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Flinders Estate – Lake Development
Dispersive Soil Management Plan:
Addendum for Lake Development (Planning)

Client: Pacific International Development Corporation

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Wholistic Environment
ABN: 73 6063 04901
Suite 3, 247 Bayview St
Runaway Bay Qld 4216
07 5537 9485

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Transmission Register

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Name	Email Address
Tom Regan	t.regan@thepacificgroup.com.au
Matt McLaren	mattmc@urbansolutions.net.au
Gavin Johnson	gavinj@urbansolutions.net.au

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Definitions

For the purpose of this ESC Plan the following definitions apply:

Term	Definition
Agricultural lime	Crushed limestone (calcium carbonate), which is used to raise pH to more optimal levels.
Amelioration	The application and incorporation of soil conditioners such as dolomite, gypsum or lime, organics, or chemical fertilisers to correct adverse soil qualities that affect soil stability and/or plant growth.
Conforming	Soil that passes MRTS16 specifications.
Dispersible or dispersion	Process by which clay particles are repelled by electrostatic forces and mechanical forces and separate from each other forming a suspension of clay particles in water.
Dolomite	An anhydrous carbonate mineral composed of calcium magnesium carbonate, ideally $CaMg(CO_3)_2$. The word dolomite is also used to describe the sedimentary carbonate rock, which is composed predominantly of the mineral dolomite (also known as dolostone).
Duplex soil	A soil where there is a sharp texture-contrast between the A and B-horizons. A duplex soil is often characterised by a sandy or loamy surface horizon with a sharp to clear boundary to a clay subsoil. Refer to Texture-Contrast Soil
Electrical conductivity	The measurement of how much electricity moves through a solution – the saltier the solution, the more electricity moves through it, and the higher the electrical conductivity reading.
ESP (Exchangeable sodium percentage)	ESP is calculated as the proportion of the cation exchange capacity occupied by the sodium ions and is expressed as a percentage. *i.e.* ESP = Exchangeable {(Na)/(Ca + Mg + K + Na)} x 100 In Australia, soils with an ESP greater than 6 % are considered to be sodic. However, soil dispersion problems may occur at a higher or lower ESP depending upon clay type. Strongly sodic soils have an ESP of 15% or greater.
Field pH	pH of soil in distilled water – 1:5 (soil:water) / Portable Kit (Raupach Indicator)
Flocculation	Process where the attractive forces between clay particles is greater than the repulsive forces, resulting in the formation of larger aggregates (the converse process is dispersion).
Gypsum	Calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$). It is often used as a soil amendment to improve structure, or to address sodicity.

Term	Definition
Lime	Lime is available in many forms such as agricultural lime (crushed limestone) dolomite, quicklime, and hydrated lime. In this report it refers to agricultural lime.
pH	See Field pH.
Plant available water	The amount of water between field capacity and permanent wilting point which is available to a plant
Salinity	The presence of soluble salts in soil or water
Shallow Sandy Texture-contrast (dispersive) soil	A soil where there is a sharp texture-contrast between the A and B-horizons. Characterised by a thin sandy or loamy surface horizon with a sharp boundary to a dispersive clay subsoil.
Deep Sandy Texture-contrast (dispersive) soil	A soil where there is a sharp texture-contrast between the A and B-horizons. Characterised by a thick (<200mm) sandy or loamy surface horizon with a sharp boundary to a non-dispersive clay subsoil.
Siltation	Pollution of water by silt or clay particles
Solum	The solum of a soil consists of a set of horizons that are related through the same cycle of pedogenic processes, and refers to the combined A, E, B horizon sequence. The solum is the true seat of soil-forming processes and is the principal habitat for soil organisms, however it is not necessarily confined to the zone of major biological activity. A solum does not have a maximum or a minimum thickness.
Standard	Relevant Australian and International Codes and Standards.
Surface Layers	Surface layers that extend down from the ground surface and are generally darkened (compared to any underlying layers) due to the accumulation of organic matter. (Normally referred to as topsoil)
Subsurface Layers	Subsurface layers that occur below, and are very similar to, the surface layer in texture and structure but are usually paler in colour (due to much less organic matter).
Subsoil	Subsoil, which refers to any layer below the subsurface layer (or below the surface layer if there is no subsurface layer) that has much higher clay content, brighter colours or markedly different structure. These may extend into sandstone.
Texture-contrast	An abrupt change in texture between the surface and subsoil. In these soils, a surface sand layer overlies a sandy clay soil that has a dispersive clay component.
Topsoil	See 'Surface Layers'.

Terms and Acronyms

The following terms, definitions and acronyms are used in this plan:

Abbreviation	Definition of abbreviation
AS	Australian Standard
ASPAC	Australasian Soil and Plant Analysis Council
CMP	Construction Management Plan
EIS	Environmental Impact Statement
EMP	Environmental Management Plan
ESC	Erosion and Sediment Control
ESCP	Erosion and Sediment Control Plan
DSMP	Dispersive Soils Management Plan
IECA	International Erosion and Sediment Control Association (Australasia)
MRTS16	Main Roads Technical Standard MRTS16– Vegetation Ground Works

SUMMARY

As part of the Flinders Development, it is proposed to construct two (2) dams across an unnamed tributary of Woollaman Creek, which passes through the site, and to fill it with catchment runoff supplemented with water from external sources, most probably Wyaralong Dam.

