



Decommissioning Lake Mokoan Program

ADDENDUM TO REVIEW OF MODIFIED LAKE MOKOAN PROPOSAL

- Final 2
- 12 December 2007



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1. Introduction

This document forms an addendum to the report: “Review of Modified Lake Mokoan Proposal” (SKM, 2007). This addendum should be read in conjunction with the SKM (2007) report.

SKM (2007) presented a review of the revised Lake Mokoan embankment design proposed by a group of Broken System irrigators operating under the banner of Justice for the Broken Valley, which was formulated in collaboration with Murrumbidgee Irrigation Limited (MIL) (“the proponents”). Following SKM’s review comments, the proponents arranged for an independent technical review of their proposal by GHD (GHD, 2007a) and have subsequently modified their proposal to address issues raised in this review. This document discusses their revised proposal as presented in their email of 7 August 2007.

1.1 Geotechnical and Cost Assumptions

The original design and costing of Modified Lake Mokoan embankments are based on the Barren Box Swamp (BBS) example from the Murrumbidgee catchment in New South Wales, as detailed in column 2 of Table 1. Barren Box Swamp is the major recycle point for the Murrumbidgee Irrigation Area (URS, 2003). MIL has recently partitioned Barren Box Swamp with a view to conserving water, improving operating efficiency and restoring the former ephemeral wetland. It is understood that the BBS embankments were constructed “in the dry” using ramped embankment construction methods and utilising scrapers for placement and compaction. The proponents have assumed the similar construction methods can be utilised for the construction of the Lake Mokoan embankments, with some localised coffer dam and dewatering measures.

Following the GHD review, the proponents have revised their proposed embankment design, with these changes presented in column 3 of Table 1. The original and revised MIL embankment sections are also presented in Appendix A for reference. The SKM embankment design is provided in Appendix B for comparison.



- Table 1 Specifications for Modified Lake Mokoan embankment specifications, based on Barren Box Swamp (MIL, 2007) and Modified Lake Mokoan embankment specifications, based on Barren Box Swamp and addressing GHD review comments.

Component	Specifications for Modified Lake Mokoan embankment specifications, based on Barren Box Swamp (MIL, 2007)	Specifications for Modified Lake Mokoan embankment specifications, based on Barren Box Swamp and addressing GHD review comments
<i>Crest width</i>	5 m	5 m
<i>Embankment batter slope</i>	2.5H:1V (upstream) and 3H:1V (downstream)	3H:1V (upstream) and 3H:1V (downstream)
<i>Freeboard</i>	1.5 m	1.5 m
<i>Compaction standard</i>	95% SMDD at +/- 2% of OMC	95% SMDD at +/- 2% of OMC
<i>Sand filter</i>	Vertical (600 mm width, 4.7m high), horizontal (1500 x 500mm at 100 m c/c)	Vertical (600 mm width, 4.7m high, now extends to base of cut-off trench), horizontal (1500 x 500mm at 50 m c/c)
<i>Gravel Toe Drain</i>	Horizontal (1500 x 500mm)	Horizontal (1500 x 500mm)
<i>Upstream protection</i>	600 mm thick graded Riprap on geofabric	600 mm thick graded Riprap on geofabric, 200mm thick gypsum stabilised layer on upstream batter and crest
<i>Downstream protection</i>	2% Gypsum and Hydro mulch, 200mm thick topsoil	2% Gypsum and Hydro mulch, 50mm thick topsoil
<i>Stripping depth</i>	0.2 m	0.2 m
<i>Cut off depth</i>	0.3 m (below stripping depth)	3.0 m (below stripping depth), filled with gypsum stabilised clay
<i>Cut off width</i>	4.0m at base, with 1v:1.5h side slopes	4.0m at base, with 1v:1.5h side slopes
<i>Foundation Treatment</i>	None	200mm thick gypsum stabilised foundation interface

The proponents of the Modified Lake Mokoan design have estimated that the cost of constructing embankments to the original design would be \$15.6 million. This cost excludes contingencies, and survey, design, project management and contract administration costs, which were assumed to be 40% (contingencies) and 10% (remaining costs) of total capital expenses, respectively (MIL, 2007).

The available documentation does not specify the source of embankment material and it is assumed they propose re-using material excavated on site.

