TEST CERTIFICATE

SGS Australia Pty Ltd
24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

ABN 44 000 964 278
ph +61 (0)2 9597 5599
fax +61 (0)2 9597 3442

EMERSON CRUMB TEST

CLIENT: K & H Geotechnical Services
19a May Street
PROJECT: Dargues Reef Gold Project

Laboratory Number: 59214

Sample Source: TP17 Upstream Southern Bank 0.3-1.1m

Sample Description: SANDY CLAY: orange-brown, medium plasticity, fine to coarse sand, trace of fine to medium gravel.

1. IMMERSION

Does not slake	→	Class 7 swells (Organic Soils)	
Slakes	yes	Class 8 does not swell (Laterised)	

2. COMPLETE DISPERSION

Class 1 complete	
Class 2 partial	
No Dispersion	yes

3. REMOULDING

Class 3 disperses	yes
Does not disperse	

4. CARBONATE & GYPSUM (Acid Indicator)

Class 4 present	
Absent	

5. VIGOROUS SHAKING

Class 5 disperses	
Class 6 no dispersion	

EMERSION CLASS NO.: 3

Water used: Distilled water at 20°C

Date Tested: 23.7.10

Tested By: HA

Sampled By: Client

Test Procedure: AS 1289 3.8.1

Job Number: 095-094

Approved Signatory: Chris Lloyd

Date: 26.7.10

ilac-MRA **NATA**

This document is issued in accordance with NATA's accreditation requirements

Accreditation No. 1459

File C:\Electronic Excel Reports\AS 1289 3.8.1 Emerson Crumb Test, Issue 2, May 2010, JL

TEST CERTIFICATE

SGS Australia Pty Ltd
24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

EMERSON CRUMB TEST

CLIENT: K & H Geotechnical Services
19a May Street
PROJECT: Dargues Reef Gold Project

Laboratory Number: 59213

Sample Source: TP16 / Creek Bed / 0.2-0.6m

Sample Description: SILTY SAND: orange-brown, fine to coarse sand, low plasticity, trace of clay.

1. IMMERSION

Does not slake	→	Class 7 swells (Organic Soils)	
Slakes	yes	Class 8 does not swell (Laterised)	

2. COMPLETE DISPERSION

Class 1 complete	
Class 2 partial	
No Dispersion	yes

3. REMOULDING

Class 3 disperses	
Does not disperse	yes

4. CARBONATE & GYPSUM (Acid Indicator)

Class 4 present	
Absent	yes

5. VIGOROUS SHAKING

Class 5 disperses	yes
Class 6 no dispersion	

EMERSION CLASS NO.: 5

Water used: Distilled water at 20°C — Date Tested: 23.7.10

Tested By: HA — Sampled By: Client

Test Procedure: AS 1289 3.8.1 — Job Number: 095-094

Approved Signatory: Chris Lloyd — Date: 26.7.10

ilac MRA **NATA**

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TEST CERTIFICATE

SGS Australia Pty Ltd
24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

EMERSON CRUMB TEST

CLIENT: K & H Geotechnical Services
19a May Street
PROJECT: Dargues Reef Gold Project

Laboratory Number: 59212

Sample Source: TP 15 Tributary Nth (0.5-2m)

Sample Description: SANDY CLAY: orange-brown, low plasticity, fine to coarse sand, trace of fine to medium gravel.

1. IMMERSION

Does not slake	→	Class 7 swells (Organic Soils)	
Slakes	yes	Class 8 does not swell (Laterised)	

2. COMPLETE DISPERSION

Class 1 complete	
Class 2 partial	
No Dispersion	yes

3. REMOULDING

Class 3 disperses	
Does not disperse	yes

4. CARBONATE & GYPSUM (Acid Indicator)

Class 4 present	
Absent	yes

5. VIGOROUS SHAKING

Class 5 disperses	yes
Class 6 no dispersion	

EMERSION CLASS NO.: 5

Water used: Distilled water at 20°C
Date Tested: 23.7.10

Tested By: HA
Sampled By: Client

Test Procedure: AS 1289 3.8.1
Job Number: 095-094

Approved Signatory: Chris Lloyd
Date: 26.7.10

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SGS Australia Pty Ltd
24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

EMERSON CRUMB TEST

CLIENT: **K & H Geotechnical Services**
19a May Street
PROJECT: **Dargues Reef Gold Project**

Laboratory Number: 59211

Sample Source: TP 14 - Upstream Northern Bank (0.3m - 1.0m)

Sample Description: SANDY CLAY: orange-brown, medium plasticity, fine to coarse sand, trace of fine to medium gravel.

1. IMMERSION

Does not slake	→	Class 7 swells (Organic Soils)	
Slakes	yes	Class 8 does not swell (Laterised)	

2. COMPLETE DISPERSION

Class 1 complete	
Class 2 partial	
No Dispersion	yes

3. REMOULDING

Class 3 disperses	
Does not disperse	yes

4. CARBONATE & GYPSUM (Acid Indicator)

Class 4 present	
Absent	yes

5. VIGOROUS SHAKING

Class 5 disperses	yes
Class 6 no dispersion	

EMERSION CLASS NO.: 5

Water used: Distilled water at 20°C — Date Tested: 23.7.10

Tested By: HA — Sampled By: Client

Test Procedure: AS 1289 3.8.1 — Job Number: 095-094

Approved Signatory: Chris Lloyd — Date: 26.7.10

ilac-MRA **NATA**

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24 Bermill Street (PO Box 2014)
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EMERSON CRUMB TEST

CLIENT: K & H Geotechnical Services
19a May Street
PROJECT: Dargues Reef Gold Project

Laboratory Number: 59210

Sample Source: TP12 Upstream Northern Bank 0.3-1.4m

Sample Description: SANDY CLAY: orange-brown, medium plasticity, fine to coarse sand, trace of fine to medium gravel.

1. IMMERSION

Does not slake	→	Class 7 swells (Organic Soils)	
Slakes	yes	Class 8 does not swell (Laterised)	

2. COMPLETE DISPERSION

Class 1 complete	
Class 2 partial	
No Dispersion	yes

3. REMOULDING

Class 3 disperses	
Does not disperse	yes

4. CARBONATE & GYPSUM (Acid Indicator)

Class 4 present	
Absent	yes

5. VIGOROUS SHAKING

Class 5 disperses	
Class 6 no dispersion	yes

EMERSION CLASS NO.: 6

Water used: Distilled water at 20°C | Date Tested: 23.7.10

Tested By: HA | Sampled By: Client

Test Procedure: AS 1289 3.8.1 | Job Number: 095-094

Approved Signatory: [signature] Chris Lloyd | Date: 26.7.10

ilac-MRA **NATA**

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Accreditation No. 1459

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SGS Australia Pty Ltd
24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

FALLING HEAD PERMEABILITY

CLIENT: **K & H Geotechnical Services**
19a May Street Parkes NSW 2870
PROJECT: **Dargues Reef Gold Project**

Job Number:	095-094
Laboratory Number:	59210
Sample Source:	TP12 / Upstream Northern Bank / 0.3-1.4m
Sample Description:	SANDY CLAY: orange-brown, medium plasticity, fine to coarse sand, trace of fine to medium gravel.

Remould Data: 98% of MDD at OMC

Initial Moisture Content:	17.0	(%)
After Test Moisture Content:	-	(%)
Initial Dry Density:	1.73	(t/m^3)
Compaction Ratio Before Test:	98.2	(%)
Coefficient of Permeability (k):	**3E-08**	(m/sec)

Being the average of 4 tests ranging from 5.5E-08 to 3.7E-09 (m/sec)

Tested in accordance with AS 1289 6.7.2 2000

Date Tested:	23.07.10
Sampled By:	Client
Comments:	-

Approved Signatory: Chris Lloyd **Date:** 30.7.10

ilac-MRA NATA

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Accreditation No. 1459

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TEST CERTIFICATE

SGS Australia Pty Ltd
24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

FALLING HEAD PERMEABILITY

CLIENT: **K & H Geotechnical Services**
19a May Street Parkes NSW 2870
PROJECT: **Dargues Reef Gold Project**

Job Number:	095-094
Laboratory Number:	59211
Sample Source:	TP14 - Upstream Northern Bank (0.3m - 1.0m)
Sample Description:	SANDY CLAY: orange-brown, medium plasticity, fine to coarse sand, trace of fine to medium gravel.

Remould Data: 98% of MDD at OMC

Initial Moisture Content:	19.5	(%)
After Test Moisture Content:	-	(%)
Initial Dry Density:	1.64	(t/m^3)
Compaction Ratio Before Test:	97.8	(%)
Coefficient of Permeability (k):	**2E-10**	(m/sec)

Being the average of 4 tests ranging from 3.7E-10 to 7.7E-11 (m/sec)

Tested in accordance with AS 1289 6.7.2 2000

Date Tested: 23.07.10

Sampled By: Client

Comments: -

Approved Signatory: Chris Lloyd **Date:** 30.7.10

ilac-MRA NATA

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Accreditation No. 1459

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SGS Australia Pty Ltd
24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

FALLING HEAD PERMEABILITY

CLIENT: **K & H Geotechnical Services**
19a May Street Parkes NSW 2870

PROJECT: **Dargues Reef Gold Project**

Job Number:	095-094
Laboratory Number:	59212
Sample Source:	TP 15 / Tributary Nth / (0.5-2m)
Sample Description:	SANDY CLAY: orange-brown, low plasticity, fine to coarse sand, trace of fine to medium gravel.

Remould Data: 98% of MDD at OMC

Initial Moisture Content:	14.2	(%)
After Test Moisture Content:	-	(%)
Initial Dry Density:	1.82	(t/m^3)
Compaction Ratio Before Test:	97.8	(%)
Coefficient of Permeability (k):	**5E-10**	(m/sec)

Being the average of 4 tests ranging from 8.3E-10 to 1.7E-10 (m/sec)

Tested in accordance with AS 1289 6.7.2 2000

Date Tested:	23.07.10
Sampled By:	Client
Comments:	-

Approved Signatory: Chris Lloyd **Date:** 30.7.10

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24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

FALLING HEAD PERMEABILITY

CLIENT: **K & H Geotechnical Services**
19a May Street Parkes NSW 2870
PROJECT: **Dargues Reef Gold Project**

Job Number:	095-094
Laboratory Number:	59213
Sample Source:	TP16 / Creek Bed / 0.2-0.6m
Sample Description:	SILTY SAND: orange-brown, fine to coarse sand, low plasticity, trace of clay.

Remould Data: 98% of MDD at OMC

Initial Moisture Content:	15.3	(%)
After Test Moisture Content:	-	(%)
Initial Dry Density:	1.79	(t/m^3)
Compaction Ratio Before Test:	98.4	(%)
Coefficient of Permeability (k):	**8E-07**	(m/sec)

Being the average of 4 tests ranging from 1.2E-06 to 3E-07 (m/sec)

Tested in accordance with AS 1289 6.7.2 2000

Date Tested: 20.7.10

Sampled By: Client

Comments: -

Approved Signatory: Chris Lloyd Date: 26.7.10

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TEST CERTIFICATE

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24 Bermill Street (PO Box 2014)
Rockdale DC NSW 2216
Australia

FALLING HEAD PERMEABILITY

CLIENT: **K & H Geotechnical Services**
19a May Street Parkes NSW 2870
PROJECT: **Dargues Reef Gold Project**

Job Number:	095-094
Laboratory Number:	59214
Sample Source:	TP17 Upstream Southern Bank 0.3-1.1m
Sample Description:	SANDY CLAY: orange-brown, medium plasticity, fine to coarse sand, trace of fine to medium gravel.

Remould Data: 98 of MDD at OMC

Initial Moisture Content:	19.3	(%)
After Test Moisture Content:	-	(%)
Initial Dry Density:	1.68	(t/m^3)
Compaction Ratio Before Test:	97.7	(%)
Coefficient of Permeability (k):	**3E-10**	(m/sec)

Being the average of 4 tests ranging from 7.9E-10 to 9.1E-11 (m/sec)

Tested in accordance with AS 1289 6.7.2 2000

Date Tested: 20.07.10

Sampled By: Client

Comments: -

Approved Signatory: Chris Lloyd **Date:** 30.7.10

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FALLING HEAD PERMEABILITY

CLIENT: **K & H Geotechnical Services**
19a May Street Parkes NSW 2870
PROJECT: **Dargues Reef Gold Project**

Job Number:	095-094
Laboratory Number:	59215
Sample Source:	TP18 Upstream Northern Bank 0.5-1.1m
Sample Description:	SANDY CLAY: orange-brown, medium plasticity, fine to coarse sand, trace of fine to medium gravel.

Remould Data: 98% of MDD at OMC

Initial Moisture Content:	14.9	(%)
After Test Moisture Content:	-	(%)
Initial Dry Density:	1.74	(t/m^3)
Compaction Ratio Before Test:	98.0	(%)
Coefficient of Permeability (k):	**6E-10**	(m/sec)

Being the average of 4 tests ranging from 2E-09 to 1.1E-10 (m/sec)

Tested in accordance with AS 1289 6.7.2 2000

Date Tested:	22.07.10
Sampled By:	Client
Comments:	-

Approved Signatory: [signature] Chris Lloyd **Date:** 30.7.10

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FALLING HEAD PERMEABILITY

CLIENT: **19a May Street Parkes NSW 2870**
Dargues Reef Gold Project
PROJECT: **095-094**

Job Number:	K & H Geotechnical Services
Laboratory Number:	59216
Sample Source:	TP20 - Upstream Southern Bank (0.5m - 1.1m)
Sample Description:	SANDY CLAY: light-brown, low medium plasticity, fine to coarse sand, trace of fine to medium gravel.

