RILEY CONSULTANTS

PROPOSED KERIKERI K3A DAM CONCEPT DESIGN AND COSTING

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CONCEPT DESIGN AND COSTING

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PROPOSED KERIKERI K3A DAM
CONCEPT DESIGN AND COSTING

1.0 Introduction

Riley Consultants Ltd (RILEY) has been commissioned by Mr Toby Kay on behalf of Northland Regional Council (NRC) (The Client), to undertake a conceptual engineering design and cost estimate for a water storage dam at the Kerikeri K3A site.

The purpose of this study is to identify any fatal flaws and constraints at a preliminary level, and develop concept options for a storage dam. The present scope of work includes:

- Identification of potential geotechnical issues based on desktop study and the initial site visit (e.g. dam foundations, materials available for dam construction, reservoir stability).
- Use of available contours for a first pass estimate of reservoir/dam geometry.
- Assessment of dam zoning options.
- Preliminary indication of spillway/diversion requirements and outlet facilities.
- A construction cost estimate based on the concept design.
- Recommendations for further investigation etc., if applicable, and likely regulatory requirements.

No subsurface investigation has been undertaken as part of this study. However NRC provided LIDAR topographic data which was used for conceptual dam design and construction cost estimates.

1.1 Limitations, Constraints, and Other Factors

It is acknowledged no intrusive geotechnical investigations have been undertaken. Thus, design concepts presented in this report rely upon site walkover observations, published and assumed geological information.

2.0 Previous Studies and Reports

As the basis for the study, the following documents were provided to RILEY:

- Kerikeri Detention Dam Modelling, DHI Water and Environment Ltd (DHIWEL), June 2014.
- Kerikeri Detention Dam K3A Additional Modelling, DHIWEL, December 2014.
- Kerikeri Detention Dam Study: Preliminary Assessment Report, Opus International Consultants Ltd (OICL), July 2013.
- Kerikeri Results Analysis xlsx spreadsheet, DHIWEL, June 2014.
- Kerikeri Dam K3A Catchment HIRDS v3 data csv spreadsheet, Northland Regional Council, September 2014.

- Kerikeri Dam K3A Concept Drawing on LIDAR, Northland Regional Council, September 2014.
- Kerikeri Dam Cross Section K3A, Northland Regional Council, September 2014.

We understand a Kerikeri Flood Options Feasibility Assessment was also carried out previously (Haigh Workman, 2012), however; we have not sighted this document.

The OICL report focused on preliminary evaluations of five potential sites for dam construction, of which the analysis concluded K3A was the most favourable site. This was on the basis of results from terrain evaluation, geotechnical desktop study, and preliminary hydraulic analysis.

Further hydrological modelling was undertaken by DHIWEL in June 2014. This included assessment of a detention dam at the K3A site, using a 1% Annual Exceedance Probability (AEP) design flood for a 12 hour duration storm based on HIRDS data and including an allowance for climate change. Subsequent to this, in December 2014, DHIWEL assessed a dual use water supply/flood detention dam at the same location for the 1% AEP (with climate change) design flood based on 12, 24, 48, and 72 hour storm durations. For these assessments, the reservoir was assumed to be full (water level at bell mouth invert level) as a start-up condition for the model runs.

3.0 Site Description and Regional Geology

The proposed site is located on the Kerikeri River, approximately 2.5km west of the Waipapa industrial area. The proposed dam footprint lies on private farmland, accessed off State Highway 10. The concept involves damming the Kerikeri River to establish a reservoir for two purposes: (1) water supply, and (2) buffer storage for floodwater detention in extreme rainfall events.

3.1 Walkover Inspection

A walkover inspection was undertaken by Mr Don Tate and Miss Kaley Crawford-Flett (RILEY), Mr Toby Kay, and representatives of NRC, on 20 October 2014.

The inspection team undertook a walkover inspection of the following areas:

- Proposed left and right abutment slopes.
- The proposed location of the auxiliary spillway channel at the left abutment.
- The proposed dam footprint along the approximate embankment centreline.
- The incised river channel at the proposed dam location.
- Rock exposures at an existing quarry site, located approximately 300m upstream of the proposed dam location on the right bank of the river valley.

The purpose of this inspection was to view the proposed site and identify any obvious features or constraints that could affect the conceptual design or costing.

3.2 Regional Geology

Inspection of the New Zealand Geological Society 1:250,000 Geological Map (Whangarei Area) suggests that bedrock in the area is classified as the Kerikeri Volcanic Group: mainly basalt flows, with rhyolite in the right abutment region. The existing riverbed comprises recent alluvial deposits, with some older Mid-Pleistocene deposits of alluvial, swamp, and estuarine origin to the downstream south of the site. Minor regions of Ruatangata sandstone of the late Eocene period, and scoria cones of the Kerikeri Volcanic Group are mapped in the surrounding terrain.

Bedrock of the Kerikeri Volcanic Group is of the Late-Miocene to Pliocene period, approximately two to eight million years of age. No active faults are mapped within 200km of the proposed dam location (GNS, 2014).

4.0 Design Standard and Potential Impact Classification

4.1 General

The New Zealand Dam Safety Guidelines (NZSOLD, 2000) produced by the New Zealand Society on Large Dams (NZSOLD) outline design criteria based on a dam's Potential Impact Category (PIC). The PIC categories related to the potential consequences of a dam breach, which can include potential loss of life, economic, social, and environmental impacts. We note there is limited explicit guidance on flood detention dams in these guidelines.

In July 2008, new Building (Dam Safety) Regulations were published as part of the Building Act 2004. These regulations define the three dam classifications (High, Medium, and Low) based on the consequences of dam failure. The main factors in the classification include the following:

- Population at Risk (PAR).
- Potential damage to residential houses, critical infrastructure, and time to restore to operation.
- Effects on natural environment and community recovery time.

This methodology is slightly different to that used in the NZSOLD Guidelines, which are currently being revised for consistency with the new regulations. Though these regulations have not yet been implemented (the latest timeframe for implementation is July 2015), the method outlined in the regulations is considered the appropriate method to use for this project.

4.2 Potential Impact Classification

A tentative overview of the PIC assessment is provided in Tables 1 and 2, on the following pages. The present assessment does not consider a dam break inundation map, which should be commissioned in future stages of dam design.

4.2.1 Assessed Damage Level

Based on a brief review of GIS plans[1], the low-lying area within 5km downstream of the dam contains tens of residential houses and buildings, which would be at risk of varying degrees of inundation in the dam breach situation. A number would likely be considered destroyed. The damage level with respect to residential houses is, therefore, assessed as major, perhaps catastrophic (refer Table 1 overleaf). Confirmation of the downstream inundation zone is required.

