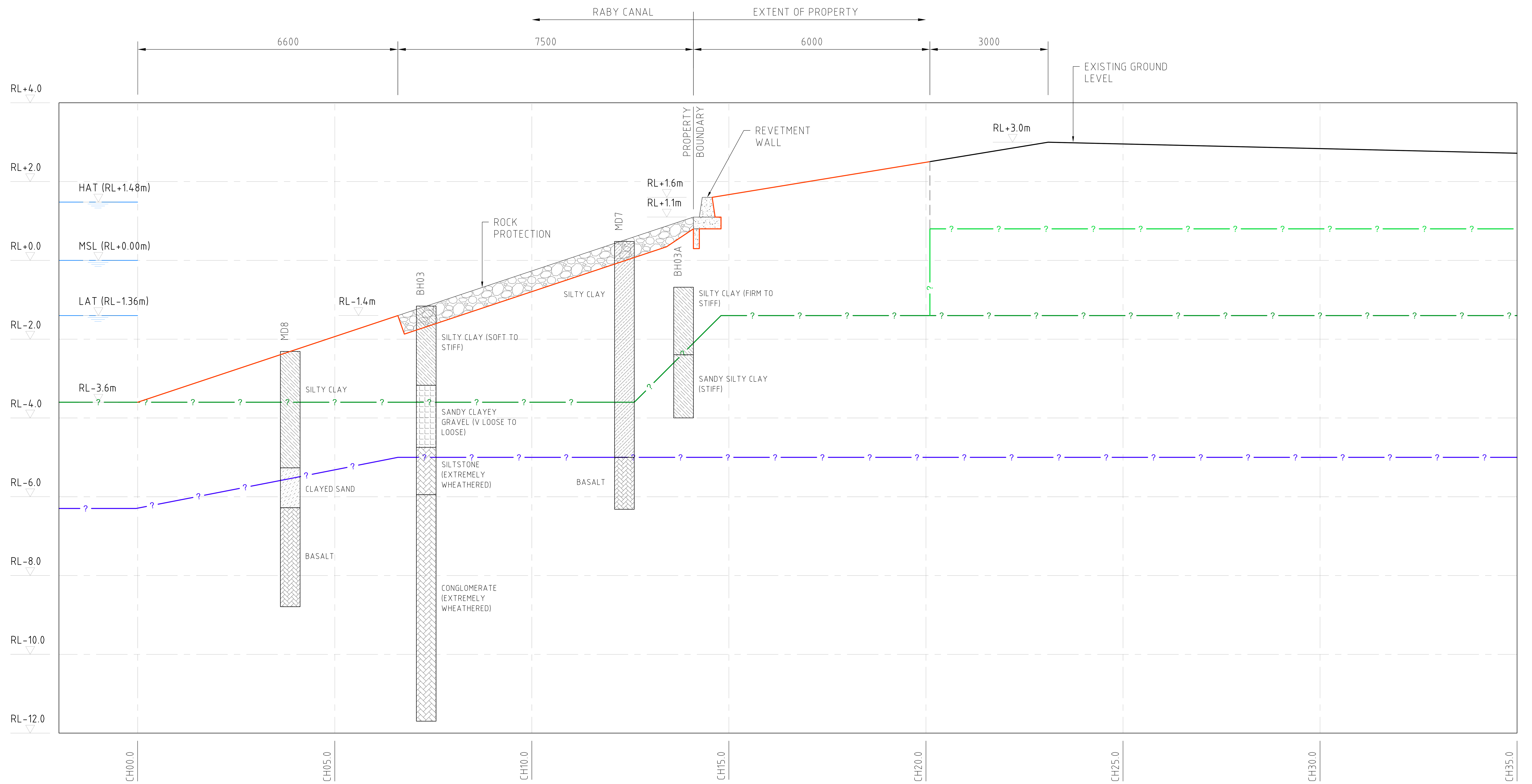
DRAWN	DRAWING CHECK	REVIEWED	APPROVED
H.W.	H.W.	D.R.	A.H.
DESIGNED: A.H.	DESIGN REVIEW: A.H.	DATE 24-10-17	DATE 24-10-17

TITLE: JET GROUTING STABILISATION WORKS
GEOTECHNICAL SITE INVESTIGATION LAYOUT

SCALE	DRAWING No	REV
1:100 (A1)	5040198-DD-02	1

A1

DATE: 10/24/2017 10:11 AM LOGIN NAME: HALWIN WINATA - MENARD BACHY
LOCATION: \\AUSTRESS-NAS-01\Zeus\Employees\Halwin Winata\2017\2017-QLD-16672 Raby Bay Trial\MD Dwgs\5040198-DD-02[1] - RBT-JG Work - Geotechnical Layout - AB.dwg



SECTION 1/02
SCALE 1:50

LEGENDS:

- GROUND LEVEL (ALLOTMENT FILL)
- TOP OF GRANULAR BACKFILL
- TOP OF FIRM TO STIFF CLAY
- TOP OF STIFF TO V.STIFF CLAY
- TOP OF HARD CLAY (BASALT)

NOTES:

1. ALL DIMENSION ARE IN mm UNLESS SPECIFIED OTHERWISE;
2. ALL LEVELS ARE IN m AHD, UNLESS SPECIFIED OTHERWISE;
3. THIS DRAWING TO BE READ IN CONJUNCTION WITH:
   - MENARD'S GEOTECHNICAL ASSESSMENT AND DESIGN OF JET GROUTING COLUMNS FOR SLOPE STABILISATION WORKS.

REFERENCES:

1. RABY BAY - GEOTECHNICAL INVESTIGATION & MONITORING FOR PROPOSED STABILISATION TRIAL BY GOLDER ASSOCIATES, DATED 25 FEBRUARY 2016 (REF. NO. 1529649-035-REV1);
2. RABY BAY CANAL BATTER STABILITY UPDATE - GEOTECHNICAL INVESTIGATION ANALYSIS REPORT BY KELLOGG BROWN & ROOT, DATED 24 JUNE 2013 (REF. NO. BEJ809.002- W-REP-003 REV. 0);
3. MASTHEAD DRIVE TRIAL AREA - STAGE 8 - TYPICAL CROSS SECTIONS REFERENCED 86006-36 REV F.

AS BUILT

REV	DATE	DRAWN	REV'D	APP'D	REVISION
1	24-10-17	H.W.	D.R.	A.H.	AS BUILT
0	23-03-17	H.W.	A.H.	A.H.	ISSUED FOR CONSTRUCTION
A	17-01-17	H.W.	A.H.	M.K.	ISSUED FOR APPROVAL

MENARD

CLIENT: REDLAND CITY COUNCIL
PROJECT: RABY BAY TRIAL
TRIAL SITE 4: 81-83 MASTHEAD DRIVE

DRAWN	DRAWING CHECK	REVIEWED	APPROVED
H.W.	H.W.	D.R.	A.H.
DESIGNED A.H.	DESIGN REVIEW A.H.	DATE 24-10-17	DATE 24-10-17

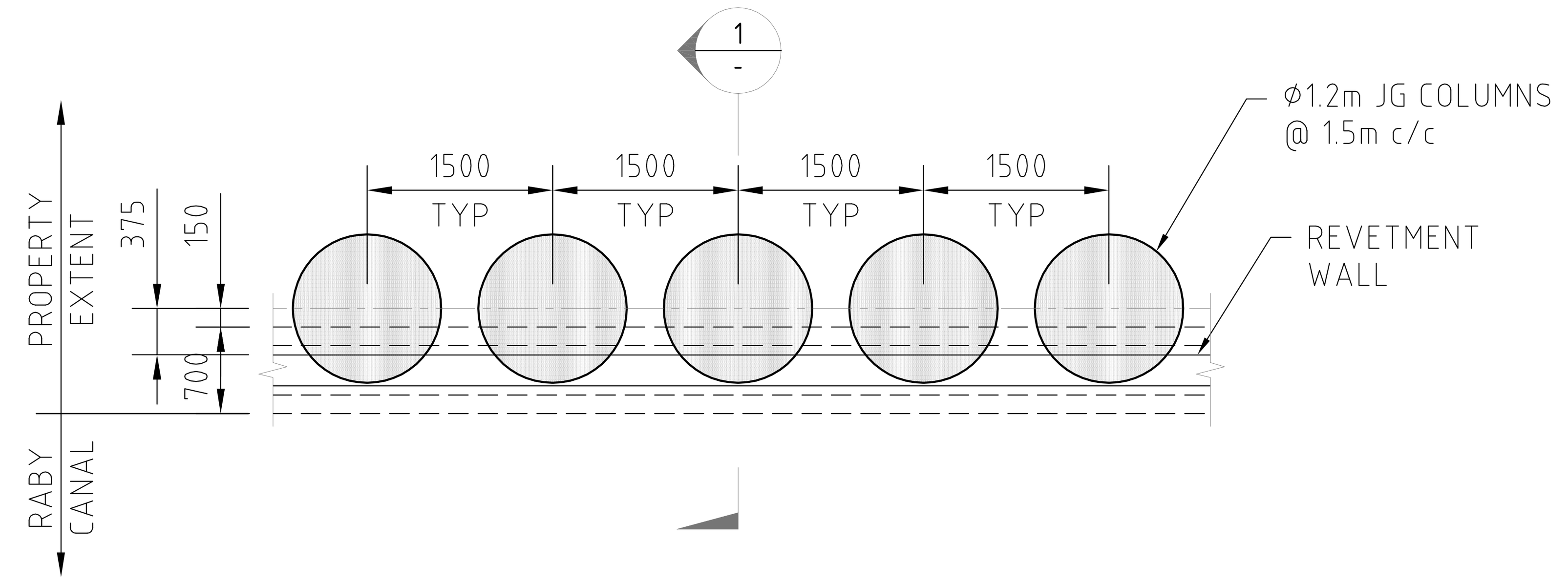
TITLE: JET GROUTING STABILISATION WORKS
INFERRED GEOTECHNICAL PROFILE & ADOPTED GROUND MODEL

SCALE 1:50 (A1) | DRAWING No 5040198-DD-03 | REV 1

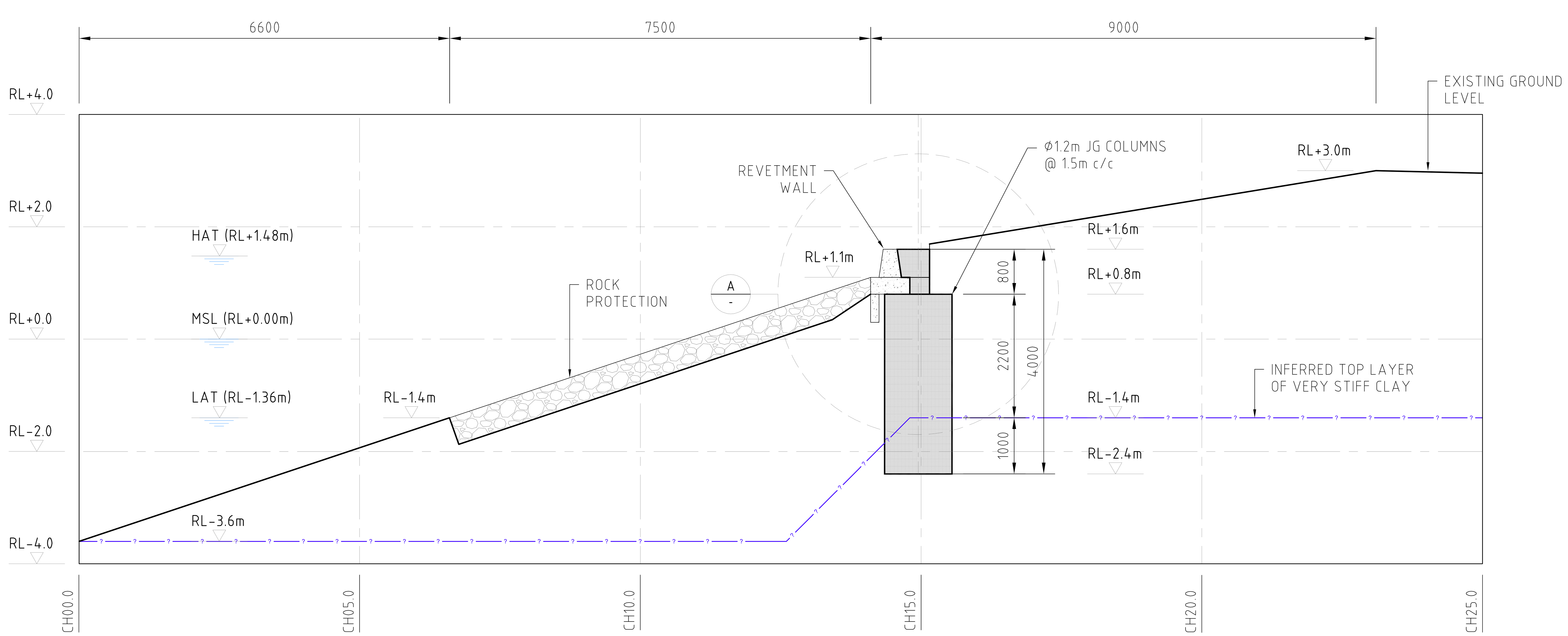
DATE: 10/24/2017 10:23 AM LOGIN NAME: HALWIN WINATA - MENARD BACHY
LOCATION: \\AUSTRESS-NAS-01\Zeus\Employees\Halwin Winata\2017\2017-QLD-16672 Raby Bay Trial\MO Dwgs\5040198-DD-03[1] - RBT-JG Work - Geotechnical Section - AB.dwg

NOTES:

1. ALL DIMENSION ARE IN mm UNLESS SPECIFIED OTHERWISE;
2. ALL LEVELS ARE IN m AHD, UNLESS SPECIFIED OTHERWISE;
3. THIS DRAWING TO BE READ IN CONJUNCTION WITH:
   - MENARD'S GEOTECHNICAL ASSESSMENT AND DESIGN OF JET GROUTING COLUMNS FOR SLOPE STABILISATION WORKS.



