

**Lower Maungakotukutuku Dam  
Interpretative Geotechnical Report**

August 2010

Kapiti Coast District Council

**Issue 2**

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Approved for issue:

Peter Amos

Date

2/8/10

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## **1.0 Executive Summary**

### **The dam site is underlain by greywacke bedrock.**

The greywacke bedrock is moderately to highly jointed and sheared. The rock mass however is relatively competent, as demonstrated by the near vertical sides of the inner gorge, which has withstood multiple seismic events over tens of thousands of years.

### **The left abutment greywacke has been hydrothermally altered.**

The greywacke beneath the left abutment intercepted by drillhole LM1 has been hydrothermally altered millions of years ago. This accords with observations in the inner river gorge just upstream from the dam site. The extent of this altered greywacke is yet to be defined.

### **The permeability of the greywacke rock mass is low.**

Tests within the drillholes indicate the greywacke rock mass has a very low permeability. It is anticipated that foundation treatment, such as grouting, required to control seepage under the dam, would therefore be limited.

### **No large scale discontinuities have been identified.**

No faults, or low angle discontinuities of significance have been encountered within the drillholes. This concurs with the lack of surface displacement displayed at the damsite, inferring an absence of potentially active faults. No sub-horizontal discontinuities or through going faults of recent origin have been encountered, although drilling has yet to fully investigate the dam foundation.

### **Overburden on the terraces would need to be stripped.**

Approximately 6m of alluvial and colluvial overburden was intercepted on the right bank terraces with inferred thickening of overburden at the right abutment. Minor alluvium and a wedge of colluvium is present on the left bank. This overburden would be stripped to prepare the dam foundation.

### **The site is considered suitable for siting a gravity dam and diversion tunnel.**

The current level of investigation has located no fatal flaws. Further investigation necessary to fill in gaps in the geological information would be required as part of subsequent detailed design.

### **The previous cost estimate is not changed.**

No revision of the cost estimate previously provided by Technical Memorandum 10 is required based on the findings of the geotechnical investigations reported herein.

## 2.0 Scope of Interpretative Geotechnical Report

This report assesses the reconnaissance level geological mapping and data from the drilling programme recently undertaken of the Lower Maungakotukutuku Dam site and surrounds.

It addresses the suitability of the site for construction of a Roller Compacted Concrete (RCC) dam as described by Technical Memorandum 10<sup>1</sup>. Two reservoir volumes and corresponding dam heights were assessed by Technical Memorandum 10. The proposed layouts showing plan and sections for each of the reservoir volume scenarios are shown on Drawings WS909/20/21, 22, 23 and 24, included in Appendix A. The significant characteristics of each scenario are summarised in Table 2.1.

**Table 2.1. Significant Characteristics of Maungakotukutuku Dam Scenarios 1 and 2**

	Scenario 1	Scenario 2
Dam Crest	RL 123.5	RL 121.5
Spillway Crest (full supply level)	RL 120.5	RL 118.5
Dam Height	31.5 m	29.5 m
Live Storage	1,931,000 m <sup>3</sup>	1,431,000 m <sup>3</sup>
Dead Storage	350,000 m <sup>3</sup>	350,000 m <sup>3</sup>
Spillway Capacity	120 m <sup>3</sup> /s	120 m <sup>3</sup> /s

A companion Factual Report<sup>2</sup> contains the detailed information on the reconnaissance level geological mapping and physical geotechnical investigations.

## 3.0 Dam Site Ground Conditions

### General

Inspection of the river gorge and detailed logging of the holes drilled across the foundation of the proposed dam confirms that beneath both abutments and central dam area there is greywacke bedrock at relatively shallow depths.

A geological section across the dam site, based upon reconnaissance level geological mapping and the drilling investigations is shown in Drawing WS909/20/25, included in Appendix A.

No landslides have been identified at the dam site and reservoir area from the examination of aerial photographs.

### Physiography

The site spans a section of gorge immediately downstream from a flat-floored basin. At the dam site the valley is approximately symmetrical with steep slopes extending above the proposed abutment from about RL 120 m.

The right bank has a well-developed alluvial terrace at about RL 104m. An equivalent terrace on the left bank is small and constrained in area.

Within the base of the valley there is a 10m deep inner river gorge, which traverses through the dam site and continues downstream.

<sup>1</sup> Damwatch 2010., TM10 for Maungakotukutuku Dam.

<sup>2</sup> Damwatch 2010. Lower Maungakotukutuku Dam – Factual Geotechnical Report.

### **Colluvium**

Colluvium mantles the steeper slopes of each abutment. This was intercepted by drillholes LM1 and LM5 drilled in the left and right abutment respectively.

A small debris tongue extends out onto the terrace approximately 60m upstream from the right abutment. While interpreted as a mass movement deposit the source may be “erosional” rather than a failure in bedrock. This feature would be further investigated as part of final design.

The colluvium under the dam footprint would be stripped during preparation of the dam foundation.

### **River Alluvium**

River alluvium was encountered to a depth of approximately 6m in drillholes LM3 and LM4, and extend over the right bank terrace. This would have been deposited during previous valley aggradation.

Groundwater within the river alluvium is perched upon the underlying greywacke. Based upon drilling observations from LM3 and LM4 groundwater levels within the river alluvium are of the order of 1m below ground surface and the permeability within the river alluvium is low.

As with the colluvium, the river alluvium under the dam footprint would be stripped during preparation of the dam foundation.

### **Left Bank Bedrock**

Beneath the left bank the greywacke is pervasively altered, evidenced by the green rock exposed in the gorge and in drillhole LM1. The greywacke is strongly sheared however most discontinuities are compact and indurated.

The alteration and shearing is interpreted as a consequence of geological processes, most likely associated with the Rangitata Orogeny c.100 million years before present which, have hydrothermally altered the greywacke.

Core from drillhole LM1, or rock outcrop exposed within the river gorge, is generally assessed as being moderately strong to very weak. In parts both drillhole core and rock outcrop can be easily broken.

The rock mass quality is considered to be greater than may be inferred based solely on inspection of the drillhole core based on:

- The green rock mass exposed in the gorge upstream of the dam site supporting near vertical free-standing rock faces up to 10m high;
- Core recovery from LM1 generally 100%.

Towards the river gorge the greywacke bedrock shows less green alteration. There is significant oxidation of the rock in close proximity to the adjacent gorge wall as would be expected. Very close jointing and minor shearing was evidenced in drillhole LM2. The rock mass however remains intact, with minor inferred relaxation demonstrated by the adjacent steep stable gorge walls.

Quite large zones of little or no core recovery, observed in boreholes LM2 and 3 may possibly be faults, however, it is considered that these sections of little or no core recovery are unlikely to be faults based on the following:

- The zones of little or no core recovery intercepted steep features, so a long intercept but a relatively narrow feature; and
- Had faults with major gouge material been intercepted the fault and gouge material would have been cored.
- No surface displacements found in the damsite area in the geological reconnaissance.

