Appendix E

QA/QC

RPD Calculations

RPD Calculations: Former Tokanui Psychiatric Hospital

Parameter	TP21 (SUR)	DUP01	RPD (%)	TP23 (1.2m)	DUP02	RPD (%)
Total Recoverable Arsenic	3	3	0.00	3.00	3.00	0.00
Total Recoverable Boron	< 20	< 20	-	< 20	< 20	-
Total Recoverable Cadmium	0.11	0.11	0.00	< 0.10	< 0.10	-
Total Recoverable Chromium	7	7	0.00	7	7	0.00
Total Recoverable Copper	14	15	6.90	15	13	14.29
Total Recoverable Lead	39	41	5.00	14.3	12.3	15.04
Total Recoverable Nickel	5	5	0.00	4	3	28.57
Total Recoverable Zinc	55	57	3.57	41	38	7.59

Note: Results in *I talics* exceed 30% RPD. Results in red exceed 50% RPD

Parameter	TP25 (SUR)	DUP03	RPD (%)	TP27 (1.0m)	DUP04	RPD (%)
Total Recoverable Arsenic	3	3	0.00	5.00	7.00	*33.33*
Total Recoverable Boron	< 20	< 20	-	< 20	< 20	-
Total Recoverable Cadmium	0.14	0.15	6.90	0.24	0.2	18.18
Total Recoverable Chromium	24	23	4.26	13	11	16.67
Total Recoverable Copper	18	17	5.71	29	26	10.91
Total Recoverable Lead	17.8	17.9	0.56	220	270	20.41
Total Recoverable Nickel	12	12	0.00	6	6	0.00
Total Recoverable Zinc	79	77	2.56	139	134	3.66

Note: Results in *I talics* exceed 30% RPD. Results in red exceed 50% RPD

Parameter	TP29 (SUR)	DUP05	RPD (%)	TP31 (1.0m)	DUP06	RPD (%)
Total Recoverable Arsenic	3	3	0.00	2.00	< 2	-
Total Recoverable Boron	< 20	< 20	-	< 20	< 20	-
Total Recoverable Cadmium	< 0.10	< 0.10	-	< 0.10	< 0.10	-
Total Recoverable Chromium	9	9	0.00	6	6	0.00
Total Recoverable Copper	15	14	6.90	10	11	9.52
Total Recoverable Lead	19.1	18	5.93	15.5	15.2	1.95
Total Recoverable Nickel	4	4	0.00	3	3	0.00
Total Recoverable Zinc	52	48	8.00	32	34	6.06

Note: Results in *I talics* exceed 30% RPD. Results in red exceed 50% RPD

Parameter	TP4 (SUR)	DUP07	RPD (%)	TP6 (SUR)	DUP08	RPD (%)
Total Recoverable Arsenic	5	5	0.00	5.00	4.00	22.22
Total Recoverable Boron	< 20	< 20	-	< 20	< 20	-
Total Recoverable Cadmium	0.19	0.29	*41.67*	0.18	0.28	*43.48*
Total Recoverable Chromium	10	13	26.09	9	9	0.00
Total Recoverable Copper	24	28	15.38	24	37	*42.62*
Total Recoverable Lead	43	46	6.74	35	37	5.56
Total Recoverable Nickel	7	11	*44.44*	8	8	0.00
Total Recoverable Zinc	73	144	*65.44*	82	191	*79.85*

Note: Results in *I talics* exceed 30% RPD. Results in red exceed 50% RPD

Parameter	TP47 0.1m	DUP01	RPD (%)	TP52 0.1m	DUP02	RPD (%)
Total Recoverable Arsenic	6	5	18.18	5.00	6.00	18.18
Total Recoverable Boron	< 20	< 20	-			-
Total Recoverable Cadmium	0.54	0.56	3.64	0.1	0.1	0.00
Total Recoverable Chromium	12	12	0.00	13	13	0.00
Total Recoverable Copper	47	48	2.11	30	28	6.90
Total Recoverable Lead	26	27	3.77	21	18.5	12.66
Total Recoverable Nickel	6	5	18.18	9	7	25.00
Total Recoverable Zinc	104	101	2.93	47	45	4.35

Note: Results in *I talics* exceed 30% RPD. Results in red exceed 50% RPD

DUP01 + DUP02 collected in April 2023 Investigaiton

Appendix F

Environment Waikato Groundwater Bore Database Search

Well Number	Distance to Start Point	Well Name	Drilling Date	Company Name	Easting	Northing	Latitude	Longitude	Location Accuracy	Elevation	Static Water Level	Geothermal	Depth	Max Diameter	Consents/water use
72_4297	849.57	Bore 72 - Station 4297	29/09/2008	Barham United Welldrillers Limited	1804063	5783529	-38.07301	175.3264		40	12.75	No	80	200	Construct a well for municipal, stock and domestic water supply purposes
72_10906	850.08	Bore 72 - Station 10906			1804682	5784846	-38.06101	175.33308	<100.0m			No			to construct, use and maintain a well for nursery irrigation
72_4997	905.92	Bore 72 - Station 4997	07/04/2010	Barham United Welldrillers Limited	1803626	5785210	-38.05797	175.32095		41	7.5	No	79.5	100	Construct a well for household water supply and stock watering purposes
72_5356	950.97	Bore 72 - Station 5356	16/05/2011	Barham United Welldrillers Limited	1804119	5783434	-38.07385	175.32707		40	10.5	No	79	100	Construct a well for municipal, stock and domestic water supply purposes
70_1114	963.55	Bore 70 - Station 1114	02/07/1997	Brown Bros (N.Z.) Limited	1804303	5783468	-38.0735	175.32916		35.2		No	2		Construct a well for groundwater monitoring purposes
70_1117	963.55	Bore 70 - Station 1117	02/07/1997		1804303	5783468	-38.0735	175.32916		35.2		No	5	50	Construct a well for municipal, stock and domestic water supply purposes
70_1119	963.55	Bore 70 - Station 1119	03/07/1997		1804303	5783468	-38.0735	175.32916		35.2		No	3.5	50	NA - unable to locate
70_1116	963.55	Bore 70 - Station 1116	02/07/1997		1804303	5783468	-38.0735	175.32916		35.2		No	5	50	NA - unable to locate
70_1121	963.55	Bore 70 - Station 1121	03/07/1997		1804303	5783468	-38.0735	175.32916		35.2		No	5.5	50	NA - unable to locate
70_1115	963.55	Bore 70 - Station 1115	02/07/1997		1804303	5783468	-38.0735	175.32916		35.2		No	3.5	50	NA - unable to locate
70_1118	963.55	Bore 70 - Station 1118	02/07/1997		1804303	5783468	-38.0735	175.32916		35.2		No	5	50	NA - unable to locate
70_1120	963.55	Bore 70 - Station 1120	03/07/1997		1804303	5783468	-38.0735	175.32916		35.2		No	4	50	NA - unable to locate

Appendix G

Landfill Area/Volume Estimates

Area A Summary

Area A west: uncontrolled fill, no reduction in volume applied
Area A east: fill in trenches 3m wide, with 1m spacings between, apply 25% volume reduction

	Area A west (m^3)	Area A East (m^3)	Max volume estimate (m^3)	Min volume estimate (m^3)
Topsoil	242	874	1116	1116
Cover	600	6150	6750	6750
Fill	2903	13411	16313	12960
Natural	236	1363	1599	1258

Volume Calculations - Area A West

Area: 1180 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP1	Topsoil	0.2	0.2	0.218	0.044	52
	Cover	0.7	0.5		0.109	129
	Fill	3	2.3		0.502	593
	Natural	-	0.2		0.044	52
TP2	Topsoil	0.25	0.25	0.149	0.037	44
	Cover	0.8	0.55		0.082	97
	Fill	3.3	2.5		0.373	440
	Natural	-	0.2		0.030	35
TP3	Topsoil	0.2	0.2	0.118	0.024	28
	Cover	0.7	0.5		0.059	70
	Fill	3.6	2.9		0.343	405
	Natural	-	0.2		0.024	28
TP4	Topsoil	0.3	0.3	0.089	0.027	32
	Cover	1	0.7		0.063	74
	Fill	4	3		0.268	316
	Natural	-	0.2		0.018	21
TP35	Topsoil	0.1	0.1	0.180	0.018	21
	Cover	0.7	0.6		0.108	127
	Fill	3.1	2.4		0.431	508
	Natural	-	0.2		0.036	42
TP38	Topsoil	0.2	0.2	0.175	0.035	41
	Cover	0.5	0.3		0.052	62
	Fill	3	2.5		0.437	516
	Natural	-	0.2		0.035	41
TP39	Topsoil	0.3	0.3	0.070	0.021	25
	Cover	0.8	0.5		0.035	41
	Fill	2.3	1.5		0.105	124
	Natural	-	0.2		0.014	17