Following the meeting of 7 June 2007, the proponents have now made allowance for limited coffer dams during construction in conjunction with their previously proposed dewatering strategy is discussed in more detail in Section 2.1.3.



2. Design and Construction Methodology

This chapter presents a review of the geotechnical, design, construction methodology and costing assumptions adopted by the proponents for the preliminary design of embankments for the Modified Lake Mokoan proposal (3.5m depth option). This chapter draws on SKM's previous experience working on the *Lake Mokoan Spit Embankment Pre-Feasibility Study* (SKM, 2004). The key issues of project risk and design adequacy are highlighted in this section, which considers the effects of the changes in the proponents' design as a result of the GHD technical review.

2.1 Geotechnical Issues and Embankment Design and Construction

2.1.1 Geotechnical Issues

The key geotechnical conditions for consideration are:

- Likely significant depth of soft silt and clay deposits and extensive organic deposits as evidenced by the dead trees and previous land use prior to flooding. The SKM study (2004) found that local soil deposits generally comprise saturated alluvial sand, clay and silt.
- Clay sourced from this area is proven to be highly dispersive in nature, as evident in the continuing erosion/piping problems of the main dam embankment and as detailed in existing geotechnical reports (Wrigley Dillon, 2006).
- The Spit Bank has been assessed to be a lunette formation and therefore likely to have sections with high sand content and therefore high permeability.

On the basis of this understanding of the geotechnical conditions applying to the area, a number of critical concerns are raised regarding the Modified Lake Mokoan proposal. These concerns are as follows:

- To address the dispersive soils, the revised proposal now allows for treatment of a 200mm thick layer along the foundation interface and the embankment perimeter (upstream and downstream batters and crest) with gypsum to stabilise the dispersive soils (2% application rate assumed). However, the body of the embankment will remain untreated and the adequacy of the proposed 200mm thick layer (especially if the gypsum is mixed with the soil using agricultural machinery) is unproven.
- The saturated nature of the soils at the embankment alignments is likely to result in delays during construction due to the required moisture conditioning (drying) as well as restricting access to this area due to soft ground conditions and no provision has been made for this.
- There is no formal geotechnical data to support the proposed design and construction methodology. The proposal assumes geotechnical conditions similar to Barren Box Swamp



but without any supporting information. Informal investigations (limited hand augering) are not regarded as sufficient or adequate information to support the assumptions utilised in the proponents' design and construction methodology.

2.1.2 Embankment Design

The Modified Lake Mokoan embankment design and the revised proposal (refer Table 1) do not fully address the anticipated geotechnical conditions. There are a number of aspects of this design which are of concern and represent project risk. These design inadequacies are:

- **Depth of stripping** – the depth of stripping of only 200mm, even when combined with the increased cut-off trench depth of 3m, may mean that soft soil layers or layers affected by desiccation cracking could still exist beneath the embankment.
- **Downstream protection** - a provisional 200mm thick layer treated with 2% gypsum. Both the depth of this layer and the percentage of gypsum used (assuming it will be mixed into the soil with agricultural equipment) appear inadequate. The topsoil layer is now proposed as 50mm thick (over the 200mm thick gypsum stabilised layer) and will be treated with fertiliser and hydromulched to revegetate the slope. This revised depth of topsoil is regarded as inadequate and it is not clear from where this material will be sourced. Given this material is unlikely to be available on site, there is a significant transport cost risk for this. It is also noted that this downstream slope treatment will not be adequate for areas where water will be temporarily impounded against the downstream face and protection with rip rap and geofabric to above the water level will be required.
- **Vertical sand filter** – this filter now extends into the foundation in accordance with accepted practice. However, as it does not extend up to crest level, it provides only nominal protection against piping caused by storage levels above FSL permeating either through the embankment or through desiccation cracks above FSL.
- **Horizontal filter drain** - the proposed horizontal sand filter drain, comprising a discontinuous 1.5m wide, 0.5m thick layer at 50m intervals is not considered adequate as it will not prevent piping along the embankment / foundation interface between drain locations. It is noted the foundation interface will now be gypsum stabilised over a depth of 200mm however, as noted above, the adequacy of this measure should be assessed to ensure it is effective in reducing the likelihood of piping.
- **Degree of compaction** - the specified degree of compaction (95% of Standard Maximum Dry Density – (SMDD)) and moisture conditioning at +/- 2% of Optimum Moisture Content, (OMC)) is not considered suitable for dispersive soils as the compaction should be performed at a higher standard (minimum of 97% SMDD) and moisture conditioning must be at OMC or higher (preferably 2-3% over OMC). It is understood that GHD has recommended compaction at 95% and 0 to +2% of OMC and the proponents have not yet accepted this advice. If a lower



compaction/moisture content is adopted by the proponents, this raises concerns for the integrity of the unstabilised embankment fill, especially given the proposed method of construction and compaction.