Table 1: Determination of Assessed Damage Level (reproduced from Building (Dam Safety) Regulations, 2008)

Damage Level	**Specified Categories**				
	Residential Houses[1]	**Critical or Major Infrastructure[2]**		**Natural Environment**	**Community Recovery Time**
		Damage	**Time to Restore Operation[3]**		
Catastrophic	More than 50 houses destroyed	**Extensive and widespread destruction of and damage to several major infrastructure components**	**More than one year**	**Extensive and widespread damage**	**Many years**
Major	**Four to 49 houses destroyed and a number of houses damaged**	Extensive destruction of and damage to more than one major infrastructure component	Up to 12 months	**Heavy damage and costly restoration**	**Years**
Moderate	One to three houses destroyed and some damaged	Significant damage to at least one major infrastructure component	Up to three months	Significant but recoverable damage	Months
Minimal	Minor damage	Minor damage to major infrastructure components	Up to one week	Short-term damage	Days to weeks

Notes:
1. In relation to residential houses, destroyed means rendered uninhabitable.
2. Includes:
   a) lifelines (power supply, water supply, gas supply, transportation systems, wastewater treatment, telecommunications (network mains and nodes rather than local connections));
   b) emergency facilities (hospitals, police, fire services);
   c) large industrial, commercial or community facilities, the loss of which would have a significant impact on the community; and
   d) The dam, if the service the dam provides is critical to the community and that service cannot be provided by alternative means.
3. The estimated time required to repair the damage sufficiently to return the critical or major infrastructure to normal operation.

Areas likely to be affected by a dam breach will exceed the area covered by the 100-year flood extent shown on the NRC website http://www.nrc.govt.nz/floodmaps.

[1] Far North Maps, supplied by Far North District Council http://apps.geocirrus.co.nz/Viewer.html?Viewer=FarNorthMaps-Public

In the event of an uncontrolled dam breach, the proposed K3A water supply scheme could be destroyed, and any community facilities based at the reservoir (e.g. Fish and Game reserves and boating/water sport facilities) may be rendered inoperable. Waipapa and Kerikeri communities are located within 3km to 5km downstream of the dam and the associated infrastructure could be impacted, though these communities may be elevated sufficiently higher than inundated extents from a dam breach. A number of bridges would be inundated, and significant sections of State Highway 10 (SH10) and a number of local roads would likely be inundated also. The critical major infrastructure damage level is, therefore, assessed as catastrophic. The damage to, and destruction of, large areas of farmland could take many years to recover. In addition, due to overflows from the Kerikeri River to the Waipapa Stream, the downstream reaches of both channels will also be affected, including Waipapa Landing, as well as the Kerikeri Basin. This potential for extensive and widespread environmental damage results in a major to catastrophic classification (as per Table 1 above).

A number of community facilities would be damaged or destroyed. As well as residential housing and other non-residential rural buildings, the industrial area bordering SH10 south of Waipapa could be heavily impacted, or destroyed. This industrial area lies less than 3km downstream of the dam, in an area of relatively flat topography adjacent to the current Kerikeri River valley. Approximately 5km downstream, a number of community facilities at Kerikeri could be damaged, causing severe losses to the wider Kerikeri community that would take a number of years to fully recover. Members of the local horticultural community may also rely on dam water supply, which would take many years to reinstate. The community damage level is, therefore, assessed as major to catastrophic.

4.2.2 Population at Risk and Likely Dam Classification

In addition to the permanent residential population associated with inundated houses near the Kerikeri River and SH10 (to be confirmed through preparation of appropriate dam break inundation maps), the temporary and transient population in the inundation zone should be considered. Users of SH10 and horticultural/seasonal workers in the downstream area may vary from 10 to 100+, depending on the time of year.

Table 2: Determination of Dam Classification (Reproduced from Building (Dam Safety) Regulations, 2008)

Assessed Damage Level	Population at Risk			
	0	1 to 10	11 to 100	More than 100
Catastrophic	High	**High**	**High**	**High**
Major	Medium	Medium/High (see Note 4)	High	High
Moderate	Low	Low/Medium/High (see Notes 3 and 4)	Medium/High (see Note 4)	Medium/High (see Notes 2 and 4)
Minimal	Low	Low/Medium/High (see Notes 1, 3, and 4)	Low/Medium/High (see Notes 1, 3, and 4)	Low/Medium/High (see Notes 1, 3, and 4)

Notes:
1. With a PAR of five or more people, it is unlikely that the potential impact will be low.
2. With a PAR of more than 100 people, it is unlikely that the potential impact will be medium.
3. Use a medium classification if it is highly likely that a life will be lost.
4. Use a high classification if it likely that two or more lives will be lost.

Given that the highest assessed level of damage is catastrophic, the PAR assessment of between 1 and 100+ persons, and the high likelihood of loss of two or more lives, the sunny day dam classification is deemed High (Table 2). This is the most severe PIC. Accordingly, the rainy day and overall PIC classifications for the proposed K3A dam are determined to be high.

It is acknowledged this PIC rating may be conservative based on our initial assessment. However, detailed dam break studies may confirm/refine an appropriate PIC classification.

4.3 Recommended Design Criteria

Based on the High PIC, the recommended design criteria are summarised in Table 3.

A flood diversion standard has not been defined at this stage, as the NZSOLD Guidelines do not have explicit criteria. This will be an important component of future studies.

Table 3: Design Criteria Summary

Loading Event	Criteria	Discussed Further in Section
Flooding		
Service Spillway	1% AEP (plus climate change) event to be passed without the auxiliary spillway operating.	6.2.1
Auxiliary Spillway	Maximum Design Flood (MDF) 1:10000 AEP event to Probable Maximum Flood (PMF) to be passed without dam overtopping (freeboard)	6.2.2
Seismic		
Operating Basis Earthquake (OBE)	Only minor damage in the 1:150 return period event (no yield)	7.3
Maximum Design Earthquake (MDE)	Repairable damage in the 1:10,000 return period event	7.3

5.0 Hydrology

Hydrological studies are excluded from this conceptual design report, however, a summary of assumptions, variables, and estimates are presented in the following sections.

For any future hydrological analysis, NRC has advised that river gauge records are available from several sources. Aishes site 3501 is located on the Kerikeri River, 3km upstream from the proposed dam site. This site had a catchment area of 26.2km^2 and was operational between May 1976 and February 1979. The discharge/head rating for this site was not well established and requires further analysis.

In the adjacent Maungaparerua catchment (tributary of the Kerikeri River), a NIWA site has been operational since 1967. The site has a V-notch weir and catchment area of 11km^2. Up until April 2012 the site had an automatic rain gauge.

5.1 Scope and assumptions

As instructed (refer NRC email dated 19 September 2014), in the scope of conceptual dam and spillway design, RILEY shall rely on hydrological modelling results from simulations, assumptions, HIRDS data, and flood estimates undertaken by third parties (refer report references in Section 3.0). In addition to the above, there is further reliance on:

1. Initial spillway and dam geometry as advised by NRC and used within the hydrological modelling; and
2. Published information and reputable engineering references for appropriate dam, spillway, and hydraulic design.

A summary of results, estimates, flood volumes (based on the critical storm duration) and assumptions relevant to dam hydrology is shown below:

- Catchment area to dam = 27.8km^2.
- Peak inflow 24 hour, 1% AEP (with climate change) design event ≈ 246m^3/s.
- Available storage = 12.1M m^3 (assuming lake level at RL 105.0m).
- Flood inflow volume for the 24 hour, 1% AEP (with climate change) event = 7.11M m^3
- Flood storage volume required for the 24 hour, 1% AEP (with climate change) event = 6.55M m^3

5.2 Catchment Description and Area

The K3A Dam catchment area is covered in pasture, however there is bush, scrub, and tree cover particularly near the river banks. Residential dwellings are situated approximately 1km north and north-west of the proposed dam site (NRC advised that the dam crest level of RL 105.0m is preferred as it avoids flooding of residential dwellings upstream of the dam). NRC has advised this nominal level (RL 105.0m) was based on interpreted LIDAR data and that elevation of floor levels and services (e.g. septic tanks and soakage fields) was not assessed.