Check area weighting is correct: Weighting should =1 ----> 1.000

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.205	0.100	0.300
Cover	0.508	0.300	0.700
Fill	2.460	1.500	3.000

Volume totals

Topsoil	242 m^3
Cover	600 m^3
Fill	2903 m^3
Natural	236 m^3

Volume Calculations - Area A East

Area: 6815 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP5	Topsoil	0.1	0.1	0.075	0.008	51
	Cover	1	0.9		0.068	462
	Fill	4.2	3.2		0.241	1643
	Natural	-	0.2		0.015	103
TP6	Topsoil	0.1	0.1	0.110	0.011	75
	Cover	1.2	1.1		0.120	821
	Fill	4.3	3.1		0.340	2314
	Natural	-	0.2		0.022	149
TP7	Topsoil	0.2	0.2	0.136	0.027	185
	Cover	1	0.8		0.109	742
	Fill	2.9	1.9		0.258	1761
	Natural	-	0.2		0.027	185
TP8	Topsoil	0.1	0.1	0.108	0.011	74
	Cover	1.3	1.2		0.130	886
	Fill	3.6	2.3		0.249	1697
	Natural	-	0.2		0.022	148
TP9	Topsoil	0.1	0.1	0.122	0.012	83
	Cover	0.9	0.8		0.098	665
	Fill	3.2	2.3		0.281	1913
	Natural	-	0.2		0.024	166
TP10	Topsoil	0.2	0.2	0.147	0.029	200
	Cover	0.8	0.6		0.088	600
	Fill	3	2.2		0.323	2199
	Natural	-	0.2		0.029	200
TP11	Topsoil	0.1	0.1	0.127	0.013	86
	Cover	1.1	1		0.127	863
	Fill	1.3	0.2		0.025	173
	Natural	-	0.2		0.025	173
TP12	Topsoil	0.1	0.1	0.116	0.012	79
	Cover	1.2	1.1		0.128	869
	Fill	2.7	1.5		0.174	1185
	Natural	-	0.2		0.023	158
TP40	Topsoil	0.1	0.1	0.059	0.006	40
	Cover	0.7	0.6		0.036	243
	Fill	2	1.3		0.077	525
	Natural	-	0.2		0.012	81

Check area weighting is correct: Weighting should =1 ----> 1.000

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.128	0.100	0.200
Cover	0.902	0.600	1.200
Fill	1.968	0.200	3.200

Volume totals

Topsoil	874 m^3
Cover	6150 m^3
Fill	13411 m^3
Natural	1363 m^3

Volume Calculations - Area B

Area: 2790 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP13	Topsoil	0.2	0.2	0.349	0.070	195
	Cover	0.5	0.3		0.105	293
	Fill	3.2	2.7		0.944	2633
	Natural	-	0.2		0.070	195
TP14	Topsoil	0.2	0.2	0.216	0.043	121
	Cover	0.8	0.6		0.130	362
	Fill	1.2	0.4		0.087	242
	Natural	-	0.2		0.043	121
TP15	Topsoil	0.1	0.1	0.324	0.032	90
	Cover	0.5	0.4		0.129	361
	Fill	1	0.5		0.162	452
	Natural	-	0.2		0.065	181
TP16	Topsoil	0.1	0.1	0.110	0.011	31
	Cover	0.2	0.1		0.011	31
	Fill	0.5	0.3		0.033	92
	Natural	-	0.2		0.022	61

Check area weighting is correct: 1.000 Weighting should = 1

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.157	0.100	0.200
Cover	0.375	0.100	0.600
Fill	1.225	0.300	2.700

Volume totals

Topsoil	437 m^3
Cover	1047 m^3
Fill	3418 m^3
Natural	558 m^3

Volume Calculations - Area C

Area: 1180 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP17	Topsoil	0.1	0.1	0.381	0.038	45
	Cover	0.7	0.6		0.228	269
	Fill	3.7	3		1.142	1347
	Natural	-	0.2		0.076	90
TP18	Topsoil	0.2	0.2	0.619	0.124	146
	Cover	0.6	0.4		0.248	292
	Fill	0.6	0		0.000	0
	Natural	-	0.2		0.124	146

Check area weighting is correct: 1.000 Weighting should = 1

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.162	0.100	0.200
Cover	0.476	0.400	0.600
Fill	1.142	0.000	3.000

Volume totals

Topsoil	191	m^3
Cover	562	m^3
Fill	1347	m^3
Natural	236	m^3

Volume Calculations - Area D

Area: 2443 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP27	Topsoil	0.2	0.2	0.334	0.067	163
	Cover	0.4	0.2		0.067	163
	Fill	1.7	1.3		0.435	1062
	Natural	-	0.2		0.067	163
TP30	Topsoil	0.05	0.05	0.273	0.014	33
	Cover	0.3	0.25		0.068	167
	Fill	3.2	2.9		0.792	1934
	Natural	-	0.2		0.055	133
TP31	Topsoil	0.2	0.2	0.194	0.039	95
	Cover	0.2	0		0.000	0
	Fill	0.2	0		0.000	0
	Natural	-	0.2		0.039	95
TP36	Topsoil	0.1	0.1	0.199	0.020	49
	Cover	0.2	0.1		0.020	49
	Fill	2	1.8		0.357	873
	Natural	-	0.2		0.040	97

Check area weighting is correct: 1.000 Weighting should = 1

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.139	0.050	0.200
Cover	0.155	0.000	0.250
Fill	1.584	0.000	2.900

Volume totals

Topsoil	340 m^3
Cover	379 m^3
Fill	3869 m^3
Natural	489 m^3

Volume Calculations - Area E

Area: 659 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP25	Topsoil	0.1	0.1	1.000	0.100	66
	Cover	0.3	0.2		0.200	132
	Fill	0.3	0		0.000	0
	Natural	-	0.2		0.200	132

Check area weighting is correct: 1.000 Weighting should = 1

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.100	0.100	0.100
Cover	0.200	0.200	0.200
Fill	0.000	0.000	0.000

Volume totals

Topsoil	66 m^3
Cover	132 m^3
Fill	0 m^3

Volume Calculations - Area F

Area: 932 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP26	Topsoil	0.2	0.2	1.000	0.200	186
	Cover	0.5	0.3		0.300	280
	Fill	4.5	4		4.000	3728
	Natural	-	0.2		0.200	186

Check area weighting is correct: 1.000 Weighting should = 1

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.200	0.200	0.200
Cover	0.300	0.300	0.300
Fill	4.000	4.000	4.000

Volume totals

Topsoil	186	m^3
Cover	280	m^3
Fill	3728	m^3

Volume Calculations - Area G

Area: 1305 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP19	Topsoil	0.1	0.1	0.179	0.018	23
	Cover	0.5	0.4		0.071	93
	Fill	0.5	0		0.000	0
	Natural	-	0		0.000	0
TP20	Topsoil	0.2	0.2	0.251	0.050	66
	Cover	0.4	0.2		0.050	66
	Fill	0.4	0		0.000	0
	Natural	-	0		0.000	0
TP21	Topsoil	0.1	0.1	0.196	0.020	26
	Cover	0.8	0.7		0.137	179
	Fill	0.8	0		0.000	0
	Natural	-	0		0.000	0
TP22	Topsoil	0.2	0.2	0.254	0.051	66
	Cover	0.2	0		0.000	0
	Fill	0.2	0		0.000	0
	Natural	-	0.2		0.051	66
TP23	Topsoil	0.1	0.1	0.093	0.009	12
	Cover	0.1	0		0.000	0
	Fill	0.1	0		0.000	0
	Natural	-	0.2		0.019	24
TP24	Topsoil	0.1	0.1	0.026	0.003	3
	Cover	0.1	0		0.000	0
	Fill	0.1	0		0.000	0
	Natural	-	0.2		0.005	7

Check area weighting is correct: 1.000 Weighting should = 1

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.151	0.100	0.200
Cover	0.259	0.000	0.700
Fill	0.000	0.000	0.000

