ACID SULFATE MANAGEMENT PLAN
FOR A PROPOSED DEVELOPMENT

Turtle Cove Haven Retirement Village

At

RIVER HEADS

Prepared For

REMC

By

Bio-Track Pty Ltd

27 April, 2018

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This report has been prepared by Peter Edmiston B.App.Sc.(Hons), M.Phil. for and on behalf of Bio-Track Pty Ltd (ABN 91 056 237 275).

Peter Edmiston
Director Bio-Track

Technical Assistance
The evaluation of technical reports is sometimes difficult. Bio-Track remains available to answer questions regarding this report. Users of this report are encouraged to contact Peter Edmiston on (07) 3289 7179 to resolve technical issues raised within this report that require clarification.

Peter Edmiston

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ACID SULFATE MANAGEMENT PLAN
FOR A PROPOSED DEVELOPMENT AT
1493-1501 Wynnum Rd Tingalpa

1 INTRODUCTION

Bio-Track Pty Ltd has been commissioned by REMC to prepare an acid sulfate soil management plan (ASSMP) for a proposed development (Turtle Cove Retirement Village) at River Heads. It is assumed the reader will have access to other documents providing a project overview and civil design details.

This report places a priority on management of ASS. The body of this report is devoted to management.

Section 2 provides a summary of most important requirements. It is essential contractors understand this section. The principal contractor needs to be briefed regarding the requirements of this acid sulfate management plan. In particular, the requirement to undertake validation testing of lime treated soil and record the movement of soil must be understood.

Please note, post-construction compliance reporting relies upon **accurate record keeping**. In the absence of accurate records it may be necessary to re-sample and re-test soil. Where tests fail, additional treatment may be required. The cost of non-compliant soil conditions can be extremely high.

It is essential the source of imported fill is recorded as well as the volume involved and placement location.

Land development is normally controlled by local government approvals. These approvals will reference specific acid sulfate soil management procedures, where they are required. Disturbance of ASS land without the necessary approval/s can not be recommended.

The purpose of this ASSMP is to provide effective control of acid sulfate soil (ASS) that would be disturbed as a consequence of the proposed construction activity. The methods proposed are intended to satisfy the requirements for effective control of ASS using techniques described in the Queensland Acid Sulfate Soil Technical Manual, Soil Management Guidelines Ver 3.8, 2002. The details of development approval conditions relating to ASS must be understood prior to the start of a project.

Soil excavation that affect soils above 5 m AHD is not considered by this ASSMP.

Any form of acidity has the potential to cause corrosion of construction materials that are susceptible to corrosion. Design engineers should consider this when specifying construction materials. A generic lime treatment rate for soil in contact with roads, paths and buried services is provided. However, a wide range of management options are available.

Civil, structural and mechanical design is not addressed by this report and the appropriate persons should be consulted for this information.

Appendix 1 contains a site description, soil chemical analysis data, site drawings and field observations. Please contact Bio-Track for assistance and data interpretation relating to this report.
A large body of reliable ASS information is available on the internet from Australian state government web sites. It is not the intention of this report to duplicate this reference material.

The soil conditions beyond the area of study and below the depth of testing remain unknown. Extrapolating the lime treatment rates to manage unknown soil conditions is not recommended and is not approved by current acid sulfate soil regulatory guidelines. Further assessment is required before disturbance of untested soil is undertaken.

2 SUMMARY OF CONTROL MEASURES

2.01 Lime Treatment of Disturbed Soil

* ***Use agricultural lime (calcium carbonate) for soil treatment, not other forms (e.g. calcium hydroxide/ calcium oxide).***

* the required treatment rate is tabled below. If accurate control is maintained over the depth of excavation then the lime treatment rate can be varied by depth. If depth control can not be ensured then lime treat at the highest rate for all depths. Averaging of the treatment rate across a depth range should not be undertaken. Averaging only works when the soil is completely mixed and this is impractical on a construction site.

Natural Soil Depth Range	**Lime Treatment Rate**	
Soil Disturbed Above 5 m AHD	Not classified as ASS, no treatment	
Treatment of ASS Soil		
	kg/m3	litres/m3 *
0.2 m below natural ground level RETAINED topsoil (re-used on site)	0	0
0.2 m below natural ground level EXPORTED topsoil (exported from the site)	14	10.0
0.2 to 0.5 metres below ground level	14	10.0
0.5 metres to 1.0 metres below ground level	27	19.3
1.0 metres to 1.8 metres below ground level	35	25
below 1.8 metres	UNKNOWN further investigation required	
Protection of Services		
Service trenches for services located below 5 m AHD in untreated ASS	5 kg of agricultural lime spread per square metre of trench floor. Backfill with lime treated soil at the above recommended treatment rates	

Table 1: Lime Treatment Rates

* The density of dry agricultural lime is approximately 1.4 tons/m3 or 1.4 kg/litre.

2.02 Capping and Separation of Untreated Acid Sulfate Soil

Potential Hazard
Shallow groundwater may exist two m below the lowest constructed surface. No groundwater data is available but it may have a pH of ~4.5.

Buildings, drainage lines and constructed waterbodies require separation from underlying acid soil. Acid soil water can migrate upward and result in corrosion or acidification of surface water. Separation is required to prevent this. The following separation distances are required between the receptor and untreated acid sulfate soil.

Receptor	**Minimum Separation (m)**	**Conditions**
Housing Land Surface	0.5	Groundwater > 2 m below ground level *
Housing Land Surface	1.0	Groundwater 1- 2 m below ground level *
Housing Land Surface	1.5	Groundwater <1 m below ground level *
Water Body Floor	0.5 m	
Drainage Line	0.5 m	
Roads, gutters, foundations	0.3	
* Long term groundwater level after construction. If land is raised by filling then allow for this.		

Table 2: Capping & Separation Requirement

The capping (separation) material must be either lime treated ASS or non-ASS soil. The compaction of the separation material should be to the appropriate standard as defined by engineering design.

Alternative protection measures include a sacrificial lime bed or membrane barrier.

2.03 Water Acidity Control

* dewatering volumes are likely to be limited to ingress of rainwater and runoff as groundwater is expected to be located below the depth of excavation. The pH of water discharged must be in the range of 6.5 to 8.5.

* if excavation of lakes or other ponded water areas is considered then further study will be required to assess the effect upon groundwater and the ponded water quality.

2.04 Validation of Lime Treated Soil

The soil sample is to be a composite of at least 10 well mixed sub-samples. Validation testing of lime treated samples will require time for sampling, sample transport to a laboratory, sample drying and analysis. This process can easily require 5-7 working days. The treatment pad and any storage areas need to be sized to accommodate treated soil that remains to be validated.

Validation testing of lime treated soil is to be at a rate of one test per 500 m3 of lime treated soil

The sample is deemed to pass when:

* ***the pH_{KCl} is >6.5, and***
* ***the equivalent sulphur is <0.03%***

Volumes of soil which have samples that fail should be subject to re-testing or further lime treatment and then re-testing.

2.05 Construction Records

* a construction record must be maintained describing the movement of soil. This would include dates and volumes. The source and placement of all soil, any treatment and all validation test results must be recorded. Future land holders need to have knowledge of the soil properties. Any off-site movement of soil must be recorded.

* a record must be kept of soil sampling and validation test results

* a record must be kept of the water quality of all discharged waters. Testing is to include date and time/s, approximate volume, and the pH, suspended solids and turbidity of the discharged water.

2.06 Offsite Placement of Excavated Soil

It is preferred to retain treated soil on the development area. If off-site placement is required then the following actions must be undertaken:

* the land holder must agree in writing to accept the treated material
* the land holder must be provided with copies of soil analysis reports and a written declaration of the volume and placement location
* prior to placement local authority must be provided with copies of soil analysis reports and a written declaration of the volume and placement location. Check with the local authority to ensure the placement complies with any local regulations.
* transport of treated soil should be performed using covered vehicles and no drainage water must escape onto public access areas

3 SOIL DESCRIPTION

The soil is acidic, non-sulphidic with an elevated sulfate content. The texture is a silty clay. The profile description indicates the soil is periodically oxidised and reduced. The site elevation is below 5 m AHD. The elevation, topography, soil observations and chemistry indicate the soil is an actual acid sulfate soil and than sulphide can be expected at depth. The existing acidity levels range from slight to strongly acid. The level of acidity exceeds the guideline values defining an acid sulfate soil and an acid sulfate management plan is required.

Potential Hazards

* deep stormwater drains having acid batters and acid seepage water
* deep excavation for control basins exposing acid soil
* construction de-watering basins being constructed into acid soil
* corrosion of metal and concrete services by aggressive soil (acid and saline conditions)
* poor growth of plants in topsoil mixed with acid sub-soil
* acid seepage water being released if high groundwater conditions prevail (e.g. after wet season events>
* erosion of acid soil in stormwater.

ALL of the above hazards can be adequately controlled with appropriate design. This needs to be addressed by the appropriate specialist and contractors.

Low lying coastal areas are frequently highly variable across small distances. Care is required if soil conditions change from those described in the attached geotechnical report.

4 SOIL MANAGEMENT

The land owner is responsible for environmental protection and compliance with regulation and development conditions.

Prior to the commencement of earthworks a site meeting/s will be undertaken. This meeting/s will be used to define the roles and responsibilities for management of acid sulfate soil. It is essential the site foreman/manager understands the requirements for management of acid sulfate soil. It is essential all contractors who are involved with or affected by the ASSMP are informed of their responsibilities and are provided with sufficient information and or training to competently perform their duties.