The Preliminary Assessment Report (Opus, 2013) states the catchment area is 30.46km^2 (or 3046ha), whereas NRC has supplied information indicating the catchment area is 27.8km^2. It was noted, within the Opus report, that two potential dam sites were considered within the K3 catchment, an upper site (K3A) and lower site (K3B). As the upper site was recommended, the selection of the upper site is likely to account for the revised catchment area revision.

For conceptual design purposes, the catchment area value of 27.8km^2 was adopted. The catchment area was estimated by NRC in GIS using LIDAR data where available, and 20m contours and aerial imagery

5.3 Probable Maximum Flood Estimation

For the purpose of sizing the auxiliary spillway, which is designed to pass floods in excess of the 1% AEP flood event and up to the Probable Maximum Flood (PMF), an estimate of the PMF peak flow was undertaken.

Two approximations were used to estimate the PMF, namely:

1. The PMF is equivalent to three to four times the 1% AEP peak flow, which gives a PMF in the range of 740m^3/sec to 985m^3/sec.
2. Using PMF and catchment area for Kotuku scale upwards to achieve PMF for Kerikeri K3A. This results in a PMF estimate of 803m^3/sec.

Given the reservoir is large (12,131,000m^3), it is reasonable to expect attenuation of flow, thus an auxiliary spillway with capacity to pass 850m^3/sec to 1,100m^3/sec should accommodate the estimated PMF flows of say between 800m^3/sec and 1,000m^3/sec.

6.0 Hydraulic Design

6.1 Scope and assumptions

The scope for hydraulic design was to confirm a potential concept for auxiliary/service spillway design, type, and capacity. A summary of results, estimates, assumptions, and initial dimensions relevant to hydraulic design is shown below:

- Proposed dam crest of RL 105.0m, and nominal invert levels for the service and emergency spillways of RL 98.0m and RL 102.3m, respectively.
- Service spillway to comprise Bellmouth inlet with 6m diameter which tapers to a 3m diameter vertical shaft, curved and horizontal sections.
- Nominal details for the emergency spillway – 130m wide, 3m depth, side/cut slope batters 1V:1H and spillway channel slope 1V:10H.

6.2 Spillway Design

6.2.1 Service Spillway

From existing hydrological studies commissioned by NRC, a 1% AEP flood event with 24 hour and climate change adjusted peak inflow was estimated to be ~246m^3/sec (refer Section 5.1). RILEY analyses indicate the 6m diameter Bellmouth spillway can pass flows up to approximately 95m^3/sec, which was estimated using Bellmouth crest discharge formulas as per USBR (1987). It was noted from the DHIWEL December 2014 hydraulic modelling results, the Bellmouth spillway could pass up to 108m^3/sec. DHIWEL's report indicates the curvature of the Bellmouth crest is ignored, which may account for this slight discrepancy.

The Bellmouth spillway shaft would taper/reduce to 3m diameter in the vertical shaft, curved and horizontal sections. RILEY Dwg: 14269-FIG. 4 indicates the curved section, which can be refined within subsequent design stage(s).

6.2.2 Auxiliary Spillway

Auxiliary spillways, sometimes referred to as emergency spillways, are used to pass larger spill events up to and including the PMF. As per Section 6.1, RILEY adopted dimensions initially proposed by NRC and assessed their suitability. Our estimates indicate a spillway with the proposed dimensions (130m wide, 3m depth) and spillway capacity (up to 1,128m^3/sec) would suffice.

The attached RILEY Dwg: 14269-FIG. 1 indicates the auxiliary spillway discharges to an existing, natural gully situated adjacent to the left abutment, approximately 100m downstream from the downstream toe. The spillway location was selected for the purpose of cost estimate, however, it is noted the spillway alignment/geometry may be refined following assessment of potential instability near the inlet. (Note: RILEY Dwgs: 14269-FIG. 2 and -FIG. 3 show alternative spillway alignments). In the proposed configuration, the spillway alignment passes through a saddle situated between two RL 116.0m hilltops.

Hydrological studies provided by NRC indicate the peak reservoir level, during the 1% AEP flood event, would be RL 102.22m. As a result, the conceptual design includes the auxiliary spillway sill crest elevation at RL 102.3m.

Flood flows up to the PMF contain significant erosion potential, thus it is reasonable to assume some erosion may occur. It is proposed that rip-rap be placed at the interface between the spillway downstream toe and natural ground, to minimise erosion. During subsequent design stages, requirements for erosion protection near the auxiliary spillway crest and inlet should also be considered.

6.3 Dam freeboard

RILEY calculations indicate the PMF flows discharged via the auxiliary spillway could be up to 1,000m^3/sec. It is noted that at this peak flow, the reservoir level would be at/near the dam crest. Hence, the concept design includes a 0.8m high crest wave wall, which may also serve as a safety barrier to prevent vehicles entering the reservoir.

6.4 Stilling Basin Design

Discharged flows from the service spillway have significant erosion potential which must be controlled. Service spillway velocities could be up to 9m/sec. A stilling basin such as a Saint Anthony Falls (SAF) stilling basin or equivalent (e.g. USBR) may be appropriate. The Kotuku Dam (currently under construction) features a SAF type stilling basin 4m high and 10m long.

It would be expected rock armour or rip-rap could be placed downstream of the stilling basin to provide further erosion protection measures. Furthermore, it would be prudent to provide a vehicle access road to the stilling basin area, to facilitate maintenance and inspections.

6.5 Other Hydraulic Considerations

Algae bloom issues are known to exist at Lake Manuwai, situated approximately 4km northwest of the K3A dam site. Although this report does not address detailed ecological and environmental aspects, it is envisaged that the risk for algae bloom be considered within the scope of the environmental assessment(s) required – refer Section 9.0. These assessments should consider potential mitigating measures, for example at Lake Manuwai aerators are installed for this purpose.

7.0 Conceptual Dam Design

7.1 Key Dimensions and Features

Design estimates and dimensions of the dam include the following:

- Earth dam 25m high, 300m crest length
- 5m crest width and embankment slope profiles of 1V:2.5H (upstream) and 1V:2.2H (downstream)

Key features of the dam include:

- Dual zoned earth dam.
- Continuous (vertical) chimney drain.
- Horizontal strip drainage system.

- Downstream toe drains.
- Upstream clay blanket.

7.2 Geotechnical Design Aspects

7.2.1 Observed ground conditions

Ground conditions were visually assessed during the site walkover inspection. No subsurface investigation or detailed mapping has been undertaken as part of this feasibility study.

In general, ground conditions appear consistent with published geological data for the area (Section 3.2). Specifically, the proposed left and right abutment spurs comprise moderate to relatively steep slopes, consistent with volcanic rock formations exhibiting shallow weathering. The relatively flat profile of the river valley between left and right abutments is consistent with episodic deposition of alluvial deposits. The existing river is located within a slightly incised channel, the depth of which varies below the surrounding, relatively level, floodplain at the base of the valley. LIDAR data indicates the river channel depth is 5m below the river bank, where the dam crest centreline crosses the river.