This Dispersive Soils Management Plan identifies the site-specific issues, and the suite of methods required to address potential issues associated with the exposure and re-use of locally-won soils with dispersive properties during the construction and operational phases of the project.

Extensive investigations have been undertaken that show that site soils are predominantly sandy and loamy solodics and podzolics. The texture-contrast solodic soils are characterised by a sandy surface horizon with an abrupt change to a highly-dispersive clay subsoil. When undisturbed, the combination of non-dispersive surface horizons, and good vegetation cover means that generally only minor erosion is observed in this landscape. However, once the subsoil layer is exposed to water, particularly concentrated flows, erosion can become a significant issue, especially on steeper slopes, where tunnel erosion may develop.

Untreated, or poorly managed dispersive soils can result in significant impacts upon downstream aquatic environments, and compromise physical assets due to erosion generally, but from tunnelling in particular. Sodic soils are also hostile to plant growth, and if untreated can significantly impact upon revegetation outcomes.

The implications of dispersive soils on the proposed lake development need to be considered within the context of the following:

- *Geotechnical*:
  - Re-use of site soils to construct the dam walls, with the potential risk of tunnelling causing leakage and structural failure.
  - Assets constructed upon the dam wall or lake edge (homes and roads and associated infrastructure), compromising, or being compromised by erosion.
  - Erosion of the lake edge.
- *Ecological*:
  - Aquatic environments: both downstream, and those associated with the lake itself.
  - Landscaping around and along the lake edge.
- *Lake Water Quality and Aesthetic*:
  - Turbidity in the lake resulting from erosion of the dispersive clays in the underlying soils used for the lake, and those in the catchment.
- *Financial*:
  - Construction costs associated with amelioration, and
  - Ongoing maintenance.

The dispersive properties of the subsoils are reflected in most of the underlying rock strata, which whilst hard when exposed, can quickly become soft and lose strength when wet, or slowly contribute turbidity as the clay component erodes from the exposed rock face.

<u>However, the identification and treatment of these soils is relatively simple and inexpensive when appropriate soil chemical factors and their interaction are determined</u>. Dispersion is a chemical issue, and its treatment

entails the use of a calcium-based product (gypsum, dolomite, or lime) that permanently corrects the physical instability, and the associated qualities that are hostile to plants.

More information will be required to finalise the designs associated with the dam wall and the lake edge, and also of methods to achieve the desired water quality. However none of these are insurmountable, and can be achieved with existing industry practices.

Large-scale construction on such soils presents challenges, but if properly managed, will result in more stable environments than occurred prior to disturbance. (*e.g.* Ripley Town Centre, Ecco Development, Ripley, Centenary Highway Upgrade, and many Coal Seam Gas right-of-ways and major facilities in western Qld).

The preferred design for the lake is for steep banks below water level to minimise the growth of aquatic plants along the lake edge. Based upon assessment of the material recovered for the relevant geotechnical reports, and discussions with the authors, some innovative methods will be warranted to stabilise the banks of the lake against erosion (dispersion) whilst simultaneously achieving this design.

The testing and discussion in this report is mostly in relation to the deeper subsoils. Whilst the topsoils will require amelioration for optimal plant growth, they are normally non-dispersive, and are not utilised as a construction media. Nevertheless, the suitability of the topsoil and upper subsoil is important for plant vigour, and needs to be considered within the context of plants providing protection against erosion of the underlying soils.

1 Introduction

1.1 Background

Pacific International Development Corporation (PIDC) is developing the Flinders residential development near Jimboomba, in south-east Queensland. The first Flinders precinct (Precinct 1) has been granted Material Change of Use approval for Urban Development.

As part of a new application to change the design to incorporate two (2) lakes, PIDC commissioned Wholistic Environment to prepare a Dispersive Soils Management Plan (DSMP) for these features. It has been prepared as an addendum to *'Site Based Management Plan For Dispersive Soils Proposed Flinders Subdivision, Undullah Queensland'.* (2011) Gilbert & Sutherland.

1.2 Intent of the Report

The report identifies the likely distribution and characteristics associated with dispersive soils for the proposed lake development. This information is required to assist those in the planning, engineering, environmental, and landscape professions, to understand the environmental and economic implications for the project during both construction and operational phases.

This report is intended to provide a level of detail sufficient for planning assessment by the regulatory authorities as part of the project Development Assessment. A greater level of detail will be required for final design, construction, and operational phases.