Volume totals

Topsoil	197 m^3
Cover	338 m^3
Fill	0 m^3

Volume Calculations - Area H

Area: 1979 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP32	Topsoil	0	0	0.114	0.000	0
	Cover	0.3	0.3		0.034	68
	Fill	1.5	1.2		0.137	272
	Natural	-	0.2		0.023	45
TP33	Topsoil	0	0	0.132	0.000	0
	Cover	0	0		0.000	0
	Fill	0.3	0.3		0.040	79
	Natural	-	0.2		0.026	52
TP34	Topsoil	0	0	0.254	0.000	0
	Cover	0	0		0.000	0
	Fill	0.5	0.5		0.127	252
	Natural	-	0.2		0.051	101
TP37	Topsoil	0	0	0.280	0.000	0
	Cover	0	0		0.000	0
	Fill	0.4	0.4		0.112	222
	Natural	1.1	0.2		0.056	111
TP54	Topsoil	0	0	0.055	0.000	0
	Cover	0	0		0.000	0
	Fill	0.2	0.2		0.011	22
	Natural	-	0.2		0.011	22
TP55	Topsoil	0	0	0.164	0.000	0
	Cover	0	0		0.000	0
	Fill	0.2	0.2		0.033	65
	Natural	-	0.2		0.033	65

Check area weighting is correct: 1.000 Weighting should = 1

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.000	0.000	0.000
Cover	0.034	0.000	0.300
Fill	0.460	0.000	1.200

Volume totals

Topsoil	0	m^3
Cover	68	m^3
Fill	910	m^3
Natural	396	m^3

Volume Calculations - Area I

Area: 1570 m^2

Testpit	Soils	Depth BGL	Depth	Weighting	Depth x Weight	Volume
TP50	Topsoil	0.2	0.2	0.266	0.053	84
	Cover	0.2	0		0.000	0
	Fill	1.9	1.7		0.452	710
	Natural	-	0.2		0.053	84
TP56	Topsoil	0	0	0.281	0.000	0
	Cover	0	0		0.000	0
	Fill	2.3	2.3		0.647	1016
	Natural	-	0.2		0.056	88
TP57	Topsoil	0.1	0.1	0.453	0.045	71
	Cover	0.1	0		0.000	0
	Fill	2	1.9		0.860	1351
	Natural	-	0.2		0.091	142

Check area weighting is correct: 1.000 Weighting should = 1

Soil Stats	Average (m)	Min (m)	Max (m)
Topsoil	0.099	0.000	0.200
Cover	0.000	0.000	0.000
Fill	1.960	1.700	2.300

Volume totals

Topsoil	155 m^3
Cover	0 m^3
Fill	3078 m^3

Appendix H

Flood Risk Assessment

Fraser Thomas Limited
21 El Kobar Drive : East Tamaki : AUCKLAND 2013
PO Box 204006 : Highbrook : AUCKLAND 2161
NEW ZEALAND
TEL +64 9 278 7078 : FAX +64 9 278 3697 : E-MAIL sfinnigan@ftl.co.nz

ENGINEERS • RESOURCE MANAGERS • SURVEYORS

MEMORANDUM: TOKANUI HOSPITAL – DISPOSAL SITES FLOOD RISK ASSESSMENT (REV 1)

Date: 17/07/2023

From: Tim Bohles/ Sean Finnigan

Subject: Tokanui Hospital – Disposal Sites Flood Risk Assessment

To: Toitū Te Whenua, Land Information New Zealand – Kim Wepasnick

FTL have completed a flood risk assessment focussing of the potential effect of a flood event on the existing historical landfill areas (disposal sites) at the Tokanui Hospital. The landfill extents have been estimated from the FTL 2022-23 intrusive investigation.

1.0 STORMWATER FLOW ESTIMATION

Stormwater catchments were delineated from the LINZ LiDAR survey for the immediate area, and 2007-2008 Waikato LiDAR data for the catchment area outside of the site. Two main catchments were delineated, referred to as the southern and western catchments in this Memo. The southern catchment (440ha) drains to the main stream, which flows through it in a south to north direction. The western catchment (166ha) drains through the hospital site's detention storage areas and enters the main stream near Te Mawhai Road. Refer Figure 1 for catchment locations.

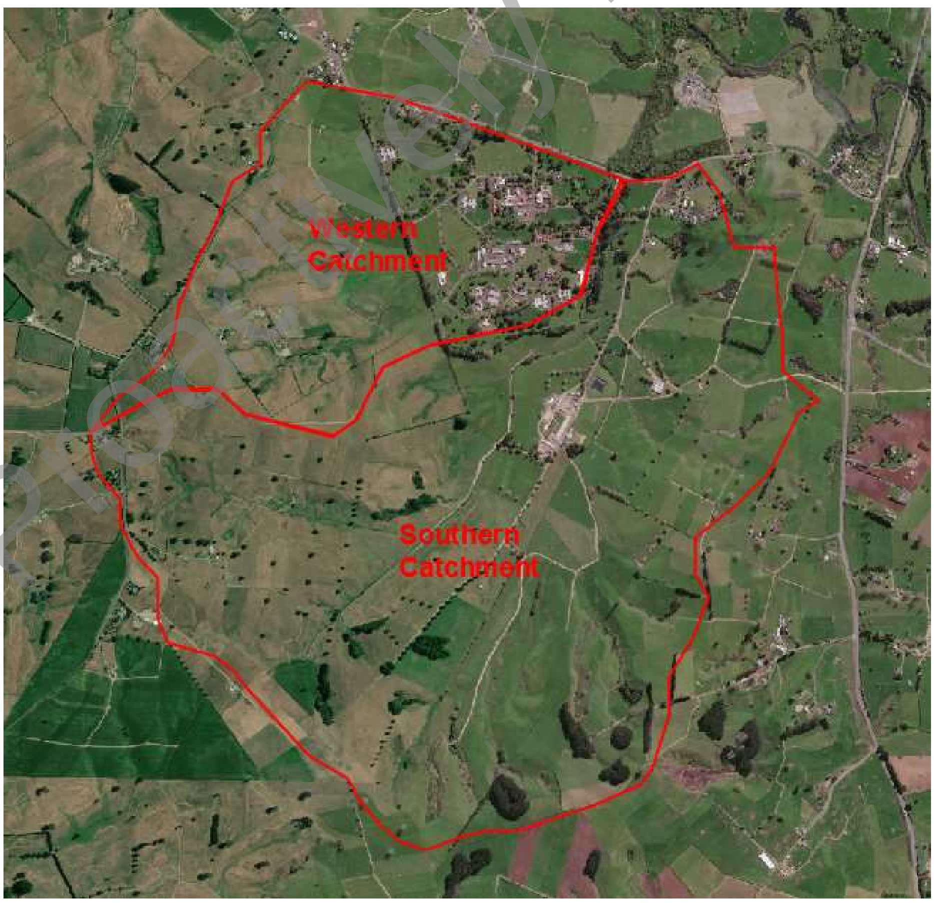

Figure 1: Catchment Locations

Stormwater flows were calculated using the Waikato Stormwater Runoff Modelling Guideline TR20/06 methodology. The catchment is primarily composed of alluvium and colluvium gravel sand and mud. A curve number of 74 was assumed for the entire area corresponding to good condition, open space with group C soils. The catchment flow hydrograph was modelled in HEC-HMS for the 1% Annual Exceedance Probability (AEP) rainfall event, as well as the 1% AEP (annual exceedance probability) event including an allowance for climate change. Climate change was accounted for by using the HIRDS RCP8.5 rainfall scenario for the years 2081-2100. This is considered more conservative than allowing for a 2.1 degree increase in climate as specified by the Waikato Stormwater Runoff Modelling Guideline. Refer Appendix A for associated calculations.

Stormwater culverts were modelled in four locations as shown on Figure 2. Culvert 1 under Te Mawhai Road was assumed to be 1500mm in diameter as it could not be located[1]. Culvert 2 under the smaller former hospital access road was assumed to be 1350mm in diameter as it also could not be located. Culvert 3 was surveyed and is 1350mm in diameter. Culvert 4 is 1000mm in diameter, based on historic plans provided by LINZ. The assumed culvert diameters were based on the expectation that culverts 1 and 2 would be at least as large as culvert 3 and engineering judgement.

