ACID SULFATE DESKTOP

JOB NUMBER: 23-1883

Acid Sulfate Soils Desktop Assessment

PROJECT

Waikato Thoroughbred Racing

CLIENT

Referral – REV 2
17 April 2026

Acid Sulfate Assessment Report

23-1883 **Acid sulfate soils – desktop assessment** **Pencarrow Road, Tamahere**

Prepared for: Waikato Thoroughbred Racing **Project no:** 23-1883

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Revision	Date	Status	Authorised by:
A	09/12/2025	Issued	**Simon Cathcart | Environmental Manager** **BSc, MSc (Hons), CEnvP, CPESC**
1	27/02/2026	Draft Referral	**Simon Cathcart | Environmental Manager** **BSc, MSc (Hons), CEnvP, CPESC**
2	17/04/2026	Final referral	 **Simon Cathcart | Environmental Manager** **BSc, MSc (Hons), CEnvP, CPESC**

EXECUTIVE SUMMARY

Waikato Thoroughbred Racing (WTR) has engaged BCD Group Ltd to prepare a referral application under the Fast Track Approvals Act 2024 to develop a greenfield thoroughbred racing and equine hub.

The purpose of the Project is to create a unique, world class greenfield racing hub designed for horse training, racing and other equine related activities, while bringing the expertise and strength of the local racing fraternity together in a centralised location.

This enables the local racing industry to be more streamlined, competitive, sustainable and future focused while bringing potential international investment and creating a 'destination' for horse racing in New Zealand, also increasing tourism opportunities for the wider region.

A key driver behind the proposed greenfield equine hub and racecourses is enabling the consolidation of four separate racecourse facilities (Te Rapa, Waipa and Cambridge thoroughbred courses, and the Cambridge harness track).

These facilities duplicate assets and resources and, given their current condition require significant levels of upgrades and investment to provide fit-for-purpose facilities that meet the higher standards of the modern-day racecourse experience. The retirement of these areas also frees up significant tracts of land within existing urban areas for future development, increasing housing supply.

To support the development's financial viability and enhance the site's long-term vibrancy as a racing, entertainment, commercial and community precinct, the proposal includes a range of complementary activities on the remaining land.

These include equine support services, rural residential housing, a retirement living community, a village centre and a bloodstock sales precinct.

As part of this undertaking BCD Group has completed a preliminary assessment of the risk associated with acid sulfate soils at the Site due to the Waikato Regional Council acid sulfate risk screening map showing the Site as in a medium / high risk area.

This report represents a desktop assessment for the presence of acid sulfate soils, including undertaking field screening of 28 samples at six sampling locations.

All sampling locations had at least one indicator of the presence of acid sulfate soils. Based on this assessment, acid sulfates are potentially present and cannot be conclusively ruled out when adhering the Waikato Regional Council "Acid Sulfate Soils Decision Tree". Therefore, the production of a more comprehensive Acid Sulfate Management Plan (ASMP) is recommended once the civil earthworks related design progresses past concept. The ASMP will provide an integrated management approach to earthworks that incorporates the handling and management of acid sulfate soils, mitigating potential risks posed by exposing acid sulfate soils during the work.

This report is subject to, and must be read in conjunction with, the limitations set out in Section 9.

Contents

1 INTRODUCTION

1.1 Background

BCD Group have been engaged by Waikato Thoroughbred Racing (WTR) to undertake a Preliminary Site Investigation (PSI) of the farmland properties where the development is proposed, located at Pencarrow Road, Tamahere, Waikato (the Site). The Site location is show in **Appendix A**.

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Masterplans for the Site are included in **Appendix B**.

This plan shows:

- A main track, backtrack, warmup track and harness track
- Stabling and support areas for events
- Carparking
- Commercial and residential development
- irrigation ponds

Earthworks across the Site will be required for:

- Excavation of the irrigation pond
- Stripping of topsoil and levelling of the Site
- Recontouring of the Site
- Demolition of existing structures at the Site
- Construction of foundations
- Development of roads and other surface infrastructure
- Development of subsurface infrastructure.

Depths of excavations, earthworks staging and excavation methodology are currently unknown. Currently a rough approximation of these puts cut and fill volumes at 37,000 m^3 and 30,000 m^3, with a maximum cut depth of 4 m and a maximum fill depth of 3 m. In addition to this cut and fill, a 300,000 m^3 cut may be required for the removal of topsoil and 40,000 m^3 fill for the infilling of drains. The final site cover will vary across the Site and will include racetrack, grassed areas and impermeable surfaces.

The Site has been identified on the Waikato Regional Council Acid Sulfate Soils risk map as a high and medium risk area. Acid sulfate soils are soils containing iron sulfates. The exposure of these to oxygen and water leads to the generation of sulfuric acid. The subsequent leachate can then cause the mobilisation of metals, and impact subsurface infrastructure.

Acid sulfate soils are divided into two categories:

- Actual acid sulfate soils are acid sulfate soils which are already acidic and presently generating acid via the oxidation sulfate. They tend to have a pH less than 4, however a pH ranging between 4-5 may indicate some existing acidity.
- Potentially acid sulfate soils are acid sulfate soils having unoxidized sulfate. These contain the potential for future oxidation and generation of acids. When left in a waterlogged state they do not tend to pose a significant risk, however if drained or excavated they can oxidise and turn into actual acid sulfate soils. Potential acid sulfate soils tend to have a pH of greater than 4 and are commonly neutral.

Actual and potentially acid sulfate soils can be part of the same soil horizons, with the actual acid sulfate soils overlying the potential acid sulfate soils

1.2 Purpose

The purpose of this assessment is to undertake a desktop assessment for the potential risk of acid sulfate soils being present at the Site, followed by some high-level screening to field truth the findings of the desktop assessment, inform potential site selection choices, and make recommendations as to further assessment which may be required.

1.3 Scope

The following scope of works was undertaken as part of this assessment

- Undertake a desktop assessment including a review of the relevant background information including regional council information
- Collect samples at the site and undertake a field screening assessment for the potential presence of acid sulfate soils
- Document the above in a report, including recommendations for further assessment (if required).

1.4 Assumptions

BCD has made the following assumptions as part of this assessment:

- Information obtained from client and third parties is complete and accurate, and represents the current planning for the Site.
- The observations made during this investigation are representative of the conditions that have occurred or are occurring within or adjacent to the Site

2 REGULATORY CONTEXT

2.1 Waikato Regional Council

Waikato Regional Council considers discharges from acid sulfate soils to be regulated by Section 15 of the Resource Management Act (1991) as, through the activity of a person, acid sulfate soils may discharge contaminants including acid or mobilise hazardous substances such as metals via the activities of a person. This discharge may then change the physiochemical and biological condition of the land and / or water where it is discharged.

Consequently, acid sulfate soils are regulated under the Waikato Regional Plan rules, as a land disturbance activity under rules in Section 5.1 of the plan (which regulates soil disturbance) and Section 5.2 of the plan (managing discharges onto or into land). Additionally, Section 3.5 (managing discharges to water) may be relevant in some cases.

As per the WRC acid sulfate guidance document (Waikato Regional Council, 2025), WRC considers assessment of the risk of acid leaching potential from ASS for resource consents is likely to be required for land disturbance activities where:

- Disturbance is proposed to occur in an area identified in the Waikato Region – Acid Sulfate Soils Preliminary Risk Assessment map as having a 'medium' or 'high' probability of occurrence of acid sulfate soils; and
- The disturbance will be:
    - Greater than 250 m^3
    - Deeper than 1 m, and / or
    - Associated with a drainage activity, and / or
    - If there are any other factors associated with the proposed activity that might increase the risk of disturbance of acid sulfate soils.

Where a discharge of contaminants is otherwise identified and is not regulated by any specific rule, it is considered a discretionary activity.

2.2 WRC acid sulfate soil risk assessment

WRC undertook a spatial assessment to assess the potential presence of acid sulfate soils across the Waikato region (Waikato Regional Council, 2024). This was used to develop a risk screening map, ranking the areas across the Waikato based on a higher, medium, or lower risk for the presence of acid sulfate soils.

A map showing the risk areas of the Site is included in **Appendix C**.

Most of the Site is underlain by a medium risk ranking for acid sulfate soils, with a band of high potential risk running through the middle. An area of the western boundary of the Site shows lower risk soils.

2.3 Applicability to Site

The WRC acid sulfate guidance (Waikato Regional Council, 2025) outlines a decision tree, based on the Tasmania Department of Primary Industries, Parks, Water and Environment (DDPIPWE) Tasmanian Acid Sulfate Soil Management Guidelines (TDPIPWE, 2009). A copy of the decision tree is shown below in Figure 1 below.

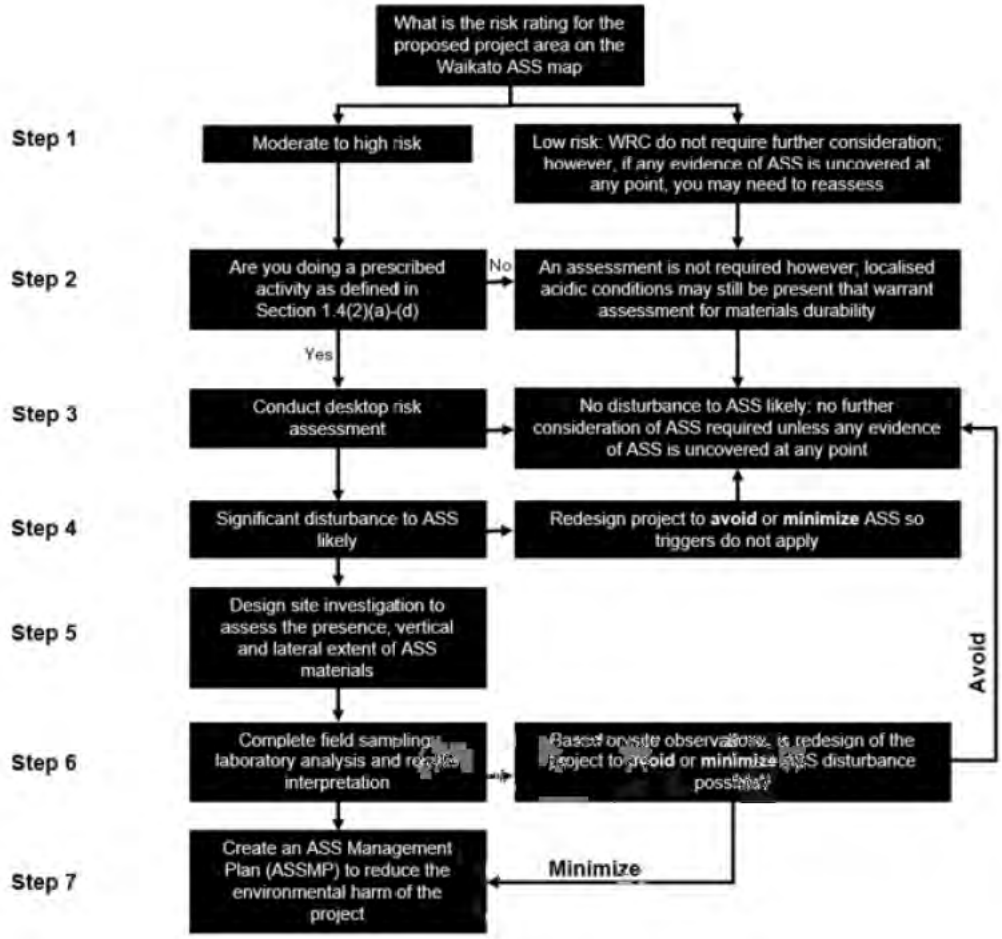

Figure 1: Acid sulfate decision tree

An assessment against this applicability is included below in Table 1.

Table 1: Acid sulfate assessment

Step	Assessment
Is the Site in a moderate to high-risk area?	Yes – this has been identified on the WRC risk map
Is the work: Soil disturbance in an area risked as medium or high risk? AND Is the disturbance Greater than 250 m^3 Deeper than 1 m bgl Associated with a drainage activity If there are other activities associated with the proposed activity that might increase the risk of disturbance of acid sulfate soils	Yes – while details of earthworks at the Site are currently unconfirmed, based on provisional information they will disturb more than 250 m^3, be undertaken deeper than 1 m bgl, and may be associated with a change in groundwater level.
Conclusion – undertake a desktop assessment to assess the presence of acid sulfate soils at the Site.	

3 SITE DESCRIPTION

The site is located at Pencarrow Road, approximately 8 km northwest from Cambridge town. A map of the Site is included in Figure 2below, and is a collection of titles and addresses, as included in

Figure 2 Site figure
Table 2.

Table 2: Site information

Attribute	Details
Address and legal description	37 Hooker Road and 38 Duncan Road, Tamahere, Hamilton Section 2 SO 547526 [RT 1027516] 69.6678 ha 90 Duncan Road, Tamahere, Hamilton Lot 2 DP 16925 [RT SA383/181] 14.212 ha 536 Pencarrow Road, Tamahere, Hamilton Lot 2 DP 471383 [RT 650204] 18.5194 ha 592 Pencarrow Road, Tamahere, Hamilton Lot 1 DP 471383 [RT 650205] 23.8694 ha 636 Pencarrow Road, Tamahere, Hamilton, Section 49 SO 457609 [RT: 632409] 37.6439 ha 644 Pencarrow Road, Tamahere, Hamilton Section 46 SO 457609 [RT 632392] 1.355 ha
Site area	Approximately 1,655,000 m^2
Territorial authority and regional council	Waikato District Council / Waikato Regional Council

3.1 Site layout

The site consists of two farms, both with internal roading and drainage throughout.

The southern property (defined as 90 Duncan Road and 37 Hooker Road and 38 Duncan Road) has the milking sheds, farm equipment storage, effluent treatment ponds, sileage storage and cattle yards towards the centre of the site. The access road to this infrastructure enters the site from the southeastern boundary, off Duncan Road. Two farmhouses are situated along the southern side of this road.

The northern property (defined as 536, 592, 636 and 644 Pencarrow Road) has milking sheds, cattle yards, farm equipment storage sheds, sileage storage and farm housing located near the northwestern corner, accessed by a driveway off Pencarrow Road on the northeastern boundary. This property also has sheds and a dwelling to the west corner of site, also accessed off Pencarrow Road, to the south of the main farm infrastructure.

Both properties are currently functioning dairy farms and have workers on site every day. The site cover mostly consists of pasture, with hedging along paddock fences, and a stand of Kahikatea trees within the southern property to the southwest of the farming infrastructure.

3.2 Site uses

The Site is currently operated as a dairy farm. The surrounding land uses are summarised in the table below:

Table 3. Surrounding land use

Direction	Land use
North	State Highway 1 runs along the northern boundary, and across the highway there is an Artificial Insemination (Reproduction Specialty Group (NZ) Limited) facility. Beyond these, the land use is primarily agricultural farmland and residential use. There is a gully system approximately 300m+ to the north of the site.
East	Duncan road runs along the eastern boundary, with predominantly residential lifestyle blocks or small rural properties across the road.
South	Hooker road runs along the southern boundary, with predominantly residential lifestyle blocks or small rural properties across the road. The Waikato River is located approximately 500m+ from the boundary.
West	Pencarrow Road runs along the eastern boundary, with predominantly residential lifestyle blocks or small rural properties across the road.

3.3 Environmental setting

3.3.1 Topography

The site has generally level contours, with steeper slope angles towards the western boundary. The western side of the site has a hill sloping down to the east, with contours from the BCD surveying programme (BCD, 2025)showing a difference in elevations between 60 m and 53 m RL (NZVD2016). The southeastern corner of the site is also slightly elevated at 56.9 m RL.

3.3.2 Soils

The Landcare Research SMap (Landcare Research, 2025) shows that the site is predominantly underlain by Typic Orthic Allophanic (LOT) soils, with an area of Typic Orthic Gley (GOT) soils intruding into the site from the eastern boundary. There are also Typic Orthic Granular (NOT) soils coming into the site across the western boundary.

3.3.3 Geology and groundwater

In accordance with the BCD Group Geotechnical Assessment Report (BCD Group, 2025), the underlying geology of the site primarily consists of the Hinuera Formation described as volcanogenic alluvium, comprised of cross-bedded sand, silt and gravel with interbedded peat. The Hinuera Formation is found throughout the Waikato alluvial plain and is typically deposited in a series of levees and swales of differing material composition representing the various depositional environments of the ancient, braided Waikato River system. (Lowe, 2010). There is also Walton Subgroup geology underlying the hill topography on the western side of the site. The low hills of the Waikato Basin

consist of several meters of airfall tephra from multiple events, collectively termed the Hamilton Ash, which in turn overlies the pre-Hamilton Ash deposits collectively known as the Walton subgroup.

The BCD Group Geotechnical Assessment Report has been reviewed and the 14 hand auger investigations across the site found soils consistent with the underlying geology. Groundwater was encountered at varying depths between 0.9 m to 2.8 m below ground level (bgl) at the time of investigation in November. Based on the piezometer gradients installed during this assessment groundwater is anticipated to be flowing to the north.

3.4 Site inspection

A site inspection was undertaken on 12 November 2025 during the fieldwork. Assessment focused on the drainage system. Water in the drains had sediment, and no observations of unusually clear or milky blue-green water were observed, and no signs of distressed vegetation were observed on the edges of the drains. No physicochemical assessment was undertaken of the water in the drains. No corrosion of concrete structures or iron staining were observed. No jarosite minerals or mottling was observed in the Site drains. No sulfuric odours were identified during the walkover. Representative photos are included below.

Figure 3: Examples of waterways at the Site

4 HISTORICAL SITE USE

As part of the wider project a Preliminary Site Investigation (PSI) is being undertaken for the Site (BCD Group, 2025). The findings of this are summarised below:

4.1 Historical aerial photography

Historical aerial photography is shown below in Table 4. Photographs are included in **Appendix D**.

Table 4: Historical aerial photography

Year	Source	Onsite comments	Offsite comments
1939	Retrolens	The Site is an active farm. Buildings can be observed, as well as hedges separating paddocks. A stand of trees can be observed in the south of the Site.	The surrounding land is being used for farming in all directions.
1953	Retrolens	The land remains mostly unchanged; however, a drainage	The surrounding land use remains broadly unchanged.

		network has been dug through the Site.	
1967	Retrolens	The site remains broadly unchanged	The surrounding land use remains broadly unchanged.
1974	Retrolens	The site remains broadly unchanged	The surrounding land use remains broadly unchanged.
1995	Retrolens	Trees have been removed along the drains	The surrounding land use remains broadly unchanged.
2005	Google Earth Pro	The Site remains broadly unchanged.	The surrounding land use remains broadly unchanged.
2024	Google Earth Pro	The Site remains broadly unchanged.	The surrounding land use remains broadly unchanged.

In summary, the Site has been used for farming since sometime before 1939 and has operated as a farm since until the present.

4.2 Previous reporting

As part of the project BCD engaged Awa Ecology to undertake an ecological impact assessment of the Site (Awa Ecology, 2025). Observations from this report including the assessment of waterways and aquatic biota can be used to inform the impacts of acid sulfates at the Site. An assessment of the freshwater environments was undertaken. No fish or large invertebrates were captured during the fish survey. eDNA sampling identified the presence of shortfin eel in the drain network.

An assessment of the ecological values of the waterbodies on the Site was also undertaken. One wetland, a remnant kahikatea stand and associated wetland was found to be high ecological value, with the artificial watercourses and wetlands at the site being low to negligible value. The report also states that the water bodies are ephemeral and dry up during drier months. No surface water or groundwater quality assessment was undertaken by Awa as part of their scope of works.