JG TYPICAL LAYOUT
SCALE 1:50



SECTION 1
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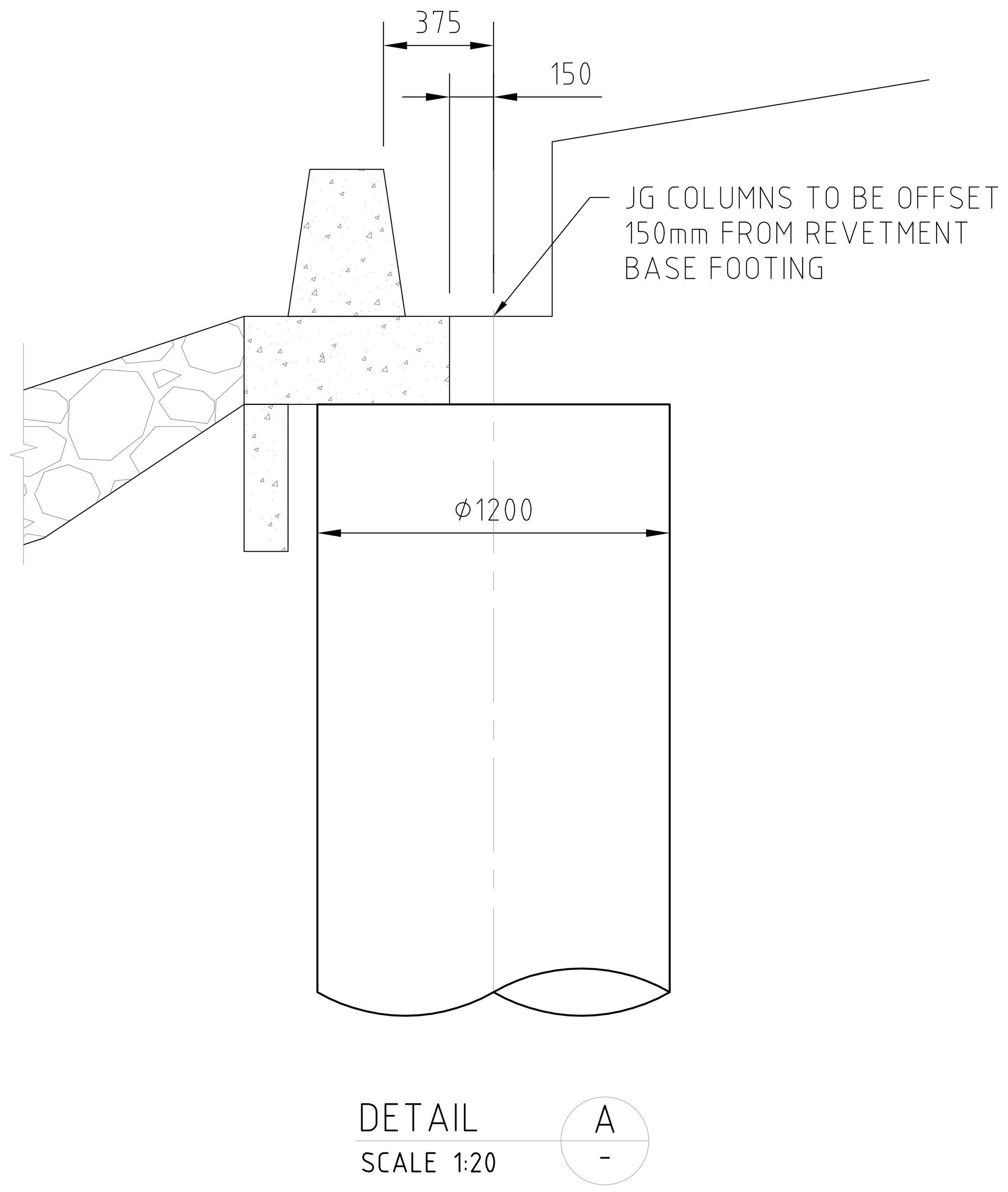


DETAIL A
SCALE 1:20

KEY MAP
SCALE 1:1000

AS BUILT

REV	DATE	DRAWN	REV'D	APP'D	REVISION
1	24-10-17	H.W.	D.R.	A.H.	AS BUILT
0	23-03-17	H.W.	A.H.	A.H.	ISSUED FOR CONSTRUCTION
A	17-01-17	H.W.	M.K.	M.K.	ISSUED FOR APPROVAL

menard

CLIENT: REDLAND CITY COUNCIL
PROJECT: RABY BAY TRIAL
TRIAL SITE 4: 81-83 MASTHEAD DRIVE

DRAWN	DRAWING CHECK	REVIEWED	APPROVED
H.W.	H.W.	D.R.	A.H.
DESIGNED: A.H.	DESIGN REVIEW: A.H.	DATE 24-10-17	DATE 24-10-17

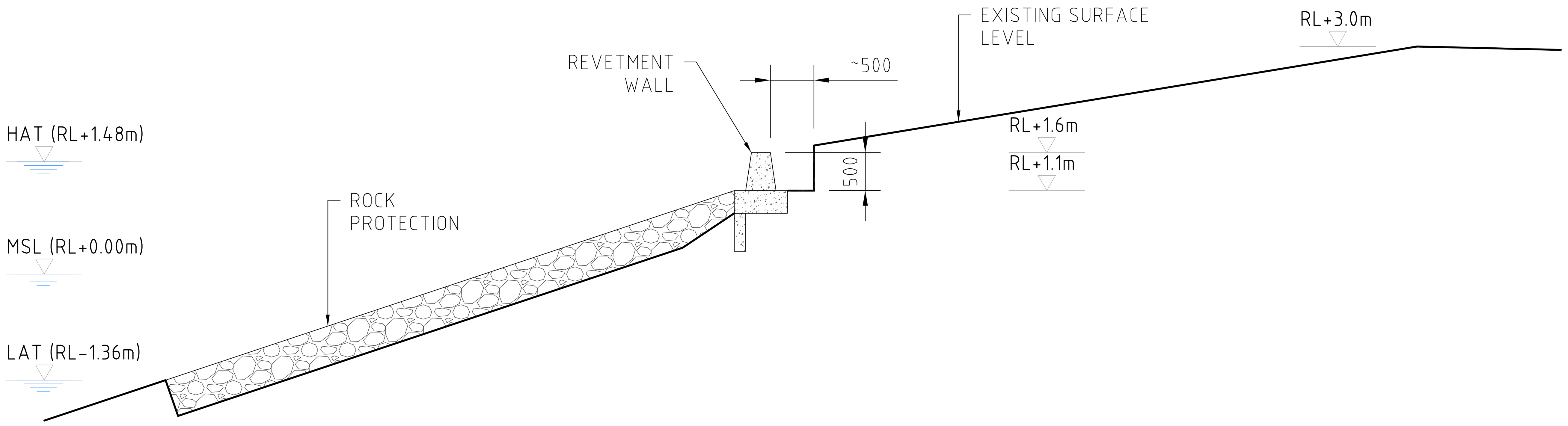
TITLE: JET GROUTING STABILISATION WORKS
GENERAL ARRANGEMENT

SCALE: 1:50 (A1) | DRAWING No: 5040198-DD-04 | REV: 1

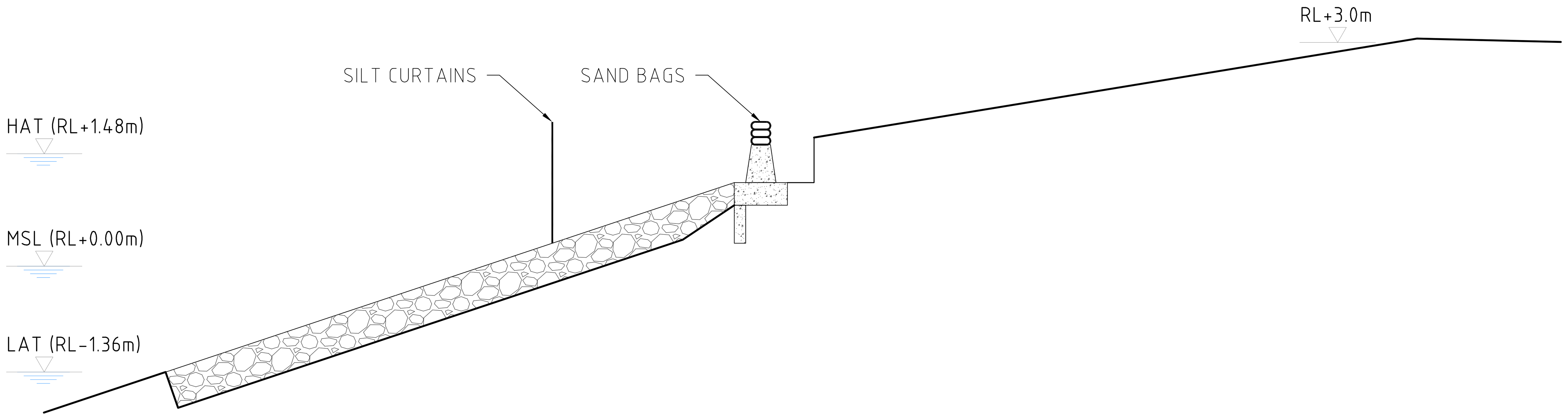
DATE: 10/24/2017 10:15 AM LOGIN NAME: HALWIN WINATA - MENARD BACHY
LOCATION: \\AUSTRESS-NAS-01\Zeus\Employees\Halwin Winata\2017\2017-QLD-16672 Raby Bay Trial\MO Dwgs\5040198-DD-04-05[1] - RBT-JG Work - JG General Arrangement - AB.dwg

CONSTRUCTION SEQUENCE:

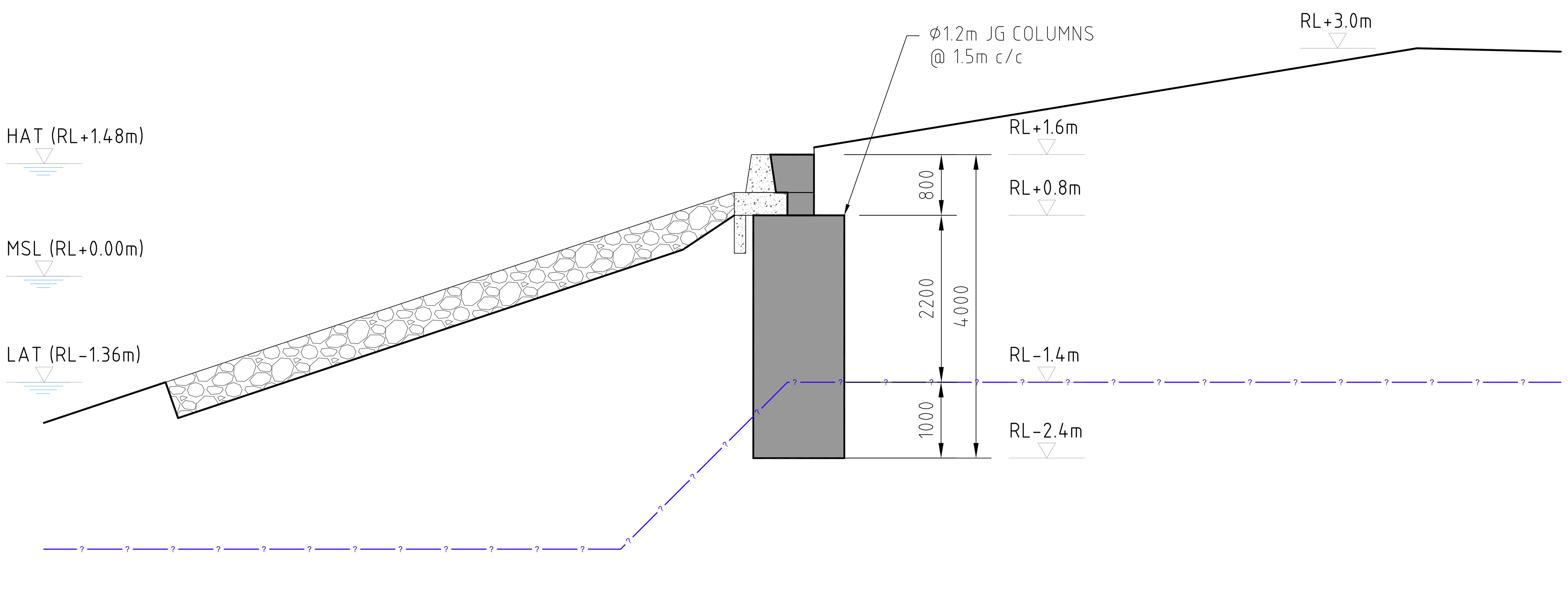
1. STAGE 0 - PREPARATORY WORKS, i.e. SITE SPECIFIC DESIGN, MOBILISATION AND RELOCATION OF PONTOONS AND BOATS;
2. STAGE 1 - EXCAVATION OF A TRENCH FOR COLLECTION OF SPOIL FROM JET GROUTING. THIS WOULD BE PERFORMED USING A SMALL EXCAVATOR OR, IF ACCESS IS MORE RESTRICTED USING VACUUM EXCAVATION TECHNOLOGY;
3. STAGE 2 - INSTALLATION OF ENVIRONMENTAL PROTECTION MEASURES, SUCH AS SAND BAGS, SILT CURTAINS;
4. STAGE 3 - INSTALLATION OF JET GROUT COLUMNS UNDER THE REVETMENT WALL.



STAGE 1 - TRENCH EXCAVATION
SCALE 1:50



STAGE 2 - INSTALLATION OF ENVIRONMENTAL PROTECTION MEASURE
SCALE 1:50



STAGE 3 - JET GROUTING
SCALE 1:50

AS BUILT

REV	DATE	DRAWN	REV'D	APP'D	REVISION
1	24-10-17	H.W.	D.R.	A.H.	AS BUILT
0	23-03-17	H.W.	A.H.	A.H.	ISSUED FOR CONSTRUCTION
A	17-01-17	H.W.	M.K.	M.K.	ISSUED FOR APPROVAL

REV	DATE	DRAWN	REV'D	APP'D	REVISION

menard

CLIENT: REDLAND CITY COUNCIL
PROJECT: RABY BAY TRIAL
TRIAL SITE 4: 81-83 MASTHEAD DRIVE

DRAWN	DRAWING CHECK	REVIEWED	APPROVED
H.W.	H.W.	D.R.	A.H.
DESIGNED	DESIGN REVIEW		
A.H.	A.H.	DATE 24-10-17	DATE 24-10-17

TITLE: JET GROUTING STABILISATION WORKS
CONSTRUCTION SEQUENCE

SCALE: 1:50 (A1) | DRAWING No: 5040198-DD-05 | REV: 1

A1

DATE: 10/24/2017 10:17 AM LOGIN NAME: HALWIN WINATA – MENARD BACHY
LOCATION: \\AUSTRESS-NAS-01\Zeus\Employees\Halwin Winata\2017\2017-QLD-16672 Raby Bay Trial\MO Dwgs\5040198-DD-04-05[1] – RBT-JG Work – JG General Arrangement – AB.dwg

PLAN VIEW
SCALE 1:100

NOTES:

38 OUT OF X40 COLUMNS WERE INSTALLED. LAST 2 COLUMNS ON THE EASTERN SIDE OF 85 MASTHEAD DRIVE WERE NOT INSTALLED DUE TO EXCESIVE MOVEMENT OF THE REVETMENT WALL.

KEY MAP
SCALE 1:1000

AS BUILT

REV	DATE	DRAWN	REV'D	APP'D	REVISION
0	24-10-17	H.W.	D.R.	A.H.	AS BUILT

REV	DATE	DRAWN	REV'D	APP'D	REVISION

menard

CLIENT: REDLAND CITY COUNCIL
PROJECT: RABY BAY TRIAL
TRIAL SITE 4: 81-83 MASTHEAD DRIVE

DRAWN	DRAWING CHECK	REVIEWED	APPROVED
H.W.	H.W.	D.R. (RPEQ NO. 3668575) DATE 24-10-17	A.H. (RPEQ NO. 3668575) DATE 24-10-17
DESIGNED A.H.	DESIGN REVIEW M.K.		

TITLE: JET GROUTING STABILISATION WORKS LAYOUT

SCALE: 1:100 (A1) | DRAWING No: 5040198-DD-06 | REV: 0

A1

DATE: 10/24/2017 10:32 AM LOGIN NAME: HALWIN WINATA - MENARD BACHY
LOCATION: \\AUSTRESS-NAS-01\Zeus\Employees\Halwin Winata\2017\2017-QLD-16672 Raby Bay Trial\MO Dwgs\5040198-DD-06[0] - RBT-JG Work - JG Layout - AB.dwg

Appendix B

Trial assessment

B1 Assessment ratings guides

B1.1 Tender assessment ratings guide

Table 13: Rating guide, from [8]

Rating	Description
0	Inadequate or non-appropriate offer, many deficiencies, does not meet criteria
1	Marginal offer, some to many deficiencies, partly meets criteria
2	Marginal offer, some deficiencies, partly meets criteria
3	Fair off, few to some deficiencies, almost meets criteria
4	Fair off, few deficiencies, almost meets criteria
5	Acceptable offer, few to no deficiencies, just meets criteria
6	Good offer, no deficiencies, meets criteria
7	Good offer, no deficiencies, exceeds some criteria
8	Very good offer, exceeds most criteria
9	Very good offer, exceeds all criteria
10	Outstanding offer, greatly exceeds criteria

B1.2 Trial assessment ratings guide

Table 14: Rating guide (adapted from Table 13)

Criterion	Rating guide
1 Cost	$\text{Rating} = \left(\frac{\text{Lowest price}}{\text{Price}}\right) \times \text{Maximum achievable rating}$
2 Impacts due to construction	0 Many features are removed or significantly damaged by construction. Option cannot be undertaken near sensitive features. Construction is very slow, i.e. ≥4 weeks per 20m. Access is very difficult, e.g. requiring cranes or extensive traffic management). All vessels and pontoons must be moved. Construction has significant impact on surrounding area, a large amount of materials stored onsite, and/or large site footprint that requires extensive remediation. Construction is very noisy. 5 Minor features are removed or minor damage is incurred. Option may have to be adjusted near sensitive features. Construction is moderately paced, i.e. 2 weeks per 20m, with some efficiencies. Works are undertaken by barge but equipment/materials/foot access through properties. Some but not all pontoons and vessels must be moved, or vessels must be moved but pontoons do not require moving. Construction has limited impact on surrounding area, materials are easily stored offsite, and/or the site footprint is moderate requiring some limited remediation. Construction methods may cause noise but noise can be contained to certain times of day. 10 Nearby features are not removed or damaged. Option can be undertaken near sensitive features. Construction is quick, i.e. ≤1 week per 20m. All access from the canal or all access through properties. No vessels or pontoons need to be moved. Construction has no or minimal impact on the surrounding area, materials are minimal or easily stored offsite and the site footprint is minimal requiring no or minimal remediation. Construction methods are not noisy.