Groundwater levels within the greywacke bedrock beneath the left bank are not known. It is anticipated that towards the inner river gorge where the rock is unconfined and joints may open that the groundwater levels will be close to the river level.

No large scale discontinuities, such as faults have been encountered by the drillholes beneath the left abutment.

Overall the rock mass beneath the left bank is considered suitable for founding a dam. Further investigation and assessment of the rock mass properties, specifically strength and deformation characteristics, will be required for analysis and design of the dam foundations. It is anticipated that if a left bank diversion was used the rock mass quality encountered will improve with increased distance from the inner river gorge.

### **Inner River Gorge**

The inner river gorge is characterised by very steep walls up to 10m high, with local lower gradients where joint bound wedges have fallen out. No “fresh” failures were apparent during reconnaissance level geological mapping.

The gorge is sinuous in plan and does not appear to be controlled by a particular discontinuity. No faults have been identified, which is consistent with the steep walls of the gorge.

Across the section of the dam footprint the greywacke is generally strong to very strong, siliceous and black, however there are sub-vertical shear zones within the sides of the inner river gorge. One shear zone comprised light grey pulverised rock with a high clay content. This shear zone is approx 300mm wide and aligned on a bearing of approx N 120° E. Other sub-vertical shear zones were between 100mm to 300mm wide and also aligned sub-parallel to the proposed axis of the dam. These shear zones are very weak and easily broken.

Within the base of the gorge localised gravel bars have accumulated between deeper pools where the stream has eroded into the greywacke bedrock. These gravel bars could be between 0.5m to 1.0m thick.

### **Right Bank Bedrock (comprising terrace and abutment)**

In the right terrace dam foundation area the greywacke is jointed and sheared, with minor oxidation apparent at the top of the greywacke. Near the inner river gorge, the rock mass is interlocked and stands near vertical forming the gorge wall similar to the opposite side of the gorge.

Away from the inner river gorge, drillhole LM4 and LM5 encountered closely jointed and sheared bedrock which is largely unaltered.

Sheared zones examined in the drillhole core and in the sides of the river gorge are very weak. Either side of the sheared zones the rock is strong.

Groundwater levels within the greywacke bedrock beneath the right bank are not known. It is anticipated that towards the inner river gorge where the rock is unconfined and joints may open that the groundwater levels will be close to the river level.

No large scale discontinuities, such as faults have been encountered by the drillholes beneath the right abutment

Overall the rock mass beneath the right bank is considered suitable for founding a dam. As with the left bank, further investigation and assessment of the rock mass properties, specifically strength and deformation characteristics, will be required for analysis and design of the dam foundations. Construction of a diversion structure in the right bank is expected to be feasible.

### **Rock Mass Permeability**

The permeability tests used a single packer which isolated basal sections of the drillhole. Test sections were determined as the drillholes were progressed based on inspection of the drillhole core. The defined units of permeability are expressed as Lugeons. Permeability tests within the greywacke bedrock generally indicated very low permeability, with Lugeon values less than 1. This is consistent with the tight rock masses observed within the inner river gorge during reconnaissance level geological mapping.

Two exceptions to very low permeability were recorded in LM2:

- One test zone between true drill length 6.2m and 7.9m recorded Lugeon values of the order of 30 Lu with a Lugeon pattern indicating wash-out behaviour. This is rationalised by the proximity of this test section to the unconfined face of the river gorge. This result is not considered representative of the rock mass.
- A second test zone between true drill length 25.1m and 28.7m recorded Lugeon values of between 2 to 3 Lu, before the test had to be terminated due to failure of the packer. There is uncertainty regarding this test. The results are inconsistent with all other findings from the site and were not included in the overall assessment of rock mass permeability.

It is anticipated that limited foundation treatment, such as grouting, would be required to control seepage under the dam.

## **4.0 Reservoir**

### **General**

As noted previously, no landslides have been identified within the reservoir basin from the examination of high level aerial stereographic pair photographs.

### **Saddles**

The two saddles on the north-west perimeter of the reservoir were inspected. The location of the saddles is shown on Drawing WS909/20/27, included in Appendix A.

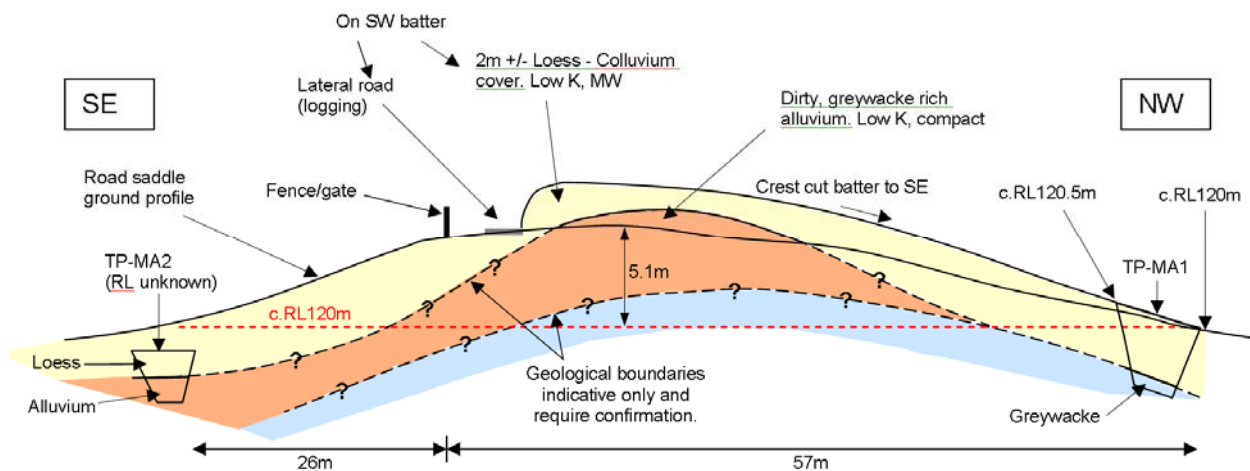
At the southern most saddle (road saddle) test pitting identified greywacke bedrock overlain by loess and alluvium. A geological field section through the road saddle is shown in Figure 4.1. Levels shown on the section were estimated based upon topographic mapping and require verification with survey control.

It is suggested these materials will have very low permeability and it anticipated that no treatment of the saddle will be necessary for a reservoir full supply level of RL 120.5m.

At the northernmost saddle surface inspection indicated that a very small saddle dam may be required. The need for and design of a small saddle dam, should it prove necessary, would be included as part of a detailed design.

Survey control is required to establish the extent of earthworks required for either saddle.