Remould Data: 98% of MDD at OMC

Initial Moisture Content:	18.2	(%)
After Test Moisture Content:	-	(%)
Initial Dry Density:	1.70	(t/m^3)
Compaction Ratio Before Test:	98.3	(%)
Coefficient of Permeability (k):	**2E-08**	(m/sec)

Being the average of 4 tests ranging from 2.8E-08 to 8.1E-09 (m/sec)

Tested in accordance with AS 1289 6.7.2 2000

Date Tested: 23.07.10

Sampled By: Client

Comments: -

Approved Signatory: Chris Lloyd **Date:** 30.7.10

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APPENDIX I

Tailings Testing Laboratory Test Reports

Knight Piésold CONSULTING

ABN: 44 000 964 278
ph: 1300 781 744
fx: (08) 9458 3700

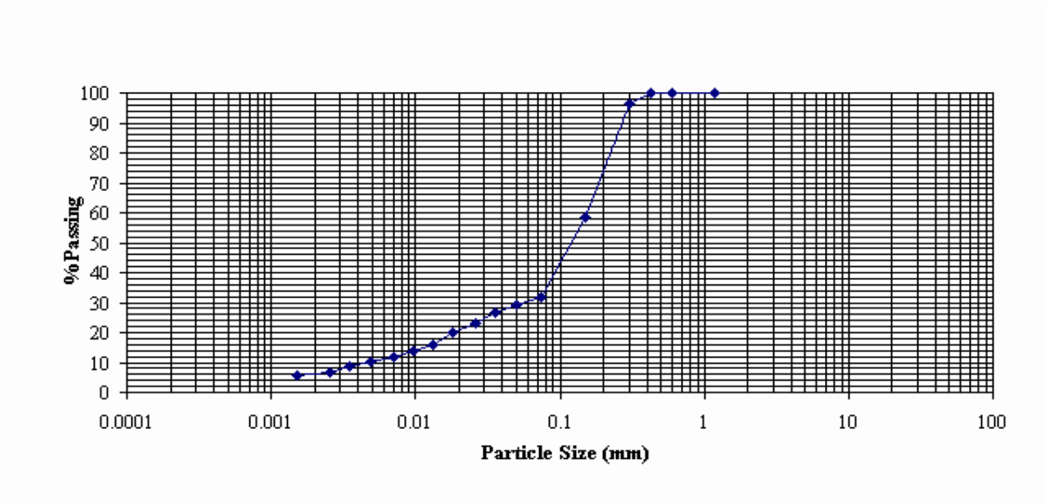
TEST CERTIFICATE

SGS Australia Pty Ltd
PO Box 219 Bentley WA 6982
36 Railway Parade
Welshpool WA 6106

Client:	Knight Piesold Pty Ltd	Client Job No:	PE801-00139
Order No:	P07727	Project:	Dargues Reef Gold Project
Tested Date:	30/08/2010	Location:	
SGS Job Number:	10-01-2165	Sample No:	10-MT-11133
Lab:	Welshpool	Sample ID:	Combined Tailings

PARTICLE SIZE DISTRIBUTION - SIEVING AND HYDROMETER ANALYSIS

AS1289.3.6.1 & AS1289.3.6.3



SIEVING	(AS1289.3.6.1)	HYDROMETER	(AS1289.3.6.3)
Sieve Size	Passing	Particle Diameter	Finer
(mm)	%	(mm)	%
53.0		0.0495	29
37.5		0.0356	27
19.0		0.0258	23
9.5		0.0183	20
4.75		0.0133	16
2.36	100	0.0097	14
1.18	100	0.0070	12
0.600	100	0.0049	10
0.425	100	0.0035	9
0.300	97	0.0025	7
0.150	59	0.0015	6
0.075	32		

Method of Dispersion : Mechanical ; Hydrometer Used : Glass, -5 to 60g/l soil Colloids

Loss after Pretreatment: No Pretreatment

Note: Sample supplied by client.

Approved Signatory: (Mark .Matthews) Date: 3/09/2010

This document is issued in accordance with NATA's accreditation requirements

Accreditation No.: 2418 Form No.PF-(AU)-[IND(MTE)]-TE-S303.LCER/B/19.08.09

Client Address: PO Box 1302 West Perth WA 6872

Site No.: 2411
Cert No.: 10-MT-11133-S303
Page: 1

SGS

ABN: 44 000 964 278
ph: 1300 781 744
fx: (08) 9458 3700

TEST CERTIFICATE

SGS Australia Pty Ltd
PO Box 219 Bentley WA 6982
36 Railway Parade
Welshpool WA 6106

Client:	Knight Piesold Pty Ltd	Client Job No:	PE801-00139
Order No:	P07727	Project:	Dargues Reef Gold Project
Tested Date:	31/08/2010	Location:	
SGS Job Number:	10-01-2165	Sample No:	10-MT-11133
Lab:	Welshpool	Sample ID:	Combined Tailings

PLASTICITY INDEX

AS 1289.3.9.2(Single Point Cone Method), 3.2.1(Plastic Limit), 3.3.2(Plasticity Index), 3.4.1(Linear Shrinkage)

AS 1289.3.9.2	
Liquid Limit (%)	**27**
AS 1289.3.2.1	
Plastic Limit (%)	**NP**
AS 1289.3.3.2	
Plasticity Index (%)	**NP**
AS 1289.3.4.1	
Linear Shrinkage (%)	**0.5**
History of Sample	Oven Dried at <50ºC
Method of preparation	Dry Sieved
Nature of Shrinkage	Flat
Length of mould (mm)	125

Note: Sample supplied by client.

Approved Signatory: (Mark .Matthews) Date: 3/09/2010

This document is issued in accordance with NATA's accreditation requirements

Accreditation No.: 2418 Form No.PF-(AU)-[IND(MTE)]-TE-S324.LCER/D/02.09.09
Client Address: PO Box 1302 West Perth WA 6872

Site No.: 2411
Cert No.: 10-MT-11133-S324
Page: 1

SGS

ABN: 44 000 964 278
ph: 1300 781 744
fx: (08) 9458 3700

TEST CERTIFICATE

SGS Australia Pty Ltd
PO Box 219 Bentley WA 6982
36 Railway Parade
Welshpool WA 6106

Client:	Knight Piesold Pty Ltd	Client Job No:	PE801-00139
Order No:	P07727	Project:	Dargues Reef Gold Project
Tested Date:	31/08/2010	Location:	
SGS Job Number:	10-01-2165	Sample No:	10-MT-11133
Lab:	Welshpool	Sample ID:	Combined Tailings

FINE PARTICLE DENSITY

AS1289.3.5.1

FINE FRACTION

SOIL APPARENT	
PARTICLE DENSITY (g/cc)	**2.71**
at temperature	25 º C

Note: Sample supplied by client.
(Fine Fraction)
Deviation from Standard Method: Sample boiled in sand bath to remove trapped air, not vacuum extracted

Approved Signatory: (Mark .Matthews) Date: 1/09/2010

This document is issued in accordance with NATA's accreditation requirements

Accreditation No.: 2418 Form No.PF-(AU)-[IND(MTE)]-TE-S415.LCER/A/01.01.2009

Client Address: PO Box 1302 West Perth WA 6872

Site No.: 2411
Cert No.: 10-MT-11133-S415
Page: 1

ANALYTICAL REPORT

T. ROWLES
KNIGHT PIÉSOLD PTY LIMITED
PO Box 1302
WEST PERTH, W.A. 6872
AUSTRALIA

JOB INFORMATION

JOB CODE	:	752.0/1011127
No. of SAMPLES	:	1
No. of ELEMENTS	:	33
CLIENT O/N	:	P07728 : 2/2 (Job 2 of 2)
SAMPLE SUBMISSION No.	:	PE801-0139
PROJECT	:	Dargues Reef
STATE	:	Solutions
DATE RECEIVED	:	20/08/2010
DATE COMPLETED	:	13/09/2010
DATE PRINTED	:	13/09/2010
PRIMARY LABORATORY	:	Genalysis Main Laboratory

LEGEND

X	= Less than Detection Limit
N/R	= Sample Not Received
*	= Result Checked
( )	= Result still to come
I/S	= Insufficient Sample for Analysis
E6	= Result X 1,000,000
UA	= Unable to Assay
>	= Value beyond Limit of Method

MAIN OFFICE AND LABORATORY
15 Davison Street, Maddington 6109, Western Australia
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Tel: +61 8 9251 8100 Fax: +61 8 9251 8110
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KALGOORLIE SAMPLE PREPARATION DIVISION
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Tel: +61 8 8162 9714 Fax: +61 8 8349 7444

JOHANNESBURG LABORATORY
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Jet Park, Gauteng, South Africa 1459
Tel: +27 11 552 8149 Fax: +27 11 552 8248

TOWNSVILLE LABORATORY
9-23 Kelli Street, Mt St John, Bohle, Queensland, Australia 4818
Tel: [illegible] Fax: [illegible]

GENALYSIS LABORATORY SERVICES PTY LTD
ABN 32 008 787 237

SAMPLE DETAILS

DISCLAIMER

Genalysis Laboratory Services Pty Ltd wishes to make the following disclaimer pertaining to the accompanying analytical results.

Genalysis Laboratory Services Pty Ltd disclaims any liability, legal or otherwise, for any inferences implied from this report relating to either the origin of, or the sampling technique employed in the collection of, the submitted samples.

SIGNIFICANT FIGURES

It is common practice to report data derived from analytical instrumentation to a maximum of two or three significant figures. Some data reported herein may show more figures than this. The reporting of more than two or three figures in no way implies that the third, fourth and subsequent figures may be real or significant.

Genalysis Laboratory Services Pty Ltd accepts no responsibility whatsoever for any interpretation by any party of any data where more than two or three significant figures have been reported.

SAMPLE STORAGE DETAILS

GENERAL CONDITIONS

SAMPLE STORAGE OF SOLIDS

Bulk Residues and Pulps will be stored for 60 DAYS without charge. After this time all Bulk Residues and Pulps will be stored at a rate of $3.00 per cubic metre per day until your written advice regarding collection or disposal is received. Expenses related to the return or disposal of samples will be charged to you at cost. Current disposal cost is charged at $75.00 per cubic metre.

SAMPLE STORAGE OF SOLUTIONS

Samples received as liquids, waters or solutions will be held for 60 DAYS free of charge then disposed of, unless written advice for return or collection is received.

752.0/1011127 (13/09/2010) CLIENT O/N: P07728 : 2/2

Page 3 of 9
Part 1/6

ANALYSIS

ELEMENTS	Ag	Al	As	B	Ba	Ca
UNITS	ug/l	mg/l	ug/l	mg/l	ug/l	mg/l
DETECTION LIMIT	0.01	0.01	0.1	0.01	0.05	0.01
DIGEST						
ANALYTICAL FINISH	/MS	/OES	/MS	/OES	/MS	/OES
SAMPLE NUMBERS						
0001 Combined Tailings (Solution)	0.01	0.16	1.4	0.12	97.70	55.34
CHECKS						
0001 Combined Tailings (Solution)	X	0.16	1.2	0.12	98.87	56.42
STANDARDS						
0001 Alcoa9-OES		2.00		0.45		46.28
0002 Alcoa-High3-MS						
0003 Alcoa-High3-MS	21.10		104.1		21.24	
0004 SOLN-001						
BLANKS						
0001 Control Blank	X	X	X	X	X	0.01

GENALYSIS LABORATORY SERVICES PTY LTD
ABN 32 008 787 237

, 752.0/1011127 (13/09/2010) CLIENT O/N: P07728 : 2/2

ANALYSIS

ELEMENTS	Cd	Cl	Co	Cr	Cu	EC
UNITS	ug/l	mg/l	ug/l	mg/l	mg/l	mS/cm
DETECTION LIMIT	0.02	5	0.1	0.01	0.01	0.01
DIGEST						
ANALYTICAL FINISH	/MS	/VOL	/MS	/OES	/OES	/METER
SAMPLE NUMBERS						
0001 Combined Tailings (Solution)	0.10	155	0.2	X	0.01	1.00
CHECKS						
0001 Combined Tailings (Solution)	0.13	160	0.2	X	0.01	1.00
STANDARDS						
0001 Alcoa9-OES				0.48	0.06	
0002 Alcoa-High3-MS						
0003 Alcoa-High3-MS	19.91		913.7			
0004 SOLN-001						
BLANKS						
0001 Control Blank	X		X	X	X	

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ANALYSIS

ELEMENTS	F	Fe-Sol	Hg	K	Mg	Mn
UNITS	mg/l	mg/l	ug/l	mg/l	mg/l	mg/l
DETECTION LIMIT	0.1	0.01	0.1	0.1	0.01	0.01
DIGEST						
ANALYTICAL FINISH	/SIE	/OES	/MS	/OES	/OES	/OES
SAMPLE NUMBERS						
0001 Combined Tailings (Solution)	1.0	0.22	X	18.9	14.00	0.16
CHECKS						
0001 Combined Tailings (Solution)	1.0	0.22	X	18.7	14.23	0.16
STANDARDS						
0001 Alcoa9-OES		3.76		3.8	58.55	0.50
0002 Alcoa-High3-MS						
0003 Alcoa-High3-MS			20.4			
0004 SOLN-001	1.0					
BLANKS						
0001 Control Blank		X	X	X	X	X

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ANALYSIS

ELEMENTS	Mo	Na	Ni	P	Pb	pH
UNITS	ug/l	mg/l	mg/l	mg/l	ug/l	NONE
DETECTION LIMIT	0.05	0.1	0.01	0.1	0.5	0.1
DIGEST						
ANALYTICAL FINISH	/MS	/OES	/OES	/OES	/MS	/METER
SAMPLE NUMBERS						
0001 Combined Tailings (Solution)	9.86	137.2	X	X	X	7.8
CHECKS						
0001 Combined Tailings (Solution)	10.16	137.4	X	X	X	7.8
STANDARDS						
0001 Alcoa9-OES		250.2	0.48	1.0		
0002 Alcoa-High3-MS						
0003 Alcoa-High3-MS	19.42				19.8	
0004 SOLN-001						
BLANKS						
0001 Control Blank	X	X	X	X	X	

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Part 5/6

ANALYSIS

ELEMENTS	S	SO4	Sb	Se	Sn	TDSEva
UNITS	mg/l	mg/l	ug/l	ug/l	ug/l	mg/Kg
DETECTION LIMIT	0.1	0.3	0.01	0.2	0.1	20
DIGEST						
ANALYTICAL FINISH	/OES	/CALC	/MS	/EMS	/MS	/GRAV
SAMPLE NUMBERS						
0001 Combined Tailings (Solution)	38.4	115.2	34.29	1.7	3.6	620
CHECKS						
0001 Combined Tailings (Solution)	38.4	115.0	34.63	1.5	3.6	640
STANDARDS						
0001 Alcoa9-OES	19.9	59.7				
0002 Alcoa-High3-MS				105.7		
0003 Alcoa-High3-MS			20.77		20.5	
0004 SOLN-001						
BLANKS						
0001 Control Blank	X	X	X	X	X	

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ANALYSIS

ELEMENTS	U	V	Zn
UNITS	ug/l	mg/l	mg/l
DETECTION LIMIT	0.005	0.01	0.01
DIGEST			
ANALYTICAL FINISH	/MS	/OES	/OES
SAMPLE NUMBERS			
0001 Combined Tailings (Solution)	28.238	X	0.01
CHECKS			
0001 Combined Tailings (Solution)	28.221	X	0.02
STANDARDS			
0001 Alcoa9-OES		0.48	0.49
0002 Alcoa-High3-MS			
0003 Alcoa-High3-MS	19.631		
0004 SOLN-001			
BLANKS			
0001 Control Blank	X	X	X

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METHOD CODE DESCRIPTION

/MS Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed by Inductively Coupled Plasma Mass Spectrometry.