5 SOIL SCREENING ASSESSMENT

5.1 Investigation objective

The objective of this investigation is to undertake a high-level screening of the soils at the Site to gain an indicative understanding as to the potential for acid sulfate soils to inform potential site-selection choices for the redevelopment of the Site. It is not intended to fully characterise the material underlying the Site as the design process has not progressed enough to confirm the full extent of excavations, further assessment will be required to characterise the Site.

5.2 Media to be sampled

Soil samples will be collected to assess the potential presence of acid sulfate soils in the top 2.0 m bgl in the areas of higher risk identified during this assessment. As per the sampling guidance samples should be collected up to 1.0 m below the anticipated depths of excavations.

Three samples (HA 03, 10 and 14) were selected to assess the higher risk areas of the Site. Three locations (HA 02, 07 and 11) were selected to assess the lower risk areas of the Site.

While groundwater and surface water has been identified at the Site, a screening of the soils will be undertaken first, followed by an assessment of the ground and surface water as required in a future stage of assessment.

5.3 Screening criteria

Water Quality Australia guidance document "National Acid Sulfate Soils Guidance National acid sulfate soils sampling and identification methods manual (2018) (Sullivan, Ward, & Toppler, 2018) provides a set of guidance criteria for the presence of acid sulfate soils. If these are observed during sampling, then acid sulfate soils are potentially present at the Site and may require further sampling or assessment.

Contaminant	Criteria
Acid sulfate soils	$pH_F < 4$
	$pH_{FOX} < 3$
	Difference between pH_F and $pH_{FOX} > 1$
	Effervescence
	Release of sulfuric gasses

If these criteria are exceeded, then further comparison against Tables A2 (Interpretation of some pH_F test ranges) and A3 (interpretation of pH_{FOX} test results) of the guidance document should be made to assess the presence of acid sulfate soils. These tables, as well as the remainder of the field sampling methodology, are included in **Appendix E**.

5.4 Field indicators

Field indicators of acid sulfate soils include:

- Iron staining in the surface material, or excavated material left exposed to the environment. This is likely to be a red / orange colour in the soil profile.
- Clear or milky green water in surface water at the Site
- Jarosite minerals –yellow crystals observed in the soil profile.
- Corrosion and iron staining of nearby concrete or steel structures
- Sulfuric odours
- Distressed vegetation, including dead, dying or stunted vegetation

If these are observed at the Site, they may require further assessment.

5.5 Sample design

Site sampling utilises a judgemental based sampling approach, based on the higher risk areas of the Site identified during the desktop assessment. Five sampling locations were selected across the Site. Sampling targeted every half metre of soil profile as part of the high-level screening.

5.6 Quality assurance / quality control

The following quality assurance/quality control programme has been undertaken as part of this assessment:

- Use of appropriately qualified and trained staff.
- Undertaking calibration of field screening equipment in accordance with manufacturer guidelines.
- Appropriate handling of samples in the field
- Undertaking of field screening as soon as possible following their excavation.

6 SAMPLE RESULTS

6.1 Summary of works undertaken

Fieldworks were undertaken between 12 and 14 November 2025. A total of 28 samples were collected from six locations. A map showing sampling locations is included in **Appendix E.**

An additional sampling location (HA 07) was adopted. This was the only deviation from the Sampling and Analysis Plan outlined in Section 5.

6.2 Field observations

Underlying geology generally complied of silts with interbedded sands, and sands of various thickness. Full logs are included in **Appendix E.**

Mottling was observed in all locations, mostly in the surface soils but sometimes running through the soil profile to a depth of at least 2 m bgl. Photographs are shown in **Appendix E.**

Groundwater was encountered at depths of between 0.9 – 2.8 m bgl.

6.3 Sampling and analysis

Samples were collected in line with the SAP outlined in Section 5.

Samples were collected with the use of a hand auger. Decontamination was undertaken between each location, with soil being cleaned off the auger, followed by washing in a solution of Decon90, followed by rinsing with water.

Samples were placed in a plastic bag and put into an iced chilly bin until field screening sampling could be undertaken. Samples were analysed within half an hour of being collected during the fieldwork.

Field screening kits and deionised water were supplied by ALS Analytica. A WTW ProfiLine pH 3110 portable pH meter was used for field screening. The pH meter was calibrated daily as per the manufacturer's instructions.

Field screening was undertaken in accordance with the methodology outlined in the NASSSIMM document. Samples were treated with a mixture of deionised water, followed by addition of 30% hydrogen peroxide. Results of sampling were recorded on field sheets.

6.4 Results

A table outlining the results of the assessment are included in **Appendix E**

Exceedances of applicable criteria are included in Table 5.

Table 5: Exceedances

Criteria	Location with exceedance
pH_F < 4	None
pH_{FOX} < 3	None
Difference between pH_F and pH_{FOX} > 1	All sampling locations
Effervescence	HA 14
Release of sulfuric gasses	HA 02, HA 07

None of the samples produced a pH pH_F < 4 or pH_{FOX} < 3. None of the sampling locations had both a Difference between pH_F and pH_{FOX} > 1 and a strong reaction with H_2O_2.

As discussed in Section 5.3, this field screening has not identified the presence of acid sulfates at the Site.

There was no obvious correlation between results of the field screening and the depths of the samples. Mottling tended to be observed in the shallower soils, but mottling could be observed down to a depth of 2 m bgl in some locations. Results did not show a distinction between higher and medium risk areas of the Site.

7 DISCUSSION

7.1 Preliminary conceptual site model

A preliminary conceptual site model is included below showing the source pathway receptor linkages between the release of acidity from soils and the potential impacts on the receiving environment.

Table 6: Conceptual site model

Contaminant	Pathway	Receptor	Discussion
Acid sulfate soils – release of acidity from oxidation of sulfates.	Disturbance of soil mobilising acidity and potentially increasing the solubility of metals in soils at the Site.	Groundwater underlying the Site	Potentially complete – if acidity is released during earthworks, then metals may be mobilised into the groundwater underlying the Site.
		Surface water at the Site	Potentially complete – if acidity is released from the soils from earthworks, then the pH of the surface water and metal concentrations may be impacted.
		Biota in surface waters	Potentially complete – if acidity is released from the soils during earthworks, then the biota in surface water receptors may be impacted by the change in pH and the mobilisation of metals into the environment.
		In ground infrastructure and foundations	Potentially complete – if acidity is released from the soils following earthworks, acidity may impact the in-ground infrastructure and building foundations.
	Potable water extracted from the aquifer underlying the Site	Humans, animals	Potentially complete – if contaminants are mobilised from the acidification then it may be ingested through future users of groundwater from the Site.

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Summary

BCD has undertaken a desktop assessment of the Site for the presence of acid sulfate soils. The desktop assessment has identified that the Site is regarded as high risk by WRC for the presence of acid sulfate soils.

A site inspection did not identify indicators of acid sulfate soils such as distressed vegetation or clear or milky green water in the drains at the Site.

Six locations were field screened for the presence of acid sulfate soils. Field observations identified mottled soils underlying the site, showing the potential presence of iron.

Field screening of samples at the Site identified that all six locations had at least one of the five indicators of the potential presence of acid sulfate soils in one sample. No vertical relationship between these could be identified. No relationship between the results of the field screening and the higher and medium risk areas of the Site could be delineated.

8.2 Further assessments

While the presence of acid sulfate soils at the Site has not been confirmed, the field observations and sampling align with the WRC mapping programme and identify that there is a risk of acid sulfate soils underlying the Site. These may cause a discharge if they are disturbed.

WRC considers that the potential discharge would be a Discretionary Activity (as discussed in Section 2.1). Following the decision tree outlined in the WRC guidance, the best pathway for consenting includes undertaking a more in-depth assessment to confirm the presence of acid sulfate soils and development of a management plan to manage the soils. This assessment would allow for more certainty around the presence (if any) and potential impacts of the acid sulfate soils at the Site. This would provide:

- Guidance for the management requirements for earthworks to mitigate the effects from the earthworks at the Site.
- Potential treatment requirements for soils to mitigate the generation of acid
- A greater level of delineation of the acid sulfate soils at the Site to more allow more effective management and design for the Site.
- Information which to be used in the detailed design of subsurface infrastructure at the Site (such as the choice of materials used in the assets, treatment options for the soil to protect the asset, or the anticipated lifespan of the asset)
- Inform soil reuse and disposal options for soil at the Site. These would otherwise potentially be limited due to the discharge from the excavated soils, or restrictions on landfill acceptance of potentially acid sulfate containing soils.

Currently the design of the Site has not been confirmed, and indicative areas and depths of soil disturbance have been provided. Future sampling would be targeted towards the areas of the Site where soil disturbance is to be undertaken, especially in areas where excavations were anticipated to be below the groundwater table and exposing unoxidised sulfates to oxygen.

It is noted that while the Site is in a medium and higher risk area, over 17% of the Waikato is classified in one of these categories. An excerpt from the risk map showing the Cambridge – Te Awamutu – Hamilton region and the areas of risk are shown in Figure 4 below.

Key colour	Risk ranking
	High
	Medium
	Low

Figure 4: Waikato acid sulfate risk

Any future work would include a balance between the acceptable risk posed by the acid sulfate soils, and the cost of the assessment.

Standard construction methodologies and mitigation measures as outlined in the ASMP will need to be employed to address any potential adverse environmental effects.

8.3 Recommendations

This high-level desk top assessment has not been able to conclusively rule out the presence of acid sulfate soils within the proposed construction area associated with the Project. Consequently, the following recommendations are made:

- Following the Waikato Regional Council process associated with acid sulfate soils (Figure 1) the Project will ultimately require an Acid Sulfate Soils Management Plan be produced.

- To support an application for a land use resource consent an *Acid Sulfate Management Plan* (ASMP) should be developed that will address the investigation, sampling, handling and disturbance of soils associated with the construction of the racing facility.
- That the ASMP should incorporate the management of acid sulfate soils, erosion and sediment control, dust management, and contamination management as it relates to the construction of the racing facility.

9 REPORT LIMITATIONS

The recommendations and opinions made in this report are based upon data from observations made on-site, conducted hand augers at discrete locations. Inferences about the nature and continuity of subsoils away from the exploration holes are made but cannot be guaranteed. Actual conditions onsite may vary more gradually or abruptly than that inferred from the investigations. Steps can be taken to reduce the likelihood of unexpected conditions arising onsite. As the soil conditions are created and vary by natural processes and human activity, the report is based on soil conditions at the time of the investigation. Soil conditions onsite can change, particularly after long periods of time from the date of investigation.

This report has been prepared for our client for their purposes and the regulatory authority in relation to the consent application within the scope of this report. It is based on our understanding of the proposed development. Should any changes to the nature of the development occur, BCD should be asked to provide comment on the ongoing applicability of recommendations made in this report. It is not to be relied upon or used out of context by any other person without reference to BCD Group Ltd. The reliance by other parties on the information or opinions contained in this report shall, without prior review and agreement in writing, be at such parties' sole risk. To avoid misinterpreting this report, we recommend that the assistance of geotechnical professionals familiar with the project and scope of this report is maintained.

This report covers acid sulfate soil risk considerations only. This report does not assess risk of contamination of soils, geotechnical advice or provide an assessment of flood risk and FFL recommendation. We recommend the proposed works be checked against current District and Regional Council plans or checked by a registered planner.

10 REFERENCES

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Appendix A Site plan

Client: WAIKATO THOROUGHBRED RACING TE RAPA · CAMBRIDGE · WAIPA

Contractor:

BCD GROUP

Sheet: Site Location

Project Title: Waikato Thoroughbred Racing
Pencarrow, Hooker & Duncan Roads

Revision	Date	By	Reason
01	12/12/2025	SL	Master Planning

Drawn: SL
Engineer: SL
SCALE: N/A
At: A3
Job Number: 23-1883
Sheet Number:
Revision: 01

All dimensions to be verified on site before making any shop drawings or commencing any work

Notes:
Elevation Contours are in terms of NZVD2016, generated using QGIS based on 2021 Lidar sourced from LINZ.
Aerial imagery, property boundaries, etc sourced from LINZ.

Client: WAIKATO THOROUGHBRED RACING — TE RAPA · CAMBRIDGE · WAIPA

Contractor:

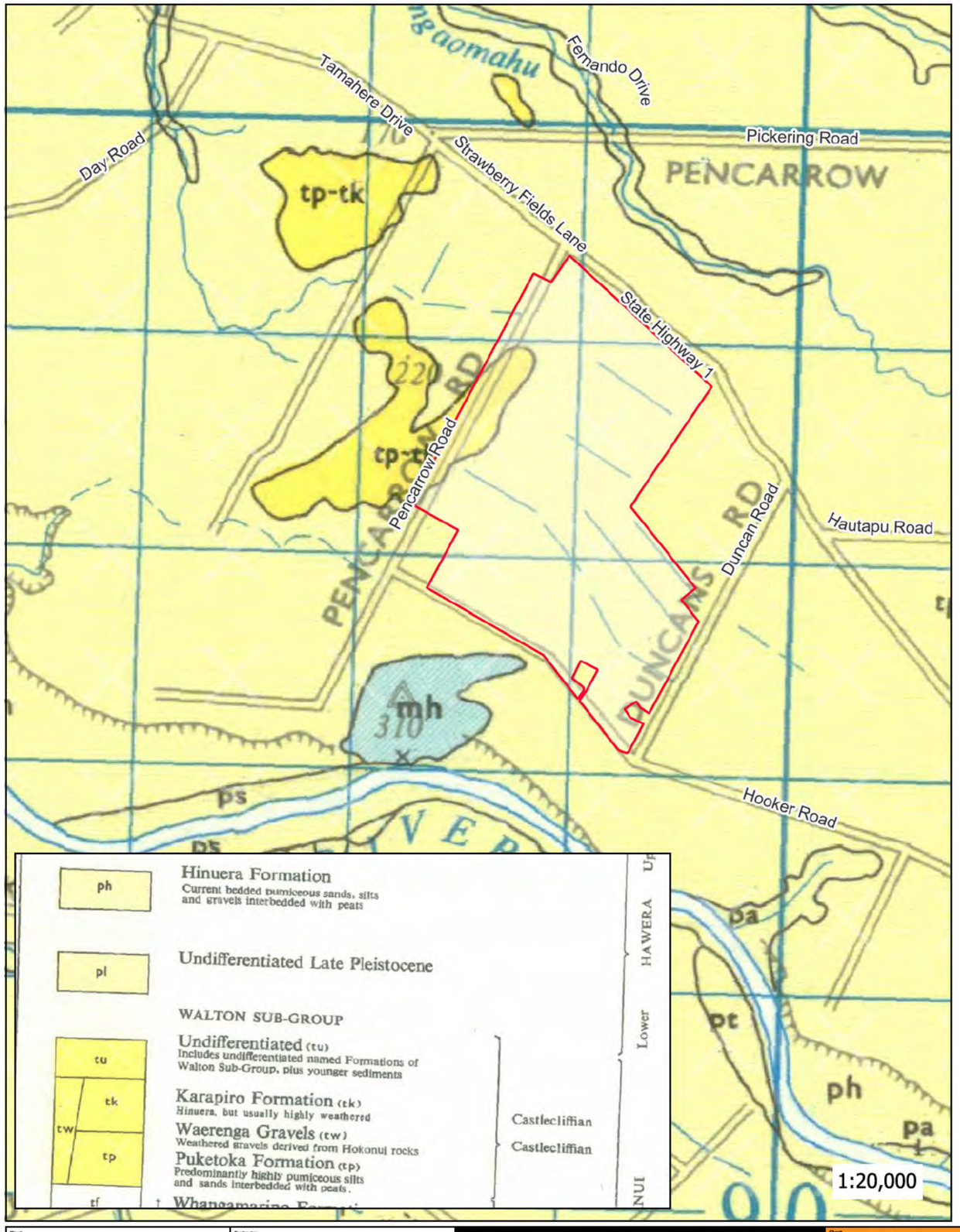
BCD GROUP

Sheet: Internal Infrastructure

Project Title: Waikato Thoroughbred Racing
Pencarrow, Hooker & Duncan Roads

Revision	Date	By	Reason
02	27/02/2026	BB	Fast Track Referral Application
01	12/12/2025	SL	Master Planning

Drawn: SL
Engineer: SL
SCALE: 1000
At: A3
Job Number: 23-1883
Sheet Number:
Revision: 02



Client: WAIKATO THOROUGHBRED RACING TE RAPA · CAMBRIDGE · WAIPA

Contractor

BCD GROUP

Sheet: Geological and Soil Type Map

Project Title: Waikato Thoroughbred Racing
Pencarrow, Hooker & Duncan Roads

Revision	Date	By	Reason
01	03/12/2025	SL	Master Planning

Drawn: SL
Engineer: SL
Scale: NA
At: A3
Job Number: 23-1883
Sheet Number:
Revision: 01

Appendix B Proposed master plans

DESIGNGROUP STAPLETON ELLIOTT + COX

WTR WAIKATO THOROUGHBRED RACING
WTR GREENFIELDS RACECOURSE

FAST TRACK REFERRAL APPLICATION

Issued for Fast Track Referral Application
Version 01 • April 2026 • For Review

COX designgroup stapleton elliott

CONTENTS

1

OVERALL SITE

1.1 LOCATION PLAN

N

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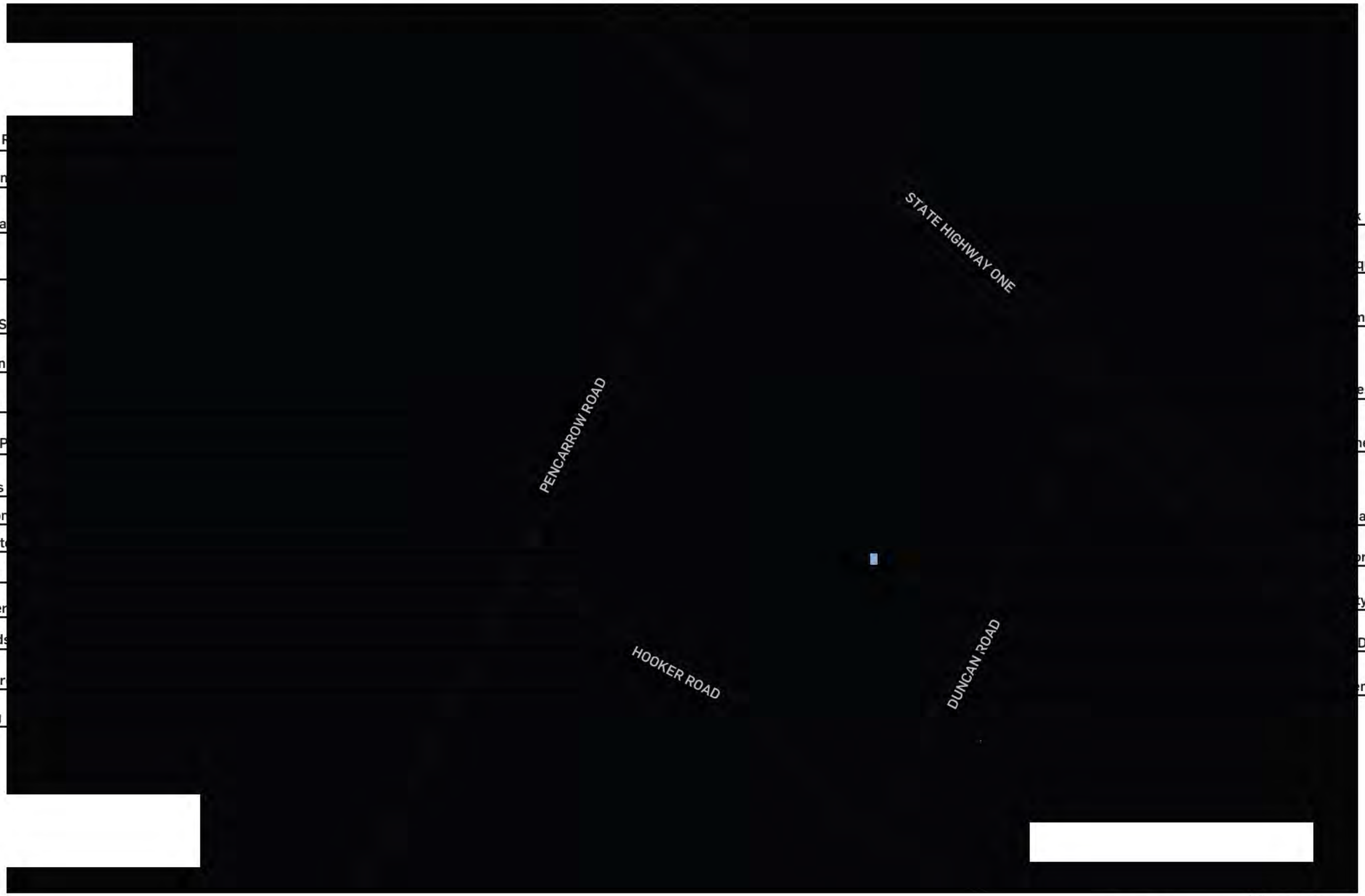
1.2 EXISTING SITE PLAN