Photo 1: Proposed dam site – view from right abutment toward left abutment, along approximate dam centreline.

The banks of the incised river channel were partially vegetated at the time of inspection, with some exposures of alluvial silt and fine sand along the channel. No rock exposures were observed within the river channel at the proposed dam location; however, NRC informed RILEY that rock exposures have been exposed by river flows within 1km downstream.

At the time of the inspection, scrub had been cleared on the proposed right abutment spur, apparently within recent months. This area is shown vegetated in aerial photographs retrieved from the NRC GIS system (as of February 2015). A small excavation had been cut within the cleared zone at the base of the right abutment, likely as a source of road metal. Rock at the right abutment displayed a shallow weathering profile, comprising completely weathered to un-weathered volcanic rhyolite (Photo 2). No obvious large or persistent defects were noted in the parent rock. The weathered soils were typically exposed as firm to hard, non-plastic, silty, fine sand.

The left abutment comprised grassed farmland, and no large soil or rock exposures were apparent. A small spring was noted near the top of the spur near the upstream left extent of the proposed auxiliary spillway channel, and a re-vegetated scarp was observed on the north-western face of the left abutment spur. This scarp feature is approximately 60m wide and 60m long, and relatively shallow (approximately 2m to 4m depth). The scarp is located immediately downstream of a bend in the existing river, suggesting that slip or slump movement may have occurred due to bank erosion or loss of support at the toe of the slope.

Rock exposures were briefly inspected at the right bank quarry location, 300m upstream of the proposed dam site. Our main observations include:

- The quarry excavation consists of cut rock faces, at a near-vertical batter, and up to approximately 10m in height.
- Slightly weathered to un-weathered rock was exposed at shallow depths (within 30cm of ground surface).
- The cut rock faces appeared slightly to un-weathered.
- No obvious pronounced or persistent open joint sets were observed.
- Slight seeps were noted from small joints in near-vertical quarry faces.
- Infilled rock seams appeared hard and of quartzite origin (Photo 3). No clay seams were observed.

Photo 2: Rock exposure at proposed right abutment location.

Photo 3: Infilled rock seams, irregularly oriented, at base of upstream quarry.

In general, no obvious critical ground conditions were noted during the walkover inspection. The mass properties of the surrounding reservoir, abutment, and foundation rock formations will require significant investigation to ensure that adequate strength and low-permeability conditions can be achieved for dam construction.

7.2.2 Dam Fill Materials, Zoning, and Seepage Control

The embankment dam concept presented on RILEY Dwg: 14269-FIG. 4 (within Appendix B) comprises three distinct zones: Zone 1 (upstream shoulder), Zone 1B (downstream shoulder), and the drainage system. The inclusion of zoned materials and drainage systems within this design is consistent with current dam design practice, as per Geotechnical Engineering of Dams (2005, Fell et al). The majority of the material is assumed to be obtained from the spillway excavation.

Upstream shoulder material (Zone 1) comprises highly to completely weathered (residual soil) basalt or rhyolite. It is envisaged Zone 1 will be clay or predominantly clay material as the purpose of this zone is to control seepage using low permeability material. If the majority of the spillway cut is within rock material, then a thinner clay core would be necessary.

Zone 1B, the downstream shoulder, may consist of weathered volcanic rock (basalt or rhyolite), but coarser than that of Zone 1. The purpose of Zone 1 and the downstream shoulder is to provide stability as well as some seepage control.

A full length (continuous) chimney drain and horizontal strip drainage systems is included within the dam concept design, to provide seepage control of the earth dam and foundation. Six horizontal strip drains are proposed with various widths, which are determined by the location and whether the drain is primary (critical), or secondary.

Other geotechnical elements include rip-rap for erosion protection of the upstream face and downstream toe, near the service spillway outlet.

At this stage, foundation permeability is unknown and also the degree of features such as joints or fissures. These features will have implications for seepage control and the extent of ground treatment required. The concept design includes provision of an upstream clay blanket, extending 50m from the dam toe which is a conservative estimate.

Use of clay blankets can be effective in minimising seepage in dam foundations. If ground conditions were found to be favourable, whereby permeability in the dam foundation and presence of geotechnical defects (e.g joints) in the upstream area was acceptably low, the use/inclusion/extent of an upstream clay blanket could be re-evaluated.

7.3 Earthquake Loading Considerations

Stability analyses was not undertaken as part of the conceptual design process. It is anticipated future design stages (e.g preliminary, feasibility or detailed design) will include dam design refinements and stability analyses. Liquefaction could be a potential issue at this site within the alluvium materials encountered and should be assessed within future design stages.

Our review forthcoming NZSOLD Guidelines, which have been revised and yet to be issued in 2015, indicates owners of high PIC dams (Section 4.3.2) should have a site specific seismic hazard assessment, using deterministic and probabilistic analyses.

7.4 Water supply infrastructure

An intake tower is required to convey municipal and irrigation water supplies. The concept design allows for an intake tower affixed to the upstream end of the 3m by 4m diversion box culvert. The box culvert was not specifically designed, thus future design stages should refine this structure including assessment of an appropriate diversion flood standard.

Prior to lake filling, the diversion culvert would be decommissioned via plugging the inlet with a concrete seal. The intake tower would be affixed downstream of the plug, as shown in RILEY Dwg: 14269-FIG. 4, attached.

One aspect, which should be explored in further design stages, is the height of the intake tower. If dead storage is anticipated to be at RL 97.0m/RL 98.0m, NRC may prefer to terminate the top of the intake tower say 2m to 3m higher (RL 100.0m) to allow for personal entry and/or maintenance access. Under flood conditions such as the 1% AEP event or larger event(s), the intake tower would be completely submerged and should be designed accordingly.

In addition to the intake tower height, future design stages should also consider the advantages, disadvantages, and cost comparison of concrete and steel towers. We understand the Kerikeri Irrigation Company steel intake towers perform well, however they require constant maintenance. An access platform should also be provided for observation and maintenance purposes.

It should be noted that for the purposes of concept design, a 3m diameter concrete intake tower is shown (RILEY Dwg: 14269-FIG. 4). However it is acknowledged NRC may prefer a steel truss intake tower, similar to that in place at the existing Kerikeri Irrigation Scheme dams. Steel truss intake tower is included within the cost estimate presented in Section 8.0 and Appendix A.

The concept design includes elements similar to the water supply infrastructure used in the North Dam (one of the nearby Kerikeri Irrigation Schemes). The design includes two main 700mm diameter trunk culverts for the municipal and irrigation water supplies. Up to four horizontal 350mm diameter inlet feeder culverts would be placed at various heights up the convey raw water to the 700mm trunk culvert. The 700mm culverts would comprise a vertical section (within the intake tower), a 90º bend at the base, and a horizontal section as illustrated in RILEY Dwg: 14269-FIG 5. The horizontal culvert section could be supported via wall mounted brackets and/or floor mounted pedestals.

Further design refinements are expected as preliminary or detailed design stages shall ensure the water supply infrastructure is appropriately sized to meet municipal and irrigation supply demands.