Depending on the scale and duration of the project, regular monitoring of surface and shallow groundwater should be undertaken. The maximum recommended interval between sampling events should be 30 days. Where the period of bulk earthworks is less than 30 days then one before and after construction sampling event would suffice.

If significant volumes of discharge water are anticipated then the background water quality conditions should be examined. Immediately prior (within 2 weeks) to the commencement of works, it is recommended samples of upstream and downstream receiving surface waters (permanent water) and local shallow (0-6 m) groundwater be tested for electrical conductivity, pH, titratable acidity and dissolved metals. It is recommended surface waters should also be tested for turbidity and suspended solids. These samples provide a description of background conditions.

It is desirable, but not essential, that an independent person/organisation be assigned the task of supervising the ASSMP. This role should be assigned prior to the commencement of works. The auditor should report directly to the project manager. Items of special concern include:

* management of runoff water leaving the site
* monitoring of lime application rates and mixing procedures
* soil treatment validation procedures, including sampling, analysis and interpretation of results
* record keeping including movement of soil, off-site placement of soil
* non-conforming soil and water conditions
* management of severe weather conditions
* management of soil within quarantine control areas

4.01 Lime Treatment Strategy

A safety factor of 2 has been used. The treatment rate is calculated using the worst case of all samples within the specified depth range having a % S_{eq} > 0.XX 03%. The rates assume an in-situ bulk density is 1.8 tons/cubic metre.

4.02 Segregation of Excavated Soil

It many cases it will be desirable to do some of the following:

- strip topsoil (0.2 m) for subsequent re-use or export
- segregate high concentration from low concentration ASS with different rates of treatment (or reburial). Refer to Table 1 for a schedule for segregation and treatment.

4.03 Lime Application

For soil treatment use **agricultural lime** (calcium carbonate), not other forms (e.g. calcium hydroxide/calcium oxide). If other forms of lime are considered then specialist advice needs to be obtained regarding the treatment rates, process and placement. Treatment with calcium hydroxide and calcium oxide will result in higher pH values which are likely to exceed 8.5. This can result in adverse environmental consequences where runoff and drainage water has a pH greater than 8.5. Calcium hydroxide and calcium oxide have aggressive dust and appropriate workplace practices must be used.

It is recommended the disturbed soil is spread across fill areas in layers with the appropriate quantity of lime being spread across the surface. The lime is then cultivated through the layer to provide uniform mixing. The depth of the fill layer will be affected by compaction requirements, machinery, the physical condition of the soil and operator preference. The exact method of mixing is of no consequence provided lime is mixed uniformly through the placed soil. It is stressed care should be taken with mixing as validation samples will subsequently be taken for chemical analysis. If the uniformity of mixing is poor the validation tests are likely to fail.

It is recommended a control mix of soil and lime is carefully prepared. For example if the treatment rate is 5 kg/ton then this is equivalent to 5 grams of lime per kilogram of soil. Carefully weigh the materials and mix them. The lime fragments are normally visible. Retain this material in a clear plastic bag as a visual reference. When lime is added to the soil in the field the visual properties should be approximately similar. The control mix provides a graphic example of what to expect and deviation from this provides an immediate indication of a mixing problem.

4.04 Rapid Lime Treatment & Placement

If it is intended to use the excavated material as trench or other fill, then there will be construction delays associated with lime treatment, validation sampling and validation testing. This is potentially significant during wet weather or due to high ground water, when ingress of water is a major problem. There may also be problems with storage of excavated material or problems associated with securing treated soil in confined or sensitive areas. To minimise the delay, one option is to treat all excavated soil at **three** times the design treatment rate listed in Table 1. The treated soil can then be used for construction. Validation sampling is still required. ***The contractor needs to fully understand the need for accurate dosing and mixing. If validation tests fail, the material may need to be subsequently excavated and re-treated.***

4.05 Lime Storage

Agricultural lime and hydrated lime (builders lime, calcium hydroxide) needs to be stored on-site in a secure manner. It is recommended the hydrated lime (normally supplied in bags) is held in a locked shipping container or similar site building. It is recommended the agricultural lime is held in a bunded storage area. If supplied in bulk then the lime should be covered with plastic to prevent erosion by wind or water and dust becoming a nuisance.

4.06 Bunding of Excavated Soil

* It is proposed to bund any area with untreated disturbed soil, either at the excavation site or placement site.
* It is proposed to **size the bund to retain a Q=2, 60 minute storm event plus a 200 mm freeboard**. For relatively flat areas a surrounding bund height of 500 mm is likely to be adequate.
* All excavated soil will be stored in a bunded area by the end of the working day unless lime treatment has been undertaken.

* The bund must either be constructed from non-ASS material or from lime treated ASS material.

* The bund should drain to a sump or other water collection point.

* The bund floor and wall should be clay or other impermeable material to minimise infiltration of water. The floor should have a hydraulic conductivity of less than 1×10^{-4} m/d for a minimum depth of 400 mm or have an equivalent resistance to the passage of drainage water. Compaction is likely to be required to achieve this level of hydraulic conductivity.

* **Any water trapped within the bund or excavation site must be pH tested prior to discharge. The pH must be adjusted to be within the range of 6.5 to 8.5 prior to discharge**.

* If a bund is impractical smaller stockpiles can be covered with plastic sheeting or similar materials to exclude rainwater. The stockpile must not be located in a runoff flow path.

4.07 Treatment Pad Design

If lime is incorporated with soil at a specific mixing area then the treatment pad should be bunded.

If the pad floor is constructed from untreated acid sulfate soil then the floor must be lime treated as specified in Table 1.

4.08 Imported Fill

Fill excavated from locations with an elevation above 5 m AHD is generally exempt from ASS regulation. Exceptions include deep quarry material and industrial material that contains sulphide. It is essential the source of imported fill is recorded as well as the volume involved and placement location. Acid sub-soil is commonly located above 5 m AHD and the level of acidity may exceed ASS guideline thresholds. Accurate knowledge of the location of this fill will avoid confusion between untreated ASS and untreated imported fill.

4.09 Treatment of Undisturbed Soil

Undisturbed soil will not require treatment. (Undisturbed soil is soil that is not affected by earthworks.) Soil that is filled over and remains covered does not require treatment.

5 WATER MANAGEMENT

It is recommended the contractor has access to a pH meter to permit rapid on-site measurement of pH. Inexpensive meters can be used provided they are maintained and calibrated. An accuracy of 0.2 pH units is sufficient for field work. Colourimetric indicator solutions are unreliable with coloured, turbid and weakly buffered waters and are not recommended.

5.01 Runoff Control

It is recommended a runoff diversion drain be constructed to divert runoff water away from untreated excavated soil and excavation areas should these lie within a runoff pathway. The drain should be checked daily to ensure it is serviceable.

5.02 Ponded Water

The pH of water should be checked prior to any off-site discharge. The pH should lie in the range of 6.5-8.5. Strongly acid water typically has a high aluminium concentration which results in flocculation of suspended solids. Strongly acid ponded water frequently has an unusually high clarity when compared with other ponded water. The acid water sometimes has a blue/greenish tint. The pH of unusually clear or coloured water should be checked.

The presence of rusty precipitates in ponded and seepage water is extremely common for acid soil or where anaerobic seepage water becomes oxidised on contact with air. The pH of water with rusty precipitates should be checked.

If the pH is less than 6.5 then the pH can be raised by adding builders lime (slaked lime or calcium hydroxide). The builders lime is more soluble than agricultural lime but agricultural lime can be used if necessary. The lime should be added in doses, mixed and the pH measured. The pH is likely to resist change until it rises towards a value of 5.5. After this it will often rise quickly with small additions of lime. The mixed water will be turbid but should settle overnight. It is preferable to allow the sediment to settle prior to any discharge. If discharge of turbid water is necessary then sediment can be removed by filtration through sand filter tanks or by slow overland flow across grassed areas.

Water quality should conform to the following criteria prior to discharge:

pH	6.5-8.5	
turbidity	< 75	NTU
suspended solids	< 50	mg/L

Where the receiving water has a pH between 5.5 and 6.5 then the discharge water can have a pH equal to or more than this pH.

If water quality water quality control thresholds have been specified for other purposes, in other studies, then the most conservative value should be adopted.

5.03 Fill Loading Effects

Fill placement on acid sulfate soil has the potential to create environmental problems due to the following processes.

- importing of acid sulfate soil as fill
- extrusion of soft, underlying acid sulfate soil, to oxidise sulphide and generate acidity
- extrusion of soft, underlying acid sulfate soil, to expose soil and release acidity
- compression of saturated pore space that forces groundwater to be discharged
- compression of saturated pore space that modifies the flow of groundwater and forces discharge of acid groundwater
- compression of saturated pore space that modifies the flow of groundwater and lowers the groundwater level, resulting in oxidation of potential acid sulfate soil

The dimensions of the fill area and topography will not provide a significant barrier to groundwater movement and little or no modification of the groundwater flow behaviour is predicted.

Mass displacement of underlying soil as an extrusion is not predicted to occur. Whilst some soil movement will occur, this will be of a minor nature and no exposure of ASS is predicted.

The area and extent of fill loading, combined with the sub-soil observations indicate there will be no significant change to the direction of groundwater flow as a consequence of the fill load.