/EMS Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed by Enhanced Inductively Coupled Plasma Mass Spectrometry.

/OES Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed by Inductively Coupled Plasma Optical (Atomic) Emission Spectrometry.

/SIE Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed by Specific Ion Electrode.

/VOL Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed by Volumetric Technique.

/CALC Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Results Determined by calculation from other reported data.

/GRAV Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed by Gravimetric Technique

/METER Genalysis Main Laboratory

No digestion or other pre-treatment undertaken. Analysed with Electronic Meter Measurement

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APPENDIX J

Dargues Reef Gold Project, Tailings Storage Facility, Dam Breach Assessment

Knight Piésold CONSULTING

CORTONA RESOURCES

DARGUES REEF GOLD PROJECT

TAILINGS STORAGE FACILITY, DAM BREACH ASSESSMENT

Ref. PE801-00139/08
November 2011

Rev. No.	Date	Description	KP Approved	Client Approved
A	24 November 2011	Issued for Client Review		

Knight Piésold Pty Limited
A.B.N. 67 001 040 419
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AUSTRALIA

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KP_svr\...\PE801-139_8 Dargues Reef Gold Project Dam Breach Assessment Rev A

1. INTRODUCTION

1.1 GENERAL

Cortona Resources Limited is developing the Dargues Reef Gold Project, situated in the Lachlan Fold Belt of the Southern Tablelands region of New South Wales (NSW). As part of the final design of the tailings storage facility (TSF), a risk review was performed to determine the consequence categories of dam failure as set out in the NSW Dams Safety Committee (DSC) guidelines *"DSC3A – Consequence Categories for Dams"* (DSC3A) (Ref. 1) and *"DSC3F – Tailings Dams"* (DSC3F) (Ref. 2). Knight Piesold (KP) assessed the release of tailings and water consistent with various potential failures of the proposed Dargues Reef TSF to confirm the initially determined consequence category discussed in *"Dargues Reef Gold Project – Bankable Feasibility Study, Tailings Management"* (Ref. 3).

The Dargues Reef Project is a gold prospect located approximately 14 km south of the town of Braidwood and approximately 60 kilometres (km) south-east of Canberra. The operation will mine 330,000 tonnes per annum using conventional long hole open stope mining methods via a decline. A paste fill process will be used in the stoped out areas and waste rock will also be used as stope backfill allowing maximum ore body extraction and limiting haulage of waste to surface.

1.2 NEW SOUTH WALES GUIDELINES

The main aim of the NSW Dams Safety Committee guideline DSC3A, reproduced in Appendix A, is to provide guidance for determining the consequence categories of a dam failure so that the Government of NSW can "appropriately and consistently" determine the level of safety management required for the structure and if the dam needs to be prescribed as falling under the DSC's regulatory oversight under the NSW Dams Safety Act, 1978.

There are two types of consequence category discussed in Section 5 of DSC3A which indicate the conditions that exist in the vicinity of the dam immediately prior to onset of a dam failure:

- Sunny Day Consequence Category (SDCC), which refers to failures that occur without any attendant natural flooding;
- Flood Consequence Category (FCC), which refers to failures that occur in association with a natural flood.

As set forth by DSC3A, both the SDCC and FCC are to be assessed for a given dam. The higher of these two consequence categories is then used by the DSC to determine if the dam needs to be prescribed.

Section 5.2 of DSC3A details how Population at Risk (PAR) and Probable Loss of Life (PLL) are used in two-tier rating system for assigning Consequence Categories. KP notes that this system was adapted from the ANCOLD *"Guidelines on Risk Assessment"* (Ref. 4). This system was employed in *"Dargues Reef Gold Project – Bankable Feasibility Study, Tailings Management"* to make an initial determination of the Consequence Category for the proposed Dargues Reef TSF Dam as follows.

A tabulation of the assessed severity of damage and loss, based on Table 2 of DSC3A is given in Table 1.1. PAR was assessed to be in the range of 1 to 10 and PLL was assessed as 0. On this basis, a Consequence Category of *Low* is indicated for the design of the TSF.

Table 1.1: Consequence categories for dams

	Type	KP Comments	Severity of damage and loss
Social	Loss of cultural amenity	Dam failure could result in significant physical damage to items of local heritage	Minor
Natural Environment	Area of impact	0.1 km^2 to 1 km^2	Minor
	Duration of impact	1 month to 3 years	Minor
	Impacts on conservation value	Physical damage will be limited to areas that are extensively cleared of vegetation	Negligible
	Impacts on plants and animal habitat	Physical damage will be limited to areas that are extensively cleared of vegetation	Negligible
	Riverine landscape processes	Localised impacts in river connectivity expected	Minor
DSC3A Table 2: Consequence Categories Based on Population at Risk (PAR)			
Population at Risk **(PAR)**	The box cut entrance to underground workings is located roughly 400 m downstream (south-west) of the TSF embankment toe on the opposite side of Majors Creek. The process plant site and nearest office are located about 580 m downstream of the proposed TSF embankment toe. The paste hole, vent riser and escape-way are located 140 m, 200 m, and 225 m downstream (south) of the TSF embankment toe, respectively. A safety bund is recommended for construction about each of the last three items to mitigate their risk of inundation. The population at risk (PAR) is assessed to be 1 to 10.		Low
DSC3A Table 1: Consequence Categories Based on Probable Loss of Life (PLL)			
Probable Loss of Life **(PLL)**	There will be regular routine inspections of the facility by operating personnel. It is unlikely that dam failure would occur without warning. Mine staff will be trained, including attendance at DSC Dam Safety Management Courses. Warning systems will be in place. The probable loss of life (PLL) is assessed to be 0.		Low

Additional guidance for the assignment of consequence categories, specific to tailings dams, is given in DSC3F. The augmented risk matrix provided in DSC3F recognises the difficulties of quantitatively determining the environmental consequences of dam failure. The matrix is reproduced in Table 1.2. A consequence category of *Significant* is indicated for the design of the TSF. Of the two assessed values, the consequence category of *Significant* is the more conservative of the two and was selected to form the design basis for the Dargues Reef TSF.

Table 1.2: Consequence categories assessment

Population at Risk - PAR	Receiving Environment	Severity of Damage or Loss			
		Negligible (Benign Liquid)	Minor (Benign Solid)	Medium (Saline Liquid / Unsightly Solid)	Major (Acid / Toxic Tailings)
< 1	Remote / Degraded	Very Low	Very Low	Low	Significant
1 – 10	Rural / Productive	Low	Low	Significant	High C
10 – 100	Urban / Sensitive		Significant	High C	High B
100 – 1000				High A	High A
> 1000					Extreme

Section 5.3 of DSC3A provides specific guidance regarding the background conditions to be used for assessment of the SDCC. These should represent "worst case" conditions at a time when background stream flows are normal. For evaluation of the SDCC, the initial volume of water in the decant pond was assumed to be at the invert of the emergency spillway, at reduced level (RL) 711.0 m, at the end of the operational life of the TSF. KP notes that this is a significantly more conservative assumption than the results of operational water balance modelling (during the last year of operations) indicate:

- Under "Average" conditions the maximum decant pond RL is 709.0 m;
- Under "1 in 100 Annual Exceedance Probability Wet" conditions the maximum decant pond RL is 709.6 m.

Nonetheless, a starting decant pond level of 711.0 m indicates the "worst case" scenario that could exist, regardless of its likelihood.

Section 5.4 of DSC3A provides specific guidance on background conditions to be used for assessment of the FCC. These should represent “normal” (or average) background conditions (i.e. decant pond RL) that exist immediately prior to a flood event caused by extreme rainfall:

- The starting TSF pool level was set at the maximum predicted under “Average” conditions during the last year of operations (RL 709.0 m);
- The selected flood event is the Probable Maximum Precipitation Design Flood (PMPDF).

The incremental consequences of failure for the FCC are to be assessed by comparing the results of flood inundation modelling for both “failure” and “non-failure” scenarios, with all other background assumptions held constant.

1.3 TAILINGS STORAGE FACILITY DESIGN

The TSF will comprise a cross-valley storage with a zoned embankment. The design incorporates a basin underdrainage system to reduce seepage, and a toe drain located at the upstream toe to lower the phreatic surface adjacent to the embankment. The upstream toe drains and underdrainage system drain by gravity to a collection sump located at the upstream toe of the embankment. Supernatant water will be decanted from the facility via a decant tower located at the head of valley. Solution recovered from the underdrainage and decant systems will be pumped back to the plant for re-use in the process circuit. An emergency spillway will be constructed for each raise to control the discharge of any extreme storm events exceeding the design event.

Tailings will be discharged into the facility by sub-aerial deposition methods, via spigots spaced at regular intervals along the embankment crest, so as to maximise tailings density and evaporation of water. Deposition will occur mainly from the embankment towards the valley in order to form a supernatant pond towards the north-east perimeter of the facility.

A general arrangement of the final embankment footprint is shown on Figure 1.1 showing the TSF relative to site infrastructure. The TSF final storage capacity (for tailings) is 890,000 tonnes (t).

1.4 SITE CONDITIONS

Site conditions can be summarised as follows:

- The Dargues Reef project site occurs in the western part of a large granitic pluton, the Braidwood Granodiorite, which trends approximately north-south and extends from north of Braidwood to south of Majors Creek.
- The terrain comprises a series of rolling hills, and ephemeral creeks. Ground level at the base of the main drainage through the TSF basin falls at a gradient of about 8 to 10% towards the south-west.
- The drainage in the area of the TSF is dominated by an ephemeral creek, which becomes very narrow and densely vegetated towards the south-west.
- Average annual rainfall at the site is 724 mm and average evaporation is 1,615 mm. Point precipitation depths for storm events of 1 day duration for Annual Exceedance Probabilities (AEP) of 1 in 100, 1 in 200, 1 in 500 and 1 in 10,000,000 are 281 mm, 325 mm, 393 mm and 1390 mm, respectively, (note that the 1 in 10,000,000 AEP storm corresponds to Probable Maximum Precipitation (PMP) estimated for the project site.)
- The seismic acceleration used for the assessment of the operational basis earthquake is 0.07g. For the maximum credible earthquake, the seismic acceleration is 0.11g.

2. FAILURE MODES

2.1 GENERAL

A review of historical tailings dam failures indicates the following trends:

- Active dams are more susceptible to failure than inactive dams. That is, tailings dam failures are more likely to occur during operation than following de-commissioning. This is due in most cases to inadequate design and/or unsatisfactory operating practices. Properly designed and correctly operated facilities maintain adequate factors of safety against failure.
- Upstream constructed dams are more susceptible to liquefaction flow events and are solely responsible for all major liquefaction failures.
- Slope instabilities or earthquakes cause two-thirds of all upstream embankment accidents. However, embankment slope failures caused by seismic events may be prevented by appropriate design.
- Seepage related phenomena are the main failure modes for non-upstream tailings dams. Accordingly, seepage and its effect on embankment stability should be considered and allowed for as part of a thorough design review.
- Earthquakes are of little consequence for most non-upstream dams. Massive downstream constructed embankments, generally speaking, are significantly more stable than upstream constructed embankments.
- For inactive dams, overtopping is cited as the primary failure mode in nearly 50% of the incidents. Overtopping is normally mitigated by constructing temporary spillways during the facility operating life and a permanent spillway following de-commissioning.

There are some failure modes for which tailings dams are particularly susceptible. For example, for upstream constructed dams; nearly 60% of documented failures have occurred because of earthquakes or slope failures. The remaining 40% of failures have been due to overtopping, foundation failure, seepage or structural failure.

2.2 FAILURE MODE TYPES

The failure modes analysed which could result in a potential release of supernatant water, tailings slurry and/or waste dump material (resulting in a risk to human life) are as follows:

- Supernatant water overtopping or penetrating through the embankment, followed by continual erosion of the embankment, resulting in a total breach and release of the supernatant pond with some nominal tailings slurry also being mobilised;
- Piping failure through internal erosion of the embankment, gradually developing to an embankment breach, releasing the supernatant pond and tailings slurry;
- Embankment breach, resulting in a release of tailings slurry mass with minimal supernatant water release associated with the failure.