**Figure 4.1. Geological field section through the road saddle.**

## 5.0 Potential Borrow Areas

A potential greywacke aggregate source for both RCC and conventional concrete was identified 250 m upstream of the dam and within the central part of the valley floor. Specifically trial pit MA-5 encountered slightly weathered closely jointed greywacke at a depth of 2.6m.

Further investigation is necessary to prove this as a source of aggregate.

## 6.0 Conclusions

We conclude that:

- The dam is underlain by greywacke bedrock. The greywacke bedrock is moderately to highly jointed and sheared, however the rock mass is relatively competent as demonstrated by the near to sub vertical sides of the gorge which have withstood multiple seismic events over tens of thousands of years.
- The greywacke beneath the left bank, west of borehole LM2, has been hydrothermally altered millions of years ago and appears as a green altered greywacke.
- On the dam axis the greywacke within the inner river gorge and beneath the right bank is black, siliceous and strong to very strong, also with shear zones, which comprise pulverised rock with a high clay content which are very weak. Within the inner river gorge the shear zones appear steeply dipping and are aligned sub-parallel to the axis of the dam.
- No large scale discontinuities have been identified. No faults, or low angle discontinuities of recent origin or significance have been encountered by the within the drillholes. This aligns with the lack of surface displacement displayed at the damsite, inferring an absence of potentially active faults.
- Permeability tests within the drillholes indicate the greywacke to be of very low permeability. It is anticipated that limited foundation treatment, such as grouting, would be required to control seepage under the dam.

- There is approximately 6 m of alluvial and colluvial overburden on the terraces which would need to be stripped to prepare the dam foundation. Groundwater is perched within the overburden on top of the underlying greywacke.
- No landslides have been identified on either dam abutment or within the reservoir perimeter based upon the examination of high level aerial stereographic pair photographs and limited walkover.
- Subject to further investigations there is potential for a suitable aggregate source within the central valley upstream from the dam site.
- The site is considered suitable for siting a dam. The current level of investigation has located no fatal flaws. In particular there are no sub-horizontal discontinuities or through going faults of recent origin. Further investigation is required to quantify the rock mass quality beneath both banks. This will provide rationalisation of the “weaker” materials observed in sections of core within the drillholes against the freestanding rock faces observed in the inner river gorge and would be part of detailed design.
- The rock mass quality is anticipated to be suitable for the construction of a diversion tunnel beneath either the left or right bank. Rock mass quality is anticipated to improve away from the inner river gorge.
- The cost estimate presented in Lower Maungakotukutuku TM10 is not changed by the findings of the geotechnical investigations reported herein.

## **7.0 Further Investigations and Recommendations**

Further investigations would be required to enable the detailed analysis and design of the dam and reservoir. It is anticipated that investigations would include:

- Survey control - Locate drillholes and refine relief around dam, gorge and saddles.
- Drillholes – Cover gaps in dam foundation drilling and cover proposed diversion. Investigate quarry area for suitable aggregate source.
- Geological mapping - Detailed follow up on reconnaissance level geological mapping, e.g. try and map the zone of altered greywacke. Extend mapping beyond dam site abutments. Full walkover of reservoir basin.
- Geophysics - Seismic lines on both banks to refine the overburden to greywacke bedrock contact. Investigate zoning and rock mass quality of the bedrock.
- Test Pitting - Confirmation of borrow areas.
- Laboratory Testing.
- Rock mass quality assessment.

## Appendix A Drawings

WS909/20/21	Lower Maungakotukutuku RCC Dam – Scenario 1 - General Arrangement – Reservoir Inundation
WS909/20/22	Lower Maungakotukutuku RCC Dam – Scenario 1 – Plan and Typical Sections
WS909/20/23	Lower Maungakotukutuku RCC Dam – Scenario 2 - General Arrangement – Reservoir Inundation
WS909/20/24	Lower Maungakotukutuku RCC Dam – Scenario 2– Plan and Typical Sections
WS909/20/25 R4	Lower Manugakotukutuku Dam – Geotechnical Drilling Setting Out
WS909/20/27	Lower Manugakotukutuku Dam – Test Pit Locations

No large scale discontinuities, such as faults have been encountered by the drillholes beneath the left abutment.

Overall the rock mass beneath the left bank is considered suitable for founding a dam. Further investigation and assessment of the rock mass properties, specifically strength and deformation characteristics, will be required for analysis and design of the dam foundations. It is anticipated that if a left bank diversion was used the rock mass quality encountered will improve with increased distance from the inner river gorge.

### **Inner River Gorge**

The inner river gorge is characterised by very steep walls up to 10m high, with local lower gradients where joint bound wedges have fallen out. No “fresh” failures were apparent during reconnaissance level geological mapping.

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Within the base of the gorge localised gravel bars have accumulated between deeper pools where the stream has eroded into the greywacke bedrock. These gravel bars could be between 0.5m to 1.0m thick.

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Sheared zones examined in the drillhole core and in the sides of the river gorge are very weak. Either side of the sheared zones the rock is strong.

Groundwater levels within the greywacke bedrock beneath the right bank are not known. It is anticipated that towards the inner river gorge where the rock is unconfined and joints may open that the groundwater levels will be close to the river level.

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It is anticipated that limited foundation treatment, such as grouting, would be required to control seepage under the dam.

## **4.0 Reservoir**

### **General**

As noted previously, no landslides have been identified within the reservoir basin from the examination of high level aerial stereographic pair photographs.

### **Saddles**

The two saddles on the north-west perimeter of the reservoir were inspected. The location of the saddles is shown on Drawing WS909/20/27, included in Appendix A.

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At the northernmost saddle surface inspection indicated that a very small saddle dam may be required. The need for and design of a small saddle dam, should it prove necessary, would be included as part of a detailed design.

Survey control is required to establish the extent of earthworks required for either saddle.