The vertical (downward) displacement of underlying soil following filling is estimated to be of the order of 0-0.5 m. A more accurate assessment could be made following detailed geotechnical study of the mechanical properties and construction techniques but the cost does not appear justified given the wide margins for error.

A temporary rise in groundwater level of less than 1 m is anticipated. The groundwater is predicted to remain within natural ground and not emerge as seepage or infiltrate the fill.

This change will be affected by the level of groundwater at the time of construction, relative to the adjacent soil porosity. For example, during dry weather when the level is low, porosity changes to the deeper saturated sub-soil is small and groundwater changes are also likely to be small. Over time, the ground water pore pressure will equilibrate across the site and the groundwater level is predicted to return toward the original long term level. A more accurate assessment could be made following detailed hydrological study of the soil properties, groundwater conditions and construction techniques but the cost does not appear justified given the wide margins for error.

5.04 Protection of Services Against Corrosion

Please note that this report does not represent a specialist corrosion study.

As a generalisation, sedimentary/depositional lowland soil (< 5 m AHD), has a significant risk of having a significant corrosion hazard. Sulphidic acid sulfate soils becomes highly corrosive when oxidised. For construction using methods that are sensitive to corrosive soils (e.g. screw piles) it is recommended specialist advice is obtained for corrosion hazard assessment.

Piling below the watertable into material that remains anaerobic should not be exposed to acidity resulting from oxidation of sulphide. However, hazards associated with existing acidity and solutes may remain important.

The wetting/drying zone close to the watertable is particularly aggressive.

Soil affected by marine influences (e.g. tidal, atmospheric salt, saline groundwater) can be expected to have elevated sulfate sulphur which can be aggressive to concrete.

The soil below 5 m AHD is regarded as corrosive, especially to metals.

Please note that whilst treating with lime will reduce the risk of corrosion it can not be regarded as a complete solution. The design of services needs to incorporate the normal range of responses to a potentially corrosive environment (e.g. utilise corrosion resistant materials, increase the concrete cover over steel reinforcing and the increase the thickness of protective coatings).

Lime treatment is designed to control the pH of treated soil and prevent the damage of services by acidity. It will not prevent sulfate sulphur corrosion of concrete. If the sulfate sulphur is actually or potentially above 2000 mg/kg sulphur then sulfate damage to concrete may occur. Samples tested as part of this study are not above this value. Design engineers should include an allowance for potential corrosion where sulfate sulphur levels are elevated or may occur.

Chloride and soil electrical resistivity measurements are recommended where steel services are used in low lying areas. Almost all soil affected by seawater or sea salts is likely to be corrosive to steel services. Acid groundwater will be aggressive to services, particularly where there is a significant movement in groundwater (vertically or horizontally). Some further information is provided in Appendix 1.

Soil subject to saturated conditions (e.g. poor drainage, perched, seasonal and permanent groundwater) will encourage upward migration of moisture through porous materials. Subsequent evaporation of moisture on exposed surfaces will lead to the deposition of salts and the growth of salt crystals. The expanding precipitates can result in exfoliation of construction materials and subsequent reduction in the service life. Lowland soils (e.g. below 5 m AHD) have an increased risk of this problem which is not technically a corrosion problem. Engineering advice is recommended if such conditions are likely.

Recommendations relating to management of corrosion are provided to assist civil and structural engineers with their design. It is **not intended** to be interpreted as a formal design. Such designs should be made by the civil/structural design specialists. The decisions made by engineers and other appropriately qualified design staff are accepted as being the most appropriate outcome and over-ride the more generic advice provided in the report.

6 VALIDATION

Validation testing is regarded as an essential component of the management plan. Due to the variable nature of mixing soil and lime, care must be exercise to obtain a representative sample for validation analysis.

The engineer, project manager, geotechnical officer or other suitably qualified person must ensure the validation testing has been performed and the results are satisfactory. A copy of the test certificates is to be submitted to the local authority (or referral agency).

6.01 Validation Sampling

* The sub-samples must be representative of the treated soil volume. The location of the samples should span the depth as well as the horizontal area for placed soil. For stockpiled soil the samples should be evenly spaced through the soil mass.

* The distribution of lime in a lime treated soil mass is typically highly variable on a small scale. Whilst this mixing is adequate on a "landscape" scale it makes accurate sampling difficult. It can be expected to collect some sub-samples with no lime and others with a high lime content. It is necessary to collect a large number of sub-samples to form a composite sample that provides an "average" lime content.

* This process will take from one hour to one day per composite sample depending on the time required for sub-sample extraction. If sampling is biased towards samples with a high lime content the analysis results will be at odds with the known volume of lime that was applied.

  Use a sampling device to obtain a minimum of 10 and up to 40 approximately equal volumes of limed soil. The minimum sub-sample size should be in the range of 100-200 cc in volume. Mix these carefully on a plastic sheet or container taking care to avoid segregation of the fine and coarse fraction. Quarter down to retain a 200 gram composite sample.

* The location of the sample area/depth is to be recorded.

* Perform validation testing at one test per 500 cubic metres of treated material.

  Validation testing should include chemical analysis (chromium reducible sulphur test suite).

* It is recommended the sampling and mixing method is carefully documented and performed according to plan. A proportion of samples will "fail". This is statistically predictable even though the correct rate of lime has been applied. Adherence to rigorous sampling and mixing techniques makes it difficult to blame the sampling stage should a test fail.

* Samples are regarded as successfully treated provided they meet the following criteria:

  a) oxidised pH >6.5
  b) equivalent sulphur content below 0.03%

* In the event of a validation test failure a re-test is required. If the subsequent test fails then the material must be re-limed to meet the test standard.

6.02 Scheduling of Validation Sampling

Validation testing of lime treated samples will require time for sampling, sample transport to a laboratory, sample drying and analysis. This process can easily require 5-7 working days. Where soils are treated and then placed the schedule of placement should allow sufficient time for the validation process. In the event of samples failing the validation test it will be necessary to add additional lime and re-test the treated material again.

If soils are segregated into treated and non-treated material then both the treated and non-treated material should be subject to validation testing.

7 RECORD KEEPING

* **It is essential to maintain a record of the volume of excavation material and the location of placement**. The record is to be updated at the end of each working day. An example of one record format is provided in Figure 2. It is important to develop and maintain an accurate record of imported soil, exported soil and soil moved during cut and fill operations. Future land holders should have accurate information regarding the origin and treatment of soil and any validation test results.

* Maintain a copy of all purchase and delivery documentation describing the quantity of lime delivered to the site

* Engage a suitably responsible person (eg. geotechnical engineer, engineer, surveyor, project manager, etc) to supervise the lime treatment procedure to ensure the correct quantity of lime is applied. A daily record of this activity is to be maintained.

* If any water is retained on the site and requires discharge then a record of the water pH and any corrective action is to be maintained by a suitably responsible person.

* All records (eg. validation analysis, excavation, placement, lime delivery, lime treatment and water quality) are to be retained for a period of five years by the project manager.

8 CORRECTIVE MEASURES

In the event of non-compliance with any aspect of the ASSMP the following measures will be implemented:

* measurements will be repeated immediately to confirm non-compliance
* construction activity will cease if non-compliant conditions are demonstrated
* corrective action will be taken within one working day
* in the event of corrective action failing to return the environmental conditions to a state of compliance within two working days following action will be undertaken:
    * the local authority will be notified within one working day
    * a suitably qualified person will be engaged to study the nature of the problem within one working day
    * the local authority will be informed on a daily basis of field conditions and corrective action until such time as compliant conditions are achieved.
    * a record will maintained of field conditions and corrective actions

9 IMPORTANT LIMITATIONS

Significant variation in soil properties is normal, especially for low lying soils. It is normal for soils to be "patchy", with some areas of low hazard close to others with higher hazard. Acid soil often has brown (rusty) colours associated with iron and yellow/orange/ tan mottles. Sulphidic soil is found in anaerobic conditions which are usually pale grey to black. The appearance of the soil should be noted. It will often be desirable to undertake additional sampling and analysis where soil conditions are different from those described in the original field investigation. A conservative approach is recommended.

Should the design change to involve disturbance of soil with unknown properties then this should be subject to further investigation before disturbance. This includes soil lying outside and below the area of original investigation. The level of investigation specified by the state and local authorities should be adopted.

This report does not specifically address the effects of aggressive or corrosive soil upon structures or any other services. Saline, sulphurous or acid soil (or groundwater) can have a serious corrosive effect on some structures and this needs to be considered by an appropriately qualified person.

Figure 2: Examples of Construction ASS Management Recording

MATERIAL	Date OR Period	Name of Company/Person Responsible	Volume (m3)	Placement Location	Placement Depth	Origin of Supply	Lime Treatment Rate (kg lime/m3)
Exported Soil Sourced From Below 5 m AHD							
Imported Fill that is placed below 5 m AHD							
Lime treated in-situ soil, taken from areas below 5 m AHD.							
Topsoil (from below 5 m AHD) **Exported** From Site							
Topsoil Imported To Site							
Volume of **Water Discharged** During Construction							

Balance Sheet Bulk Earthworks-Disturbed Acid Sulfate Soil													
Project Name						Cut Total		m3	0			ALL soil disturbed below 5 m AHD that is subject to the acid sulfate management plan must be accounted for. Ideally tonnage of cut will equal tonnage of placement but in practice volumes are estimated. If a significant change in volume between cut and fill volume occurs then please record this and provide a description of the density.	This person accepts responsibility for the accuracy of this record.
Contractor						Stockpile Total		m3	0				
Supervisor						Placement Total		m3	0				
						Lime Total		tons	0				
Date of Action	Cut Location	Cut Elevation	Cut Volume	Stockpile Location	Stockpile Volume	Lime Rate	Placement Location	Placement Elevation	Volume Placement	Lime Rate	Lime Total	Comments For This Action	
	code/cell	m ahd	m3	code/cell	m3	kg/m3	code/cell	m ahd	m3 Placement	kg/m3	tons		Name of Recorder.