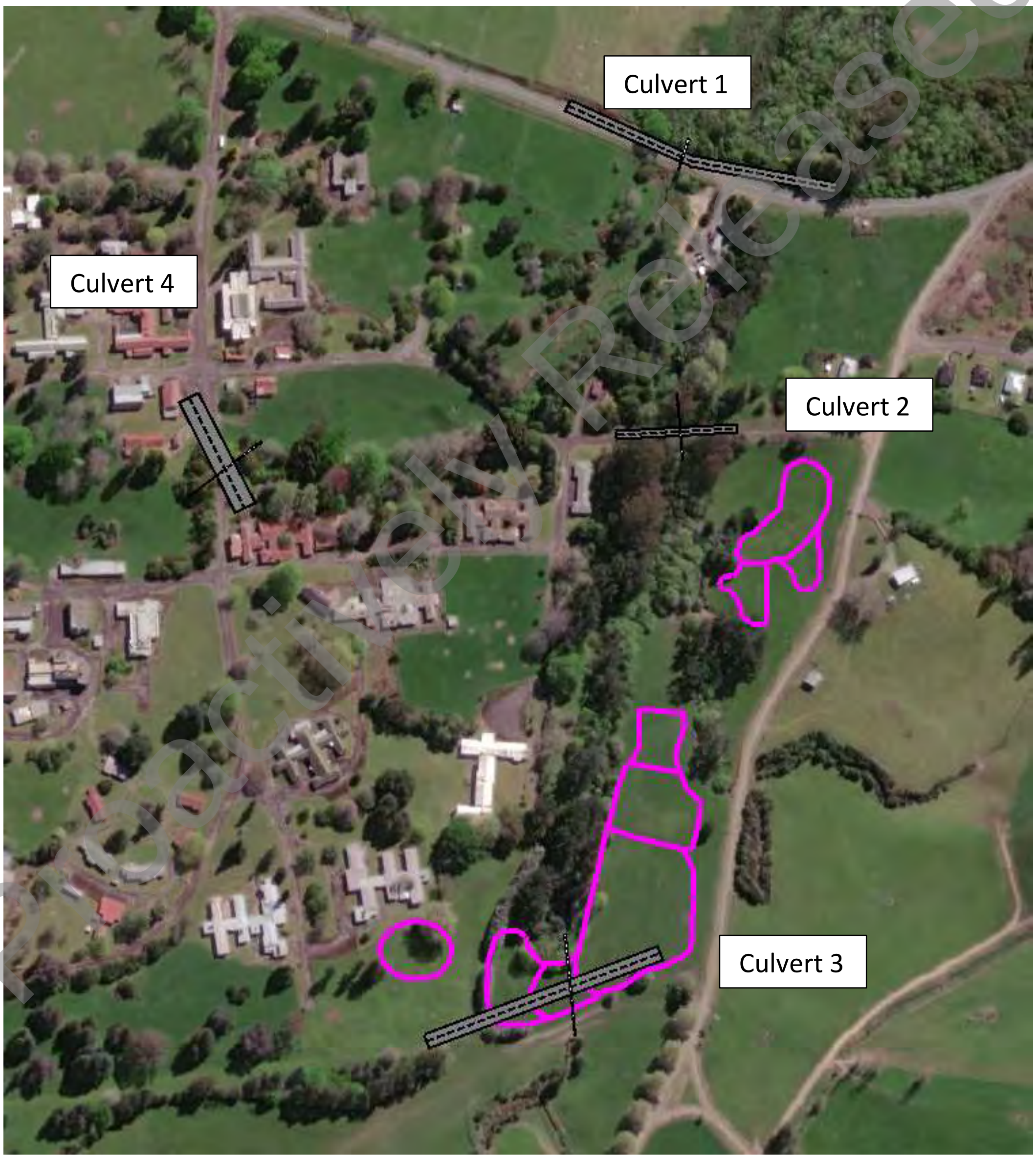

Figure 2: Culvert Locations

2.0 STORMWATER MODELLING

2.1 Methodology

[1] Since the modelling was undertaken, Waipa District Council have advised that this culvert is a 1600mm dia concrete pipe (according to their RAMM records) installed in the early 1970s. The modelling has not been revised for this minor change, as it is not expected to have a significant effect on the results.

The flood extent was modelled using HEC-RAS 2D software. A TIN surface was formed from the LINZ LiDAR and 2007-2008 Waikato LiDAR. A uniform Mannings roughness of 0.06 was assumed for the entire area. This Mannings roughness value represents a clay channel bed with light brush and trees. Surveyed stream cross sections at six locations (refer Appendix B) were used to validate that the LiDAR was reasonably accurate within the area. This is commented on further in section 2.7 of this Memo.

2.2 Modelling Scenarios

Four scenarios were modelled:

- Scenario 1: All culverts fully blocked – 1% AEP + allowance for climate change
- Scenario 2: All culverts fully operational – 1% AEP + allowance for climate change
- Scenario 3: All culverts fully operational – 1% AEP storm event
- Scenario 4: All culverts fully operational, but removing the access road bund/Culvert 2 to allow flows to drain through the stream more easily- 1% AEP + allowance for climate change

Site inspections of the culverts found that culverts 3 and 4 appear to be fully operational while both culverts 1 and 2 could not be located – some ponding does occur upstream of both of these culverts, suggesting that they are partially blocked to a reasonable extent. Hence, the most realistic scenarios, representing the actual current situation, allowing for climate change, are considered to be somewhere between Scenarios 1 and 2.

Scenario 4 was included as a possible mitigation option. The culvert 2 embankment comprises a former road crossing of the stream into the hospital site, which is now redundant. The culvert 2 embankment level is approximately 36m RL, while the Te Mawhai Road embankment (over Culvert 1) is approximately 33m RL. Preliminary flood modelling showed flood levels are largely controlled by these embankments. Hence, this scenario was included to test whether removal of this culvert and associated embankment would result in a significant reduction in flood levels due to the elevation difference of the two embankments.

2.3 Flood Extents

Flood maps were generated for the four scenarios and are shown on FTL Drawing 33097/12, with further information in Appendix A. These show that there is a high risk of some of the historic landfilling areas being inundated by the 1% AEP storm event, with and without climate change, as summarised in the following table. The main areas at risk of flooding are in order of decreasing severity: Area A (west) and H > Area G > Area C > Area B > Area A (east) > Area I. Areas D, E and F are all outside the modelled flood extent for all four scenarios.

For Scenario 4, removal of Culvert 2 and the associated embankment results in a significant reduction compared with other scenarios. It reduces flooding to less than Scenario 3 (1% AEP storm event) in all locations, except in Areas A (west) and H and upstream of this because this area is controlled by the Culvert 3 embankment.

Table 1: Flood Modelling Results – Flooded Areas

Scenario	3	2	1	4
Culvert Status	Fully operational	Fully operational	All blocked	Fully operational
Storm Event	1% AEP	1% AEP + CC	1% AEP + CC	1% AEP + CC
Mitigation Option	None	None	None	Culvert 2 and associated embankment removed
Area	**Flooded Areas, m^2 (% of total area)**			
A West (1,180m^2)	1,180 (100%)	1,180 (100%)	1,180 (100%)	1,130 (96%)
A East (6,820m^2)	420 (6%)	1,480 (22%)	2,400 (35%)	350 (5%)
B (2,790m^2)	790 (28%)	1,340 (48%)	2,540 (91%)	380 (14%)
C (1,180m^2)	760 (64%)	960 (81%)	1,180 (100%)	490 (42%)
D (2,440m^2)	0 (0%)	0 (0%)	10 (0.4%)	0 (0%)
E (660m^2)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
F (930m^2)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
H (1,980m^2)	1,740 (88%)	1,980 (100%)	1,980 (100%)	1,810 (91%)
I (1,570m^2)	0 (0%)	20 (1%)	110 (7%)	0 (0%)

2.4 Flood Levels

Flood levels vary depending on the scenario and location. Flood levels have been indicated on FTL Drawing 33097/12.

2.5 Scour/Erosion Effects

Stream channels evolve over time to convey a certain level of flow commonly referred to as the "channel forming flow" or "bankfull discharge" which generally ranges from recurrence intervals of 1 to 2.5 years. Streams will adjust and further evolve when flows are altered as a result of land use changes, development in the catchment, damming, or other mechanisms. Higher discharge rates can result in erosive processes leading to channel widening and increases in channel cross-section area.

Shear stress is often used to predict whether streams are stable or not. Shear stress increases with increasing flow depth and increasing water surface gradient.