- There is approximately 6 m of alluvial and colluvial overburden on the terraces which would need to be stripped to prepare the dam foundation. Groundwater is perched within the overburden on top of the underlying greywacke.
- No landslides have been identified on either dam abutment or within the reservoir perimeter based upon the examination of high level aerial stereographic pair photographs and limited walkover.
- Subject to further investigations there is potential for a suitable aggregate source within the central valley upstream from the dam site.
- The site is considered suitable for siting a dam. The current level of investigation has located no fatal flaws. In particular there are no sub-horizontal discontinuities or through going faults of recent origin. Further investigation is required to quantify the rock mass quality beneath both banks. This will provide rationalisation of the “weaker” materials observed in sections of core within the drillholes against the freestanding rock faces observed in the inner river gorge and would be part of detailed design.
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## 7.0 Further Investigations and Recommendations

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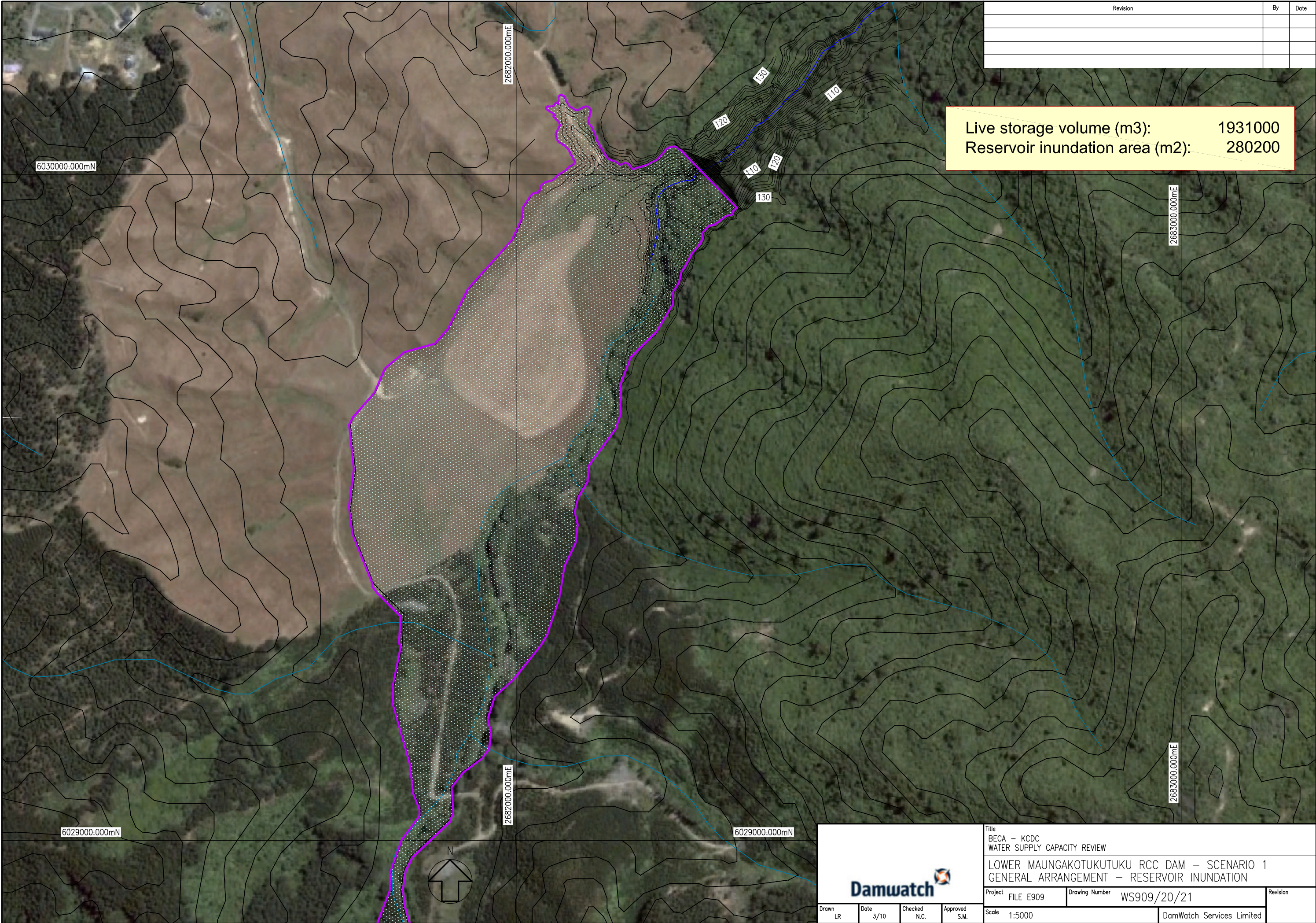
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## Appendix A Drawings

WS909/20/21	Lower Maungakotukutuku RCC Dam – Scenario 1 - General Arrangement – Reservoir Inundation
WS909/20/22	Lower Maungakotukutuku RCC Dam – Scenario 1 – Plan and Typical Sections
WS909/20/23	Lower Maungakotukutuku RCC Dam – Scenario 2 - General Arrangement – Reservoir Inundation
WS909/20/24	Lower Maungakotukutuku RCC Dam – Scenario 2– Plan and Typical Sections
WS909/20/25 R4	Lower Manugakotukutuku Dam – Geotechnical Drilling Setting Out
WS909/20/27	Lower Manugakotukutuku Dam – Test Pit Locations






Revision	By	Date

Live storage volume (m3): 1931000  
Reservoir inundation area (m2): 280200

20 May 2010 4:17pm

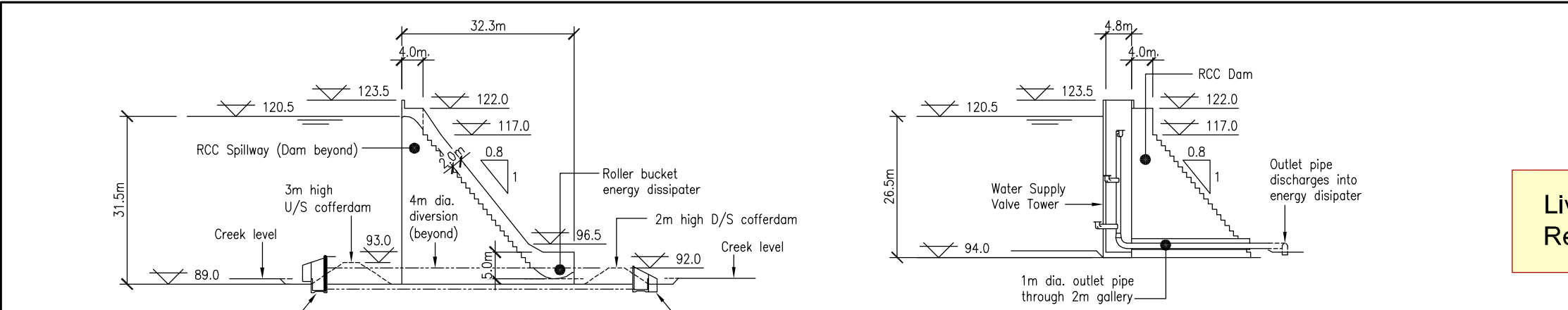
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Drawn	LR	Date	3/10	Checked	N.C.
				Approved	S.M.



