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Penrith Lakes Development Corporation
PO Box 457
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6 March 2014

Attention: Robert Golaszewski

Dear Sir

RE: Geotechnical Considerations for Landforms in the Penrith Lakes Scheme

1 INTRODUCTION

1.1 Background

The Penrith Lakes Site is located north of Penrith, to the west of Castlereagh Road and east of the Nepean River. The Penrith Lakes Development Corporation (PLDC) has been in operation since 1980 when existing sand and gravel quarry operators merged to form the Corporation. Its purpose was to:

- Co-ordinate the orderly extraction of sand and gravel from the 1,935 hectare site, and
- Carry out progressive rehabilitation works in order to dedicate land to the NSW Government for recreation and for future urban development.

The quarry is nearing the end of its commercial life. On completion of quarrying some 1,500 hectares of remediated land will be dedicated to the NSW Government. The majority of remediated land has been developed for public recreational lake and park facilities (Parkland). Some of the land may be retained by PLDC for future residential subdivision (Future Urban Land).

1.2 Purpose of this Report

Coffey has been assisting PLDC with landform design and construction since the early 2000's. This report presents a brief summary of geotechnical considerations associated with the design and construction of landforms that will be utilised as either Parkland or Future Urban Land, depending on end land use criteria.

Coffey understands that PLDC is in the process of submitting a staged Development Application for the Penrith Lakes Scheme. Coffey has previously prepared document GEOTLCOV24000HA-WO dated 14 November 2013 which was prepared to support the first stage of the application.

This document updates and elaborates on the information previously submitted. The purpose is to demonstrate that geotechnical aspects associated with the Scheme are being appropriately managed. Coffey understands that PLDC is submitting a staged development application relating to the Penrith Lakes Scheme.

2 SUBDIVISION PLAN

Drawing PLDC - 11710 Rev F (attached) provides the PLDC proposed subdivision plan. The Plan shows the Stage 1 subdivision of the Scheme into 23 Lots, including Lot 4 (total area of about 350 hectares) which is the intended Future Urban Area. PLDC has advised Coffey it may proceed with development of the Future Urban Area for residential purposes within Lot 4, subject to further staged development applications.

Drawing PLDC - 11710 Rev F also shows the proposed further subdivision of Lot 4 into super lots of 2 hectares. Each of the super lots will contain areas of land that has been remediated to a standard agreed by Coffey and PLDC as suitable to facilitate future low density, articulated masonry veneer housing founded on Class H2 waffle raft footing systems. Presently the remediation process within Lot 4 is in progress.

Those areas of the Scheme not intended as Future Urban Land will be remediated to a create landforms suitable for parkland for passive recreation. This remediation process is nearing completion.

3 GEOTECHNICAL CONDITIONS

3.1 Definitions

Overburden: Site soils overlying the quarry resource at Penrith Lakes. Some of the Overburden remains in situ (In Situ Overburden) in areas not quarried.

Historical Fill is excavated Overburden that was placed about parts of the site during historic quarrying activities and is at an uncertain level of compaction.

Engineered Fill is material placed and compacted in accordance with an engineering specification prepared by Coffey in order to achieve specified certain material properties and characteristics.

3.2 Geological Setting

The Penrith Lakes site is located within Quaternary Age alluvial soils of the Cranebrook Formation. Typically the natural soil profile comprised:

- In Situ Overburden comprising sand, silt and clay, varying from about 6m to 10m thickness, over;
- Sands and gravels (Primary Raw Feed) varying from 6m to 10m in thickness, over;
- Shale or sandstone bedrock. Rock levels vary from about 4m AHD to 10m AHD.

3.3 Impact of Quarrying

As part of historical quarry operations, large areas of the Penrith Lakes site were excavated to rock level. Prior to about 2000, the excavated overburden was distributed about parts of the site as Historical Fill, which for the purpose of landform remediation is not considered as Engineered Fill.

In addition to the Historical Fill, some of the former quarry pits were used for tailings disposal. The tailings are formed by washing and sieving Primary Raw Feed to sort the gravel and sand from the silts and clays.