In summary, whilst the overall embankment geometry is considered satisfactory, the embankment stripping depth and treatment of the dispersive soils (adequacy of the 200mm thick stabilised layer, adopted compaction standards, incomplete filter details) raise concerns regarding the adequacy of the embankment design for the Lake Mokoan site. This relates to piping failure, especially considering the high consequence of failure downstream compared with Barren Box Swamp (which had significantly lower consequence of failure).

2.1.3 Embankment Construction

The Modified Lake Mokoan embankment construction methodology is based on the assumption that construction can be done “in the dry” using scrapers for excavation/placement using “ramped” embankment construction methods. There are two principal issues with respect to this assumption, namely:

1. Adequacy of the Cofferdam proposals

The details on the proposed dewatering and coffer dam arrangement in the proponents’ latest proposal (received 13 July 2007) include:

- Drain Sergeant’s Swamp via the outlet channel and limit inflows to Green Swamp to the level of the Gould/Swamp Road embankment
- Construct a coffer dam across P0 (unknown point) to P1 to P2 using local borrow material. A total coffer dam volume of 13,000m³ is specified with contradictory crest elevations of RL161.5/162.0 for this coffer dam
- Drain Winton Swamp to expose the embankment alignment P7 to P8 to P9 and install a temporary culvert structure
- No formal coffer dam is proposed to protect the P7 to P9 alignment however the use of “stripped material” to create a temporary bund to protect these works is noted.

In relation to the proposed construction sequence, insufficient detail has been provided on the proposed coffer dam construction between P0 to P1 to P2 (embankment size/dimensions, stripping, slope protection etc) to enable its viability to be assessed. Similarly, the suitability of the Gould / Swamp Road embankment (which is frequently submerged and has a bridge crossing) to retain inflows to the east of Green Swamp has not been established. The proposal to construct a temporary bund to protect the P7 to P9 embankment construction area using “stripped material”, which will likely comprise saturated dispersive silts and clays with a high organic content, is not



considered to be suitable. No basis has been provided to establish the suitability of these measures to prevent flood inflows from impacting the works.

2. Soil Compaction Requirements

In relation to the construction of the proposed embankments, the saturated cohesive soils in the area to the north of the spit will most likely preclude the use of scrapers, and fill placement and compaction using ramped construction (i.e. non-horizontal fill layers) is not deemed suitable for a properly engineered embankment built to satisfy ANCOLD requirements. In our experience, ramped construction methods lead to variable moisture conditioning and compaction and it is very difficult to achieve the required compaction levels even if the material is at OMC when excavated (which is unlikely to be the case at Lake Mokoan with material that has been underwater for over 35 years).

The proposal assumes the sloping fill layers will be 200mm thick and laid by scraper on an approximate 1 to 15 slope, placed and compacted to 95% SMDD and +/-2% of OMC – as outlined above. This degree of compaction and moisture conditioning is not deemed appropriate for the dispersive soils at Lake Mokoan.

In summary, the proposed construction techniques are not considered applicable or appropriate for construction of the embankments at Lake Mokoan which are required to be built to a high standard given the nature of the dispersive soils and the significant downstream consequences of failure.

2.2 Embankment Cost Estimates

Embankment costs have been estimated as part of the review of the Modified Lake Mokoan design. The approach makes use of the assumptions of the SKM (2004) study. A comparison of the proponents' cost estimate and that was undertaken as part of this review is presented in Table 2 below.