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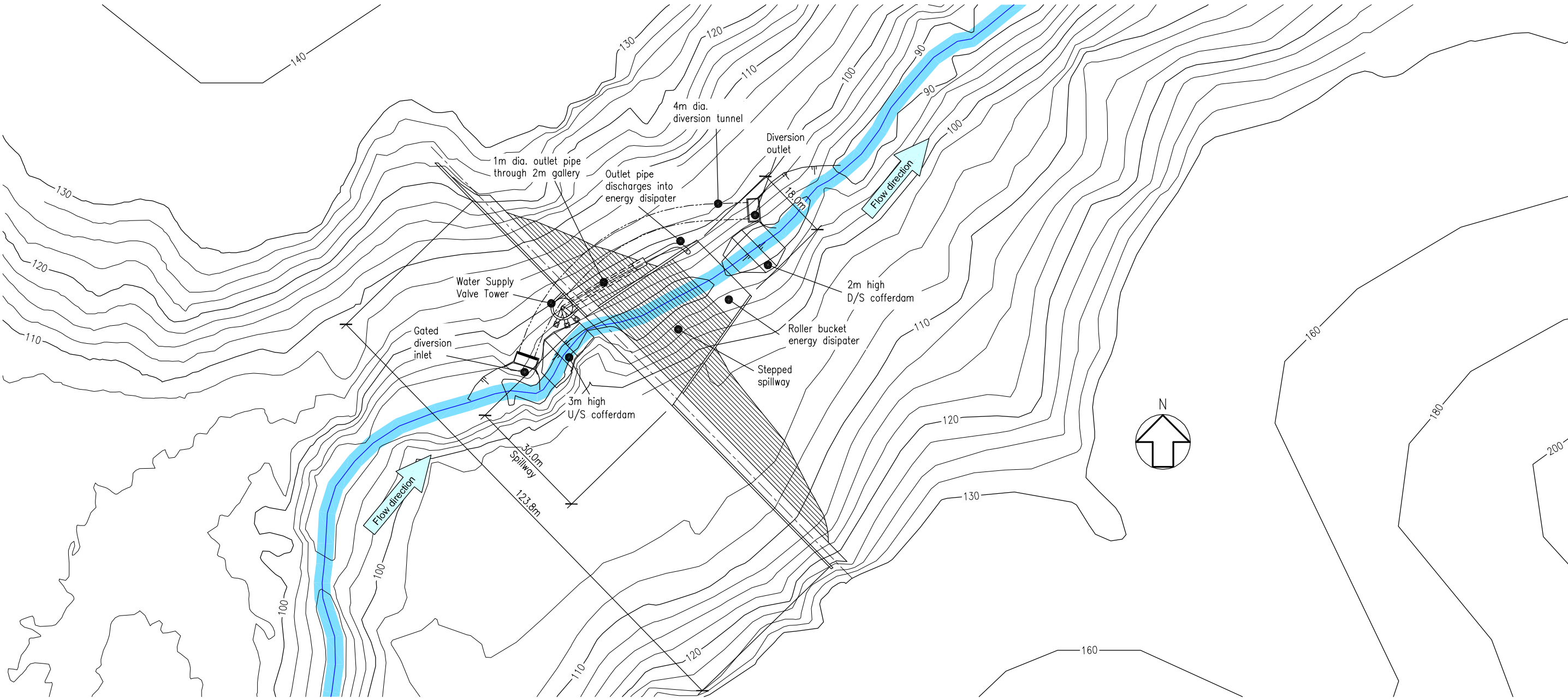
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SPILLWAY CROSS SECTION

