Lynas Advanced Materials Project: Conceptual Design for Residue Storage Facility - Gebeng

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Lynas Advanced Materials Project

Conceptual Design for Residue Storage Facility - Gebeng

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SYNOPSIS

As part of the Advanced Materials Project to be constructed in Malaysia, WorleyParsons Services Pty Ltd was request by Lynas Malaysia Sdn Bhd to prepare a conceptual design for a residue storage facility using ‘base case’ conditions. Based on anticipated residue characteristics and disposal conditions, the volume of residue produced per annum and over the lifespan of the project was calculated and used in conjunction with a waste strategy/philosophy directed towards the creation of a geotechnically stable and environmentally neutral long-term storage facility. Potential re-use of process by-products and post-closure potential site development were emphasised in the conceptual design. The conceptual design of the residue storage facility is described in terms of design objectives, design parameters and assumptions, facility operation and conceptual design details and drawings.

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PROJECT 302/14205 - LYNAS ADVANCED MATERIALS PROJECT

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CLIENT APPROVAL	DATE
0A	Issued for internal review	P Baker/W Miller	T Loh/S Rutkowski	N/A	19-Oct-07	N/A	
0B	Issued for Information	P Baker/W Miller	T Loh/S Rutkowski	N/A	12-Nov-07		N/A
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1	Approved for Construction	P Baker/W Miller	T Loh/S Rutkowski	N/A	16-Jan-08		N/A

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1. INTRODUCTION

The project is for the development of the Advanced Materials Plant by Lynas Malaysia Sdn Bhd for the production of high purity lanthanide compounds within the Gebeng Industrial Estate (GIE), Kuantan State, Malaysia. The raw material is poly-metallic Lanthanide Concentrate from the Mt Weld mine in Western Australia, which will be imported through the sea port at Kuantan and delivered to the plant by road.

Lynas Corporation Ltd. is a publicly traded company listed on the Australian Stock Exchange and is involved in the production of Lanthanide products. The Advanced Materials Plant will consist of a number of processing areas:

1. Cracking & Separation Plant, consisting of the sections;
   - Cracking;
   - Waste Gas Treatment;
   - Leaching (primary, secondary, tertiary);
   - Upstream Extraction;
   - Downstream Extraction;
   - Product Finishing;
2. Utilities;
3. Water Treatment and Residue Management; and
4. Off-plot.

The Concentration Plant (to be located in Mt. Weld, Western Australia) will produce an intermediate Lanthanide Concentrate which is the feedstock for the Cracking & Separation Plant (C&S Plant). In the Concentration Plant, the ore will be processed via crushing, ball milling, flotation (rougher, scavenger and cleaner cells), concentrate thickening and filtration, and tailings dewatering and storage to obtain an Iron Oxide Material (IOM) residue and a Lanthanide Concentrate.

Lanthanide Concentrate will be transferred to the Advanced Materials Plant within the GIE in Malaysia where it is subjected to the cracking and separation process involving concentrated acid in a rotary kiln and water leaching of the calcine. Following three stages of leaching and solid-liquid separation, solvent extraction will be used to separate, purify and concentrate the lanthanide elements. The lanthanide elements are finally precipitated and calcined to produce a range of carbonate and oxide products.

2. PROJECT DESCRIPTION

The Advanced Materials Project involves processing lanthanide concentrate from Mt. Weld in Western Australia, at a processing site that utilises chemical treatment processes. A description of the process is provided in WorleyParsons report 13229-PM-RP-001 (2007).

As a result of the lanthanide concentrate processing, three separate residue streams are produced; Flue Gas Desulphurisation residue (FGD); Neutralisation Underflow residue (NUF); and Water Leach Purification residue (WLP).

The three residue streams (FGD, NUF, and WLP) are subjected to pressure filtration and assumed to be in paste form (moisture contents between 30% and 40%), once processed and ready for storage in the Residue Storage Facility (RSF). Residues with moisture content between 30% and 40% are often referred to as paste. Rheological testing on the paste residue streams expected from the process plant indicates that the paste residues are not suitable for pumping. Therefore, the FGD, NUF and WLP residue streams will be transported by vehicle, deposited, spread and traffic compacted to form the respective residue deposits. This type of residue storage produces a stable land-form and reduces the seismic risk for the RSF.

A summary of the three residue streams in terms of anticipated disposal conditions, surface water runoff management, lining requirements and potential residue end use is provided in Table 1. These topics will be discussed in greater detail in later sections of this report.

Table 1: Residue Streams Summary

Residue Stream	Expected Disposal Condition	Supernatant Water and Surface Water Runoff	Lining Required	Potential Residue End Uses
FGD	Paste	Captured and contained in storage pond and returned to waste water treatment facility	Dual Liner System (HDPE/low permeability clay)	Sale
NUF	Paste	Captured and contained in storage pond and returned to waste water treatment facility	Dual Liner System (HDPE/low permeability clay)	Sale
WLP	Paste	Captured and contained in storage pond and recycled into cracking and separation process stream	Dual Liner System (HDPE/low permeability clay)	Storage or sale

3. WASTE DESIGN VOLUME AND SURFACE AREAS

3.1 Quantity of Waste Generated

The anticipated annual dry mass and volume of residue per annum over a 10 year project lifespan generated by the lanthanide extraction process for the three streams is summarised in Table 2.

Table 2: Average Quantities of Residue Generated

Residue Stream	Annual Dry Mass Year 1 (tpa)	Assumed Dry Density (t/m^3)	Annual Volume Year 1 to Year 2 (m^3)	Annual Volume Year 3 to Year 10 (m^3)	10 Year Volume (m^3)
FGD	27,900	1.05	26,600	53,200	478,800
NUF	85,300	1.05	81,300	162,600	1,463,400
WLP	32,000	0.70	45,800	91,600	824,400
Total	**145,200**		**153,700**	**307,400**	**2,766,600**

Annual dry residue mass for each stream is subject to change (decrease and increase) pending further refinement of the processing systems.