■ **Table 2 Estimated Modified Lake Mokoan embankment costs.**

Estimate		Design and cost assumptions	Total estimated cost to construct (\$million)
#	Name		
1	MIL	The volume of required materials has been estimated based on Barren Box Swamp example Some costs included for coffer dams Unit material costs have not been verified for site Contingencies 40% & Survey and Design rates 10% No provision to limit leakage through Spit	16.2
1a	MIL Revised (GHD comments)	The volume of required materials has been estimated based on Barren Box Swamp example Improved embankment design Some costs included for coffer dams Unit material costs have not been verified for site Contingencies 40% & Survey and Design rates 10% No provision to limit leakage through Spit	23.4
2	SKM Review Estimate	The volume of required materials has been estimated based on SKM (2004) design with provision for coffer dams Unit material costs from SKM (2004) Contingencies and survey and design rates as typically adopted by G-MW (40% & 15% respectively) No provision to limit leakage through Spit	38.3
2.1	Spit Embankment	If required, construction methodology and cost to be confirmed, indicative upper limit cost for a fully engineered contour embankment with coffer dam is \$11.4M	49.7

The proponents for the Modified Lake Mokoan design have estimated the total cost to construct the embankments to be \$23.4 million (Estimate 1a), compared with an estimated cost determined as part of SKM's current review of \$38.3 million (Estimate 2).

Under this review, the estimated costs for embankments, built to accepted engineering standards and to meet ANCOLD risk guidelines is \$38.3 million. The key differences in the cost estimates between the two designs for capital cost items are summarised in Table 3 below (based on information provided by the proponents on 18 June 2007 and 9 August 2007).



■ **Table 3 Cost Estimate Differences (Capital Cost Items)**

Element	MIL Alternative Proposal Design (x\$1000) (Estimate 1)	MIL Revised Design (GHD Comments) (x\$1000) (Estimate 1a)	SKM Review Design (x\$1000) (Estimate 2)
Stripping	\$90	**	\$1,400
Coffer Dams	See below	**	\$1,900
Coffer Dam Settlement Allowance	N/A	**	\$1,800
Embankment Construction	\$2,000	**	\$11,300
Sand Filter Drains	\$1,450	**	\$6,100
Rip Rap	\$2,315	**	\$2,200
Downstream embankment protection	\$844	**	Included above
Road Base for embankment	\$428	**	Included above
Clearing of dead trees, dealing with water (inclusive of coffer dams), replacement of dead trees into borrow pit, clearing of site on completion)	\$3,671	**	Included above
Capital Cost TOTAL	\$10,798	\$15,605	\$24,700

** Insufficient data provided in MIL documentation to itemise these costs

Note that all the above costs presented in Table 3 do not include contingencies and survey and design which are included in the totals presented in Table 2.

The main reasons for the difference in capital costs for key design elements essentially remain the same as discussed in our previous report (SKM 2007), and are summarised as follows:

- The proponent's quantity estimates for embankment volumes are significantly less than those calculated by SKM due to limited accuracy and detail of the natural surface profiles used in MIL's methodology;
- The MIL proposal's unit rates still appear to be too low given the soil conditions likely to be encountered;
- The MIL proposal does not allow for a bulking factor in the quantity estimates and this will have an impact on their embankment construction costs;
- The proposed revised construction methodology includes temporary embankments / coffer dams in some areas, but no specific costs or details have been included to permit assessment of these measures. The review design allows for the construction of properly constructed coffer dams to protect the construction site from the existing dead storage and flood inflows;



- The MIL proposal allowance for stripping of top soil / unsuitable material is minimal in contrast to SKM's review design which allows for substantial stripping of top soil/unsuitable material in the light of the anticipated foundation conditions.

The current variation in estimated project costs for the embankments is summarised as follows:

- Proponent's cost estimate - \$16.2 million
- Proponent's revised cost estimate (GHD review) - \$23.4 million
- SKM design - \$38.3 million

The differences in embankment construction costs relate to significant differences in the volume calculations for the embankments, lack of consideration of the embankment design requirements dictated by the soil conditions and the higher design standard required to meet ANCOLD requirements for downstream consequence of failure (particularly the adjacent munitions factory and highway) and current best practice. The review estimate also includes sufficient allowances e.g. bulking factors, and design and survey fees as adopted by G-MW for similar projects at this stage of development.

From review of the proposed Modified Lake Mokoan design and supplied documentation, it appears the Barren Box Storage embankment design and construction methodology was adopted without due regard for the nature of the soil conditions at Lake Mokoan or the high consequence of failure on downstream infrastructure.