WATER SUPPLY CROSS SECTION

Live storage volume (m3): 1931000  
Reservoir inundation area (m2): 280200

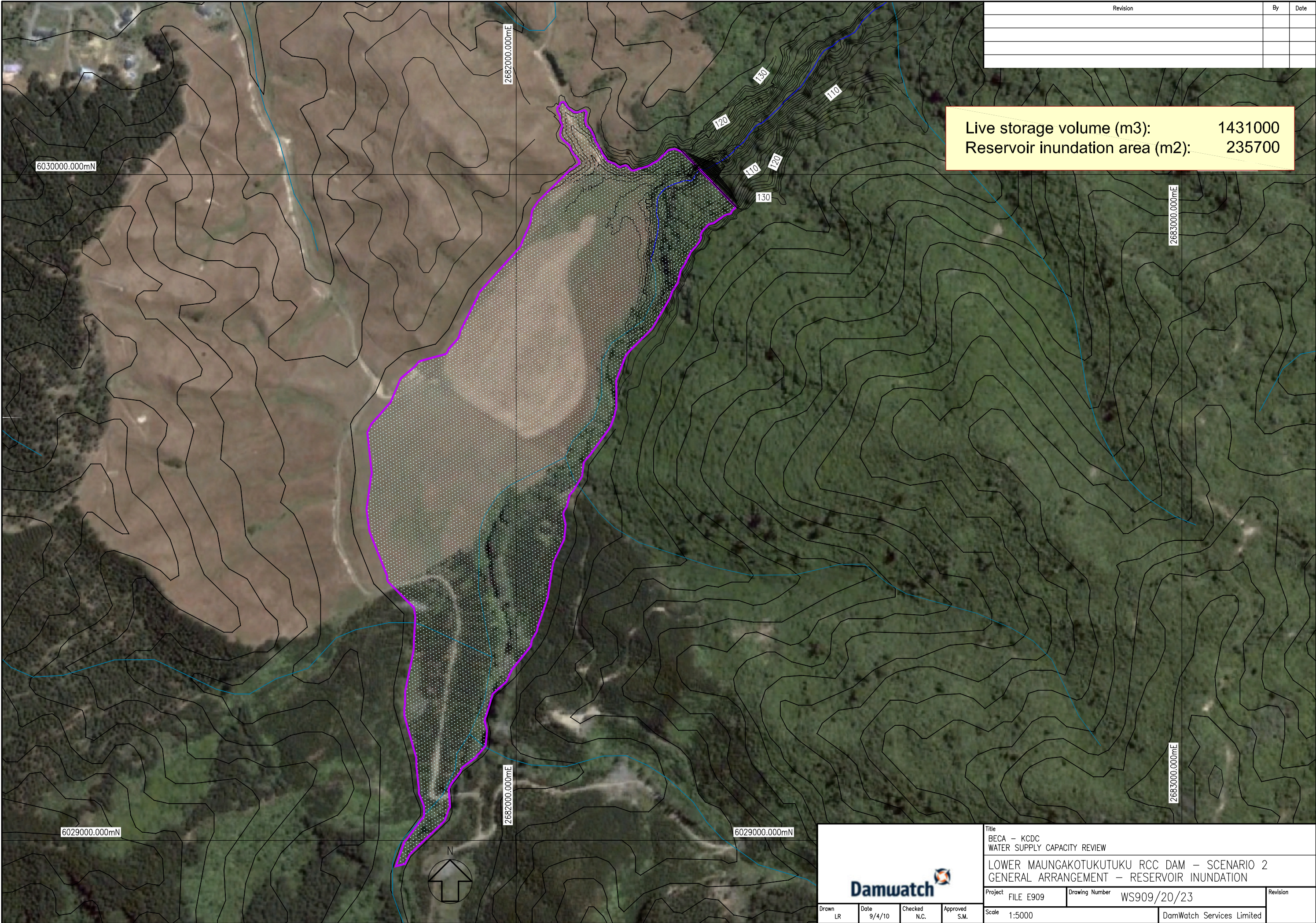


PLAN

Graphic Scales 1:1000 0 10 20 30 40 50 m


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Revision	By	Date

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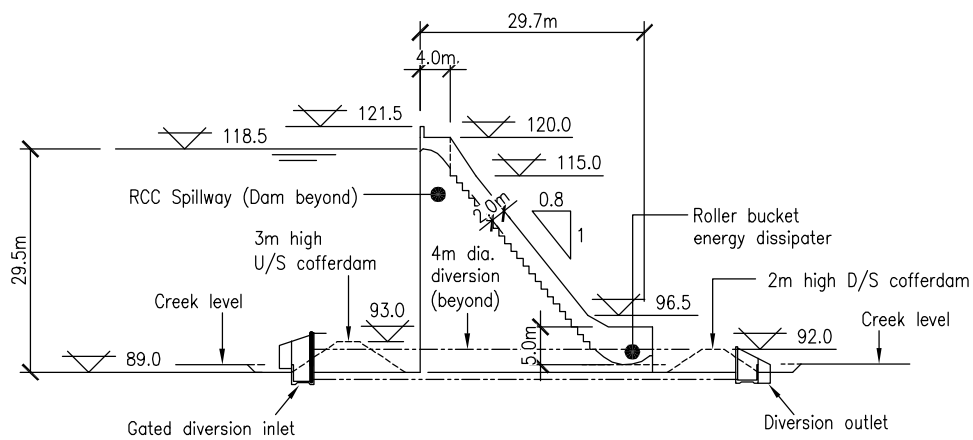
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Drawn LR	Date 9/4/10	Checked N.C.	Approved S.M.		



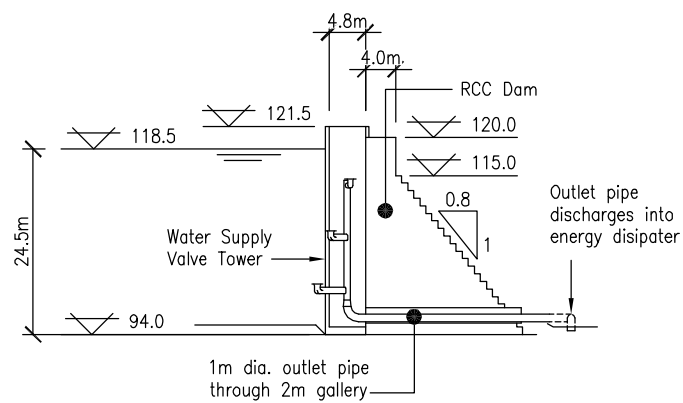
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20 May 2010 4:21pm