Culvert 2 is located below all landfill areas. During a storm event, stream flows and velocities will gradually increase, until the culvert starts to throttle these flows/velocities, resulting in water ponding upstream of the culvert, increasing the flow depth but decreasing the water surface gradient. For simplicity here, flow velocity has been adopted as a proxy for shear stress effects, as velocity is affected both by flow depth and water surface gradient. If Culvert 2 was removed, Culvert 1 would still exhibit a throttle effect, but the associated ponding does not extend as far upstream as previously, and hence some of the areas abutting the landfill may experience higher stream velocities than currently and hence be subject to greater scour/erosion than the current situation. Similarly, if a storm were to hit with a peak rainfall very soon after the beginning of the storm, velocities within the channel may be greater as the stream may not have began backing up (i.e. more of a flash flood situation). These situations have been covered under the modelled scenarios, and the maximum velocity within the stream channel was found to be relatively low during the peak of an extreme storm event, due to backing up of water over the crossing at culverts 1 and 2. A maximum of 1.2m/s was calculated for the fully blocked scenario, where water will overtop culvert 2 and rush down the stream. Otherwise typical velocities are predicted to be between 0.5-0.7m/s. Under the NZ Transport Agency Stormwater Treatment for State Highway Infrastructure, the maximum permissible velocity to control stream erosion for stiff clays is 1.14m/s. It is therefore considered that stream erosion is unlikely to be an issue, based on the limited modelling undertaken to date.

Furthermore, historical plans show this stretch of the stream and further downstream to the Pūniu River were historically a swamp (see Figure 3), which is consistent with observations of water ponding in this area and the stream bed being relatively flat, with a measured gradient from LiDAR data of 0.5% between cross-sections C and E.

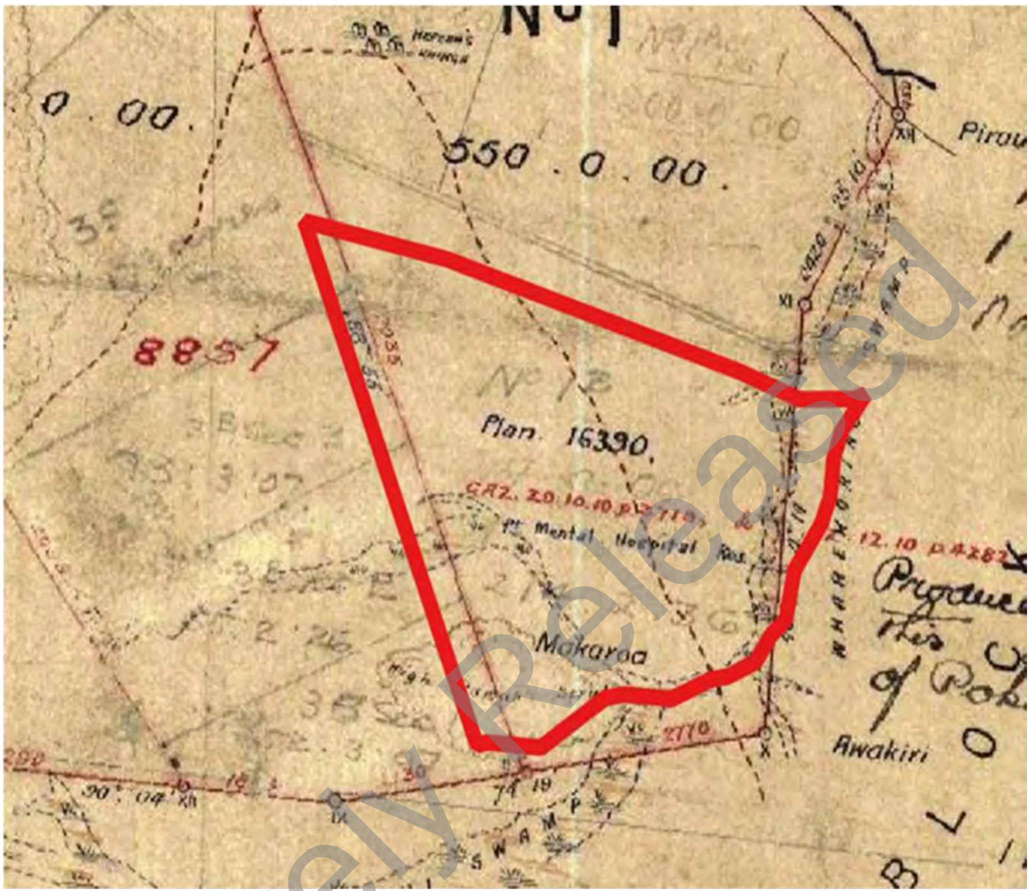

Figure 3: Tokanui Hospital Site – Historical Plan showing former swamps (from CFG, 2023)

2.6 Discussion

The HEC-RAS modelling showed that the landfill areas A, B, C, G and H are currently likely to be inundated to varying extents during a 1% AEP storm event, particularly if the culverts are blocked or become blocked during the storm, with these effects worsening with predicted climate change. This ponded water may result in increased infiltration into the landfill and potentially increase the leaching of contaminants from affected landfill areas.

The velocity through the stream is likely to be low indicating that it is unlikely that significant erosion will occur.

Landfill area A effectively dams the stream, with culvert 1 passing under it. Modelling has shown this area to be inundated during a 1% AEP event, with the culvert being overtopped and flood waters flowing overland through Area A . Velocities over the bunded area where the culvert passes may be moderate-high. This could result in localised scour/erosion along the overland flowpath, potentially exposing the underlying landfill materials, and in the worst case, uplifting some of these materials and carrying them into the stream. This effect has not been quantified as part of the modelling done to date.

Flood levels could be significantly reduced by removing the access road at culvert 2. This would prevent the inundation of the majority of the landfill areas during a 1% AEP storm. However, it should be noted that this access road acts to detain water within the catchment, and removing it may result in higher peak flows downstream. Downstream discharges were calculated as 2.5m^3/s for the completely blocked scenario 1, 10.7m^3/s for the unblocked scenario 2, and 33m^3/s for scenario 4 which allowed for the culvert 2 embankment being removed. Overall this shows that the bund performs a good detention function for the overall catchment.

Below Culvert 1, the stream flows approximately 700m before entering the considerably larger Pūniu River. Mangatoatoa Marae is located on the eastern side of the stream before the confluence with the Pūniu River. There are no other buildings along this section of the stream. Downstream effects of culvert 2 removal are considered likely to be less than minor, as the Marae is approximately 9m above the level of the stream, and as such should not be affected by an increase in the stream flows. This can be checked as part of further design work for removal of this culvert.

Removal of culvert 2 may also have some ecological benefits, which the project ecologists should be able to comment on.

2.7 Modelling Limitations

The accuracy of this modelling is subject to the following main limitations:

- Use of estimated diameters for culverts 1 and 2. Once these culverts are located and their dimensions confirmed, the model can be rerun to check effects on flood levels. However, the culverts are not expected to be significantly larger than assumed for this assessment and hence flood extents and levels are considered unlikely to change significantly.
- The surveyed stream cross-sections agreed reasonably well with LiDAR survey data at cross-sections, but were consistently higher than LiDAR survey data at cross-sections A-D. LiDAR data was used in the model to avoid surface discontinuities affecting running of the model, but the ground surface could potentially be higher by 0.3-0.8m from cross-sections A-D, resulting in some increases in flood level in these areas. This is not anticipated to have a significant effect on the flood extents however, as the cross sections are fairly consistent in shape relative to LiDAR, and as such will still spread out a similar amount. If this were to have an effect, the flood extents on landfill areas A or B might be slightly reduced.
- Use of a uniform Mannings roughness of 0.06. Flooding has been shown to primarily be controlled by water backing up behind Culvert 2 and hence flood levels are not expected to be sensitive to variations in Mannings values. This could be checked through sensitivity testing if required.
- Only the 1% AEP storm has been modelled to date. Hence, the critical storm which results in the onset of flooding over landfilled areas and the frequency of flooding has not yet been established.

3.0 CONCLUSION

Flood modelling has shown that there is a potential hazard posed by flooding of former landfill areas in a 1% AEP storm event with and without climate change. Several areas are estimated to be inundated in a 1% AEP storm event. Area H and A (west) of the landfill are likely to be eroded by flood waters. There is potential for flood levels to be significantly reduced by removal of the access road at culvert 2; however this may result in increases to peak flows downstream and associated increased flood levels in the stream but a preliminary assessment indicates this is unlikely to affect the only nearby downstream property with buildings – the Mangatoatoa Marae. This should be checked during the next phase of work.

4.0 DISCLAIMER

The professional opinion expressed herein has been prepared solely for, and is furnished to our client, Toitū Te Whenua Land Information New Zealand, on the express condition that it will only be used for the purpose for which it is intended.

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We do not assume any liability for misrepresentation or items not visible, accessible or present at the subject site during the time of the site inspection; or for the validity or accuracy of any information provided by our client or third parties that have been utilised in the preparation of this report.