designgroup stapleton elliott

1.3 INDICATIVE PROPOSED SITE LAYOUT PLAN



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stapleton elliott

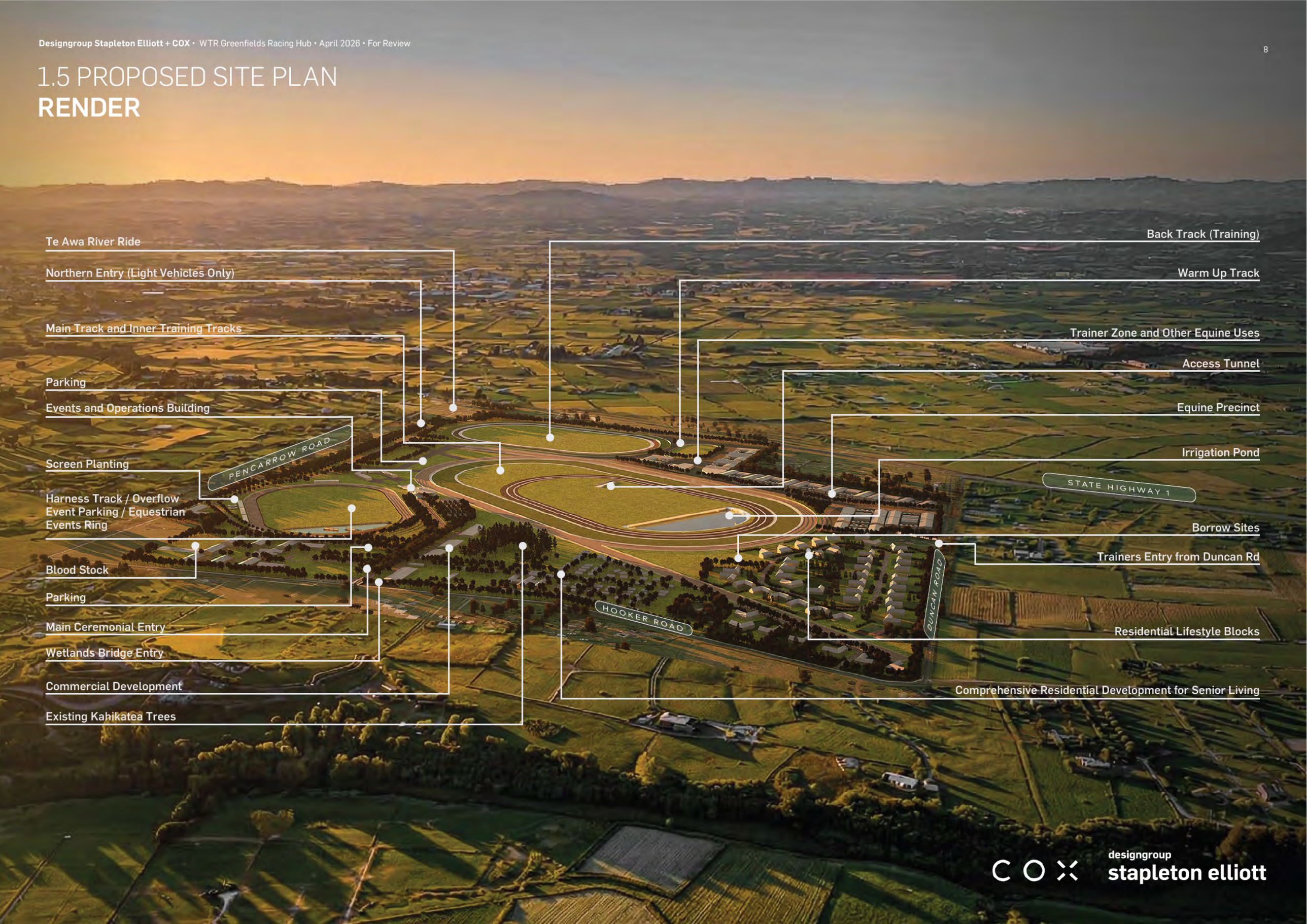
1.4 INDICATIVE COMMERCIAL ZONES

N

1	**Commercial Equire Services**	Area ~26,500m2 GFA – 18,000m2. Max 2 floors
2	**Bloodstock**	Areas ~63,200m2 GFA – 20,000m2. Max 2 floors
3	**Village Centre**	Area - 15,000m2 GFA - 15,000m2. Max 4 floors
4	**Training Areas**	Area ~150,000m2 GFA - 100,000m2. Max 2 floors
5	**Rural Residential Development**	Area ~153,600m2 40-50 2,500m2 Lots GFA per lot 800m2. Max 2 storey buildings
6	**Comprehensive Residential Development for Senior Living**	Area ~68,000m2 70 Villas @ average 100m2 GFA - 7,000m2. Single storey 200 apartments @ average 50m2 GFA – 10,000m2. Max 4 floors Community Centre GFA - 500m2. Max 2 floors

All figures are approximate. Indicative only.

1.5 PROPOSED SITE PLAN
RENDER



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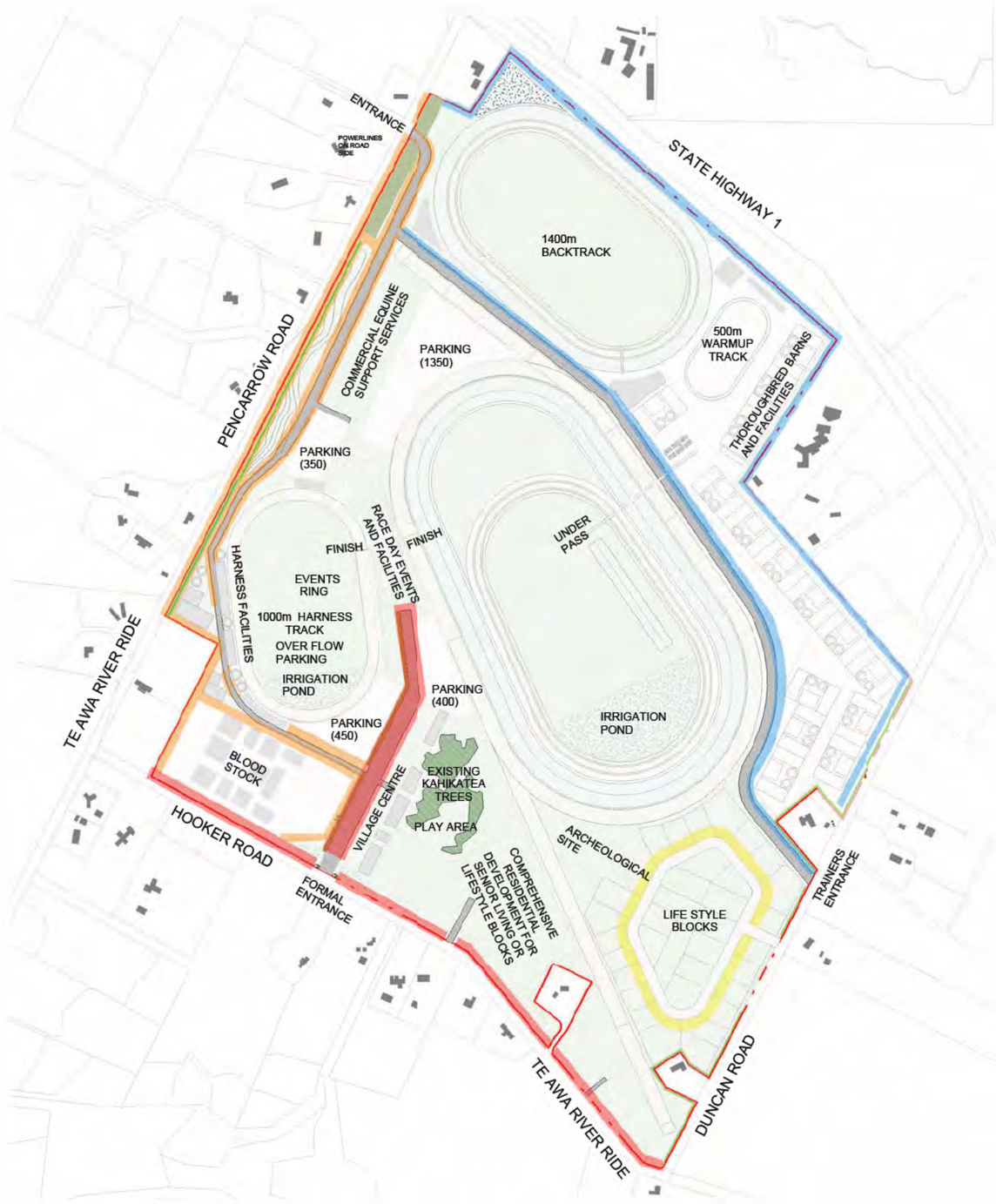
LANDSCAPE

2

2.1 LANDSCAPE
SITE PLAN



N

Landscape Site Plan

SCALE @ A3 -1 : 10000

PROPOSED SPECIMEN TREES

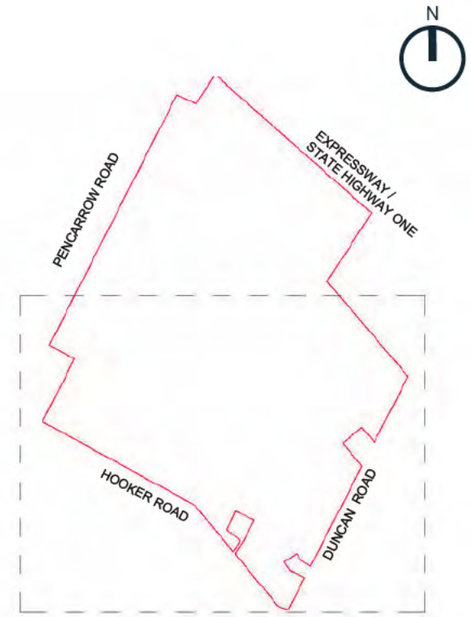
- *Populus* 'Crows Nest' - upright poplar - 5m Spacings
- *Liriodendron tulipfera* - tulip tree - 10m Spacings
- *Platanus x acerifolia* - London plane tree - 10m Spacings
- *Prumnopitys taxifolia* - matai - 15m Spacings

VEGETATION

- Hedge - Griselinia 'Ardmore Green'
- Existing Vegetation
- Proposed Native Shrub Planting

NOTE: Refer to Architectural Documentation for Racetrack and Facilities Locations.
Refer to Civil's Documentation for Swale Design.

2.2 LANDSCAPE - EXISTING TREES



LOCATION EXISTING TREE HEALTH

- Excellent
- Good
- Fair
- Poor

VEGETATION

- Existing Kahikatea Grove

NOTE: Refer to Arboricultural Specialist's Report for Existing Tree Schedule and Species to be removed / retained

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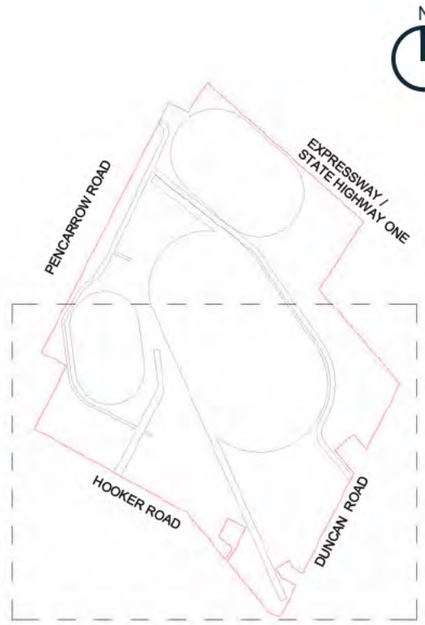
2.3 LANDSCAPE - EXISTING TREES TO BE RETAINED



LOCATION OF EXISTING TREES

- Retain
- Remove
- To be transplanted
- Existing Kahikatea Grove to be retained

NOTE: Refer to Arboricultural Specialist's Report for Existing Tree Schedule and Species to be removed / retained

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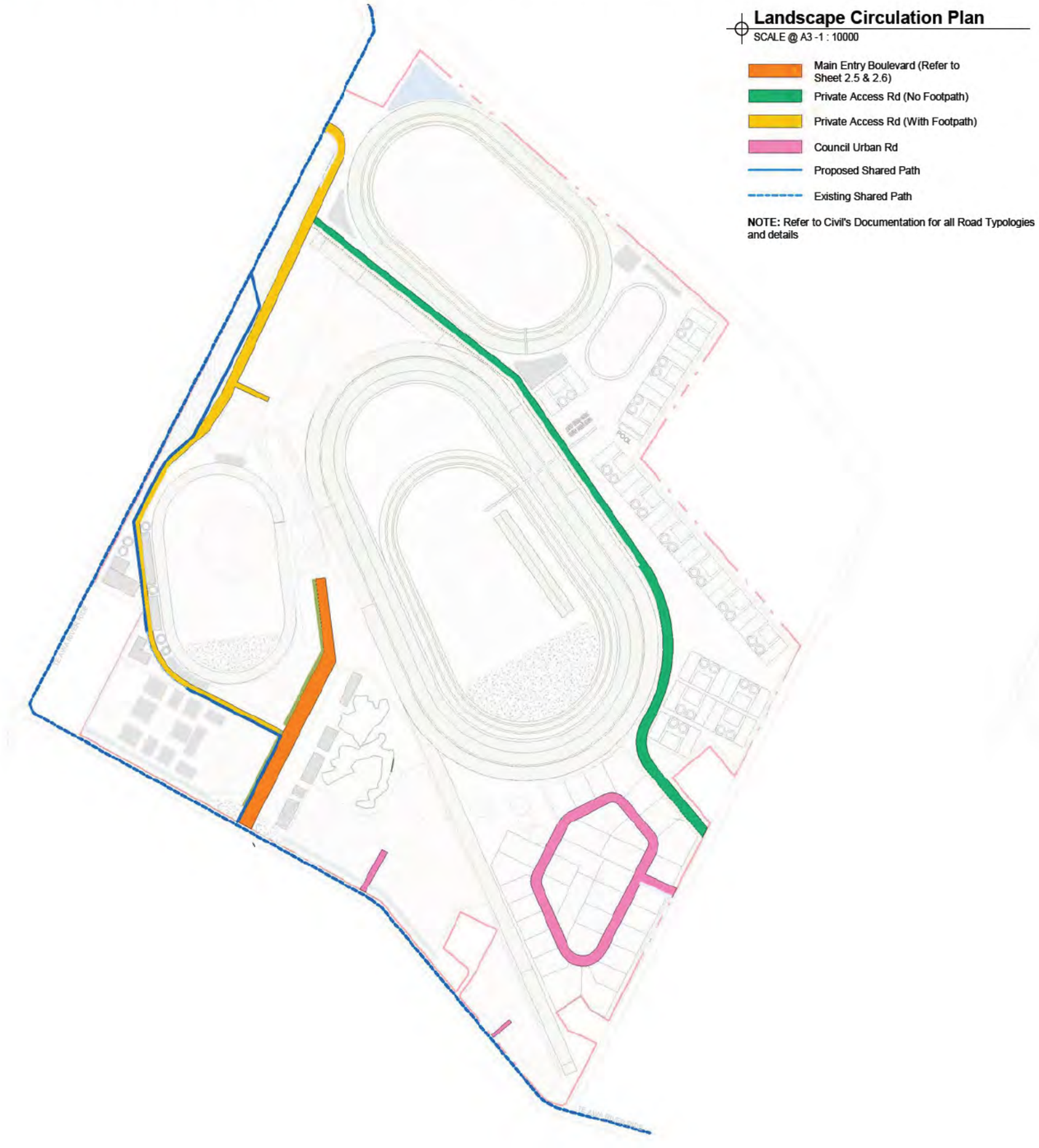
2.4 LANDSCAPE
CIRCULATION AND SWALE CONCEPT PLANS



Landscape Circulation Plan
SCALE @ A3 -1 : 10000

- Main Entry Boulevard (Refer to Sheet 2.5 & 2.6)
- Private Access Rd (No Footpath)
- Private Access Rd (With Footpath)
- Council Urban Rd
- Proposed Shared Path
- Existing Shared Path

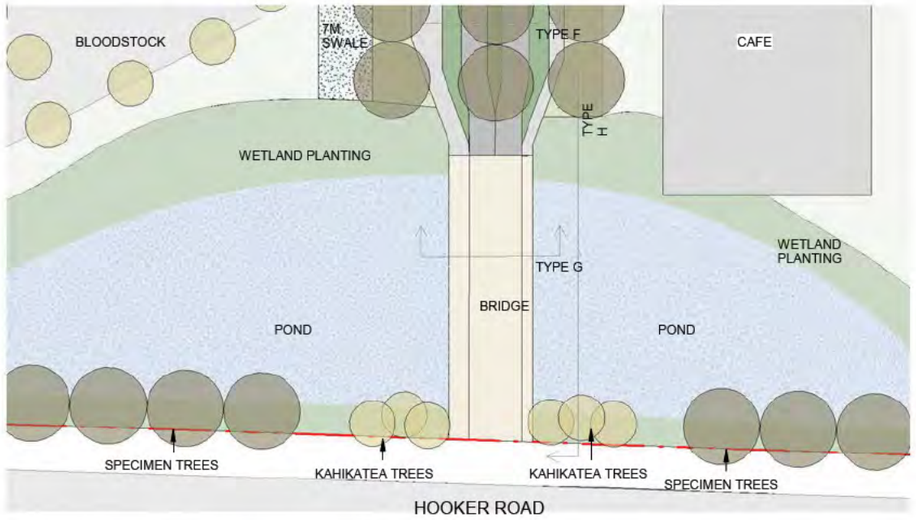
NOTE: Refer to Civil's Documentation for all Road Typologies and details

Landscape Site Swales Plan
SCALE @ A3 -1 : 10000

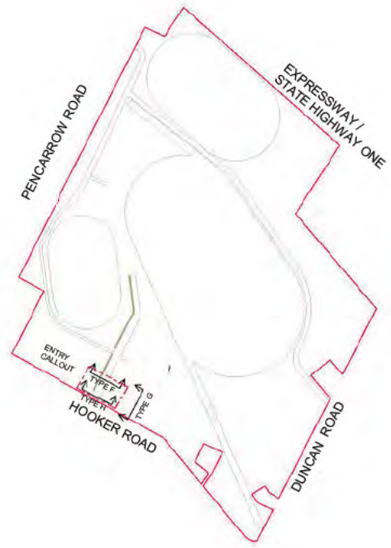
- Swale - 10m Wide
- Swale - 7m Wide
- Swale - 5m Wide
- Rain Garden - 2.5m Wide