Graphic Scales 1:1000 0 10 20 30 40 50 m

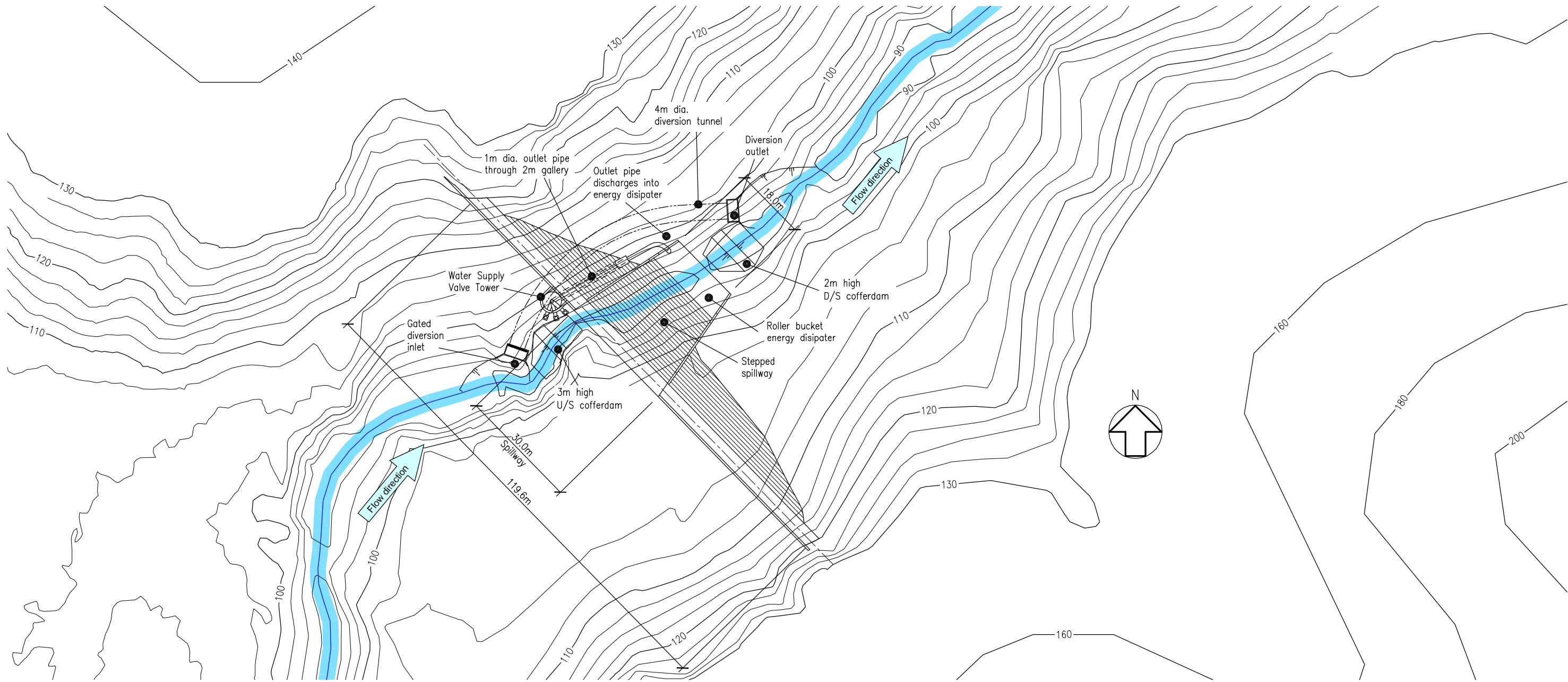


SPILLWAY CROSS SECTION



WATER SUPPLY CROSS SECTION

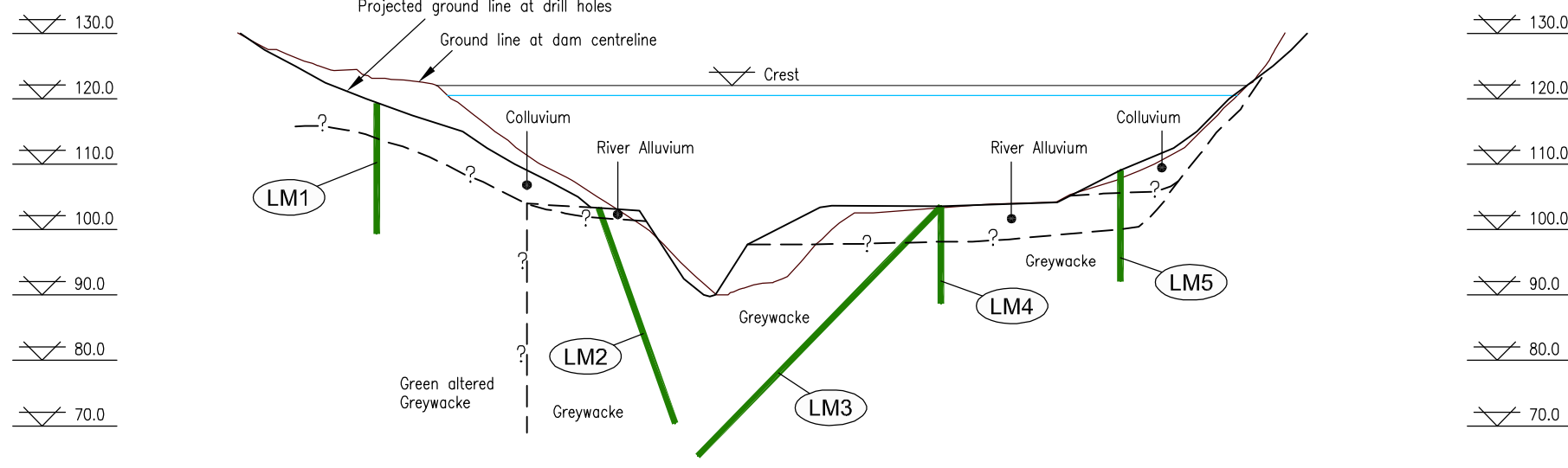
Live storage volume (m3): 1431000  
Reservoir inundation area (m2): 235700



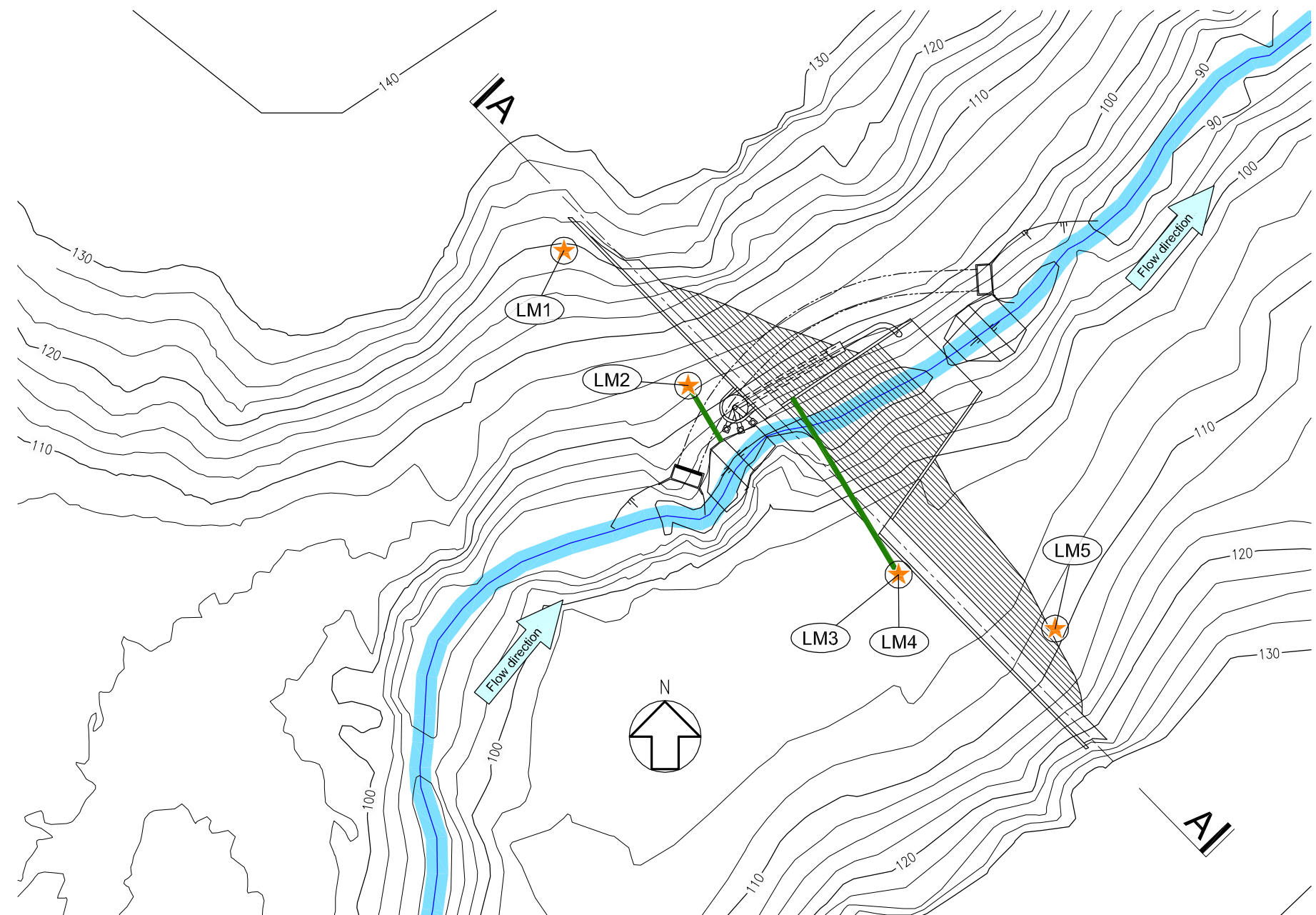
PLAN

	Title BECA – KCDC WATER SUPPLY CAPACITY REVIEW		
	LOWER MAUNGAKOTUKUTUKU RCC DAM – SCENARIO 2 GENERAL ARRANGEMENT – PLAN AND TYPICAL SECTIONS		
Project	FILE E909	Drawing Number	WS909/20/24
Scale	1:1000	DamWatch Services Limited	
Drawn LR	Date 9/4/10	Checked N.C.	Approved S.M.