Criterion	Rating guide
3 Performance	0 No reduction in rate of movement is experienced relative to baseline (if established). Signs of failure or distress develop to a similar magnitude as before construction. 5 Some reduction of movement is experienced relative to baseline (if established). Option shows few signs of distress, or signs of distress are minor. 10 No further movement is experienced, relative to baseline (if established). No signs of distress are evident.
4 Maintenance	0 Option provides minimal service life and durability, i.e. <5 years. Future works or repairs are required and will be costly. Maintenance period (i.e. amount of time before maintenance is required) is minimal, e.g. <2 years. If relevant, option cannot be easily inspected or accessed for maintenance, and access for repair is very difficult, e.g. requiring cranes or extensive traffic management). Maintenance requires significant labour and materials. 5 Option provides moderate service life and durability, i.e. 20 years. Future works or repairs are required but are moderately costly. If relevant, option can be easily inspected or accessed for maintenance and access for repair combines barge and foot access. Maintenance requires moderate labour and materials. 10 Option provides excellent service life and durability, i.e. ≥50 years. Future works or repairs are not required and maintenance is not required (i.e. option can be left or augmented in situ). If relevant, option can be easily inspected and accessed.
5 Constructability and programme	0 Option is dangerous to personnel or the environment. Construction is very slow (i.e. ≥4 weeks per 20m) or can only be undertaken during limited times (e.g. only at very low tides). Option is not adaptable to varied site conditions or geometries (i.e. can only be used in very specific circumstances). Option is extremely difficult to remove and replace (at end of life or for repair, if relevant). 5 Option can be constructed safely but there are some risks to personnel or environment that must be managed. Construction is moderately paced (i.e. 2 weeks per 20m) and/or can be undertaken at least 50% of available working time. Option is somewhat adaptable to varied site conditions or geometries (i.e. can be used across a majority of sites within Raby Bay estate). Option can be removed and replaced replace (at end of life or for repair, if relevant) with some access requirements, disruptions to residents and/or minor impact to nearby features. 10 Option can be constructed safely and there are no or minimal risks to personnel or environment. Construction is quick (i.e. ≤1 week per 20m) and can be undertaken at most or all times. Option is highly adaptable to varied site conditions and geometries and can be undertaken at all or almost all sites within Raby Bay estate. Option can be removed or replaced with minimal access requirements, disruptions or impacts to nearby features, or does not require removal at all (e.g. can be left or augmented in situ).
6 Understanding of the project	0 Contractor demonstrated no understanding of the project aim, scope and constraints. Option and approach do not at all limit impact, cost or performance. 5 Contractor demonstrated some understanding of the project aim, scope and constraints. Option and approach provide moderate limits to impact, cost and performance 10 Contractor demonstrated an excellent understanding of the project aim, scope and constraints. Works have minimal impact, are cost effective and perform well.
7 Quality control	0 No quality control documentation, records or as-built documentation. 5 Standard quality control documentation, records and as-built documentation providing the minimum acceptable amount of detail. 10 Excellent quality control documentation, records and as-built documentation providing a high level of detail.
8 Previous experience	This has been excluded for the Trial Assessment, as noted in Section 4.3.1.

B2 Contractor cost tables

B2.1 Ecospec costs

Table 15: Summary of Ecospec costs

Section	Item	Unit	Quantity	Rate	Amount
Schedule B of contract	Design Engineer Input Trials	LS			
	Mobilisation	LS			
	Construction Cost of Canal Repair	m			
	Demobilisation	LS			
	Sub-total				
Wall top-up	Wall top-up	m			
	Sub-total				
Landscaping	Landscaping works	LS			
	Additional works to below gangway at No. 7 and fence line at No. 11	LS			
	Sub-total				
TOTAL					**519,504.00**

B2.2 Mainmark costs

Table 16: Summary of Mainmark costs

Section	Item	Unit	Quantity	Rate	Amount
Schedule B of contract	Mobilisation/Demobilisation	LS			
	Construction Cost of Canal Repair	m			
	Design Solution of Trial Section	LS			
	Cost for Professional Indemnity Insurance	Year			
	Cost for Public Liability Insurance	Year			
	Sub-total				
TOTAL					**360,114.00**

B2.3 Menard costs

Table 17: Summary of Menard costs

Section	Item	Unit	Quantity	Rate	Amount
Schedule B of contract	Mobilisation	LS			
	Construction of Canal Repair	m			
	Demobilisation	LS			
	Preparation of design, methods and OHSE	LS			
	Access with Barge with Plant laydown on land	LS			
	Construction - Access barge/Laydown on land	m			
	Reinstatement of laydown area	LS			
	Project specific purchase item	LS			
	Supply erection and maintenance of Security fence	LS			
	Sub-total				
Wall top-up	Design	LS			
	Top-Up wall - LA55 Product	m			
	Additional Landscaping	LS			
	Sub-total				
Landscaping	Removal Works	LS			
	Reinstatement	LS			
	Sub-total				
Other variations	Additional Survey	LS			
	Delay Costs - 13-14 June	LS			
	Sub-total				
TOTAL					**507,342.00**

Note: Only 38 of the proposed 40 columns were installed, correlating to 57m length of stabilisation. However 60m length of wall top-up and landscaping was undertaken.

Table 18: Summary of Menard costs (estimated for barge-based batching plant)

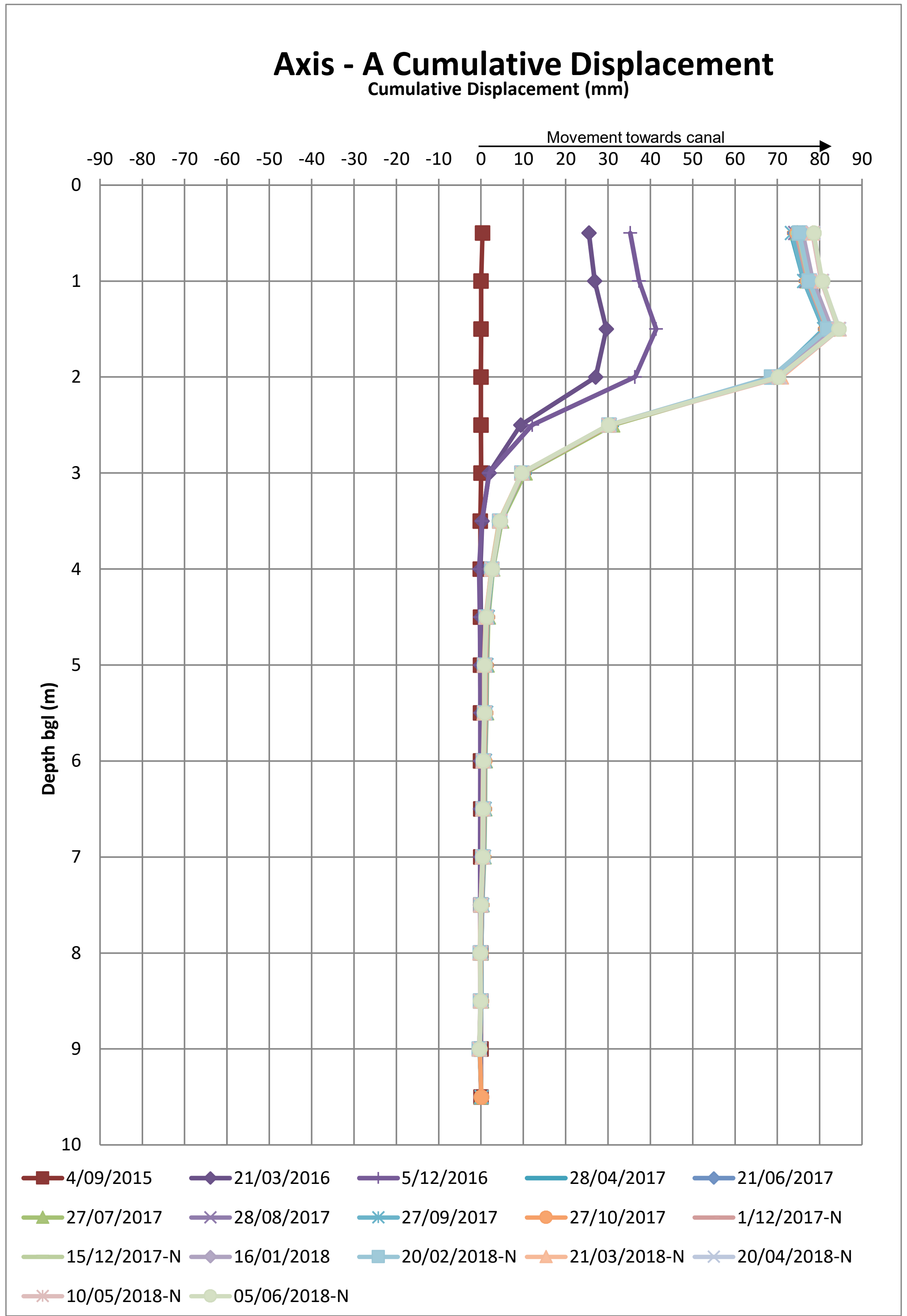
Section	Item	Unit	Quantity	Rate	Amount
Schedule B of contract	Mobilisation	LS			
	Construction of Canal Repair	m			
	Demobilisation	LS			
	Preparation of design, methods and OHSE	LS			
	Access with Barge with Plant laydown on land	LS			
	Construction - Access barge/Laydown on land	m			
	Reinstatement of laydown area	LS			
	Project specific purchase item	LS			
	Supply erection and maintenance of Security fence	LS			
	Sub-total				
Wall top-up	Design	LS			
	Top-Up wall - LA55 Product	m			
	Additional Landscaping	LS			
	Sub-total				
Landscaping	Removal Works	LS			
	Reinstatement	LS			
	Sub-total				
Other variations	Additional Survey	LS			
	Delay Costs - 13-14 June	LS			
	Sub-total				
TOTAL					**540,742.00**

Note: Only 38 of the proposed 40 columns were installed, correlating to 57m length of stabilisation. However 60m length of wall top-up and landscaping was undertaken.

B3 Monitoring data

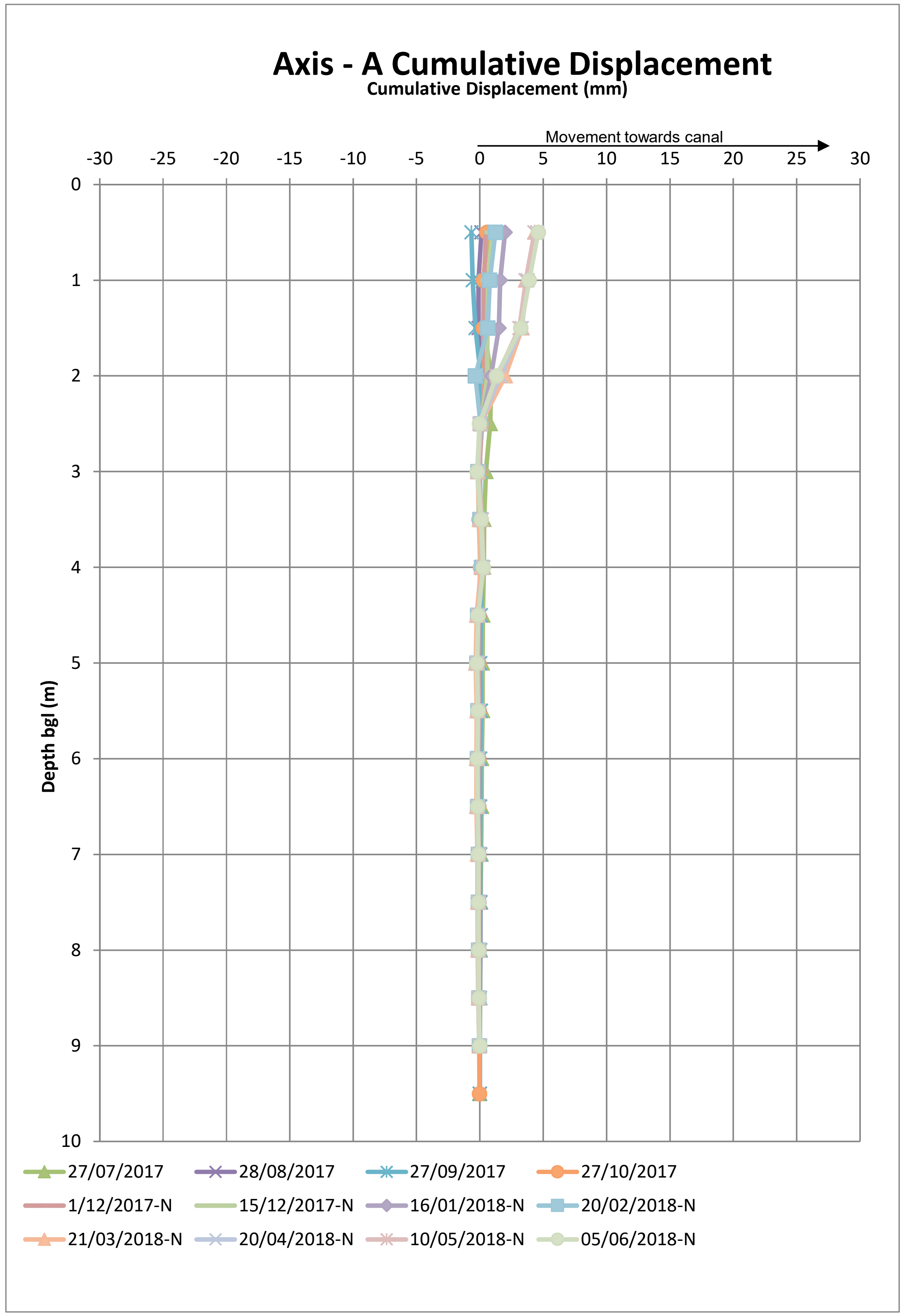
B3.1 Inclinometer measurements

Inclinometer A-axis measurements are extracted from the Golder technical memorandum *Raby Bay Inclinometer, Tiltmeter and Survey Readings June 2018*, dated 14 June 2018 (ref. 1529649-084-TM-Rev0) [11].