The base case RSF design assumes that the FGD, NUF, and WLP residue streams will undergo dewatering resulting in paste for deposition and storage within the RSF.

3.2 RSF Footprint Area

Based on drawings provided of the proposed site, a conceptual layout of the RSF was developed. Drg. No. 302-14205-CI-DSK-0001 presents the conceptual RSF layout configured for the storage of all three residue streams assuming 8m high embankments. Based on the configuration shown in Drg. No. 302-14205-CI-DSK-0001 the approximate available surface area for residue storage is summarised in Table 3.

Table 3: Approximate Surface Area for each Residue Stream

Residue Stream	Approximate Surface Area Available for Residue Storage (m^2)
FGD	46,000
NUF	154,000
WLP	80,000
Total	**280,000**

The surface areas presented in Table 3 are approximate (±10%) and will require further refinement as the RSF design proceeds. Further modifications to overall layout, RSF embankment configuration, pond sizing, and use of dried compacted residue as construction materials are ongoing to minimise surface area requirements. The RSF footprint area may also be reduced by reclamation of residues for reprocessing or sale.

4. WASTE MANAGEMENT STRATEGY/PHILOSOPHY

The waste management strategy for the three residue streams is directed towards the creation of an environmentally-neutral long-term storage facility by means of a RSF design which maximises the potential recycling of process by-products. Even if by-products are not utilised in the future, the RSF design will be capable of permanent storage (for the period of 5-6 years) of the residue and result in a stable and useful final landscape.

4.1 Potential Reuse of Residue Streams

An alternative approach to long-term storage of residue is the potential reuse of the waste streams by identifying potential beneficial uses for some (or all) of them. The latter approach regards the residue and other materials generated by the project as by-products rather than waste. This approach has been explored for the various residue streams generated by the Advanced Materials Project (WorleyParsons Report No. 13229-PM-RP-001, 2007) and the results are summarised below.

Each of the residue types has a high magnesium and phosphorus content, and therefore may be used in the fertiliser industry.

The FGD stream, consisting predominantly of gypsum (manufactured calcium sulphate) could find useful sales in the Malaysian plasterboard market, although the product would need to compete with both virgin gypsum and a range of other (similar) by-product or manufactured gypsum types.

The NUF residue contains a high level of magnesium. Although the content of aluminium may not be considered desirable, the calcium sulphate is considered to complement the materials.

The WLP residue also contains relatively high levels of the nutrients phosphorus and magnesium.

Residues may need to be stored until processing and sale of the materials becomes commercially viable. Accordingly, the residues need to be stored with an emphasis on future availability while maintaining environmental controls and geotechnical stability.

4.2 Post-Closure Potential Site Development

Post-closure site development options have been explored and are summarised in WorleyParsons Report No. 13229-PM-RP-001 (2007). Potential land use options identified include residential, agricultural, industrial, recreational, and commercial. The preferred option is to establish a stable landform suitable for industrial development.

Potential post-closure site development options for the RSF site will be dependent on the height of the residue cell embankment, material properties of the residue streams, and existing ground conditions.

A layout using cellular design maintaining separation of the three residue streams and capped at the end of the project is proposed. This will satisfy the condition of accessibility to the stored residue materials should sale of the materials become economically viable in the future. The height of the embankments is currently limited to 8m in order to achieve a stable landform (pending further geotechnical assessment of residue properties, embankment parameters and existing ground conditions). This may allow use of the site as a commercial/industrial area pending consideration of environmental and geotechnical constraints dependent on the type of development proposed if the alternative of sale of stored residue is not pursued.

Should material properties of the residue streams be such that a final land mass without sufficient stiffness to support typical commercial or industrial structures be achievable, the RSF area will be able to provide passive and recreational end uses once capped for permanent storage and environmental conditions (if any) are satisfied.

4.3 Surface Water Runoff

The surface water management system for the RSF will comprise a segregated system from that designed for the process plant. Surface water from the RSF area will not mix with surface water from the process plant area. Any supernatant liquors and rainfall runoff associated with RSF cells will report to dedicated RSF retention ponds prior to return to the waste water treatment facility (WWTF) or to the cracking and separation process in the case of the WLP storage cells. Water will be treated to meet approved criteria and ultimately released off-site.

During operation the surface of active FGD, NUF and WLP residue containment cells will be continuously contoured by earthmoving equipment to a slope of approximately 100H:1V as residue are placed and compacted to direct surface water towards a single supernatant/surface runoff pond within the RSF cells. The WLP containment cell will have a separate dedicated surface water retention pond.

Supernatant liquors and rainfall runoff from the FGD and NUF residue will be directed or pumped via pipeline to a common high density polyethylene (HDPE) lined surface water retention pond with capacity for the 1 in 100 year storm event based on climatic data for the region. Water from this pond will be returned to the nearest pipeline access point for return to the WWTF in the process plant. Water from the WWTF will be assessed against approved criteria and ultimately discharged off-site.

Surface water runoff must be removed from the RSF cells within days of accumulation to prevent the residue mass from absorbing water and resulting in a residue surface that is untrafficable for extended periods of time limiting placement of residue within RSF cells. The FGD/NUF surface water retention pond will be sized to accommodate these potential water volumes until this water can be processed by the WWTF.

The composition of supernatant liquors and surface water runoff from the WLP residue is not expected to be suitable for release back into the environment. Instead this water stream will be recycled into the cracking and separation process stream and as such, surface water runoff will be directed or pumped to a separate HDPE-lined surface water retention pond with capacity for the 1 in 100 year storm event based on climatic data for the region. Supernatant liquors and rainfall runoff from the WLP residue will be pumped via pipeline to the nearest pipeline access point for return to the cracking and separation facility.