7.5 River Diversion and Flood Risk During Construction

It is proposed the Kerikeri River would be diverted through the 3m by 4m box (diversion) culvert as shown in RILEY Dwgs: 14269-FIG. 1, -FIG. 2, -FIG. 4, and –FIG. 5. The river would also be routed through appropriately designed upstream and downstream approach channels, and a temporary diversion bund will be required, but have not been designed within the scope of this study. However excavation associated costs are inclusive of these items. The bund, upstream and downstream channels shall need to be designed to convey/contain flood events and further design refinements (e.g. selection of diversion culvert size) and selection of appropriate flood protection and river diversion structures is recommended. Such design refinements should consider the likelihood for large wood debris (tree trunks), such as those observed during the site inspection (Photo 4). Accumulated wood debris, such as the example below, impedes flow on the Kerikeri River and would affect river diversion structure(s) and channel(s).

Photo 4: Accumulated wood debris observed during K3A dam site inspection

As an initial construction stage, a cofferdam approximately 9m high could be formed which offers flood protection. The cofferdam (refer RILEY Dwg: 14269-FIG. 4) is incorporated within the permanent embankment.

8.0 Cost Estimate Through Construction

8.1 Excavation Assumptions

For the purpose of cost estimation and conceptual design for the dam, the following was assumed:

- Up to 2m undercut at the dam abutments, where we expect undercut depth to reduce further up the abutments (as the dam height decreases).
- Up to 5m undercut in the valley floor, where overlying alluvium and/or colluvium should be undercut to competent founding material.
- Total undercut volume 60,000m^3.
- Total embankment fill required 227,000m^3

The cut volume/quantity of the auxiliary spillway is determined from slope profiles and dimensions as shown on RILEY Dwgs: 14269-FIG. 2 and –FIG. 4. The majority of the dam fill is assumed to be from the considerable spillway excavation

Due to the need for additional fill for the embankment dam, it was assumed fill shall be sourced from the adjacent quarry and/or additional nearby borrow sites.

8.2 Cost Estimate Basis

A cost estimate was prepared within the present scope of work as a basis for feasibility assessment. The itemised cost schedule is presented in Appendix A. In general, rates used in the construction cost estimate are based on smaller earth dam projects and the conceptual earth dam design presented in this report.

The following items are estimated as a percentage of construction cost:

- Preliminary and general - includes surveying, site establishment and disestablishment, testing, QA.
- Contingency - 25% of all costs.
- Engineering - includes investigation, design and construction supervision (15%).

As detailed in Appendix A, the total estimated cost for the Kerikeri K3A dam, in its proposed form, is $13,766,000. Table 4 below summarises key cost items:

Table 4: Summary of Major Construction Cost items

Description	Value ($NZD)
Preliminary and General	1,061,250
Earthworks (including Earthworks Management)	3,330,000
Internal Drainage	1,018,000
Intake Works and Diversion Culvert	1,222,000
Spillway, Erosion Protection, and Outlet Works	2,050,000
Engineering (Design and Supervision)	1,469,250
Miscellaneous Items	1,114,500
Contingency Sum	2,501,000
TOTAL	**13,766,000**

This estimated cost assumes suitable foundation conditions and availability of suitable borrow materials in reasonable proximity to the dam site. A provision for foundation treatment is included within this cost estimate (Appendix A), however allowance for reservoir slope stabilisation measures are not considered. A full geotechnical investigation and analysis will be required in order to assess the likely need for additional geotechnical engineering components.

As stated on the previous page approximately $1,470,000 (15% of the construction cost) is attributed to engineering design and supervision. This amount can be further delineated as follows:

- $367,500 for feasibility assessment, preliminary design and investigations (geotechnical and hydrological) to resource consent level
- $367,500 for detailed design to building consent level
- $735,000 for engineering supervision / contract / completion

(first two items: 7.5%; third item: 7.5%)

These should be regarded as indicative estimates.

Cost estimate exclusions include: (1) land purchase costs; (2) applicable legal fees; (3) resource and building consent costs; (4) and GST.

An environmental assessment will be required (see Section 9.0). Approximate costs for such an assessment could range from $200,000 to $300,000, which is two to three times the cost of the Kotuku environmental assessment. Environmental assessment costs are not included within the scope of the cost estimate provided in Table 4.

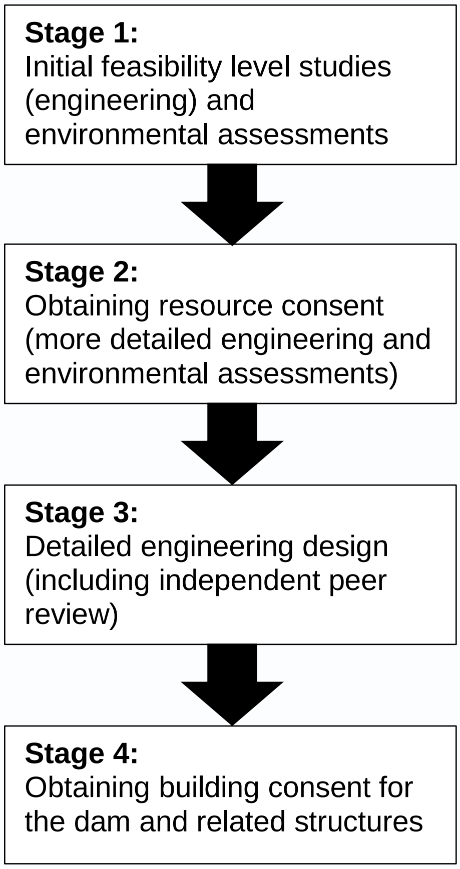
9.0 Strategy for Future Investigations and Consenting

The dam will require resource consents under the Resource Management Act and a building consent under the Building Act. The general flowchart for the various stages of investigation and consenting are summarised in Figure 1 on the following page.

The focus of engineering feasibility will be on geotechnical aspects (e.g. foundation conditions, materials for dam construction, slope instability including the reservoir) and also on hydrological aspects (e.g. flood hydrology up to the PMF, water demand aspects). It is usual practice to stage these investigations with updating of cost estimates as the process continues. In parallel with the engineering studies, environmental assessment will be required. These would typically include aspects of ecology, archaeology, social, landscape/visual, and cost/benefit studies.

An overall time scale of three to four years as a minimum, from initial investigations to lodgement of a building consent is envisaged. For comparison, the Kotuku Dam project took two years for the equivalent. However, we would expect greater environmental issues for this dam which permanently impounds water and is also of a larger scale than Kotuku. The Kotuku project also obtained resource consents without needing a public hearing

Figure 1: Flowchart for potential future dam development stages



10.0 Summary

A list of the main summary points from this report is as follows:

- The PIC rating for the K3A dam is assessed as High. This is on the basis of the potential downstream effects and loss of life. While this is a conservative estimate it is expected further detailed dam break analysis may confirm or revise this rating.
- The service and auxiliary spillways have been sized to pass the 1% AEP and PMF events respectively. Supplied hydrological information was used to determine spillway capacities.
- Ground conditions observed from the site walkover appear consistent with published geological information. A number of possible materials for dam construction have been identified.
- It is anticipated targeted, staged ground investigations may be undertaken as part of further assessment on geological aspects such as slope stability, dam materials, foundation analyses, liquefaction hazard assessment, and foundation permeability.
- A zoned dam utilising a fully intercepting chimney drain is the preferred concept. The majority of the fill volume is assumed to be from the considerable spillway cut on the left abutment.
- The total cost estimate for the K3A dam is $13,766,000, which includes a $2,501,000 contingency sum (25%).

