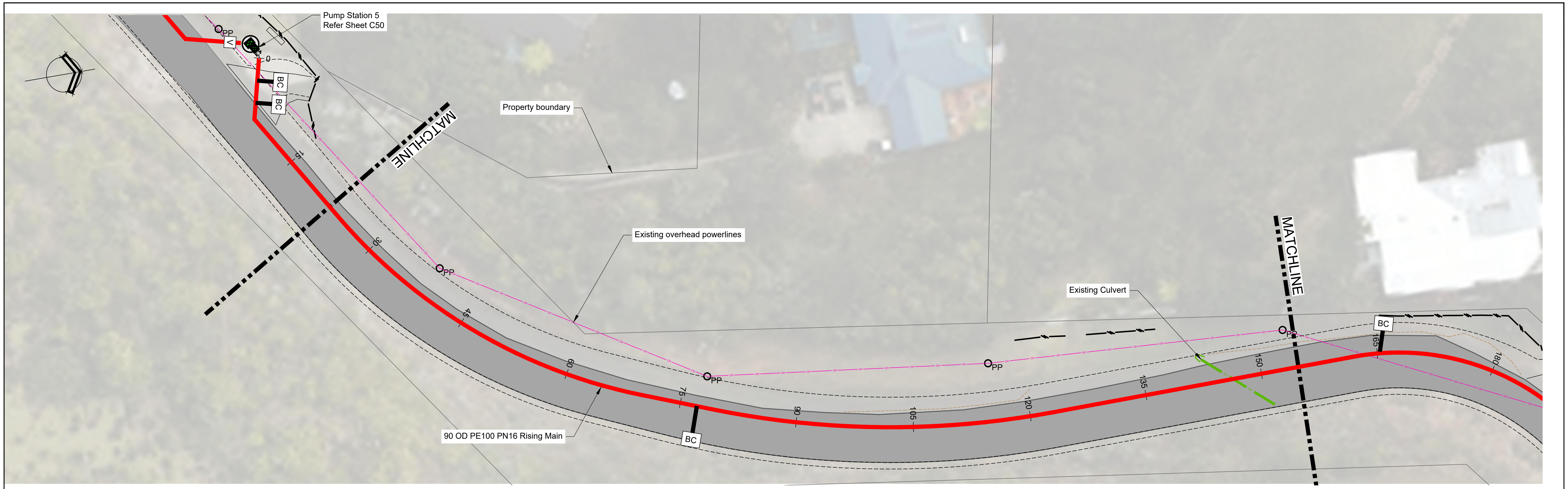
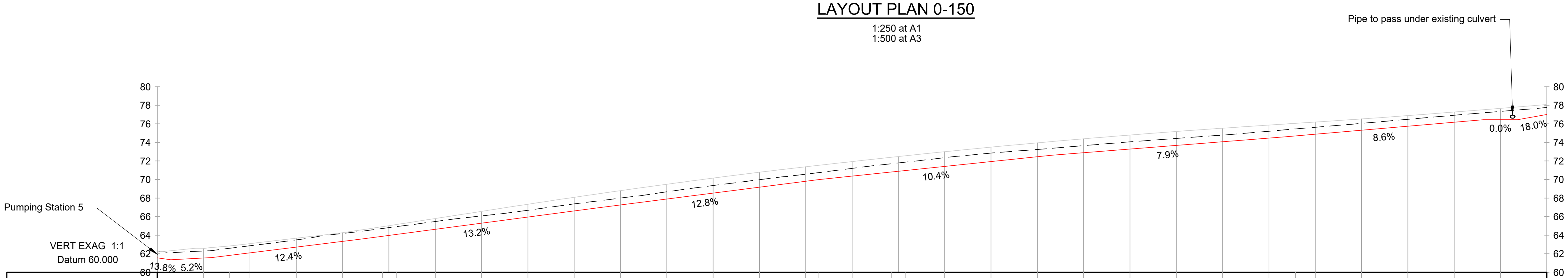


LAYOUT PLAN 0-150

1:250 at A1
1:500 at A3



STATION (m)		5.00	7.81	10.00	15.00	20.00	24.34	25.00	30.00	35.00	40.00	45.00	50.00	55.00	60.00	65.00	69.95	70.00
GROUND LEVEL (m) (Existing)		62.59	62.59	63.09	63.67	64.27	64.73	65.02	65.80	66.57	67.33	68.08	68.80	69.49	70.15	70.78	70.57	71.37
PIPE COVER (m)	0.75	0.76	0.76	0.76	0.78	0.85	0.84	0.84	0.84	0.78	0.73	0.76	0.75	0.78	0.82	0.80	0.76	0.76
PIPE TYPE	90OD PE100 HDPE PN16																	

STATION (m)	75.00	79.28	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	122.85	125.00	130.00	135.00	140.00	145.00	
GROUND LEVEL (m) (Existing)	71.93	71.71	72.48	72.99	73.49	73.95	74.39	74.79	75.18	75.53	75.86	75.45	76.19	76.53	76.89	77.27	77.67	
PIPE COVER (m)	0.83	0.89	0.90	0.94	0.91	0.78	0.76	0.77	0.75	0.72	0.74	0.75	0.75	0.74	0.75	0.76	0.90	0.75
PIPE TYPE	90OD PE100 HDPE PN16																	

LONGSECTION 0-150

1:250 at A1
1:500 at A3

LEGEND

- Existing Telecom/Telecom Pits
- Existing stormwater (culvert / piped)
- Existing power (underground)
- Existing power (overhead)
- Existing property boundary
- Proposed foul sewer rising main
- AV Air Relief Valve
- GHD Road Alignment in plan
- GHD Road Alignment Surface
- Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

100 mm
75 mm
50 mm
40
30
20
10
0

0	For Construction	ACS	ESG	ACS	ACS	29/11/23
Revision		**Des**	**Drn**	**Rvd**	**App**	**Date**

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Client
Australian Government
Department of Infrastructure, Transport, Regional Development and Communications

Project Title
Norfolk Island
KAVHA Wastewater Scheme

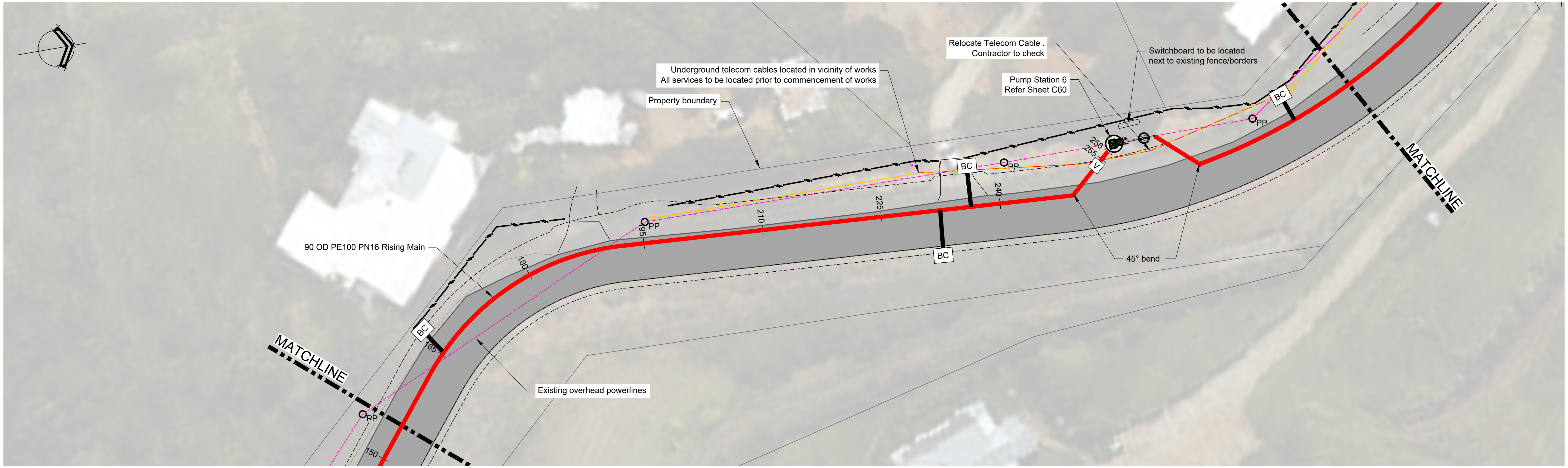
Sheet Title
Pumpstation 5 to Pumpstation 6
Layout Plan and Longsection

Scale (A1 Original) 1:250 m

Issue For Construction

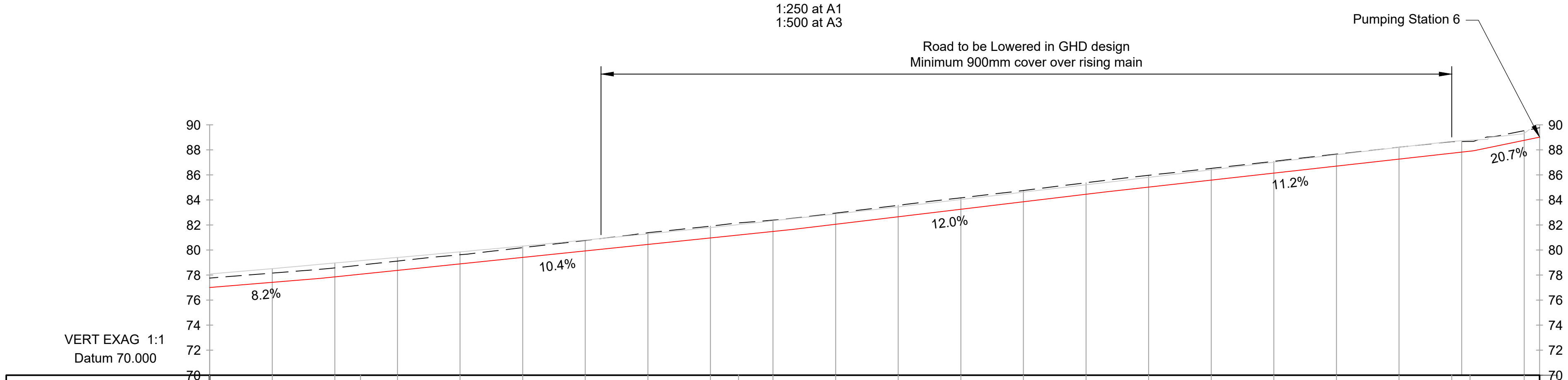
Project No	**Sheet**	**Revision**
000770	C20	0

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\000770 Norfolk C18_PS5-PS6



LAYOUT PLAN 150-256

1:250 at A1
1:500 at A3



STATION (m)	150.00	155.00	160.00	162.06	165.00	170.00	175.00	180.00	185.00	190.00	192.24	195.00	200.00	205.00
GROUND LEVEL (m) (Existing)	78.09	78.51	78.97	78.79	79.40	79.85	80.32	80.79	81.28	81.79	82.16	82.33	82.87	83.44
PIPE COVER (m)	0.75	0.73	0.72	0.73	0.74	0.73	0.78	0.84	0.93	0.94	0.96	0.90	0.89	0.91
PIPE TYPE	90OD PE100 HDPE PN16													

STATION (m)	210.00	215.00	220.00	225.00	230.00	235.00	240.00	245.00	249.21	250.00	255.00	256.22
GROUND LEVEL (m) (Existing)	84.04	84.62	85.21	85.80	86.40	87.01	87.61	88.20	88.65	88.73	89.32	
PIPE COVER (m)	0.91	0.90	0.92	0.94	0.93	0.94	0.96	0.94	0.92	0.84	0.76	0.75
PIPE TYPE												

LONGSECTION 150-256

1:250 at A1
1:500 at A3

LEGEND

—·—·—	Existing Telecom/Telecom Pits
—·—·—	Existing stormwater (culvert / piped)
—·—·—	Existing power (underground)
—·—·—	Existing power (overhead)
—··—··—	Existing property boundary
━━━	Proposed foul sewer rising main
AV	Air Relief Valve
– – –	GHD Road Alignment in plan
———	GHD Road Alignment Surface
– – –	Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

Revision		Des	Drn	Rvd	App	Date
0	For Construction	ACS	ESG	ACS	ACS	29/11/23

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Client
Australian Government
Department of Infrastructure, Transport, Regional Development and Communications

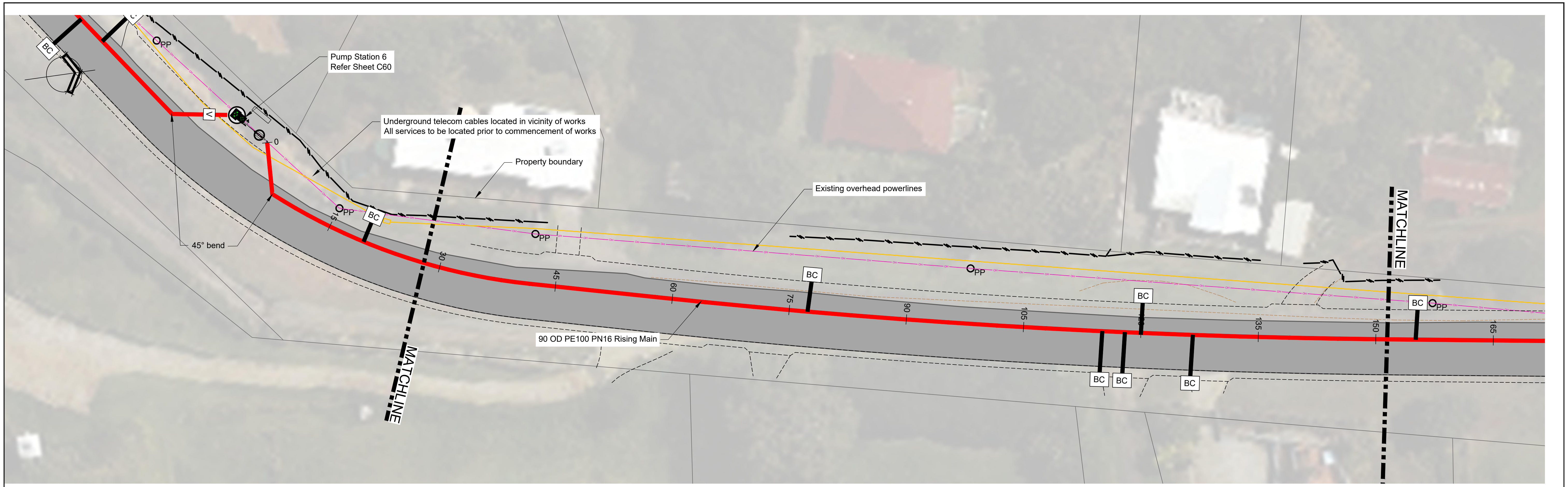
Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Pumpstation 5 to Pumpstation 6
Layout Plan and Longsection