The different failure modes were considered for different periods of operation. The initial stages typically have low embankment levels and low tailings slurry and pond volumes, hence are unlikely to cause significant risk to life. Typically the final stages of operation are the most critical for water release due to the highest quantity of tailings, pond levels and water storage capacities. Following closure, the supernatant pond will be removed and the tailings beach will be shaped to provide positive drainage to the closure spillway, and the facility will be capped.

Accordingly, the final stage of operation was selected for assessment of both the SDCC and FCC as a dam failure during this stage would be expected to have the greatest potential impact downstream of the facility.

2.3 SELECTED FAILURE MODES FOR ANALYSIS

2.3.1 Overtopping Failure

The failure of the facility was modelled due to an overtopping incident which continues to erode the embankment, resulting in a total breach and release of the supernatant pond. Potentially, overtopping of the TSF could be caused by either an extreme rainfall event or decant pump breakdown. These two possibilities starting decant pond level of the scenarios that are to be evaluated:

- Overtopping failure initiated by an extreme rainfall event (at a starting pool RL of 709.0 m – see Section 1.2) sets one of the possible FCC scenarios;
- Overtopping failure initiated by a decant pump break down (at a starting decant pond level of 711.0 m – see Section 1.2) sets one of the SDCC scenarios.

2.3.2 Piping Failure

A failure of the embankment and release of supernatant water due to a piping failure development requires a combination of conditions to occur. Typical causes of piping failures are as follows:

- Construction liner integrity – caused by incorrect installation or damage during operation resulting in seepage into the embankment, potentially reducing stability and increasing piping potential;
- Earthquake – minor displacements in embankment not enough to cause an immediate failure, causing cracks within the embankment;
- Decant pump breakdown/rainfall event – resulting in an increased decant pond with increased seepage and driving force acting on the piping zone;
- Filter incompatibility – incompatible material grading curves resulting in internal erosion beneath embankment zones.

Tailings spigotting will take place from the embankments for the purpose of pushing the decant pond away from the embankment and facilitating formation of a tailings beach adjacent to the embankment. Water retention directly against the embankment may occur for short periods following storm events in the early stages of the TSF operation, but the water will be displaced away from the embankment over time. The zoned embankment and HDPE liner, combined with the proposed tailings deposition plan, should render piping failure far less likely to occur than other failure modes.

Regardless, piping failure scenarios are also investigated for the purposes of Consequence Category assessment as follows:

- Piping failure initiated by an extreme rainfall event (at a starting decant level of 709.0 m – see Section 1.2) sets the second possible FCC scenario;
- Piping failure initiated by a decant pump breakdown (at a starting decant pond level of 711.0 m – see Section 1.2) sets the second possible SDCC scenario.

2.3.3 Embankment Failure

An embankment failure could occur following a seismic event exceeding the design acceleration, or as a result of a construction flaw in the embankment. Both are considered unlikely as the TSF has been designed to withstand seismic events, and the facility will be constructed with a high degree of supervision and to stringent quality standards. If such a failure did occur it could result in a rapid release of water and tailings.

The water flow component is considered as part of the modelling in the scenarios above. For solids movement with minimal supernatant water, a tailings flow slide analysis was performed. The final height was selected as having the largest potential to travel the furthest distance and was also modelled as having the lowest factor of safety for maximum credible earthquake events. This covered both operational and closure conditions.

Accordingly, the tailings flow slide component should be considered *in addition to* the greater of the SDCC of FCC scenarios as it can accompany either consequence category.

3. EMBANKMENT WATER BREACH

3.1 GENERAL

There are four critical elements in the analysis of an embankment water breach:

- Breach parameter estimation (for setting the ultimate size and shape of the breach along with the time it takes to form);
- Breach peak discharge and breach hydrograph estimation;
- Breach flood downstream routing;
- Estimation of hydraulic conditions at critical downstream locations.

Empirical methods are used to predict time to failure and breach geometry, along with peak breach discharges. These methods rely on statistical analysis of data obtained from documented failures and result in predictive equations that can be applied directly.

Parametric hydrologic models are used to simulate the progression of a breach and calculate the resulting peak discharge and breach hydrographs based on parameters (breach geometry and development time) that have been pre-determined through empirical means. These models are also employed to calculate the downstream routing of the resulting flood, and estimate peak flow conditions at critical downstream locations (the models are also used to determine environmental run-off from background precipitation events into the system being modelled).

Results from the hydrologic modelling form one of the primary inputs to parametric hydraulic models which may then be used to estimate the resulting inundation caused by the peak routed breach outflow.

3.2 DESIGN / ANALYSIS METHODOLOGY

3.2.1 Breach Parameter Estimation

Four widely used and accepted empirically derived methods for overtopping and piping water breaches are:

- Froehlich (1995a, 1995b, 2008) method for estimating breach width, breach side-slope ratio, breach formation time and peak breach outflow as detailed in *"Peak Outflow from Breached Embankment Dam"* (Ref. 5), *"Embankment Dam Breach Parameters Revisited"* (Ref. 6), and *"Embankment Dam Breach Parameters and Their Uncertainties"* (Ref. 7);

- Von Thun and Gillette (1990) method for estimating breach width, breach side-slope ratio, and breach formation time as detailed in *"Guidance on Breach Parameters"* (Ref. 8);
- USBR (1982, 1988) method for estimating breach width, breach formation time and peak breach outflow as detailed in *"Guidelines for defining inundated areas downstream from Bureau of Reclamation dams"* (Ref. 9) and *"Downstream hazard classification guidelines"* (Ref. 10);
- MacDonald and Langridge - Monopolis (1984) method for estimating breach volume (and consequently width), breach side-slope ratio, breach formation time and peak breach outflow as detailed in *"Breaching Characteristics of Dam Failures"* (Ref. 11).

Estimates of the peak breach outflow (and outflow hydrograph) use values of B, z, t_f and H_b (refer to Appendix B for parameter definition) with either an assumed linear or sinusoidal breach progression to "grow" the breach from non-existence to the ultimate state. Hydraulic parameters (flow, velocity, volume, etc.) are then obtained by the approach being taken for downstream routing.

Wahl (2004) formulated a means for computing an approximate 95% confidence interval about the estimated breach parameters through statistical analysis of a comprehensive database of dam failures and various empirical breach parameter estimation methods. This research is documented in *"Uncertainty of Predictions of Embankment Dam Breach Parameters"* (Ref. 12).

The various breach parameter estimation methods were used to establish a test matrix of potential combinations of dam failure initiation event (FCC or SDCC), failure mode (overtopping: (to) or piping (PI)), parameter estimation method and assumed breach progression method. A calculation summary for each method along with the resulting test matrix is included in Appendix B.

3.2.2 Breach Hydrology

A portion of the Majors Creek catchment covering roughly 19.6 km^2 was de-lineated for assessing the FCC and SDCC. This area and the various sub-catchments de-lineated within it for peak flow estimation are illustrated on Figure 3.1.

Estimates of effective run-off from design storms events, along with breach outflow hydrograph estimation and breach flood downstream routing was performed using a hydrologic rainfall/run-off model created using *"Hydrologic Modeling System HEC-HMS, Version 3.4"* (HEC-HMS) (Ref. 13). Probable Maximum Precipitation (PMP) formed the precipitation input for the FCC evaluations of this model. PMP (see Appendix B) was estimated using methods and procedures taken from the following sources:

- *"The Estimation of Probable Maximum Precipitation in Australia; Generalised Short-Duration Method (GSDM)"* (Ref. 14);
- *"Generalised Southeast Australia Method (GSAM) for Estimating Probable Maximum Precipitation"* (Ref. 15);
- *"Australian Rainfall and Run-off, Volume 1 – A Guide to Flood Estimation"* (ARR) (Ref. 16).

KP notes that the critical duration determined for passage of the PMPDF was determined as 24 hours when the TSF spillway was being designed (as discussed in the main design report; KP Ref. PE801-00139/05). Accordingly, the duration selected for FCC assessment is 24 hours, as this will produce the maximum outflow for both failure and non-failure FCC scenarios.

Section 5.4 of DSC3A notes that a minimum of two floods should be considered during FCC assessment: the PMPDF and the Dam Crest Flood (DCF) as defined in the ANCOLD *"Guidelines on Risk Assessment"*. KP determined during spillway sizing that the planned TSF spillway has sufficient capacity to convey the PMPDF starting at "Average" or "1 in 100 AEP Wet" pool RL levels during operations and at closure. Under closure conditions for the proposed Dargues Reef TSF dam, the PMPDF coincides with the DCF. Under operational conditions, the peak water surface predicted during passage of the PMPDF is 0.5 m below the TSF dam crest. Extreme precipitation estimation methods discussed in ARR do not allow for extrapolation of rainfall for events larger than the PMP. Accordingly, the DCF was deemed infeasible for this particular configuration. It was not computed nor was it used for FCC assessment as the failure scenarios considered were assumed to occur during the last month of operations, when the greatest potential volume of impounded water could be evacuated by a dam breach.

Additional methods employed in the HEC-HMS model created for assessing FCC and SDCC flow rates include:

- An elevation / storage / outflow rating curve for the TSF, corresponding to end of operational lifetime conditions was developed using the frustum of a cone method (for storage calculation) with the projected tailings surface results (for the elevation / storage portion of the curve). The elevation / outflow portion of the curve was created using *"HEC-RAS River Analysis System, Version 4.1"*

(HEC-RAS) (Ref. 17) for the spillway and the broad-crested weir equation (for any dam crest overtopping) using coefficients taken from *"Handbook of Hydraulics, Seventh Edition"* (Ref. 18);

- Initial loss / continuing loss (IL / CL) model for calculating rainfall excess, with parameters taken from ARR;
- Transformation of rainfall excess to run-off hydrographs performed using the Clark synthetic unit hydrograph method, with times of concentration and basin storage coefficients assigned to each identified sub-catchment using relationships taken from ARR;
- Channel hydrologic routing performed using Muskingum-Cunge methodology, with 8-point approximations of channel cross-sections, channel segment lengths of 300 m, slopes calculated from available topography and Manning's hydraulic roughness (n) values assessed for channel and overbank sections using guidance from *"Open-Channel Hydraulics"* (Ref. 19).

Additional details concerning the formulation of the HEC-HMS breach hydrology model for the analysed portion of the Majors Creek catchment is given in Appendix B.

3.2.3 Breach Hydraulics

Breach inundation modelling for the various FCC and SDCC scenarios was performed using a hydraulic water surface profile computation model created with HEC-RAS. The Majors Creek HEC-RAS model (as formulated) uses the steady-flow version of the St. Venant equations of motion to determine water surface elevations (and consequently flow velocities) at identified locations throughout the Majors Creek catchment from the following input:

- Peak routed flow rates (for each FCC and SDCC scenario) taken from the HEC-HMS model results;
- Available channel topography estimated using cross sections taken (using AutoCAD Civil3D 2011 software) from a digital representation of the Majors Creek catchment formed by joining LIDAR topography provided by Cortona Resources in the immediate vicinity of the TSF and 3-arc second resolution digital topography obtained from Geoscience Australia. The minimum cross section sampling resolution enforced was 1 cross section for every 150 m of river length for a total modelled river course length of 9.85 km (73 cross sections);

- Cross sections were augmented in the HEC-RAS model by three-dimensional interpolation between cross sections using a minimum distance of 5 m between interpolated sections;
- Flow junctions were modelled using the conservation of energy method;
- Manning's hydraulic roughness (n) values were assessed for channel and overbank sections using guidance from *"Open-Channel Hydraulics"*; and
- Upstream and downstream boundary conditions at open ends of the flow network were assumed to correspond to normal depth, computed at the local river gradient.

Additional details concerning the formulation of the HEC-RAS breach hydraulics model for the analysed portion of the Majors Creek catchment is given in Appendix B.

3.3 RESULTS OF MODELLING

For the various FCC and SDCC scenarios involving a dam breach, i.e. Failure (F) scenarios, the breach outflow hydrograph was computed using the HEC-HMS model and the results of all four breach parameter estimation methods for both overtopping and piping failure mechanisms. The breach hydrograph (superimposed on top of estimated background stream flow) was also routed downstream for each scenario with the HEC-HMS model to generate time to peak and peak flow rate at various locations downstream of the TSF dam.

Referring to the sub-catchment de-lineation map shown on Figure 3.1, peak flow results at two locations: CP05 (the confluence of Majors Creek, flowing generally south-east and the Majors Creek West tributary, flowing generally north-east past the town of Majors Creek until combining with Majors Creek) and CP01 (the downstream end of the analysed area, roughly 6.2 km downstream of the TSF dam) were examined to screen the hydrologic results for the most representative breach parameter estimation method, which was selected to be the Froehlich (2008) methodology because:

1. It resulted in conservative estimates.
2. It represents the most recent developments in parametric breach parameter estimation.

For both SDCC and FCC assessments, the peak outflows from the OT and PI breach mechanisms were very similar (see Appendix B). However, the OT results were generally higher and were consequently selected for detailed inundation map preparation (along with the non-failure (NF) PMPDF-caused FCC scenario).

After the screening of hydrologic results by breach parameter estimation method and failure mechanism, the modelling runs selected for inundation map preparation were:

- NF_PMPDF, the non-failure scenario for the TSF dam coincident with a Probable Maximum Precipitation Design Flood (this is one of the two ultimate FCC scenarios for assessment).
- F01_PMPDF_OT, the overtopping failure scenario for the TSF dam caused by a PMPDF (this is the second ultimate FCC scenario for assessment).
- F02_SD_OT, the overtopping failure of the TSF dam occurring during a “Sunny Day” scenario (this forms the sole SDCC scenario for assessment).

Inundation maps for the three aforementioned modelling runs are presented graphically as follows:

- NF_PMPDF scenario results are presented on Figure 3.2 (inundation key map) and on figures 3.2.1 through 3.2.3 (inundation detail maps).
- F01_PMPDF_OT scenario results are presented on Figure 3.3 (inundation key map) and on figures 3.3.1 through 3.3.3 (inundation detail maps).
- F02_SD_OT scenario results are presented on Figure 3.4 (inundation key map) and on figures 3.4.1 through 3.4.3 (inundation detail maps).