At closure, residue cells will be capped with suitable low-permeability materials to prevent infiltration into the permanently stored residue mass and a landform will have been created with positive surface drainage. Surface water runoff from capped cells will not interact with stored residue and the final site topography will encourage surface water to drain off-site to prevent ponding and standing water.

5. EXPECTED SUBSURFACE CONDITIONS

5.1 Subsurface Ground Conditions

A geotechnical site investigation at the Gebeng site has recently been carried out and the interpretation and assessment of test pit and borehole logs, soil samples, and laboratory testing results will provide geotechnical parameters required for the final RSF design.

Ground conditions within the upper 4m of the soil profile are consistent across the site. The uppermost two horizons – the fill and underlying organic clay are continuous across the site while there are local variations in the marine/alluvial horizons beneath the organic clay where the materials may be lensed and discontinuous.

Prior to placement of general fill, vegetation, tree stumps and roots were removed. Placement of fill commenced four years ago and earthworks continued for approximately twelve months. The fill was won from local borrow and comprises two main types:

- Lateritic Fill: Clayey sandy gravel with distinctive red-brown colour: and

- Sandstone Fill: Clayey gravelly sand.

Clayey gravelly sand is the dominant fill type used on site. The gravel component consists of fine to coarse, subangular gravel of medium strength sandstone. The fill contains occasional cobbles of sandstone and is yellow-brown in colour.

Across the site, the depth to the base of the fill varies from 0.8m to 1.8m (average 1.3m). Based on SPT N-values of between 4 and 10 the material is loose – suggesting that the fill was placed and traffic compacted.

The fill was placed over the in situ swampy soil comprising very soft medium plasticity organic clay which can vary in thickness from 0.6m to 1.7m. This unit contains softened roots up to 20 mm diameter throughout and occasional tree trunks up to 1.5m long and 0.3m thick. Hand shear vane tests returned undrained shear strength values between 7 kPa and 15 kPa corresponding to very soft to soft consistency. The organic clay generally grades into a non-organic medium plastic green-brown soft clay of alluvial origin, otherwise the organic clay is directly underlain by blue-grey or light grey silty/clayey sand believed to have been deposited in a shallow-marine setting.

The silty/clayey marine sand was encountered in the majority of test pits with a variable thickness between test pits from 0.3m to greater than 2.1m (and extending beyond the depth of the test pit).

SPT N-values of between 2 and 13 indicate the sand is loose. Where slow seepage of groundwater was observed, the marine sand began to slump suggesting the material has low cohesion.

The marine sand is underlain by dark grey-brown sandy clay. Interpreted as alluvial clay, the material is soft with medium plasticity.

Ground conditions within the upper 4m of the subsurface profile is summarised in Table 4.

Table 4: Summary of Subsurface Profile (to 4.5m depth)

Geological Unit	Depth to Base of Unit	General Description
Fill	Up to 1.8m	Clayey gravelly SAND, yellow-brown, medium strength sandstone gravel, moist, loose; locally clayey GRAVEL, red-brown, ironstone gravel, moist, loose.
Swamp Deposit	3.0m	Silty CLAY, low to medium plasticity, dark grey, soft roots throughout, high organic content, very soft to soft. Thickness 0.6 to 1.7m
Alluvium	>4.2m	Silty CLAY, locally sandy, green-brown, medium plasticity, soft. Thickness 0.2 to >2.2m
Marine Sand	>4.2m	Silty/Clayey SAND, fine to medium grained, blue-grey and light grey, loose, medium plastic fines. Thickness 0.3 to >2.1m
Alluvium	>4.2m	Silty/Sandy CLAY, medium plasticity, dark grey-brown, moist, soft.

Short-term (total stress) and long-term (effective stress) design parameters in terms of undrained shear strength, bulk density and friction angle have been estimated based on the visual assessment of materials and in situ tests (hand shear vane and standard penetration tests) to provide data required for the preliminary assessment of embankment stability discussed in Section 7.

5.2 Groundwater

In all test pits excavated, only minor seepage of groundwater was encountered in the upper 3.5m of the soil profile, with the water believed to be present in isolated sandy lenses within the organic clay and underlying units.

Where encountered in the test pits, slow but steady seepage of water into the pits occurred below 3.5m depth. Four test pits were left open up to 3 days and the water level monitored. After 2 days, the water level in the pits had risen to between 1.3m and 2.5m depth below ground level.

Seven monitoring wells are present around the site. The water levels in the wells at the time of the investigation were between 0.95m and 3.5m below ground level.

The observations in the test pits and monitoring wells suggest that the water table is between 3.5m and 4.0m depth. The organic clay and underlying clay horizon may act as an aquitard that once penetrated by a borehole or test pit allows the water to rise to a piezometric level that in places is less than 1m below ground level.

6. CONCEPTUAL DESIGN AND DESCRIPTION OF RSF

6.1 Design Objectives

The RSF will be designed for environmentally acceptable and geotechnically stable long-term permanent storage of all three residue streams. The design will also accommodate potential access to stored residue should markets for the materials be identified in the future. A dual liner system of high density polyethylene (HDPE) overlying a compacted low-permeability clay liner will be implemented to minimise potential migration of leachate from the RSF cells.

Another important objective of the design is the implementation of a water management system for supernatant liquor and surface water runoff from RSF containment cells. The RSF water management system will incorporate contoured residue surfaces, dedicated retention ponds and ultimately water return to the process plant area for either recycling within the process or treatment in the waste water treatment facility (WWTF) before being discharged off site.

It should be noted that the following conceptual design requires complete geotechnical assessment and analysis in terms of existing ground conditions and residue properties to ensure satisfactory performance throughout the lifespan of the facility.

6.2 Design Parameters and Assumptions

Production parameters used for the RSF design are discussed in Section 3 and presented in Table 2. The RSF design includes the following assumptions:

- Fill may be added as required to ensure that depth to groundwater from the bottom of the RSF is more than 1m and the RSF design will ensure that residue solids are isolated from direct interaction with groundwater. This soil layer comprising fill underlying the RSF would be an unsaturated zone inhibiting potential contaminant migration.