1.3 Implications of Dispersive Soils for the Proposed Lakes

Untreated, or poorly managed dispersive soils can result in significant impacts upon downstream aquatic environments, and compromise physical assets due to erosion generally, but from tunnelling in particular. Sodic soils are also hostile to plant growth, and if untreated can significantly impact upon revegetation outcomes.

The implications of dispersive soils on the proposed lake development need to be considered within the context of the following disciplines:

- *Geotechnical*:
  - Re-use of site soils to construct the dam wall, with the potential risk of tunnelling causing leakage and structural failure.
  - Assets constructed upon the dam wall or lake edge (homes and roads and associated infrastructure), compromising, or being compromised by erosion.
  - Erosion of the lake edge.
- *Ecological*:
  - Aquatic environments: both downstream, and those associated with the lake itself.
  - Landscaping around and along the lake edge.
- *Aesthetic*:
  - Turbidity in the lake resulting from erosion in the upper catchment/lake edge.
- *Financial*:
  - Construction costs associated with amelioration, and
  - Ongoing maintenance.

1.4 Scope of Study

The scope included a review of existing information, further soil testing, and consultation with other specialists:

- Attendance at meetings of the professional design team to discuss soil, water, and engineering-related issues and their implications.
- The review of two reports prepared for PIDC by Gilbert and Sutherland:
  - *Site Based Management Plan For Dispersive Soils Proposed Flinders Subdivision, Undullah Queensland. August 2012*
  - *Dispersive Soils Assessment And Management Plan, Flinders Development "Balance Land", Undullah Queensland. June 2015*
- Fieldwork by the authors associated with the preparation of a DSMP for the main access road. This resulted in a report for PIDC: *Flinders Drive, Undullah - Site Soil Investigation: Assessment, Treatment, and Rehabilitation (Incorporating Dispersive Soil Management Plan). 14 April 2015*.
- Examination of broad-scale (1:250,000) soils mapping for the site. Noble (1996)
- A review of relevant geotechnical reports.
- A review of a bulk soil samples and drill core collected by the geotechnical team, and discussions held with them with in regard to their characteristics and probable distribution around the proposed lake.
- Subsequent chemical testing of 17 deep subsoils that are considered to be representative of the site subsoils based upon the aforementioned technical review and discussions.
- A review of water quality data from SEQ Water for Wyaralong Dam, and the collection and analysis of water samples from Wyaralong Dam and the upper reaches of Teviot Brook.

2 Methodology

2.1 Field Surveys and Sample Selection

The authors have previously undertaken field surveys for the preparation of a soil management plan for the proposed main access road (Flinders Lakes Drive). This has provided a good basic understanding of the site soils, and their variability, albeit at relatively shallow depths.

Prior to, and since that time, Morrison Geotechnic Nerang office has undertaken a subsoil drilling programmes of the site as a whole, and of the lake in particular. Examination of both sample and core collected by the geotechnical team was undertaken by Mr. Dennis Baker, and following discussions with these professionals; sub-samples were collected for initial screening and subsequent laboratory testing. The results are discussed later in this report.

A survey been undertaken by the authors of the water quality associated with Wyaralong Dam and (its major tributary) Teviot Brook, and the results interpreted in relation to the proposed lake.

2.2 Emerson Dispersion Test Limitations

Soils can disperse because of:

- High amounts of exchangeable sodium (sodic soil),
- High magnesium (magnesic soil), or
- High concentrations of magnesium relative to calcium (especially if the absolute concentrations of both are very low).

Soil dispersion is most commonly determined by carrying out texture, slaking, and clouding tests. A soil that forms a cloud of soil particles and/or slakes (falls apart) when placed in a dish of distilled water is likely to have some dispersive characteristics.

An Emerson Class Number of 1 and 2 denotes dispersive soils. Emerson Class Numbers of 5 are rated non-dispersive.

Unfortunately few users understand the significant limitations of this test. Other chemical characteristics may result in a low Emerson Class Number, when in actual fact the soil may have a high tendency to dispersion. In the presence of high soluble aluminium and salinity there is a natural flocculating effect and a consequent tendency to underestimate the dispersion.

Soils that pass an Emerson dispersion test may later disperse because the stabilising salts are subsequently washed out of the profile. (*e.g.* on a batter or dam wall), or through (human-induced) changes to pH that reduces the exchangeable aluminium.)

Consequently, samples were tested chemically in order to understand their characteristics, and the appropriate method of chemical amelioration.

3 Site Characteristics

3.1 Site Description

The wider Flinders site is located approximately 50km south of the Brisbane CBD and approximately 20km north-northwest of Beaudesert. It falls within both Logan City municipality and the Greater Flagstone Priority Development Area. It is in a strategically central location between Flagstone, Bromelton, Yarrabilba, and Ripley, all being areas which are all undergoing rapid growth.

The first Flinders precinct (Precinct 1) is situated on Lot 3 on SP311896 and Lot 200 on SP133189 (996.78ha) and has been granted Material Change of Use approval for Urban Development.

The proposed lakes have a combined area of approximately 26.5 ha.