A key result of all three scenarios, see figures 3.2.1, 3.3.1, and 3.4.1, is that none of infrastructure downstream of the TSF (box cut entrance to underground workings, process plant site, offices, labs, workshops, paste hole, vent rise and escape-way) are indicated as being inundated. This confirms the initial assessment of PAR as shown in Table 1.1.

In order to determine the incremental consequences of failure versus non-failure during the PMPDF (for FCC assessment), a set of inundation comparison maps were prepared showing NF_PMPDF and F01_PMPDF_OT results as Figure 3.5 (inundation comparison key map) and figures 3.5.1 through 3.5.3 (inundation comparison detail maps). Inspection of these figures show that the additional inundation caused by a failure of the TSF during a PMPDF is relatively minor and diminishes to being negligible at the downstream boundary of the area of concern (roughly 6 km downstream of the TSF). KP notes that no additional impact is observed in the area adjacent to the town of Majors Creek (from STA 21+950.0 to STA 20+300.0 – see Figure 3.5.2). These inundation comparison maps indicate that a failure of the TSF during a PMPDF is not expected to place additional population at risk outside of anyone between the red and blue lines on figures 3.5 through 3.5.3 shortly after a breach occurs.

A comparison of FCC and SDCC results was also made through the preparation of an additional set of inundation comparison maps contrasting F01_PMPDF_OT (FCC) and F02_SD_OT (SDCC) scenarios. These maps are presented as Figure 3.6 (inundation comparison key map) and figures 3.6.1 through 3.6.3 (inundation comparison detail maps). Inspection of these figures shows that:

- TSF failure during a PMPDF, i.e. the FCC, results in a larger total amount of inundated area;
- The SDCC has no discernable impact upon the town of Majors Creek;
- It is difficult to determine whether the SDCC or the *additional* impact of FCC caused by a TSF failure results in a larger amount of inundated area.

KP recommends that the FCC, specifically a potential overtopping failure of the Dargues Reef TSF dam during a probable maximum precipitation design flood, be used for assessment of the consequence category as per DSC3A.

4. EMBANKMENT TAILINGS BREACH

4.1 GENERAL

An analysis of a flow slide type release of tailings from the ultimate stage TSF was performed following the discussion of failure modes in Section 2. A number of methods of analysing the flow of slurry and run-out from a breached tailings dam have been presented over the years. These methods have been based on reviews of past failures and attempts to predict the flow slides using analytical means. Two methods have been selected and utilised for this study, as follows:

- The method proposed by Blight (1981) as discussed in "*The Flow of Slurry from a Breached Tailings Dam*" (Ref. 20);
- The method proposed by Vick (1991) as discussed in "*Inundation Risk from Tailings Dam Flow Failures*" (Ref. 21).

Blight considered a number of failures and concluded that, generally speaking, the outflow of tailings is significantly affected by ground conditions outside the facility prior to the onset of the slide (either wet or dry) and the size of the tailings pond. According to the Blight methodology, the resulting inundation from a tailings slide will be similar to that which occurs from an uncontrolled release of water. An analysis of uncontrolled releases of water due to dam failure is presented in Section 3 (for a volume of water containing tailings slurry travelling downstream) hence; these results have not been reproduced here.

Vick proposed a simplified equilibrium model using a two-dimensional equilibrium of forces to predict the final flow slide run-out distance. This method is based on case histories and is considered to give results where a minimal pond is associated with the failure or dry conditions exist downstream. Some nominal tailings will be carried downstream with the natural stream flow over time; however the bulk of the tailings spilled will remain within the main valley immediately downstream.

4.2 VICK METHOD ANALYSIS

Application of the Vick methodology results in prediction of the probability of occurrence of the flow slide travelling a certain distance. The analysis assumes that the tailings shear strength is 3.6 kPa and results in a final breach profile at a slope between 3.7% and 5.2% downstream. The results of the analysis are summarised in Table 4.1.

Table 4.1: Results of the Vick Method Analysis

Final Embankment	
Run-out Distance from Toe (m)	Probability of Exceedance (%)
25	89
65	61
100	40
115	26
130	17
135	12

This method suggests that a flow slide run-out distance of up to approximately 150 m from the toe of the facility is possible. Based on the above results of flow run-out distance, a deposition modelling package *RIFT TD* (Ref. 22) was used to overlay the predicted tailings slide path on top of downstream topography in order to determine the extent and impact zone of the tailings run-out. Based on the profile and ground geometry, this equates to a tailings release of about 30,000 t. Layouts of the predicted tailings run-out are shown in figures 4.1 and 4.2.

Figure 4.2 indicates that that none of the downstream infrastructure (box cut entrance to underground workings, process plant site, offices, labs, workshops, paste hole, vent riser and escape-way) are indicated as being inundated by a potential tailings run-out caused by an embankment breach. However, owing to uncertainties in embankment breach mechanics and as an additional safety measure, KP recommends that a safety bund of minimum 1.5 m in height is constructed around the paste hole, vent rise and escape-way to further mitigate their risk of inundation.

5. CONCLUSIONS

Three major failure scenarios were assessed:

- An overtopping water breach initiated by a probable maximum precipitation design flood. The initial TSF pool level for this scenario corresponds with average conditions during the last month of planned operations. This defines the flood consequence category referred to in DSC3A;
- An overtopping water breach occurring during a sunny day (i.e. without coincident precipitation), the initial TSF pool level for this scenario corresponds with the invert elevation of the main spillway. This defines the sunny day consequence category referred to in DSC3A;
- An embankment failure which precipitates a tailings run-out, which could occur *in addition* to either of the other two major failure scenarios.

Analysis of breach formation parameters led to the selection of the Froehlich (2008) methodology (Refs. 5 – 7) for estimating key geometric and temporal variables describing a potential failure of the Dargues Reef TSF. The overtopping breach mechanism was selected over the piping breach mechanism because it resulted in more conservative breach outflows.

Water inundation as a result of the first two major failure scenarios is illustrated in figures 3.3 through 3.5.3. Tailings release through a potential embankment failure is illustrated in figures 4.1 and 4.2. The results of these assessments indicate that expected inundation and potential tailings run-out does not impact the downstream infrastructure (box cut entrance to underground workings, process plant site, offices, labs, workshops, paste hole, vent rise and escape-way). Additionally, the town of Majors Creek is not expected to be impacted by a breach of the facility.

From comparison of the FCC and SDCC, KP recommends that the FCC is used for consequence assessment. Accordingly, the consequence category for the TSF dam corresponds to the FCC, which is the PMPDF for this facility. Inspection of the results indicates that the consequence category assessment of *Significant* provided in the *"Dargues Reef Gold Project – Bankable Feasibility Study, Tailings Management"* reasonable.