GOLDER	CLIENT Redland City Council	PROJECT Raby Bay	
	DRAWN EJS / DATE: 12/06/2018	Inclinometer SC1 (base reading 27/08/2015)	
	CHECKED SB / DATE: 12/06/2018	Cumulative Displacement Axis - A	
	SCALE: NA / A4	PROJECT No. 1529649	FIGURE No. A1.1

J:\Geo\2015\1529649-Raby Bay\Technical Doc\Fieldwork\Inclinometer Readings\Reports\Inclinometer Readings Updated 2018-06-05\[2018-06-05 - Inclinometer-SC1.xlsx]Axis - A 90 mm



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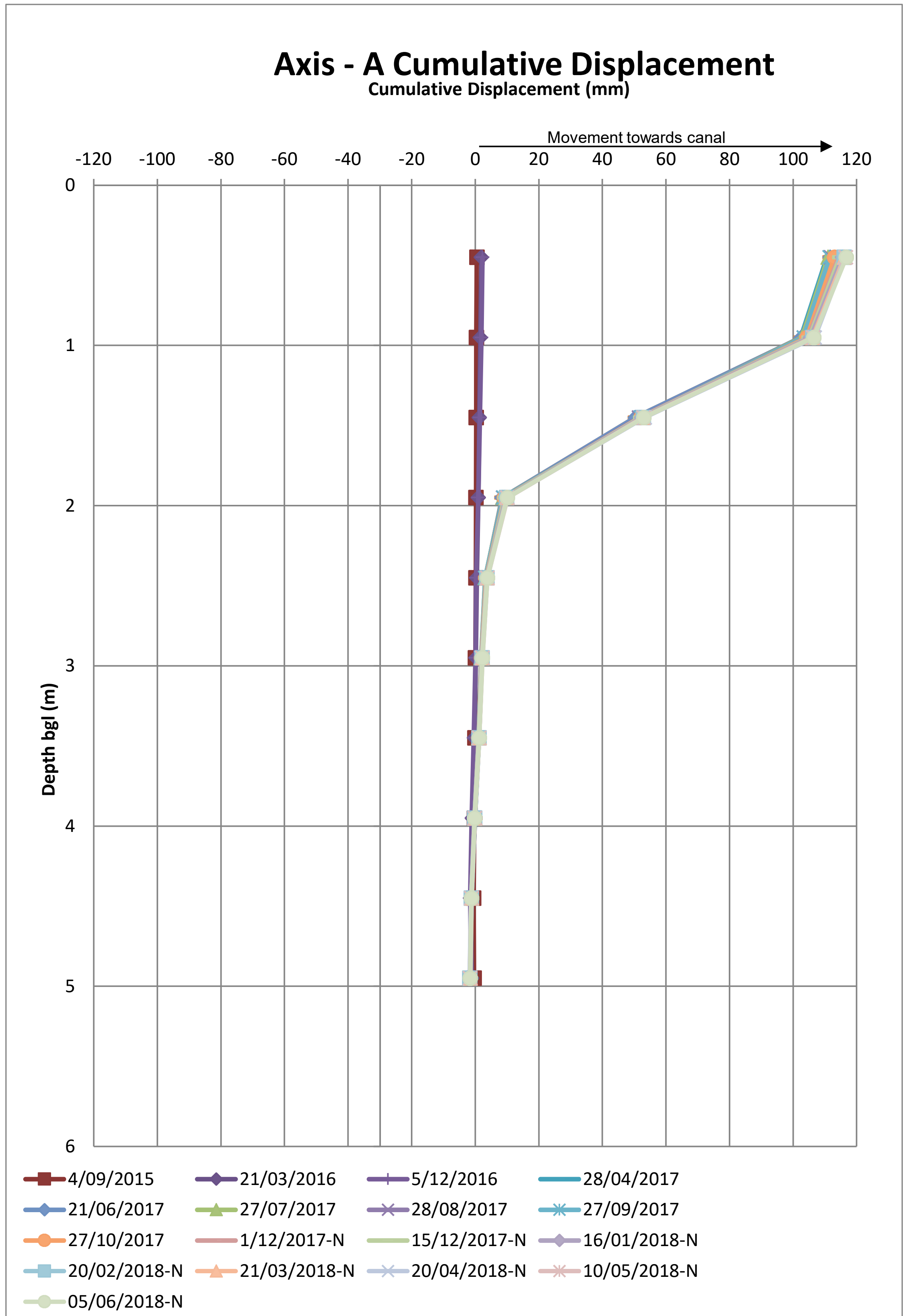
GOLDER	CLIENT Redland City Council	PROJECT Raby Bay	
	DRAWN EJS / DATE: 12/06/2018	Inclinometer SC1 (base reading 21/06/2017)	
	CHECKED SB / DATE: 12/06/2018	Cumulative Displacement Axis - A	
	SCALE: NA / A4	PROJECT No. 1529649	FIGURE No. A1.1

J:\Geo\2015\1529649-Raby Bay\Technical Doc\Fieldwork\Inclinometer Readings\Reports\Inclinometer Readings Updated 2018-06-05\[2018-06-05 - Inclinometer-SC1.xlsx]Axis - A 90 mm



GOLDER

CLIENT Redland City Council		PROJECT Raby Bay	
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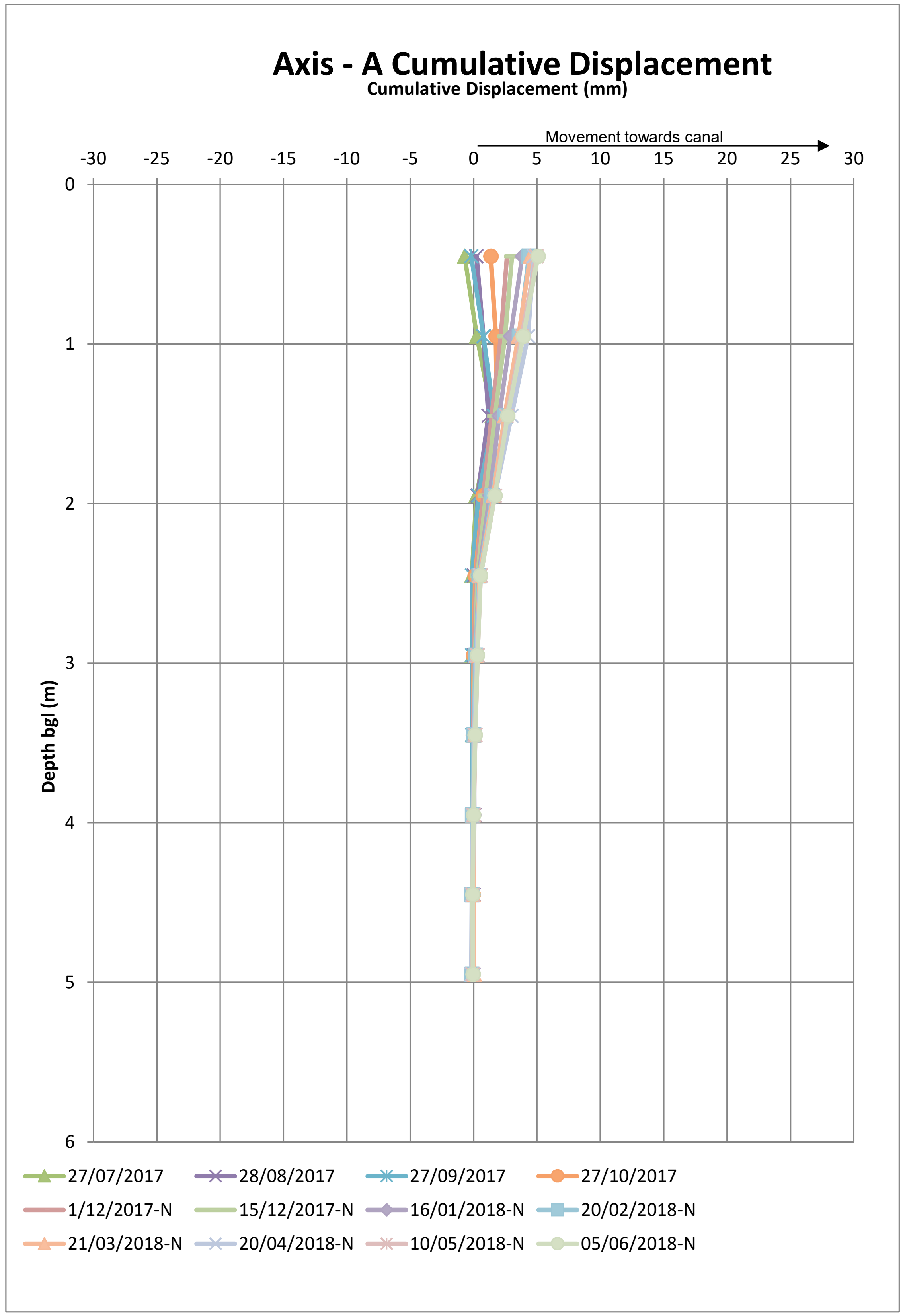
CHECKED SB	DATE: 12/06/2018	Cumulative Displacement Axis - A	
SCALE: NA	A4	PROJECT No. 1529649	FIGURE No. A1.3

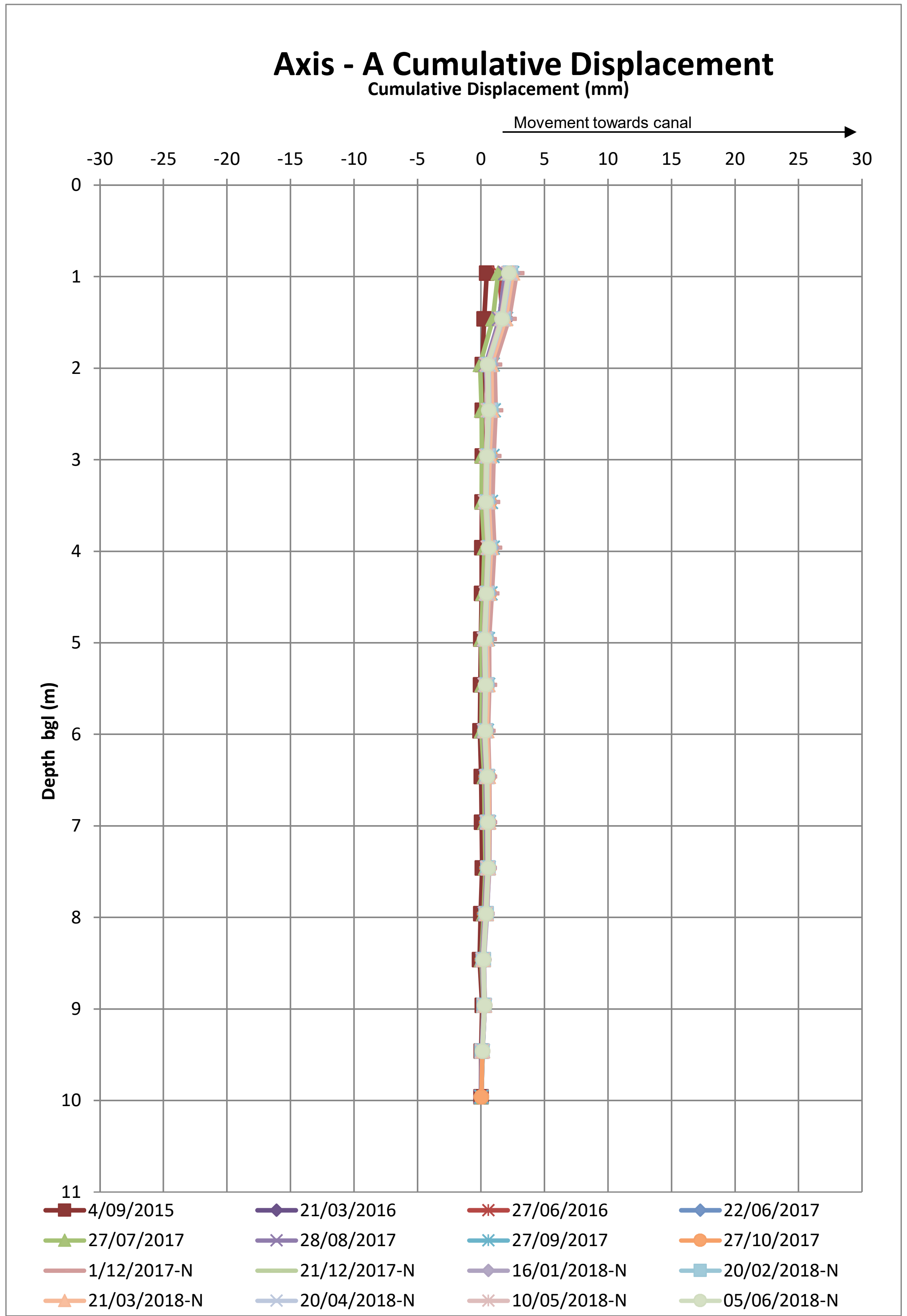
C:\Users\chvincent\Documents\[Time in Lieu.xlsx]Sheet1



GOLDER

CLIENT Redland City Council		PROJECT Raby Bay	
DRAWN EJS	DATE: 12/06/2018	Inclinometer SC5 (base reading 21/06/2017)	
CHECKED SB	DATE: 12/06/2018	Cumulative Displacement Axis - A	
SCALE: NA	A4	PROJECT No. 1529649	FIGURE No. A1.3

C:\Users\chvincent\Documents\[Time in Lieu.xlsx]Sheet1



CLIENT	Redland City Council	PROJECT	Raby Bay
DRAWN	EJS	DATE: 12/06/2018	Inclinometer SC8 (base reading 27/08/2015)
CHECKED	SB	DATE: 12/06/2018	Cumulative Displacement Axis - A
SCALE:	NA	A4	PROJECT No. 1529649 — FIGURE No. A3.2

GOLDER

J:\Geo\2015\1529649-Raby Bay\Technical Doc\Fieldwork\Inclinometer Readings\Reports\Inclinometer Readings Updated 2018-06-05\[2018-06-05 - Inclinometer-SC8.xlsx]Resultant

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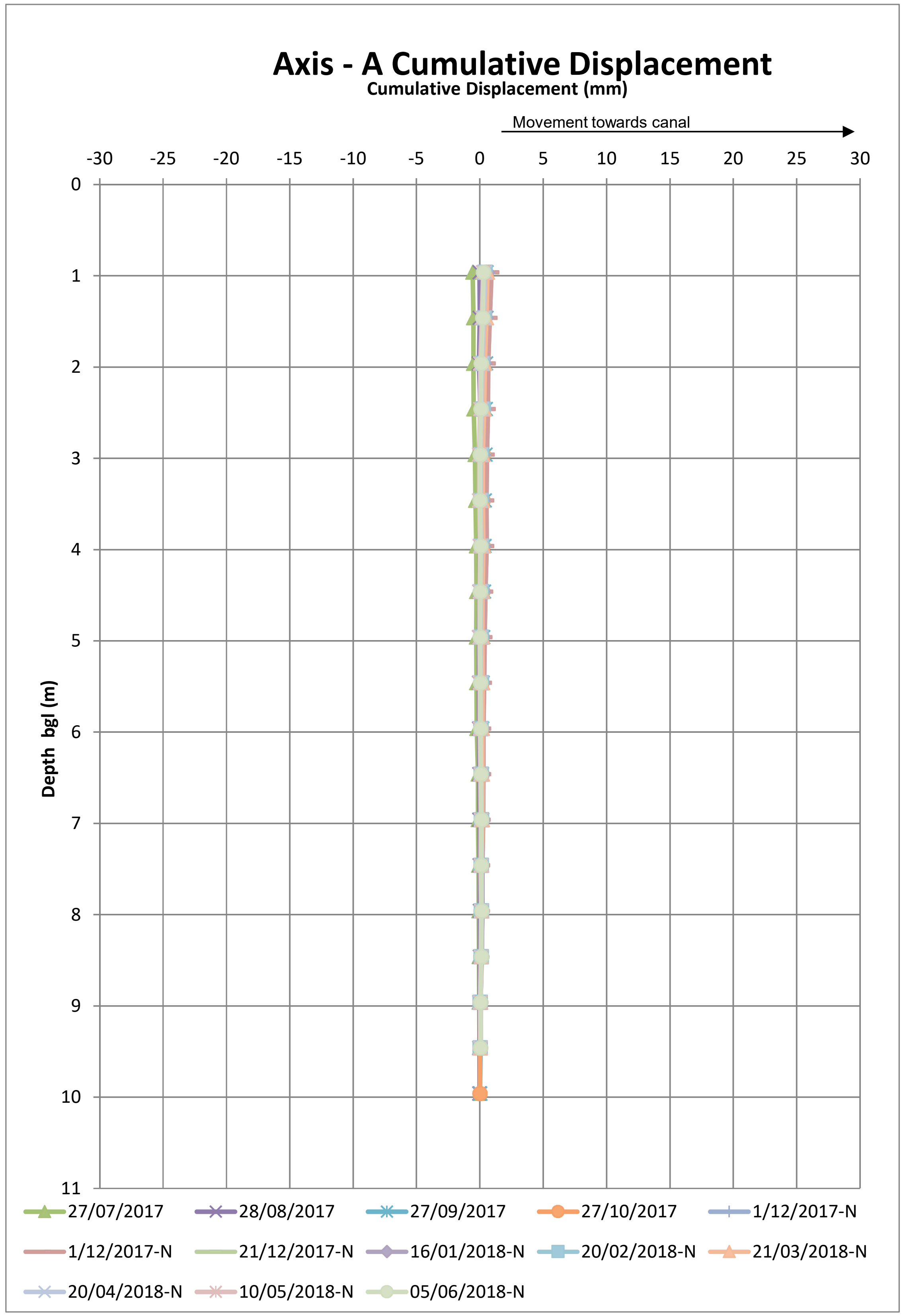
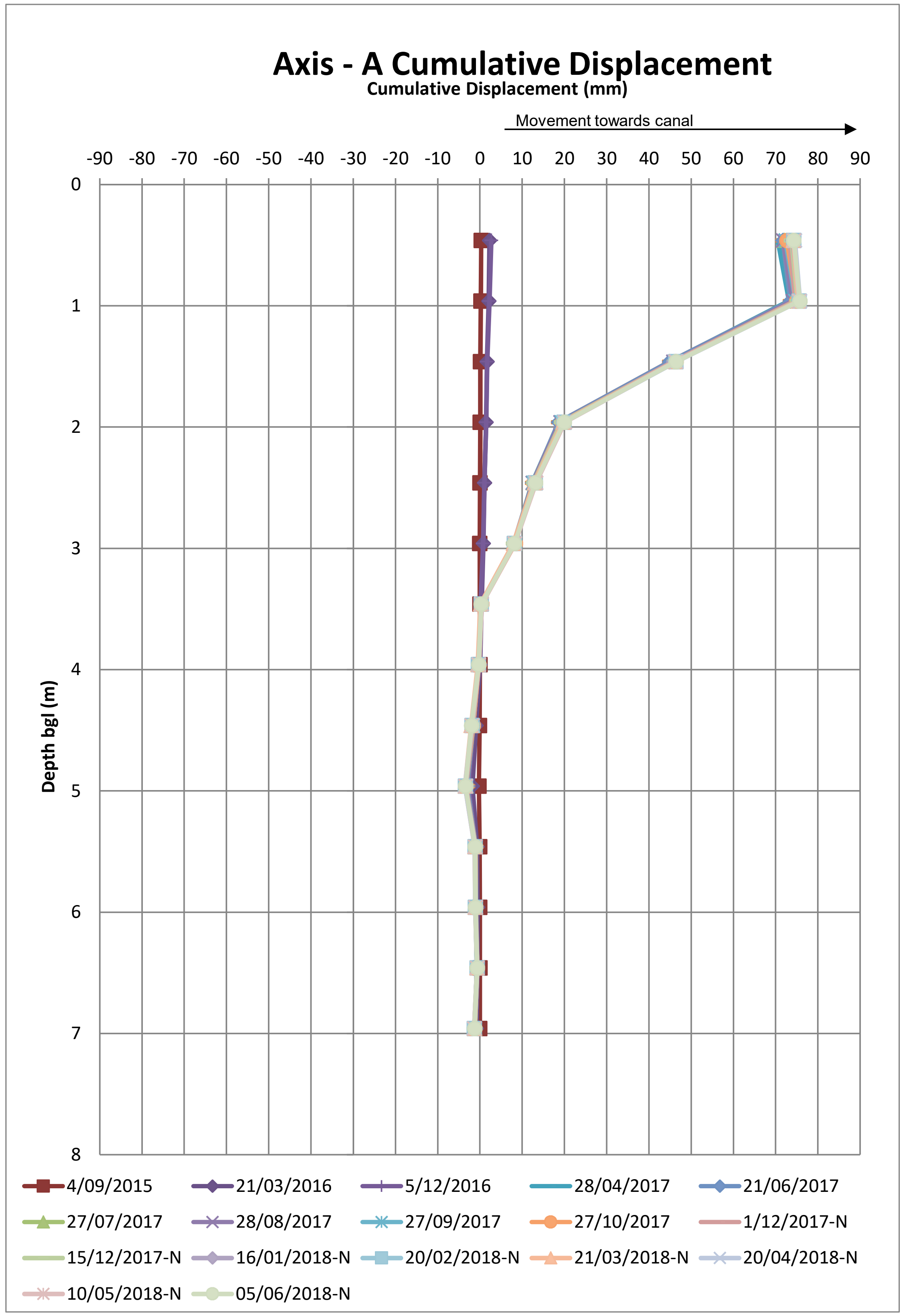