- Approximately three to four years, as a minimum based on the concept design, is the expected timeframe from initial investigations to lodgement of a building consent.

11.0 Limitation

This report has been prepared solely for the benefit of Northland Regional Council as our client with respect to the brief. The reliance by other parties on the information or opinions contained in the report shall, without our prior review and agreement in writing, be at such parties' sole risk.

12.0 References

References cited within this report and used for calculations include the following:

Bell, G., Fell, R., MacGregor, P., & Stapledon, P. 2005. *Geotechnical Engineering of Dams*.

Chanson, H. 2004. *Hydraulics of Open Channel Flow (2nd Edition).*

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DHI Water and Environment Ltd. December 2014. *Kerikeri Detention Dam K3A Additional Modelling.*

NZSOLD. 2000. *New Zealand Dam Safety Guidelines*.

Opus International Consultants Ltd. July 2013. *Kerikeri Detention Dam Study: Preliminary Assessment Report.*

Riley Consultants Ltd. December 2012. *Kotuku Detention Dam – Preliminary Design Report and Hydraulic Optimisation*.

United States Bureau of Reclamation (USBR). 1987. *Design of Small Dams (3rd Edition)*.

APPENDIX A

Cost Estimate

SCHEDULE OF QUANTITIES

Kerikeri 3A Dam Concept

ITEM	DESCRIPTION	UNIT	QUANTITY	RATE	TOTAL
0.1	**Preliminary and General**				
0.11	Establishment, disestablishment, QA, QC, Survey, as-builts, access	LS	1	1,061,260.80	$1,061,260.80
1.0	**Earthworks Management**				
1.1	Silt control	LS	1	200,000.00	$200,000.00
1.2	Temporary river diversion	LS	1	40,000.00	$40,000.00
1.3	Dewatering of excavations	LS	1	35,000.00	$35,000.00
2.0	**Earthworks**				
2.1	Clearing and topsoil stripping: dam, spillway and borrow areas	m^2	80,000	1.50	$120,000.00
2.2	Foundation excavation (to spoil/to stockpile)	m^3	60,000	6.50	$390,000.00
2.3	Spillway cut to waste excess	m^3	63,000	6.00	$378,000.00
2.4	Dam embankment: Borrow to (clay) fill	m^3	50,000	8.00	$400,000.00
2.5	Spillway excavation to fill	m^3	177,000	7.00	$1,239,000.00
2.6	Clay blanket	m^3	32,000	10.00	$320,000.00
2.7	Topsoiling+grassing	m^2	54,000	2.00	$108,000.00
2.8	Foundation preparation / treatment	LS	1	100,000.00	$100,000.00
3.0	**Internal Drainage**				
3.1	Excavation, drainage material, pipes				
3.1.1	Chimney drain	m^3	8250	100.00	$825,000.00
3.1.2	Strip drain filter material, pipes				
	i) filter material (Type F1)	m^3	615	100.00	$61,500.00
	ii) drainage material (Type F2)	m^3	310	80.00	$24,800.00
	iii) main blanket drain (Type F2 material)	m^3	210	80.00	$16,800.00
	iv) Outlet pipes (225 dia)	m	30	170.00	$5,100.00
3.1.3	Toe drain				
	i) filter material	m^3	275	100.00	$27,500.00
	ii) pipework	m	300	100.00	$30,000.00
3.1.4	Wingwalls				
	i) blanket drain outlets	No	8	930.00	$7,440.00
	ii) stream outlet	No	2	2,100.00	$4,200.00
3.1.5	Collector channels				
	i) drain outlets	No	2	2,500.00	$5,000.00
	ii) mainstream	m	300	35.00	$10,500.00
4.0	**Intake Structure and Diversion Culvert**				
	Intake structure foundation (includes concrete, formwork, steel)	m^3	90	1,800.00	$162,000.00
	Intake structure/tower	LS	1	130,000.00	$130,000.00
	Valve chamber (includes concrete, steel, formwork)	LS	1	40,000.00	$40,000.00
	Diversion box culvert (including concrete, steel, formwork)	m	140	6,000.00	$840,000.00
	120m of water infrastructure steel pipework 2x 700mm diameter (from intake tower to downstream end of box culvert)	LS	1	50,000.00	$50,000.00
5.0	**Spillways, Erosion Protection and Outlet Works**				
5.1	Rock riprap (dam and erosion protection)	m^3	12500	75.00	$937,500.00
5.2	Service spillway comprising 5m diameter Bellmouth inlet + 3m diameter pipe section	m	105	7,500.00	$787,500.00
5.3	Stilling basin (concrete, formwork, steel)	LS	1	300,000.00	$300,000.00
5.4	Trimming downstream channel	LS	1	25,000.00	$25,000.00
6.0	**Miscellaneous**				
6.1	Gauge house	LS	1	75,000.00	$75,000.00
6.2	Instrumentation - piezometers	No.	20	1,500.00	$30,000.00
6.3	Embankment surface survey network	No.	20	500.00	$10,000.00
6.4	Spillway/berm crossings	LS	1	10,000.00	$10,000.00
6.5	Wave wall	m	300	330.00	$99,000.00
7.0	**Allowance for misc. small items**				
	Misc items		10%	890,510.00	$890,510.00
8.0	**Engineering (includes design and supervision)**				
	Engineering (includes design and supervision)		15%	1,469,340.00	$1,469,340.00
9.0	**Project Contingency Sum**				
	Percentage of all sub-items from 1.0 to 8.0		25%		$2,500,920.00
	Grand total				**$13,765,870.00**