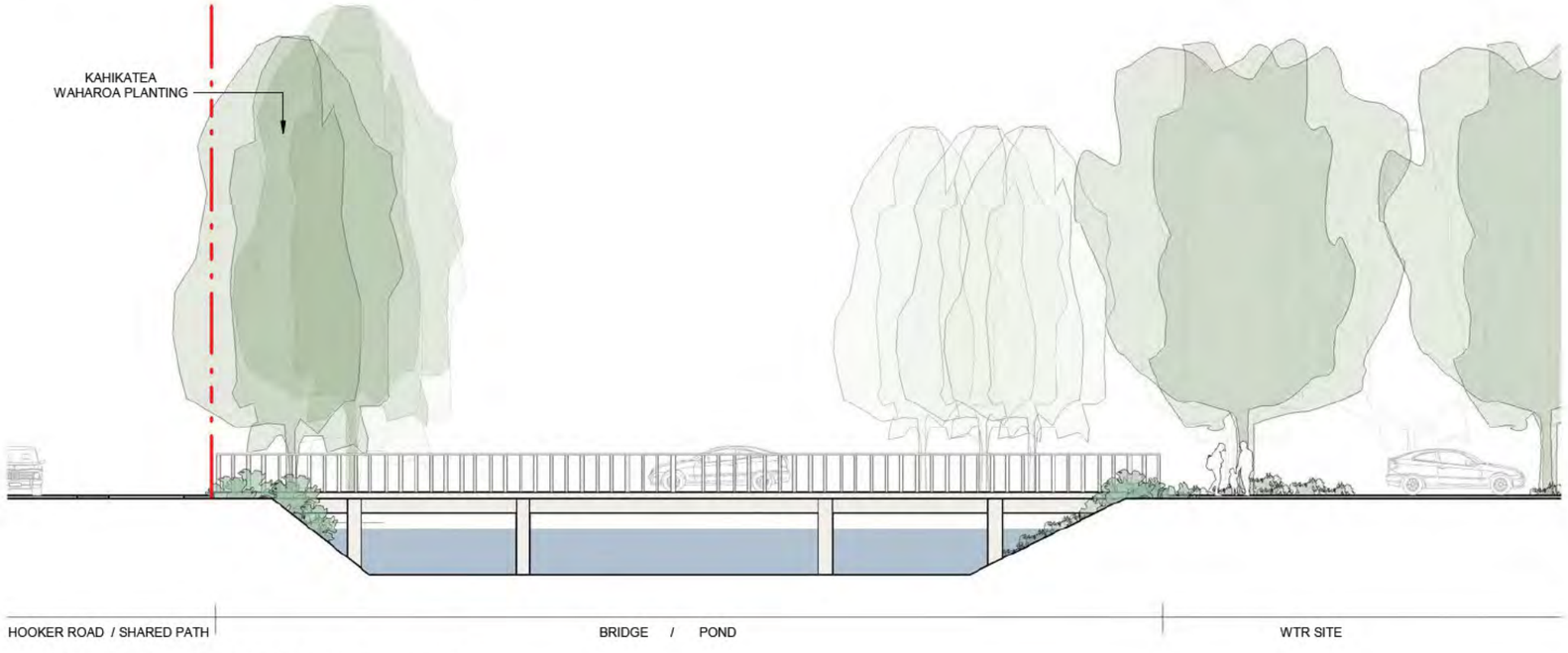
NOTE: Refer to Civil's Documentation for Swale Design.

2.5 LANDSCAPE
LANDSCAPE - EDGE CONDITIONS - HOOKER ROAD ENTRY

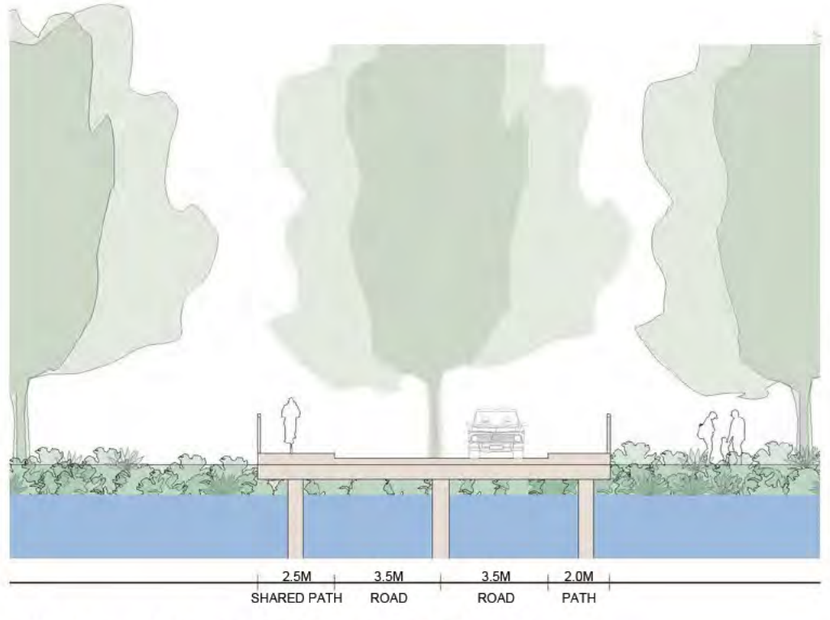


Landscape Callout - Hooker Rd Main Entry Boulevard
SCALE @ A3 -1 : 800





Landscape Section-TYPE H_ Hooker Rd Entry
SCALE @ A3 - 1 : 200



Landsape Section-TYPE G_ Hooker Rd Entry to Main Boulevard
SCALE @ A3 - 1 : 200

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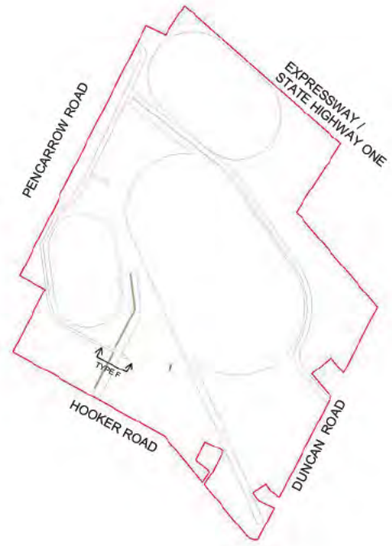
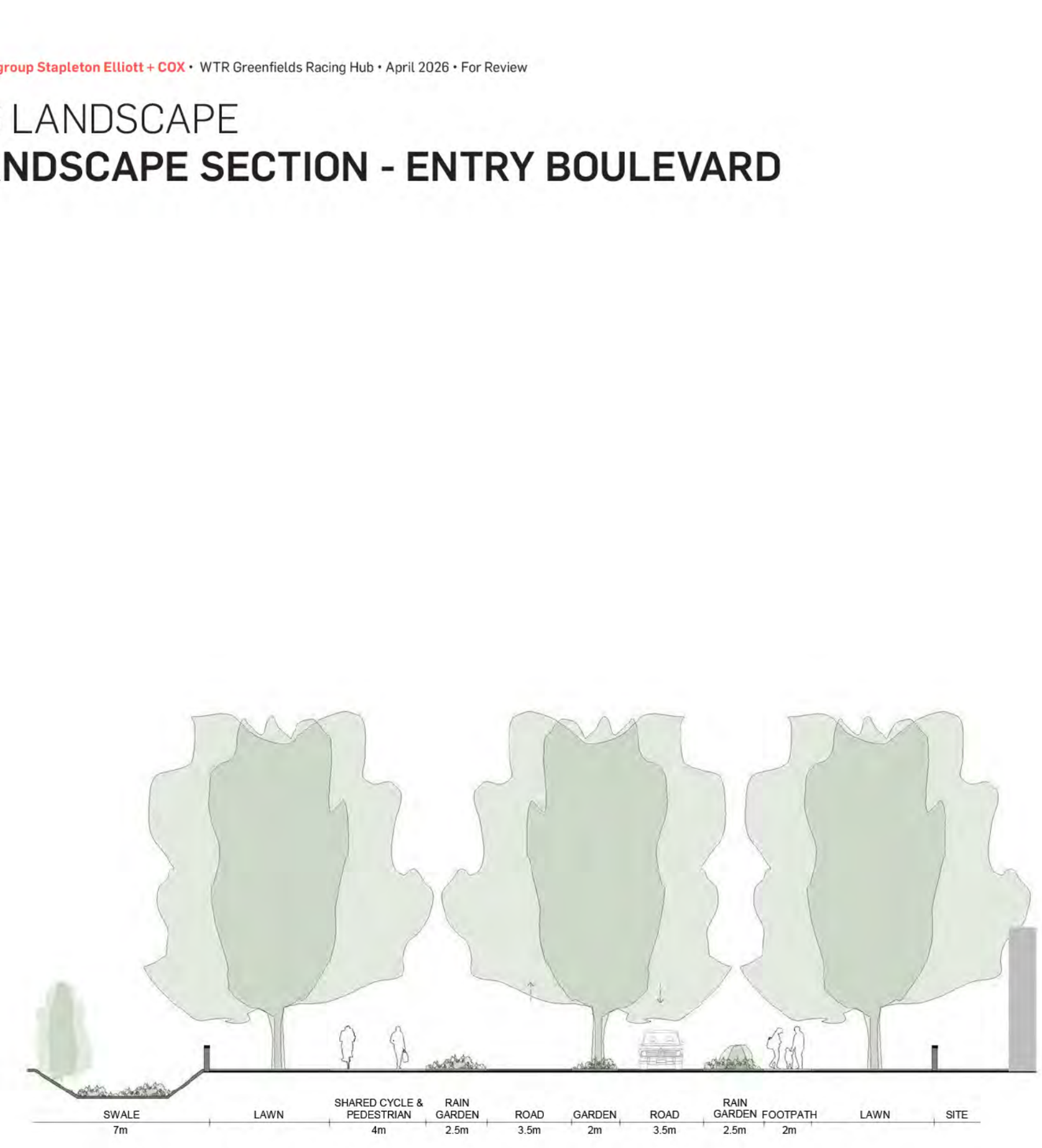
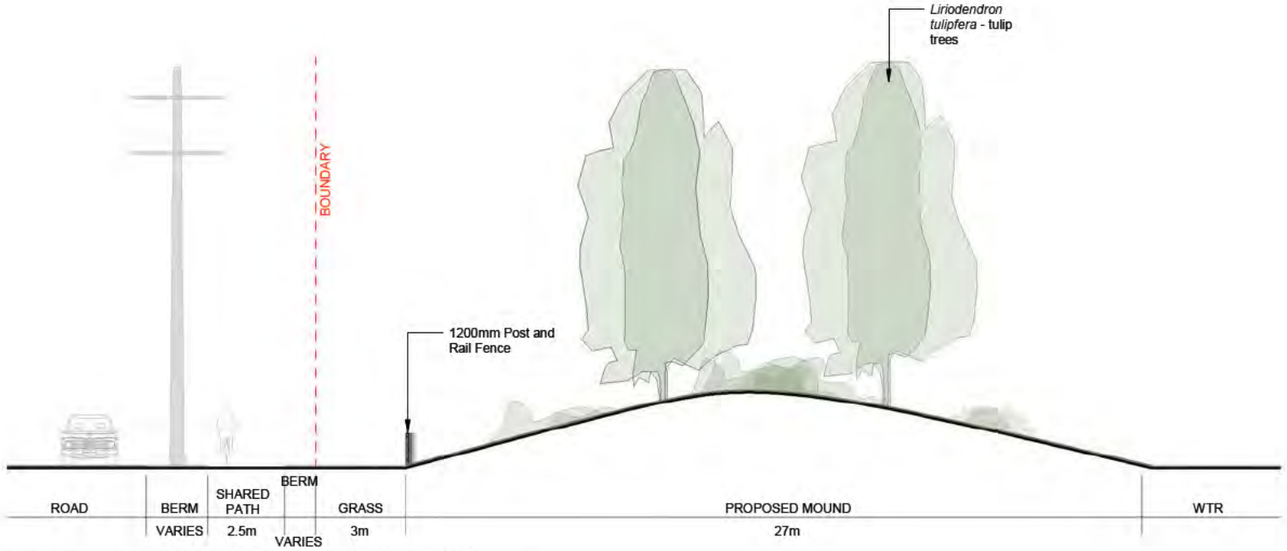
2.6 LANDSCAPE
LANDSCAPE SECTION - ENTRY BOULEVARD



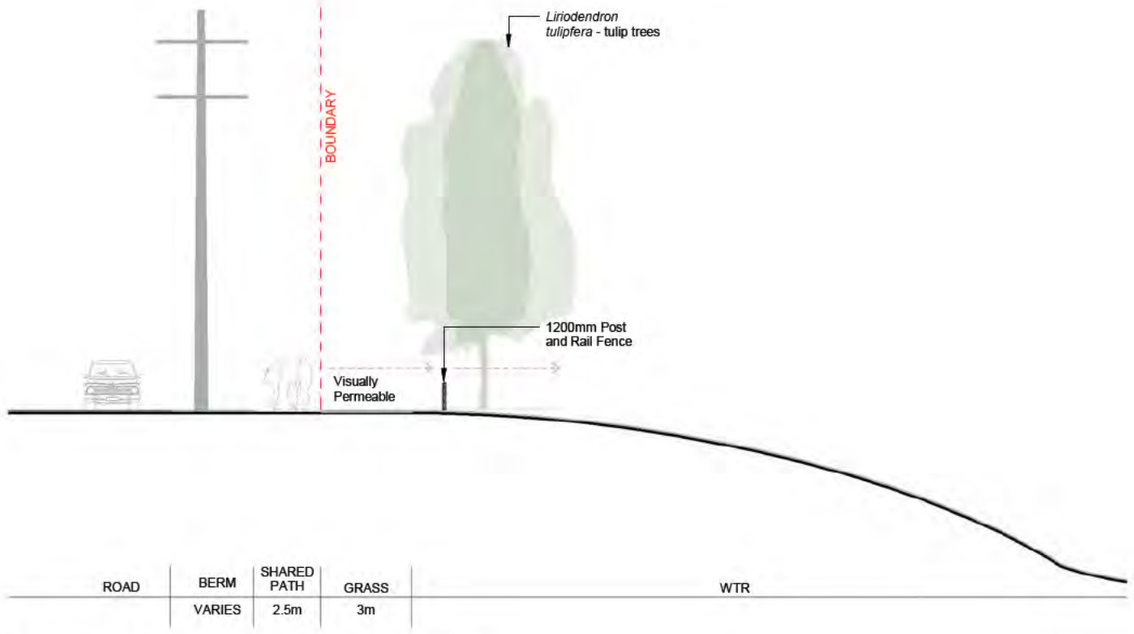


Landscape Section -TYPE F_Main Entry Boulevard
SCALE @ A3 - 1 : 200

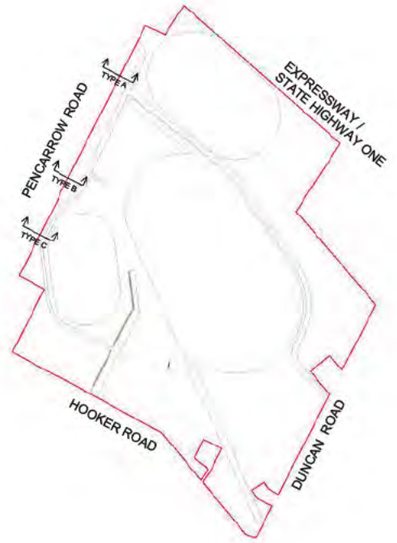
2.7 LANDSCAPE
LANDSCAPE - EDGE CONDITIONS - PENCARROW ROAD

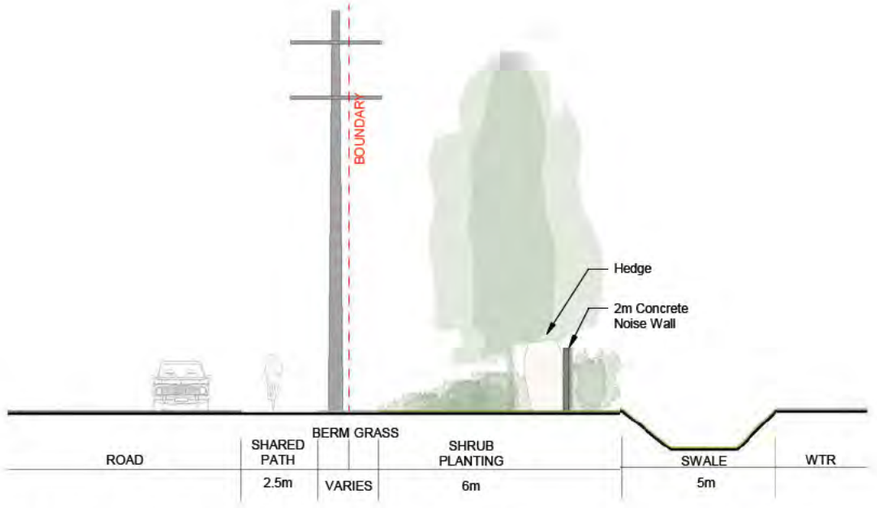


Landscape Section -TYPE A_Pencarrow Road
SCALE @ A3 - 1 : 200



Landscape Section -TYPE B_Pencarrow Road
SCALE @ A3 - 1 : 200





Landscape Section -TYPE C_Pencarrow Road
SCALE @ A3 - 1 : 200

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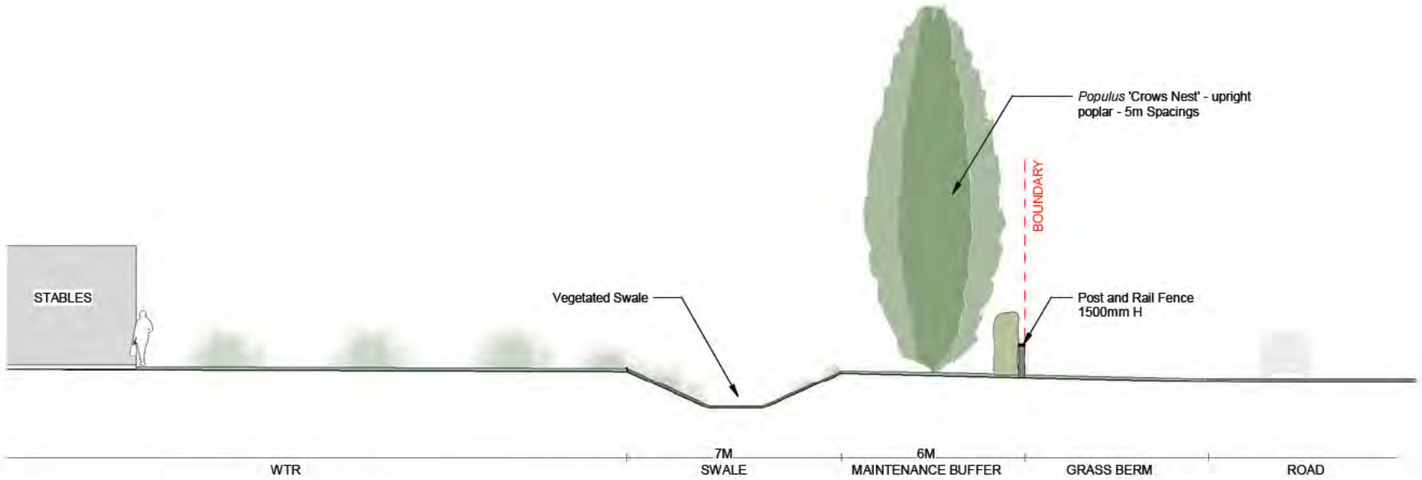
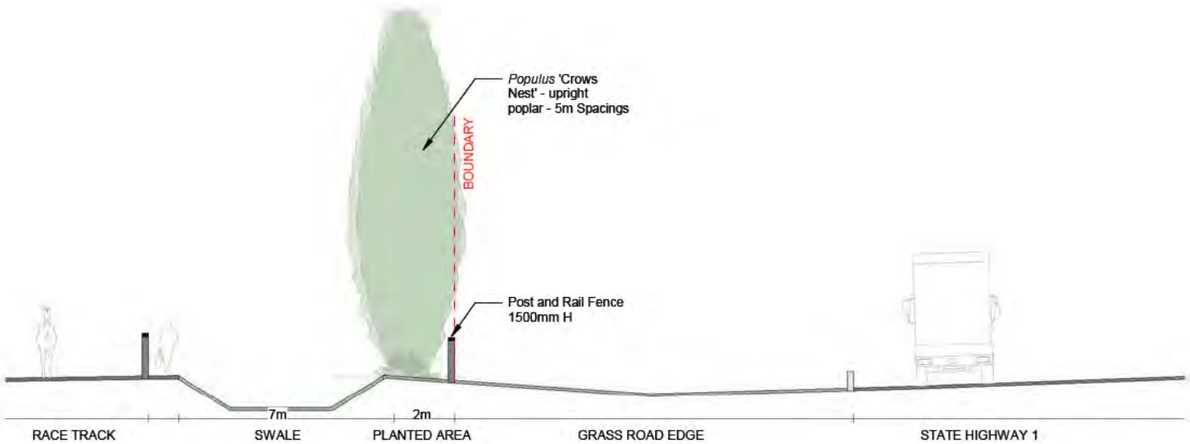
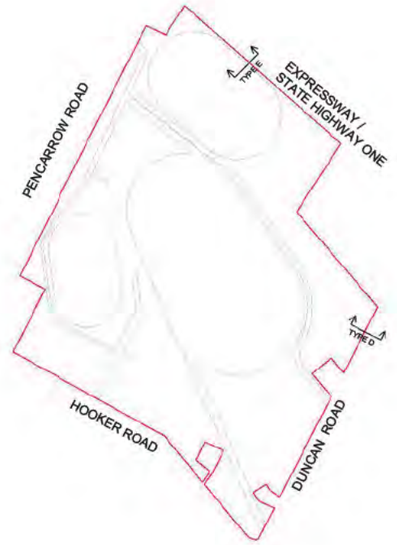
2.8 LANDSCAPE
LANDSCAPE - EDGE CONDITIONS - DUNCAN ROAD + EXPRESSWAY