6. REFERENCES

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FIGURES

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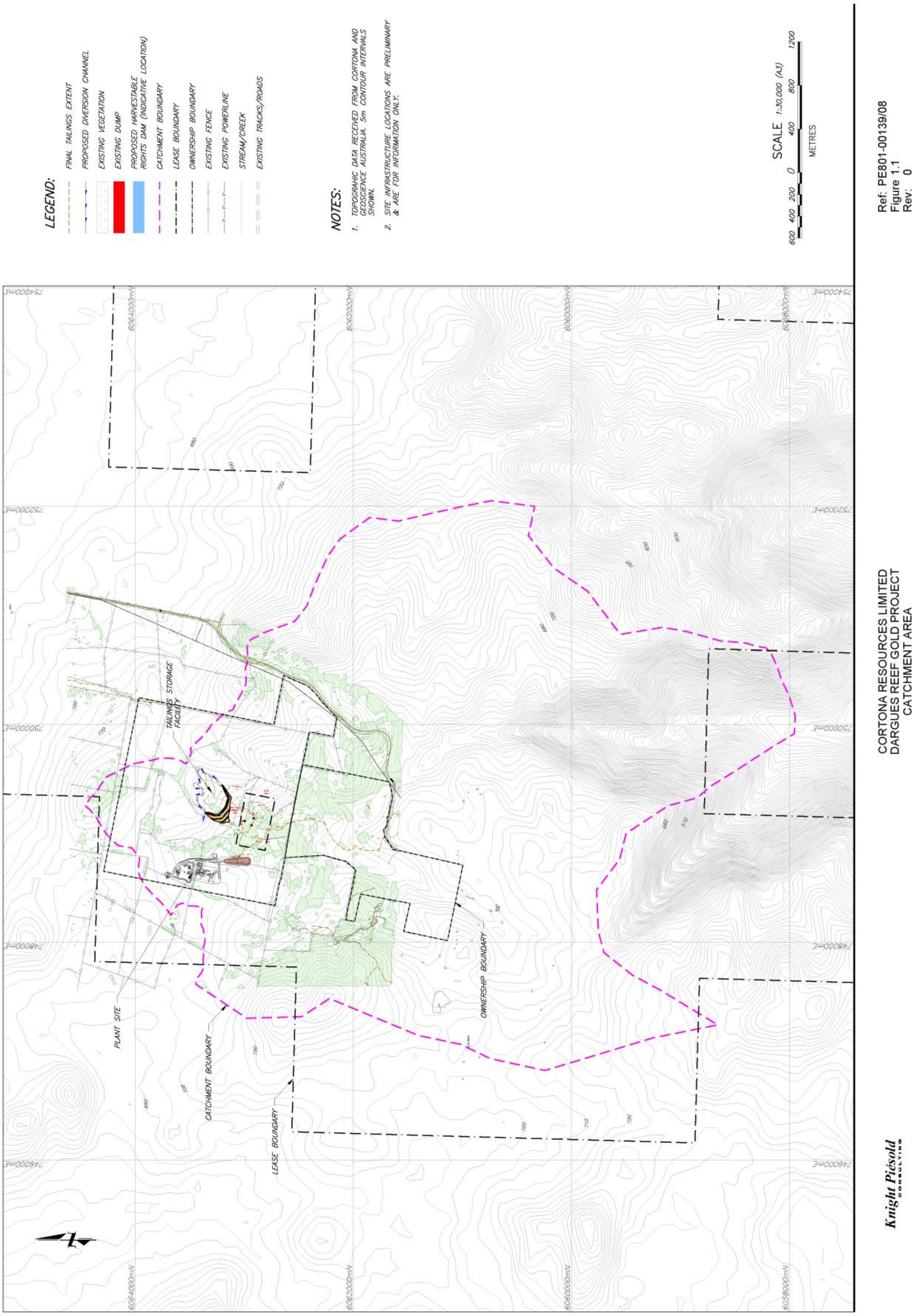
CONSULTING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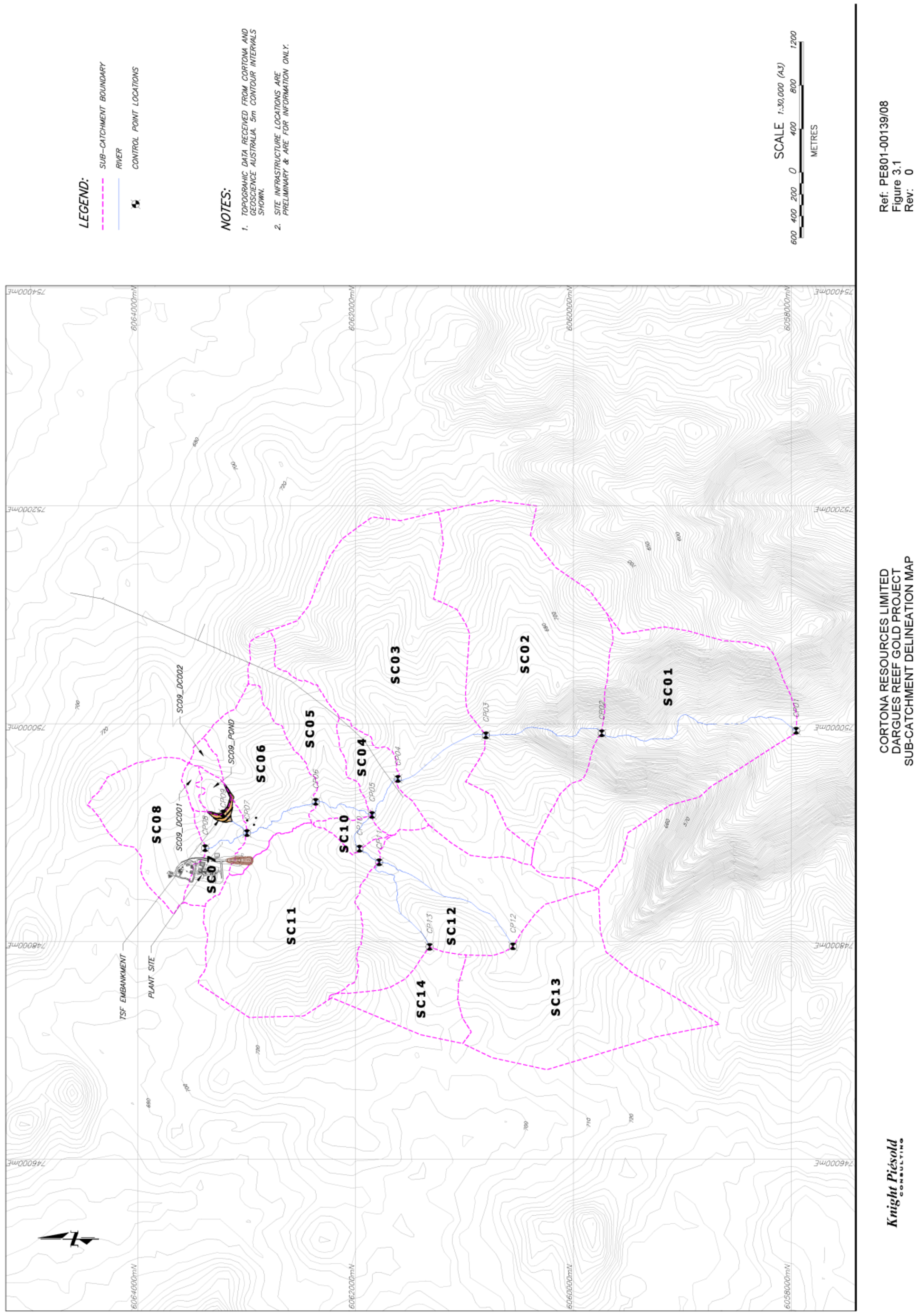
FINAL TAILINGS EXTENT
PROPOSED DIVERSION CHANNEL
EXISTING VEGETATION
EXISTING DUMP
PROPOSED HARVESTABLE RIGHTS DAM (INDICATIVE LOCATION)
CATCHMENT BOUNDARY
LEASE BOUNDARY
OWNERSHIP BOUNDARY
EXISTING FENCE
EXISTING POWERLINE
STREAM/CREEK
EXISTING TRACKS/ROADS
NOTES:
1. TOPOGRAPHIC DATA RECEIVED FROM CORTONA AND GEOSCIENCE AUSTRALIA. 5m CONTOUR INTERVALS SHOWN.
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:30,000 (A3)
600 400 200 0 400 800 1200
METRES
TAILINGS STORAGE FACILITY
PLANT SITE
CATCHMENT BOUNDARY
LEASE BOUNDARY
OWNERSHIP BOUNDARY
6064000mN
6062000mN
6060000mN
6058000mN
754000mE
752000mE
750000mE
748000mE
746000mE
Ref: PE801-00139/08
Figure 1.1
Rev: 0
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
CATCHMENT AREA
Knight Piésold CONSULTING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SUB-CATCHMENT BOUNDARY
RIVER
CONTROL POINT LOCATIONS
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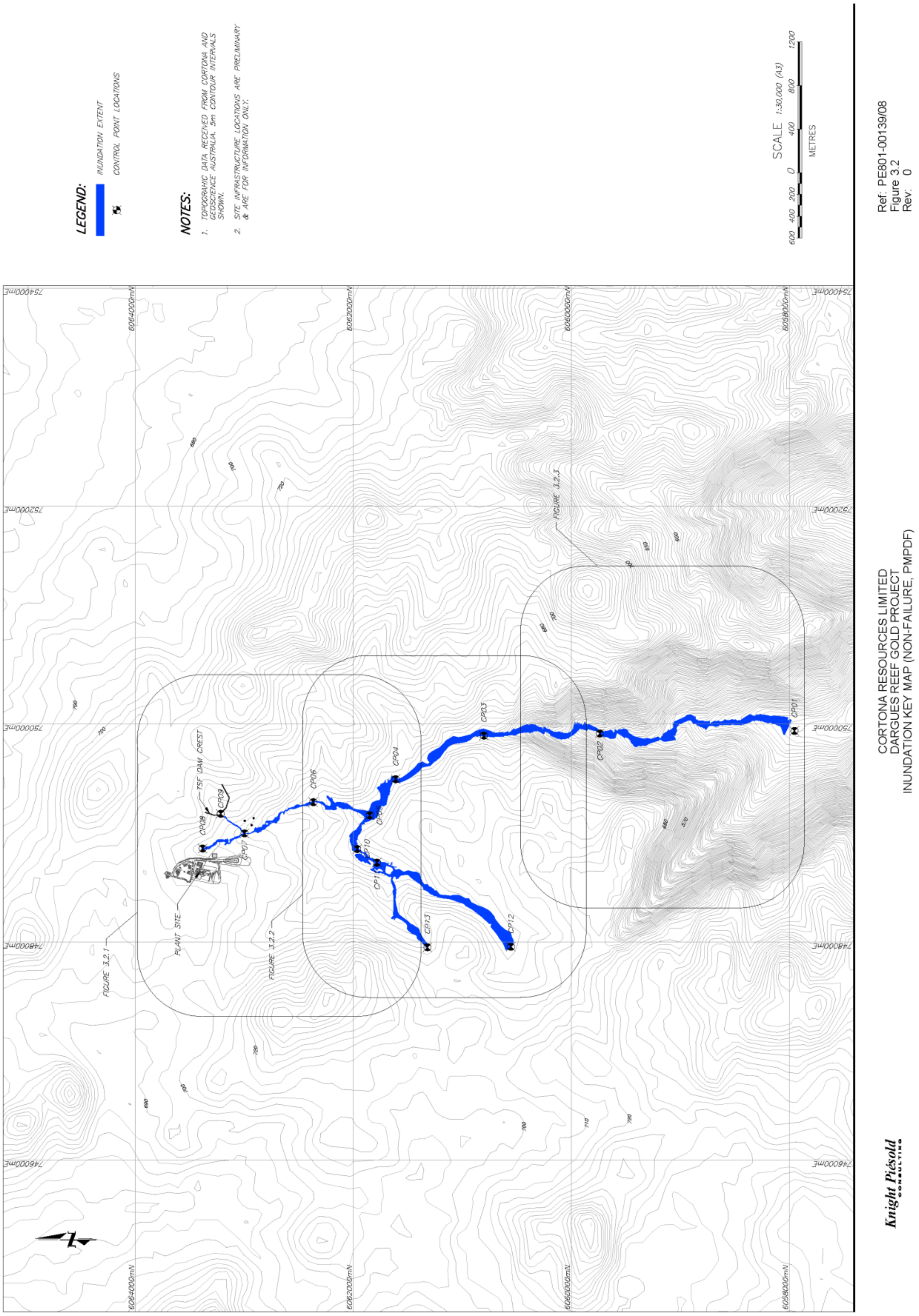
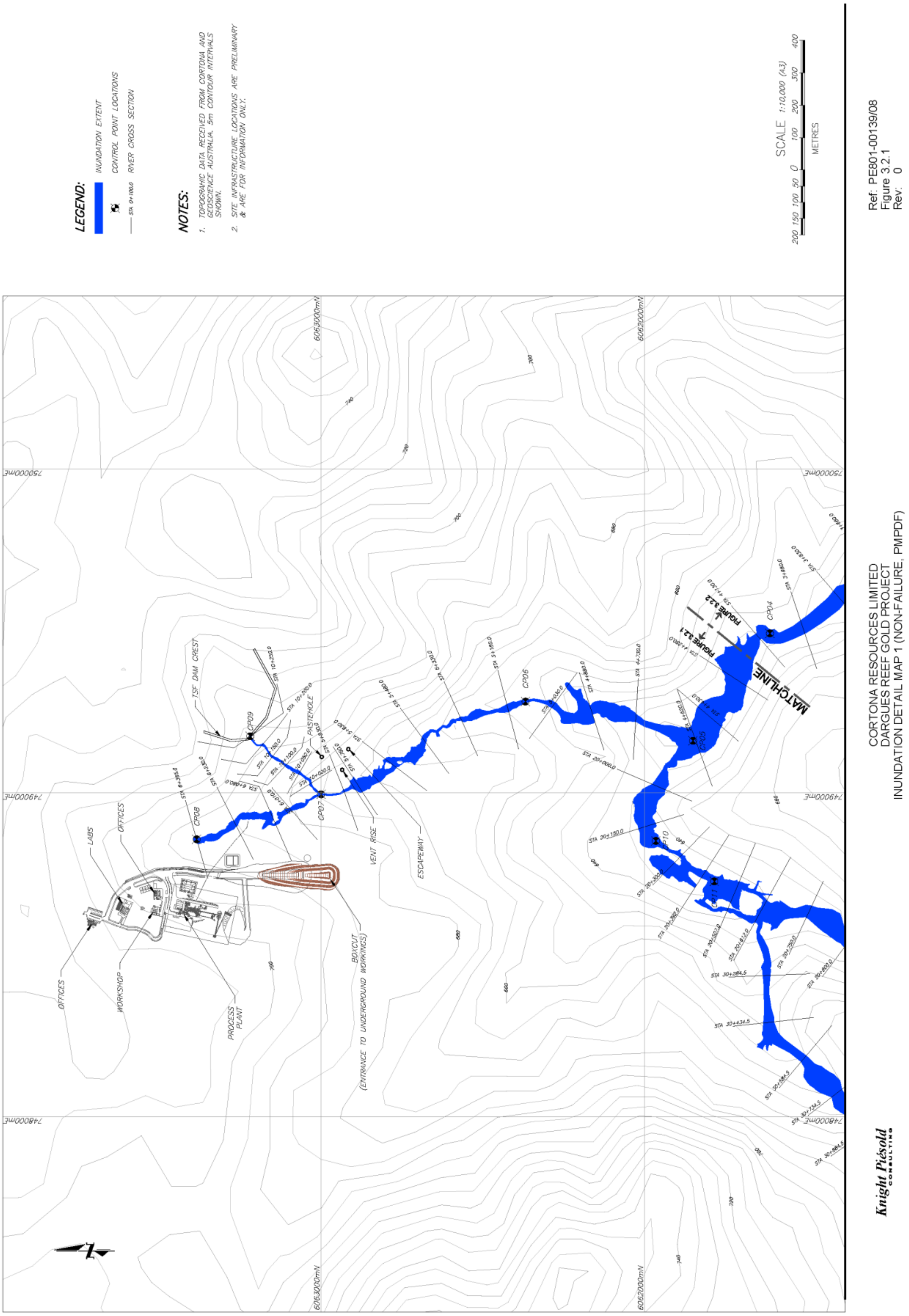
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:30,000 (A3)
600 400 200 0 400 800 1200
METRES
SC01
SC02
SC03
SC04
SC05
SC06
SC07
SC08
SC10
SC11
SC12
SC13
SC14
SC09_DC002
SC09_POND
SC09_DC001
TSF EMBANKMENT
PLANT SITE
Knight Piésold CONSULTING
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
SUB-CATCHMENT DELINEATION MAP
Ref: PE801-00139/08
Figure 3.1
Rev: 0