3. Associated Infrastructure

The discussion on the following items remain unchanged from the SKM (2007) report:

- Capital Costs
- Flood Pumping
- Outlet Structure
- Wetland Outlet Structure
- Sergeants Swamp Outlet Channel
- Spillway

3.1 Preliminaries and Water Diversion Costs

The proponents have included a cost item described as “Preliminaries Water diversion etc.” with a cost of \$708,000. No further details for this item have been provided. As the SKM design includes coffer dams to allow construction at the site to proceed when there are catchment inflows, no further cost for water diversion is required at this stage. The proponent's design includes some allowance for coffer dams but insufficient details are provided to allow formal assessment of these measures. However, based on the limited information provided, the allowance of \$708,000 appears to be quite low given uncertainty surrounding required works to allow construction in wet conditions.



4. Conclusions

4.1 Geotechnical, Construction and Cost Considerations

The Modified Lake Mokoan proposal geotechnical design and construction provisions are considered to be generally inadequate, although improvements to the embankment design are noted following the GHD review. The following are the remaining key geotechnical, construction and cost issues of significance to this review of the revised Modified Lake Mokoan proposal:

- The depth of organic/soft sediment on the submerged portion of the embankment alignment will directly affect the required stripping depth and will impact the magnitude of settlement during construction. Based on available site information, it is considered that the depth of stripping required has been significantly underestimated. No geotechnical investigations or other information is presented to support the assumed stripping depth.
- The proposed embankment construction methodology assumes dewatering of the alignment area and construction “in the dry” using scrapers. No supporting case was presented to justify this assumption other than it was successful for construction of the Barren Box Swamp storage for Murrumbidgee Irrigation. The saturated and possibly silty nature of the foundation soils would preclude the use of scrapers in most areas and SKM regards the assumed construction methodology as imprudent and a significant project cost and delay risk. The ramped method of embankment construction utilising scrapers for placement and compaction is not recommended for the construction of embankments to meet ANCOLD risk requirements.
- Available information indicates that embankment construction would require the construction of coffer dams to allow construction “in the dry”, to provide effective moisture conditioning and to minimise the risk of flooding on the construction works. Whilst informal coffer dams are now proposed, these are not considered to be adequate based on the supplied information.
- The rip rap provision is considered to be inadequate for the downstream sides of embankments where water will be impounded and a continuous horizontal sand filter drain should be used along the downstream foundation interface.
- The proposal assumes the site materials can be re-used with minimal preventative measures against piping (200mm thick gypsum stabilised perimeter, vertical sand filter drain and intermittent horizontal sand filter drain) despite these clay materials being dispersive in nature (highly dispersive in some areas).
- The proposed vertical sand filter does not extend above FSL to protect against piping due to flood levels or future desiccation cracking of the crest. Combined with the inadequate compaction and moisture specification (95% at +/- 2% of OMC using ramped construction and scrapers), this raises concerns about the long term performance of the proposed embankments.



- The specified treatment rate of 2% gypsum and depth of 200mm for the stabilised layer is considered inadequate, especially as it is likely to be placed using agricultural machinery with associated mixing inefficiencies.
- The revised topsoil depth of 50mm is not considered adequate for downstream protection or re-establishment of vegetation.
- The contingency rates adopted by the proponents have been revised (to 40%) but include items which the proponents have not considered in detail e.g. the full impact of geotechnical conditions on their design, which, when fully costed, would exceed the contingency allowance.

The proposal has been based on the embankment design and construction methodology from Barren Box Swamp without due regard for lack of knowledge of conditions at Lake Mokoan and the significant downstream consequence of failure. Hence the revised proposed embankment design and method of construction still constitute a significant project cost risk. Also, proposed flood management measures including informal coffer dams are not detailed or justified.

In view of the above, and on the basis of available information, an appropriate cost estimate for the construction of embankments is at least \$38.3 million, excluding the cost of the Spit Bank treatment and \$49.7 million including the Spit Bank treatment (see Table 2). This significantly exceeds the \$23.4 million cost estimate endorsed by the proponents of the Modified Lake Mokoan design (MIL, 2007). It is SKM's view after considered review, that the proposal cost and construction risks are underestimated for constructing these embankments to the required engineering standard.