Scale (A1 Original) 1:250 m
Issue For Construction
Project No 000770
Sheet C21
Revision 0

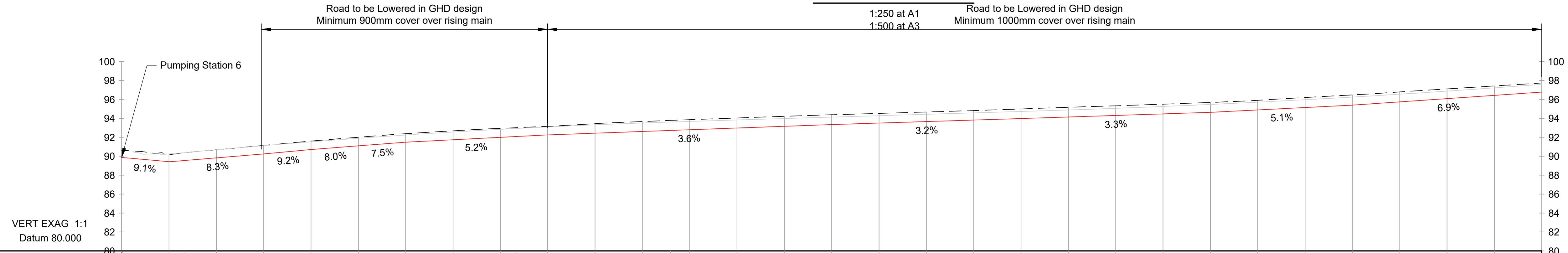
100 mm
75 mm
50 mm
40
30
20
10
0

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\000770 Norfolk C18_PS5-PS6



LAYOUT PLAN 0-150

1:250 at A1
1:500 at A3



STATION (m)	0.00	5.00	6.59	10.00	15.00	20.00	25.00	30.00	35.00	40.00	41.56	45.00	50.00	55.00	57.99	60.00
GROUND LEVEL (m) (Existing)		90.24	90.38	90.68	91.12	91.52	91.90	92.24	92.55	92.84	93.01	93.09	93.32	93.51	93.78	93.68
PIPE COVER (m)	0.75	0.76	0.83	0.85	0.90	0.90	0.90	0.90	0.94	0.95	0.93	0.90	1.01	1.05	1.06	1.06
PIPE TYPE	90OD PE100 HDPE PN16															

STATION (m)	65.00	70.00	75.00	80.00	85.00	90.00	95.00	100.00	105.00	110.00	115.00	120.00	125.00	130.00	135.00	140.00	145.00	
GROUND LEVEL (m) (Existing)	93.83	93.98	94.13	94.28	94.43	94.58	94.73	94.89	95.06	95.26	95.47	95.71	95.97	96.25	96.55	96.88	97.22	
PIPE COVER (m)	1.06	1.05	1.04	1.02	1.01	1.00	1.01	1.02	1.02	1.03	1.04	1.02	1.05	1.07	1.04	1.02	0.99	0.97
PIPE TYPE	90OD PE100 HDPE PN16																	

LONGSECTION 0-150

1:250 at A1
1:500 at A3

LEGEND

— T —	Existing Telecom/Telecom Pits
— SW —	Existing stormwater (culvert / piped)
— P —	Existing power (underground)
— OH —	Existing power (overhead)
— · —	Existing property boundary
▬	Proposed foul sewer rising main
AV	Air Relief Valve
- - -	GHD Road Alignment in plan
——	GHD Road Alignment Surface
- - -	Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

100 mm 75 mm 50 mm 40 30 20 10 0

0	For Construction	ACS	ESG	ACS	ACS 29/11/23
Revision		**Des**	**Drn**	**Rvd**	**App** **Date**

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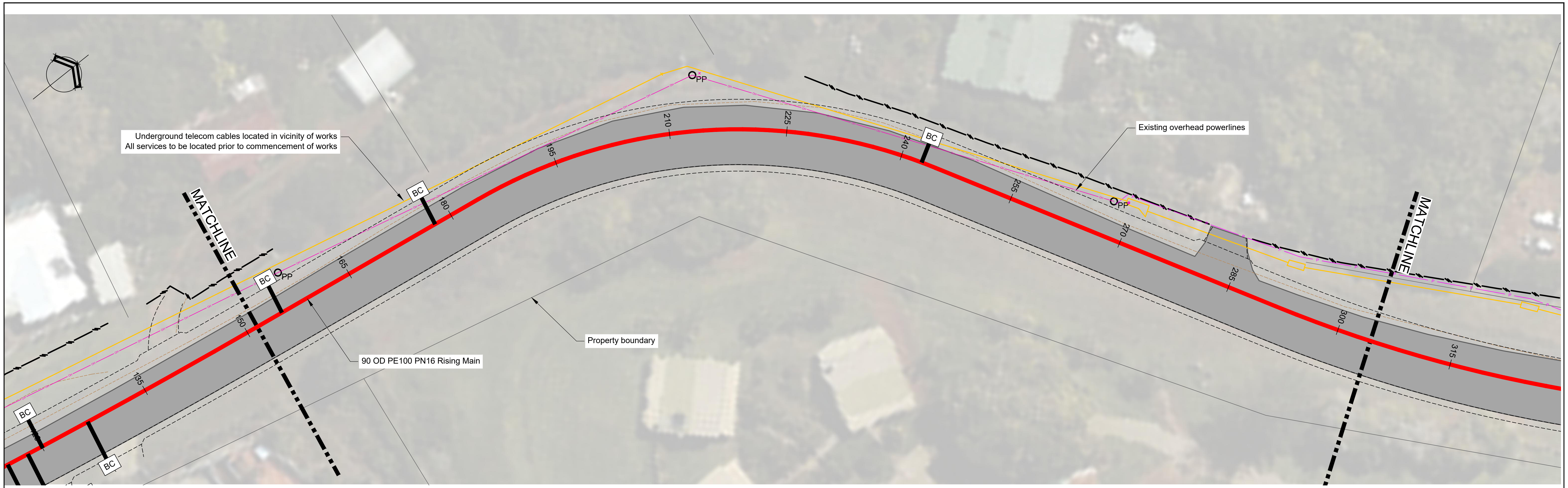
Client
Australian Government
Department of Infrastructure, Transport, Regional Development and Communications

Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Pumpstation 6 to Existing Manhole
Layout Plan and Longsection

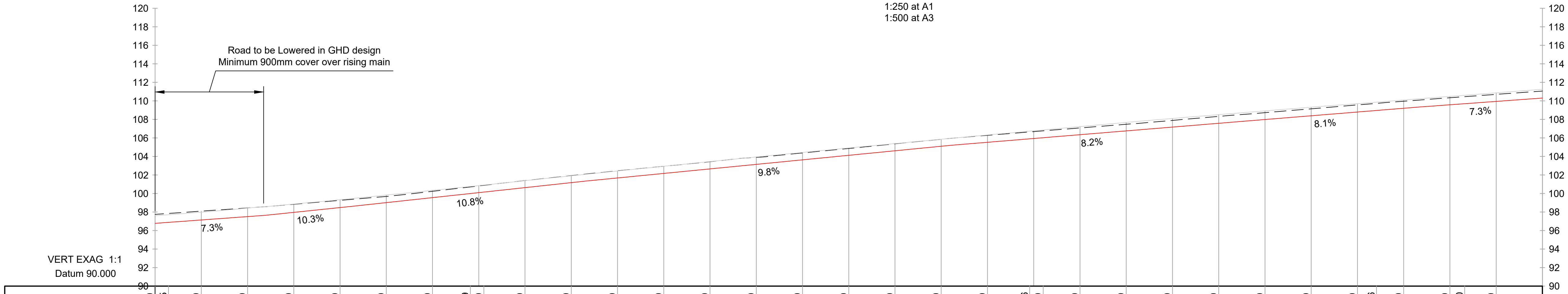
Scale (A1 Original) 1:250 m
Issue For Construction
Project No 000770
Sheet C22
Revision 0

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\000770 Norfolk C18_PS6-MH



LAYOUT PLAN 150-300

1:250 at A1
1:500 at A3



STATION (m)	150.00	151.45	155.00	160.00	165.00	170.00	175.00	180.00	184.09	185.00	190.00	195.00	200.00	205.00	210.00	215.00	220.00
GROUND LEVEL (m) (Existing)	97.59	97.84	97.98	98.41	98.86	99.33	99.82	100.34	100.71	100.85	101.38	101.90	102.42	102.94	103.44	103.94	104.43
PIPE COVER (m)	0.97	0.96	0.95	0.93	0.87	0.78	0.67	0.68	0.71	0.72	0.75	0.75	0.76	0.77	0.77	0.76	0.74
PIPE TYPE	90OD PE100 HDPE PN16																

STATION (m)	225.00	230.00	235.00	240.00	244.56	245.00	250.00	255.00	260.00	265.00	270.00	275.00	280.00	282.06	285.00	290.00	291.60	295.00	
GROUND LEVEL (m) (Existing)	104.91	105.39	105.85	106.31	106.64	106.77	107.22	107.67	108.09	108.50	108.91	109.31	109.69	109.73	110.09	110.48	110.45	110.87	
PIPE COVER (m)	0.73	0.75	0.75	0.75	0.74	0.74	0.73	0.71	0.72	0.74	0.73	0.75	0.76	0.77	0.76	0.76	0.76	0.76	0.75
PIPE TYPE	90OD PE100 HDPE PN16																		

LONGSECTION 150-300

1:250 at A1
1:500 at A3

LEGEND

—T—	Existing Telecom/Telecom Pits
—SW—	Existing stormwater (culvert / piped)
—P—	Existing power (underground)
—OH—	Existing power (overhead)
—·—·—	Existing property boundary
🟥	Proposed foul sewer rising main
AV	Air Relief Valve
- - -	GHD Road Alignment in plan
——	GHD Road Alignment Surface
- - -	Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

0 10 20 30 40 50 mm 75 mm 100 mm

0 For Construction	ACS	ESG	ACS	ACS	29/11/23
Revision	**Des**	**Drn**	**Rvd**	**App**	**Date**

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Client
Australian Government
Department of Infrastructure, Transport, Regional Development and Communications

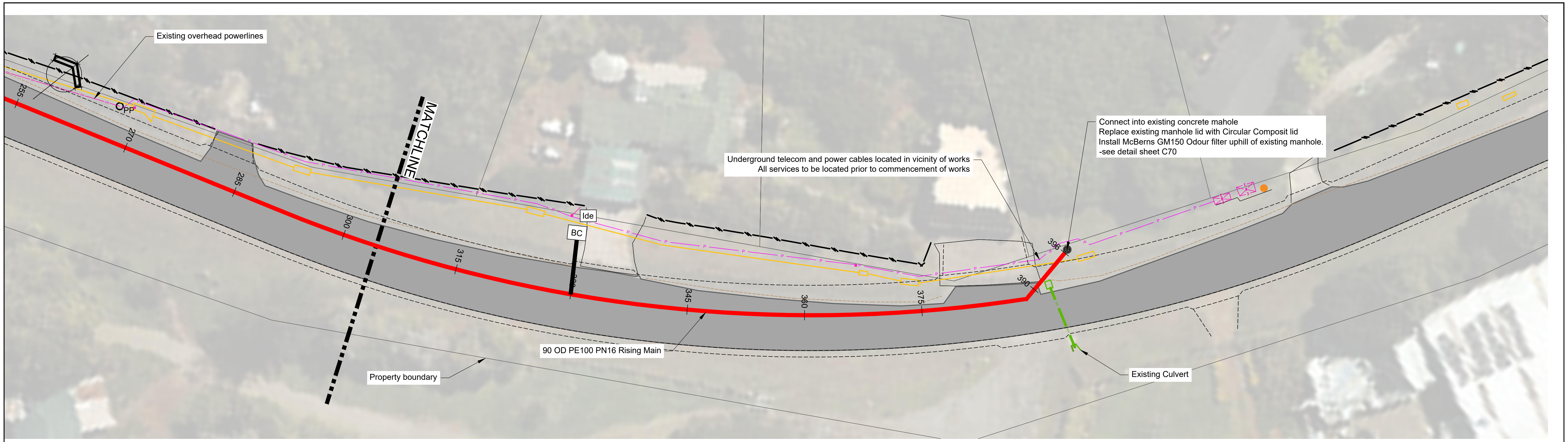
Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Pumpstation 6 to Existing Manhole
Layout Plan and Longsection

Scale (A1 Original) 1:250 m
Issue For Construction

Project No	**Sheet**	**Revision**
000770	C23	0

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\000770 Norfolk C18_PS6-MH



Existing overhead powerlines

Underground telecom and power cables located in vicinity of works
All services to be located prior to commencement of works

Connect into existing concrete mahole
Replace existing manhole lid with Circular Composit lid
Install McBerns GM150 Odour filter uphill of existing manhole.
-see detail sheet C70