Landscape Section - TYPE D_Duncan Road
SCALE @ A3 - 1 : 200



Landscape Section - TYPE E _Expressway
SCALE @ A3 - 1 : 200



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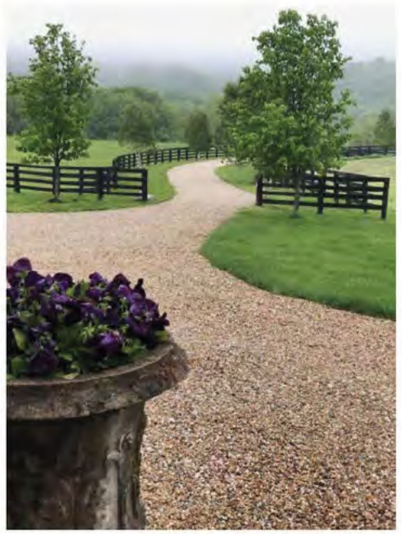
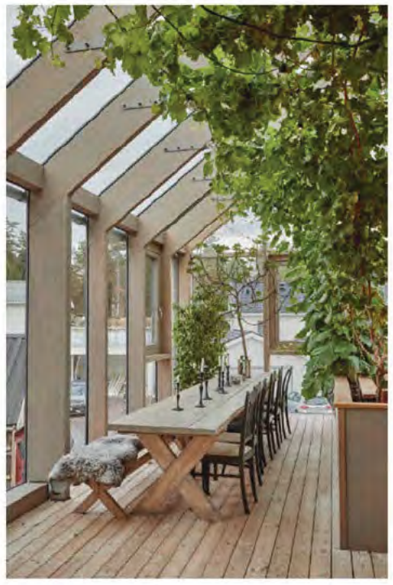
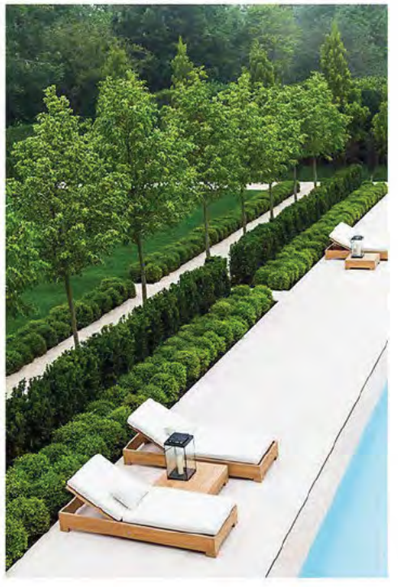
2.9 LANDSCAPE
LOOK AND FEEL



2.10 LANDSCAPE
LOOK AND FEEL





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2.11 LANDSCAPE
INDICATIVE PLANT PALETTE

NOTE: Indicative plant selection to be reviewed by Mana Whenua for comment prior to final selections.
Proposed NZ native plants labelled in green.

Carpinus betulus fastigiata - upright hornbeam

Liriodendron tulipfera - tulip tree

Betula 'Jacquemontii' - white barked birch

Psuedopanax 'Cyril Watson' - houpara

Ligustrum 'Rotundifolium' - Japanese privet

Geniostoma ligustrifolium - hangehange

Griselinia littoralis - kapuka

Populus nigra - Lombardy poplar

Vitex lucens - puriri

Michelia figo - port wine magnolia hedge

Citrus 'Tahitian Lime' - lime hedge

Beilschmiedia tawa - tawa

Dacrycarpus dacrydiodes - kahikatea

Macropiper subs. psittacorum - kawakawa

Laurelia nz - pukatea

Laurus nobilis - bay hedge

Dichondra repens - Mercury Bay weed

Hydrangea spp. - hydrangea

Pratia angulata - pānakenake

2.12 LANDSCAPE
INDICATIVE PLANT PALETTE

NOTE: Indicative plant selection to be reviewed by Mana Whenua for comment prior to final selections.
Proposed NZ native plants labelled in green.

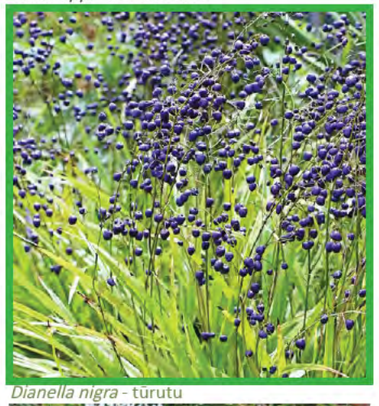
Miscanthus spp. - maiden grass

Salvia spp. - sage

Hebe spp. - hebe

Libertia grandiflora - mikoioi

Guara spp. - bee blossom



Dianella nigra - tūrutu

Carex flag. green - mānia

Lavandula spp. - lavender

Achillea spp. - bloodwort

Achillea spp. - bloodwort

Carex comans bronze - maurea

Hemerocallis spp. - day lilies

Rosmarinus spp. - rosemary

Daphne spp - daphne

Zephyranthes candida - rain lilies

Acorus 'Mini Green' - Japanese sweet flag

Chionochloa spp. - dwarf toetoe

3

RACE DAY FACILITIES

3.1 RACE DAY FACILITIES
RENDER

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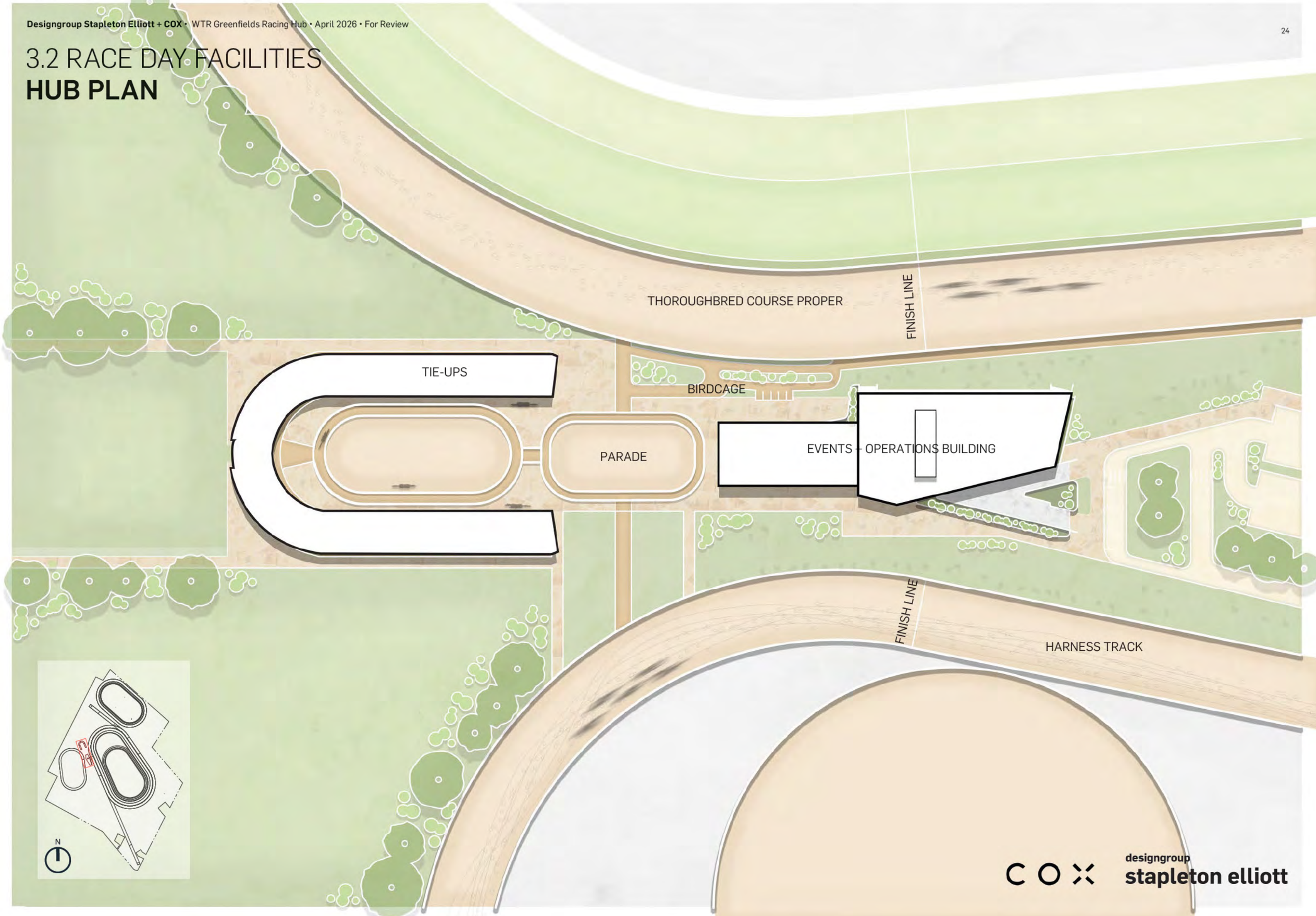
stapleton elliott

3.2 RACE DAY FACILITIES
HUB PLAN



3.3 EVENT + OPERATIONS BUILDING
RENDER 1

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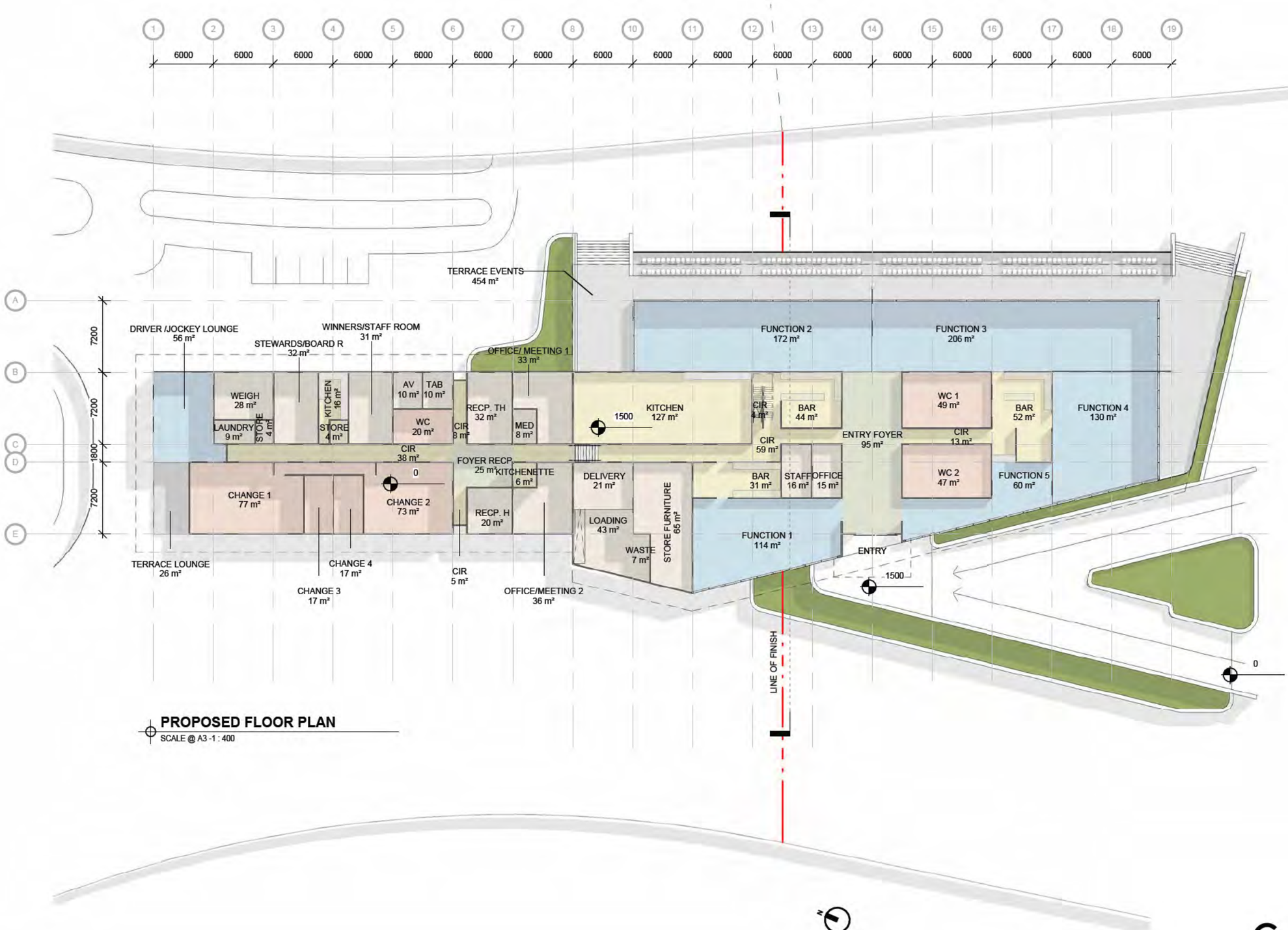
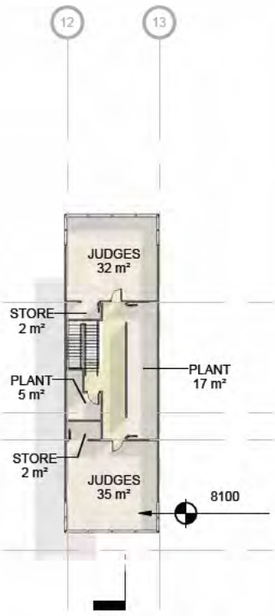
3.4 EVENT + OPERATIONS BUILDING
PLAN



PROPOSED FLOOR PLAN
SCALE @ A3 -1 : 400



PROPOSED TOWER PLAN
SCALE @ A3 -1 : 400

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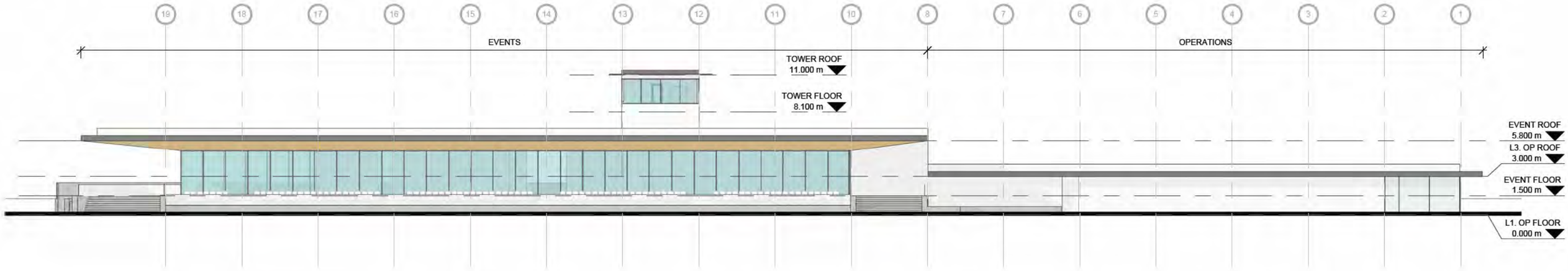
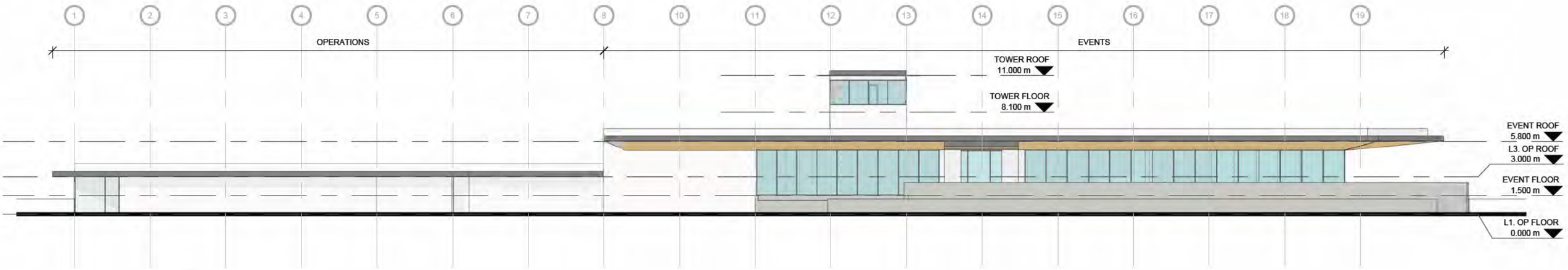
3.5 EVENT + OPERATIONS BUILDING
ELEVATIONS 1 + 2



North Elevation
SCALE @ A3 -1 : 300



South Elevation
SCALE @ A3 -1 : 300

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3.6 EVENT + OPERATIONS BUILDING
SHORT SECTION

SHORT SECTION
SCALE @ A3 - 1 : 200

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3.7 EVENT + OPERATIONS BUILDING
RENDER 2