The objective is to provide an accurate record of the location and depth of all disturbed acid sulfate soil, all lime treatment, all validation and all exported ASS. If fill is imported and placed below 5 m AHD then the origin and final placement must also be recorded. For larger and long term projects, a daily record should be kept. Where soil is moved more than once this should be recorded.

10 APPENDIX 1 SUPPORTING INFORMATION

DETERMINATION OF ACID SULFATE SOIL PROPERTIES

CERTIFICATE OF ANALYSIS

Bio-Track

Analysis By: Bio-Track Pty Ltd ABN 91 056 237 275 781 Mt. Glorious Road Highvale, Brisbane, Australia, 4520 Ph. 07 3289 7179

LAB REFERENCE LR190318.556 DATE OF REPORT 29 MARCH 2018 @08:32:55
CLIENT NAME Peter Kelsey c/o Dirts (Qld) Pty Ltd P.O Box 276 Hervey Bay 4655
PROJECT NAME Turtle Cove YOUR PROJECT/JOB REFERENCE 18-074
SAMPLING DATE NUMBER OF SAMPLES 40 Samples supplied by client SAMPLE TYPE:Soil/Solid
DATE RECEIVED 19/03/2018 9:37:43 AM PACKAGING Plastic Bag Ground Oven Dry Samples DISPOSED ON 18/05/2018

Sample ID as received. METHODOLOGY: As per (DNR QASSIT May 2004), oven dried (85'C), >1000 um shell removed, fine grind. All reported values gravimetric, dry mass.
%sEQ (equivalent sulphur) calculated as moles TAA/624 + %S Cr + %sNAS - sANC_BT (sNAS included irrespective of pH).
LIME1 rates calculated to neutralise TPA (or TAA if >TPA)+ aS_RAS -ANC_BT/1.5 LIME2 rates calculated to neutralise TAA + aS_POS or S_Cr + aS_RAS -ANC_BT/ 1.5
NB. Lime rates assume 97% lime neutralisation but DO NOT include any safety factors. Suggested factor=1.5-2. Rates are kg/ton. Multiply by bulk density to convert to kg/m3.
Fineness Factor (FF)=1.5 CBN POS= moles carbonate alkalinity released by oxidation assuming (Ca POS - Ca KCl) + (Mg POS - Mg KCl) is due to carbonate solution.
Blanks represent unmeasured values, zeros & <0.x represent measured values. If pH KCl>4.5 then s-RAS (calculated from acid extract) may be zero for undisturbed soil. Ca NAS is the acid reactive calcium calculated as the difference between 1 M KCl and 4 M HCl soluble Ca.

ID. DEPTH	pH	pH	TAA	TPA	TSA	S KCl	S P	S POS	S Cr	s-NAS	s EQ	Ca KCl	Ca P	Mg KCl	Mg P	CBN POS	LIME1	LIME2	sANC_BT	Ca NAS
mm	KCL	ox	m/t	m/t	m/t	%	%	%	%	%	%	mg/kg	mg/kg	mg/kg	mg/kg	m/t	kg/t	kg/t	%	mg/kg
Analytical Method Codes	23A	23B	23F	23G	23H	23Ce	23De	23Ee	22B	s20Je	s	23Vh	23Wh	23Sm	23Tm	a23U&X			s19A2	20E
BH1 500	4.35		37			<0.01			<0.01	<0.01	0.065	84		112				2		<10
BH1 1000	5.12		4			<0.01			<0.01	<0.01	0.011	68		60				0		<10
BH1 1500	4.18		61			0.01			<0.01	<0.01	0.101	56		156				3		<10
BH1 1800	3.80		147			0.01			<0.01	<0.01	0.236	34		269				7		<10
BH2 500	4.11		78			<0.01			<0.01	<0.01	0.127	639		719				4		<10
BH2 1000	3.92		150			0.02			<0.01	<0.01	0.243	124		303				8		<10
BH2 1500	4.01		116			0.02			<0.01	<0.01	0.187	236		384				6		<10
BH2 1800	4.04		140			0.02			<0.01	<0.01	0.225	204		384				7		<10
BH3 500	6.05		16			0.01			<0.01	<0.01	0.029	2447		1043				1		<10
BH3 1000	5.48		7			0.02			<0.01	<0.01	0.015	2271		996				0		<10
BH3 1500	4.47		15			<0.01			<0.01	<0.01	0.027	1518		839				1		<10
BH3 1800	4.47		12			0.01			<0.01	<0.01	0.020	1522		841				1		<10
BH4 500	4.23		45			0.03			<0.01	<0.01	0.082	400		480				3		<10
BH4 1000	4.00		86			<0.01			<0.01	<0.01	0.142	518		1396				4		<10
BH4 1500	4.09		52			0.01			<0.01	<0.01	0.087	364		999				3		<10
BH4 1800	4.04		60			0.01			<0.01	<0.01	0.098	364		1001				3		<10
BH5 500	4.76		24			<0.01			<0.01	<0.01	0.041	349		177				1		<10
BH5 1000	4.44		53			0.02			<0.01	<0.01	0.092	201		148				3		<10
BH5 1500	3.98		194			0.02			<0.01	<0.01	0.315	64		189				10		<10
BH5 1800	3.99		169			0.02			<0.01	<0.01	0.273	48		212				9		<10
BH6 500	4.60		40			<0.01			<0.01	<0.01	0.066	272		136				2		28
BH6 1000	4.77		15			<0.01			<0.01	<0.01	0.024	156		144				1		<10
BH6 1500	4.32		31			<0.01			<0.01	<0.01	0.051	172		962				2		<10
BH6 1800	4.32		32			<0.01			<0.01	<0.01	0.053	200		1000				2		<10

Signatory P. [signature] For and on behalf of Bio-Track Pty Ltd

DETERMINATION OF ACID SULFATE SOIL PROPERTIES

CERTIFICATE OF ANALYSIS

Bio-Track

Analysis By: Bio-Track Pty Ltd ABN 91 056 237 275 781 Mt. Glorious Road Highvale, Brisbane, Australia, 4520 Ph. 07 3289 7179

LAB REFERENCE LR190318.556 DATE OF REPORT 29 MARCH 2018 @08:33:11
CLIENT NAME Peter Kelsey c/o Dirts (Qld) Pty Ltd P.O Box 276 Hervey Bay 4655
PROJECT NAME Turtle Cove YOUR PROJECT/JOB REFERENCE 18-074
SAMPLING DATE NUMBER OF SAMPLES 40 Samples supplied by client SAMPLE TYPE:Soil/Solid
DATE RECEIVED 19/03/2018 9:37:43 AM PACKAGING Plastic Bag Ground Oven Dry Samples DISPOSED ON 18/05/2018