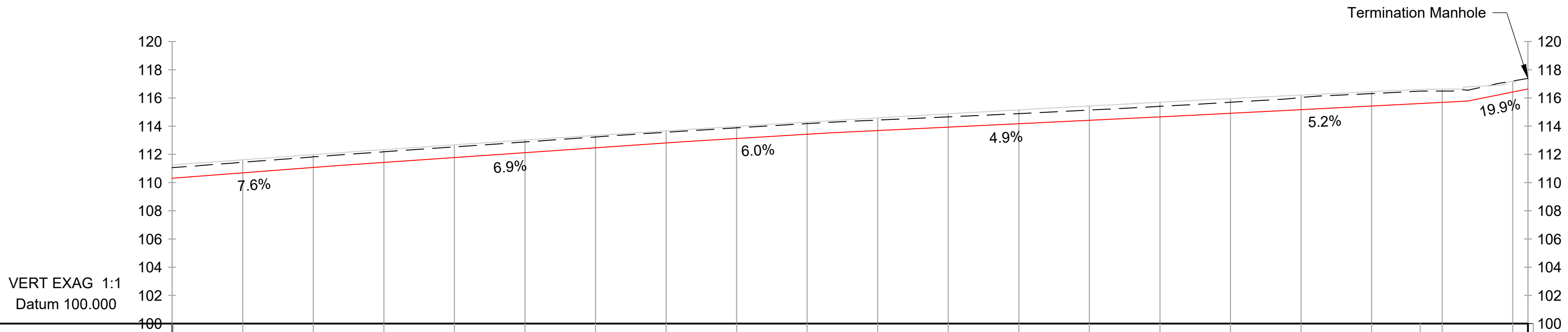
90 OD PE100 PN16 Rising Main

Property boundary

Existing Culvert

LAYOUT PLAN 300-396

1:250 at A1
1:500 at A3



STATION (m)	GROUND LEVEL (m) (Existing)	PIPE COVER (m)
300.00	111.24	0.75
305.00	111.61	0.75
310.00	111.98	0.75
315.00	112.33	0.76
320.00	112.67	0.76
325.00	113.01	0.76
330.00	113.34	0.77
335.00	113.67	0.76
340.00	113.98	0.75
345.00	114.28	0.76
350.00	114.58	0.74
355.00	114.87	0.73
360.00	115.15	0.72
365.00	115.43	0.72
370.00	115.69	0.74
375.00	115.95	0.78
380.00	116.20	0.86
385.00	116.44	0.88
388.45	116.48	0.88
390.00	116.63	0.79
395.00	117.16	0.78
396.08		0.75

PIPE TYPE: 90OD PE100 HDPE PN16

LONGSECTION 300-396

1:250 at A1
1:500 at A3

LEGEND	
—T—	Existing Telecom/Telecom Pits
—SW—	Existing stormwater (culvert / piped)
—P—	Existing power (underground)
—OH—	Existing power (overhead)
—·—	Existing property boundary
—	Proposed foul sewer rising main
AV	Air Relief Valve
- - -	GHD Road Alignment in plan
—	GHD Road Alignment Surface
- - -	Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

100 mm 75 mm 50 mm 40 30 20 10 0

0	For Construction	ACS	ESG	ACS	ACS 29/11/23
Revision		**Des**	**Drn**	**Rvd**	**App** **Date**

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Client
Australian Government
Department of Infrastructure, Transport, Regional Development and Communications

Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Pumpstation 6 to Existing Manhole
Layout Plan and Longsection

Scale (A1 Original) 1:250 m

Issue
For Construction

Project No	Sheet	Revision
000770	C24	0

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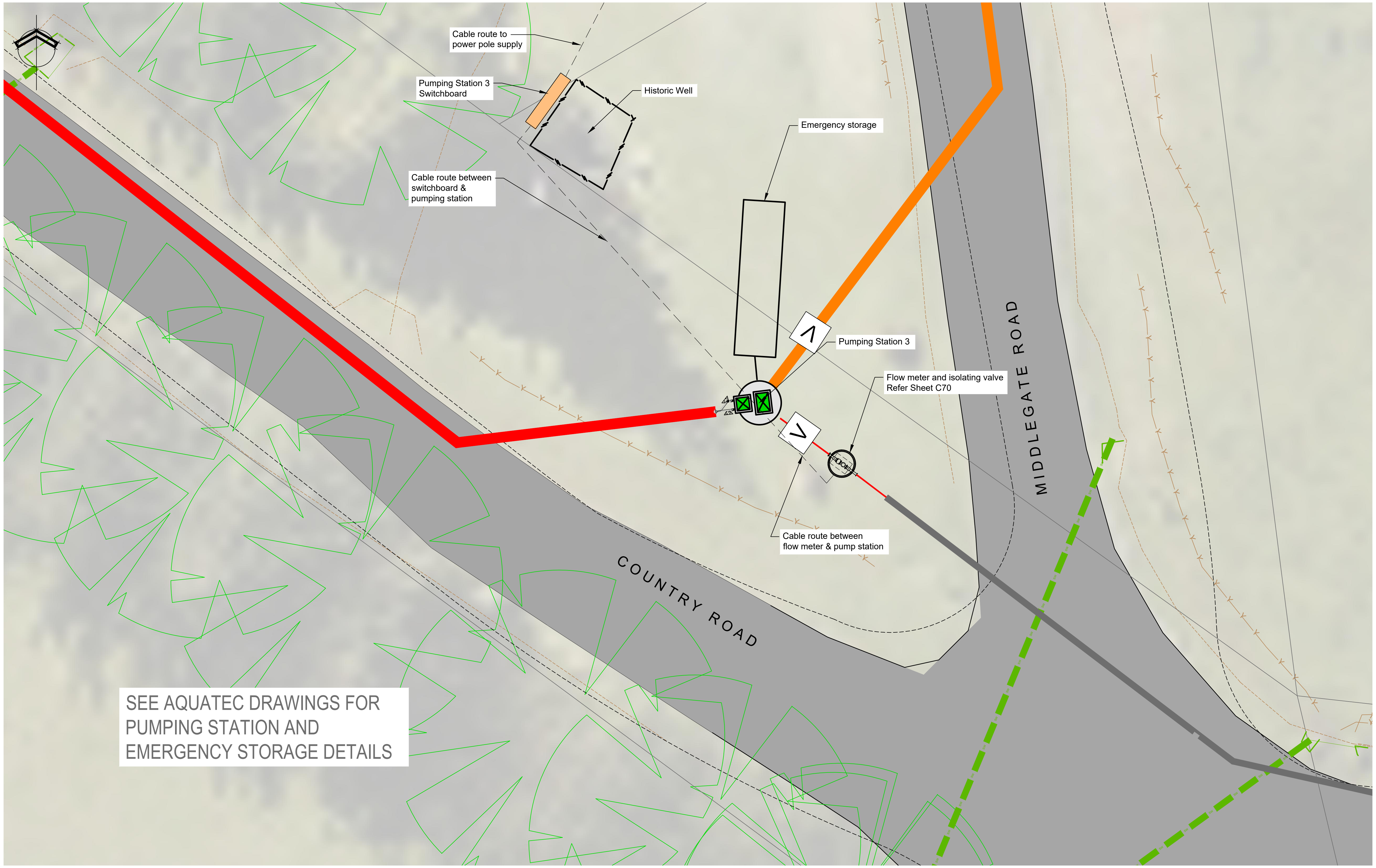

PUMP STATION LAYOUT PLAN

1:100 at A1
1:200 at A3

LEGEND

- Existing Telecom/Telecom Pits
- Existing stormwater (culvert / piped)
- Existing power (underground)
- Existing power (overhead)
- Existing property boundary
- Proposed foul sewer rising main
- AV Air Relief Valve
- GHD Road Alignment in plan
- GHD Road Alignment Surface
- Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

100 mm
75 mm
50 mm
40
30
20
10
0

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\000770 Norfolk_Stage 2A_PS

0 For Construction	ACS	ESG	ACS	ACS	29/11/23
Revision	**Des**	**Drn**	**Rvd**	**App**	**Date**

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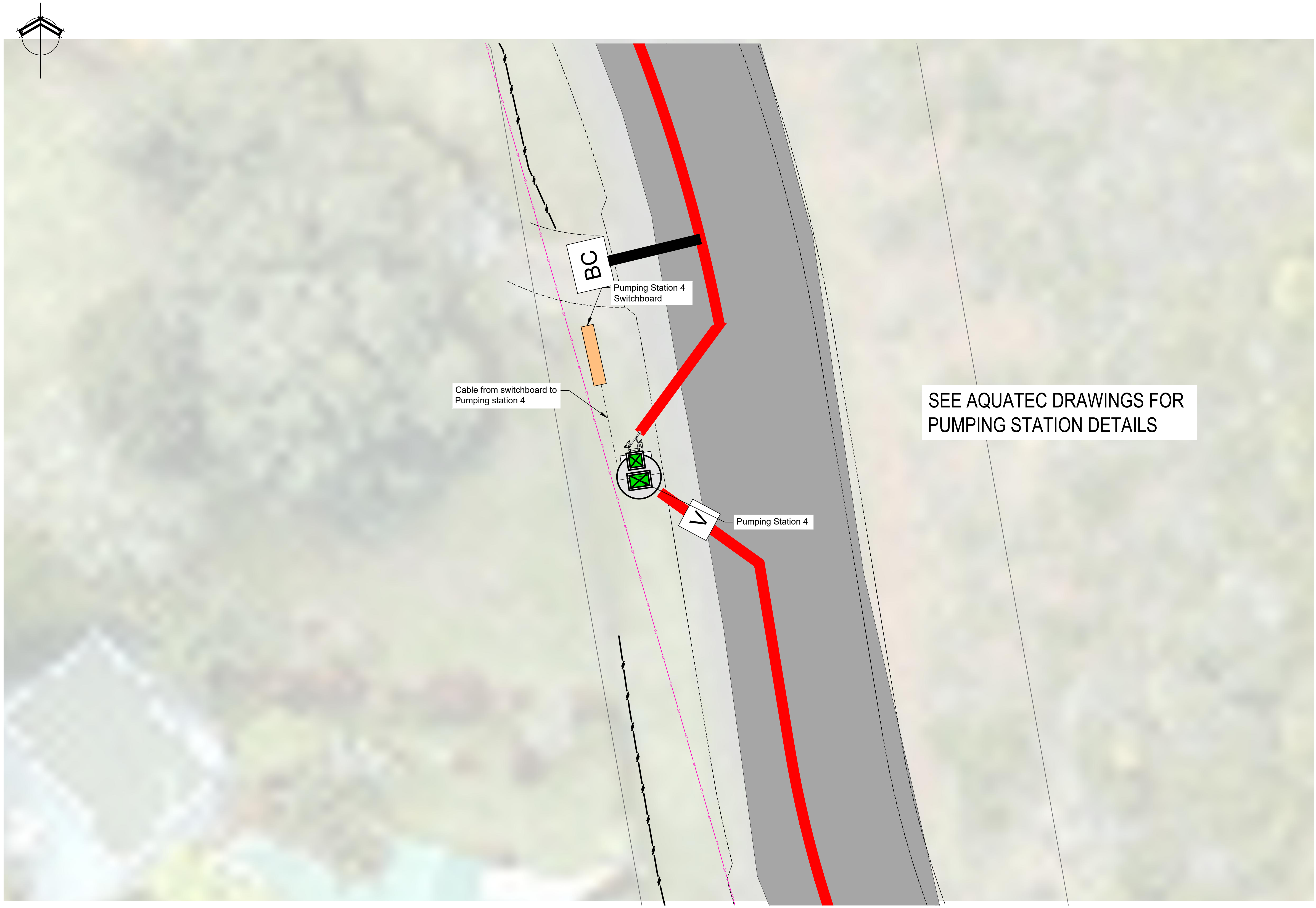
Client
Australian Government
Department of Infrastructure, Transport,
Regional Development and Communications

Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Pumpstation 3 Details

Scale (A1 Original) metres 1:100 m
Issue For Construction
Project No 000770
Sheet C30
Revision 0



SEE AQUATEC DRAWINGS FOR PUMPING STATION DETAILS

PUMP STATION LAYOUT PLAN

1:100 at A1
1:200 at A3

LEGEND

— T —	Existing Telecom/Telecom Pits
— SW —	Existing stormwater (culvert / piped)
— P —	Existing power (underground)
— OH —	Existing power (overhead)
— · —	Existing property boundary
—	Proposed foul sewer rising main
AV	Air Relief Valve
—	GHD Road Alignment in plan
—	GHD Road Alignment Surface
- - -	Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

0 10 20 30 40 50 mm 75 mm 100 mm

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\000770 Norfolk_Stage 2A_PS

Revision		Des	Drn	Rvd	App	Date
0	For Construction	ACS	ESG	ACS	ACS	29/11/23

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Client
Australian Government
Department of Infrastructure, Transport, Regional Development and Communications