LEGEND:
INUNDATION EXTENT
CONTROL POINT LOCATIONS
NOTES:
1. TOPOGRAPHIC DATA RECEIVED FROM CORTONA AND GEOSCIENCE AUSTRALIA. 5m CONTOUR INTERVALS SHOWN.
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:30,000 (A3)
METRES
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION KEY MAP (NON-FAILURE, PMPDF)
Ref: PE801-00139/08
Figure 3.2
Rev: 0
FIGURE 3.2.1
FIGURE 3.2.2
FIGURE 3.2.3
PLANT SITE
TSF DAM CREST
CP01
CP02
CP03
CP04
CP06
CP07
CP08
CP09
CP12
CP13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INUNDATION EXTENT
CONTROL POINT LOCATIONS
RIVER CROSS SECTION
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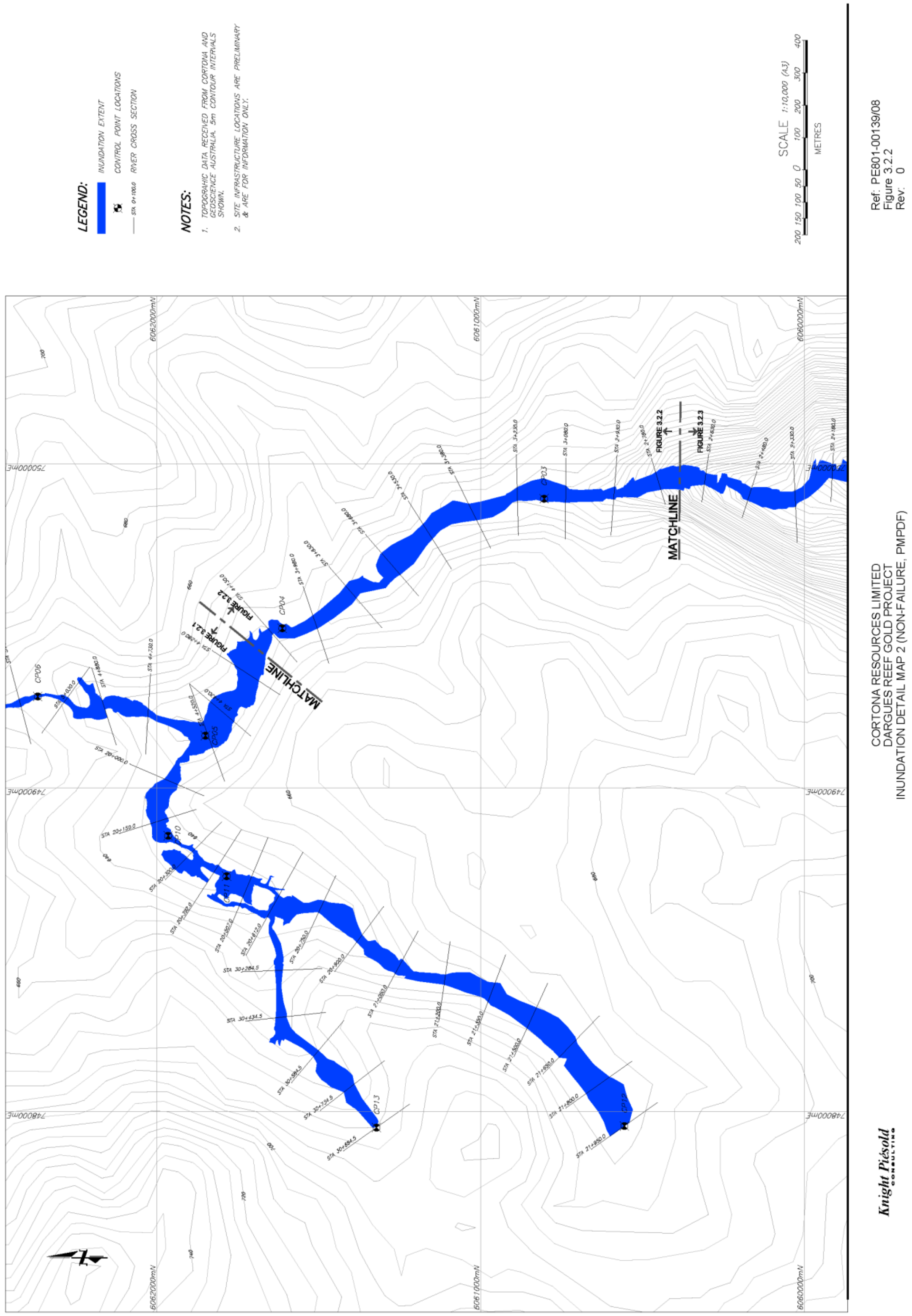
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:10,000 (A3)
METRES
MATCHLINE
TSF DAM CREST
PASTEHOLE
VENT RISE
ESCAPEWAY
BOXCUT (ENTRANCE TO UNDERGROUND WORKINGS)
PROCESS PLANT
WORKSHOP
OFFICES
LABS
CP04
CP05
CP06
CP07
CP08
CP09
Ref: PE801-00139/08
Figure 3.2.1
Rev: 0
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION DETAIL MAP 1 (NON-FAILURE, PMPDF)
Knight Piésold CONSULTING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CONTROL POINT LOCATIONS
RIVER CROSS SECTION
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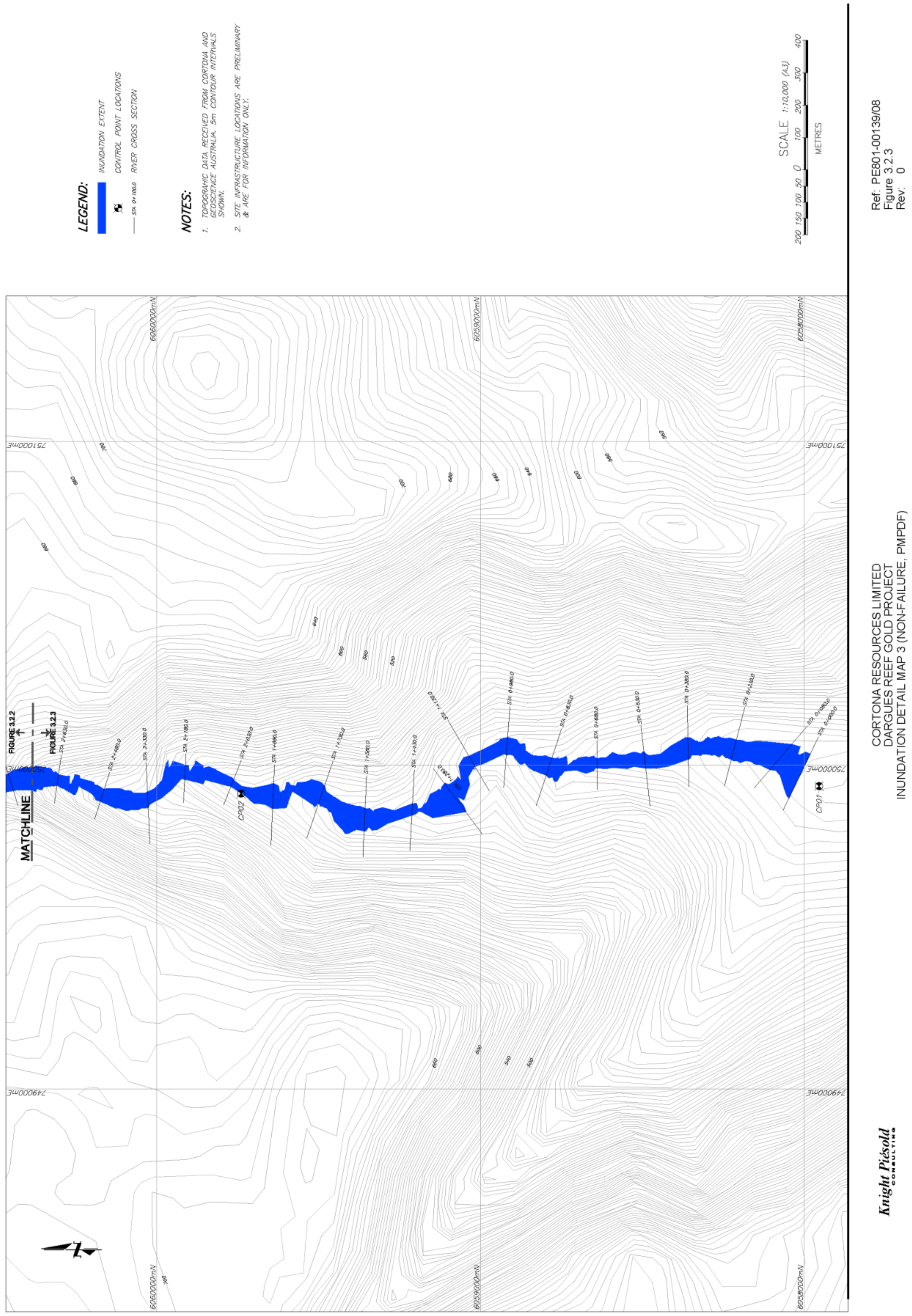
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:10,000 (A3)
METRES
MATCHLINE
FIGURE 3.2.1
FIGURE 3.2.2
FIGURE 3.2.3
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION DETAIL MAP 2 (NON-FAILURE, PMPDF)
Ref: PE801-00139/08
Figure 3.2.2
Rev: 0
Knight Piésold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INUNDATION EXTENT
CONTROL POINT LOCATIONS
RIVER CROSS SECTION
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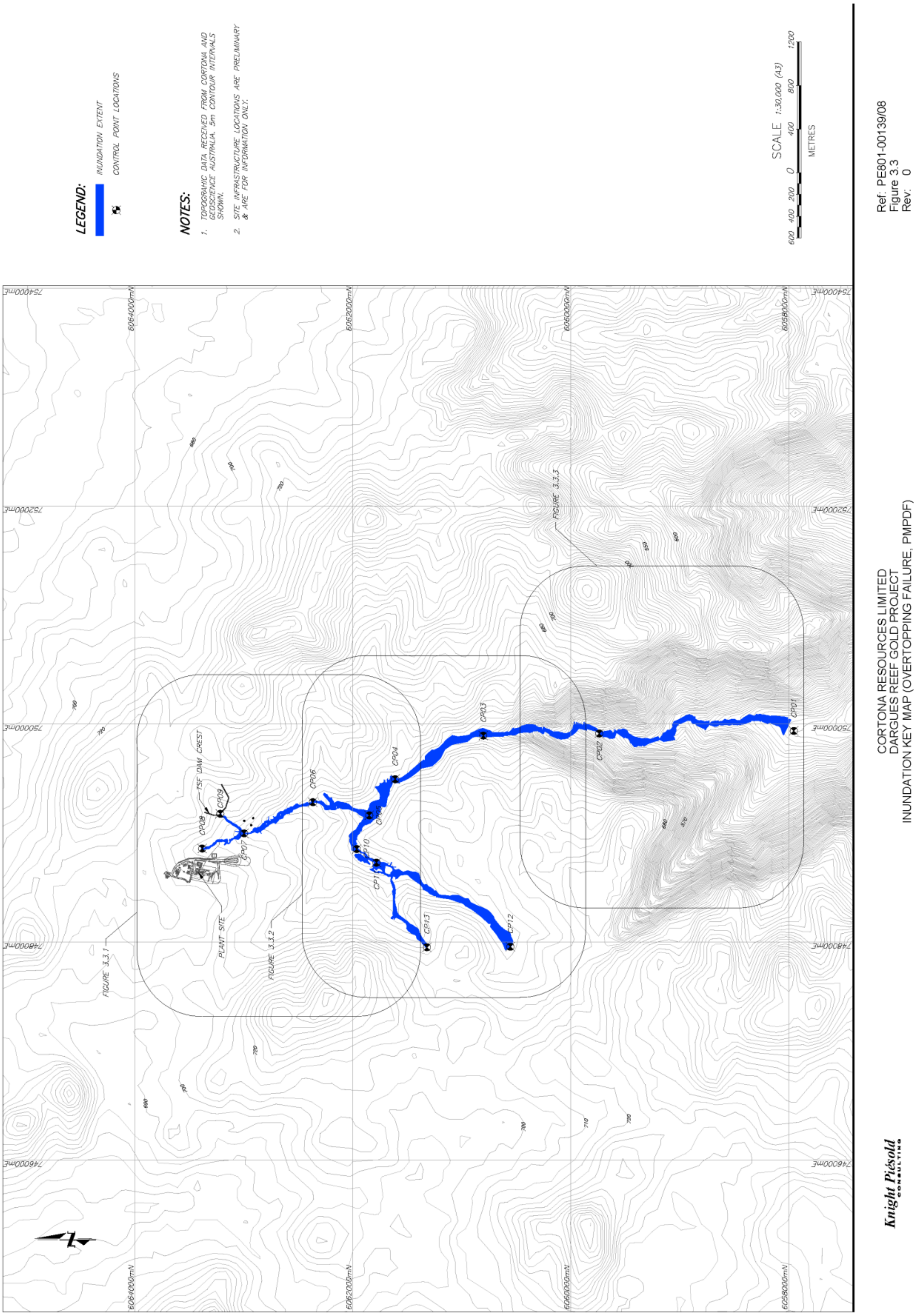
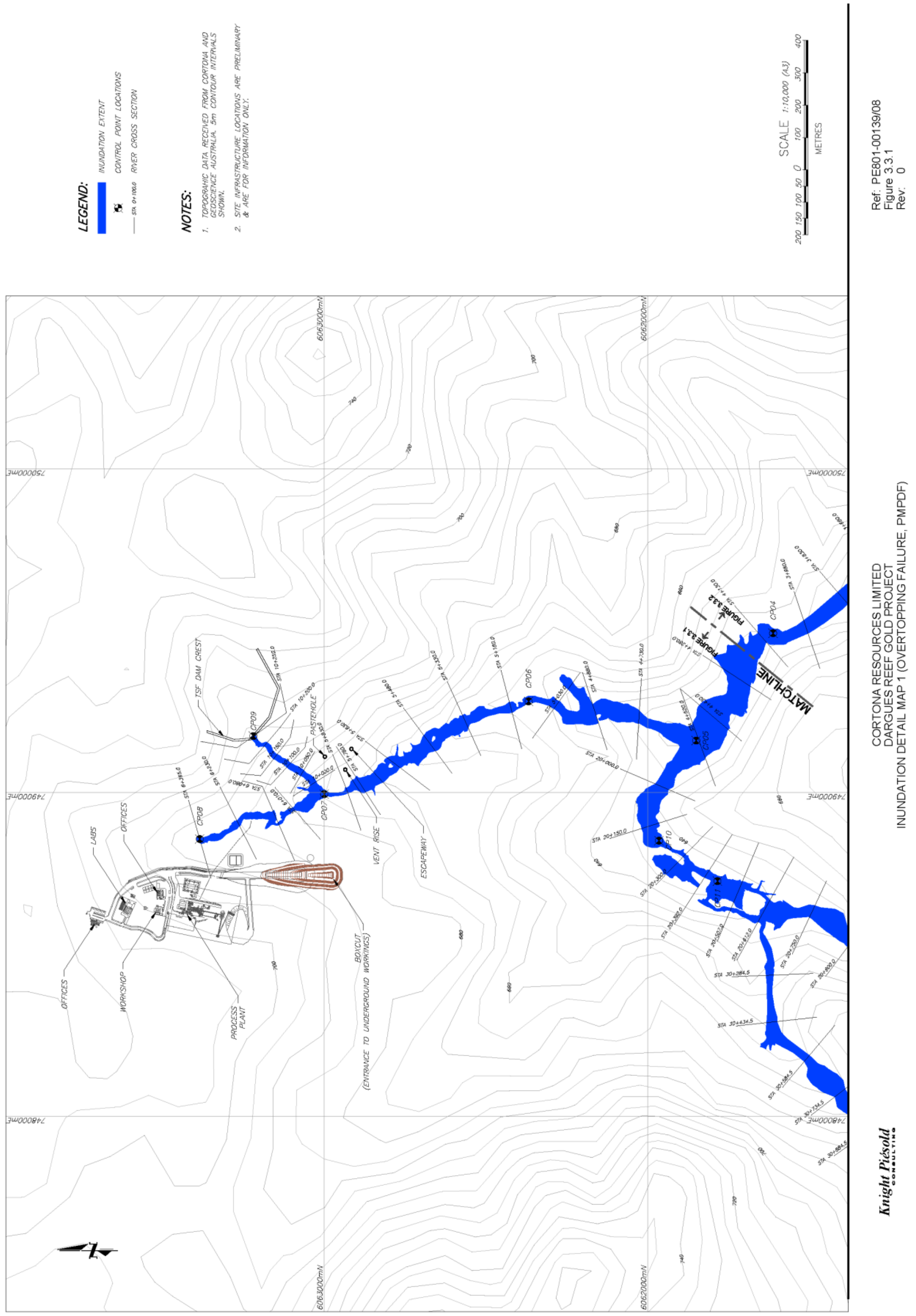
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:10,000 (A3)
METRES
MATCHLINE
FIGURE 3.2.2
FIGURE 3.2.3
CP01
CP02
6060000mN
6059000mN
6058000mN
751000mE
750000mE
749000mE
Ref: PE801-00139/08
Figure 3.2.3
Rev: 0
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION DETAIL MAP 3 (NON-FAILURE, PMPDF)
Knight Piésold