- The FGD, NUF, and WLP streams will have a paste consistency at a moisture content between 30% and 40%. These residues will be stockpiled and allowed to air-dry to achieve a moisture content of less than 25% before being spread and traffic compacted with a front-end loader and dozer.

6.3 Residue Facility Design for NUF, FGD and WLP

It is anticipated that initial RSF cells will be sized for 4 years storage capacity (when the embankment is raised 2 m annually to a maximum height of 8 m) with additional area on site currently predicted to accommodate approximately 5 and 6 years of permanent residue storage. Drg. No. 302-14205-CI-DSK-0001 presents the RSF final layout. Typical embankment sections for the NUF, FGD and WLP RSF cells are shown on Drg. Nos. 0002, 0003 and 0004, respectively.

The RSF has been designed as a paddock-style facility with a final perimeter embankment limited to 8m in height. Initially, RSF cells will be constructed on existing filled ground for each residue stream with storage capacity for one years' production of the respective residue streams. Additional adjoining cells to increase storage capacity will be constructed based on filling curves and staged storage predictions throughout the lifespan of the facility. Final embankment heights are subject to analysis to confirm slope stability, settlement and other geotechnical constraints

Suitable fill material with required geotechnical properties will be used for the initial embankment construction. Downstream perimeter walls have been designed with a 3H:1V batter slope – an angle considered consistent with the desire to establish a stable long-term landform. Erosion protection such as coarse rock (rip rap) or geotextile will be required for perimeter walls. A crest width of 4 m has been chosen but can be modified to suit the envisaged construction equipment. Upstream slope and divider wall batter angles have been designed at 2H:1V with the exception of the initial upstream slopes which will be at 3H:1V to optimise liner construction effectiveness.

Foundation soils beneath the embankment footprint should be scarified and recompacted prior to placement of embankment fill. Depending on ground conditions, it may be necessary to scarify and recompact the foundation soils in the basin areas to establish a trafficable platform on which to commence dual liner construction and residue placement. Fill will be added as required to ensure depth to groundwater from bottom of RSF is more than 1m.

Embankment raises will take place on an annual basis as additional storage capacity is required. Centre-line embankment raises will be used for FGD and NUF containment cells utilising placed NUF and FGD residue (WLP will not be used as construction materials for environmental reasons). Use of the NUF and FGD residue as construction materials is provisional pending geotechnical assessment of the material properties. The FGD and NUF residue will be deposited as paste and will require air-drying prior to use as an embankment fill. Air-dried residue should be compacted to 98% standard maximum dry density or 95% modified maximum dry density, and at optimum moisture content.

A downstream configuration will be used for embankment raises for the WLP cells. This will allow a continuous implementation of the dual liner system (described below) across the cell floor all the way along the downstream embankment face to the final height of the embankment at which time the cell will be capped for closure.

Containment of residue liquor will be maintained using a dual liner system (Drg. Nos. 302-14205-CI-DSK-0002, 0003 and 0004 - Detail A) consisting of a 300 mm low-permeability compacted clay liner overlain by a 1.0 mm thick high density polyethylene (HDPE) liner. These liners are expected to isolate solid residues via a relatively low-permeability barrier and lower the risk of migration of any potential leachate into the groundwater. A 300mm thick 'cushion layer' will be placed atop the dual liner system to limit the potential for damage to liners by prolonged exposure (e.g. to ultraviolet radiation) and during construction and potential reclamation operations. This cushion layer should have a distinct colour difference from the residue to provide adequate warning for earthworks operators of proximity to the underlying liners when working or excavating residues for sale to local industries.

At some point in the future, residue materials could be reclaimed from previously completed RSF cells and the emptied cells re-used for residue storage. Care and attention to the cushion layer should be exercised during reclamation operations to prevent damage to liners.

6.4 Facility Operation for NUF, FGD and WLP

NUF, FGD and WLP residues will be placed and traffic compacted within the RSF cells with a front-end loader and dozer envisaged for this operation. The residues can therefore be placed and trimmed to establish surface contours such that pond water will be directed to the appropriate facilities either using lined diversion channels or pumped back from a pontoon-mounted pump or permanent decant structure.

The NUF, FGD, and WLP residues will require air-drying prior to being spread and traffic compacted as it arrives at the RSF as paste. Material can be stockpiled within the RSF, periodically reworked with the dozer until the material is sufficiently dry (moisture content less than 25%) to be suitable for spreading and traffic compaction. If climatic conditions are unsuitable for open air drying, drying sheds with storage capacity for the wet season may be required. Residues will require turning and mixing within the sheds to allow even drying of the materials.

During heavy rainfall and in particular the monsoonal wet season the surface of the residue is expected to become wet, soft and slippery making placement of residue during this period problematic due to the poor trafficability of the residue surface. Therefore, a temporary cover may be required to keep the area of active residue placement dry during the wet season. A potential solution to this problem is to size the drying shed with sufficient capacity so residue can be stockpiled during the wet season awaiting placement in the RSF during drier weather.

As part of the fill/construct methodology for the RSF, cells will be capped once design capacity is achieved creating a landform with positive drainage. Capping is envisaged to comprise a 500mm thick rock-fill layer to serve as a capillary break, overlain by low permeability clayey soil and topsoil to lower the risk of infiltration. Interaction between rainfall and surface water runoff from capped cells and permanently stored residues will be minimised and the final site topography will encourage surface water to drain off-site to prevent ponding and standing water.

7. PRELIMINARY ASSESSMENT OF EMBANKMENT SLOPE STABILITY

A preliminary embankment slope stability assessment has been conducted based on the subsurface profile encountered during the site investigation and estimated design parameters in order to ensure the factor of safety (FOS) of slopes against global failure.

Four cases were considered in the stability assessment, as follows:

Case 1a: Short-term undrained (normal groundwater level)
This case represents the immediate short-term condition after the embankment is raised under anticipated normal groundwater table conditions.