5. References

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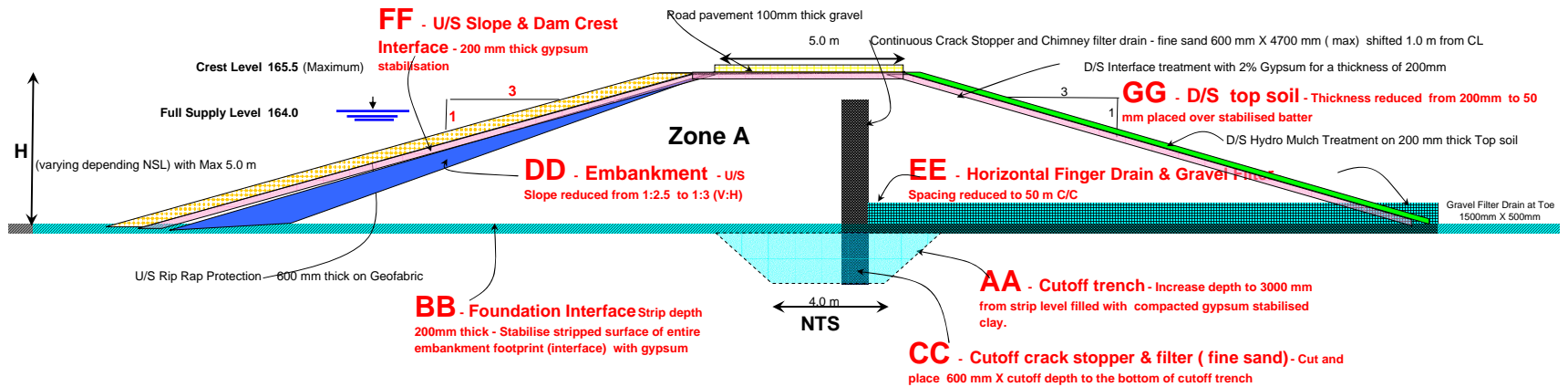
Appendix A Proponents Original and Modified Proposed Embankment Sections

Lake Mokoan Project



Modified Wetland Proposal

GHD Improvement to Dam Wall



Note 1 : GHD suggested improvement is preliminary only with limited available information and will need to be firmed up with further detailed geotechnical investigation

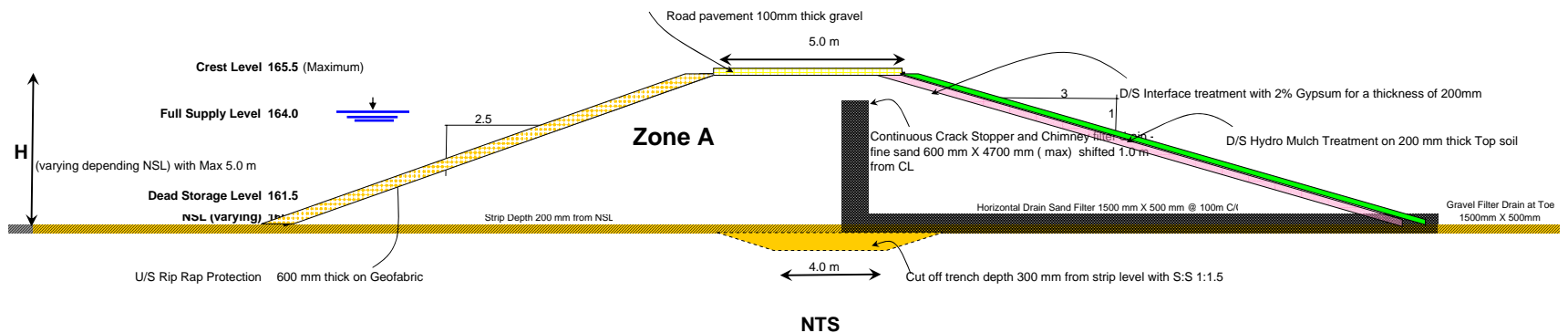
Note 2 : Defensive measures refer to assumed reactive and dispersive clay conditions at the site