A further area of approximately 3,000 ha will also form part of the Flinders development. This is referred to as the 'Balance Land'.

3.2 Topography

The project land ranges in elevation from approximately 30m above sea level within the Undullah Creek floodplain to the south-east of the site up to 230m above sea level on the Mount Elliot Road ridge top to the north of the balance land. Slopes range from <1% in the floodplain up to >25% on the elevated upper ridge to the northwest of the balance land.

The broader Flinders site lies within the lowland freshwater catchment of the Logan River. Intermittent surface water flows occur in the waterways within the wider Flinders site.

The major surface water features in the balance land include Woollaman Creek and Undullah Creek.

- **Undullah Creek** flows from the north-west to the south-east (largely parallel to Undullah Road) and is fed by several gullies to the north-east. It then joins Woollaman Creek (entering from the west) at its southern end.
- **Woollaman Creek** drains a more substantial catchment to the west of the site and flows from west to east along the southern site boundary before discharging into Teviot Brook, some 1.4km downstream of the site.

3.3 Soil Description and Classification

The majority of the soils encountered around the lake are characterised as strong texture-contrast soils. That is a sandy upper layer, with an abrupt change to a dispersive clay subsoil. The upper layer is shallow on the hill-slopes, but may be very deep (≈ 1-1.5m) in the gullies as a consequence of erosion of sediment from the upper slopes.

Based upon the field assessment and supporting laboratory analysis, the soils associated with the proposed lake are dominated by Sodosols / Dermosols / Chromosols. (As per Isbell (2002) *Australian Soils Classification.*)

Both the Sodosols and Chromosols are characterised as having dispersive properties.

There will be significant earthworks associated with the construction for the lakes and the dam walls that will result in the exposure of some deep subsoils. Whilst some of these are rock, they have varying degrees of weathering and strength. Much of this deeper (less weathered) 'rock' reflects the characteristics exhibited by the weathered soils, with dispersion being a notable component.

4 Subsoil: Physical and Chemical Characteristics

The discussion in this report is in relation only to the subsoils collected from the deep drilling cores for the proposed lakes. Whilst the topsoils often require amelioration for optimal plant growth, they are normally non-dispersive, and are not utilised as a construction media.

4.1 Soil Sampling Procedure and Analytes

Core and bulk samples collected by Morrison Geotechnic were examined, some to a depth of 15m below ground level. Of these, a total of 31 subsoil samples were selected as being representative of the subsoil layers. These were sent to Phosyn (an ASPAC accredited laboratory) for analysis.

The soil properties (soil test parameters) assessed for the bulk samples from the ‘Flinders Lake Area Project’ (March 2016) project are:

- Soil pH;
- Salt content (EC);
- ESP ratio (% sodium of total cations);
- Exchangeable cations (Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K) and Aluminium (Al));
- Calcium to Magnesium ratio;
- Effective Cation Exchange Capacity (ECEC);
- Texture.

4.2 Soil Profile Layer Property Assessment

Based on the samples observed, the physical soil properties for the soil layers are summarised as:

1. Surface layers: A sandy-clay upper subsoil layer of texture-contrast soils.
2. Upper Subsoil Layers are Sodosols with dispersive properties.
3. Deeper Subsoils:
   - Stiff Sandy Clay with sodic dispersive properties.
   - Deeper Sandstone, or Dispersive Clay Subsoil of Hard to Soft Sandstones that are cemented but also have dispersive properties.

4.3 pH

The level of pH strongly influences the ability of plants to take up nutrients from a soil and the ability of the vegetation to be sustainable. It can also result in the dissolution of aluminium, which stabilises a potentially dispersive soil. The choice of ameliorant (lime, gypsum, or dolomite) is largely made based upon pH.

4.3.1 Alkaline Subsoils

With a few exceptions, the samples can be described as alkaline subsoils:

- Soils of *B horizon or deeper subsurface layers or Residual Sandstone from* which the Texture-Contrast dispersive soils of the area are derived, with
- Very Strongly to extremely acid to mostly alkaline pH Levels in the solum.

These soils will need to be treated with agricultural gypsum. The rate is dependant upon the exchangeable cation results.

4.3.2 Acid Subsoils

There were some acid subsoils noted in the boreholes:

- Extreme acidic subsoil clay pH requiring amelioration using Agricultural Dolomite or Lime depending upon the soil cation balance.

The soils are strongly acid, with the lowest pH being 5.3. These are not ideal for plant growth and require amelioration with agricultural dolomite or lime, the rate being dependent upon the exchangeable cation results.

4.4 Dispersive Characteristics of Underlying Rock Strata

The dispersive properties of the subsoils are reflected in most of the underlying rock strata. Whilst hard when exposed, they can quickly become soft and lose strength when wet, or slowly contribute turbidity as the clay component erodes from the exposed rock face.

5 Soil Erosion Hazard

Soil erosion hazard is recognized as dependent on site-specific factors such as rainfall (climate), landform (slope steepness and length), soil chemistry, land use and land management factors.