CLIENT	Redland City Council	PROJECT	Raby Bay
DRAWN	EJS	DATE: 12/06/2018	Inclinometer SC8 (base reading 22/06/2017)
CHECKED	SB	DATE: 12/06/2018	Cumulative Displacement Axis - A
SCALE:	NA	A4	PROJECT No. 1529649 — FIGURE No. A3.2

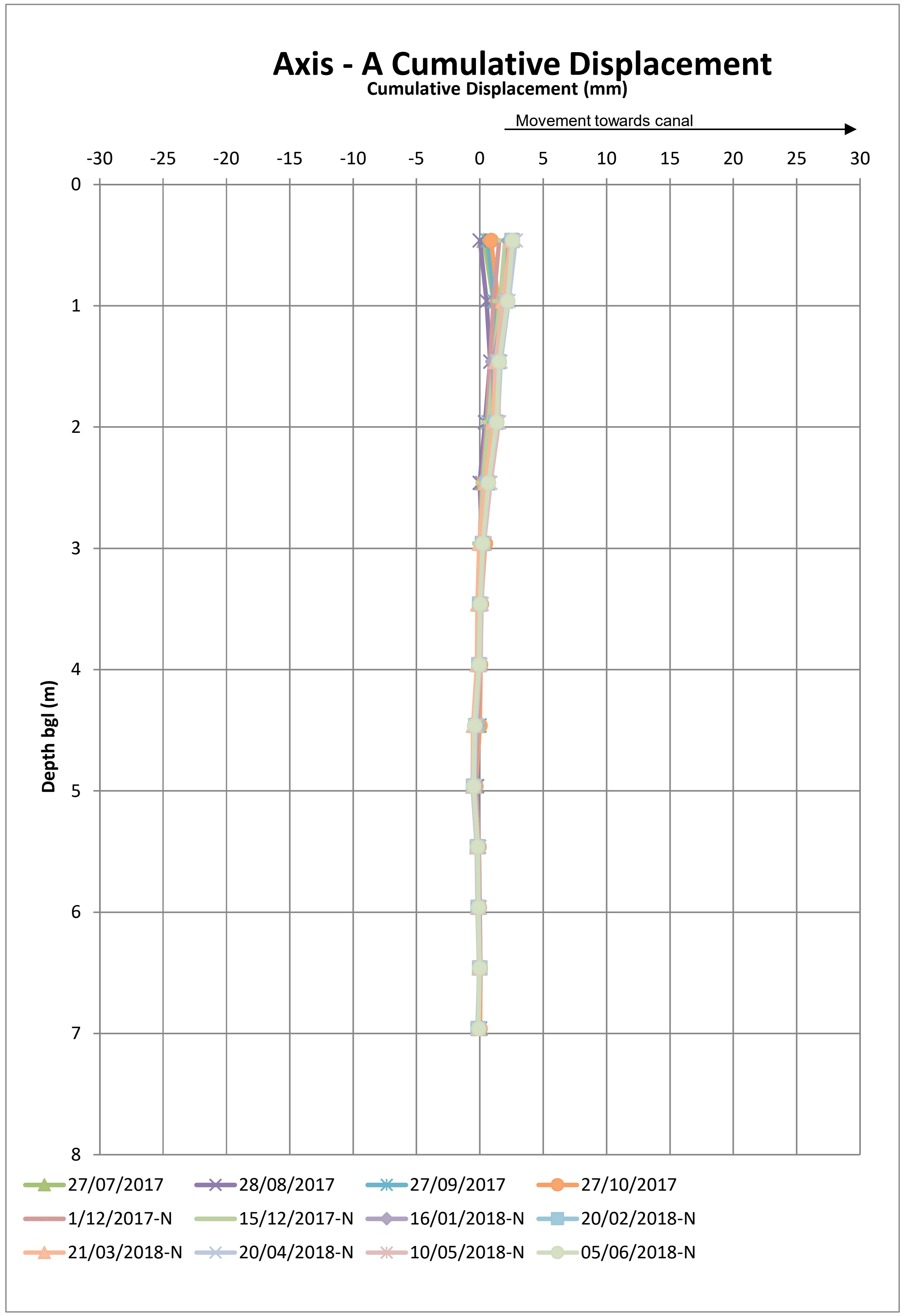
GOLDER

J:\Geo\2015\1529649-Raby Bay\Technical Doc\Fieldwork\Inclinometer Readings\Reports\Inclinometer Readings Updated 2018-06-05\[2018-06-05 - Inclinometer-SC8.xlsx]Resultant



GOLDER

CLIENT	Redland City Council			PROJECT	Raby Bay
DRAWN	EJS	DATE:	12/06/2018	Inclinometer SC9 (base reading 27/08/2015)	
CHECKED	SB	DATE:	12/06/2018	Cumulative Displacement Axis - A	
SCALE:	NA		A4	PROJECT No. 1529649	FIGURE No. A1.5



GOLDER

CLIENT	Redland City Council			PROJECT	Raby Bay
DRAWN	EJS	DATE:	12/06/2018	Inclinometer SC9 (base reading 21/06/2017)	
CHECKED	SB	DATE:	12/06/2018	Cumulative Displacement Axis - A	
SCALE:	NA		A4	PROJECT No. 1529649	FIGURE No. A1.5

B3.2 Tiltmeter measurements

Tiltmeters were installed at the Sternlight Court and Masthead Drive trial sites during the pre-construction monitoring period and were monitored until decommission prior to construction works. The Sternlight Court tiltmeters were reinstated following completion of construction works.

The lower and upper bounder tiltmeter measurements for each week are provided in Attachment E of the *Raby Bay Inclinometer, Tiltmeter and Survey Readings May 2018* report [11]. The average of the upper and lower bound measurements in the A-axis (aligned with the canal slope) has been plotted in Figure 6.

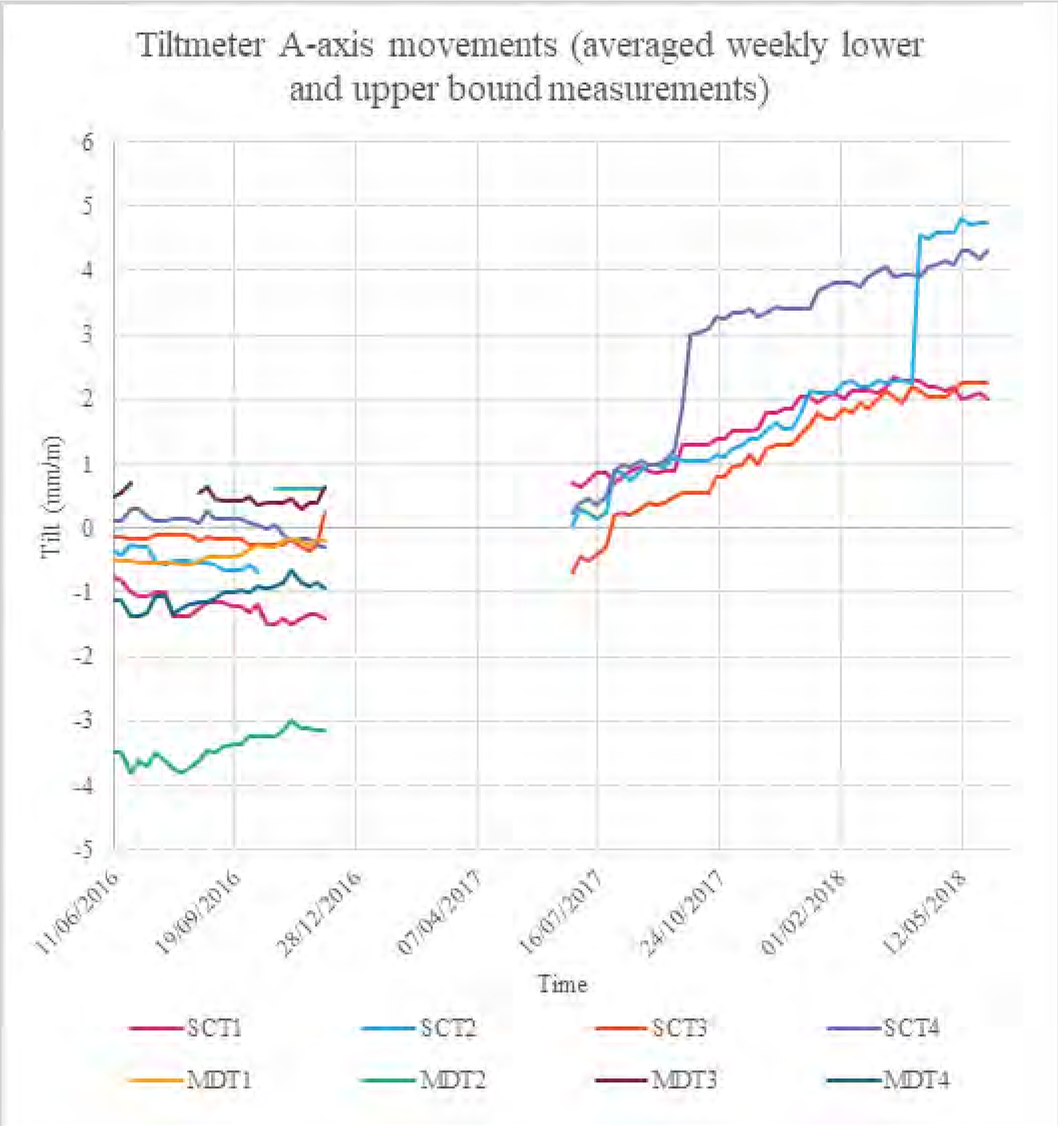


Figure 6: Tiltmeter A-axis measurements with pre-construction on left and post-construction on right (produced from measurements provided in Golder May 2018 monitoring report, ref. [11])

B3.3 Survey marker measurements

B3.3.1 Trial Site 1

B3.3.1.1 Pre-construction measurements

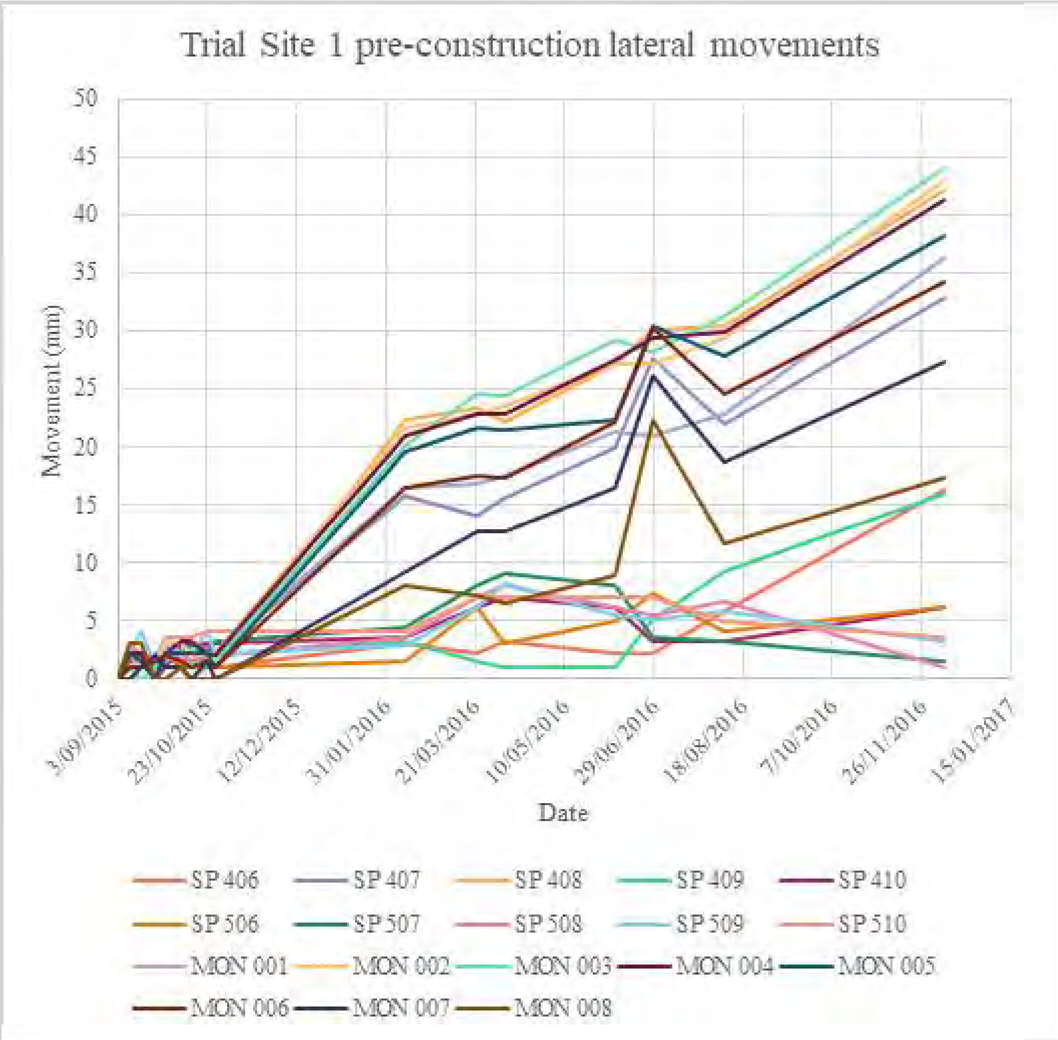


Figure 7: Trial Site 1 pre-construction lateral movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [10], mismeasurements not plotted for clarity)