200 mm  
100  
50  
10 mm  
0  
16 July 2010 4:23pm



CONCEPTUAL GEOLOGICAL SECTION A-A (LOOKING DOWNSTREAM)



PLAN

Revision	By	Date
R2 POSITION OF LM3 ALTERED	S.M.	10/5/10
R3 INCLINATION OF LM2 ALLOWED	N.C.	27/5/10
R4 ASBUILT FROM FIELD GPS PRIOR TO SURVEYING	A.K.	15/7/10

NOTES:

1. Top of drillhole Northings and Eastings based on hand held GPS with error range of the order of  $\pm 10$ m. Actual co-ordinates are subject to surveying.
2. Top of drillhole levels (and subsequently bottom of hole levels) are based on topographical contours. Actual levels are subject to survey.


Name:	LM1
Northing:	6030040.000m N
Easting:	2682237.000m E
Bearing:	Vertical
RL Top of hole:	119.327m
Dip:	90.0d
True Length:	20.00m
RL Btm of hole:	99.327m

Name:	LM2
Northing:	6030015.000m N
Easting:	2682260.000m E
Bearing:	149.0d
RL Top of hole:	103.331m
Dip:	70.0d
True Length:	35.09m
RL Btm of hole:	70.361m

Name:	LM3
Northing:	6029980.000m N
Easting:	2682299.000m E
Bearing:	329.0d
RL Top of hole:	103.602m
Dip:	45.0d
True Length:	54.03m
RL Btm of hole:	65.397m

Name:	LM4
Northing:	6029980.000m N
Easting:	2682299.000m E
Bearing:	Vertical
RL Top of hole:	103.602m
Dip:	90.0d
True Length:	14.93m
RL Btm of hole:	88.672m

Name:	LM5
Northing:	6029970.000m N
Easting:	2682328.000m E
Bearing:	Vertical
RL Top of hole:	109.115m
Dip:	90.0d
True Length:	17.02m
RL Btm of hole:	92.095m



Title

BECA – KCDC  
WATER SUPPLY CAPACITY REVIEW

LOWER MAUNGAKOTUKUTUKU DAM – GEOTECHNICAL DRILLING  
SETTING OUT – SHEET A2

Project FILE E909

Drawing Number WS909/20/25

Revision R4

Drawn LR

Date 4/10

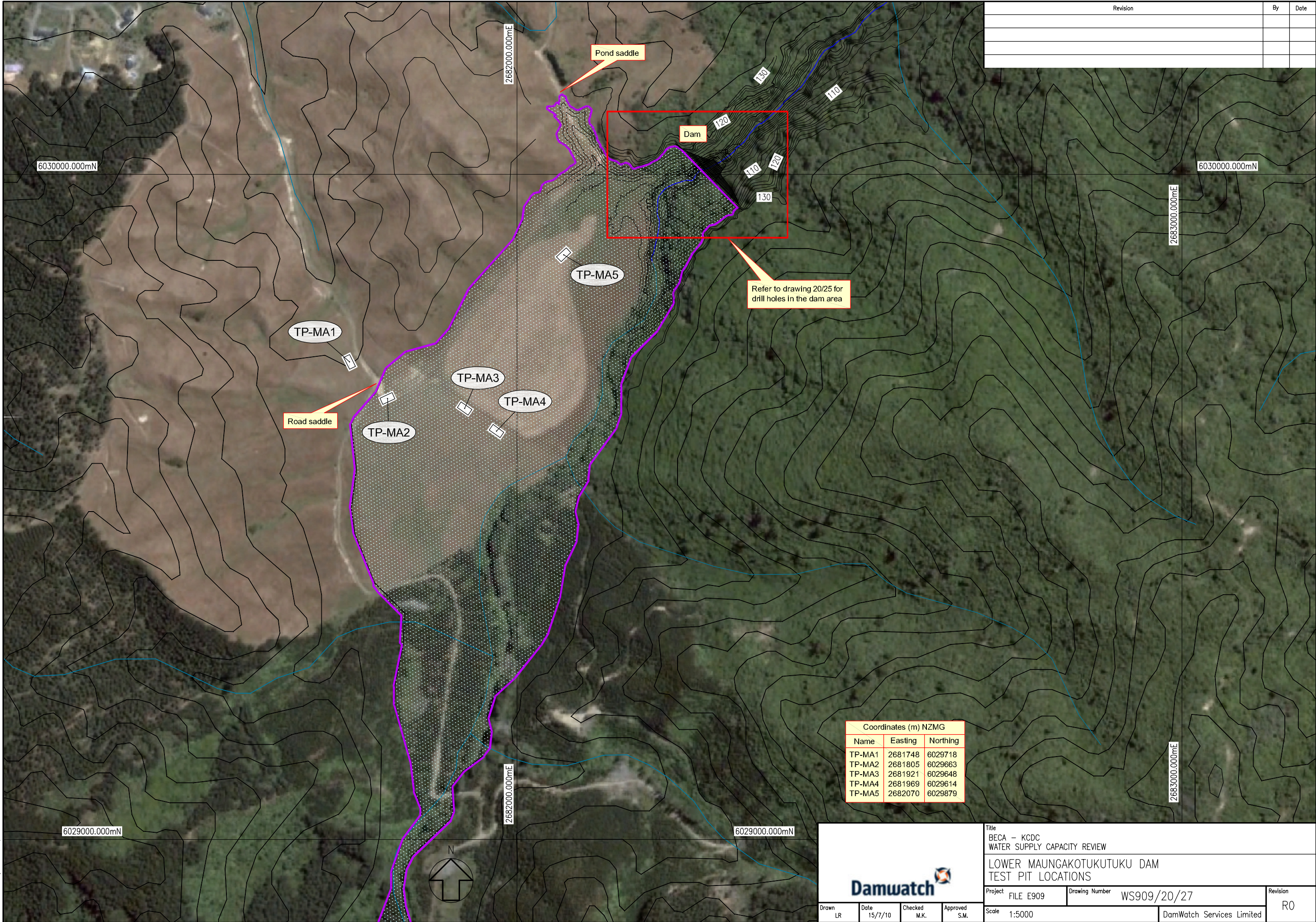
Checked N.C.

Approved S.M.

Scale 1:1000

DamWatch Services Limited





Revision	By	Date

Coordinates (m) NZMG		
Name	Easting	Northing
TP-MA1	2681748	6029718
TP-MA2	2681805	6029663
TP-MA3	2681921	6029648
TP-MA4	2681969	6029614
TP-MA5	2682070	6029879



Title BECA – KCDC WATER SUPPLY CAPACITY REVIEW		
LOWER MAUNGAKOTUKUTUKU DAM TEST PIT LOCATIONS		
Project FILE E909	Drawing Number WS909/20/27	Revision R0
Drawn LR	Date 15/7/10	Checked M.K.
Scale 1:5000		Approved S.M.
DamWatch Services Limited		