Particular issues associated with the lake development include:

- Large area of cut-to-fill.
- Long period of disturbance.
- Difficulty diverting the large, undisturbed catchment around all of the works. (Timing-dependent with regard to the dam wall construction.)
- Highly dispersive soils.
- Sediment basins would be constructed within dispersive soils.

The Erosion Risk Assessment has been assessed using two quantitative methods as per IECA (2008). The results are as follows.

5.1 TASK Erosion Hazard Assessment

5.1.1 Method

This Erosion Hazard Assessment is prepared in accordance with Appendix F of IECA (2008). It is based on a modification of the Revised Universal Soil Loss Equation (RUSLE). The TASK number is directly proportional to the estimated total soil loss within a given region (*i.e.* for a given rainfall erosivity).

$$H = T \times A \times S \times K$$

H = Numerical value of The TASK number
T = Duration of soil disturbance [months]
A = Total area of soil disturbance [m’]
S = Slope factor (Table F2 or Equation F3)
K = Soil erosivity factor (RUSLE K-factor)

The default value trigger value of 200 has been adopted.

5.1.2 TASK Calculation

H = Numerical value of The TASK number

T = 18 [months]

A = 250,000 [m^2] (assume progressive disturbance and clearing such that, on average, ¼ site open at any time)

S = 0.73 (assuming 5% slope)

K = 0.049 (Clayey sands with slight plasticity and +10% for dispersive soils)

$$H = 18 \times 90{,}000 \times 0.35 \times 0.062 = 160{,}965$$

Based upon this calculation, the site is **High Risk**.

5.2 Erosion Hazard Assessment Form

An alternative method described in Appendix F of IECA (2008) is by use of a point score system.

Using this method risk is prompted by a score of 17 or greater, or one or more of five trigger values being exceeded. In this case the score was 35, and four triggers were matched. Consequently, the site is considered to be **High Risk**.

6 Dispersive Soil Management – Construction

Dispersive soils present some particular challenges during construction:

- Become boggy when wet, with potentially long down-time after rainfall;
- Require sediment basins of suitable size, and the use of suitable coagulants to minimise downstream impacts; and
- Are highly erodible when concentrated water is put on them through temporary drainage.

To minimise construction-related impacts from the site soils, the site methods need to be in accordance with *Best Practice Erosion & Sediment Control,* IECA (2008). Appendix A contains relevant Fact Sheets associated with their management.

6.1 Sediment Basins

Based on the evidenced soil profiles and associated field texture analysis and Emerson Class and dispersion analysis, it is considered that ***'Type D'*** sediment basin(s) are required.

6.2 Progressive Clearing and Stabilisation

Progressive clearing is generally cheaper than wholesale clearing as no ESC controls are required for areas that haven't been disturbed.

Soil stabilisation should be maximised through progressive chemical amelioration of the subsoils.

Permanent stabilisation of bare areas with landscaping should be undertaken progressively to minimise the time of exposure.

6.3 Topsoil Stripping and Management

It is vitally important that subsoil is not mixed with topsoils, as the mixing of even 10% of the sodic subsoil may adversely impact plant growth. Accordingly, operators should be trained to strip a visual profile, rather than a depth *per se.*

Stockpiles shall be managed so that materials are not mixed.

6.4 Mulch Berms

Mulch berms are a more desirable option than silt fences, especially when combined with a broadcast coagulant such as gypsum. (Refer to section 6.8.1)

6.5 Drainage

Concentrated flow shall be avoided on all sodic soils. Where present, a barrier must be placed between flowing water and a dispersive soil.

Diversion controls should not be cut into, nor constructed of, untreated dispersive soils.

All temporary flow paths should be designed with a capacity for the 2yr ARI flows (plus freeboard).

6.6 Avoid Ponding

It is extremely important that ponding be avoided to prevent tunnel erosion.

6.7 Soil Compaction.

Soil compaction is one of the most useful tools for minimising the particular adverse impacts from dispersive soils, particularly tunnel erosion. A high degree of compaction reduces soil permeability, restricting the movement of water and dispersed clay through the soil matrix, which decreases the severity of dispersion and restricts tunnel development. However, dispersive soils can be difficult to compact as they lose strength rapidly at or above optimum moisture content, and thus may require greater compactive force than other soils.

6.8 Required Amelioration

The identification and treatment of dispersive soils is relatively simple, and inexpensive when appropriate soil chemical factors and their interaction are determined. Dispersion is a chemical issue, and the treatment of it is entails the use of a calcium-based product (gypsum, dolomite, or lime) that permanently over time corrects the physical instability and the associated qualities that are hostile to plants.

The testing and discussion in this report is mostly in relation to the deeper subsoils, as the topsoils are non-dispersive, and are not utilised as a construction media. However plants will provide the long-term protection against erosion of the underlying soils, and will require amelioration for optimal plant vigour.

Based upon investigations to date, the following table provides indicative treatments. The methods are shown diagrammatically in Appendix A. Future investigations during construction will determine treatments based on more specific data.