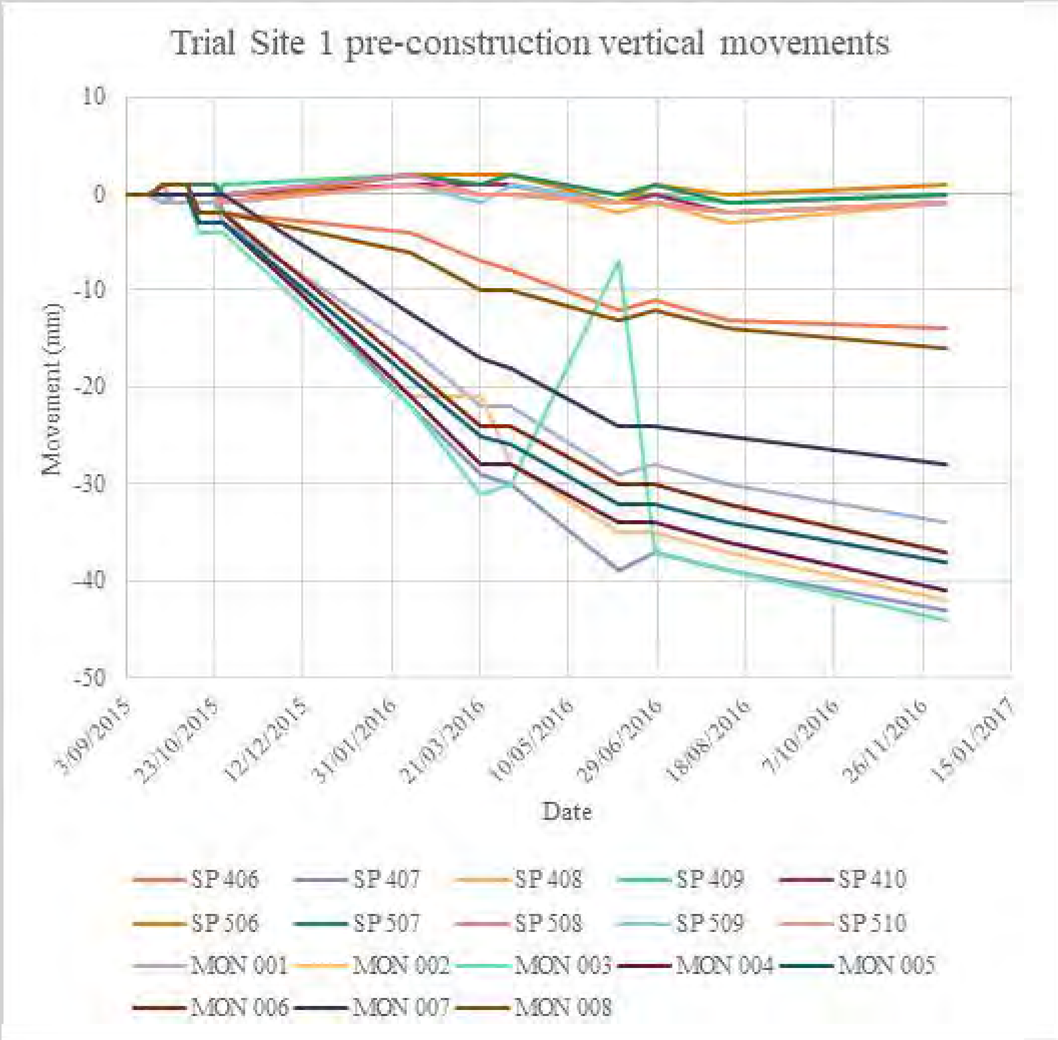


Figure 8: Trial Site 1 pre-construction vertical movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [10], mismeasurements not plotted for clarity)

B3.3.1.2 Post-construction measurements

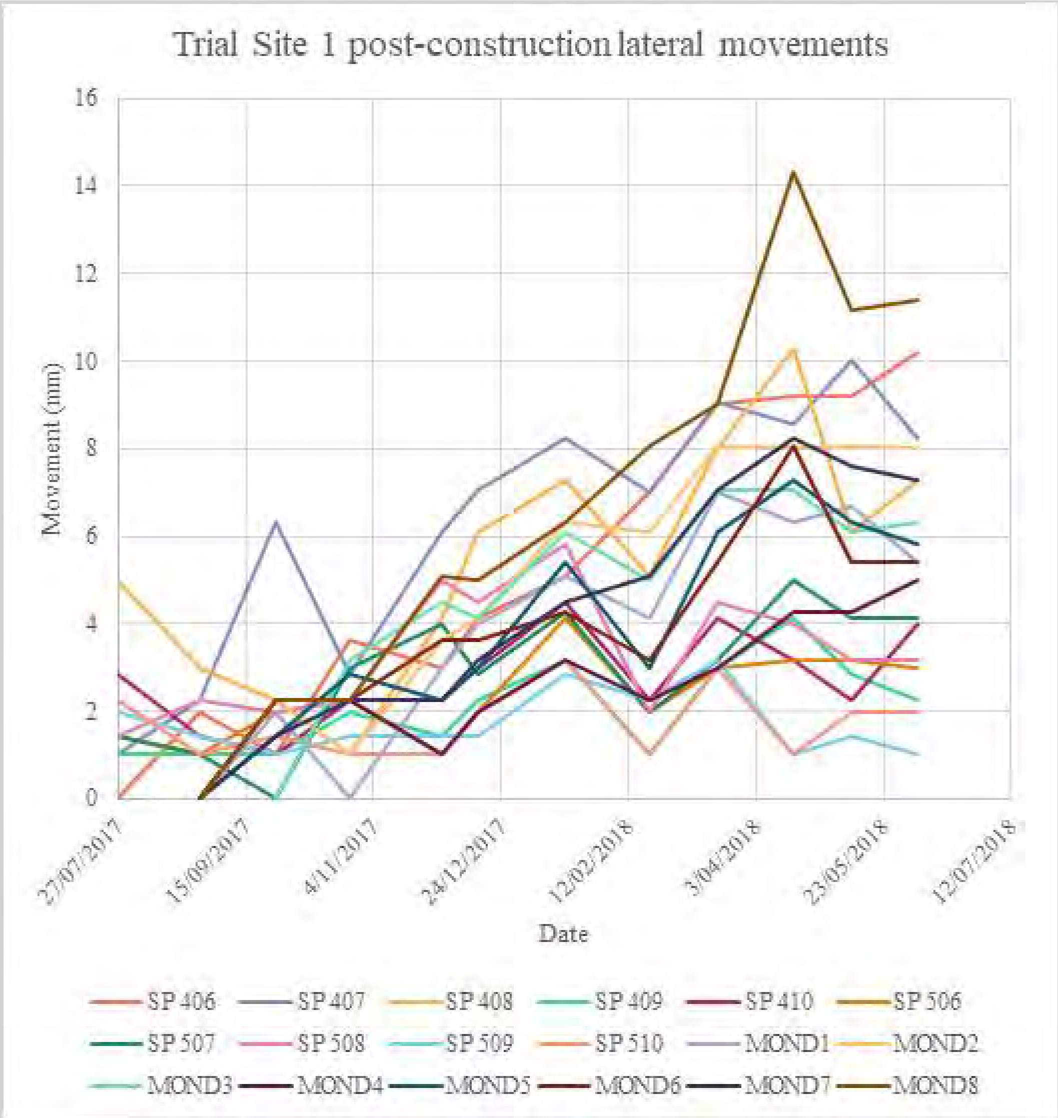


Figure 9: Trial Site 1 post-construction lateral movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [11])

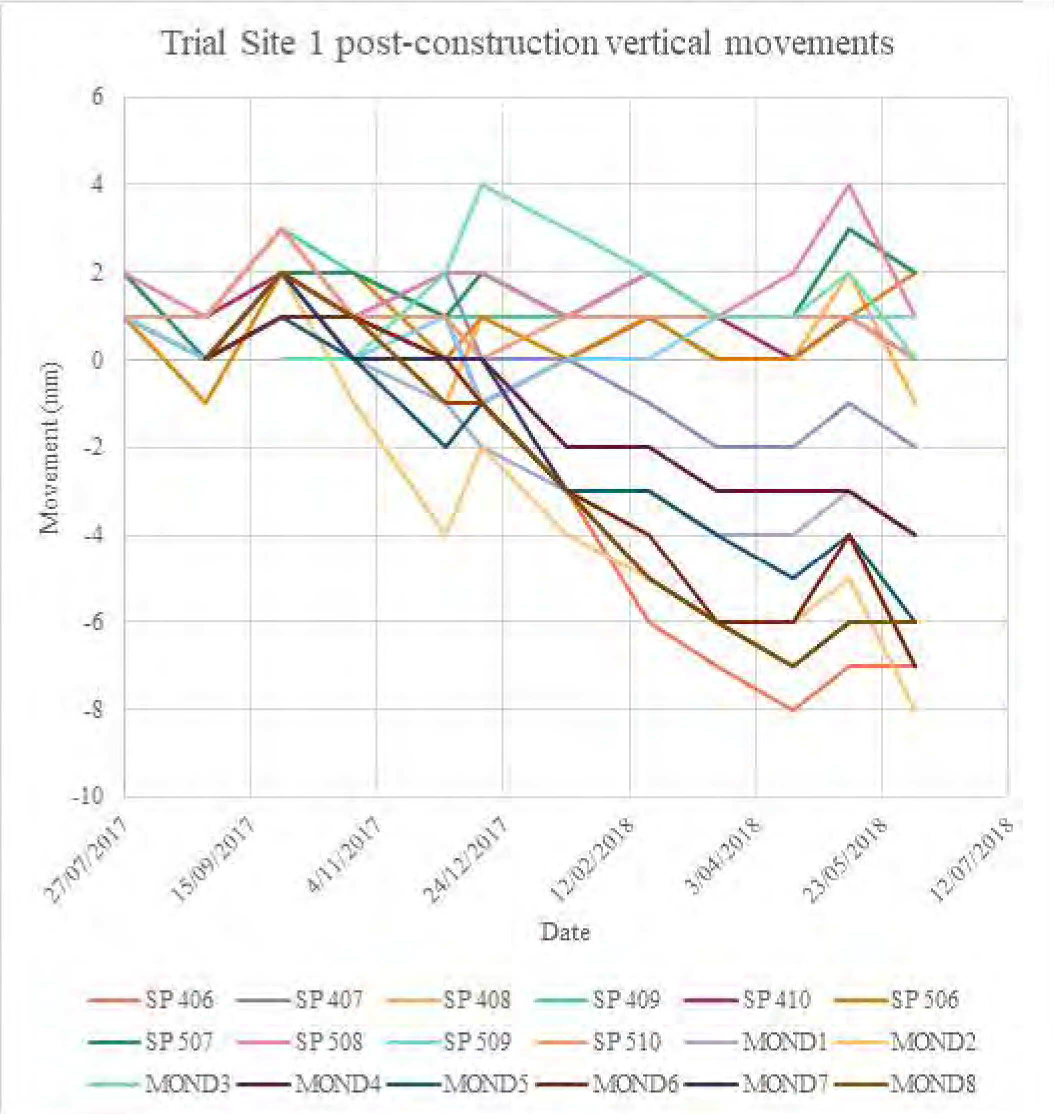


Figure 10: Trial Site 1 post-construction vertical movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [11])

B3.3.2 Trial Site 2

B3.3.2.1 Pre-construction measurements

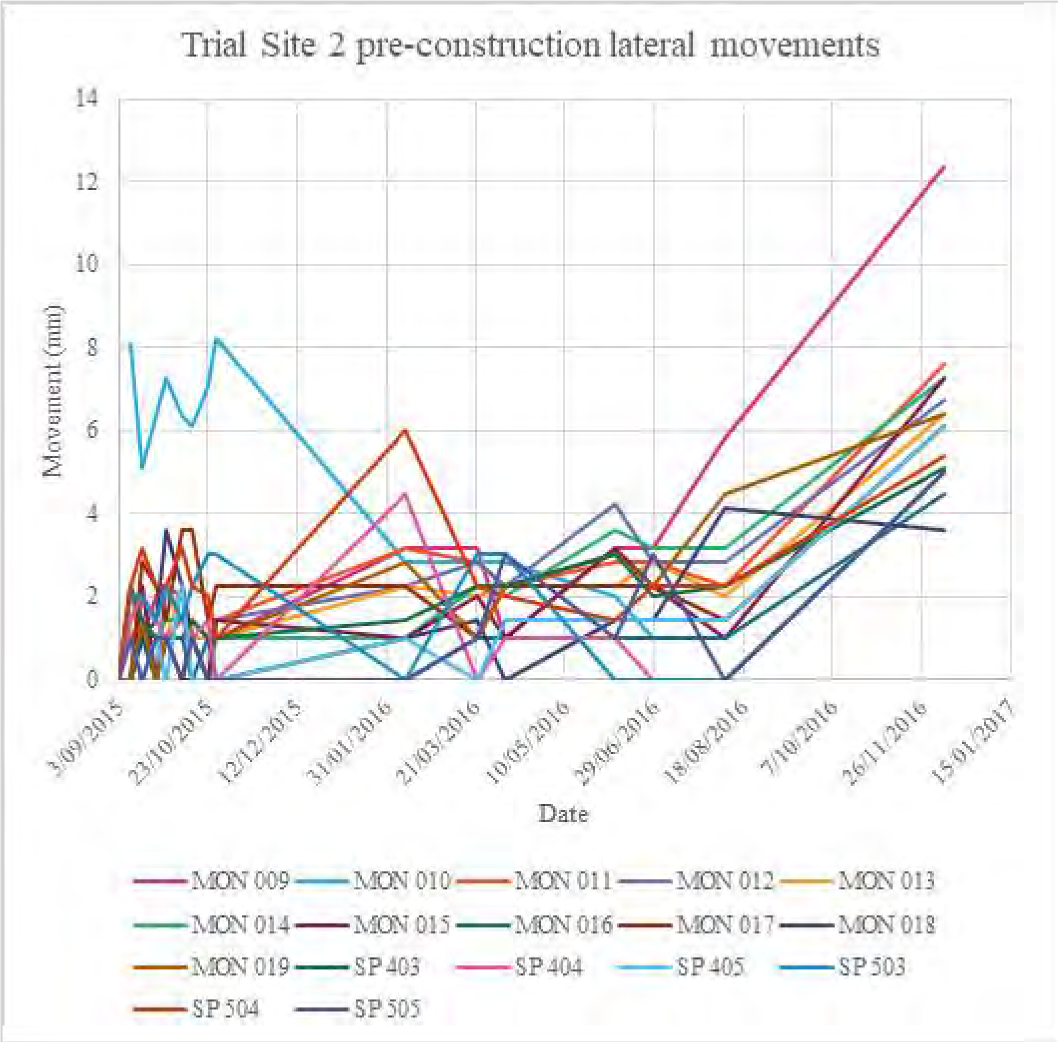


Figure 11: Trial Site 2 pre-construction lateral movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [10], mismeasurements not plotted for clarity)