The conclusions and recommendations expressed herein should be read in conjunction with the remainder of this report and should not be referred to out of context with the remainder of this report.

Yours sincerely
FRASER THOMAS LIMITED

S M Finnigan
Director – Environmental

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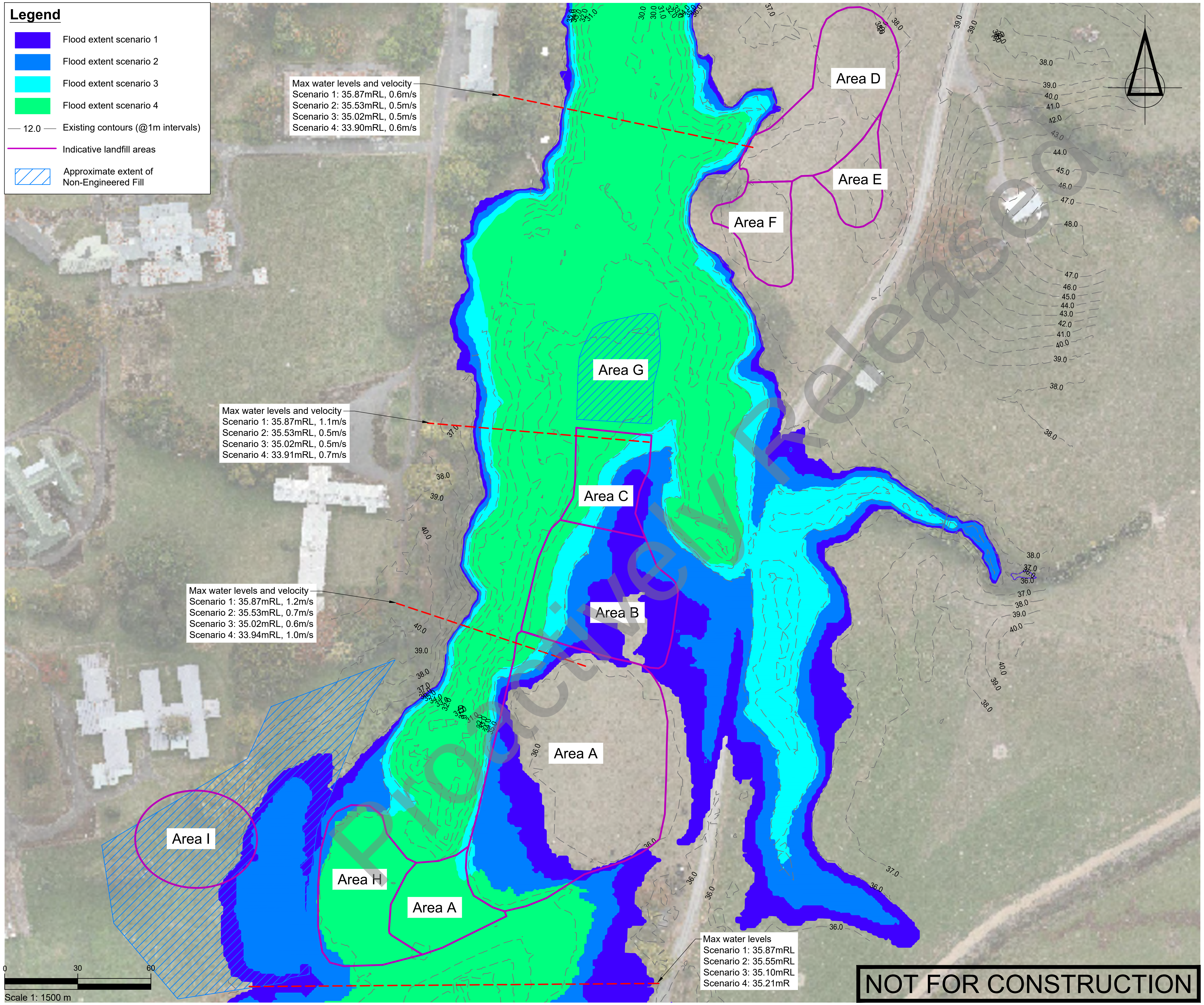
Incl:
Drawing 33097/12-15
Appendix A: Catchment and Flow Calculations

Drawings



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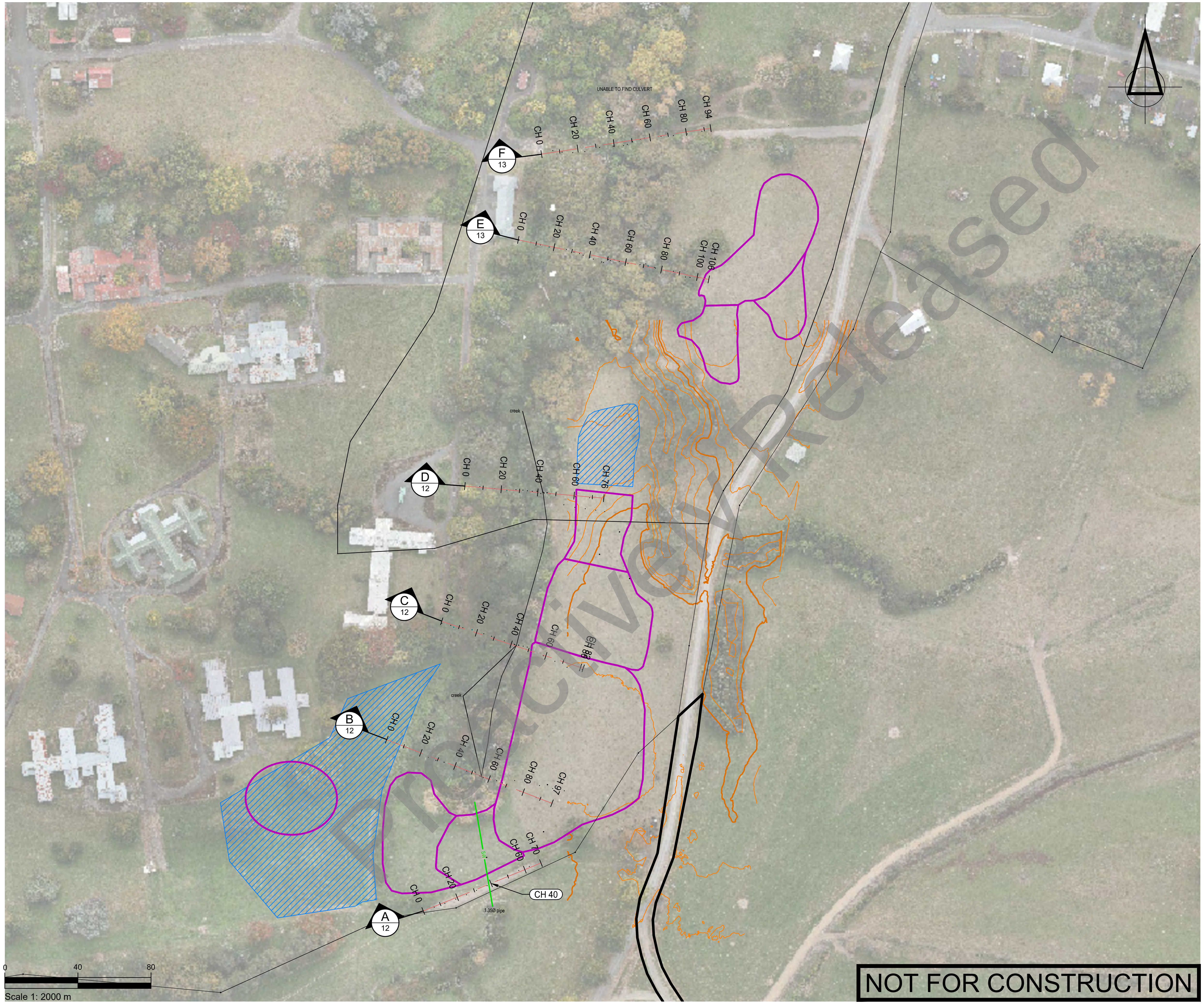

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Legend

- - - Lidar level
— Survey level

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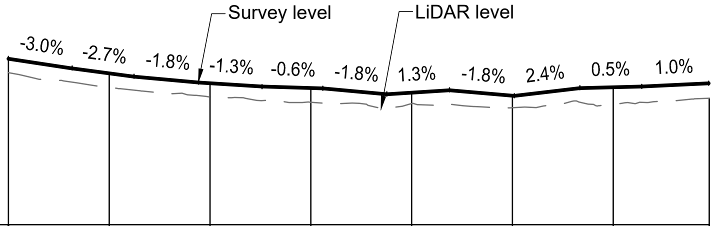