Table 6.1 Summary of Soil Amelioration for Construction and Revegetation

Soil Profile	Amelioration	
Topsoil Layers	Dolomite @ 10kg/m^3 or minimum 1.0kg/m^2 /100mm thickness well mixed. Controlled-release fertiliser (NPK: ≈ 24-2-9 + 2% Fe) such as Scott's Lawnbuilder at 40g/m^2. Revegetation shall utilise a wetting agent that is non-phytotoxic when applied at the manufacturer's recommended rate.	
Subsoil Layers	*Subsoil Layers: Acid*	Construction: Agricultural Gypsum: 15kg /m^3 Incorporate to minimum depth of 500mm
		Revegetation: *If this layer is in the plant root zone (upper 1m):* Agricultural Lime or Dolomite: 10kg /m^3 Incorporate to minimum depth of 500mm
	Subsoil Layers: Alkaline	Agricultural Gypsum: 15kg /m^3 Incorporate to minimum depth of 500mm
	Below Lake Surface. *Subsoil Layers: Alkaline*	Agricultural Gypsum: 15k to 25 kg /m^3 (Further refinement required) Incorporate to minimum depth of 500mm

6.8.1 Constructed Earthworks

Amelioration of soils for general construction purposes shall be in accordance with Table 6.1, and any further soil investigations undertaken by a suitably-qualified and experienced Soil Chemist.

6.8.2 Dam Construction

Chemical ameliorants such as hydrated lime (calcium hydroxide), gypsum (calcium sulphate), alum (aluminium sulphate) and long chain polyacrylamides have been used to prevent dispersion and piping in earth dams. Hydrated lime is the most commonly applied product with the rate varying between 0.5 to 4.0 % by weight, depending on soil chemistry and level of dispersion.

In the alkaline soils (pH >7.3) that characterise the Flinders Development, hydrated lime is not suitable due to the formation of insoluble calcium carbonate. Accordingly, gypsum is the preferred ameliorant.

Note that the specifics of the re-use of site soils for dam construction are the subject of separate specialised geotechnical and soil chemical advice.

6.8.3 Revegetation

The lake banks and surrounding verges are likely to have a high risk of tunnel erosion and treatment of the subsoils and topsoils will need to be undertaken to prevent dispersion, and maximise the stability of the surface cover. This shall be undertaken in accordance with Table 6.1, and any further soil investigations prepared by a suitably-qualified and experienced Soil Chemist.

6.9 Instream Works

Instream works shall be performed in accordance with the site-specific management options based on the assessment and characterisation of discreet stream reaches. These are detailed within the *Water Corridor Restoration Strategy*, which is a supporting document to the application.

7 Dispersive Soil Management – Lake Operation

The sections below outline the key management strategies and outcomes relating to dispersive soils for the ongoing lake operation.

It should be noted that the identification and permanent amelioration of the adverse qualities associated with dispersive soils is relatively simple. These are: physical (cover and compaction) and chemical (calcium-based products). As long as the requirements are incorporated into both the design and construction processes, no significant long-term impacts on lake water quality are anticipated.

7.1 Lake Water Quality

The client's desire for lakes that have relatively clear (low turbidity) water is challenging in an environment characterised by dispersive soils given their impact upon turbidity. Accordingly, it is recommended that the lake edge, wall, and bottom be treated to a minimum depth of 500mm for dispersion as per sections 6.7 and 6.8 of this report.

It is recommend that specific geotechnical and soil chemistry advice is incorporated into all elements of the future detailed lake civil design, and this be the subject to specialised supervision and advice during construction to take into account the specific soil conditions.

The earthworks required to create the lake may expose underlying dispersive rock layers. In this case, over-excavation, treatment, and re-compaction of such material will be required.

The design preference for deeper water along the lake edge to minimise the growth of aquatic plants needs to be considered together with soil stability and public safety.

It is noted that Wyaralong Dam is constructed in similar geology as that encountered at Flinders. Preliminary observations indicate that turbidity is not an issue around Wyaralong Dam despite less-than-optimal treatment of these soils. The moderate salt concentrations that characterise the impounded water encourage prompt settlement of the dispersive clays that enter the dam from all parts of the catchment.

As noted at Wyaralong Dam, even a low concentration of salt significantly minimises dispersion of any untreated, exposed soils on the bed or bank. This is clearly evident in the following series of photographs from Wyaralong Dam and its immediate surroundings.

As Wyaralong Dam is the likely source of initial water for the lakes, the settlement of any eroded fines is expected to be prompt. Whilst the salt concentration in the water flowing from the Flinders catchment is currently unknown, it is likely to be similar, and even if lower, it takes very little salt to settle such fines.

Wivenhoe Dam also has catchments with dispersive soils. Though used as the principle water supply for the south-east Queensland region, turbidity is not of specific concern for the catchment managers.