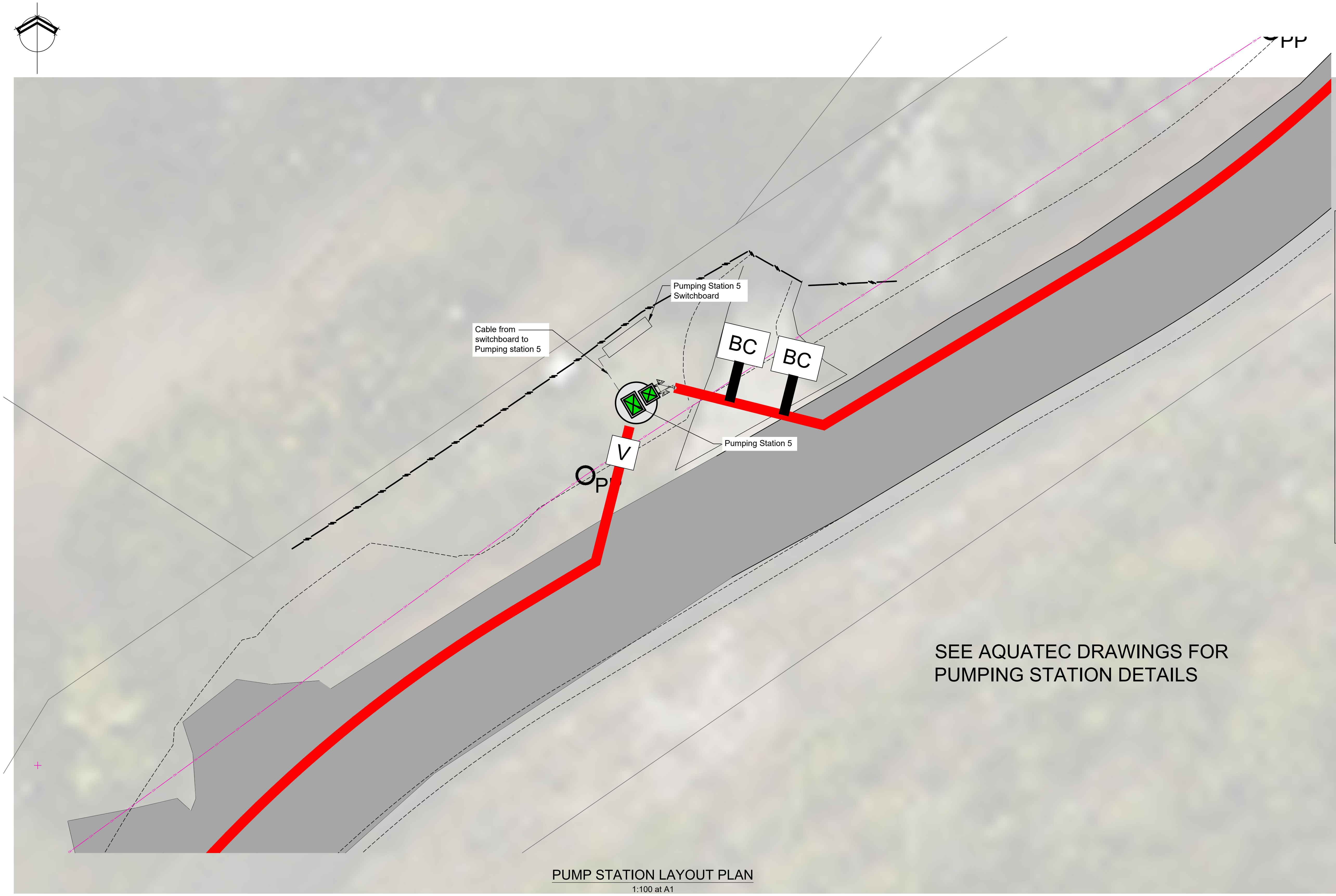
Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Pumpstation 4 Details

Scale (A1 Original)
metres 1:100 m

Issue
For Construction

Project No	Sheet	Revision
000770	C40	0



SEE AQUATEC DRAWINGS FOR
PUMPING STATION DETAILS

PUMP STATION LAYOUT PLAN

1:100 at A1
1:200 at A3

LEGEND

— T —	Existing Telecom/Telecom Pits
— SW —	Existing stormwater (culvert / piped)
— P —	Existing power (underground)
— OH —	Existing power (overhead)
— · —	Existing property boundary
🟥	Proposed foul sewer rising main
AV	Air Relief Valve
——	GHD Road Alignment in plan
——	GHD Road Alignment Surface
– – –	Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\000770 Norfolk_Stage 2A_PS

		Des	Drn	Rvd	App	Date
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Revision		**Des**	**Drn**	**Rvd**	**App**	**Date**

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Project Title
Norfolk Island
KAVHA Wastewater Scheme

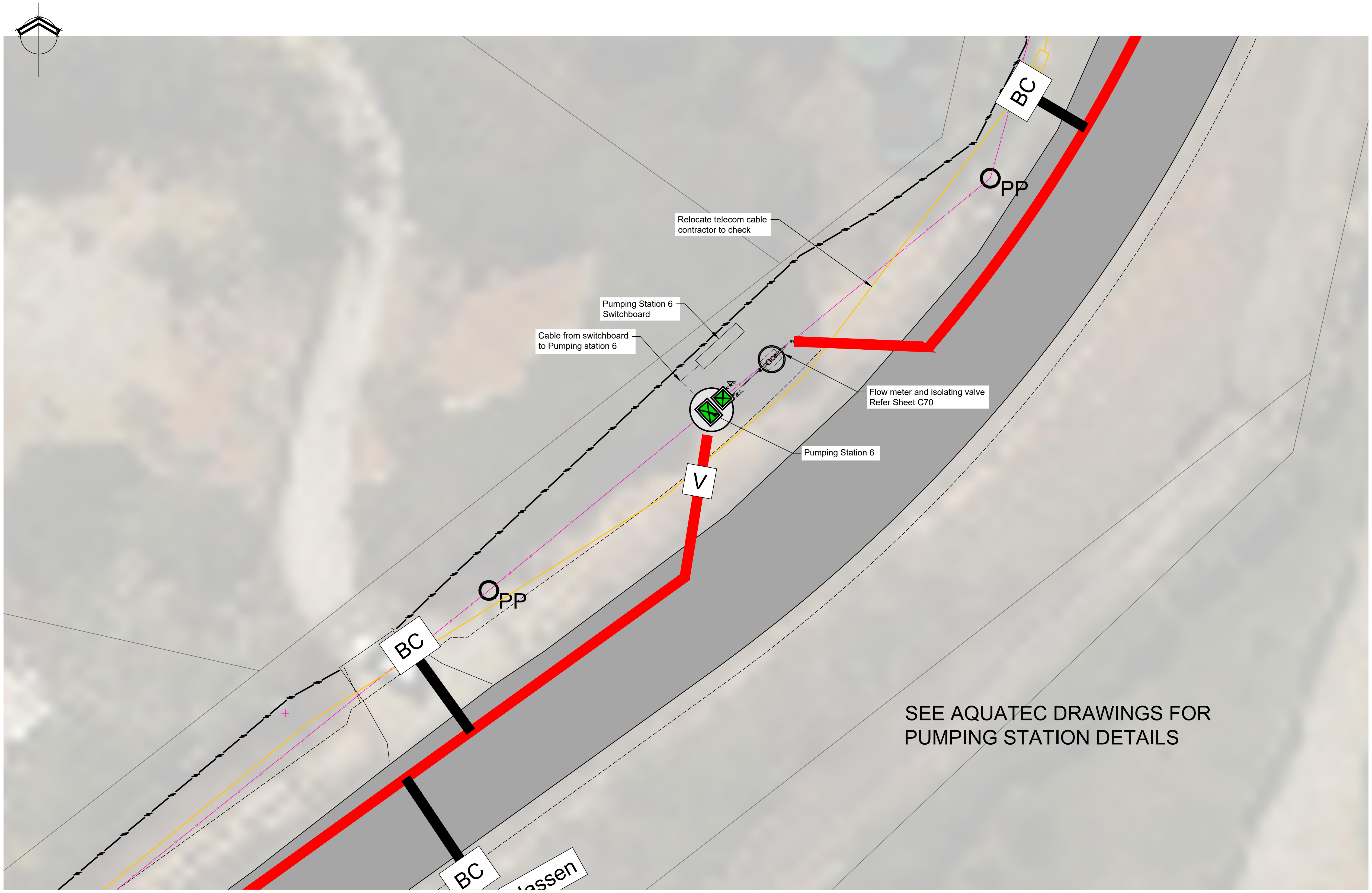
Sheet Title
Pumpstation 5 Details

Scale (A1 Original)
metres 1:100 m

Issue
For Construction

Project No 000770
Sheet C50
Revision 0

0
10
20
30
40
50 mm
75 mm
100 mm



PUMP STATION LAYOUT PLAN

1:100 at A1
1:200 at A3

LEGEND

— T —	Existing Telecom/Telecom Pits
— SW —	Existing stormwater (culvert / piped)
— P —	Existing power (underground)
— OH —	Existing power (overhead)
— - - —	Existing property boundary
🟥	Proposed foul sewer rising main
AV	Air Relief Valve
———	GHD Road Alignment in plan
———	GHD Road Alignment Surface
_ _ _ _	Existing Ground Surface

GENERAL NOTES

1. Services locations shown on the plans are indicative only, and may be incomplete. Location of all existing services to be confirmed on site prior to commencing of any works.
2. New underground power supply to pump stations to be taken from new pole mounted transformers as required - confirm location of power route on site.
3. All trench work to be reinstated as per existing.
4. Sections of shallow pipe to be concrete capped. Refer detail sheet C70.
5. 90OD PE100 Minimum Bend Radius = 2.0m.

PUMP STATION NOTES

- Pumpstation design to be as per supplied Aquatec drawings.

RISING MAIN NOTES

- When crossing above of below existing culverts, allow 150mm clearance between the rising main and the existing culvert.

SURFACE DATA

- Surface levels have been based on the scale 1 data and coordinate system used to prepare the detail survey (provided by Abbott & Macro) for the KAVHA project site

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Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Pumpstation 6 Details

Scale (A1 Original) metres 1:100 m

Issue For Construction

Project No	Sheet	Revision
000770	C60	0

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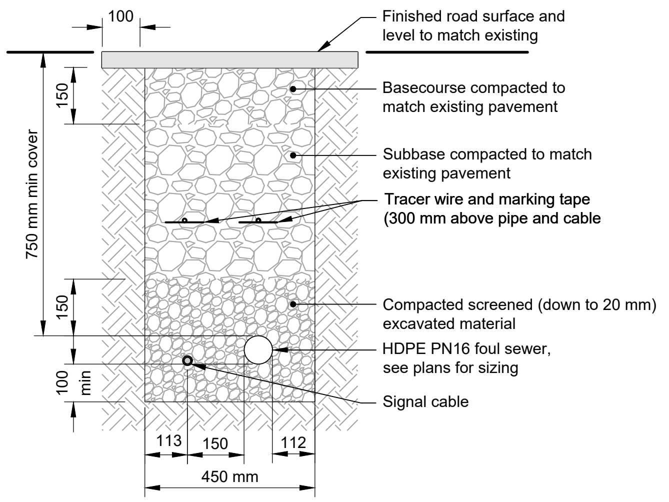
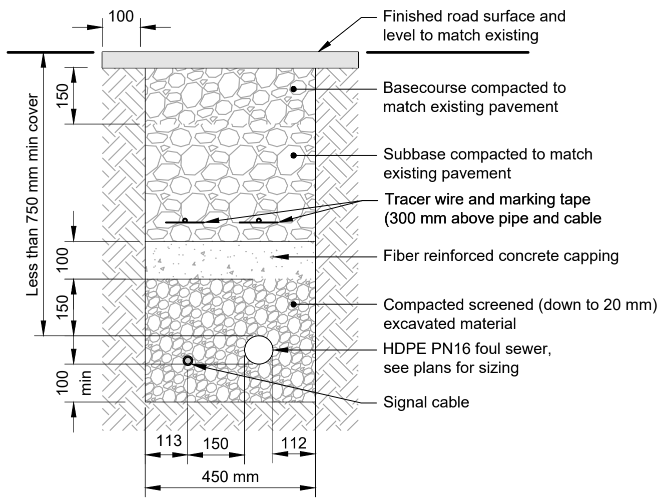


TRAFFICABLE (SEALED ROADS)

TYPICAL TRENCH DETAIL

1:10 at A1
1:20 at A3



TRAFFICABLE (SEALED ROADS) - COVER LESS THAN 750MM

TYPICAL TRENCH DETAIL

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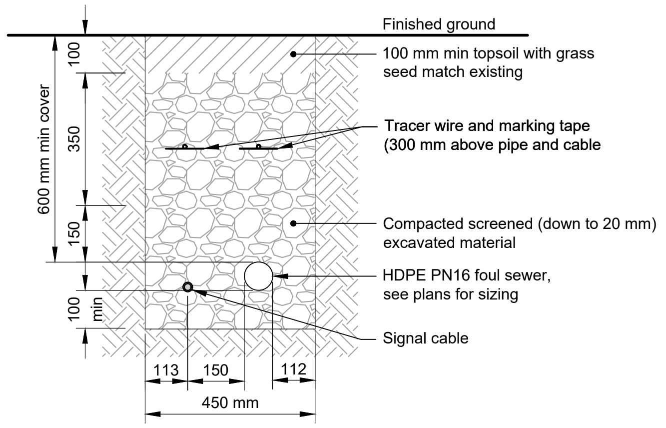
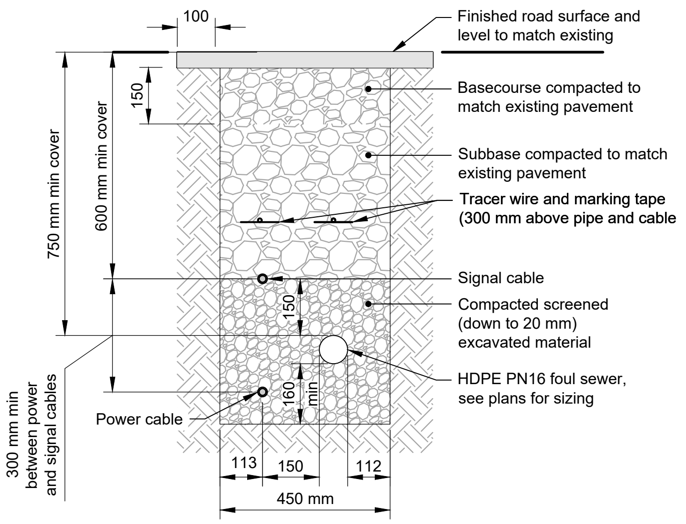
1:20 at A3



NON-TRAFFICABLE

TYPICAL TRENCH DETAIL

1:10 at A1
1:20 at A3



TRAFFICABLE (SEALED ROADS)