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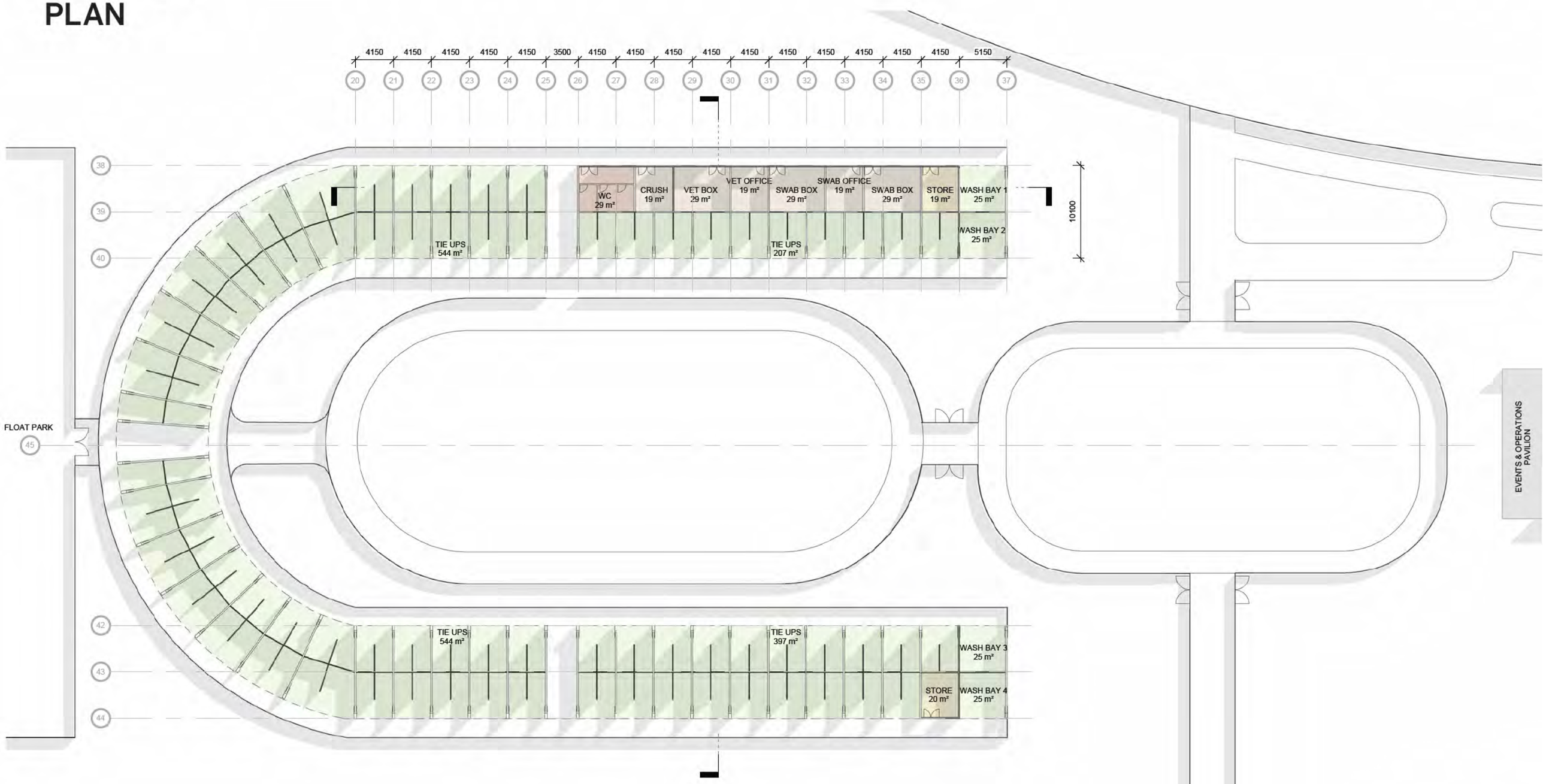
3.8 TIE-UPS
PLAN



TOTAL TIE-UP BAYS: 150

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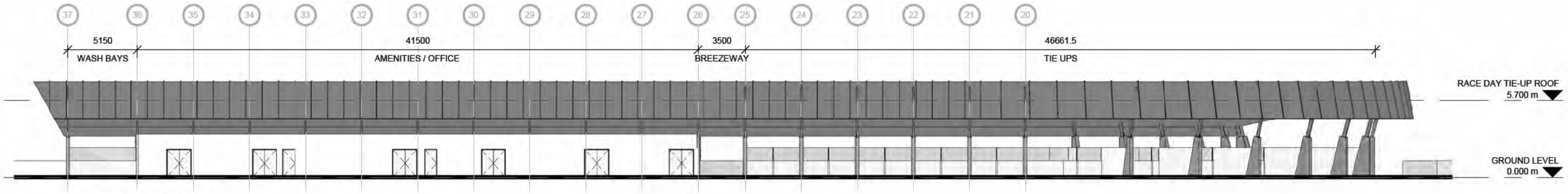
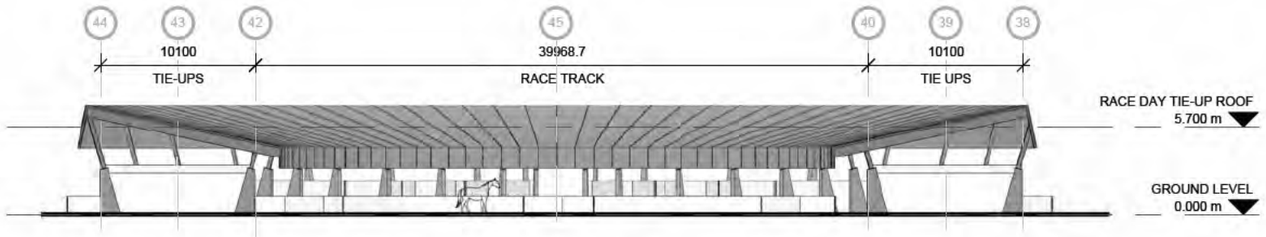
stapleton elliott

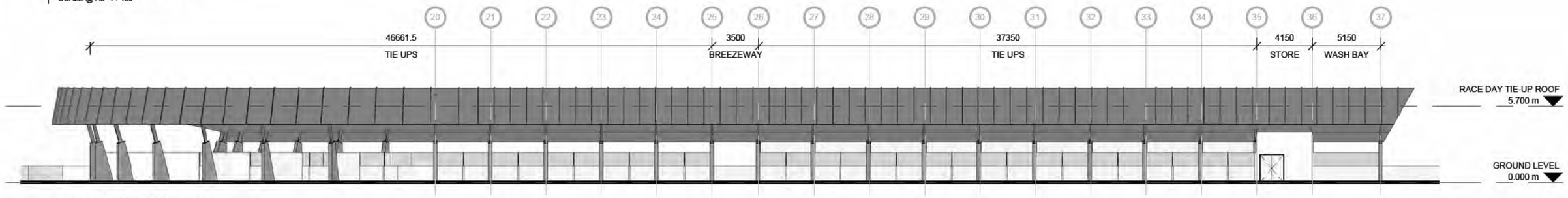
3.9 TIE-UPS
ELEVATIONS



NORTH ELEVATION
SCALE @ A3 -1 : 300



EAST ELEVATION
SCALE @ A3 -1 : 400



SOUTH ELEVATION
SCALE @ A3 -1 : 300

WEST ELEVATION
SCALE @ A3 -1 : 300

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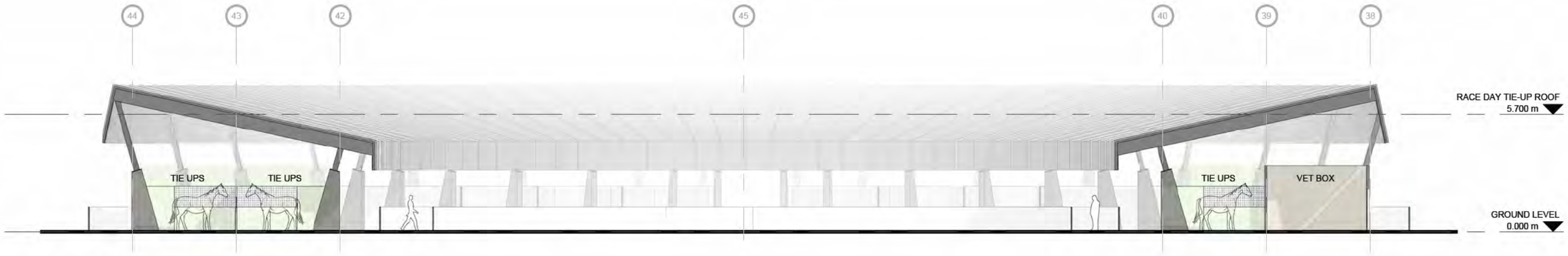
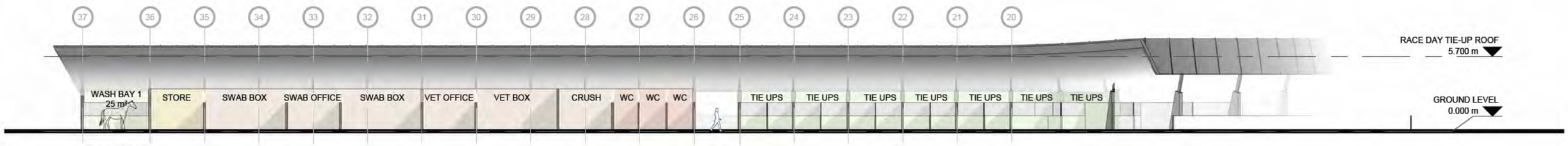
3.10 TIE-UPS
SECTIONS



SECTION 1
SCALE @ A3 - 1 : 200



SECTION 2
SCALE @ A3 -1 : 300

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3.11 TIE-UPS
RENDER 1

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stapleton elliott

3.12 TIE-UPS
RENDER 2

designgroup
stapleton elliott

3.13 TIE-UPS
RENDER 3

designgroup
stapleton elliott

3.14 HOOKER ROAD ENTRY
RENDER

designgroup
stapleton elliott

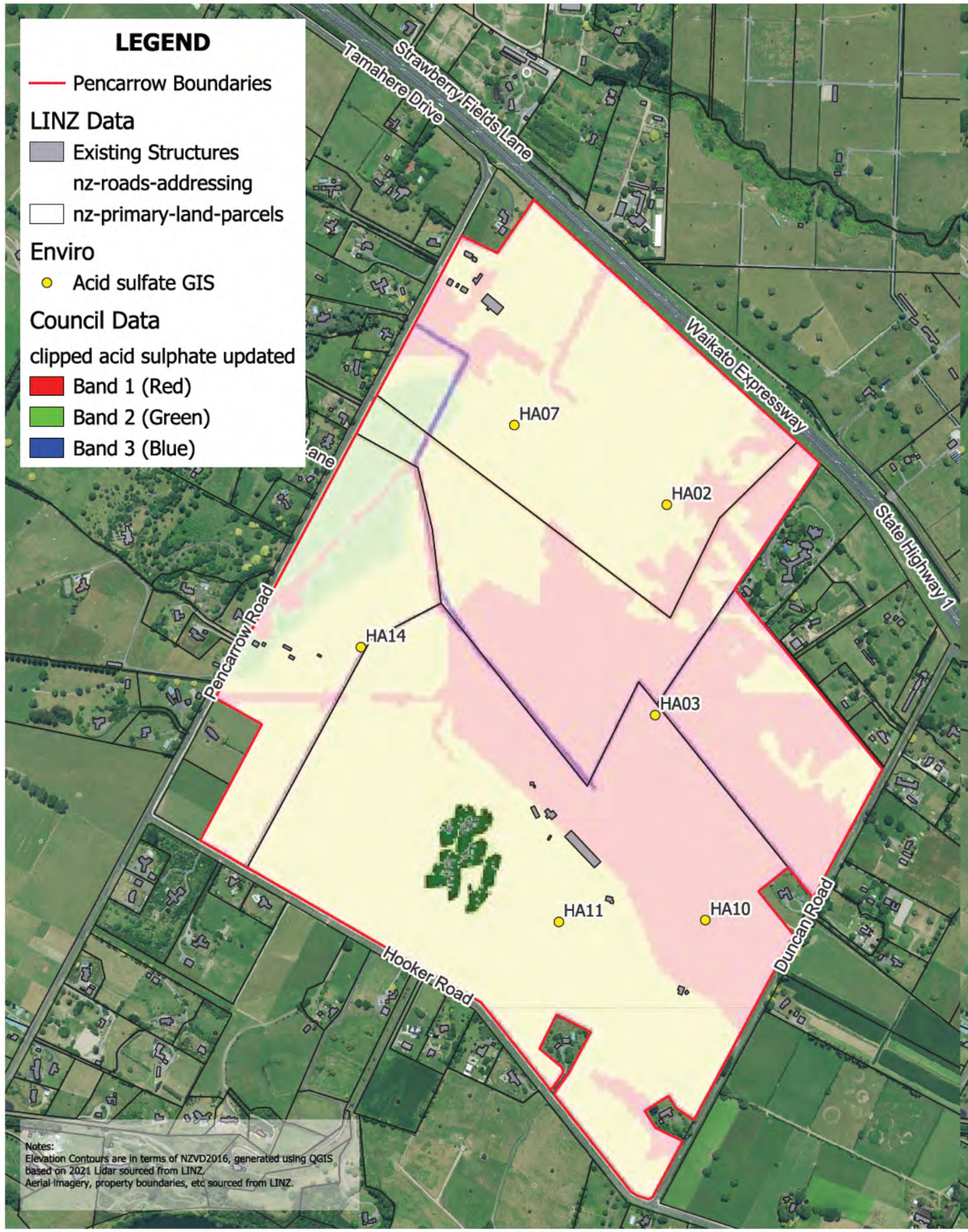
3.15 FINISH LINE
RENDER

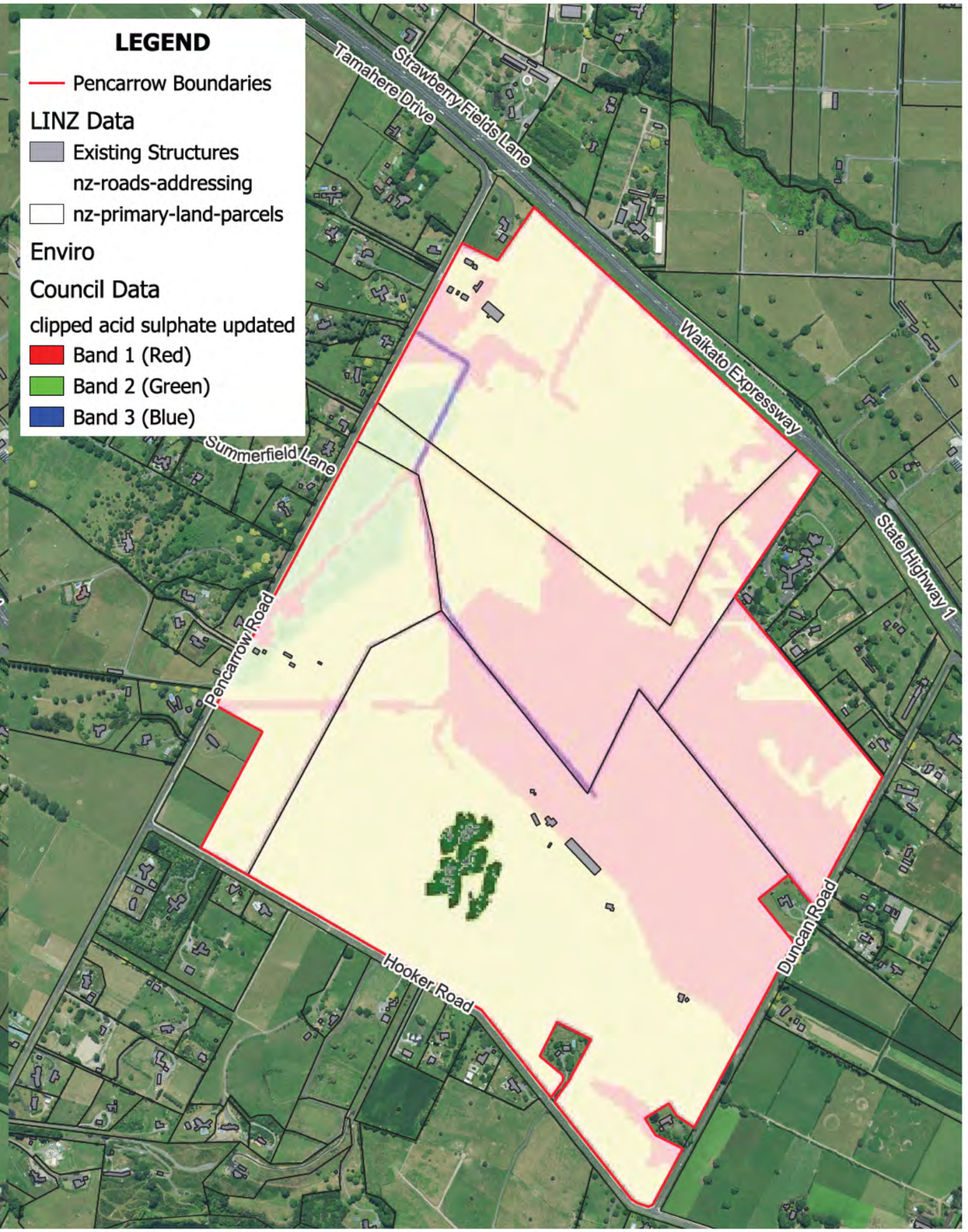
designgroup
stapleton elliott

HE MANA TŌ TE HOAHOANGA KA WHAKAATA I TE TANGATA ME TŌNA TŪRANGAWAEWAE // **THERE IS POWER IN DESIGNING ARCHITECTURE THAT REFLECTS ITS PEOPLE AND PLACE.**

COX designgroup stapleton elliott

Appendix C Acid sulfate soil risk map





Notes:
Elevation Contours are in terms of NZVD2016, generated using QGIS based on 2021 Lidar sourced from LINZ.
Aerial imagery, property boundaries, etc sourced from LINZ.