During the initial filling of the lake, the addition of a coagulant or flocculant may be required to minimise turbidity resulting form localised turbulence at the discharge point. The need for this should be planned for early in the construction sequence, but its need determined at the time of filling. The choice and dosing rate will consider any associated eco-toxicology.

Photograph 7.1. Wyaralong Dam Access Road. This photo shows the significant erosion associated with the dispersive soils in this catchment. Note that the 'topsoils' are sandy, and if stable, will prevent erosion of the underlying subsoils. It is the clay component of these that disperses and then washes away in water. The remaining component, which will be varying degrees of silt and sand will remain in situ, or having nothing to hold them together, be washed away during higher energy events (*i.e* fast-moving water).

Photograph 7.2. Site 3. Teviot Brook at McConnell Road. Shows highly turbid water from the greater catchment. This contrasts with the high quality in the lake as per Photograph 7.3

Photograph 7.3. Wyaralong Dam Recreational Area (Eastern end of lake). This photo shows the slight turbidity associated with the wave erosion, which contrasts with the otherwise high clarity in the lake. The sample was collected in a sheltered area to the left.

7.2 Upstream Water Quality Management

Note that 'Duplex Soils' that characterise the site. 'Duplex' refers to the soils having two distinct layers – the 'topsoils' are sandy, and overly an abrupt change to the underlying clay-dominated soils. It is the clay component of these that disperses and then washes away in water. If stable, the vegetated topsoil will prevent erosion of the underlying subsoils, and runoff will have low turbidity.

It is likely that there will be localised erosion within the catchment of the proposed lake that would contribute fine sediment.

The treatment of gully head erosion is very likely to be evident in the catchment, and the treatment of these specific areas will be important. The techniques for treating gully-head erosion are well developed and generally require lowering the batter angles, chemically ameliorating the subsoils, and using a high-quality topsoil / compost to encourage a stable vegetative cover. This treatment would need to be performed in accordance with this document, and the *Precinct 1 Water Quality Restoration Strategy*.

As noted in section 7.1, chemical treatment of dispersive soils permanently addresses physical instability of such soils. It is therefore expected that the proposed upstream water quality management strategies are performed in accordance with this document.

If the runoff water from the Flinders catchment continues to contribute a significant quantity of dispersive material despite the landscape treatments, and the salts levels in the lake drop over time, there may be the requirement for intervention in the upper undisturbed parts of the external catchment. This would most cost-effectively be in the form of additions of gypsum to the surface of these soils. This may be undertaken by: truck or tractor with a spreader; water cart with a cannon; or aerially with a crop-duster. The specifics should be investigated at a later stage in the programme.

8 Quality Assurance

8.1 Construction Phase Specifications

8.1.1 Construction Specifications

MRTS04 General Earthworks (October 2014) is in the process of review. The revised version is likely to contain methods for construction using dispersive soils that are useful for the project.

8.1.2 Revegetation Specifications

It is recommended that MRTS16 form part of the contract documents / drawings so as to ensure the necessary soil information is provided by the Contractor during construction to optimise the management of the soils used in this project. These should be incorporated into the landscape and open space management plans.

Any imported planting media should conform to MRTS16 full suite specification (not simply AS4419 – 2003).

Any soil conditioner (stabilised compost) used as an ameliorant should conform to pH, EC Wettability and NDI specifications as detailed in MRTS16 (refer to appendix C). Note this should apply to any soil organic matter used as an additive, or any manufactured soil imported into the project.

Any test laboratory shall be ASPAC accredited.

8.2 Auditing of Ameliorated Soil / Rehabilitation

It is recommended that supervision and auditing be undertaken on any and all ameliorated topsoil / subsoils by a **suitably-experienced soil scientist** (not a geotechnical professional as they assess soils differently). The audit should include an inspection of site soils management as well as site works such as complaints, corrective actions and reporting to assess compliance with the DSMP.

Topsoil testing shall include the following MRTS16 Sub-suite testing:

- soil pH;
- salt content (EC);
- ESP ratio (% sodium of total Cations);
- Exchangeable Cations Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K) and Aluminium (Al);
- Effective Cation Exchange Capacity (ECEC); Calcium to Magnesium ratio;
- Texture;
- Phosphorus;
- Fertility (P, K);
- Trace Elements Copper (Cu), Zinc (Zn), Manganese (Mn) & Iron (Fe);
- Sulfate;
- Boron.

8.3 Soil Testing and Soil Organic Conditioner Requirements

As a minimum suite of testing the contractor shall ensure that:

- Soil Organic Conditioner complies with attached specification for 'Soil Organic Conditioner' in appendix C.
- Sub-suite test results are supplied for any ameliorated stripped topsoil layer or subsoils ameliorated with Soil Organic Conditioner and/or agricultural lime.
- If topsoil is applied, it must conform to MRTS16 (Attached in Appendix C.)
- Soil Analysis report must be provided with each audit analysis of:

  a) Ameliorated stripped soil

  b) Any imported topsoil (if used) and

  c) Soil Organic Conditioner.