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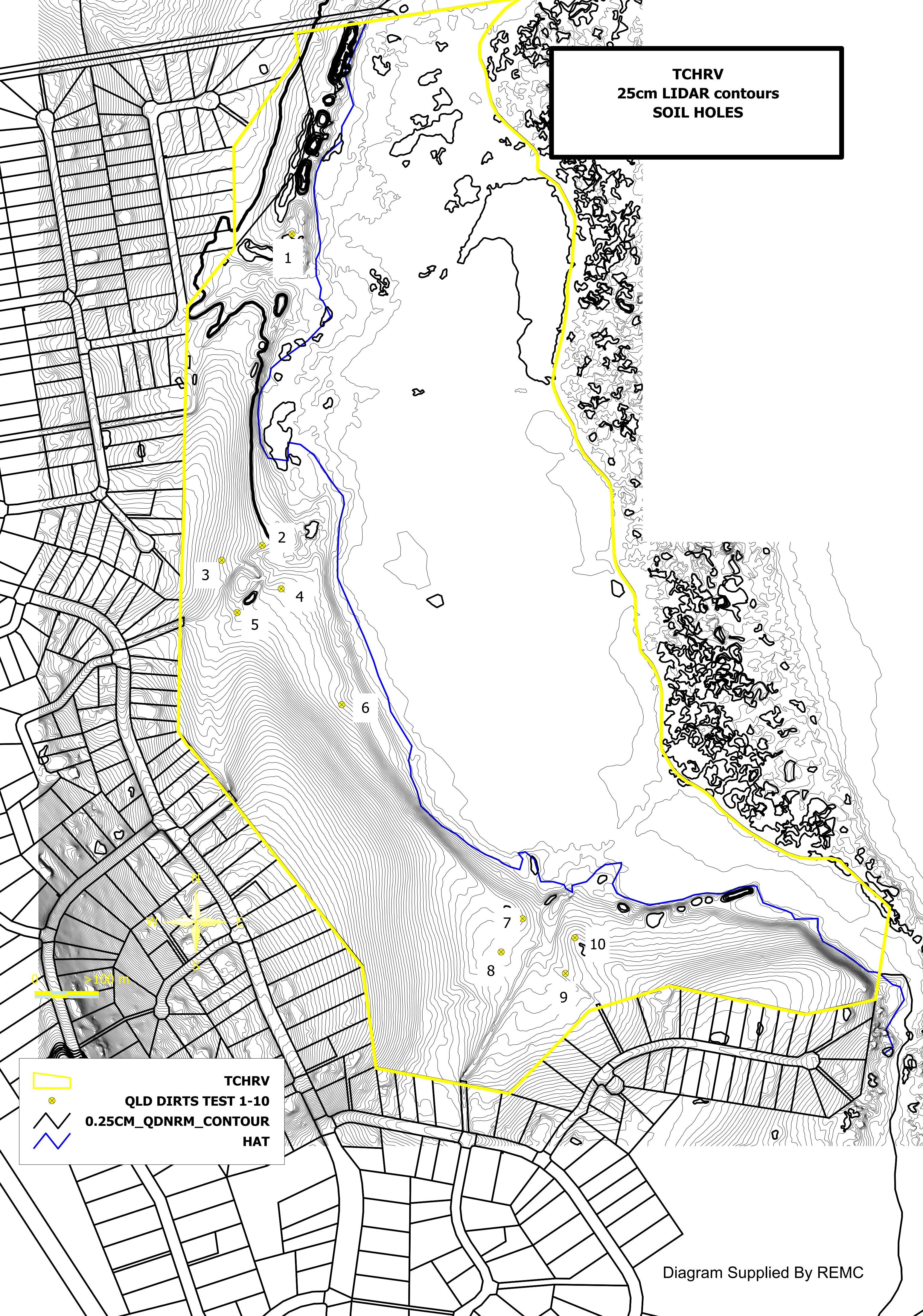
LIME1 rates calculated to neutralise TPA (or TAA if >TPA)+ aS_RAS -ANC_BT/1.5 LIME2 rates calculated to neutralise TAA + aS_POS or S_Cr + aS_RAS -ANC_BT/ 1.5
NB. Lime rates assume 97% lime neutralisation but DO NOT include any safety factors. Suggested factor=1.5-2. Rates are kg/ton. Multiply by bulk density to convert to kg/m3.
Fineness Factor (FF)=1.5 CBN POS= moles carbonate alkalinity released by oxidation assuming (Ca POS - Ca KCl) + (Mg POS - Mg KCl) is due to carbonate solution.
Blanks represent unmeasured values, zeros & <0.x represent measured values. If pH KCl>4.5 then s-RAS (calculated from acid extract) may be zero for undisturbed soil. Ca NAS is the acid reactive calcium calculated as the difference between 1 M KCl and 4 M HCl soluble Ca.

ID. DEPTH mm	pH KCL	pH ox	TAA m/t	TPA m/t	TSA m/t	S KCl %	S P %	S POS %	S Cr %	s-NAS %	s EQ %	Ca KCl mg/kg	Ca P mg/kg	Mg KCl mg/kg	Mg P mg/kg	CBN POS m/t	LIME1 kg/t	LIME2 kg/t	sANC_BT %	Ca NAS mg/kg
Analytical Method Codes	23A	23B	23F	23G	23H	23Ce	23De	23Ee	22B	s20Je	s	23Vh	23Wh	23Sm	23Tm	a23U&X			s19A2	20E
BH7 500	6.01		8			<0.01			<0.01	<0.01	0.016	1037		251				1		80
BH7 1000	6.42		<1			<0.01			<0.01	<0.01	0.002	1043		257				0		40
BH7 1500	6.35		<1			<0.01			<0.01	<0.01	0.001	677		331				0		279
BH7 1800	6.02		14			<0.01			<0.01	<0.01	0.028	803		602				1		<10
BH8 500	4.36		46			<0.01			<0.01	<0.01	0.074	64		440				2		<10
BH8 1000	4.18		69			<0.01			<0.01	<0.01	0.110	44		561				3		<10
BH8 1500	4.19		72			<0.01			<0.01	<0.01	0.115	35		559				4		<10
BH8 1800	4.17		82			<0.01			<0.01	<0.01	0.132	36		878				4		<10
BH9 500	5.16		16			<0.01			<0.01	<0.01	0.027	336		208				1		304
BH9 1000	4.37		54			<0.01			<0.01	<0.01	0.087	96		478				3		<10
BH9 1500	4.10		87			<0.01			<0.01	<0.01	0.140	52		801				4		12
BH9 1800	4.06		94			<0.01			<0.01	<0.01	0.151	37		917				5		<10
BH10 500	4.23		51			<0.01			<0.01	<0.01	0.081	38		599				3		<10
BH10 1000	4.02		95			<0.01			<0.01	<0.01	0.152	35		964				5		<10
BH10 1500	4.04		101			<0.01			<0.01	<0.01	0.162	32		1283				5		<10
BH10 1800	4.07		97			<0.01			<0.01	<0.01	0.156	40		1195				5		<10

Signatory P. Edmunds For and on behalf of Bio-Track Pty Ltd

ID.	DEPTH	pH	TAA	S KCl	S Cr	s-NAS	s EQ	Ca KCl	Mg KCl	sANC_BT	Ca NAS
LR190318.556	500	KCL	m/t	%	%	%	%	mg/kg	mg/kg	%	mg/kg
Analytical Method Codes	1000	23A	23F	23Ce	0	s2OJe	s	23Vh	23Sm	s19A2	20E
BH1	500	4.35	37	0	0	0	0.065	84	112	0	0
BH1	1000	5.12	4	0	0	0	0.011	68	60	0	0
BH1	1500	4.18	61	0.01	0	0	0.101	56	156	0	0
BH1	1800	3.8	147	0.01	0	0	0.236	34	269	0	0
BH2	500	4.11	78	0	0	0	0.127	639	719	0	0
BH2	1000	3.92	150	0.02	0	0	0.243	124	303	0	0
BH2	1500	4.01	116	0.02	0	0	0.187	236	384	0	0
BH2	1800	4.04	140	0.02	0	0	0.225	204	384	0	0
BH3	500	6.05	16	0.01	0	0	0.029	2447	1043	0	0
BH3	1000	5.48	7	0.02	0	0	0.015	2271	996	0	0
BH3	1500	4.47	15	0	0	0	0.027	1518	839	0	0
BH3	1800	4.47	12	0.01	0	0	0.02	1522	841	0	0
BH4	500	4.23	45	0.03	0	0	0.082	400	480	0	0
BH4	1000	4	86	0	0	0	0.142	518	1396	0	0
BH4	1500	4.09	52	0.01	0	0	0.087	364	999	0	0
BH4	1800	4.04	60	0.01	0	0	0.098	364	1001	0	0
BH5	500	4.76	24	0	0	0	0.041	349	177	0	0
BH5	1000	4.44	53	0.02	0	0	0.092	201	148	0	0
BH5	1500	3.98	194	0.02	0	0	0.315	64	189	0	0
BH5	1800	3.99	169	0.02	0	0	0.273	48	212	0	0
BH6	500	4.6	40	0	0	0	0.066	272	136	0	28
BH6	1000	4.77	15	0	0	0	0.024	156	144	0	0
BH6	1500	4.32	31	0	0	0	0.051	172	962	0	0
BH6	1800	4.32	32	0	0	0	0.053	200	1000	0	0
BH7	500	6.01	8	0	0	0	0.016	1037	251	0	80
BH7	1000	6.42	0	0	0	0	0.002	1043	257	0	40
BH7	1500	6.35	1	0	0	0	0.001	677	331	0	279
BH7	1800	6.02	14	0	0	0	0.028	803	602	0	0
BH8	500	4.36	46	0	0	0	0.074	64	440	0	0
BH8	1000	4.18	69	0	0	0	0.11	44	561	0	0
BH8	1500	4.19	72	0	0	0	0.115	35	559	0	0
BH8	1800	4.17	82	0	0	0	0.132	36	878	0	0
BH9	500	5.16	16	0	0	0	0.027	336	208	0	304
BH9	1000	4.37	54	0	0	0	0.087	96	478	0	0
BH9	1500	4.1	87	0	0	0	0.14	52	801	0	12
BH9	1800	4.06	94	0	0	0	0.151	37	917	0	0
BH10	500	4.23	51	0	0	0	0.081	38	599	0	0
BH10	1000	4.02	95	0	0	0	0.152	35	964	0	0
BH10	1500	4.04	101	0	0	0	0.162	32	1283	0	0
BH10	1800	4.07	97	0	0	0	0.156	40	1195	0	0
Minimum		3.98	0	0	0.00	0.00	0.001	32	136	0.00	0
Average		4.62	62	0.00	0.00	0.00	0.101	242	589	0.00	34
Maximum		6.42	194	0.02	0.00	0.00	0.315	1043	1283	0.00	304
Percentile 95		6.33	166	0.02	0.00	0.00	0.267	1025	1185	0.00	269
Percentile 99		6.41	189	0.02	0.00	0.00	0.306	1042	1265	0.00	299


TCHRV
25cm LIDAR contours
SOIL HOLES
1
2
3
4
5
6
7
8
9
10
N
W
E
S
0
100 m
TCHRV
QLD DIRTS TEST 1-10
0.25CM_QDNRM_CONTOUR
HAT
Diagram Supplied By REMC