Client: WAIKATO THOROUGHBRED RACING TE RAPA · CAMBRIDGE · WAIPA

Contractor:

BCD GROUP

Sheet: WRC Acid Sulphate Map

Project Title: Waikato Thoroughbred Racing
Pencarrow, Hooker & Duncan Roads

Revision	Date	By	Reason
02	15/04/2026	SL	Master Planning
01	03/12/2025	SL	Master Planning

Drawn: SL
Engineer: SL
SCALE: 1: 10000
At: A3
Job Number: 23-1883
Sheet Number:
Revision: 02

Appendix D Historic aerial photography

Client:

Contractor:

BCD GROUP

Sheet: Retrolens Photos

Project Title: Waikato Thoroughbred Racing
Pencarrow, Hooker and Duncan Roads

Revision	Date	By	Reason
01	11/12/2025	SL	Masterplanning

Drawn: SL
Engineer: SL

Scale: NA

At: A3

Job Number: 23-1883

Sheet Number:

Revision: 01

All dimensions to be verified on site before making any shop drawings or commencing any work

Client:

Contractor:

BCD GROUP

Sheet: Retrolens Photos

Project Title: Waikato Thoroughbred Racing
Pencarrow, Hooker and Duncan Roads

Revision	Date	By	Reason
01	11/12/2025	SL	Masterplanning

Drawn: SL
Engineer: SL

Scale: NA

At: A3

Job Number: 23-1883

Sheet Number:

Revision: 01

All dimensions to be verified on site before making any shop drawings or commencing any work

Appendix E Sample results

				Field pH (	Sulfurous smell	Jarosite / mottling?	Soil description	pHfox	Delta pH	Reaction rating	Sulfurous gas release?
Adopted screening criteria				4		Yes		3	1	H	Yes
Sampling location	Depth to groundwater	Depth	Date								
HA02.1	0.9	0.5	13/11/2025	6	No	No	Orange brown silt trace sand moist	5.03	0.97	L	No
HA02.2		0.7	13/11/2025	6.79	No	Some orange brown mottles	Light grey silty sand moist orange brown mottles	4.7	2.09	L	Yes
HA02.3		1.2	13/11/2025	6.23	No	No	Light grey sandy silt wet to saturated	4.93	1.3	L	No
HA02.4		1.4	13/11/2025	6.26	No	No	Saturated silty Sand light grey	4.96	1.3	L	No
HA02.5		1.9	13/11/2025	6.08	No	No	Sgravelly sandy silt greyish brown saturated	5.1	0.98	M	Yes
HA03.1	1	0.2	12/11/2025	5.03	No	Trace orange mottling	Silt light greyish brown	3.84	1.19	L-M	No
HA03.2		0.9	12/11/2025	6.2	No	None	Silt light greyish brown	4.98	1.22	L	No
HA03.3		1.5	12/11/2025	5.63	No	None	Sand fine to medium l grey wet to saturated	4.85	0.78	L	No
HA03.4		1.7	12/11/2025	5.67	No	None	Sand fine to medium saturated light grey	4.84	0.83	L	No
HA03.5		2	12/11/2025	5.78	No	None	Sand light grey saturated founded pumice	5.16	0.62	L	No
HA07.1	2.2	0.5	14/11/2025	6.8	No	Yes mottles	Silty trace fine sand light grey orange brown mottles	4.6	2.2	M	No
HA07.2		1	14/11/2025	6.3	No	Yes mottles	Light grey orange brown mottle	4.94	1.36	L-M	Yes
HA10.1	2	0.2	12/11/2025	4.58	No	Trace orange mottles	Light orange brown silt, dry to moist	3.57	1.01	M	No
HA10.2		0.4	12/11/2025	4.68	No	Trace orange mottles	Light grey sandy silt, mosist, brown orange mottles	3.69	0.99	L	No
HA10.3		0.6	12/11/2025	6.1	No	Orange staining	Fine light grey sand moist	4.19	1.91	L	No
HA10.4		0.9	12/11/2025	5.23	No	Trace orange staining	Silty sand, wet	4.55	0.68	L	No
HA10.5		1.2	12/11/2025	5.22	No	Orange staining	Sandy silt, light orange grey	4.52	0.7	L	No
HA10.6		1.5	12/11/2025	4.6	No	Organic silt dark brown	Wet organic silt, dark brown	3.89	0.71	L	No
HA11.1	1.7	0.2	12/11/2025	6.8	No	Trace orange mottles	Silt dark brown with roange mottles	5.36	1.44	M	No
HA11.2		0.7	12/11/2025	6.65	No	Trace orange mottles	Silty sand light grey moist to wet	5.4	1.25	L-M	No
HA11.3		1.2	12/11/2025	6.4	No	No	Light grey fine sand	5.03	1.37	L	No
HA11.4		1.7	12/11/2025	6.23	No	Trace dark brown and orange mottles	Wet might grey f-m sand trace silt	4.95	1.28	L	No
HA11.5		2	12/11/2025	6.03	No	Trace dark brown streaks	Wet light grey sand trace dark brown streaks	5.16	0.87	L-M	No
HA14.1	1.5	0.3	14/11/2025	5.1	No	Trace mottles	Silt, light grey trace orange brown mottles, moist	4.07	1.03	M	No
HA14.2		0.7	14/11/2025	5.16	No	No	Silty sand light grey moist to wet	4.55	0.61	M-H	No
HA14.3		1.3	14/11/2025	5.37	No	No	Light grey sand fine, moist	4.61	0.76	L-M	No
HA14.4		1.8	14/11/2025	6.3	No	No	Silty fine sand light grey wet saturated	5.05	1.25	L	No
HA14.5		2.1	14/11/2025	5.79	Yes	No	Bark brown organic silt saturated	3.97	1.82	L	No

Soil Description

Log Identification: HA02

R.L.
NZVD2016: 55m

Coordinates (NZTM):
N: 5807506.46, E: 1810136.80

Investigation method	Depth (meters)	Field Description	Geological Unit
Hand Auger (50mm)	0	**TOPSOIL**; dark brown. Moist.	TS
	0.5	**SILT** with trace fine sand; orange brown. Stiff to very stiff, moist, sensitive, non-plastic. - Colour becoming greyish orange.	Hinuera Formation
	1.0	Silty fine **SAND**; light grey. Loose to dense, wet - Becoming saturated - Sand becoming fine to medium.	
	1.5	Gravelly fine to medium **SAND**; greyish brown. Medium dense to dense saturated. Gravels fine to medium and subrounded	
	2.0	Sandy **SILT**; light greyish brown. Stiff, insensitive, saturated slightly plastic.	
	2.5	Fine to medium **SAND**; greyish brown. Medium dense, saturated.	
	3.0	**End of hand auger at 2.2m** - Continual collapse.	
	3.5		
	4.0		
	4.5		
	5.0		
	5.5	Groundwater encountered at 0.9m after testing.	

Field Test Data

Depth (meters)	Peak Vane Shear Strength (kPa)	Residual Vane Shear Strength (kPa)	Sensitivity	Blow count	Scala Penetrometer (blows per 100mm drop)
0				1	Plot of Scala results: Very loose (1), Loose (2–3), Medium Dense (4–6), Dense (7–10)
				2	
				2	
	83	15	5.5	2	
				1	
0.5				1	
	182	35	5.2	3	
				2	
				3	
1.0				3	
				4	
				4	
				7	
				9	
1.5				9	
				10	
				5	
				4	
	64	42	1.5	5	
				7	
2.0				5	
				5	
				6	
				6	
2.5				5	
				6	
				6	
				4	
				3	
3.0					
3.5					
4.0					
4.5					
5.0					
5.5					

Groundwater Level

Notes:
1. The stratification lines represent the approximate boundary between soil types and the transition may be gradual.
2. OB refers to hand auger over bored. HW refers to scala falling under the weight of the hammer. TS refers to topsoil. * refers to consistency based on diagnostic features
3. Soils have been described in general accordance with NZ Geomechanics Society "Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes", December 2005
4. Vane shear strengths (where reported) have been corrected in general accordance with NZ Geotech Society Inc. "Guideline for Hand Held Shear Vane Test", August 2001.
5. Scala Penetrometer testing (where reported) has been carried out in general accordance with NZS 4402 Test 6.5.2.
6. Coordinates (where reported) are presented in NZTM2000 to an accuracy of ±5m.
7. Shear vane results are multiplied by factor A and plus factor B where applicable

BCD GROUP

Job Number: 23-1883
Client: WTR Waikato Thoroughbred Racing

Shear Vane ID:3294 (19mm blade)
Calibration Expiry Date: 5/08/2026
Shear Vane Factors: A: 1.513

Location: Pencarrow Road / Hooker Road / Duncan Road

Date Of Investigation: 13/11/2025
Logged By: OT
Checked By: LR

Soil Description

Log Identification: HA03

R.L.
NZVD2016: 55m

Coordinates (NZTM):
N: 5807064.54, E: 1810112.59

Investigation method	Depth (meters)	Field Description	Geological Unit
Hand Auger (50mm)		**TOPSOIL**; dark brown. Moist.	TS
		Sandy **SILT**; light orange brown with orange streaks. Stiff, moist, moderately sensitive, slightly plastic.	Hinuera Formation
		- becoming moderately plastic and wet.	
	0.5	Silty fine **SAND**; light greyish brown with orange mottles. Loose to medium dense, wet.	
		Sandy **SILT**; light grey. Very stiff, wet, sensitive, moderately plastic. Sand is fine.	
	1.0	Silty fine to medium **SAND**; light grey. Loose to dense, saturated.	
	1.5	- 10mm thick organic silt.	
		Sandy **SILT**; light brown. Stiff to very stiff*, saturated, slightly plastic.	
	2.0	**End of hand auger at 2.0m** - No sample retained.	
	2.5		
	3.0		
	3.5		
	4.0		
	4.5		
	5.0		
	5.5	Groundwater encountered at 1m during testing.	

Field Test Data

Depth (meters)	Peak Vane Shear Strength (kPa)	Residual Vane Shear Strength (kPa)	Sensitivity	Scala Penetrometer (blows per 100mm drop) Blow count	Groundwater Level
				2	
				3	
				2	
	98	30	3.3	2	
0.5				4	
				2	
				2	
				2	
				4	
1.0	106	23	4.7	8	
				5	
				4	
				4	
				3	
1.5				5	
				4	
				3	
				8	
				6	
2.0				5	
				8	
				6	
				4	
				8	
2.5				9	
				4	
3.0					
3.5					
4.0					
4.5					
5.0					
5.5					

Scala Penetrometer (blows per 100mm drop) — Plot of Scala results: Very loose (0–1), Loose (2–3), Medium Dense (4–6), Dense (7–8), Dense (9–10)

Notes:
1. The stratification lines represent the approximate boundary between soil types and the transition may be gradual.
2. OB refers to hand auger over bored. HW refers to scala falling under the weight of the hammer. TS refers to topsoil. * refers to consistency based on diagnostic features
3. Soils have been described in general accordance with NZ Geomechanics Society "Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes", December 2005
4. Vane shear strengths (where reported) have been corrected in general accordance with NZ Geotech Society Inc. "Guideline for Hand Held Shear Vane Test", August 2001.
5. Scala Penetrometer testing (where reported) has been carried out in general accordance with NZS 4402 Test 6.5.2.
6. Coordinates (where reported) are presented in NZTM2000 to an accuracy of ±5m.
7. Shear vane results are multiplied by factor A and plus factor B where applicable

BCD GROUP

Job Number: 23-1883
Client: WTR Waikato Thoroughbred Racing

Shear Vane ID:3294 (19mm blade)
Calibration Expiry Date: 5/08/2026
Shear Vane Factors: A: 1.513

Location: Pencarrow Road / Hooker Road / Duncan Road

Date Of Investigation: 12/11/2025
Logged By: OT
Checked By: LR

Soil Description

Log Identification: HA07

R.L.
NZVD2016: 54m

Coordinates (NZTM):
N: 5807673.70, E: 1809818.62

Investigation method	Depth (meters)	Field Description	Geological Unit
		TOPSOIL; dark brown. Moist.	TS
		SILT; light orange brown. Stiff to very stiff, moist, moderately sensitive to sensitive, non-plastic.	
	0.5	- colour becoming light brown with trace orange mottles.	
		Fine to medium **SAND**; light grey with trace orange mottles. Loose to dense, moist.	
Hand Auger (50mm)	1.0	- 100mm thick SILT lens. - Sand becoming silty fine sand.	Hinuera Formation
	1.5		
	2.0	- Becoming wet. - Becoming saturated.	
	2.5		
		End of hand auger at 2.8m - No sample retained.	
	3.0		
	3.5		
	4.0		
	4.5		
	5.0		
	5.5	Groundwater encountered at 2.2m during testing.	

Field Test Data

Depth (meters)	Peak Vane Shear Strength (kPa)	Residual Vane Shear Strength (kPa)	Sensitivity	Scala Penetrometer (blows per 100mm drop)	Groundwater Level
				1	
				2	
				2	
	106	23	4.7	2	
				2	
0.5				4	
	91	38	2.4	2	
				1	
				2	
				5	
1.0				6	
				4	
				5	
				5	
1.5				4	
				5	
				5	
				6	
				5	
2.0				9	
				6	
				7	
				7	
				6	
2.5				8	
				5	
				6	
				7	
3.0				6	
3.5					
4.0					
4.5					
5.0					
5.5					

Plot of Scala results: 0 | Very loose 1 | Loose 2 3 | Medium Dense 4 5 6 7 | Dense 8 9 10

Notes:
1. The stratification lines represent the approximate boundary between soil types and the transition may be gradual.
2. OB refers to hand auger over bored. HW refers to scala falling under the weight of the hammer. TS refers to topsoil. * refers to consistency based on diagnostic features
3. Soils have been described in general accordance with NZ Geomechanics Society "Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes", December 2005
4. Vane shear strengths (where reported) have been corrected in general accordance with NZ Geotech Society Inc. "Guideline for Hand Held Shear Vane Test", August 2001.
5. Scala Penetrometer testing (where reported) has been carried out in general accordance with NZS 4402 Test 6.5.2.
6. Coordinates (where reported) are presented in NZTM2000 to an accuracy of ±5m.
7. Shear vane results are multiplied by factor A and plus factor B where applicable

BCD GROUP

Job Number: 23-1883
Client: WTR Waikato Thoroughbred Racing

Shear Vane ID:3294 (19mm blade)
Calibration Expiry Date: 5/08/2026
Shear Vane Factors: A: 1.513

Location: Pencarrow Road / Hooker Road / Duncan Road

Date Of Investigation: 14/11/2025
Logged By: SL
Checked By: LR

Soil Description

Log Identification: HA10

R.L.
NZVD2016: 55m

Coordinates (NZTM):
N: 5806635.13, E: 1810217.40

Investigation method: Hand Auger (50mm)

Depth (meters)	Field Description	Geological Unit
0.0	**TOPSOIL**; dark brown. Moist.	TS
	Sandy **SILT**; dark orange brown. Stiff*, moist, slightly plastic. Sand is fine. - colour becoming light orange brown with orange mottling.	Hinuera Formation
0.5	Silty fine **SAND**; light brown with orange streaks. Loose, moist.	
	Sandy **SILT**; light brownish grey. Very stiff, moist, sensitive, slightly plastic.	
1.0	Silty fine to medium **SAND**; light brownish grey. Medium dense to dense, moist.	
1.5	- Colour includes orange mottling and brown streaks.	
2.0	- Colour becoming dark brown. - Becoming wet. - Becoming saturated. - Sand becoming fine	
2.5		
3.0	**End of hand auger at 2.7m** - No sample retained.	
3.5		
4.0		
4.5		
5.0		
5.5	Groundwater encountered at 2.1m during testing.	

Field Test Data

Depth (meters)	Peak Vane Shear Strength (kPa)	Residual Vane Shear Strength (kPa)	Sensitivity
0.0			
0.5			
1.0	159	23	7.0
1.5			
2.0			
2.5			
3.0			
3.5			
4.0			
4.5			
5.0			
5.5			

Scala Penetrometer (blows per 100mm drop)

Plot of Scala results: Very loose | Loose | Medium Dense | Dense

Blow count	0 1 2 3 4 5 6 7 8 9 10
4	
3	
2	
2	
1	
4	
2	
3	
2	
3	
6	
8	
17	
18	
8	
16	
12	
6	
7	
8	
6	
10	
12	
12	
18	

Groundwater Level

Notes:
1. The stratification lines represent the approximate boundary between soil types and the transition may be gradual.
2. OB refers to hand auger over bored. HW refers to scala falling under the weight of the hammer. TS refers to topsoil. * refers to consistency based on diagnostic features
3. Soils have been described in general accordance with NZ Geomechanics Society "Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes", December 2005
4. Vane shear strengths (where reported) have been corrected in general accordance with NZ Geotech Society Inc. "Guideline for Hand Held Shear Vane Test", August 2001.
5. Scala Penetrometer testing (where reported) has been carried out in general accordance with NZS 4402 Test 6.5.2.
6. Coordinates (where reported) are presented in NZTM2000 to an accuracy of ±5m.
7. Shear vane results are multiplied by factor A and plus factor B where applicable

BCD GROUP

Job Number: 23-1883
Client: WTR Waikato Thoroughbred Racing

Shear Vane ID:3294 (19mm blade)
Calibration Expiry Date: 5/08/2026
Shear Vane Factors: A: 1.513

Location: Pencarrow Road / Hooker Road / Duncan Road

Date Of Investigation: 12/11/2025
Logged By: OT
Checked By: LR

Soil Description

Log Identification: HA11

R.L.
NZVD2016: 56m

Coordinates (NZTM):
N: 5806630.24, E: 1809912.81

Investigation method: Hand Auger (50mm)

Depth (meters)	Field Description	Geological Unit
	Sandy **TOPSOIL**; dark brown. Moist.	TS
0.5	Fine to medium **SAND** with some silt; greyish brown orange brown mottling. Loose to dense, moist.	Hinuera Formation
	- Sand becoming coarse and containing trace fine subrounded to sub angler gravel. Containing orange brown staining.	
1.0	- Sand becoming fine to medium and wet.	
1.5	**SILT**; whitish grey. Stiff, moist, moderately sensitive, slightly plastic.	
	Fine **SAND** with some silt; light brown. Loose to medium dense, wet to saturated.	
2.0	- becoming saturated.	
	SILT with trace fine sand; light grey with dark brown speckles. Stiff to very stiff*, moist to wet, slightly plastic.	
2.5	Fine to medium **SAND**; light grey. Medium dense, saturated.	
3.0	**End of hand auger at 2.7m** - Continual collapse	
3.5		
4.0		
4.5		
5.0		
5.5	Groundwater encountered at 1.7m after testing.	

Field Test Data

Depth (meters)	Peak Vane Shear Strength (kPa)	Residual Vane Shear Strength (kPa)	Sensitivity	Scala Penetrometer (blows per 100mm drop)
0.5				3 4 5 3 5
1.0				8 4 5 5 5
1.5	91	30	3.0	8 9 4 5 6
2.0				6 4 5 5 2
2.5				1 4 5 7 6
3.0				5 5 5 4
3.5				
4.0				
4.5				
5.0				
5.5				

Plot of Scala results: Very loose (0–1), Loose (1–3), Medium Dense (4–6), Dense (7–10)

Groundwater Level

Notes:
1. The stratification lines represent the approximate boundary between soil types and the transition may be gradual.
2. OB refers to hand auger over bored. HW refers to scala falling under the weight of the hammer. TS refers to topsoil. * refers to consistency based on diagnostic features
3. Soils have been described in general accordance with NZ Geomechanics Society "Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes", December 2005
4. Vane shear strengths (where reported) have been corrected in general accordance with NZ Geotech Society Inc. "Guideline for Hand Held Shear Vane Test", August 2001.
5. Scala Penetrometer testing (where reported) has been carried out in general accordance with NZS 4402 Test 6.5.2.
6. Coordinates (where reported) are presented in NZTM2000 to an accuracy of ±5m.
7. Shear vane results are multiplied by factor A and plus factor B where applicable

BCD GROUP

Job Number: 23-1883
Client: WTR Waikato Thoroughbred Racing

Shear Vane ID:3294 (19mm blade)
Calibration Expiry Date: 5/08/2026
Shear Vane Factors: A: 1.513

Location: Pencarrow Road / Hooker Road / Duncan Road

Date Of Investigation: 10/11/2025
Logged By: SL
Checked By: LR

Soil Description

Log Identification: HA14

R.L.
NZVD2016: 55m

Coordinates (NZTM):
N: 5807208.26, E: 1809494.55

Investigation method	Depth (meters)	Field Description	Geological Unit
Hand Auger (50mm)	0	**TOPSOIL**; dark brown with trace fine to medium subangular gravel. Dry.	TS
	0.5	**SILT** with trace fine sand; greyish brown with light grey, orange brown and dark brown streaks. Stiff to very stiff, moist, moderately sensitive, slightly plastic.	Hinuera Formation
	1.0	- Becoming sandy and moist to wet. Sand is fine. - 100mm thick organic silt layer; dark brown.	
	1.5	Coarse **SAND** with some silt; light grey. Loose to medium dense, moist to wet. - Becoming saturated.	
	2.0	Sandy **SILT**; light grey. Stiff to very stiff*, wet, non-plastic.	
	2.5	Silty fine **SAND**; light grey. Medium dense to dense, wet. - becoming saturated.	
	3.0	**End of hand auger at 2.4m** - No sample retained.	
	3.5		
	4.0		
	4.5		
	5.0		
	5.5	Groundwater encountered at 1.5m during testing.	