LEGEND:
INUNDATION EXTENT
CONTROL POINT LOCATIONS
NOTES:
1. TOPOGRAPHIC DATA RECEIVED FROM CORTONA AND GEOSCIENCE AUSTRALIA. 5m CONTOUR INTERVALS SHOWN.
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:30,000 (A3)
METRES
FIGURE 3.3.1
FIGURE 3.3.2
FIGURE 3.3.3
PLANT SITE
TSF DAM CREST
CP01
CP02
CP03
CP04
CP06
CP08
CP09
CP12
CP13
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION KEY MAP (OVERTOPPING FAILURE, PMPDF)
Ref: PE801-00139/08
Figure 3.3
Rev: 0
Knight Piésold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INUNDATION EXTENT
CONTROL POINT LOCATIONS
RIVER CROSS SECTION
NOTES:
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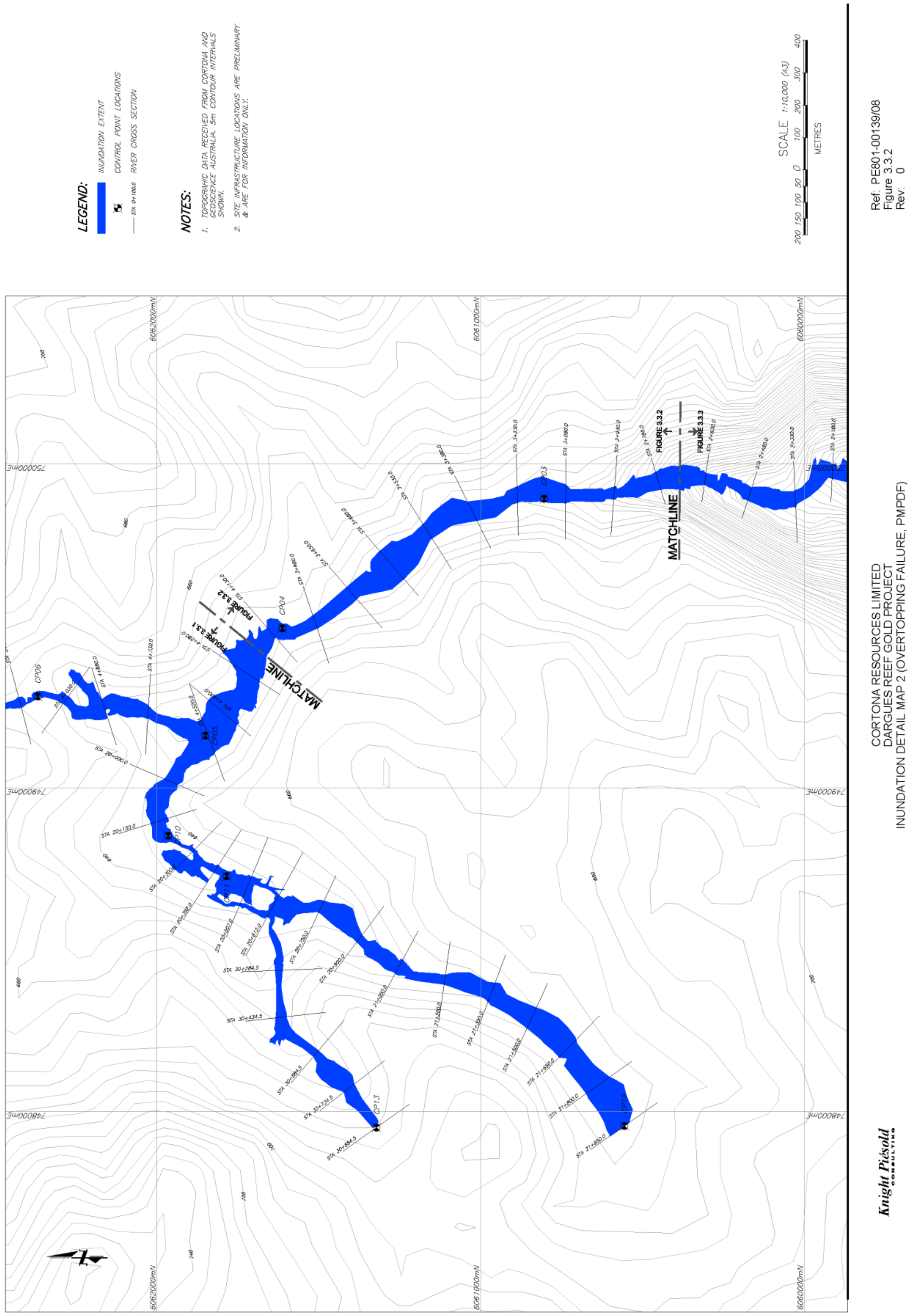
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:10,000 (A3)
METRES
MATCHLINE
TSF DAM CREST
PASTEHOLE
VENT RISE
ESCAPEWAY
BOXCUT (ENTRANCE TO UNDERGROUND WORKINGS)
LABS
OFFICES
WORKSHOP
PROCESS PLANT
CP04
CP05
CP06
CP07
CP08
CP09
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION DETAIL MAP 1 (OVERTOPPING FAILURE, PMPDF)
Ref: PE801-00139/08
Figure 3.3.1
Rev: 0
Knight Piésold CONSULTING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INUNDATION EXTENT
CONTROL POINT LOCATIONS
RIVER CROSS SECTION
NOTES:
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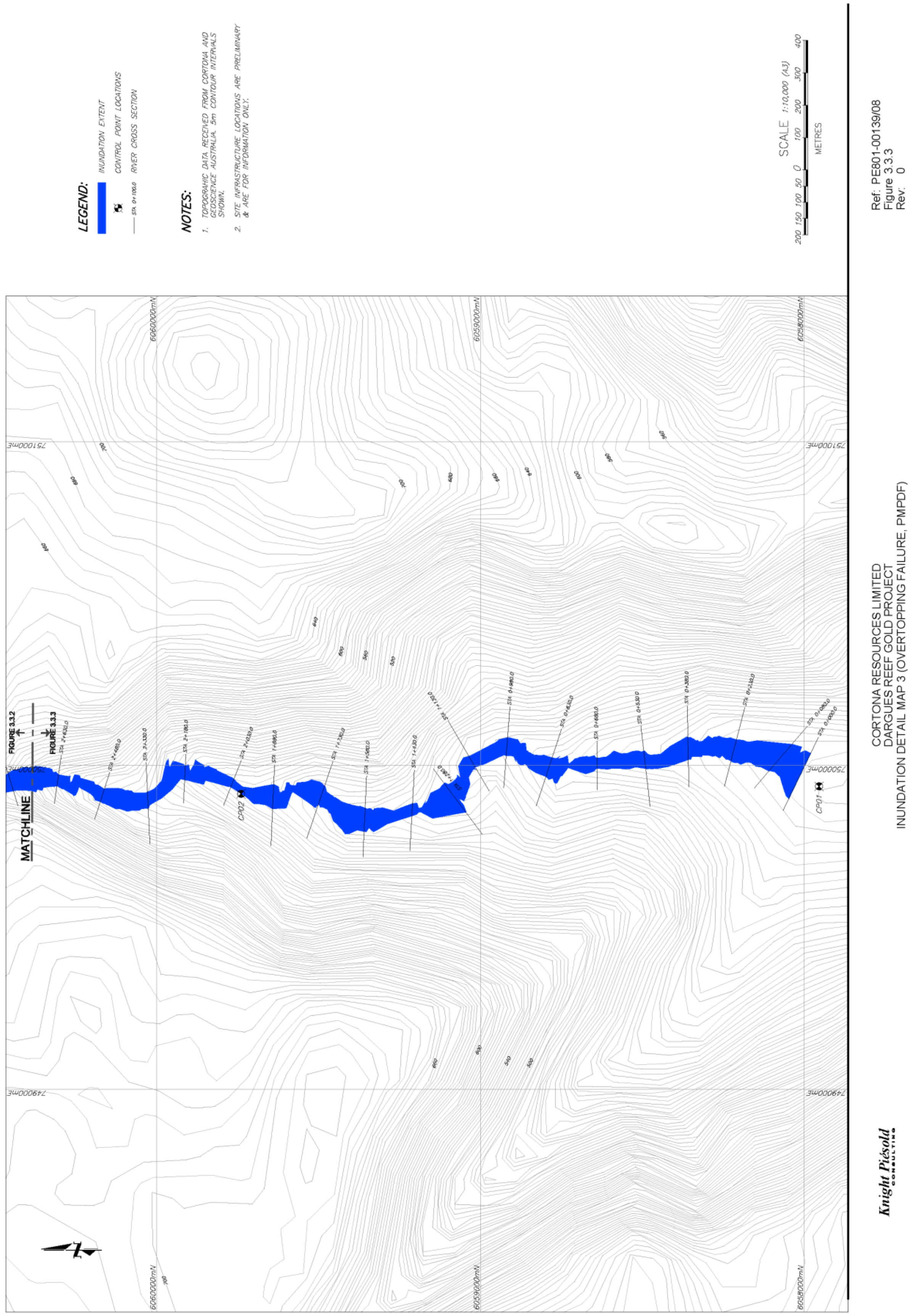
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:10,000 (A3)
METRES
MATCHLINE
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION DETAIL MAP 2 (OVERTOPPING FAILURE, PMPDF)
Ref: PE801-00139/08
Figure 3.3.2
Rev: 0
Knight Piésold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INUNDATION EXTENT
CONTROL POINT LOCATIONS
RIVER CROSS SECTION
NOTES:
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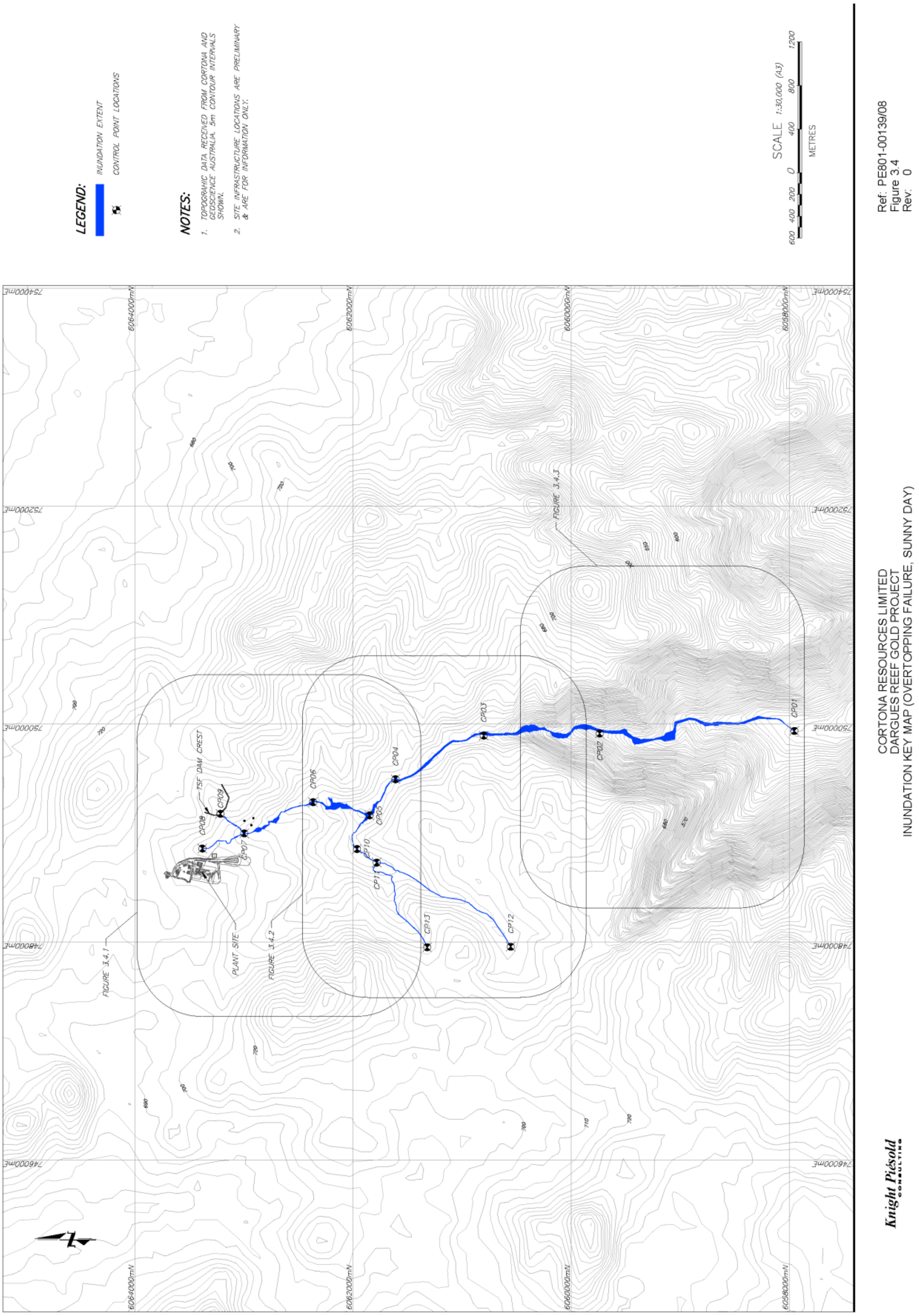
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:10,000 (A3)
METRES
MATCHLINE
FIGURE 3.3.2
FIGURE 3.3.3
CP01
CP02
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION DETAIL MAP 3 (OVERTOPPING FAILURE, PMPDF)
Ref: PE801-00139/08
Figure 3.3.3
Rev: 0
Knight Piésold


LEGEND:
INUNDATION EXTENT
CONTROL POINT LOCATIONS
NOTES:
1. TOPOGRAPHIC DATA RECEIVED FROM CORTONA AND GEOSCIENCE AUSTRALIA. 5m CONTOUR INTERVALS SHOWN.
2. SITE INFRASTRUCTURE LOCATIONS ARE PRELIMINARY & ARE FOR INFORMATION ONLY.
SCALE 1:30,000 (A3)
METRES
FIGURE 3.4.1
FIGURE 3.4.2
FIGURE 3.4.3
PLANT SITE
TSF DAM CREST
CP01
CP02
CP03
CP04
CP05
CP06
CP07
CP08
CP09
CP10
CP11
CP12
CP13
CORTONA RESOURCES LIMITED
DARGUES REEF GOLD PROJECT
INUNDATION KEY MAP (OVERTOPPING FAILURE, SUNNY DAY)
Ref: PE801-00139/08
Figure 3.4
Rev: 0
Knight Piésold