9 Study Team

9.1 Dennis Baker

Dennis holds a BSc from the University of Qld and has 46 years of experience in soil chemistry and interpretation of soil analysis, laboratory management (soil, water and plant laboratories) and as Research Scientist and Laboratory Manager.

This consists of 12 years with Qld Department of Primary Industries research scientist and 10 years with Department of Natural Resources Qld as Senior Lab Manager (in Charge) and 26 years as Consultant Soil Scientist.

He is the author of over 120 scientific publications and published reports in soil science and its applications.

Dennis is past long term executive member of Soil Science Society (now SSA), and a principal presenter in the training teams in soil chemistry and soil classification for Soil Science Australia Qld (SSA Q)

9.2 Bill Gardyne

Bill has more than 35 years national and international experience in undertaking environmental assessments, and extensive construction familiarity with large-scale green-field and pipeline projects. This work has included assessments of soils for geotechnical, erosion and sediment control purposes, and rehabilitation, particularly for the problematic soils in western Queensland.

Bill has prepared and reviewed erosion and sediment control plans and field implementation, and undertaken staff training in the latter.

He has been a Director of the International Erosion Control Association (IECA) (Australasian Chapter) since 2003, and a previous Vice-President (2003 to 2014). He is regularly called upon as an Expert Witness by both the regulator and contractors.

10 References

Baker D.E. (2011) – Origin Alliance Ipswich Motorway Upgrade – Soil Assessment Report

Baker D.E. (2011) - Ripley Urban Core for Henlia No 9 – Soils Assessment

Baker D.E. Principal Consultant - Technical Specification - Transport and Main Roads Specifications MRTS16 Landscape and Revegetation Works, October 2014

Baker D.E. Principal Consultant TMR (2006) – Main Road **Guidelines**, Landscape and Revegetation Works (Interim), MRTS11.16A , Qld Government

Baker D.E. Principal Consultant TMR (2006) – Main Road **Specification**, Landscape and Revegetation Works (Interim), MRTS16A, Qld Government Updated April 2014

Baker, D.E., and Eldershaw, V.J. (1993) *Interpreting soil analyses - for agricultural land use in Queensland*. Dept. of Primary Industries. Project Report Series QO93014, Australia.

Baker, D.E., and Eldershaw, V.J. (1993) *Interpreting soil analyses - for agricultural land use in Queensland*. Dept. of Primary Industries, Project Report Series QO93014, Australia.

Bruce R.C. and Rayment G.E. (1982), *Analytical methods and interpretations used by the Agricultural Chemistry Branch for soil and land use surveys*, Queensland Department of Primary Industries Bulletin QB82004.

DNR (1997), *Salinity Management Handbook*, Queensland Department of Natural Resources DNRQ97019.

Mortons *et.al.* (2016) *Waterway Corridor Restoration Strategy.* Unpublished report prepared for Pacific International Development Corporation.

Hardie M (2009) *Dispersive Soils and their Management - Technical Reference Manual*. Department of Primary Industries and Water, Tasmania.

Hazelton PA and Murphy BW (editors) (1992), *What do all the numbers mean? : A guide for the interpretation of soil test results*, NSW Department of Conservation and Land Management.

Isbell, R.F. (2002), *The Australian Soil Classification: Revised Edition*, CSIRO Publishing.

McDonald, R.C., Isbell, R.F., Speight, J.G., Walker, J. and Hopkins, M.S. (1990), *Australian Soil and Land Survey Field Handbook, second edition*, Inkata Press.

Morrison Geotechnic *Undullah* (May 2016) *Pacific International Development Corporation Geotechnical Investigation For Proposed Earth Embankment Dam and Associated 50ha Lake Precinct 1, Flinders Development*.

Noble, K. E. (ed.) (1996). *Understanding and managing soils in the Moreton Region.* Department of Primary industries, Training Series QE96003, Brisbane.

Rayment, G.E. and Higginson, F.R. (1992), *Australian Laboratory Handbook of Soil and Water Chemical Methods*, Inkata Press.

Reid, R.E. (1988), *Soil survey specifications* in *Australian Soil and Land Survey Handbook: Guidelines for Conducting Surveys* (Gunn, R.H., Beattie, J.A., Reid, R.E. and van de Graaff, R.H.M.), Inkata Press.

Soil Chemical Methods - Australasia by George E **Rayment** and David J **Lyons** published October 2010. The ISBN is 9780643067684.

Transport and Main Roads (2002), *Road Drainage Design Manual*, Queensland Department of Transport and Main Roads.

Transport and Main Roads (2007), *Transport and Main Roads Standard Specification MRS11.04: General Earthworks*, Queensland Department of Transport and Main Roads.

Transport and Main Roads (2008), *Transport and Main Roads Standard Specification MRS11.16B: Vegetation Works*, Queensland Department of Transport and Main Roads.

Transport and Main Roads (2009), *Transport and Main Roads Standard Specification MRS11.16: General Requirements Landscape and Revegetation Works*, Queensland Department of Transport and Main Roads.