APPENDIX B

Drawings

REV	DESCRIPTION	BY	DATE
0	FIRST ISSUE		

DESIGN: TG — CHECKED: DRT
DRAWN: MP — CHECKED: DRT
DATE DRAWN: JANUARY 2015

APPROVED FOR ISSUE: D TATE
DATE: 16/3/15

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AUCKLAND
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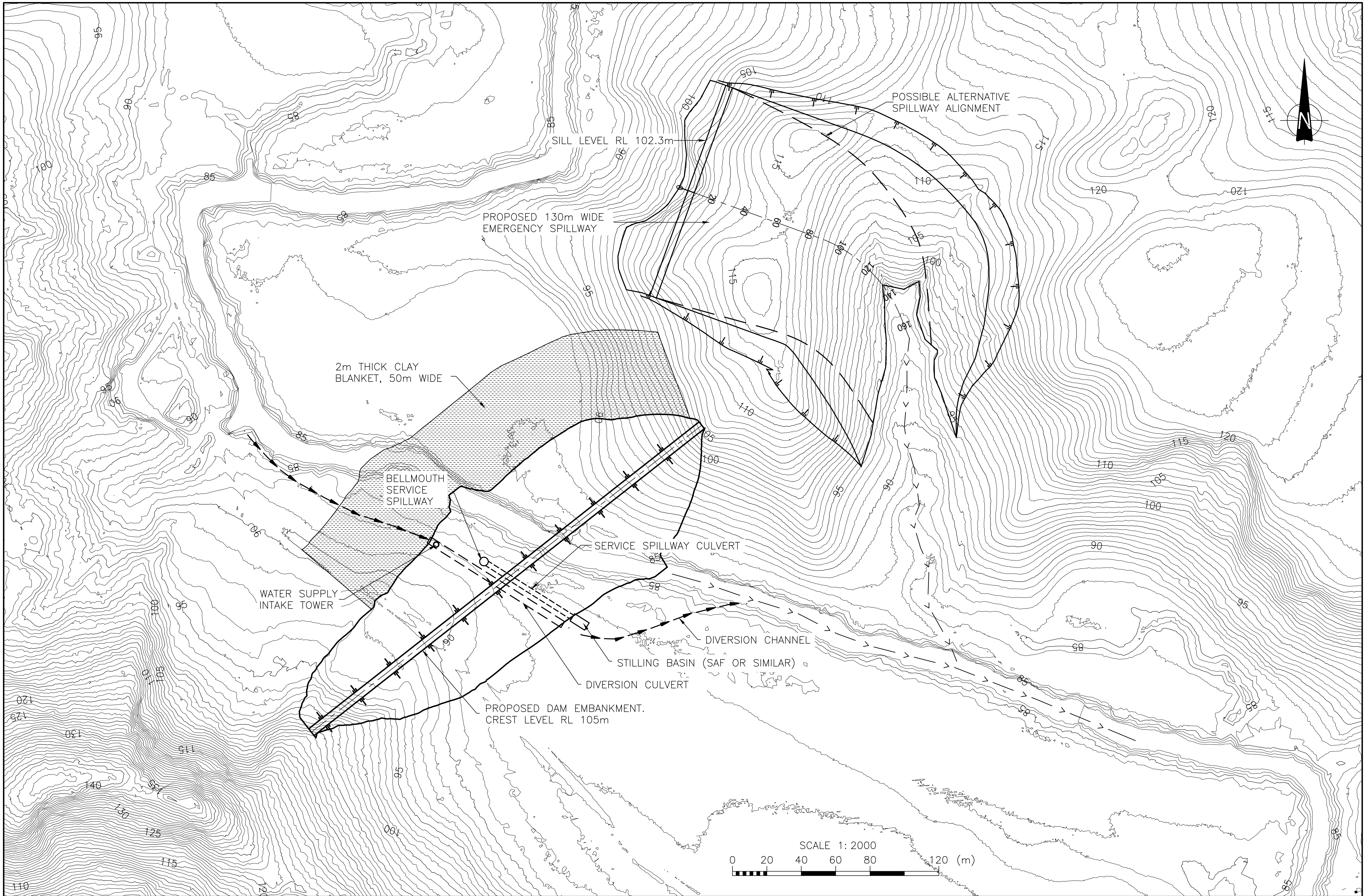
TITLE

NORTHLAND REGIONAL COUNCIL
PROPOSED KERIKERI DAM - CONCEPT DESIGN
DAM SITE PLAN

CADFILE: 14269-FIG1
SCALES (A3): 1:2000
ACENZ
DRAWING No.: 14269-FIG. 1
REV.: 0



REV	DESCRIPTION	BY	DATE
0	FIRST ISSUE		

DESIGN: TG — CHECKED: DRT
DRAWN: MP — CHECKED: DRT
DATE DRAWN: JANUARY 2015

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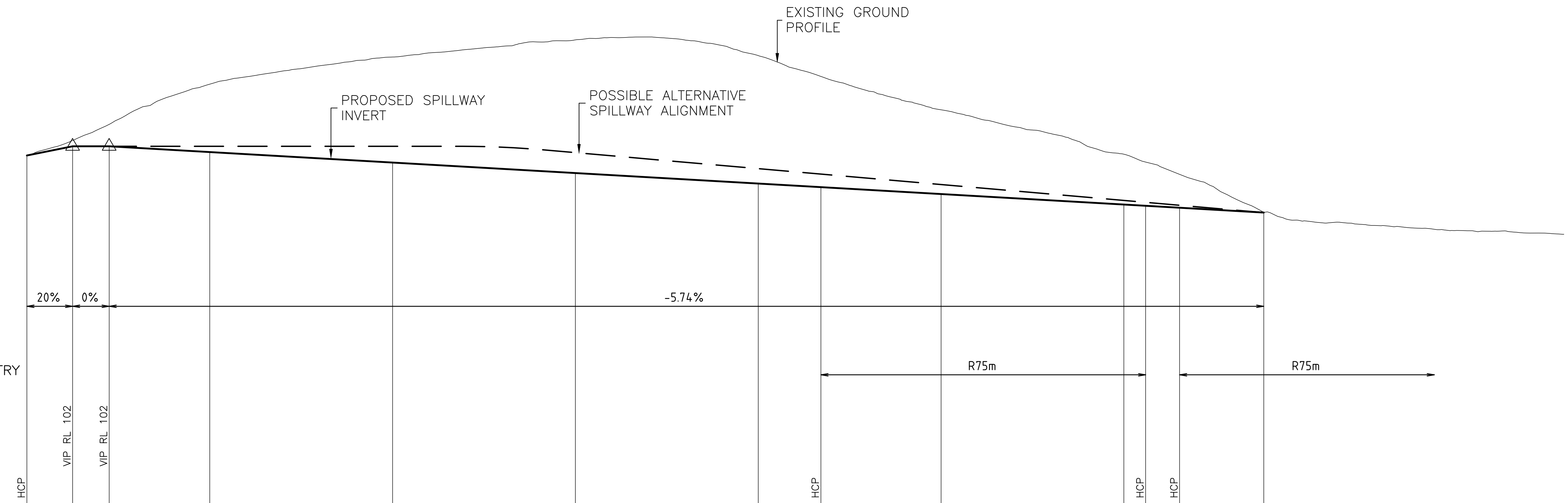
PROPOSED KERIKERI DAM - CONCEPT DESIGN

DAM LAYOUT

CADFILE: 14269-FIG2
SCALES (A3): 1:2000
ACENZ
DRAWING No.: 14269-FIG. 2
REV.: 0



DATUM 62.00

FINISHED CL LEVEL	101.00	102.30	102.30	101.37	100.22	99.07	97.92	97.53	96.78	95.63	95.49	95.28	94.75
EXISTING SURFACE	101.00	102.64	104.40	108.80	111.77	113.64	111.92	109.64	106.00	101.13	100.28	98.93	94.78
FILL(+)/CUT(−)	0.00	−0.34	−2.10	−7.43	−11.55	−14.57	−13.99	−12.11	−9.22	−5.50	−4.79	−3.65	−0.03
CHAINAGE	0.00	5.00	9.00	20.00	40.00	60.00	80.00	86.86	100.00	120.00	122.38	126.09	135.30

SPILLWAY LONG SECTION

SCALE 1:500 HOR. & VERT.