10.02 GEOTECHNICAL REPORT

DIRTS (QLD) Pty Ltd

Site Investigations, Soil, Aggregate & Concrete Testing

A.B.N. 47 113 364 757

10/3 Southern Cross Cct, Urangan Q 4655 (Po Box 276) Ph-41254862 Fax-41256593

GEOTECHNICAL INVESTIGATION REPORT

FOR

ANSCAPE PTY LTD

AT

TURTLE COVE ASSESSMENT

Date 14th March 2018 **JOB No. 18-074**

Domestic
Industrial
Roads
Testing
Service

DIRTS (QLD) Pty Ltd

(ABN 47 113 364 757)

Shed 10/3 Southern Cross Cct
Urangan Q 4655
(P O Box 276)

Tel (07) 41254862
Fax (07) 41256593
email dirtsqld@bigond.net.au
enquires Peter Kelsey

GEOTECHNICAL INVESTIGATION

CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Investigation Method AS1726	**Bore No:** 1 – GPS 0490348 7192297	**Date Sampled:** 14-3-18	**Logged By:** J.K

Depth	Sample, test etc	Graphical Log	Moisture	Consistency	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
200			SM	H	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Black/Brown
800			M	ST	(CH), SILTY CLAY, High Plasticity, Red and White mottled, Large fractured rock throughout
1200			S	S	(GP), POORLY GRADED SANDY GRAVEL, Low Plasticity, Brown, traces of Silt
1650			M/S	ST	(CH), SILTY CLAY, High Plasticity, Orange/Brown, Gravel/Ridge Pebbles throughout
1800			M	ST/ VST	(CH), SILTY CLAY, High Plasticity, Red and White mottled
					HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand	V – shear vane	D – dry	S – soft	VS – very soft
B – bulk	P – penetrometer	SM – slightly moist	L – loose	VL – very loose
U – undistributed	UCS – estimated	M – moist	D – dense	MD – mod. dense
		S – saturated	F – firm	VD – very dense
		W – wet	H – hard	St – stiff
				VSt – very stiff

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GEOTECHNICAL INVESTIGATION

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PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**1 – GPS 0490348 7192297**	**Date Sampled:**	**14-3-18**

LOCATION

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GEOTECHNICAL INVESTIGATION

CLIENT	**ANSCAPE PTY LTD**	
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No. 18-074**

Investigation Method AS1726	**Bore No:** 2 – GPS 0490312 7191919	**Date Sampled:** 14-3-18	**Logged By:** J.K

Depth	Sample, test etc		Graphical Log	Moisture	Consistency	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
150				SM	H	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Black/Brown
1800				M	ST	(CH), SILTY CLAY, High Plasticity, Red mottled Grey
						HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand	V – shear vane	D – dry	S – soft	VS – very soft
B – bulk	P – penetrometer	SM – slightly moist	L – loose	VL – very loose
U – undistributed	UCS – estimated	M – moist	D – dense	MD – mod. dense
		S – saturated	F – firm	VD – very dense
		W – wet	H – hard	St – stiff
				VSt – very stiff

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PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**2 – GPS 0490312 7191919**	**Date Sampled:**	**14-3-18**

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PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Investigation Method	**AS1726**	**Bore No:**	**3 – GPS 0490432 7192004**	**Date Sampled:**	**14-3-18**	**Logged By:**	**J.K**

Depth	**Sample, test etc**	**Graphical Log**	**Moisture**	**Consistency**	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
350			SM	H	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Black/Brown
1200			M	ST	(CH), SILTY CLAY, High Plasticity, Brown mottled Red and Orange
1800			M	ST	(CH), SILTY CLAY, High Plasticity, Brown mottled Orange and Grey with a tinge of aqua
					HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand	V – shear vane	D – dry	S – soft	VS – very soft
B – bulk	P – penetrometer	SM – slightly moist	L – loose	VL – very loose
U – undistributed	UCS – estimated	M – moist	D – dense	MD – mod. dense
		S – saturated	F – firm	VD – very dense
		W – wet	H – hard	St – stiff
				VSt – very stiff

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PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**3 – GPS 0490432 7192004**	**Date Sampled:**	**14-3-18**

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GEOTECHNICAL INVESTIGATION

CLIENT	**ANSCAPE PTY LTD**
PROJECT	**TURTLE COVE ASSESSMENT** **Job No. 18-074**

Investigation Method AS1726	**Bore No:** 4 – GPS 0490441 7191959	**Date Sampled:** 14-3-18	**Logged By:** J.K

Depth	Sample, test etc		Graphical Log	Moisture	Consistency	Materials Description Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
400				SM	H	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Black/Grey
700				M	ST	(CH), SILTY CLAY, High Plasticity, Red mottled Grey
1800				M	ST	(CH), SILTY CLAY, High Plasticity, Grey/Brown mottled Orange and Red
						HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand B – bulk U – undistributed	V – shear vane P – penetrometer UCS – estimated	D – dry SM – slightly moist M – moist S – saturated W – wet	S – soft L – loose D – dense F – firm H – hard	VS – very soft VL – very loose MD – mod. dense VD – very dense St – stiff VSt – very stiff

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GEOTECHNICAL INVESTIGATION

CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**4 – GPS 0490441 7191959**	**Date Sampled:**	**14-3-18**

LOCATION

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GEOTECHNICAL INVESTIGATION

CLIENT	**ANSCAPE PTY LTD**
PROJECT	**TURTLE COVE ASSESSMENT** — **Job No. 18-074**

Investigation Method	**AS1726**	**Bore No:**	**5 – GPS 0490338 7191896**	**Date Sampled:**	**14-3-18**	**Logged By:**	**J.K**

Depth	Sample, test etc	Graphical Log	Moisture	Consistency	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
400			SM	H	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Black/Grey
750			S	S	(GP), POORLY GRADED GRAVEL, Low Plasticity, Brown, traces of silt throughout, Sandy coarse Grain
1300			S	ST	(CH-GP), SILTY CLAY/CLAYEY GRAVEL, High Plasticity, Red/Oranges, traces of small gravel throughout
1800			M	ST	(CH), SILTY CLAY, High Plasticity, Red and Grey mottled
					HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand B – bulk U – undistributed	V – shear vane P – penetrometer UCS – estimated	D – dry SM – slightly moist M – moist S – saturated W – wet	S – soft L – loose D – dense F – firm H – hard	VS – very soft VL – very loose MD – mod. dense VD – very dense St – stiff VSt – very stiff

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enquires Peter Kelsey

GEOTECHNICAL INVESTIGATION

CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**5 – GPS 0490338 7191896**	**Date Sampled:**	**14-3-18**

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CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Investigation Method	**AS1726**	**Bore No:**	**6 – GPS 0490540 7191710**	**Date Sampled:**	**14-3-18**	**Logged By:**	**J.K**

Depth	Sample, test etc	Graphical Log	Moisture	Consistency	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
750			SM	H	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Black/Grey
1100			S	S	(GP), POORLY GRADED GRAVEL, Low Plasticity, Brown, traces of silt throughout, Sandy coarse Grain
1800			SM	ST/ VST	(CI-CH), SILTY SANDY CLAY, Moderate Plasticity, Grey mottled Orange, medium grain
					HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand B – bulk U – undistributed	V – shear vane P – penetrometer UCS – estimated	D – dry SM – slightly moist M – moist S – saturated W – wet	S – soft L – loose D – dense F – firm H – hard	VS – very soft VL – very loose MD – mod. dense VD – very dense St – stiff VSt – very stiff

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PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**6 – GPS 0490540 7191710**	**Date Sampled:**	**14-3-18**

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CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Investigation Method	**AS1726**	**Bore No:**	**7 – GPS 0490832 7191405**	**Date Sampled:**	**14-3-18**	**Logged By:**	**J.K**

Depth	Sample, test etc	Graphical Log	Moisture	Consistency	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
400			SM	H	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Grey/Brown
1200			M	ST	(CH), SILTY CLAY, High Plasticity, Brown, Gravel throughout
1400			M/S	S/ST	(CI), SILTY CLAY, Moderate Plasticity, Orange/Brown with Gravel throughout
1800			M/S	ST	(GP-CI), SILTY SANDY GRAVELLY CLAY, Moderate Plasticity, Brown
					HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand	V – shear vane	D – dry	S – soft	VS – very soft
B – bulk	P – penetrometer	SM – slightly moist	L – loose	VL – very loose
U – undistributed	UCS – estimated	M – moist	D – dense	MD – mod. dense
		S – saturated	F – firm	VD – very dense
		W – wet	H – hard	St – stiff
				VSt – very stiff

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CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**7 – GPS 0490832 7191405**	**Date Sampled:**	**14-3-18**

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CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Investigation Method	**AS1726**	**Bore No:**	**8 – GPS 0490761 7191229**	**Date Sampled:**	**14-3-18**	**Logged By:**	**J.K**

Depth	Sample, test etc	Graphical Log	Moisture	Consistency	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
350			SM	S	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Grey/Brown
850			M	ST	(CH), SILTY CLAY, High Plasticity, Brown mottled Orange/Red
1550			M	ST	(CH), SILTY CLAY, High Plasticity, Red, traces of gravel throughout
1800			M	ST	(CH), SILTY CLAY, High Plasticity, Grey mottled Red
					HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H –- hand	V – shear vane	D – dry	S – soft	VS – very soft
B – bulk	P – penetrometer	SM – slightly moist	L – loose	VL – very loose
U – undistributed	UCS – estimated	M – moist	D – dense	MD – mod. dense
		S – saturated	F – firm	VD – very dense
		W – wet	H – hard	St – stiff
				VSt – very stiff