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LIDAR LEVELS	35.01	34.72	34.53	34.42	34.40	34.32	34.38	34.50
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Cross Section A

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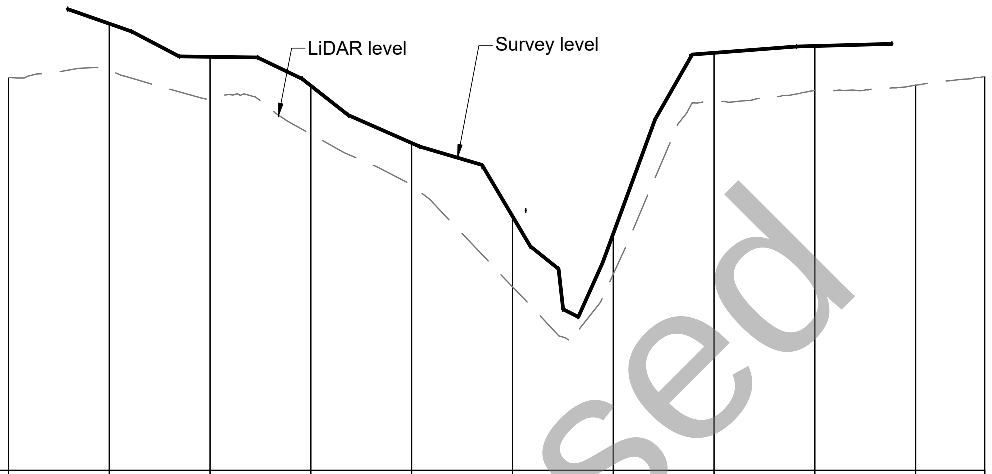

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LEVEL DIFF		0.93	0.83	0.96	0.84	1.40	0.80	0.96	0.88		
SURVEY LEVELS		36.86	36.20	35.63	34.49	33.05	32.70	36.28	36.42		
LIDAR LEVELS	35.79	35.94	35.37	34.67	33.66	31.65	31.89	35.32	35.53	35.64	35.82
CHAINAGE	0	10	20	30	40	50	60	70	80	90	97

Cross Section B

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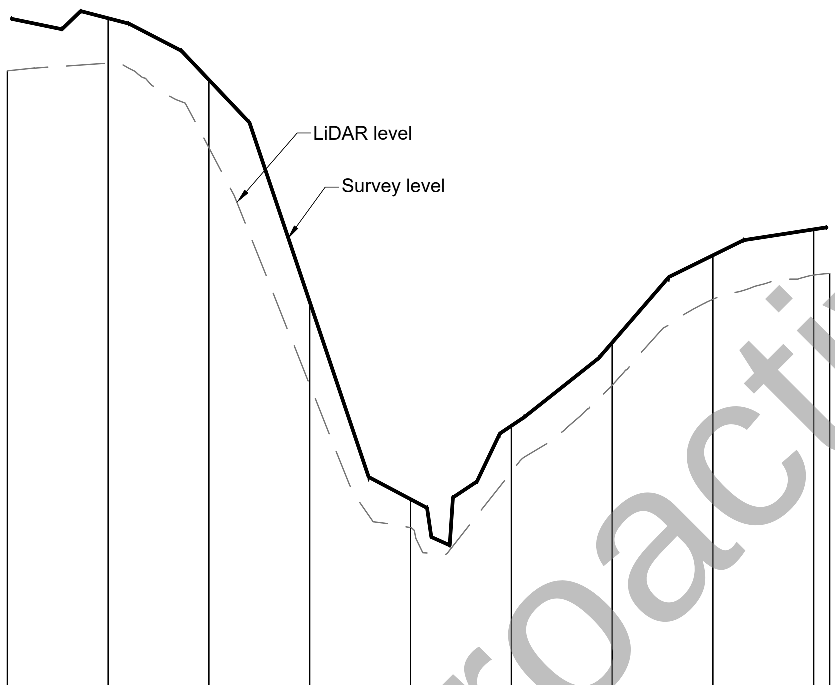

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SURVEY LEVELS		41.26	40.05	35.64	31.73	33.18	34.83	36.56	37.08	
LIDAR LEVELS	40.22	40.37	38.70	34.00	31.16	32.26	33.98	35.69	36.17	36.20
CHAINAGE	0	10	20	30	40	50	60	70	80	82

Cross Section C

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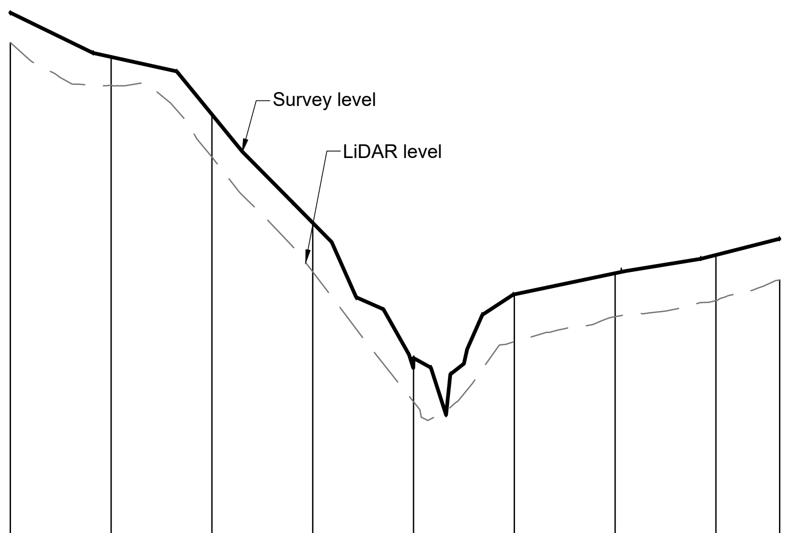

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LEVEL DIFF		0.56	0.85	0.97	0.87	0.94	0.86	0.91	
SURVEY LEVELS		37.50	36.36	34.21	31.52	32.79	33.21	33.57	
LIDAR LEVELS	37.78	36.94	35.51	33.23	30.66	31.85	32.35	32.66	33.07
CHAINAGE	0	10	20	30	40	50	60	70	76

Cross Section D

Scale 1:750 horiz, 1:150 vert

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Legend

Lidar level (dashed line)

Survey level (solid line)

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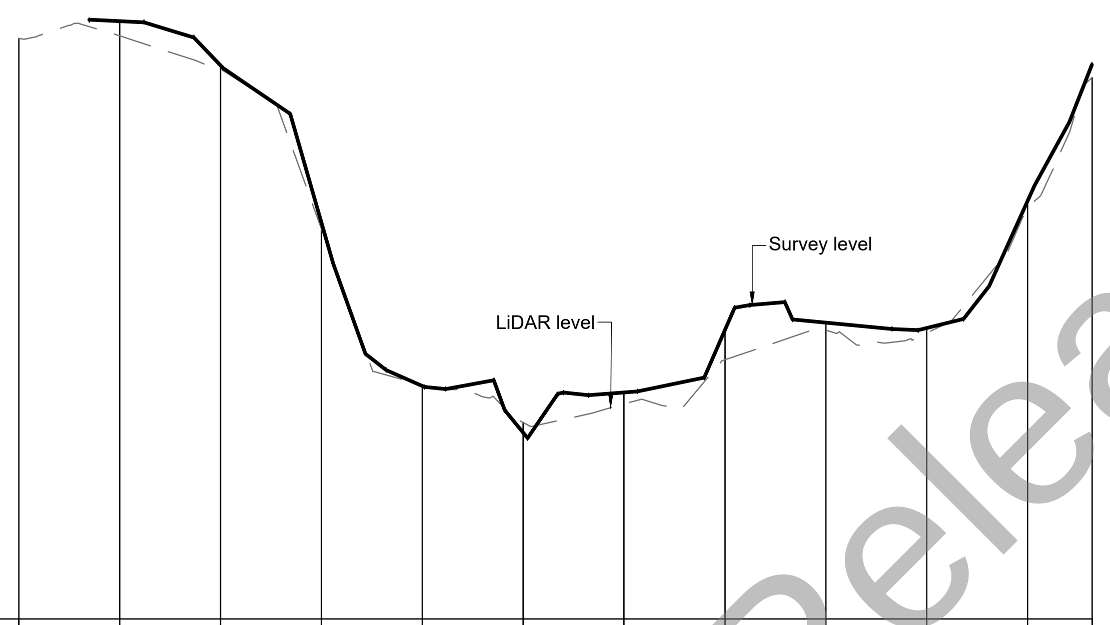