REV	DESCRIPTION	BY	DATE
0	FIRST ISSUE		

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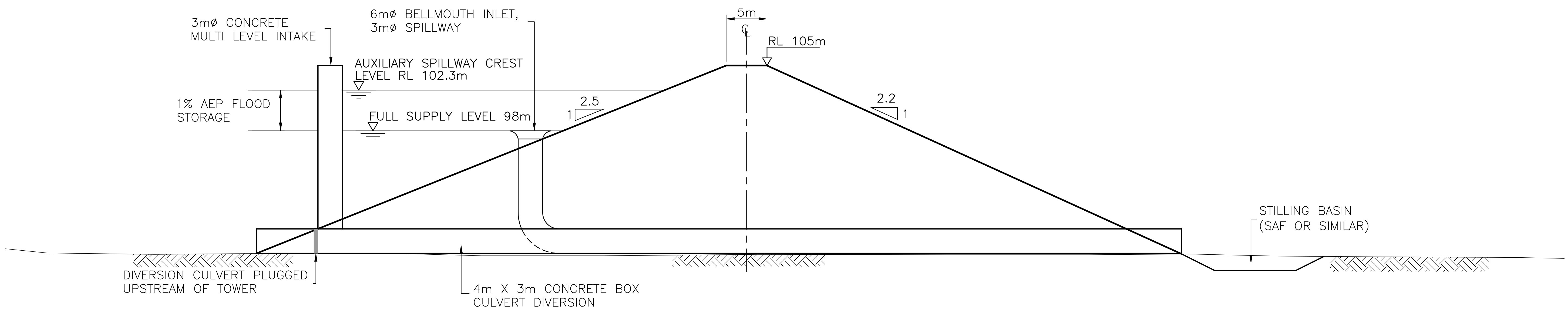
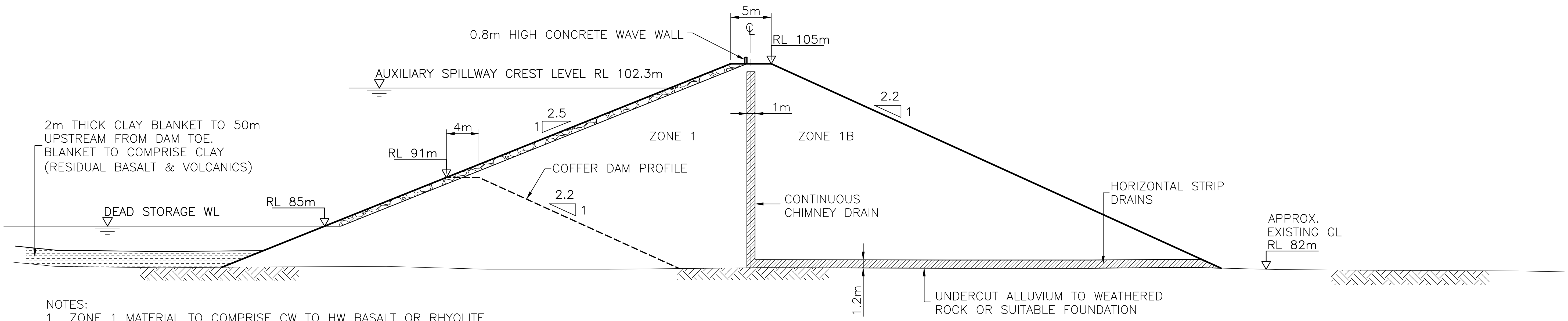
PROPOSED KERIKERI DAM - CONCEPT DESIGN
SPILLWAY LONG SECTION

CADFILE 14269−FIG3
SCALES (A3) 1:500
DRAWING No. 14269-FIG. 3
REV. 0



DAM CROSS SECTION SHOWING INTAKE

SCALE 1:500



DAM CROSS SECTION SHOWING EMBANKMENT CONSTRUCTION

SCALE 1:500

NOTES:
1. ZONE 1 MATERIAL TO COMPRISE CW TO HW BASALT OR RHYOLITE (AS DAM CORE)
2. ZONE 1B TO COMPRISE WEATHERED ROCK (AS DOWNSTREAM SHOULDER)
3. CHIMNEY DRAIN TO COMPRISE GRAVELLY SAND
4. HORIZONTAL STRIP DRAINS TO COMPRISE SANDY GRAVEL

REV	DESCRIPTION	BY	DATE
0	FIRST ISSUE		

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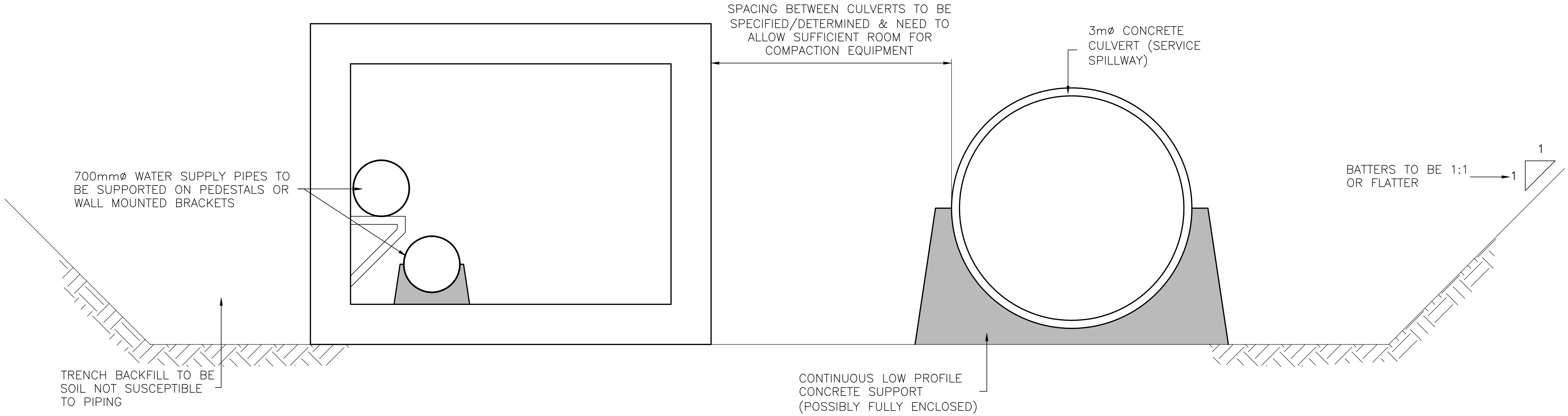
PROPOSED KERIKERI DAM - CONCEPT DESIGN
TYPICAL DAM CROSS SECTIONS

CADFILE 14269-FIG3to5
SCALES (A3) 1:500
ACENZ
DRAWING No. 14269-FIG. 4
REV. 0



TYPICAL SECTION - SERVICE SPILLWAY & DIVERSION CULVERT

SCALE 1:50

REV	DESCRIPTION	BY	DATE
0	FIRST ISSUE		

DESIGN TG · CHECKED DRT
DRAWN MP · CHECKED DRT
DATE DRAWN JANUARY 2015

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PROPOSED KERIKERI DAM - CONCEPT DESIGN

SERVICE SPILLWAY & DIVERSION CULVERT DETAILS

CADFILE 14269-FIG3to5
SCALES (A3) 1:50
ACENZ
DRAWING No. 14269-FIG. 5
REV. 0