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CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**8 – GPS 0490761 7191229**	**Date Sampled:**	**14-3-18**

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CLIENT	**ANSCAPE PTY LTD**
PROJECT	**TURTLE COVE ASSESSMENT** — **Job No. 18-074**

Investigation Method AS1726	**Bore No:** 9 – GPS 0490785 7191230	**Date Sampled:** 14-3-18	**Logged By:** J.K

Depth	Sample, test etc		Graphical Log	Moisture	Consistency	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
550				SM	S	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Grey/Brown
1400				M	ST	(CH), SILTY CLAY, High Plasticity, Red, traces of gravel throughout
1800				M	ST	(CH), SILTY CLAY, High Plasticity, Brown mottled Grey and Red, traces of gravel throughout
						HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand B – bulk U – undistributed	V – shear vane P – penetrometer UCS – estimated	D – dry SM – slightly moist M – moist S – saturated W – wet	S – soft L – loose D – dense F – firm H – hard	VS – very soft VL – very loose MD – mod. dense VD – very dense St – stiff VSt – very stiff

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GEOTECHNICAL INVESTIGATION

CLIENT	**ANSCAPE PTY LTD**		
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No.**	**18-074**

Bore No:	**9 – GPS 0490785 7191230**	**Date Sampled:**	**14-3-18**

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CLIENT	**ANSCAPE PTY LTD**	
PROJECT	**TURTLE COVE ASSESSMENT**	**Job No. 18-074**

Investigation Method	**AS1726**	**Bore No:**	**10 – GPS 0490831 7191300**	**Date Sampled:**	**14-3-18**	**Logged By:**	**J.K**

Depth	**Sample, test etc**		**Graphical Log**	**Moisture**	**Consistency**	**Materials Description** Soil or rock type: colour, particle size or plasticity, origin, other features, classification(Unified)
300				SM	S	(SM-CI), SILTY SAND/CLAY, Low – Moderate Plasticity, Grey/Brown
1200				M	ST	(CH), SILTY CLAY, High Plasticity, Brown, Orange/Brown at 700mm
1800				M	ST	(CH), SILTY CLAY, High Plasticity, Grey mottled Orange/Brown
						HOLE TERMINATED AT 1800mm

Sample:	**Test:**	**Moisture:**	**Consistency:**	
H -– hand	V – shear vane	D – dry	S – soft	VS – very soft
B – bulk	P – penetrometer	SM – slightly moist	L – loose	VL – very loose
U – undistributed	UCS – estimated	M – moist	D – dense	MD – mod. dense
		S – saturated	F – firm	VD – very dense
		W – wet	H – hard	St – stiff
				VSt – very stiff

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Bore No:	**10 – GPS 0490831 7191300**	**Date Sampled:**	**14-3-18**

LOCATION

LOCATION

Source: **Acid Sulfate Soils Laboratory Methods Guidelines, Version 2.1 June 2004**
Authors: QASSIT, Qld NRM&E, SCU, NatCASS, QASSMAC, ASSMAC
Published: Department of natural Resources, Mines and Energy, Indooroopilly, Queensland, Australia, June 2004

(Acid) Fizz test: The field test used for soils to test for the presence of carbonate minerals, whereby dilute hydrochloric acid is added to the soil. An effervescent fizzing reaction indicates the presence of carbonate minerals.

Acid Base Accounting (ABA): The process by which the various acid-producing components of the soil are compared with the acid neutralising components so that the soil's net acidity can be calculated.

Action criteria: The critical net acidity values (expressed in units of equivalent % pyrite sulfur, or equivalent mol H+/t) for different soil texture groups and sizes of soil disturbance that trigger the need for ASS management.

Actual Acidity: A component of existing acidity. The soluble and exchangeable acidity already present in the soil, often as a consequence of previous oxidation of sulfides. It is this acidity that will be mobilised and discharged following a rainfall event. It is measured in the laboratory using the TAA method. It does not include the less soluble acidity (ie. retained acidity) held in hydroxy-sulfate minerals such as jarosite.

ANC: Acid neutralising capacity. A measure of a soil's inherent ability to buffer acidity and resist the lowering of the soil pH.

ANCBT: Acid neutralising capacity by back titration. Acid neutralising capacity measured by acid digest followed by back titration of the acid that has not been consumed.

ANCE: Excess acid neutralising capacity. Found in soils with acid neutralising capacity in excess of that needed to neutralise the acidity generated by oxidation of sulfides. The soil is oxidised with peroxide, then a titration is performed with dilute hydrochloric acid to a pH of 4, followed by a second peroxide digestion. If a soil has a positive ANCE result then the TPA result is zero and vice versa.

CaA: Reacted calcium. The calcium soluble after the peroxide digest and TPA titration that was not soluble following KCl-extraction and T AA titration. (Cap -CaKCl). It can be used (in combination with MgA) to provide an estimate of the soil carbonate content, but may be an underestimate if the HCl-titration to pH 4 has not been performed as part of the TPA / ANC_E procedure.

CaHCl: Calcium soluble in 4 M HCl, which includes soluble and exchangeable calcium as well as calcium found in certain carbonate minerals (eg. dolomite, calcite, aragonite).

CaKCl: Potassium chloride extractable calcium measured following the T AA analysis, which includes soluble and exchangeable calcium as well as calcium from gypsum.

CaNAS: Net acid soluble calcium. The calcium soluble in 4 M HCl that is not soluble in 1 M KCl. (CaHCl -CaKCl. It can be used (in combination with MgNAS) to provide an estimate of the soil carbonate content, but may be an overestimate if calcium is dissolved from non-carbonate or non-acid-neutralising minerals.

Cap: Peroxide calcium. Calcium measured following the TPA analysis, which includes soluble and exchangeable calcium, calcium from gypsum, as well as calcium (eg. from carbonates) dissolved as a result of acid produced due to oxidation of sulfides by peroxide.

Chromium Suite: The acid base accounting approach used to calculate net acidity which uses the chromium reducible sulfur method to determine potential sulfidic acidity. A decision tree approach based on the pHKCl result is then used to determine the other components of the acid base account.

CIN: Inorganic carbon. (CT -CTo). It is used to estimate the carbonate content of the soil. CRS: The acronym often given to the Chromium Reducible Sulfur method.

CT: Total carbon. A measure of the total carbon content of the soil, encompassing both organic and inorganic forms.

CTo: Total organic carbon. The carbon in sample measured following a sulfurous acid digestion procedure used to remove carbonate carbon.

Existing Acidity: The acidity already present in acid sulfate soils, usually as a result of oxidation of sulfides, but which can also be from organic material or acidic cations. It can be further sub- divided into actual and retained acidity, ie. Existing Acidity = Actual Acidity + Retained Acidity.

Fineness factor: A factor applied to the acid neutralising capacity result in the acid base account to allow for the poor reactivity of coarser carbonate or other acid neutralising material. The minimum factor is 1.5 for finely divided pure agricultural lime, but may be as high as 3.0 for coarser shell material.

MgA: Reacted magnesium. The magnesium soluble after the peroxide digest and TPA titration that was not soluble following KCl-extraction and T AA titration. (Mgp -MgKCl. It can be used (in combination with CaA) to provide an estimate of the soil carbonate content, but may be an underestimate if the HCl-titration to pH 4 has not been performed as part of the TPA/ANC_E procedure.

MgHCl: Magnesium soluble in 4 M HCl, which includes soluble and exchangeable magnesium as well as magnesium found in certain carbonate minerals (eg. dolomite, magnesite).

MgKCl: Potassium chloride extractable magnesium measured following the T AA analysis, which includes soluble and exchangeable magnesium.

MgNAS: Net acid soluble magnesium. The calcium soluble in 4 M HCl that is not soluble in 1 M KC1. (MgHCl -MgKCl. It can be used (in combination with CaNAS) to provide an estimate of the soil carbonate content, but may be an overestimate if magnesium is dissolved from non-carbonate or non-acid-neutralising minerals.

Mgp: Peroxide magnesium. Magnesium measured following the TPA analysis, which includes soluble and exchangeable magnesium, as well as magnesium (eg. from carbonates) dissolved as a result of acid produced due to oxidation of sulfides by peroxide.

Monosulfides: The term given to the highly reactive iron sulfide minerals found in ASS that have the approximate formula 'FeS' and which are soluble in hydrochloric acid (as opposed to iron disulfides such as pyrite that aren't appreciably soluble in hydrochloric acid).

Net Acidity: The result obtained when the values for' various components of soil acidity and acid neutralising capacity are substituted into the Acid Base Accounting equation. Calculated as: Net Acidity = Potential sulfidic Acidity + Existing Acidity -(Acid Neutralising Capacity/Fineness Factor)

pHF: Field pH. Field determination of pH in a 'Soil:water paste.

pHFox: Field peroxide pH. Field determination of pH in a soil:water mixture following reaction with hydrogen peroxide.

pHKCl: Potassium chloride pH. pH in a 1:40 *(W/V)* suspension of soil in a solution of 1 M potassium chloride measured prior to TAA titration.

pHox: Peroxide oxidised pH. pH in a suspension of soil in a solution after hydrogen peroxide digestion in the SPOCAS method.

POCAS: An acronym standing for Peroxide Oxidation Combined Acidity and Sulfate method (Method Code 21.). This method has been superseded by the SPOCAS method.