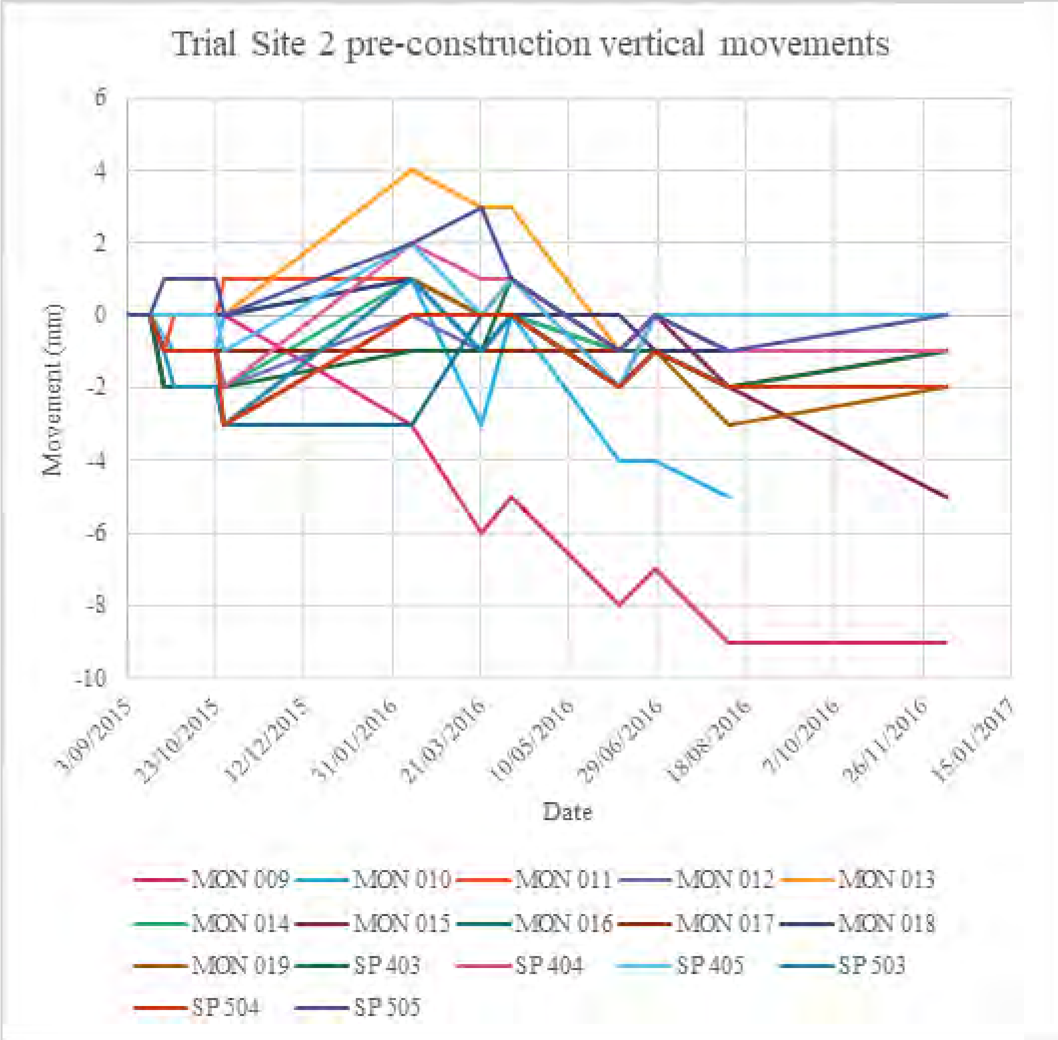


Figure 12: Trial Site 2 pre-construction vertical movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [10], mismeasurements not plotted for clarity

B3.3.2.2 Post-construction measurements

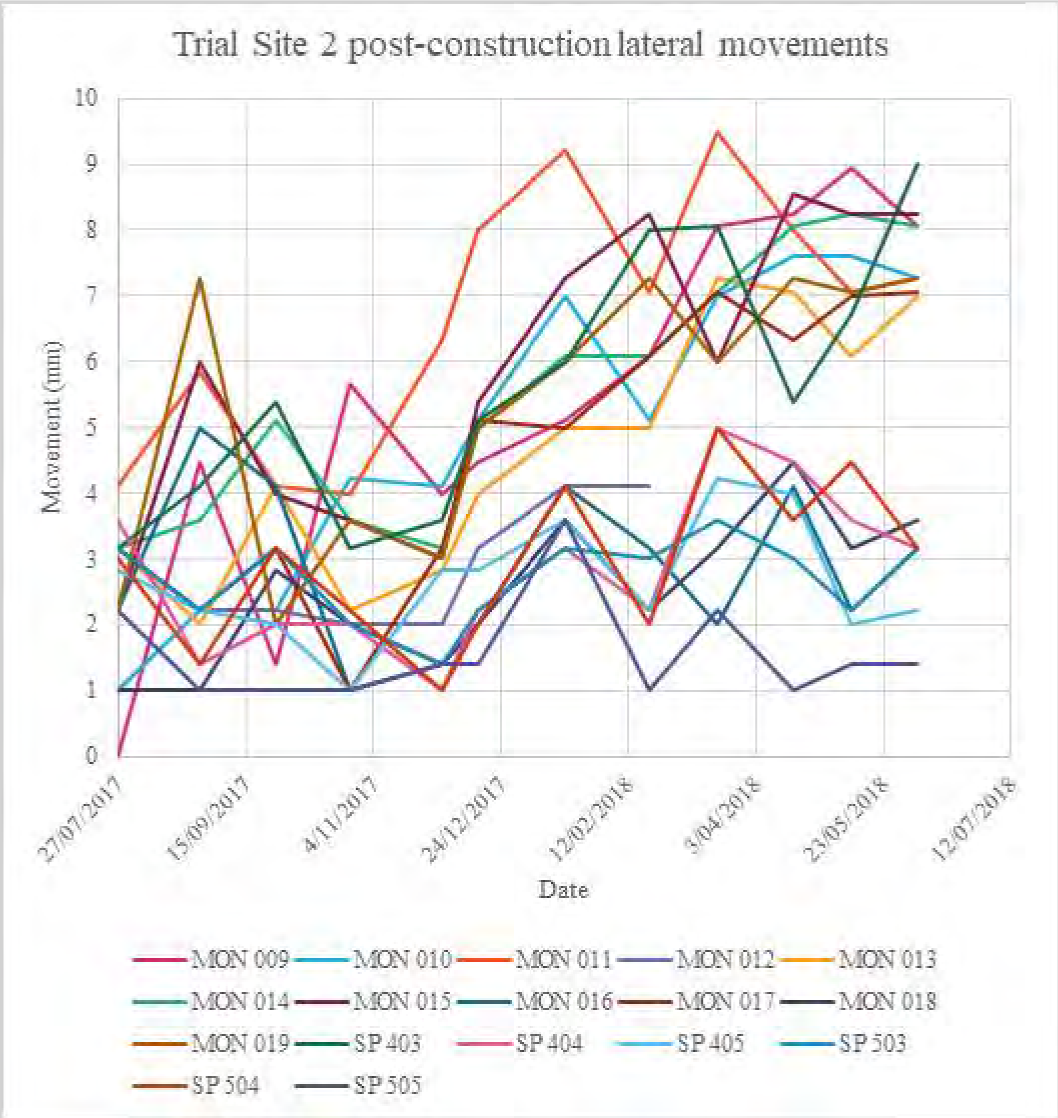


Figure 13: Trial Site 2 post-construction lateral movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [11])

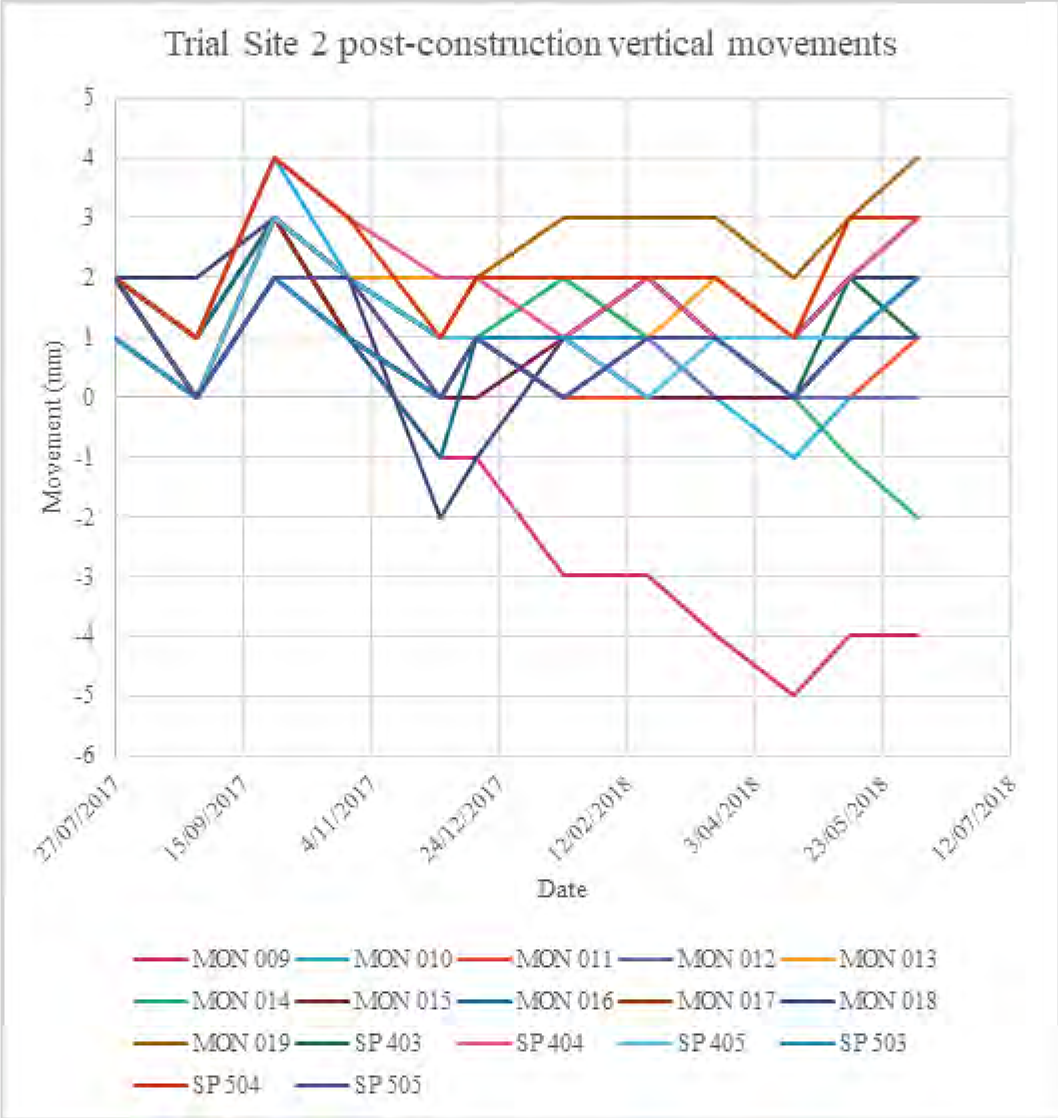


Figure 14: Trial Site 2 post-construction vertical movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [11])

B3.3.3 Trial Site 4

B3.3.3.1 Pre-construction measurements

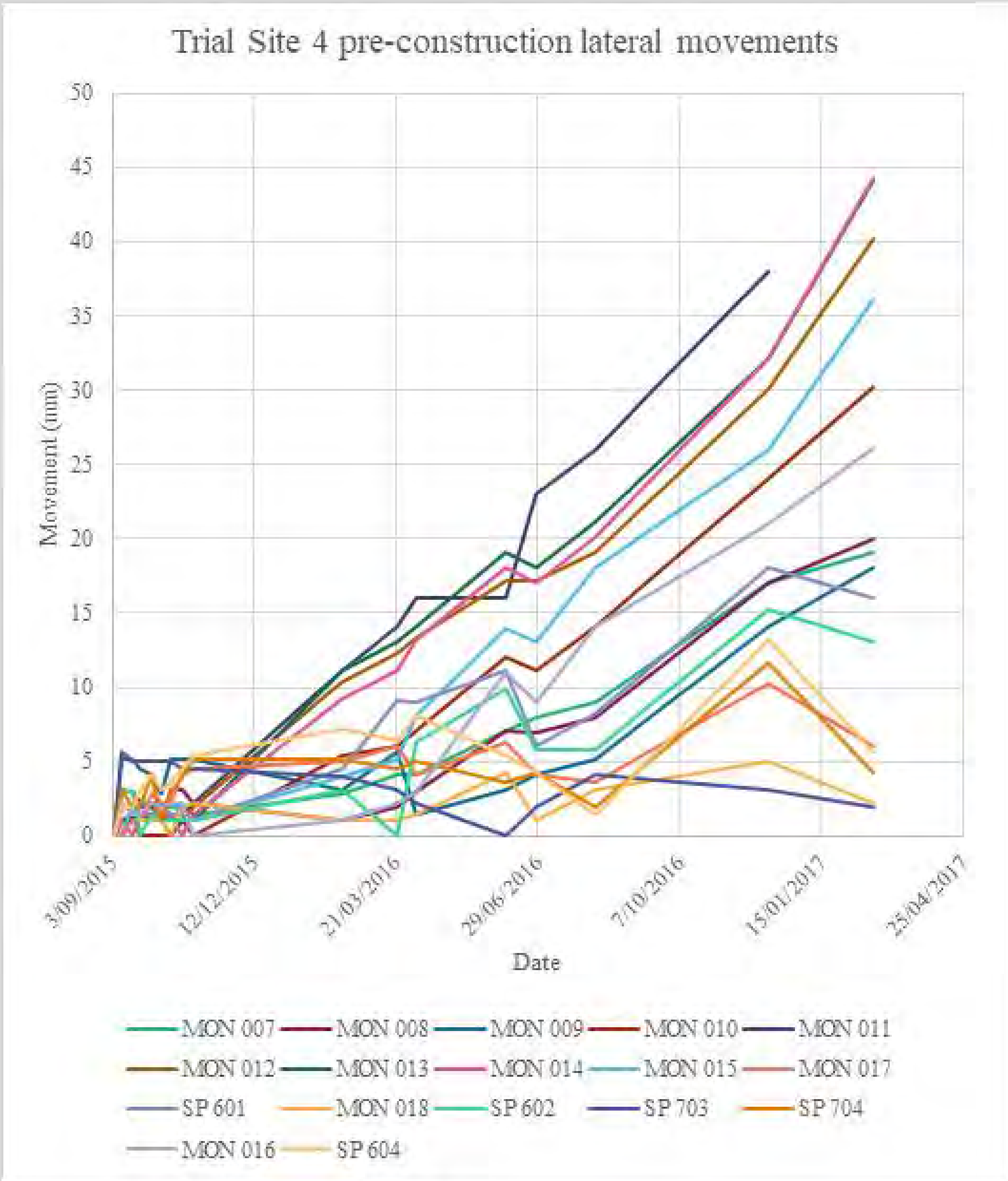


Figure 15: Trial Site 4 pre-construction lateral movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [10], mismeasurements not plotted for clarity)

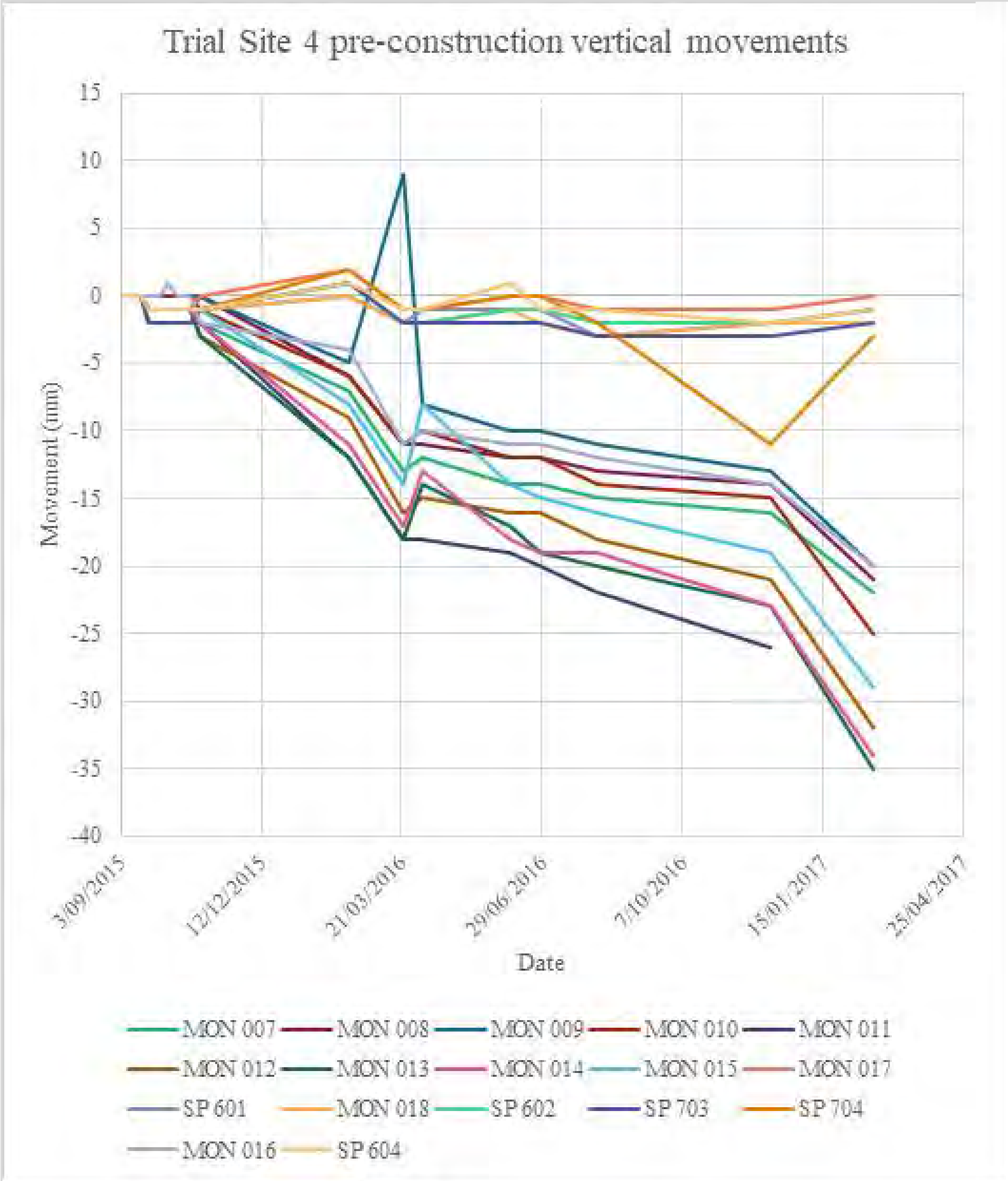


Figure 16: Trial Site 4 pre-construction vertical movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [10], mismeasurements not plotted for clarity