Case 1b: Short-term undrained (elevated groundwater level)
This case represents the immediate short-term condition after the embankment is raised and includes the influence of seasonal variation in groundwater levels.

Case 2a: Long-term drained (normal groundwater level)
This case represents the long-term condition after the embankment is raised under anticipated normal groundwater table conditions.

Case 2b: Long-term drained (elevated groundwater level)
This case represents the long-term condition after the embankment is raised and includes the influence of seasonal variation in groundwater levels.

The adopted soil parameters for both short-term and long-term stability analysis are presented in Tables 5 and 6 respectively.

Table 5: Adopted Slope Stability Analysis Soil Parameters for Imported Material

Material Above Subsoil	Unit Weight (γ)	Cohesion (c')	Angle of Friction (ϕ')
Residue	1.2 t/m^3	0kPa	20°
Embankment Raise	1.5 t/m^3	0kPa	28°
Initial Embankment Fill	1.9 t/m^3	0kPa	34°
General Fill	1.9 t/m^3	0kPa	30°

Table 5a: Adopted Subsoil Parameters for Slope Stability Analyses (Short-Term Undrained)

Subsoil Material	Unit Weight (γ)	Undrained Shear Strength (kPa)			
		Initial 2m high embankment	Raise 1 : 4m high embankment	Raise 2 : 6m high embankment	Raise 3 : 8m high embankment
Soft Clay 1	1.65t/m^3	7	10	13	16
Soft Clay 2	1.65t/m^3	11	14	17	20
Soft Clay 3	1.65t/m^3	7	10	13	16
Soft Clay 4	1.65t/m^3	11	14	17	20

Table 5b: Adopted Subsoil Parameters for Slope Stability Analyses (Long Term Drained)

Material	Unit Weight (γ)	Cohesion (c')	Angle of Friction (φ')
Soft Clay 1	1.65t/m^3	4	21°
Soft Clay 2	1.65t/m^3	4	21°
Soft Clay 3	1.65t/m^3	4	21°
Soft Clay 4	1.65t/m^3	4	21°
Clayey Sand	1.8t/m^3	0	32

The stability analyses were conducted using Slope W software and the factor of safety (FOS) against global failure on the embankment slopes was checked using the Morgenstern Price method for circular failure mode.

A summary of the slope stability analyses is presented in Table 6.

Table 6: Summary of Slope Stability Analyses

Circular Failure	**Factor of Safety (FOS)**			
Embankment Height	**Short Term Undrained**		**Long Term Drained**	
	Normal Water Level	Full Water Level	Normal Water Level	Full Water Level
Initial - 2m	1.57	1.57	NC	NC
1st raise - 4m	1.23	1.23	1.7	1.64
2nd raise - 6m	1.22	1.22	1.7	1.63
3rd raise - 8m	1.27	1.27	1.7	1.62

NC – Non-critical

In accordance with ANCOLD (Australian National Committee On Large Dams) guidelines the required FOS for short-term and long-term stability are 1.3 and 1.5, respectively. As can be seen from Table 6, the FOS against global failures for embankment height up to 8m is acceptable in the long term case but not the short term case.

The preliminary slope stability assessment indicates that the proposed embankment fill height of 8m results in a FOS of less than the acceptable minimum of 1.3 under short-term undrained conditions. This can be overcome by the placement of an additional 1.0m of well compacted select fill across the RSF area. Further assessment of the consolidation behaviour of the subsurface soils is required to confirm the short-term stability of the embankments.

8. RECOMMENDATIONS FOR FURTHER INVESTIGATION AND ANALYSIS

The conceptual design for the RSF described in this report is based on preliminary data with respect to existing ground conditions, residue characteristics and disposal methods. As design of the RSF progresses, the following recommendations should be considered:

- Residue behaviour will be influenced by water content, dominant particle size and shapes, mineral composition, size distribution, temperature, pressure, particle interaction, and compacted density. These properties will have an influence on the behaviour of the residue in terms of workability and long term behaviour over the lifespan of the project and should be determined and considered in greater detail during RSF design.

- The dispersive nature of the residue should be determined and its impact on the RSF design analysed.

- Ground conditions across the site should be assessed based on data obtained from the recently completed site investigation and subsequent laboratory testing programme.

- The groundwater regime below the proposed site of the RSF needs to be confirmed. A site-specific hydrogeological investigation should be considered.

- This conceptual model will require detailed settlement and slope stability including seismic sensitivity analyses to ensure the stability of the landform created. Based on these analyses recommendations for soil improvement across the RSF foundation area may be required to achieve acceptable factors of safety.

- RSF surface water retention ponds will require sizing to accommodate monsoon and storm events over the life of the project.

- The suitability of in situ soils at the site for use as embankment fill and general fill should be confirmed or alternative sources of material identified.

- Currently area available at the proposed site designated for the RSF has a predicted storage capacity of approximately 5 to 6 years' residue production. Options such as reuse or sale of residue by-products, chemical addition to improve achieved density of residue placed in the RSF cells and/or acquisition of additional land needs to be considered for a 10 year project lifespan.

9. INFORMATION ON INTERPRETATION, USE AND LIABILITY OF THIS REPORT

This report has been prepared in accordance with a specific brief and scope of work. It should be read in its entirety.

The responsibility of WorleyParsons is solely to Lynas Malaysia Sdn Bhd. This report is not intended for, and should not be relied upon, by any third party. No liability is undertaken to any third party.

Ground conditions are subject to continuing natural and man-made processes. They can exhibit a variety of properties that vary from place to place, and can change with time.

Site investigation involves gathering and assimilating data by means such as inspection, drilling, excavation, probing, sampling and testing. The collected data is only directly relevant to the ground at the place where and the time when the investigation was performed.

Any interpretation or recommendation given in this report shall be understood to be based on judgement and experience, not on greater knowledge of facts other than those reported.