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LIDAR LEVELS	37.52	37.57	36.91	33.73	30.65	29.90	30.27	31.14	31.73	31.67	34.12	36.74
CHAINAGE	0	10	20	30	40	50	60	70	80	90	100	106

Cross Section E

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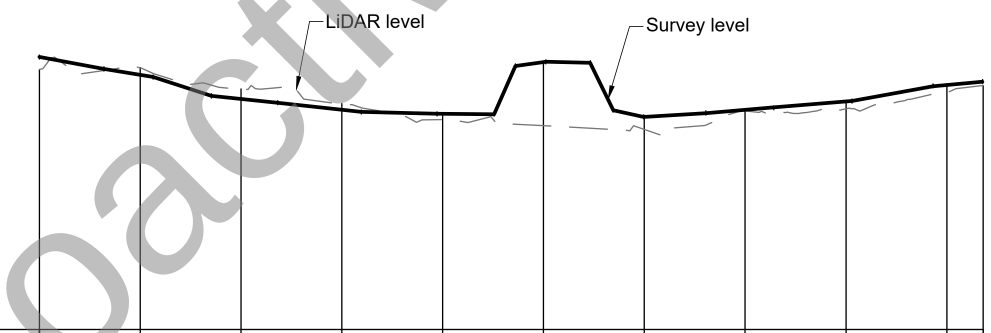

DATUM: 32.00

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SURVEY LEVELS		37.05	36.57	36.36	36.27	37.30	36.22	36.36	36.52	36.85	
LIDAR LEVELS	37.15	37.19	36.77	36.48	36.16	36.04	35.97	36.33	36.38	36.70	36.84
CHAINAGE	0	10	20	30	40	50	60	70	80	90	94

Cross Section F

Scale 1:750 horiz, 1:150 vert

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Appendix A
Catchment and Flow Calculations

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Catchment West

Catchment characteristics

	Soil Group	CN	Area (ha)	
Undisturbed pasture	C	74	160	(Pasture good condition)
Reinstated pasture	D	80	0	(Pasture good condition)
Capped area	D	89	0	(Pasture poor condition)
Total Area	160			
Weighted CN	74			
S	89.2432432			
Ia	4.46216216			

Time of concentration

Sheet and shallow concentrated flow

Length of flow	200	m		
Slope	10.500	%		
Mannings n	0.045			
Time	16.16	Minutes		

Open channel flow 1

Slope	0.037	m/m		
Mannings n	0.035			
Channel base width	0.5	m		
Channel height	0.5	m		
Channel side slope 1:	3			
Hydraulic radius	0.273			
Velocity	2.30	m/s	Q check	2.300125
Length	820	m		
Time	5.94	Minutes		

Open channel flow 2

Slope	0.0029	m/m		
Mannings n	0.035			
Channel base width	2	m		
Channel height	1.5	m		
Channel side slope	3			
Hydraulic radius	0.849			
Velocity	1.38	m/s	Q check	13.47767
Length	1030	m		
Time	12.42	Minutes		

Pipe flow N/A

Gradient
Diameter
Velocity
Length
Time

Total time of concetration

Time	34.52	Minutes
Lag time	0.38	Hours

Catchment time of concentration check

Length	2500
Height difference	54.5
Time	35.17

Catchment South

Catchment characteristics

	Soil Group	CN	Area (ha)	
Undisturbed pasture	C	74	440	(Pasture good condition)
Reinstated pasture	D	80	0	(Pasture good condition)
Capped area	D	89	0	(Pasture poor condition)
Total Area	440			
Weighted CN	74			
S	89.2432432			
Ia	4.46216216			

Time of concentration

Sheet and shallow concentrated flow

Length of flow	160	m
Slope	20.000	%
Mannings n	0.045	
Time	13.19	Minutes

Open channel flow 1

Slope	0.039	m/m		
Mannings n	0.035			
Channel base width	0.5	m		
Channel height	0.5	m		
Channel side slope 1:	5			
Hydraulic radius	0.268			
Velocity	2.33	m/s	Q check	3.497912
Length	700	m		
Time	5.00	Minutes		

Open channel flow 2

Slope	0.0061	m/m		
Mannings n	0.035			
Channel base width	2	m		
Channel height	1.5	m		
Channel side slope	3			
Hydraulic radius	0.849			
Velocity	2.00	m/s	Q check	19.46425
Length	2140	m		
Time	17.87	Minutes		

Pipe flow N/A

Gradient
Diameter
Velocity
Length
Time

Total time of concetration

Time	36.06	Minutes
Lag time	0.40	Hours

Catchment time of concentration check

Length	3000
Height difference	72
Time	39.00

Catchment Flow Summary

Western catchment 1% AEP storm

Summary Results for Subbasin "Catchment West"

Project: 33097 catchment flows   Simulation Run: 1% AEP
Subbasin: Catchment West

Start of Run:	18Jan2023, 00:00	Basin Model:	Basin 1
End of Run:	20Jan2023, 00:00	Meteorologic Model:	1% AEP
Compute Time:	27Jan2023, 15:15:23	Control Specifications:	Control 1

Volume Units: ○ MM ◉ 1000 M3

Computed Results

Peak Discharge:	15.98940 (M3/S)	Date/Time of Peak Discharge:	18Jan2023, 12:30
Precipitation Volume:	241.45920 (1000 M3)	Direct Runoff Volume:	145.59947 (1000 M3)
Loss Volume:	95.85974 (1000 M3)	Baseflow Volume:	0.00000 (1000 M3)
Excess Volume:	145.59947 (1000 M3)	Discharge Volume:	145.59947 (1000 M3)

Southern catchment 1% AEP storm

Summary Results for Subbasin "Catchment south"

Project: 33097 catchment flows   Simulation Run: 1% AEP
Subbasin: Catchment south

Start of Run:	18Jan2023, 00:00	Basin Model:	Basin 1
End of Run:	20Jan2023, 00:00	Meteorologic Model:	1% AEP
Compute Time:	27Jan2023, 15:15:23	Control Specifications:	Control 1

Volume Units: ○ MM ◉ 1000 M3

Computed Results

Peak Discharge:	41.83201 (M3/S)	Date/Time of Peak Discharge:	18Jan2023, 12:30
Precipitation Volume:	664.01280 (1000 M3)	Direct Runoff Volume:	400.39853 (1000 M3)
Loss Volume:	263.61427 (1000 M3)	Baseflow Volume:	0.00000 (1000 M3)
Excess Volume:	400.39853 (1000 M3)	Discharge Volume:	400.39853 (1000 M3)

Western catchment 1% AEP + climate change storm

Summary Results for Subbasin "Catchment West"

Project: 33097 catchment flows   Simulation Run: 1% AEP cc
Subbasin: Catchment West

Start of Run:	18Jan2023, 00:00	Basin Model:	Basin 1
End of Run:	20Jan2023, 00:00	Meteorologic Model:	Met 1
Compute Time:	27Jan2023, 12:00:55	Control Specifications:	Control 1

Volume Units: ○ MM ◉ 1000 M3

Computed Results

Peak Discharge:	21.67060 (M3/S)	Date/Time of Peak Discharge:	18Jan2023, 12:30
Precipitation Volume:	295.48160 (1000 M3)	Direct Runoff Volume:	192.84731 (1000 M3)
Loss Volume:	102.63429 (1000 M3)	Baseflow Volume:	0.00000 (1000 M3)
Excess Volume:	192.84731 (1000 M3)	Discharge Volume:	192.84731 (1000 M3)

Southern catchment 1% AEP + climate change storm

Summary Results for Subbasin "Catchment south"

Project: 33097 catchment flows   Simulation Run: 1% AEP cc
Subbasin: Catchment south

Start of Run:	18Jan2023, 00:00	Basin Model:	Basin 1
End of Run:	20Jan2023, 00:00	Meteorologic Model:	Met 1
Compute Time:	27Jan2023, 12:00:55	Control Specifications:	Control 1

Volume Units: ○ MM ◉ 1000 M3

Computed Results

Peak Discharge:	56.74596 (M3/S)	Date/Time of Peak Discharge:	18Jan2023, 12:30
Precipitation Volume:	812.57440 (1000 M3)	Direct Runoff Volume:	530.33011 (1000 M3)
Loss Volume:	282.24429 (1000 M3)	Baseflow Volume:	0.00000 (1000 M3)
Excess Volume:	530.33011 (1000 M3)	Discharge Volume:	530.33011 (1000 M3)