Consequently when the co-ordinated landform remediation strategy was introduced by PLDC there were:

- Areas of the site that had been excavated to rock that were able to be backfilled with Engineered Fill for the full depth to design ground surface level;
- Areas of the site that had been excavated to rock but contained Historical Fill to varying depths, and would therefore require engineer designed remediation strategies;
- Areas of the site that contained unconsolidated tailings to variable depths that would require ground improvement to varying extent depending on proposed end use.

3.4 Groundwater

Groundwater levels prior to quarrying are thought to have fluctuated between about 10m and 16m AHD. After the landforms are fully remediated, the long term groundwater levels are expected to stabilise at about the lake operating levels which vary for different lakes but are expected to range between about RL 10m and RL 14m AHD.

4 LANDFORM REMEDIATION METHODOLOGIES

4.1 Conventional Earthworks Construction

Conventional earthworks construction usually involves excavation of some or all of the Historical Fill and replacement with Engineered Fill to agreed standards.

This method is used more typically in Areas where no Historical Fill exists or where the level of Historical Fill is below the design thickness of Engineered Fill needed to achieve the design landform performance.

4.2 Ground Improvement by Dynamic Compaction

Dynamic compaction has been used in Future Urban Lands where the existing level of Historical Fill is close to the design ground surface level.

Dynamic compaction increases the density of Historical Fill by dropping a large weight from a significant height in a coordinated grid pattern. Coffey conducted extensive trials involving geotechnical investigation and construction monitoring to demonstrate the effect of dynamic compaction. As a result of these trials, a programme of drop height, weight, grid pattern and repetitions was specified. These trials indicated depths of influence (increased density) of 10m or more.

During the process, the upper 3m or so of the soil profile is disturbed, so this material is excavated and replaced using conventional earthworks.

4.3 Tailings Consolidation by Preload and Surcharge

Preloading is a process where Engineered Fill is constructed over compressible soils (such as tailings) and the landform is left dormant while the settlement occurs. The intention is to induce settlement that occurs as a result of the Engineered Fill placement prior to future urban development.

The Engineered Fill is constructed to the design height plus an additional height that is equal to the anticipated settlement. The process is often accelerated by providing vertical drainage and/or surcharging (addition of extra fill that will later be removed).

Preloading was used to remediate a former tailings pond in the Future Urban Area. Coffey prepared geotechnical design for the preloading and vertical drainage. Geotechnical monitoring was conducted during remediation to demonstrate that the design objectives were achieved. This method may be applied to other tailings ponds within Lot 4.

5 LANDFORM DESIGN

5.1 Future Urban Lands

When urban landform construction commenced circa 2003, the original design criteria for future urban lands was a specified limit on differential settlements for a 20m square area with a 20kPa surcharge. This is a larger footprint and higher load than a typical house, and was not consistent with subsequent Australian Standards.

Consequently, PLDC and Coffey introduced the additional general design intention of creating landforms that were capable of supporting residential development using footing systems with similar stiffness to for Class H footings systems (per AS 2870 – 1996 Residential Slabs and Footings). The intention was that engineer designed footing systems would be required, but piled footing systems would not be required.

In late 2007, PLDC requested that Coffey review geotechnical strategies for urban landform design at Penrith Lakes to more realistically reflect current residential market expectations. The design objective was to provide landforms capable of supporting articulated masonry veneer houses with Class H waffle raft footing systems that were "deemed-to-comply" with Australian Standard AS 2870 – 1996 Residential Slabs and Footings. Certain design assumptions and criteria were agreed with PLDC:

- The risk profile for footing performance is a 95% confidence limit as defined in AS 2870 – 1996, which provides a benchmark for acceptable footing performance.
- Future housing construction would be limited to two-storey, articulated masonry veneer construction to limit building loads to less than those originally specified.
- House footprints loads were based on typical modern rectangular and L-shaped building designs rather than a generic square footprint originally specified.

Residential footing systems must be designed to tolerate differential ground movements or settlements beneath the structure. These movements usually arise from seasonal shrink/swell movements in the upper soil profile due to soil reactivity. At Penrith Lakes, houses may experience differential ground movements arising from compression and creep settlements and hydro-compression (collapse) settlements due to future groundwater level rises in the landform.

The design intention was to construct a filled landform for which the ground surface movements arising from deep settlement mechanisms could be accommodated by a footing system defined in AS 2870.