POCASm: An acronym standing for the modified Peroxide Oxidation Combined Acidity and Sulfate method. This method has been superseded by the SPOCAS method.

Potential (sulfidic) acidity: The latent acidity in ASS that will be released if the sulfide minerals they contain (eg. pyrite) are fully oxidised. It can be estimated by titration (ie. TSA) if no acid neutralising material is present, or calculated from SPOS or SCR results.

Retained Acidity: The 'less available' fraction of the existing acidity (not measured by the T AA) that may be released slowly into the environment by hydrolysis of relatively insoluble sulfate salts (such as jarosite, natrojarosite, and other iron and aluminium hydroxy-sulfate minerals).

SCR: The symbol given to the result from the Chromium Reducible Sulfur method (Method 22B). The SCR method provides a measure of reduced inorganic sulfide content using iodometric titration after an acidic chromous chloride reduction. This method is not subject to interferences from organic sulfur.

SHCl: Sulfur soluble in 4 M HCI which includes soluble and adsorbed sulfate, sulfate from gypsum, as well as sulfate from hydroxy-sulfate minerals such as jarosite and natrojarosite.

SKCl: Potassium chloride extractable sulfur measured following the T AA analysis, which includes soluble and adsorbed sulfate as well as sulfate from gypsum.

SNAS: Net acid soluble sulfur. (SHCl -SKCl. The sulfur soluble in 4 M HCl that is not soluble in 1 M KCl. It provides an estimate of the sulfate contained in jarosite and similar low solubility hydroxy-sulfate minerals (and can be used to estimate retained acidity).

Sp: Peroxide sulfur. Sulfur measured following the TPA analysis, which includes soluble and exchangeable sulfate, sulfate from gypsum, as well as sulfide converted to sulfate and that released from organic matter as a result of peroxide oxidation.

SPOs: Peroxide oxidisable sulfur from the SPOCAS method. The sulfur soluble after the peroxide digest and TPA titration that was not soluble following KC1-extraction and TAA titration. (Sp -SKCl. It provides an estimate of the soil sulfide content, but is affected by the presence of organic sulfur.

SRAS: Residual acid soluble sulfur. The sulfur measured by 4 M HCI extraction on the soil residue remaining after peroxide digestion and TP A titration of the SPOCAS method. It provides an estimate of the sulfate contained in jarosite and similar low solubility hydroxy-sulfate minerals (and can be used to estimate retained acidity).

ST: Total sulfur. A measure of the total sulfur content of the soil, encompassing both organic and inorganic forms.

Sros: Total oxidisable sulfur. An estimate of soil oxidisable sulfur made from determining the sulfur not soluble in 4 M HCl. (ST -SHCl). It tends to provide an overestimate of soil sulfide content.

Self-neutralising soils: This term is given to *ASS* where there is sufficient acid neutralising capacity (with the relevant safety factor applied) to neutralise the potential sulfidic acidity held in the soil (ie. the net acidity from the Acid Base Account is zero or negative). Soils may be 'self- neutralising' due to an abundance of naturally occurring calcium or magnesium carbonates (eg. crushed shells, marine animal exoskeletons, coral) or other acid-neutralising material.

SPOCAS: An acronym standing for Suspension Peroxide Oxidation Combined Acidity and Sulfur method (Method Code 23), the peroxide-based method that supersedes the previous POCAS and POCASm methods.

SPOCAS Suite: The acid base accounting approached used to calculate net acidity based on the Suspension Peroxide Oxidation Combined Acidity and Sulfur method. A decision tree approach based on the values of pHKCl and pHox is used to decide what analytical path is followed in order to allow calculation of net acidity.

TAA: Titratable actual acidity. The acidity measured by titration with dilute NaOH following extraction with KCl-solution in the SPOCAS method. Previously referred to as Total Actual Acidity in the POCAS and POCASm methods.

TPA: Titratable peroxide acidity. The acidity measured by titration with dilute NaOH following peroxide digestion in the SPOCAS method. Previously referred to as Total Potential Acidity in the POCAS and POCASm methods.

TSA: Titratable sulfidic acidity. The difference in acidity measured by titration with dilute NaOH following extraction with KCl-solution and the acidity titrated following peroxide digestion in the SPOCAS method. (TPA -TAA). Previously referred to as Total Sulfidic Acidity in the POCAS and POCASm methods.

INTERPRETATION OF SOIL CHEMICAL ANALYSIS DATA

CONCRETE PILES

Exposure Classification	Non-Aggressive	Mild	Moderate	Severe	Very Severe
pH	>6.5	5.0-6.5	4.5-5.0	4.0-4.5	<4.0
Sulfate S mg/kg	<800	800-2000	2000-4000	4000-8000	>8000
TAA moles/ton	<20	20-50	50-80	80-150	>150
Magnesium meq/100 g	<5	5-10	>10 (requires sulfate >1000)		
Fe mg/kg	<50	50-100	>100 & pH <4.5 indicates acid sulfate		
CEC meq/100g	Values <10 indicate leached soil with low buffering against acid formation				
Chloride mg/kg	>200 indicates suppression of sulfate hazard unless acidic (pH<5)				
Al mg/kg	>50 indicates increased risk of acid/corrosive condition				

STEEL PILES

Exposure Classification	Non-Aggressive	Mild	Moderate	Severe
pH	>5	4-5	3-4	<3
Sulfate S mg/kg	Values >250 suggest the presence of acid sulfate soil or marine water effect. Check pH, acidity, iron & aluminium levels. Soil above the watertable should be tested for sulphide			
Resistivity ohm.cm	>5000	2000-5000	1000-2000	<1000
Chloride mg/kg	<5000	5000-20,000	20,000-50,000	>50,000
TAA moles/ton	<10	10-20	20-30	30-80
Fe mg/kg	<50	50-100	>100 & pH <4.5 indicates acid sulfate	
CEC meq/100g	Values <10 indicate leached soil with low buffering against acid formation			
Al mg/kg	>50 indicates acid/corrosive condition may exist			

Refer to AS 2159-2009 "Piling-Design and installation" for design data.

Refer to The 2008 draft code DR 08180 CP Piling-Design and instillation" for a revised and more comprehensive reference.

Note: The resistivity units are ohms.cm. There is an error in the 1995 standard which only lists ohms as the unit.

NOTE: The information provided represents a generic guideline. Classify using the worst case factor. For low permeability soil (eg. silt & clay) it may be possible to reduce the exposure class by one. Soils affected by the presence of acid sulfate conditions (eg. below 5 m AHD) have the potential to become extremely corrosive. Soil that is disturbed (industrial, waste disposal, fill) has a higher risk of corrosion. Soil affected by marine conditions, especially with an intermittent wet/dry cycle has a higher corrosion hazard. The soil analysis and data interpretation must take into account these factors.

10.05 LIME TREATMENT OF HIGH SULPHUR SOIL CONDITIONS

The addition of lime to soil containing high levels of sulphide or sulfate will result in the formation of calcium sulfate. There will be changes to the soil forces associated with the chemical changes. This has the potential to result in heaving of the ground. In the much longer term calcium sulfate may dissolve, increasing the soil porosity and possibly reducing the load bearing capacity. One reference is "Lime-treated Soil Construction Manual Lime Stabilization & Lime Modification", Bulletin 326, published by the American Road Builders Association Subcommittee on Lime Stabilization and published in 1959 as ARBA Technical Bulletin 243. The National Lime Association assumed publication rights in 1965. The following information is quoted from page 32. It is recommended specialist advice is obtained for soil containing more than 0.3% sulphur (as the sum of sulfate sulphur and sulphidic sulphur).

Sulfates

The presence of soluble sulfate salts can present problems when soils are stabilized with any calcium-based additive (e.g. lime, Portland cement, fly ash). Sulfates are most common in the western United States, due to the presence of naturally-occurring gypsum, although soils contaminated with industrial sulfates or synthetic gypsum base materials can also lead to problems. Sulfates in the soil combine with calcium and alumina from clay, and with water, to form the minerals ettringite and thaumasite in a highly expansive reaction. The formation of these minerals after compaction can result in significant pavement heaving and loss of strength.

Soil sulfate concentrations of less than 3,000 ppm (0.3 percent) are unlikely to cause problems. Concentrations of 3,000 to 5,000 ppm (0.5 percent) can be readily stabilized if care is taken to follow good construction practices such as using plenty of water and allowing ample time for the lime and soil to mellow between mixings. Concentrations greater than 5,000 ppm are often treated with two applications of lime, the first before the first mixing and the second after the mellowing period. The moisture content of the soil is raised to 5 percent over optimum during a multi-day mellowing period to solubilize as many sulfates as possible and to force ettringite to form before compaction.(8) Once formed, ettringite is relatively stable and is unlikely to cause future problems. After the mellowing period additional lime is added to the soil and construction proceeds normally.(9)

Sulfates are rarely distributed evenly throughout a construction site, but are found in isolated seams and pockets. Research is currently being conducted to improve methods for locating sulfate concentrations in the field in order to reduce the risk of problems and facilitate construction.

(8)

However, recent research on treating sulfates up to 7,000 ppm to reduce swell suggests using moisture contents 2% above optimum with a single application of lime (http://www.trb.org/am/ip/Practical_Papers.asp#1577).

(9)

Additional information is available at http://www.lime.org/sulfate.pdf .

(The links above may no longer exist).