If different ground or site conditions are encountered during construction activities or subsequent to the investigation performed for this report, either due to natural variability of subsurface conditions or previous construction activities, WorleyParsons should be notified of the differences and provided with an opportunity to review the recommendations contained in this report.

10. REFERENCES

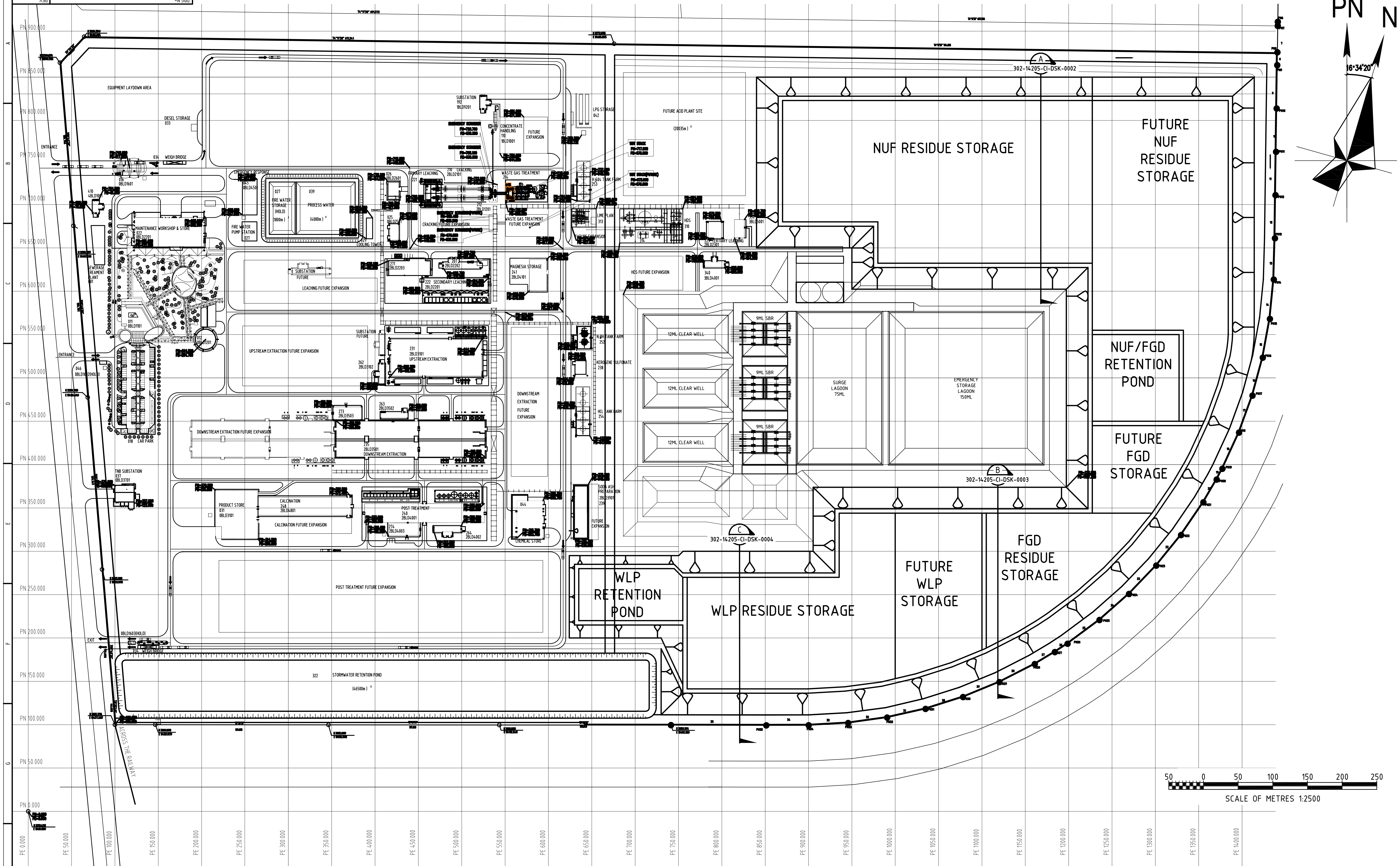
WorleyParsons report 13229-PM-RP-001, Lynas Rare Earth Lanthanide Project, Preliminary Comparison of Tailings and By-Product Disposal Options, 14 February 2007.

T&T Konsult SDN BHD, Geotechnical Investigation Report for Petronas Centralised Utility Facilities (CUF) in Gebeng, Kuantan, February 1998.

MMCE-Franky Consortium, Final Report for Additional Soil Investigation Works for Kuantan-Kerteh Railway Project Civil Works – Package 2, Volume 1, Engineering Borehole Logs, February 2001.