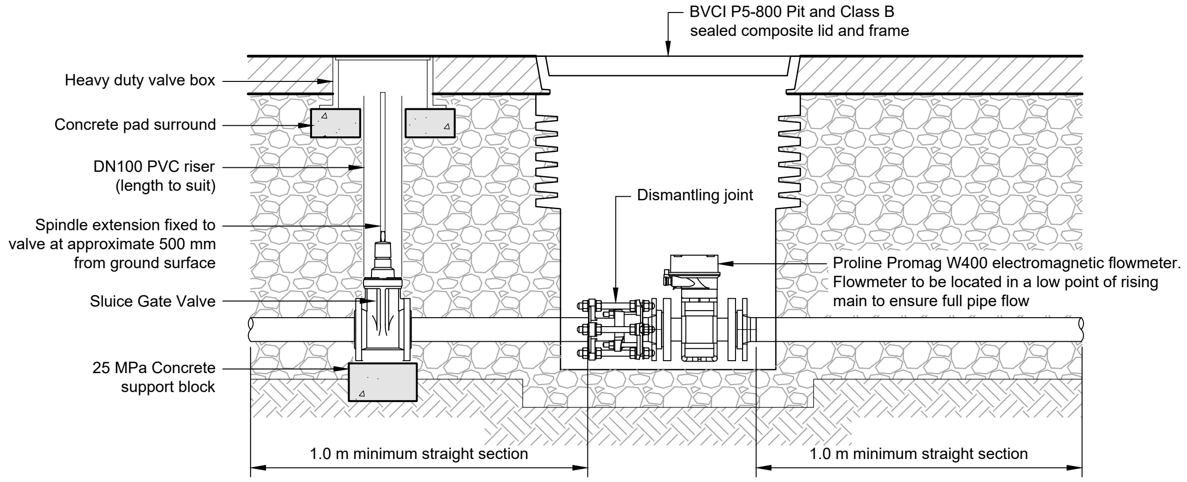
TYPICAL TRENCH DETAIL COMBINED POWER AND SIGNAL CABLES

1:10 at A1
1:20 at A3

NOTES:

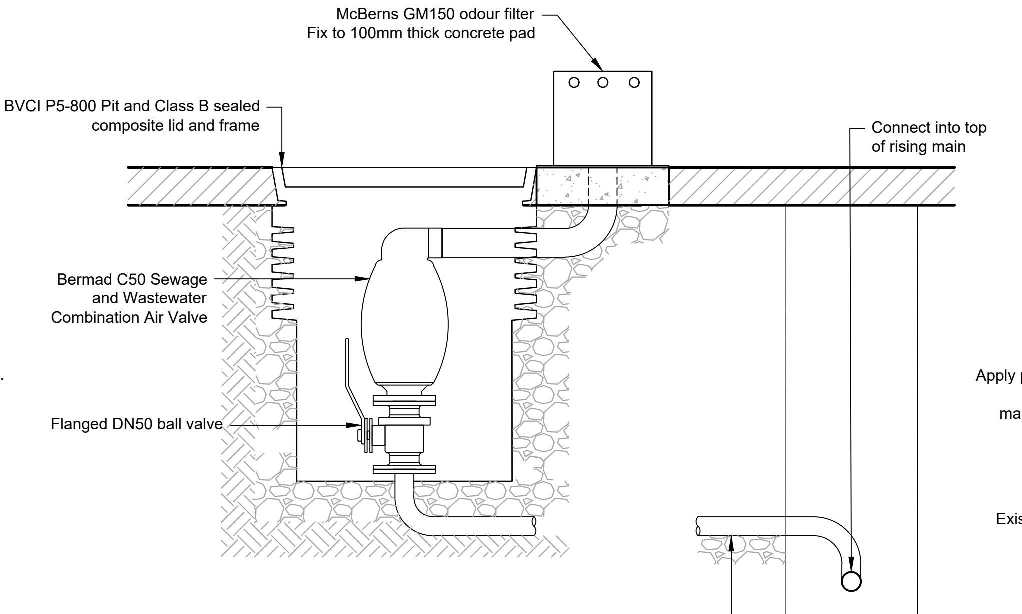
D = External Diameter of Pipe

Trench to be Reinstated to Match Existing Levels



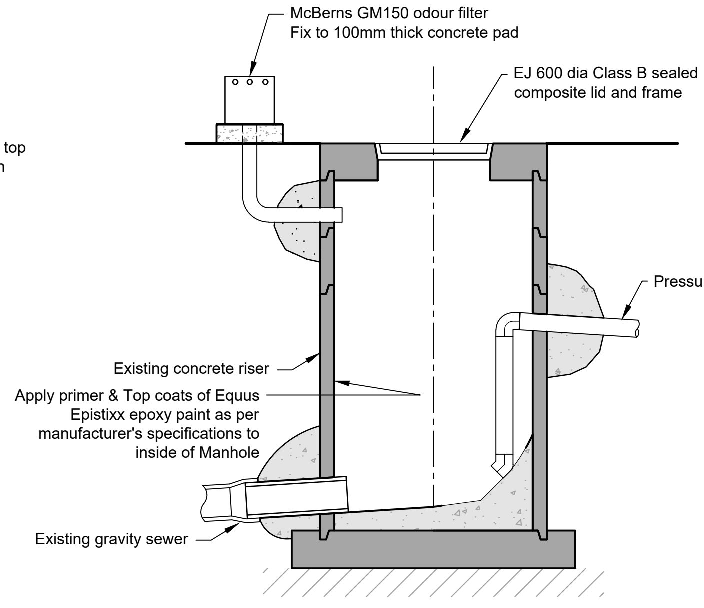
FLOW METER DETAIL

1:10 at A1
1:20 at A3



AIR VALVE DETAIL

1:10 at A1
1:20 at A3



MANHOLE DETAIL

1:20 at A1
1:40 at A3

100 mm
75 mm
50 mm
40
30
20
10
0

Revision		Des	Drn	Rvd	App	Date
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Project Title
Norfolk Island
KAVHA Wastewater Scheme

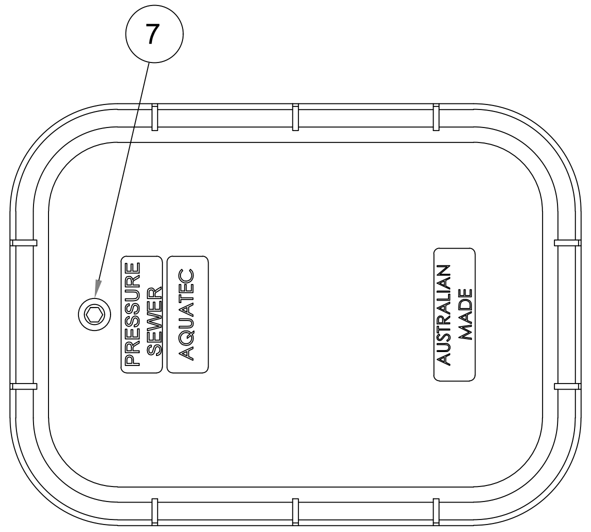
Sheet Title
Typical Details
1 of 3

Scale (A1 Original) As Shown

Issue For Construction

Project No	Sheet	Revision
000770	C70	0

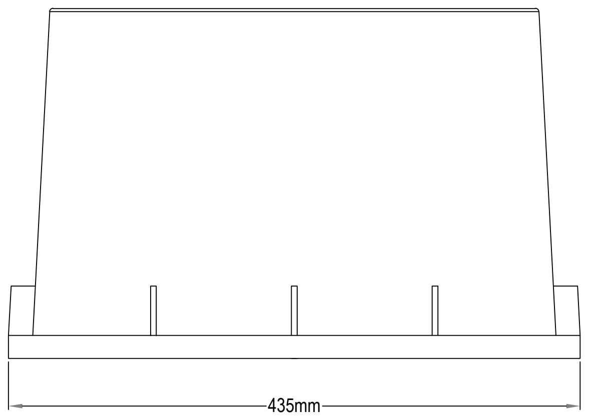
File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\Details\Pro__Norfolk_Stage 2 Details

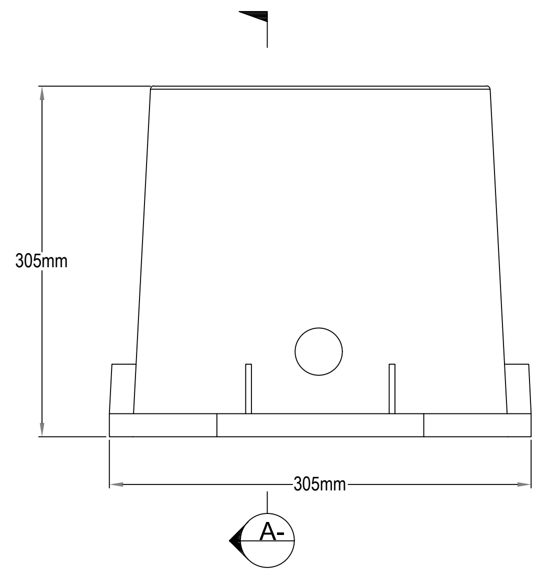


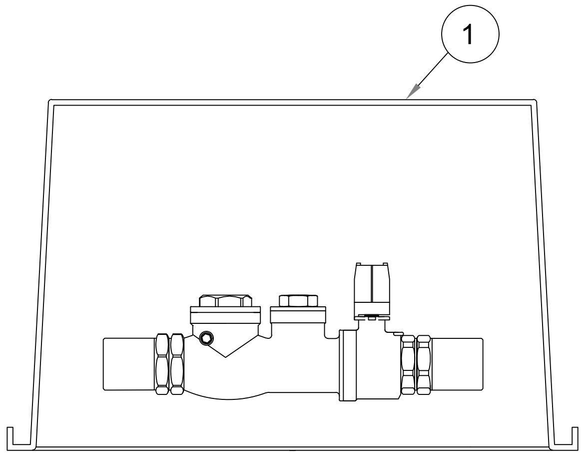
NOTES:

1	POLYETHYLENE ONE PIECE PIT WITH COVER, CLASS A
2	GR316 S/S BALL VALVE, FULL BORE
3	GR316 S/S PUMP OUT TEE
4	GR316 S/S PLUG
5	GR316 S/S SWING CHECK VALVE, FULL BORE
6	PE MALE THREAD ADAPTER
7	GR316 S/S BOLT

NOTE:
- FITTINGS 2 to 5 IS A ONE PIECE ASSEMBLY
- ITEM 6 ALSO AVAILABLE IN BRASS AND 316 S/S







SECTION A-

AQUATEC BOUNDARY CONNECTION KIT

NTS

0 10 20 30 40 50 mm 75 mm 100 mm

Revision		Des	Drn	Rvd	App	Date
0	For Construction	ACS	ESG	ACS	ACS	29/11/23

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Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Typical Details
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Scale (A1 Original)	As Shown	
Issue	For Construction	
Project No	**Sheet**	**Revision**
000770	C71	0