Lake Mokoan Project



Modified Wetland Proposal

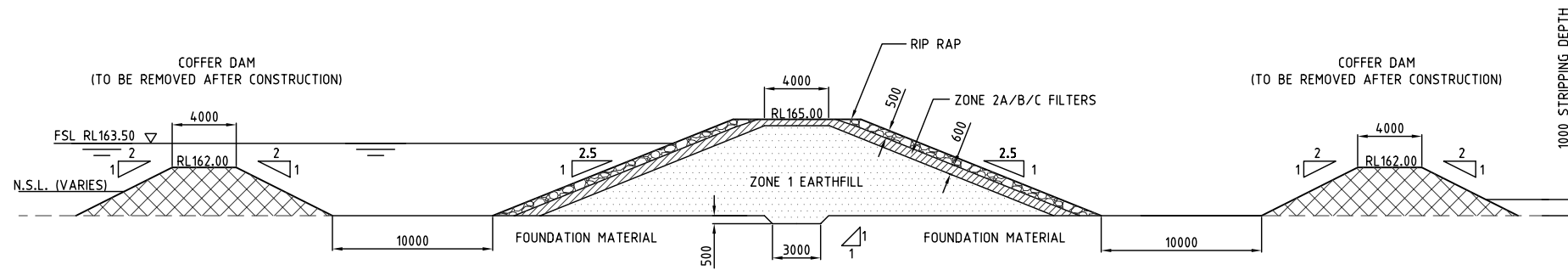
MI Original Proposal



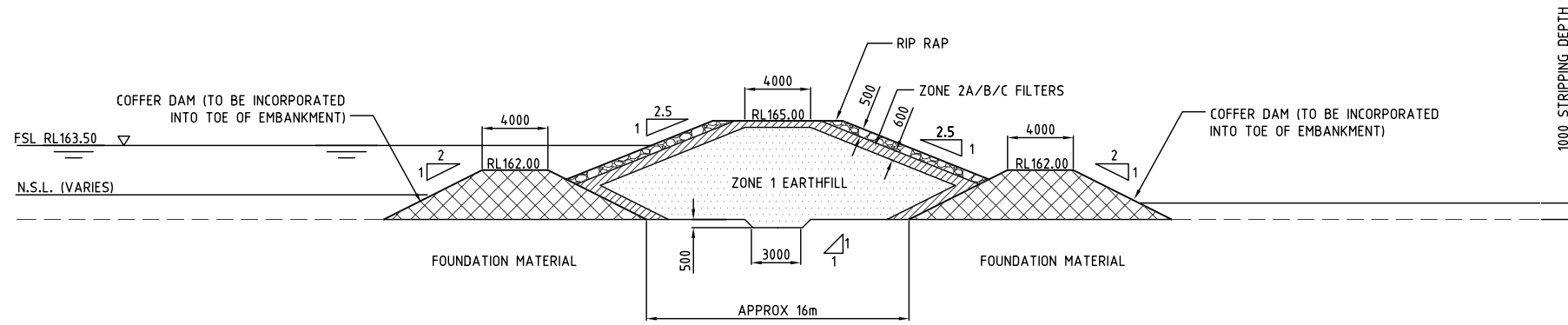
Note : Based on BBS design to suit Dispersive Clay soil with limited available information and will need to be firmed up with further detailed geotechnical investigation



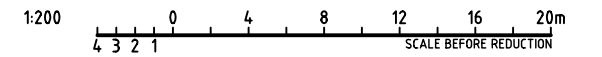
Appendix B SKM Embankment Design



EXTERNAL COFFER DAM EMBANKMENT CROSS SECTION



INTEGRATED COFFER DAM EMBANKMENT CROSS SECTION



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1	18/7/07	CJ	TS	DS	EMBANKMENT REVISED
No	DATE	DESIGN REVIEW	REV'D P.MGR	APP'D P.DIR	AMENDMENT

REF.	DRAWING NUMBER	REFERENCE DRAWING TITLE
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CLIENT DEPARTMENT OF SUSTAINABILITY AND ENVIRONMENT			
PROJECT DECOMMISSIONING LAKE MOKOAN PROGRAM			
DRAWN MAO	DRAFTING CHECK PAS	REVIEWED PROJECT MANAGER JJA	APPROVED PROJECT DIRECTOR PAS
DESIGNED JJA	DESIGN REVIEW PAS		

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