B3.3.3.2 Post-construction measurements

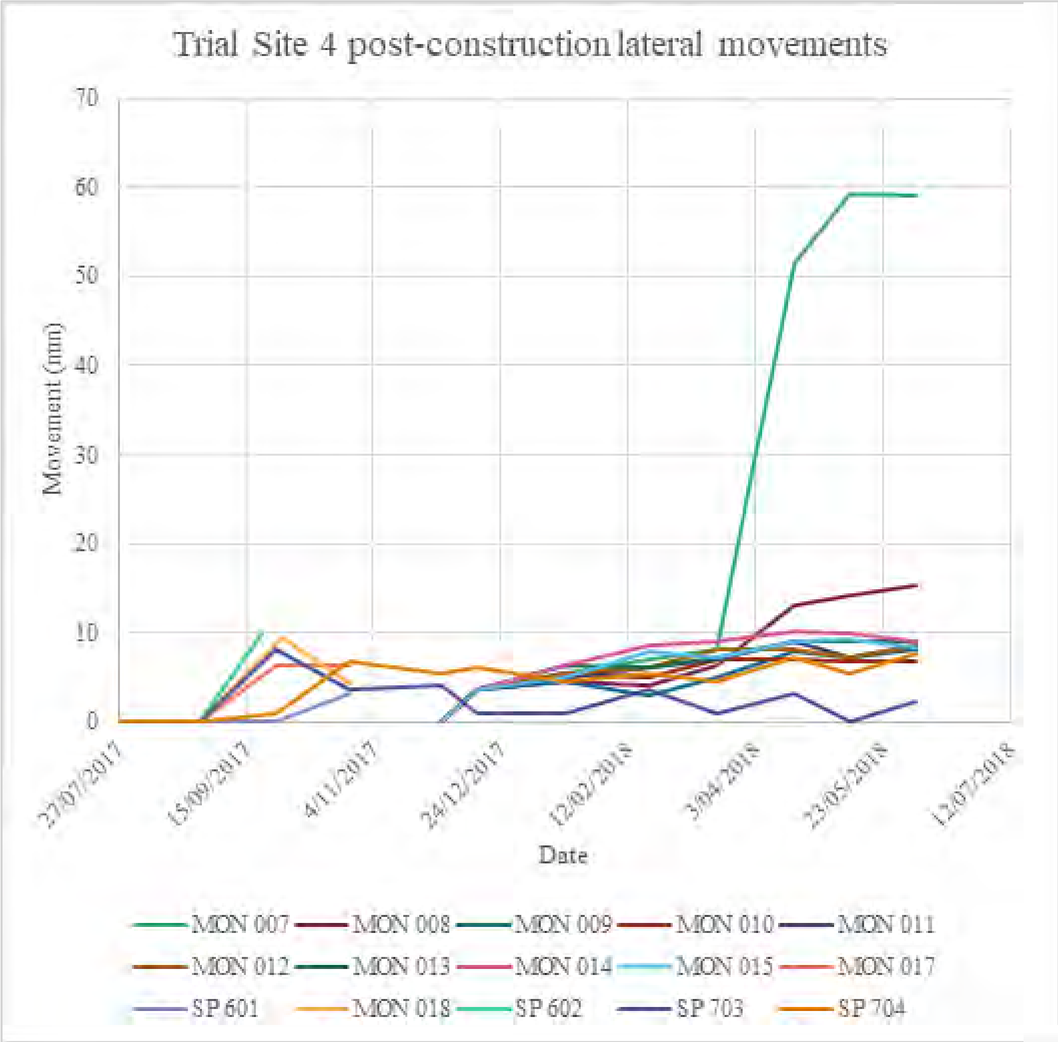


Figure 17: Trial Site 4 post-construction lateral movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [11], mismeasurements not plotted for clarity)

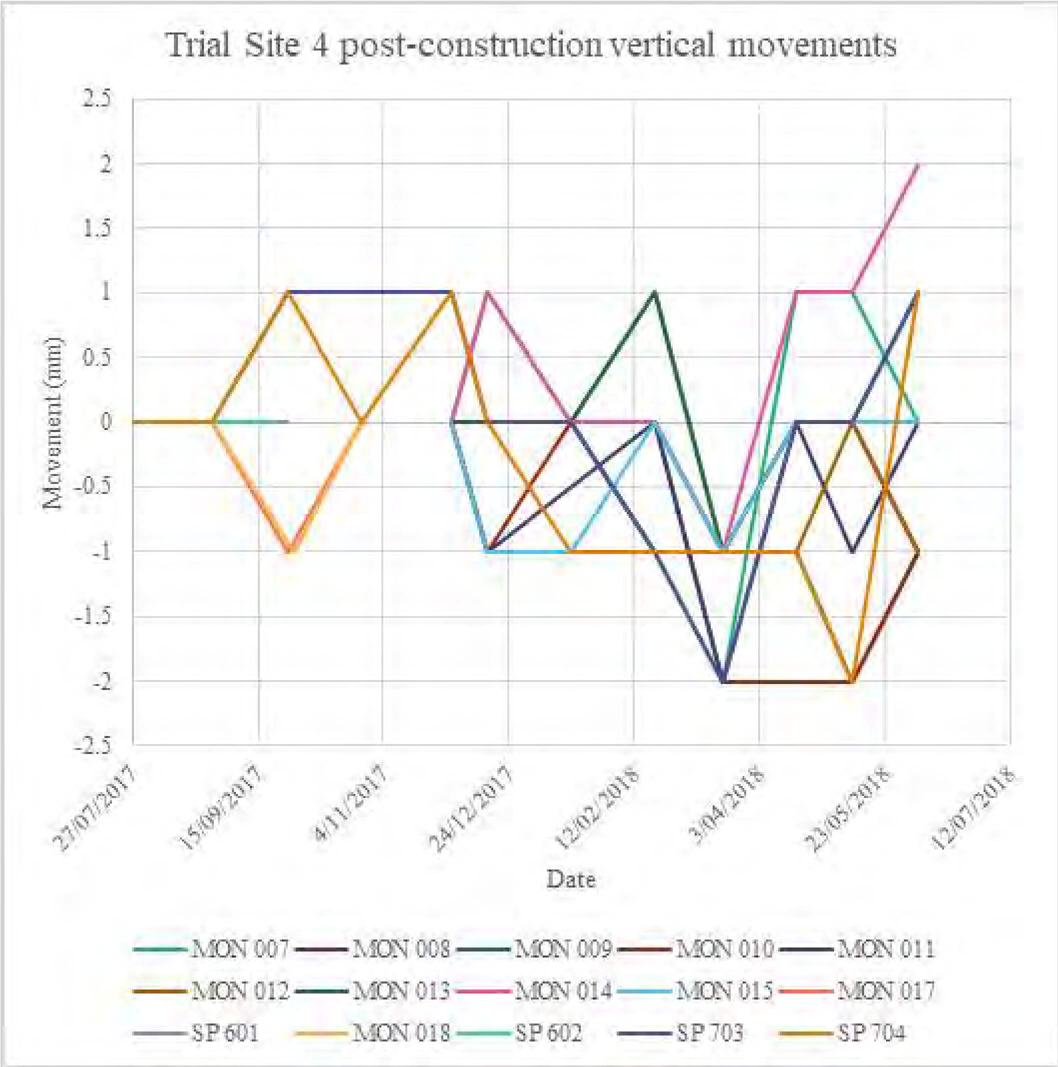


Figure 18: Trial Site 4 post-construction vertical movements (produced from measurements provided in Golder May 2018 monitoring report, ref. [11], mismeasurements not plotted for clarity)

B4 Site photos

B4.1 Trial Site 1

B4.1.1 7-9 Sternlight Court

B4.1.1.1 Southern boundary

Figure 19: 7-9 Sternlight Court - Pre-construction view of southern boundary looking west, dated 25 January 2017

Figure 20: 7-9 Sternlight Court - Post-construction view looking north from the southern boundary, dated 20 June 2018 (from [12])

B4.1.1.2 Centre

Figure 21: 7-9 Sternlight Court - Pre-construction general view looking north and view of pontoon walkway foundation slab, dated 25 January 2017

Figure 22: 7-9 Sternlight Court - Post-construction general view looking north from pontoon walkway, dated 20 June 2018 (from [12])

B4.1.2 11 Sternlight Court

Figure 23: Sternlight Court boundary between 7-9 and 11 - Pre-construction view looking north, dated 25 January 2017

Figure 24: Sternlight Court boundary between 7-9 and 11 - Post-construction view looking north, dated 20 June 2018 (from [12])

B4.2 Trial Site 2

B4.2.1 11 Sternlight Court

Figure 25: 11 Sternlight Court - Pre-construction general view looking south, dated 25 January 2017

Figure 26: 11 Sternlight Court - Post-construction general view looking south, dated 20 June 2018 (from [12])

B4.2.2 13 Sternlight Court

Figure 27: 13 Sternlight Court - Pre-construction general view looking south, dated 25 January 2017

Figure 28: 13 Sternlight Court - Post-construction general view looking south, dated 20 June 2018 (from [12])

B4.2.3 15 Sternlight Court

B4.2.3.1 Southern boundary

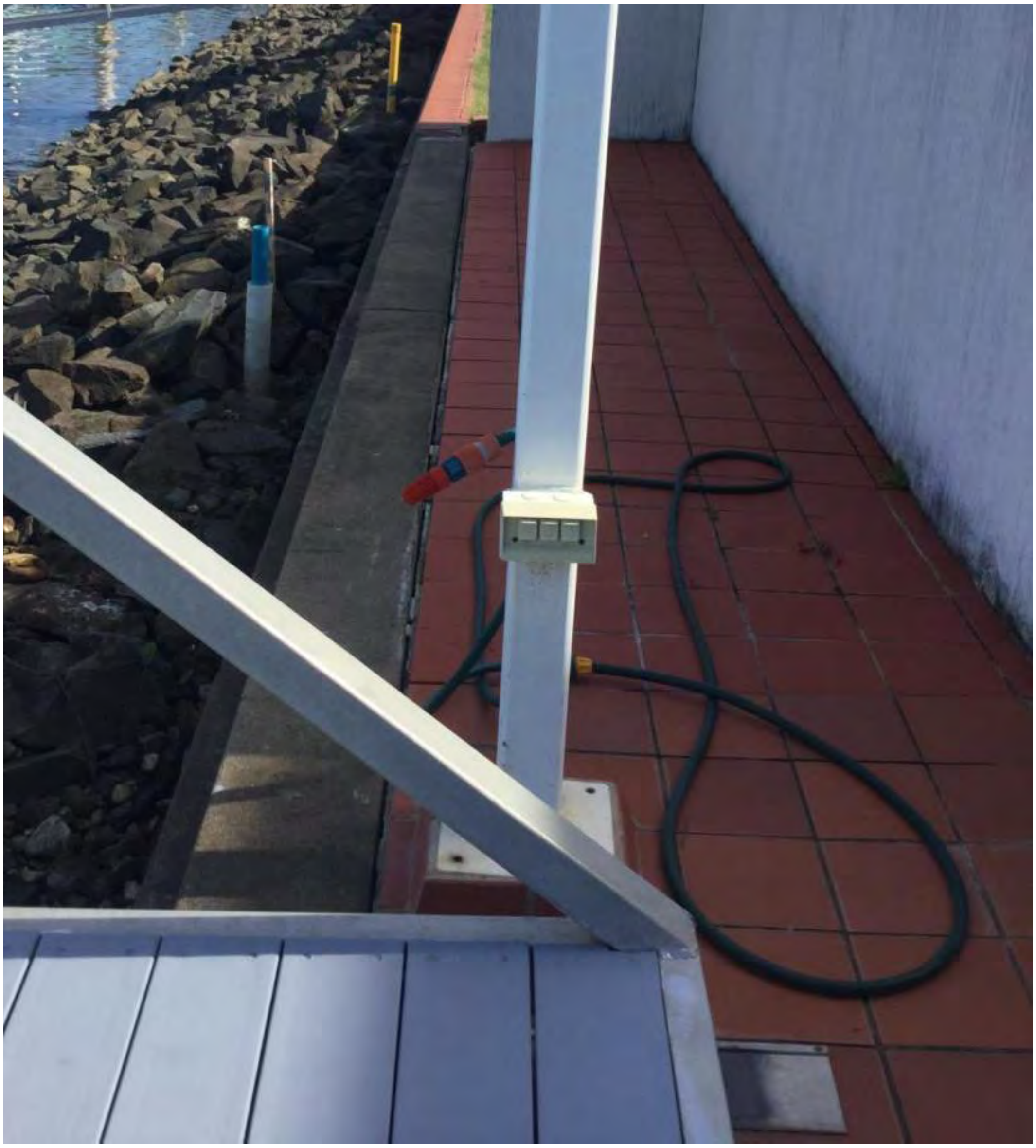


Figure 29: 15 Sternlight Court - Pre-construction general view from pontoon walkway looking south, dated 25 January 2017

Figure 30: 15 Sternlight Court - Post-construction general view from pontoon walkway looking south, dated 5 June 2017

Figure 31: 15 Sternlight Court - Post-construction general view from southern boundary looking north, dated 20 June 2018 (from [12])

B4.2.3.2 Centre-north

Figure 32: 15 Sternlight Court - Pre-construction general view from pontoon walkway looking north, dated 25 January 2017

Figure 33: 15 Sternlight Court - Post-construction general view from pontoon walkway looking north, dated 5 June 2017

Figure 34: 15 Sternlight Court - Post-construction general view from pontoon walkway looking north, dated 20 June 2018 (from [12])

B4.3 Trial Site 4

B4.3.1 81 Masthead Drive

Figure 35: 81 Masthead Drive - Pre-construction general view looking east, dated 25 January 2017

Figure 36: 81 Masthead Drive - Post-construction general view looking east, dated 20 June 2018 (from [12])

B4.3.2 83 Masthead Drive

Figure 37: 83 Masthead Drive - Pre-construction general view looking east, dated 25 January 2017

Figure 38: 83 Masthead Drive – During construction general view from 85 Masthead Drive looking west, dated 20 July 2017

Figure 39: 83 Masthead Drive - Post-construction general view looking east, dated 20 June 2018 (from [12])

B4.3.3 85 Masthead Drive

Figure 40: 85 Masthead Drive - Pre-construction general view looking east, dated 25 January 2017

Figure 41: 85 Masthead Drive - Post-construction general view looking east, dated 20 June 2018 (from [12])