Figures and Drawings

Figure 1 Approximate Location of Proposed Gebeng Site



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CLIENT

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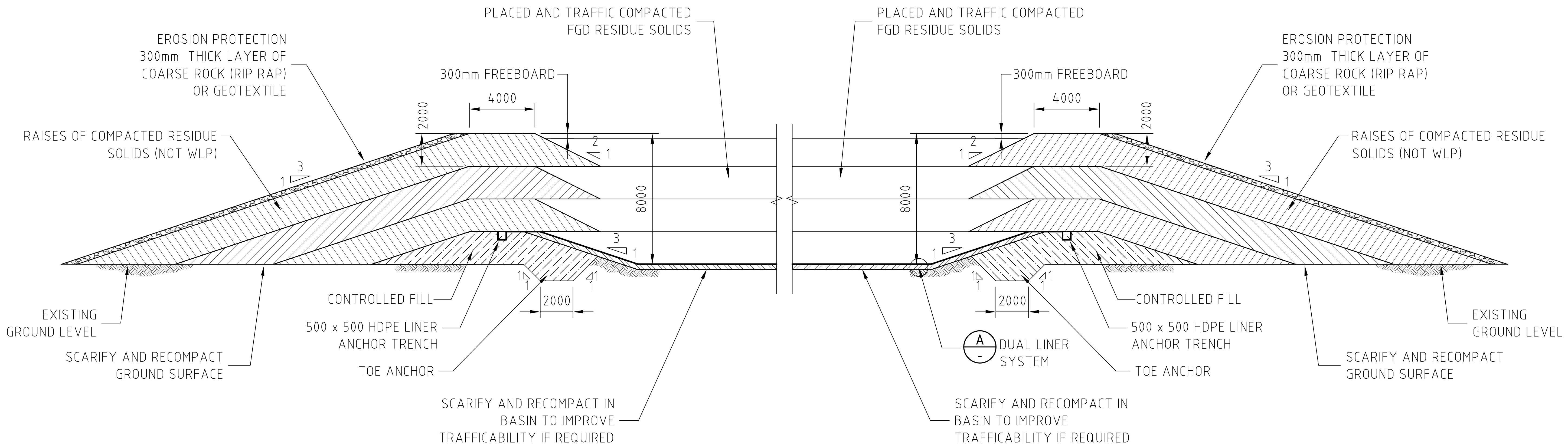
DESIGNED:	DATE:
APPROVED:	DATE:
CLIENT:	DATE:

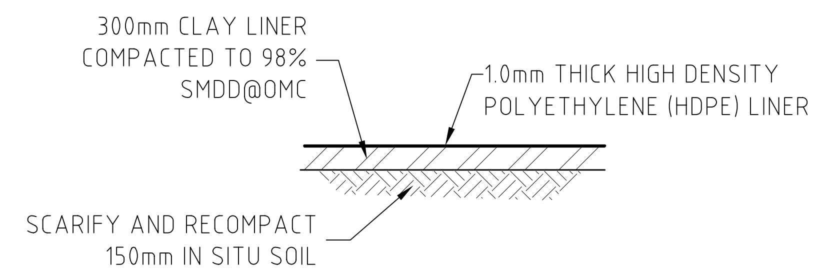
GENERAL ARRANGEMENT
LYNAS MALAYSIA PROJECT
SITE LAYOUT
RESIDUE STORAGE FACILITY DESIGN

SCALE: 1:2500
DRG No: 302-14205-CI-DSK-0001 REV C



SECTION B
302-14205-CI-DSK-0001

FGD RESIDUE STREAM



DETAIL A

DUAL LINER SYSTEM

PRELIMINARY & UNCHECKED

FOR INFORMATION ONLY

NOTES:

1. 3H:1V EXTERNAL SLOPES CONSIDERED SUITABLE CONFIGURATION FOR CLOSURE SCENARIO.
2. GROUNDWATER LEVEL TO BE CONFIRMED.
3. EXTERNAL WALLS REQUIRE EROSION PROTECTION FOR EXAMPLE 300mm COARSE ROCK (RIP RAP) OR GEOTEXTILE.
4. EMBANKMENT RAISES CONSTRUCTED FROM AIR DRIED TAILINGS COMPACTED TO 98% SMDD @ OMC OR 95% MMDD @ OMC.

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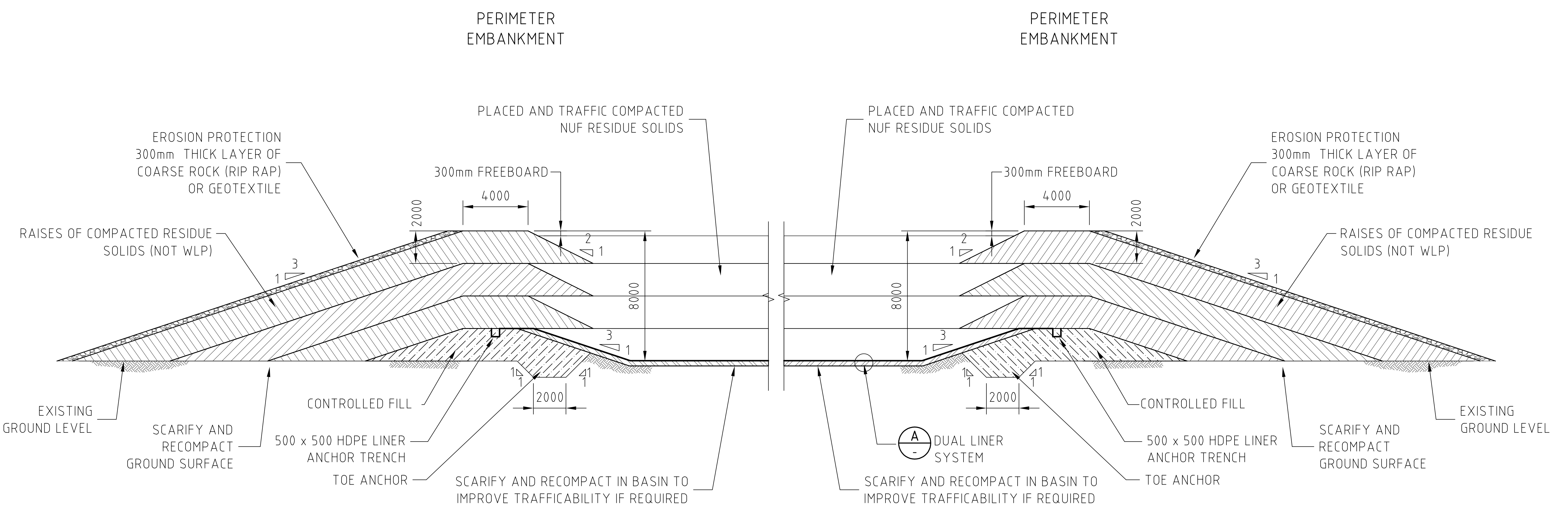
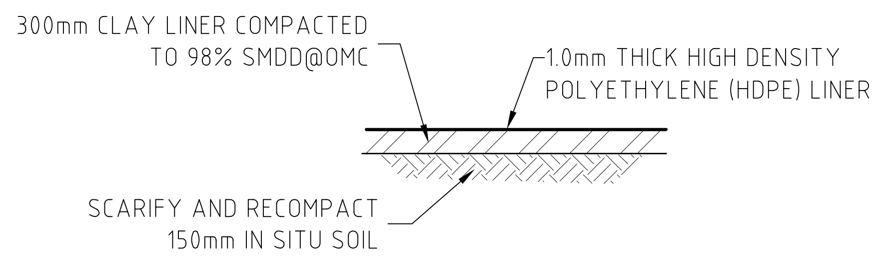
LYNAS MALAYSIA PROJECT
CONCEPTUAL TAILINGS
STORAGE FACILITY DESIGN
FGD CROSS SECTION B