Field Test Data

Depth (meters)	Peak Vane Shear Strength (kPa)	Residual Vane Shear Strength (kPa)	Sensitivity	Scala Penetrometer (blows per 100mm drop)	Groundwater Level
0				2 2 2 2 2	
0.5	182	30	6.0	2 3 3	
	91	15	6.0	4 4	
1.0				3 4 7 4 3	
1.5				3 3 3 6 OB	
2.0				OB 5 4 6 6	
2.5				9 6 7 7	
3.0					
3.5					
4.0					
4.5					
5.0					
5.5					

Plot of Scala results: Very loose (1) | Loose (2 3) | Medium Dense (4 5 6 7) | Dense (8 9 10)

Notes:
1. The stratification lines represent the approximate boundary between soil types and the transition may be gradual.
2. OB refers to hand auger over bored. HW refers to scala falling under the weight of the hammer. TS refers to topsoil. * refers to consistency based on diagnostic features
3. Soils have been described in general accordance with NZ Geomechanics Society "Guideline for the Field Classification and Description of Soil and Rock for Engineering Purposes", December 2005
4. Vane shear strengths (where reported) have been corrected in general accordance with NZ Geotech Society Inc. "Guideline for Hand Held Shear Vane Test", August 2001.
5. Scala Penetrometer testing (where reported) has been carried out in general accordance with NZS 4402 Test 6.5.2.
6. Coordinates (where reported) are presented in NZTM2000 to an accuracy of ±5m.
7. Shear vane results are multiplied by factor A and plus factor B where applicable

BCD GROUP

Job Number: 23-1883
Client: WTR Waikato Thoroughbred Racing

Shear Vane ID:3294 (19mm blade)
Calibration Expiry Date: 5/08/2026
Shear Vane Factors: A: 1.513

Location: Pencarrow Road / Hooker Road / Duncan Road

Date Of Investigation: 14/11/2025
Logged By: SL
Checked By: LR

Appendix A: Soil field tests

This Appendix provides information on how to perform field pH and carbonate tests and interpret their results. It is important to note that, while a useful exploratory tool, field tests are indicative only. They cannot be used as a substitute for laboratory analysis to determine the presence or absence of acid sulfate soils (ASS).

Further laboratory analysis is also needed to quantify the acidity and other hazards.

Details on the laboratory analyses required for ASS are provided in the National Acid Sulfate Soils Identification and Laboratory Methods Manual (Sullivan et al. 2018b).

A1.1 Soil field test equipment

It is important that prior to conducting the field tests, the appropriate testing equipment is obtained. For a basic set up the following items are required:

1) pH meter and electrode (charged and calibrated),
2) at least 2 buffer solutions (for example pH 4.0 and pH 7.0),
3) centrifuge tubes or beakers – wide, unbreakable, heat resistant and clear (for example Falcon 50 mL polypropylene),
4) centrifuge tube or jar rack marked with soil sample depths – use a separate rack for pH_F tests and pH_{FOX} tests in case they bubble over,
5) stirrers for centrifuge tubes,
6) 30% hydrogen peroxide (H_2O_2) pH adjusted to 4.5–5.5,
7) storage bottle for H_2O_2,
8) sodium hydroxide (NaOH) to raise pH of peroxide to 4.5–5.5 (pH 5.5 ideal),
9) deionised (DI) water,
10) squirt bottle for DI water,
11) tissues,
12) gloves and safety glasses,
13) protective clothing,
14) bucket to collect used soil and hydrogen peroxide,
15) bucket and brush to clean tubes for next sample,
16) recording sheets,
17) excess water for rinsing,
18) first aid kit – especially eye wash solutions, and
19) 1 M hydrochloric (HCl) acid to test for shell presence.

A1.2 Conducting field tests – some considerations

When the analytical results are reported, both the field test results and informative soil profile descriptions will aid the interpretation of the laboratory results and help provide a better

understanding of the soil properties and behaviour on the site, especially with respect to the acidity hazard.

When performing pH_F tests, soil samples must be analysed as soon as possible after sampling. If Reduced Inorganic Sulfur (RIS) are present, they are often capable of rapid oxidation causing substantially lowered pH_F values. Delayed determinations of pH_F may provide results that do not faithfully represent pH conditions in the field at the time of sampling.

The rate of reaction in the pH_{FOX} test is temperature dependent and can take up to an hour to complete under cold conditions. It is important to allow sufficient time for the reaction to occur, especially in cool weather.

Field pH tests should be performed on site, however, there are many areas (for example wetlands) where performing field tests in situ can prove difficult (for example too wet, mosquito problems). In such situations, samples should be preserved (for example kept on dry ice), taken to a suitable location for the conduct of field tests and the delay in time between sampling and 'field' analysis recorded with the field test results.

A1.3 On-site chemical and material safety precautions

A1.3.1 Hydrogen peroxide

Care needs to be taken when using hydrogen peroxide (H_2O_2) in the field. Hydrogen peroxide (30%) is used as the primary reagent in the pH_{FOX} test. The concentration is 10 times stronger than the peroxide commonly found in household medicine cabinets. The reaction of peroxide with soil containing RIS may produce sulfurous gases and generate heat in excess of 90 °C.

Caution: 30% hydrogen peroxide is a strong oxidising agent and should be handled carefully with appropriate eye and skin protection. This test is suitable for experienced operators only.

The peroxide when first received may have a pH of 3.5 or lower. Chemical companies commonly put stabilisers in the peroxide to prevent it from decomposing and releasing oxygen by keeping the pH low. The pH required for the pH_{FOX} is pH 4.5–5.5; this may be obtained by adding sodium hydroxide (NaOH; pH14).

Since both of these chemicals are highly corrosive and many of the long-term side effects are not fully known, it is recommended the following precautions are taken when performing field tests.

Always:

- use gloves, safety glasses, lab coat or protective clothes,
- conduct pH peroxide test in a well-ventilated area,
- use test tubes capable of withstanding rapid heat changes and high temperatures,
- avoid skin and eye contact with peroxide, and
- label all peroxide bottles with safety data information.

A1.3.2 Other chemicals

Several other chemicals are used in the field when sampling suspected ASS materials. Buffering solutions and potassium chloride (KCl) solutions are used to calibrate and maintain pH meters and

care should be exercised when using these substances. Follow the appropriate safety directions on Safety Data Sheets (SDS).

Hydrochloric acid (HCl) is used when performing tests to assess the presence of carbonates in soil material (see Field carbonate test). Hydrochloric acid is strongly acidic and is very corrosive to the skin, therefore, caution is required when using it. Again, follow the appropriate directions outlined in the SDS.

Store HCl separately from buffer solutions as HCl gas may slowly diffuse through the plastic bottles and alter the buffer solutions.

A1.4 Field pH tests

A1.4.1 Introduction

The pH_F and pH_{FOX} tests have been developed for rapid assessment in the field for the likelihood of ASS. These tests are easy to conduct, quick, and have a minimum set-up cost. The field tests have been developed to give reasonable indication for many soils (provided the tests are performed properly). Although these field tests may provide an indication of ASS presence, they are purely qualitative, indicative, and do not give quantitative measures of the amount of acid that has been or could be produced through the RIS oxidation process.

Field pH tests should be part of any ASS investigation. The field pH tests (both pH_F and pH_{FOX}) should be conducted at 0.25 m intervals on the soil profile, ensuring at least one test per soil layer/horizon.

It is recommended that field tests be conducted on-site. If the tests cannot be performed in the field, tests should be conducted as soon as possible, ensuring appropriate sample and preservation procedures are observed (see the Sample handling, transport and storage section in Section 6 for further details) and delays between sampling and the 'field' analysis are recorded with the results.

Samples suspected of containing monosulfides should undergo field pH testing immediately.

The field pH tests outlined below are from the Queensland Acid Sulfate Soils Investigation Team (QASSIT) Acid Sulfate Soils Laboratory Methods Guidelines (Ahern et al. 2004).

A1.4.2 Field pH test (pH_F) – NSM-1.1

The procedure for the pH_F is outlined below:

- Calibrate battery powered field pH meter according to manufacturer's instructions.
- Prepare the centrifuge tubes in a tube rack. Mark the rack with the depths to identify the top and bottom of the profile. Use separate racks for the pH_F and pH_{FOX} tests to prevent cross contamination from violent pH_{FOX} reactions.
- Conduct tests at intervals on the soil profile of 0.25 m, or at least one test per soil layer/horizon, whichever is lesser.
- For each layer place approximately half a teaspoon of soil into each of the pH_F and pH_{FOX} tubes. It is important the two sub-samples come from the same depth and are similar in characteristics. For example, do not take half a teaspoon of grey mud from the 0–0.25 m depth for one test and then select half a teaspoon from the same depth layer that has yellow mottles for the other test.

- Place enough deionised (DI) water in the pH_F test tube to make a paste similar to 'grout mix' or 'white sauce'; stir the soil:water paste to ensure all soil 'lumps' are removed (demineralised water can be substituted; never use tap water). Water must be added to the soil samples within 10 min of sampling to reduce the risk of RIS oxidation; monosulfidic material may start to oxidise in less than 5 min, substantially affecting pH_F results.
- Immediately place the pH spear point electrode into the soil:water paste, ensuring the spear point is completely submerged. Never stir the paste with the electrode as this may damage the semi-permeable glass membrane.
- Measure the pH_F with the calibrated pH meter.
- Wait for the reading to stabilise and record the pH measurement.
- All measurements should be recorded on a data sheet.

A1.4.3 Field pH peroxide test (pH_{FOX}) – NSM-1.2

It is recommended that 30% hydrogen peroxide (H_2O_2) be used in the pH_{FOX} test.

Hydrogen peroxide (30%) is highly corrosive and care should be taken when handling and using the peroxide. Safety glasses and gloves should be worn when handling and using peroxide. All chemical bottles should be clearly labelled and Safety Data Sheets (SDS) should be kept with the chemicals at all times. Appropriate health and safety precautions should be adhered to. Peroxide should be kept in the fridge when not in use.

The procedure for the field pH peroxide test (pH_{FOX}) is outlined below:

- Adjust the pH of the H_2O_2 to between 4.5 and 5.5 before going into the field. While stirring, add a few drops of dilute NaOH and regularly check the pH with a calibrated electrode until the correct range is reached. Allow the peroxide to stand for 15 min and then recheck the pH. As H_2O_2 degrades over time, only buffer small quantities at a time and refrigerate when not in use.
- Calibrate battery powered field pH meter according to manufacturer's instructions.
- Prepare heat-resistant centrifuge tubes in a tube rack. Mark the rack with the depths to identify the top and bottom of the profile. Use separate racks for the pH_F and pH_{FOX} tests to prevent cross contamination from violent pH_{FOX} reactions.
- Conduct pH_{FOX} tests at intervals on the soil profile of 0.25 m or at least one per horizon, whichever is lesser.
- To the pH_{FOX} tube, prepared while sampling for pH_F, add sufficient 30% H_2O_2 (at room temperature) to cover the soil, then stir the mixture.
- Rate the reaction of soil and peroxide using the reaction scale in Table A1.
- Allow approximately 15 min for any reactions to occur. The reaction may be rapid and vigorous if substantial RIS is present. If the reaction is violent and the soil:peroxide mix may overtop the tube, use a wash bottle to add small amounts of deionised or demineralised water to cool and calm the reaction. Do not add too much water as this may dilute the mixture and affect the pH value.
- Add a further 1–2 mL of H_2O_2, mix, allow to react for 15 min and rate the reaction. Continue this process until the soil:peroxide mixture reaction has slowed. This will ensure most of the RIS have reacted.
- If there is no initial reaction, individual tubes containing the soil:peroxide mixture can be placed in direct sunlight. This may encourage the initial reaction to occur.

- Wait for the soil:peroxide mixture to cool. This may take up to 10 min as the reaction can exceed 90 °C. Check the temperature rating of the pH meter and probe as high temperatures can damage the electrode and result in inaccurate readings. A more accurate pH is recorded if a temperature probe is used, however, this may be impractical in some field situations.
- Place the spear point pH electrode into the soil:peroxide mixture, ensuring the spear point is completely submerged. Never stir the paste with the electrode as this may damage the semi-permeable glass membrane.
- Measure the pH_{FOX} with the calibrated pH meter.
- Wait for the reading to stabilise and record the pH_{FOX} measurement.
- All measurements should be recorded on a data sheet.

Rating soil reactions of the pH_{FOX} test

Table A1 indicates the reaction scale for pH_{FOX} tests. The rate of the reaction generally indicates the level of RIS present, but depends also on texture and other soil constituents. A soil containing very little RIS may only have a slight reaction (L), however a soil containing high levels of RIS (remember the exact level of RIS cannot be determined using the pH_{FOX} test) is more likely to have an extreme/volcanic reaction (X–V), although there are exceptions. This rating scale alone should not be used to identify ASS. It is not a very reliable feature in isolation as there are other factors including manganese and organic acids which may trigger reactions. Reactions with organic matter tend to be more 'frothing' and do not tend to generate as much heat as sulfidic reactions. Manganese reactions can be quite extreme, but do not tend to lower the pH_{FOX}.

Table A1 Soil reaction rating scale for the pH_{FOX} test.

Reaction scale	Rate of reaction
L	Low reaction
M	Medium reaction
H	High reaction
X	Extreme reaction
V	Volcanic reaction

Source: DER (2015a).

A1.4.4 Interpretation of field pH tests

The pH_F test can help identify Actual ASS. While a pH_F of less than or equal to 4 is indicative of the presence of Actual ASS, it is not conclusive of the presence of ASS on its own, as naturally occurring, non ASS soils such as many organic soils (for example peats) and heavily leached soils may also have pH_F less than or equal to 4. To identify as an Actual ASS, other evidence must be presented that indicates that the low pH_F has been mainly caused by the oxidation of RIS. Such information includes the presence of jarosite in the soil layer/horizon, or the location of other Actual ASS or PASS materials within or in the nearby vicinity to the sampling location.

The difference between the pH_F and the pH_{FOX} is helpful in the preliminary identification of PASS. Combined the pH_F and pH_{FOX} results can be a useful aid with soil sample selection for laboratory analysis during Stage 2 of the field site investigations.

The pH_{FOX} result when compared to the pH_F result can give an indication of the presence of RIS in the sample. To ensure accurate results both of these tests must be conducted in the field as soon as

possible after the sample is collected as the pH of the soil sample can change relatively quickly with time (hours to days) even when recommended sample preservation techniques are employed. For example, it is not unusual for soil pH test carried out at a laboratory to differ considerably (that is greater thana pH unit) from soil pH test measured in the field after even one day of storage, and as such, a laboratory determination of pH_F at a later date cannot be relied upon to represent field conditions at the time of sampling.

Soil field pH_F and pH_{FOX} tests whilst useful exploratory tools, however, are not determinative and cannot be substituted for laboratory analysis for either the identification of ASS materials and quantification of the acidity hazards these materials pose. A recent review of the utility of these field tests in Western Australia indicated that these tests only accurately identified ASS materials in 60 to 80 per cent of cases (DER 2015a).

A comparison of pH_F and pH_{FOX} test results can often give a strong indication of the presence of ASS. The greater the drop in pH from pH_F following the addition of peroxide, the greater the likelihood of PASS, although there are exceptions. A combination of a large difference between the two pH tests, a strong reaction with peroxide and a low pH after peroxide oxidation (that is pH_{FOX} less than 3) strongly indicates the presence of PASS.

However, it is important to note that the definitive confirmation of either the presence or absence of PASS materials in the field can only be accomplished by appropriate laboratory testing.

Tables A2 and A3 provide some guidance on the interpretation of pH_F and pH_{FOX} test results, respectively.

Table A2 Interpretation of some pH_F test ranges.

pH value	Result	Comments
$pH_F \leq 4$, jarosite not observed in the soil layer/horizon	May indicate an AASS indicating previous oxidation of RIS or may indicate naturally occurring, non ASS soils	Generally not conclusive as naturally occurring, non ASS soils, such as many organic soils (for example peats) and heavily leached soils, often also return $pH_F \leq 4$
$pH_F \leq 4$, jarosite observed in the soil layer/horizon	The soil material is an AASS	Jarosite and other iron precipitate minerals in ASS such as schwertmannite require a pH < 4 to form and indicate prior oxidation of RIS
$pH_F > 7$	Expected in waterlogged, unoxidised, or poorly drained soils	Marine muds commonly have a pH > 7 which reflects a seawater (pH 8.2) influence. Oxidation of samples with H_2O_2 can help indicate if the soil materials contain RIS

Source: Adapted from DER (2015a).

Table A3 Interpretation of pH_{FOX} test results.

pH value and reaction	Result	Comments
Strong reaction of soil with H_2O_2 (that is X or V)	Useful indicator of the presence of RIS but cannot be used alone	Organic rich substrates such as peat and coffee rock, and soil constituents like manganese oxides, can also cause a reaction. Care must be exercised in interpreting these results. Laboratory analyses are required to confirm if appreciable RIS is present

pH value and reaction	Result	Comments
pH_{FOX} value at least one unit below field pH_F and strong reaction with H_2O_2 (that is X or V)	May indicate PASS	The difference between pH_F and pH_{FOX} is termed the ΔpH. Generally the larger the ΔpH the more indicative of PASS. The lower the final pH_{FOX} the better the likelihood of an appreciable RIS content. For example, a change from pH_F of 8 to pH_{FOX} of 7 (that is a ΔpH of 1) would not indicate PASS, however, a unit change from pH_F of 3.5 to pH_{FOX} of 2.5 would be indicative of PASS. Laboratory analyses are required to confirm if appreciable RIS is present
pH_{FOX} < 3, large ΔpH and a strong reaction with H_2O_2 (that is X or V)	Strongly indicates PASS	The lower the pH_{FOX} below 3, the greater the likelihood that appreciable RIS is present. A combination of all three parameters – pH_{FOX}, ΔpH and reaction strength – gives the best indication of PASS. Laboratory analyses are required to confirm that appreciable RIS is present
A pH_{FOX} 3–4 and Low, Medium or Strong reaction with H_2O_2	Inconclusive	RIS may be present; however, organic matter may also be responsible for the decrease in pH. Laboratory analyses are required to confirm the presence of RIS
pH_{FOX} 4–5	Inconclusive	RIS may be present in small quantities, or poorly reactive under rapid oxidation, or the sample may contain shell/ carbonate which neutralises some or all acid produced on oxidation. Equally, the pH_{FOX} value may be due to the production of organic acids with no RIS present. Laboratory analyses are required to confirm if appreciable RIS is present
pH_{FOX} > 5, small or no ΔpH, but Low, Medium or Strong reaction with H_2O_2	Inconclusive	For neutral to alkaline pHF with shell or white concretions, the fizz test with 1 M HCl can be used to identify the presence of carbonates. Laboratory analyses are required to confirm if appreciable RIS is present and further testing is required to confirm that effective self-neutralising materials are present

Source: Adapted from DER (2015a).

A1.5 Field carbonate test – NSM-2.1

The field carbonate test (commonly referred to as the 'fizz test') is used to determine the presence of carbonates in soil. It is a quick, easy, cheap test to conduct in the field. The test should be conducted on samples suspected of containing carbonates (for example fine shell, crushed coral, et cetera). The carbonate content of the soil can be quantified in the laboratory by the determination of the Total Organic Carbon content (NLM-5.1) (Sullivan et al. 2017b). The field carbonate test outlined below is from the QASSIT Acid Sulfate Soils Laboratory Methods Guidelines (Ahern et al. 2004).

- Place approximately one teaspoon of soil into a clean, clear test tube. It is important that test tubes used in the fizz test are not used for the field pH tests as cross-contamination may occur, affecting pH readings.
- Place two or three drops of 1 M hydrochloric acid (HCl) onto the soil sample. HCl is highly corrosive so safety precautions must be exercised.
- Rate the reaction (see Table A4).
- All measurements should be recorded on a data sheet.

Table A4 Soil reaction rating scale for the fizz test.

Reaction scale	Rate of reaction
N – non-calcareous	No audible or visible effervescence
S – slightly calcareous	Slightly audible but no visible effervescence
M – moderately calcareous	Audible and slightly visible effervescence
H – highly calcareous	Moderate visible effervescence
V – very highly calcareous	Strong visible effervescence

Source: McDonald et al. (1990).