Our analyses indicated that the design objectives could be achieved by construction of a certain thickness of Engineered Fill below design ground surface level, provided that the Engineered Fill meets certain material characteristics and compaction criteria. These minimum criteria were applied to landform construction from 2008.

Landforms constructed prior to 2008 by conventional earthworks and dynamic compaction methods were reassessed and it was assessed that these landforms would also meet the specific design objectives.

AS 2870 was modified in 2011 by introducing sub-classes of Class H sites. As a result, Future Urban Lands are currently intended to support articulated masonry veneer houses using Class H2 waffle raft footing systems that are "deemed-to-comply" with AS 2870 – 2011. This may need to be confirmed in due course to reflect the requirements of the Standard current at the time of land release.

Landforms within Lot 4 that have been constructed to Future Urban Standard are also considered suitable to provide an adequate foundation for subdivision roads, drainage and shallow underground services. Future Urban landform construction includes treatment at landform interfaces to reduce the impact of differential settlement.

5.2 Parkland

The design objective for Parkland is to limit post-construction differential settlements and total settlements to tolerable limits for passive recreation.

Most Parkland landforms constructed since Coffey's involvement at Penrith Lakes were constructed by removal of Historical Fill and replacement with Engineered Fill constructed to a Method Specification (Parkland MS) developed by Coffey and PLDC to achieve a target fill compaction. The compaction criteria for Parkland MS Engineered Fill are less stringent than for Future Urban Lands.

Occasionally, some Historical Fill is permitted to remain in the remediated landform where it has been assessed that it will not have a significant impact on the landform performance for its intended use.

Some older Parkland landforms may have been constructed by placing Engineered Fill over Historical Fill. These areas have been constructed for generally at least decade so that most potential settlement has occurred while other landforms are being constructed.

Tailings ponds that are located within Parkland areas may be developed as wetlands or may be capped. The degree of capping and consolidation constraints is less than in Future Urban Lands due to the different end land use criteria.

Landforms constructed to Parkland MS standard are expected to provide a suitable foundation for minor roads. These landforms may also be suitable to support minor drainage/infrastructure works but this has not been part of the specific design criteria for Parkland. Specific advice may be required for roads and services in parkland areas, particularly where routes transition between different parkland landform or natural ground.

5.3 Lake Shores and Landform or Elements with Specific Design Functions

Certain landforms have been designed to fulfil specific functions within Parkland and lake shore areas and these have more stringent compaction criteria, and are compacted to a density specification.

6 TECHNICAL SPECIFICATIONS FOR LANDFORM CONSTRUCTION

The governing technical specification for landform construction for the Penrith Lakes Scheme is known as the “Site Wide Technical Specification” which is subject to progressive revisions. The Site Wide Technical Specification deals with standard construction principles for the various landforms that are constructed for various purposes and end uses.

Where specific land parcels are constructed for a specific purpose, or where it may be appropriate to modify standard landform construction practices because of the history of the Area, Coffey develops site specific Technical Specifications that take precedence over the Site Wide Technical Specification. There is a separate Technical Specification for each Area that has so far been constructed as a Future Urban Landform to reflect the prevailing site conditions in each area.

Broadly the technical specifications cover:

- Preparation of existing ground prior to placement of Engineered Fill, including existing pit walls and batter slopes;
- Materials specifications for Engineered Fill;
- Stockpiling, conditioning, placement and compaction of Engineered Fill; and
- Testing and Quality Assurance for Engineered Fill construction.

6.1 Future Urban Lands

In areas that are designated as Future Urban Lands, conventional earthworks construction is monitored by Level 1 Geotechnical Inspection and Testing, as defined in AS 3798 – 2011 “Guidelines on earthworks for commercial and residential developments”.

To achieve the design objectives the Engineered Fill must achieve a certain density and stiffness or modulus. Most Engineered Fill in Future Urban lands is constructed by a method specification that was developed through field trials. The fill is accepted based on assessment of compliance with a specified construction methodology.

In the upper 3m, the Engineered Fill is constructed to a density specification. The Engineered Fill is accepted based on observations of construction methodology supplemented by a regular density testing programme.