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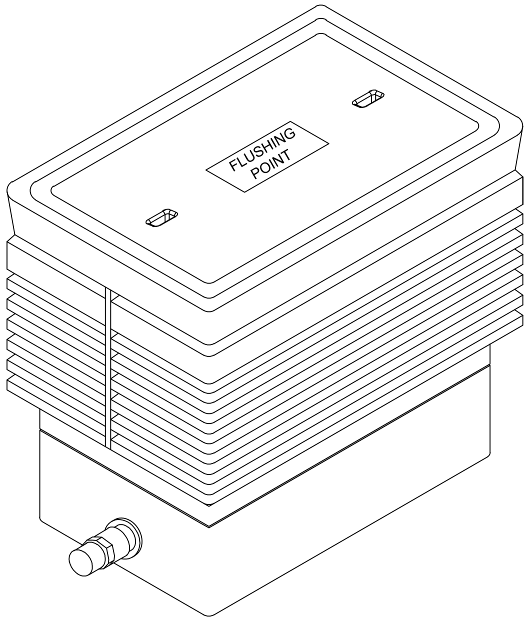
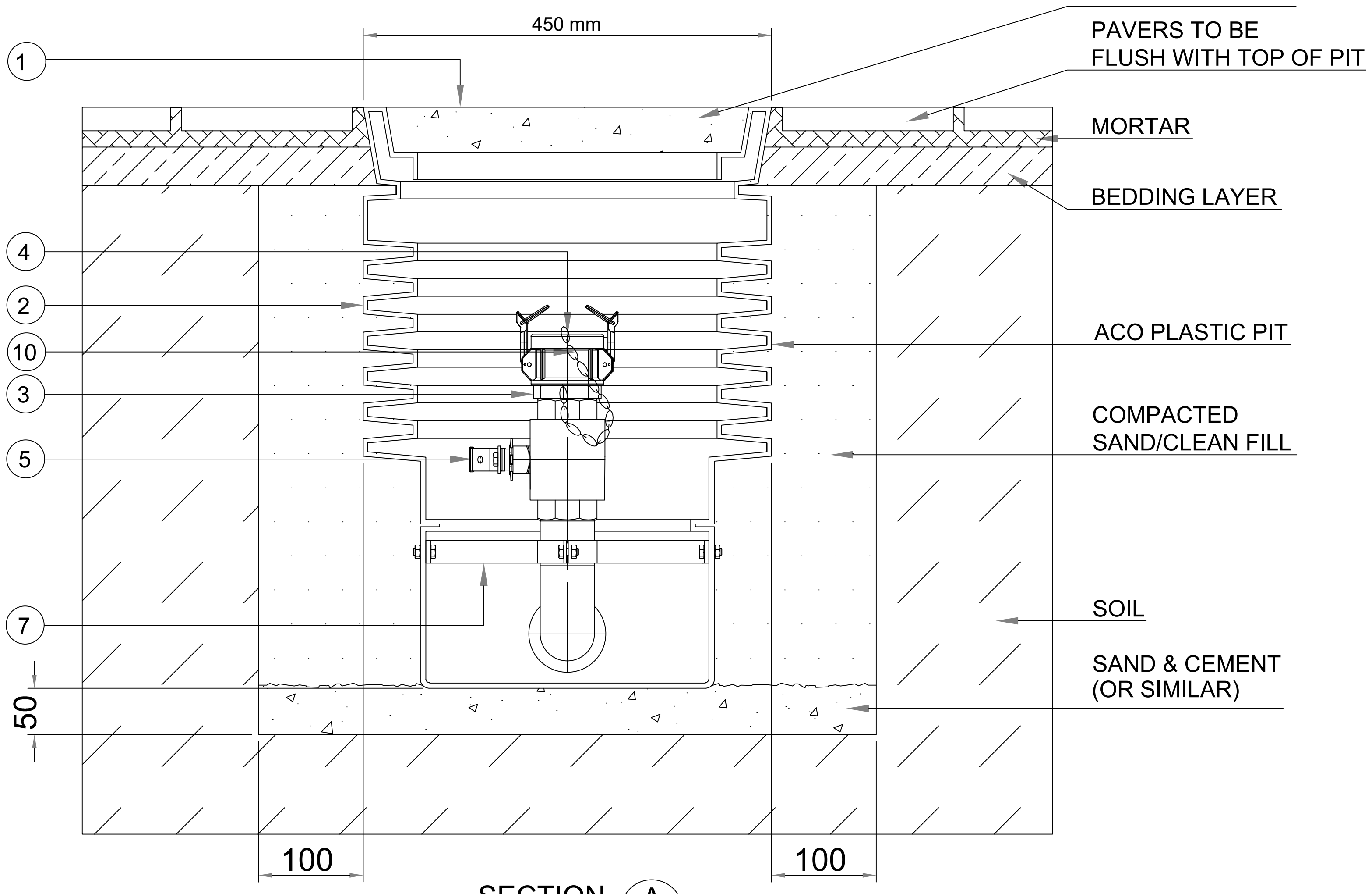
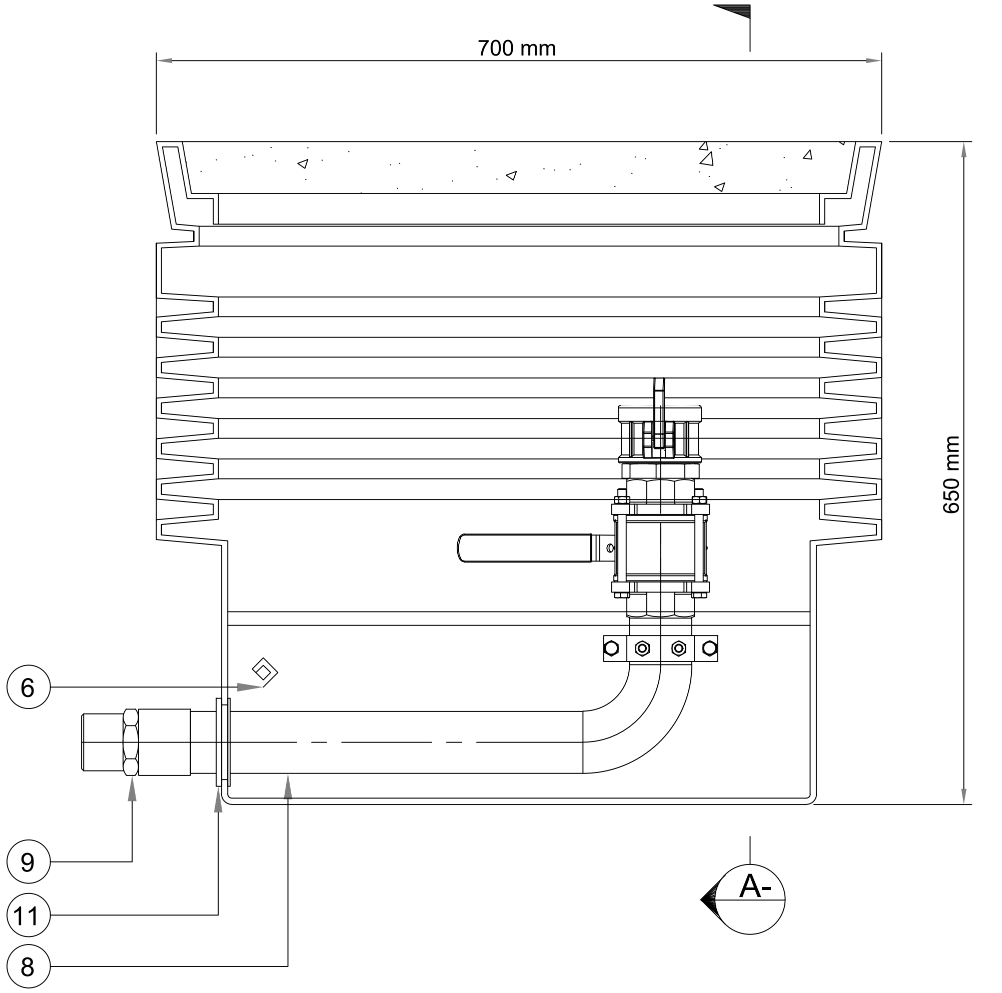


NOTES:	
1	COMPOSITE 'CLASS B' COVER TO SUIT (AS3996)
2	POLYETHYLENE PIT
3	POLYETHYLENE MALE CAMLOCK
4	POLYETHYLENE FEMALE CAMLOCK DUST CAP
5	GR316 S/S BALL VALVE, FULL BORE, LOCKABLE EYELET
6	GR 316 S/S TRACER WIRE (BY OTHERS)
7	GR316 S/S PIPE SUPPORT BRACKET
8	GR316 S/S PIPEWORK
9	POLYETHYLENE TRANSITION COUPLER (CONNECTION BY CIVIL CONTRACTOR)
10	GR316 S/S CHAIN
11	RUBBER UNISEAL
12	FITTINGS & MATERIALS TO BE IN ACCORDANCE WITH AUSTRALIAN STANDARDS



SECTION A-



AQUATEC FLUSHING POINT

NTS

0 For Construction ACS ESG ACS ACS 29/11/23

Revision **Des** **Drn** **Rvd** **App** **Date**

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Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Typical details
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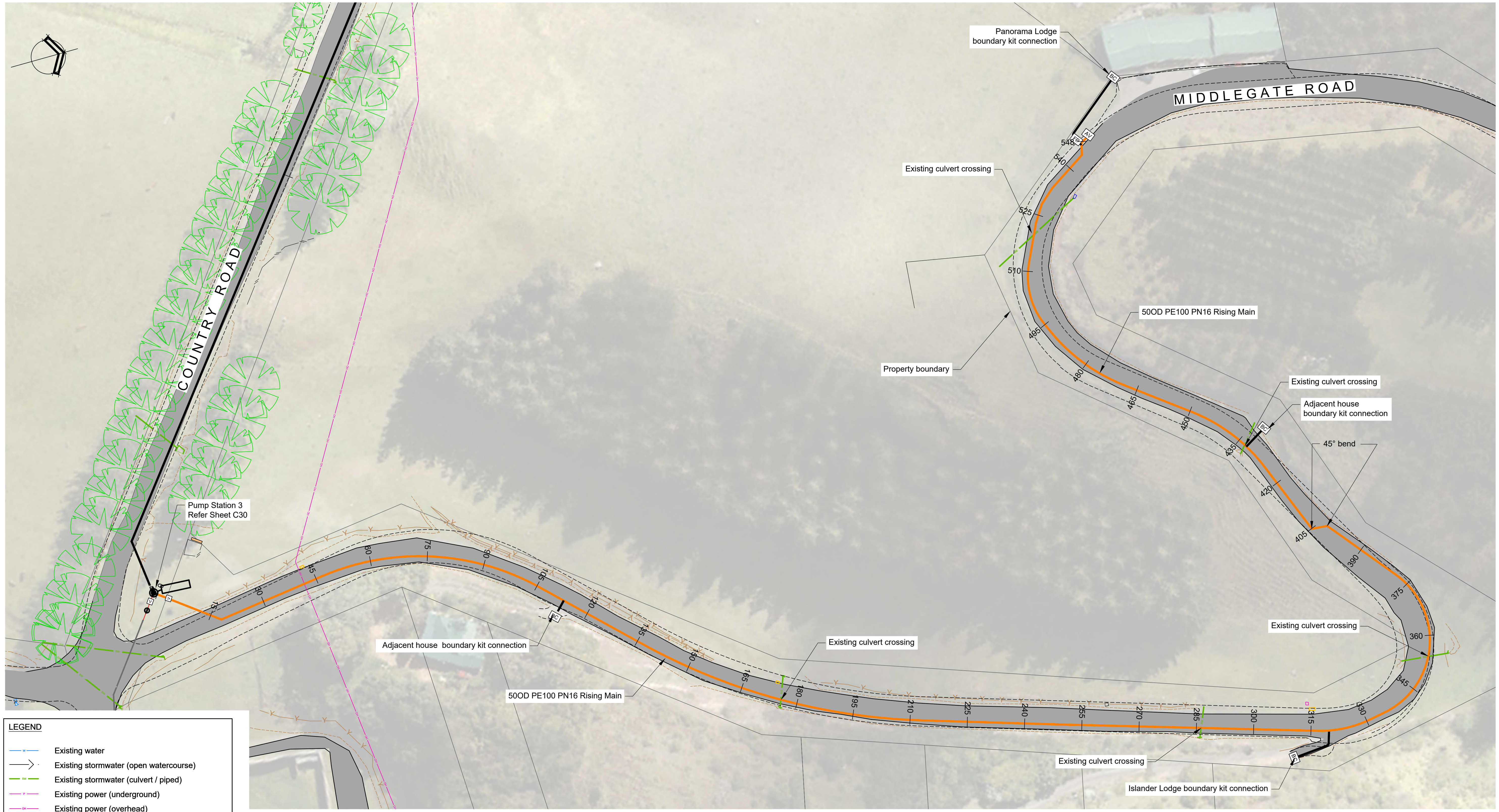
Scale (A1 Original) As Shown
Issue For Construction
Project No 000770
Sheet C72
Revision 0

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\Details\Pro__Norfolk_Stage 2 Details

0 10 20 30 40 50 mm 75 mm 100 mm



LEGEND

——	Existing water
→	Existing stormwater (open watercourse)
——	Existing stormwater (culvert / piped)
——	Existing power (underground)
——	Existing power (overhead)
——	Existing property boundary
FP	Flushing Point Kit
V	Isolation Valve Kit
AV	Air Relief Valve Kit
BC	Boundary Connection Kit
——	Proposed Rising Main PN16 40 mm OD PE100
——	Proposed Rising Main PN16 50 mm OD PE100
——	Proposed Rising Main PN16 63 mm OD PE100
------	GHD Road Alignment

LAYOUT PLAN

1:250 at A1
1:500 at A3

Revision		Des	Drn	Rvd	App	Date
0	For Construction	ACS	ESG	ACS	ACS	29/11/23

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Department of Infrastructure, Transport, Regional Development and Communications

Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Stage 2B - Middlegate Road
Layout Plan

Scale (A1 Original) 1:500 m

Issue For Construction

Project No	Sheet	Revision
000770	C80	0

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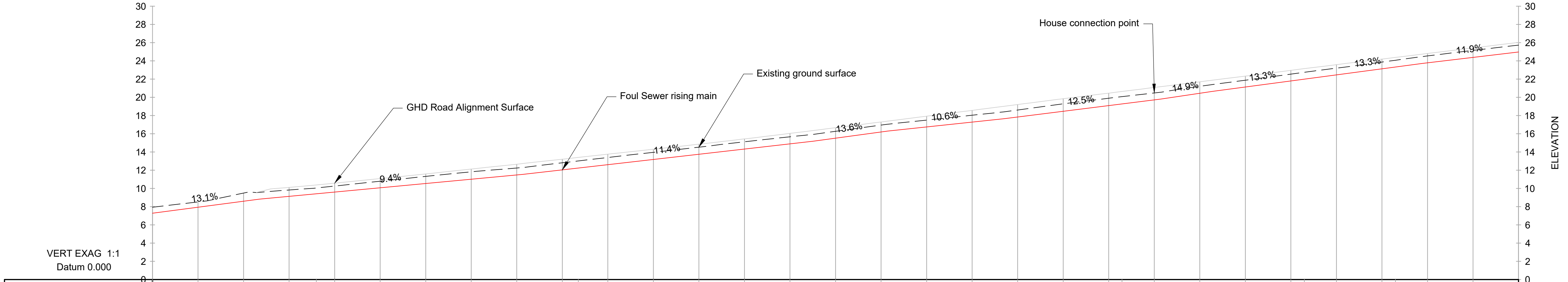
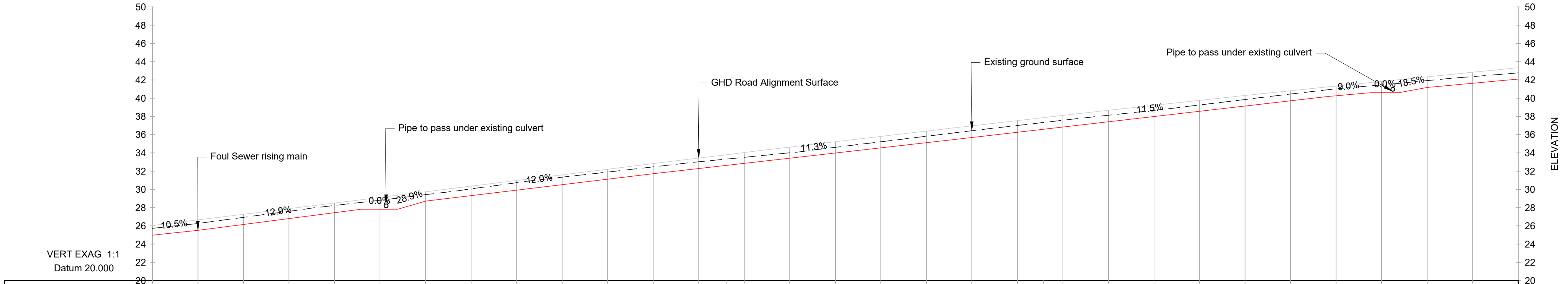


STATION (m)	0.00	5.00	10.00	15.00	18.00	20.00	25.00	30.00	35.00	40.00	45.00	46.76	50.00	55.00	60.00	65.00	70.00	75.00
GROUND LEVEL (m) (Existing)		8.52	9.49	9.82	10.04	10.26	10.79	11.32	11.82	12.24	12.81	13.02	13.39	13.96	14.53	15.12	15.66	16.27
PIPE COVER (m)		0.58	0.90	0.70	0.64	0.66	0.73	0.79	0.82	0.76	0.78	0.78	0.79	0.79	0.78	0.80	0.77	0.75
PIPE TYPE	50OD PE100 HDPE PN16																	