SCALE: 1:250 @ A3 | DRG No 302-14205-CI-DSK-0003 | REV C



SECTION A
302-14205-CI-DSK-0001

NUF RESIDUE STREAM



DETAIL A

DUAL LINER SYSTEM

PRELIMINARY & UNCHECKED

FOR INFORMATION ONLY

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3. EXTERNAL WALLS REQUIRE EROSION PROTECTION FOR EXAMPLE 300mm COARSE ROCK (RIP RAP) OR GEOTEXTILE.
4. EMBANKMENT RAISES CONSTRUCTED FROM AIR DRIED TAILINGS COMPACTED TO 98% SMDD @ OMC OR 95% MMDD @ OMC.

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CLIENT

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CLIENT:		DATE:

LYNAS MALAYSIA PROJECT
CONCEPTUAL TAILINGS
STORAGE FACILITY DESIGN
NUF CROSS SECTION A

SCALE: 1:250 @ A3
DRG No 302-14205-CI-DSK-0002
REV C

DRG No ---
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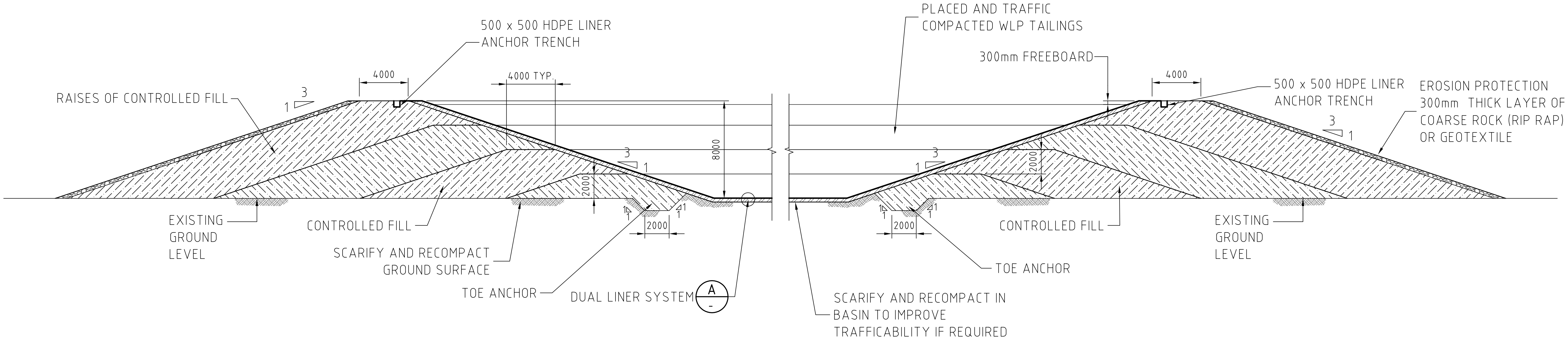
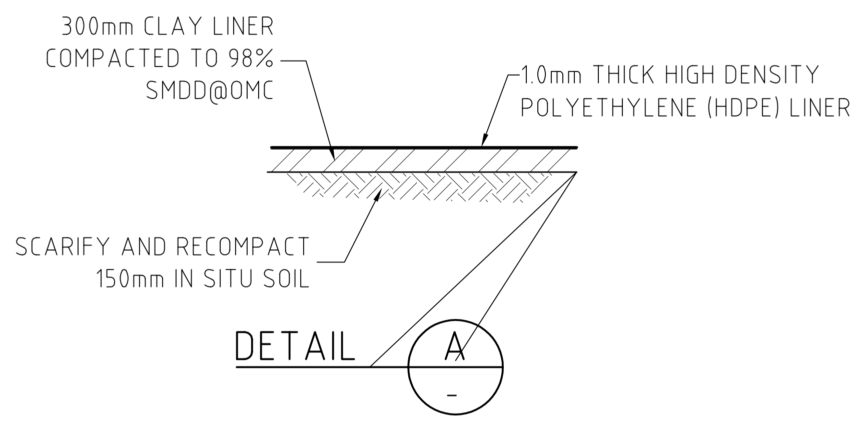


SECTION C
302-14205-CI-DSK-0001

WLP RESIDUE STREAM



DETAIL A

DUAL LINER SYSTEM

PRELIMINARY & UNCHECKED

FOR INFORMATION ONLY

NOTES:

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3. EXTERNAL WALLS REQUIRE EROSION PROTECTION FOR EXAMPLE 300mm COARSE ROCK (RIP RAP) OR GEOTEXTILE.
4. EMBANKMENT RAISES CONSTRUCTED FROM CONTROLLED FILL COMPACTED TO 98% SMDD @ OMC OR 95% MMDD @ OMC.

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CLIENT

DRAWN: AMP DATE: 09/11/07
CHECKED: DATE:
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APPROVED: DATE:
CLIENT: DATE:

LYNAS MALAYSIA PROJECT
CONCEPTUAL TAILINGS
STORAGE FACILITY DESIGN
WLP CROSS SECTION C

SCALE: 1:250 @ A3
DRG No 302-14205-CI-DSK-0004
REV C