6.2 Parkland

In areas that are designated as Parkland, conventional earthworks construction is monitored by Level 2 Geotechnical Inspection and Testing, broadly as defined in AS 3798 – 2011 "Guidelines on earthworks for commercial and residential developments", but with some additional responsibilities.

To achieve the design objectives the Engineered Fill must achieve a reasonable and relatively uniform compactions to limit total and differential settlements. Engineered Fill in Parklands Urban lands is constructed by a method specification that was developed through field trials. The fill is accepted based on assessment of compliance with a specified construction methodology.

7 LIMITATIONS

7.1 Civil Engineering and Flood Mitigation Design

References in this report to "landforms" relate to the geotechnical stratigraphy, not to the terrain. Civil engineering design of the terrain that will form the proposed Penrith Lakes Scheme has been carried out by others. Civil engineering and flood mitigation matters are addressed by other consultants reporting directly to PLDC.

7.2 Environmental Matters

A site history study was made in 2001 by Coffey for the preparation of the Penrith Lakes Scheme Master Plan Study, and was reported in *Preliminary Contamination Assessment* (reference S20418/7-BB, 28 June 2001). Based on the site history review, it was concluded that there was a low potential for widespread contamination that would preclude rezoning for residential use.

Since that site history study in 2001, Coffey assisted PLDC with some specific matters but the co-ordination and management of environmental/contamination matters has since about 2007 been addressed by another consultant.

8 SUMMARY

Since the early 2000's, Coffey has assisted PLDC to achieve their remediation objectives by developing geotechnical remediation strategies for proposed landforms at Penrith Lakes. These remediation strategies are documented in various geotechnical design reports.

The strategy for Future Urban Lands involves construction of a certain thickness of Engineered Fill below design ground surface level. The Engineered Fill has specified material characteristics and compaction criteria. Future Urban Lands is currently intended to support articulated masonry veneer houses using Class H2 waffle raft footing systems that are "deemed-to-comply" with AS 2870 – 2011. Landforms constructed to Future Urban Standard are also considered suitable to provide an adequate foundation for subdivision roads, drainage and shallow underground services.

The Site Wide Technical Specification and other site specific technical specifications document the requirements for the landform construction that have been developed by Coffey and PLDC in order to realise the geotechnical design strategies for Parkland and/or Future Urban Land. Broadly, the technical specifications stipulate required construction and verification procedures for:

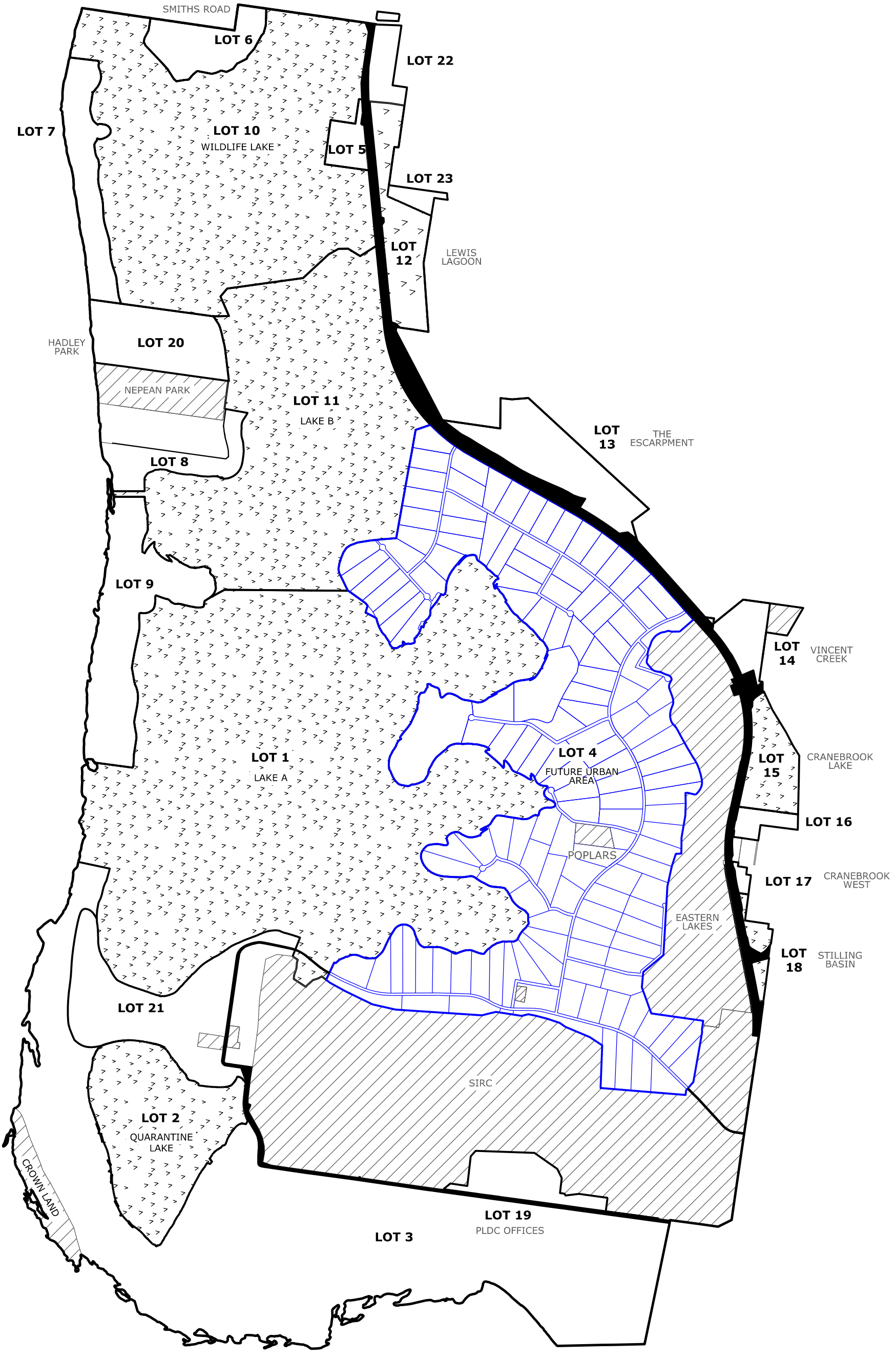
- Preparation of ground prior to placement of Engineered Fill;
- Materials specifications for Engineered Fill;
- Stockpiling, conditioning, placement and compaction of Engineered Fill; and
- Testing and Quality Assurance for Engineered Fill construction.

This report presents a brief summary of geotechnical considerations associated with the design and construction of landforms depending on end land use criteria. Specific queries should be directed to the undersigned via PLDC.

For and on behalf of Coffey

Robert Turner
Principal Geotechnical Engineer

Attachment: Drawing PLDC - 11710 Rev F



Rev	Date	Description	Drafted By	Designed By	Checked By	Approved By
F	10/02/2014	FOR INFORMATION - NOT FOR CONSTRUCTION	NAE	BJM	AFK	
E	05/02/2014	FOR INFORMATION - NOT FOR CONSTRUCTION	NAE	BJM	AFK	
D	16/01/2014	FOR INFORMATION - NOT FOR CONSTRUCTION	NAE	BJM	AFK	
C	17/12/2013	FOR INFORMATION - NOT FOR CONSTRUCTION	NAE	BJM	AFK	
B	30/10/2013	FOR INFORMATION - NOT FOR CONSTRUCTION	TPK	BJM	AFK	
A	29/10/2013	FOR INFORMATION - NOT FOR CONSTRUCTION	TPK	BJM	AFK	

Notes:

STAGE 1
Lot 1 to Lot 20

STAGE 2
Additional 200 x >2 Hectare lots

Lot 4 layout in accordance with JWP 9600/SK40 13/11/13

Legend:

Government or Privately owned land

Land to be dedicated in accordance with provisions of 1987 Deed of Agreement

LOT No. — Possible future urban areas

N

Scale Bar: 0 100 200 300 400 500 Metres

Projection: MGA Zone 56

Sheet Size: ISO A3

Print Scale: 1:20000

Title: DA5.2 Stage 2 Superlot Plan

Drawing No: PLDC - 11710

Revision: F

PENRITH LAKES

10/02/2014 3:13:19 PM J:\CorpData\Scheme\Structure Plan\2013_Structure Plan_131217_NAE_Stage 2_DA5.2_Residential Subdivision Plan_Superlot.dgn