STATION (m)	80.00	85.00	90.00	95.00	100.00	105.00	105.47	110.00	115.00	120.00	125.00	126.48	130.00	135.00	136.48	140.00	145.00	
GROUND LEVEL (m) (Existing)	16.95	17.50	18.03	18.60	19.29	19.90	19.96	20.47	21.20	21.87	22.55	22.74	23.20	23.87	24.07	24.54	25.14	
PIPE COVER (m)	0.75	0.75	0.75	0.76	0.82	0.81	0.81	0.76	0.76	0.74	0.75	0.75	0.73	0.74	0.74	0.75	0.77	0.75
PIPE TYPE	50OD PE100 HDPE PN16																	

LONGSECTION 0-150

1:250 at A1
1:500 at A3



STATION (m)	150.00	155.00	160.00	165.00	170.00	175.00	180.00	185.00	190.00	195.00	200.00	205.00	210.00	213.01	215.00	220.00	225.00
GROUND LEVEL (m) (Existing)	25.72	26.25	26.92	27.59	28.23	28.80	29.41	30.05	30.72	31.33	31.89	32.46	33.02	33.31	33.51	34.00	34.60
PIPE COVER (m)	0.75	0.75	0.78	0.80	0.79	0.99	0.71	0.75	0.82	0.83	0.78	0.75	0.75	0.69	0.67	0.59	0.63
PIPE TYPE	50OD PE100 HDPE PN16																

STATION (m)	230.00	235.00	240.00	245.00	247.84	250.00	255.00	260.00	265.00	270.00	275.00	280.00	285.00	290.00	295.00	
GROUND LEVEL (m) (Existing)	35.21	35.82	36.42	37.00	37.32	37.58	38.12	38.66	39.25	39.85	40.45	41.02	41.45	41.92	42.36	
PIPE COVER (m)	0.67	0.71	0.75	0.75	0.75	0.75	0.72	0.68	0.69	0.72	0.75	0.76	0.85	0.75	0.73	0.69
PIPE TYPE	50OD PE100 HDPE PN16															

LONGSECTION 150-300

1:250 at A1
1:500 at A3

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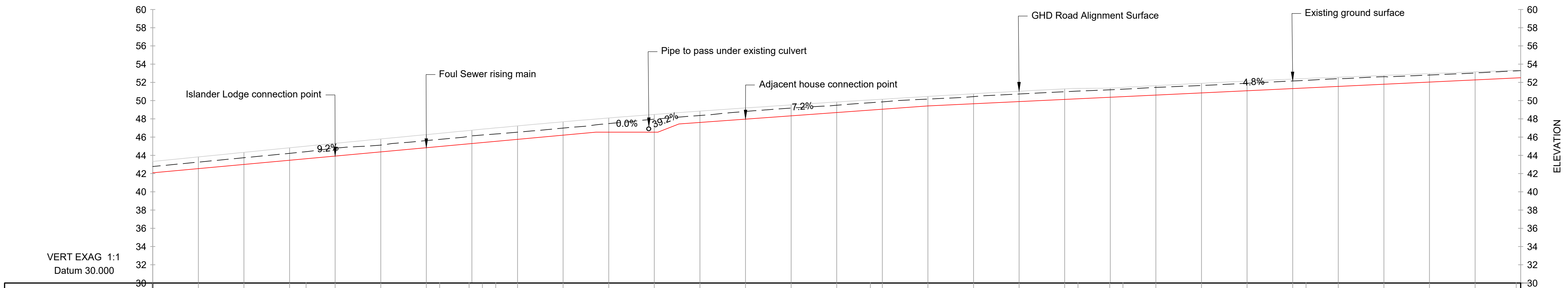
Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Stage 2B - Middlegate Road
Longsections
1 of 2

Scale (A1 Original) 1:250 m
Issue For Construction
Project No 000770
Sheet C81
Revision 0



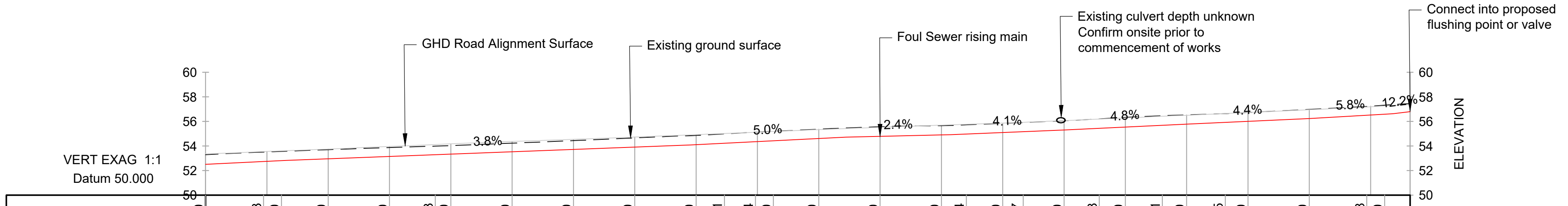
STATION (m)	300.00	305.00	310.00	315.00	316.82	320.00	325.00	330.00	330.97	334.69	335.00	335.17	340.00
GROUND LEVEL (m) (Existing)		43.26	43.74	44.22	43.63	44.78	45.12	45.62	44.93	45.27	46.13	45.31	46.54
PIPE COVER (m)	0.69	0.71	0.74	0.76	0.77	0.86	0.74	0.78	0.78	0.82	0.84	0.84	0.79
PIPE TYPE	63OD HDPE PN16					50OD PE100 HDPE PN16							

STATION (m)	345.00	350.00	355.00	360.00	365.00	370.00	375.00	378.70	380.00	385.00	390.00	395.00	400.00
GROUND LEVEL (m) (Existing)	46.99	47.49	47.97	48.37	48.82	49.19	49.50	48.97	49.86		50.45	50.73	50.98
PIPE COVER (m)	0.78	0.94	1.42	0.76	0.84	0.85	0.80	0.81	0.80	0.75	0.79	0.83	0.85
PIPE TYPE													

STATION (m)	400.83	404.93	405.00	410.00	415.00	420.00	425.00	425.39	430.00	435.00	440.00	445.00	449.51	
GROUND LEVEL (m) (Existing)	50.17	50.37	51.19	51.46	51.66	51.91	52.16	51.34	52.41	52.62	52.81	53.04	52.49	
PIPE COVER (m)	0.85	0.82	0.82	0.85	0.81	0.82	0.83	0.83	0.84	0.82	0.77	0.76	0.78	0.78
PIPE TYPE														

LONGSECTION 300-450

1:250 at A1
1:500 at A3



STATION (m)	450.00	454.73	455.00	460.00	465.00	468.73	470.00	475.00	480.00	485.00
GROUND LEVEL (m) (Existing)	53.29	53.51	53.52	53.70	53.87	53.99	54.03	54.23	54.44	54.66
PIPE COVER (m)	0.78	0.77	0.77	0.74	0.73	0.70	0.69	0.70	0.72	0.75
PIPE TYPE	50OD PE100 HDPE PN16									

STATION (m)	490.00	492.31	494.84	495.00	500.00	505.00	510.00	512.04	515.00	516.67
GROUND LEVEL (m) (Existing)	54.86	54.99	55.12	55.13	55.37	55.56	55.65	55.72	55.84	55.91
PIPE COVER (m)	0.75	0.77	0.78	0.78	0.76	0.78	0.75	0.75	0.75	0.75
PIPE TYPE										

STATION (m)	520.00	522.88	525.00	528.01	530.00	533.15	535.00	540.00	544.68	545.00
GROUND LEVEL (m) (Existing)	56.05	56.20	56.33	56.47	56.53	56.64	56.73	56.98	57.21	57.24
PIPE COVER (m)	0.75	0.77	0.79	0.78	0.75	0.71	0.72	0.75	0.71	0.72
PIPE TYPE										

LONGSECTION 450-548

1:250 at A1
1:500 at A3

Revision		Des	Drn	Rvd	App	Date
0	For Construction	ACS	ESG	ACS	ACS	29/11/23

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Project Title
Norfolk Island
KAVHA Wastewater Scheme

Sheet Title
Stage 2B - Middlegate Road
Longsections
2 of 2

Scale (A1 Original) 1:250 m
Issue For Construction
Project No 000770
Sheet C82
Revision 0

File: Z:\2_Jobs\000761 - 000770\000770 - Norfolk Island WW-STG 2&3\6_Drawings\04_Production\000770 Norfolk_Stage 2B_LS

Appendix B – Water Quality Report: Emily Bay and Upper Cascade Creek Catchments

Norfolk Island Regional Council
11-May-2017

Commercial-in-Confidence

Emily Bay and Upper Cascade Creek Catchments

Norfolk Island Water Quality Study

Emily Bay and Upper Cascade Creek Catchments

Norfolk Island Water Quality Study

Client: Norfolk Island Regional Council

ABN: 6010 3855 713

Prepared by

AECOM Australia Pty Ltd
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ABN 20 093 846 925

11-May-2017

Job No.: 60531847

AECOM in Australia and New Zealand is certified to ISO9001, ISO14001 AS/NZS4801 and OHSAS18001.

Quality Information

Document Emily Bay and Upper Cascade Creek Catchments

Ref 60531847

Date 11-May-2017

Prepared by Krystle L. Nichols

Julia Wharton

Reviewed by Courtney Henderson

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
A	11-May-2017	Issued for Client Review	Courtney Henderson Principal Environmental Scientist	

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List of Tables

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Executive Summary

Norfolk Island Regional Council (NIRC) commissioned AECOM Australia Pty Ltd (AECOM) to undertake a Water Quality Study to update a previous 2013 water quality study for the Watermill Creek (Emily Bay) and the Upper Cascade Creek catchments of Norfolk Island, Australia (herein collectively referred to as the ‘study area’). The site comprises the primary surface water catchments used by the Island’s population. The purpose of the study was to assess current perceived water quality issues (drinking water, stock water, irrigation source, recreational use in Emily Bay and ecosystem health), to determine potential risks to human health and the environment, update the previous water quality study, examine trends in data and to provide practical recommendations for improving water quality.

Water Quality Issues

Water quality of the two main surface water catchments on the Island, Watermill Creek and Upper Cascade Creek, is perceived to be of poor quality and thought to present a potential risk to human and environmental health based on historical studies. As both groundwater and surface water are utilised by the local population, various exposure pathways for contaminated water to impact human health are recognised.

Known threats to water quality on the Island include animal pathogens, organic and nutrient pollution from livestock waste due to the traditional practice of allowing livestock to graze on all freehold and leasehold land, commons, public lands and road reserves, inclusive of unrestricted access to Watermill and Cascade creeks. In addition, although sewerage system services in the form of a Water Assurance Scheme (WAS) are available in the most populated areas of the Island (Burnt Pine), the majority of households and businesses rely on individual septic systems and land-based effluent dispersal fields (soakage trenches) which may present a source of pathogens and nutrient pollution.

Anecdotal information suggests that the population has observed higher incidences of gastroenteritis in times of drought, when the primary water source (rainwater) has been depleted and water is extracted from creeks or the shallow aquifer. Further, concerns in regards to the quality of water used for recreational activities have been raised, which include observations of ear infections from swimming in Emily Bay. Observations of the decline of coral habitat in Emily Bay in a transect extending from the Watermill Creek outfall suggests adverse water quality is entering the Bay.

Sources of Water

Drinking water on the island is primarily sourced from rainwater collected on rooves, but also includes shallow aquifer, deep aquifer and surface water storages. Roof (rain) water was not tested as a component of this study. The shallow aquifer is comprised of alluvial (creek) sediments found adjacent to creeks and primary surface water pathways. The deep aquifer is present in underlying basalt rock beneath the alluvial sediments.

Water utilised for irrigation for crops and landscaping and for livestock is sourced from rainwater, surface water and extraction from aquifers. Livestock have direct access to creeks and dams within the catchment.

Results of Catchment Inspections and Water Sample Analysis

Water quality results from this study, collected from seven locations which included surface and bore water, indicate the presence of contaminants of potential concern (COPCs) inclusive of pathogens such as *Escherichia coli* (*E. coli*) and various coliforms in all samples from the shallow aquifer and surface waters tested. Sample locations were selected to cover a large geographic region across the catchments, from the top to the bottom to provide an indication of potential contamination sources.

E.coli was detected above the adopted Investigation Levels (ILs) in all samples except for deep aquifer well BH224. Elevated concentrations were reported from the top of both catchments (BH139 and BH132), which indicates contamination of the waterways and shallow aquifer at these locations which is likely to flow downgradient where there is potential to impact environmental and human receptors. Contaminants were not present in samples from one location, BH224, which appears to intersect the deeper basalt aquifer and may be protected from surface impacts by separation by an extensive weathered basalt (clay) layer.

It was noted that concentrations of *E.coli* and other COPCs downgradient of Duck Dam and wetland features across the Kingston Commons (Sample SW_EBInlet) were less than those from the upper catchment. This suggests the wetlands and dams are providing physical settling and biological filtration processes, occurring initially in Duck Dam and then more substantially in the lower wetlands of Kingston Commons prior to discharge into Emily Bay. The recruited wetland plants (mostly non-native species) are considered to be providing treatment benefits to surface water in these areas.

One sample collected from the uppermost flowing section of the western branch of Waterm ill Creek (BH139) reported the highest concentrations of COPCs. A large sewage pump station is located approximately 100 m upstream from the sample location adjacent to the creek channel, which based on the results, suggests that leaks from the pipes or sewage pump station may be impacting the water quality at the top of the catchment. The *E.coli* results from this investigation were compared to those collected previously and are considered to be consistent.

Water samples analysed for genetic markers resulted in the confirmation of bird markers from four of seven primary samples. The highest concentration of bird markers was reported from the inlet to Emily Bay and was two orders of magnitude greater than the next highest concentration (Duck Dam Inlet).

One sample, Duck Dam Inlet, reported confirmation of the human marker *Bacteroides* HF183, which is a specific marker for human sewage. As this marker was not detected in the samples upgradient, and since BH139 is adjacent to a sewer pump station, it is considered there is a contamination source impacting the catchment just upstream of where surface water discharges into the Duck Dam.

No cattle markers were detected as a result of genetic speciation analysis. This was unexpected as cattle were observed by AECOM to defecate in the waterways while samples were being collected, specifically at Duck Dam. Upon discussions with Dr Warish Ahmed of CSIRO, who undertook the speciation analyses, it was identified that the cattle marker is not present in the faeces of all cattle species and that it is likely that cattle on the Island do not carry the marker. This is further supported by anecdotal evidence from the President of the Norfolk Island Cattle Association Inc. that the cattle on Norfolk Island are of a unique breed, Norfolk Blue.

Inspection of several bores on the Island revealed that they have not been constructed to Australian Standards and are often open to the surface. This aperture allows foreign matter, inclusive of surface water containing faecal matter, to enter the bore and migrate directly into underlying aquifers.

A conceptual site model (CSM) was developed which allows for identification of potential sources of contaminants, contaminant transport mechanisms and pathways, potential receptors (human health and the environment) and possible linkages. Once sources, pathways, receptors and linkages have been identified, assessment of risks can be undertaken.

Recommendations

Based on the results of the water quality study, the primary recommendations include:

- The results of this study have identified impacts to human health and the environment, particularly drinking water sources. Given the broad scale issues identified, a holistic approach to addressing the issues is warranted with identification of short and long term goals to remedy issues based on a priority ranking of potential risks and sources. A Drinking Water Quality Management Plan (DWQMP) developed based on the information included in this report, in conjunction with previous information, will allow for identification and prioritisation of risks to be addressed from which solutions can be developed and implemented in the short and long-term while considering the limitations of the Island (resources and financial). It is considered that the development of a DWQMP will identify additional recommendations to address contamination issues, inclusive of those which require significant resources (eg. upgrade to the water treatment plant to allow for incorporation of more households onto the WAS and training programs for workers).
- Confirmation of the aquifers that bores intersect and the quality of aquifer water to provide an understanding of the resource and suitable volumes of water for extraction without impacting on other wells and the resource itself, i.e. ensure no salt water intrusion from over pumping. This will assist in identifying bores suitable for use during dry seasons to limit potential risks to human health.

- Identification and implementation of protection measures for the shallow and deep aquifers are recommended and include adequate sealing of existing extraction bores from the surface as per Australian Guidelines and decommissioning of disused wells to prevent unnecessary impacts to groundwater from surface contaminants.
- Identification and implementation of protection measures for the surface water resources are recommended and include controlling stock access to surface water (providing alternate stock watering vessels and fencing), identifying and minimising direct seepage of contamination into waterways and revegetation or extension of planted riparian zones along creeks to act as a natural filter for surface water run-off entering waterways.
- Further investigation into the apparent positive impact of wetland areas in the lower catchment areas is warranted and extension of these areas may improve water quality discharging into Emily Bay.
- Conduct monitoring of water quality in Emily Bay to assess whether potential risks to recreational users and marine habitats are likely to be realised, and if so, management procedures that can be employed to reduce risks to human health and the environment.
- Engage NSW Health to commence discussions that provide guidance and resources to assist with monitoring and compliance programs to ensure human health protection.
- Critical to the success of water quality management on Norfolk Island is the involvement of the general community to understand the issues that affect their health and livelihoods, what can be done to improve it and the benefits for all. This can be achieved by undertaking regular community sessions and educational forums to initiate and maintain an open dialogue, to ensure management measures are practical and able to be implemented, to provide information for safe water use, maintenance of septic and rainwater tanks via workshops and outdoor classrooms, and to gain support, ownership and involvement in management strategies such as revegetation of creek lines.

1.0 Introduction

1.1 Background

Maintenance of water quality in the Watermill Creek and Upper Cascade Creek catchments is vital as a significant proportion of the Island's residential population and most of the tourist accommodations are located here. As there is no reticulated water supply on the Island, a complete reliance on rainwater and bore water for drinking water and non-drinking water supplies is necessary. The Watermill Creek catchment waters discharge into Emily Bay, a popular swimming beach for locals and tourists, which flows into the South Pacific Ocean.

Over the past 50 years, the previous Administration of Norfolk Island (ANI) has undertaken or commissioned a large number of water quality investigations. An extensive monitoring program of surface water and water supply bores was undertaken across the Island over this time; however, the monitoring program ended upon the transition of the ANI to the NIRC in July 2016.

Norfolk Island Regional Council (NIRC) commissioned AECOM Australia Pty Ltd (AECOM) to undertake a Water Quality Study to update the historical report for the Watermill Creek (Emily Bay) and the Upper Cascade Creek catchments of Norfolk Island, Australia (herein collectively referred to as the 'study area'). The site comprises the primary surface water catchments and largest watersheds on the Island.

Known threats to water quality on the Island include animal pathogens, organic and nutrient pollution from livestock waste due to the traditional practice of allowing livestock to graze on all freehold and leasehold land, commons, public lands and road reserves, inclusive of unrestricted access to Watermill and Cascade creeks. In addition, although sewerage system services in the form of a Water Assurance Scheme (WAS) are available in the most populated areas of the Island (Burnt Pine), the majority of households and businesses on the Island rely on individual septic systems and land-based effluent dispersal fields (soakage trenches) which may present a source of pathogens and nutrient pollution. A study of these catchments was previously undertaken by URS Australia Pty Ltd (URS) in 2013; this report aims to update the 2013 URS report.

The location of the site is shown in Figure 1.

1.2 Objectives

The purpose of the study was to assess current perceived water quality issues (drinking water, stock water, irrigation source, recreational use in Emily Bay and ecosystem health), to determine potential risks to human health and the environment, update a 2013 water quality study and examine trends in data, and provide practical recommendations for maintaining/improving water quality.

1.3 Scope of Works

The scope of works for this project was developed based on the information provided by the NIRC and publically available information with respect to the Island's environment. The methodology to complete the scope of works was developed as a staged approach with the client.

In order to achieve the objectives described in Section 1.2, AECOM proposed the scope of works to include:

- Review of background information and available microbiological data (from analysis of surface and groundwater samples), verification of data quality control/quality assurance (QA/QC), and comparison to available historical data, where available. It was found during the field investigation that the majority of data collected under the former ANI was not provided to the new NIRC upon formation;
- Review of rainfall data and comparison with available microbiological (*E.coli*) data in attempt to explain variations in reported concentrations;

- Obtain data to update potential human sources of contamination (number of residents, number of tourist beds, number of residences connected to sewer vs septic systems, and number/type of retail/industrial premises);
- Obtain data to update potential agricultural sources (number and type of livestock);
- Inspect septic systems and sewer connections (focus on areas where issues have occurred in past four years) to verify overflow problems;
- Inspect wetlands and managed areas of creek (dredging/disturbance areas affecting water quality);
- Collection of surface and bore water samples for analysis; and
- Discuss findings with relevant stakeholders to assist with the formulation of recommendations that are feasible and practicable for Norfolk Island.

The 2013 URS report included several recommendations and provided strategic advice in relation to measures that could be undertaken to address water quality issues and potential contaminants within the Watermill Creek (Emily Bay) and Upper Cascade Creek catchments. The suggested strategic actions were developed with consideration of the capabilities and limited resources of the former Administration and WAS.

A component of the current study included the investigation of whether any of these recommendations have been adopted and, if so, the success or otherwise of implementation. The 2013 recommendations included:

- digitisation of data obtained in the past 4 years and scanning of historical hard copy data,
- adoption of a broader suite of analytes for water quality tests,
- conducting some water quality analysis on mainland Australia or in New Zealand to verify data for QA/QC,
- liaison with landowners of properties on septic systems that are within or adjacent to the WAS to determine feasibility of connection to sewer,
- trial exclusion of livestock from areas, provision of troughs, and comparison of cattle productivity,
- waterways management (staged vegetation removal, construction of treatment wetlands), and
- audit of septic systems (during wet season).

This water quality study report comprises:

- The results of data collection and site inspections;
- update and summary of the findings of the 2013 study,
- comparison of current data to historical data (where available) in order to identify any data trends, and
- provide recommendations to maintain and/or improve the water quality in the subject catchments.

This investigation has been generally undertaken in accordance with the National Environment Protection Council (NEPC), 2013 National Environment Protection (Assessment of Site Contamination) Amended Measure (NEPM) - Schedule B(1) Guideline on the Investigation Levels for Soil and Groundwater.

2.0 Site Description

The whole of Norfolk Island covers about 3,455 hectares (ha). There is a permanent population of around 1,800 with an annual average tourist population of approximately 31,000 (NIRC census data, 1987 to 2013).

A summary of the catchments which comprise the study area are presented below and are depicted on Figure 2.

2.1 Upper Cascade Creek Catchment

The area of the upper Cascade Creek Catchment covers an area of about 650 ha. The study area included in this report includes the uppermost portion of the catchment and is comprised of approximately 25 ha, located generally within the Middlegate subdivision. The catchment starts at the highest point near the Catholic Church about mid-way through the Middlegate residential subdivision (established about 40 years ago), continues downgradient through the western half of the subdivision into the commercial, residential and business mixed use zones as far as Fletcher Christian apartments.

Adjacent land uses of the Upper Cascade Catchment include residential and commercial land, inclusive of tourist accommodations and services to the north and east; Watermill Creek East Branch subcatchment to the south; and Watermill Creek West Branch subcatchment to the west.

2.2 Watermill Creek (Emily Bay) Catchment

Watermill Creek Catchment comprises an area of about 487 ha. It is the second largest watershed on Norfolk Island after Cascade Creek Catchment.

The largest urban areas on the Island are from Burnt Pine to Middlegate, established on the crest separating the Watermill and Cascade Creek catchments. The urban development (residential, commercial, minor industrial) covers an area of about 182 ha, and is mostly dispersed with low building density; approximately 105 ha of the urban area discharges into the Emily Bay catchment.

The site features of prominence observed throughout the Watermill Creek Catchment include, but are not limited to, the:

- Approximately half of the primary commercial area of the island, Burnt Pine, which includes the highest density of tourist accommodation, shops, bowls club, retail fuel facilities, and restaurants;
- Rural residential properties;
- Dams, creeks, Emily Bay recreational area (primary tourist swimming and water sports location); and
- A portion of the international airport.

Surrounding land uses include residential and commercial properties, inclusive of tourist accommodations and services to the north and east along with the Norfolk Island Central School; Emily Bay and the Pacific Ocean to the south; and residential and grazing land and the International Airport to the west.

Figure F3 includes the Island’s zoning map which presents the land use throughout the study area.

2.3 Previous Environmental Investigations

It is understood that numerous environmental investigations have been undertaken from at least 1970. While AECOM has not been provided with all of these reports, those which were provided by the NIRC and the Acting Team Leader for Waste and Environment for the NIRC (P.J. Wilson) have been reviewed and are summarised below.

2.3.1 Abell & Faulkland, 1991 – The Hydrogeology of Norfolk Island South Pacific Ocean

A hydrogeological study was undertaken across the Island to understand the geologic influences on the groundwater regime of the Island. The results identified two primary groundwater units, an upper water table aquifer within alluvial sediments and the underlying weathered basalt (also referenced as the weathered mantle), and a deeper aquifer within the basal bedrock. Groundwater is considered to move from the centre of the Island out towards the sea through a complex network of fractures and other interconnected openings in volcanic bedrock.

Groundwater moves within the shallow aquifer both laterally in the direction of the water table gradient (discharges as coastal seepage springs) and within valley floors where the ground surface intersects the water table. When the water table drops below the base of the valleys during dry periods, creeks and streams have reduced flow and can become dry.

At the base of the weathered basalt, it is likely there is vertical leakage of groundwater from this unit through bedrock fractures into the deep basalt unit. Some groundwater which moves through these fractures is either discharged as coastal seepage springs close to sea level or recharges the tuff beds and fragmented layers between lava flows to form local semi-confined aquifers. The remainder of groundwater within the deep basalt aquifer continues to move deeper where it may be either discharged as submarine seepages at and beyond the margin of the Island, or ultimately mixes with seawater below sea level.

2.3.2 EGC, 2008 – Review of Groundwater Data, Norfolk Island.

EGC undertook a water quality review of groundwater supply wells across Norfolk Island due to concerns with contamination of groundwater used for both domestic and agricultural purposes. The study included the identification of 324 groundwater wells across the island. Inspections and groundwater samples were collected from these wells. Samples were analysed for *E.coli*, nitrate, nitrite, total coliforms, pH, alkalinity and hardness. Additionally, information on water use practices and community concerns was collected via questionnaire given to well owners to complete.

Of the 296 wells sampled, 19 used for drinking water reported *E.coli* concentrations which ranged from 1 to 961 per 100 mL. The airport and a tourist accommodation were included in these results. *E.coli* was detected in a number of other wells where the drinking water status was unknown or confirmed to not be used primarily for drinking, which included tourist accommodations, the Government House and Cascade Softdrinks. In total, 51 wells (17% of samples) were reported to have been impacted with faecal contamination through the presence of *E.coli*.

A total of 301 samples were analysed for nitrates; nine wells reported concentrations in exceedance of the Australian Drinking Water Guideline (ADWG) value of 50 mg/L. A further 115 groundwater samples were reported to have nitrate levels below the ADWG value.

Nitrite concentrations was analysed in samples from 271 wells; the ADWG for nitrite is 3 mg/L which was exceeded by three samples.

Water samples which reported elevated concentrations of analytes were dispersed geographically across the Island, however, the wells which reported the highest concentrations were located within Burnt Pine and Middlegate areas of the Island.

Recommendations as a result of this study included:

- Regular emptying of septic tanks to improve functionality reduce overflows, coupled with redesign and replacement of faulty or leaking septic systems;
- Implementation of educational programs across the Island to improve awareness of best management practices for water quality disinfection and septic systems maintenance, inclusive of development of guidelines for treatment of water prior to consumption; and
- Implementation of a groundwater monitoring program with an expanded suite of analytes in order to conform to Australian Standards, and the use of a NATA-accredited laboratory for quality assurance and quality control of results.

2.3.3 Wilson, 2010 – Assessment of Groundwater Contamination in the Built-up Areas of Norfolk Island and the Lower Catchment

P.J. Wilson, the acting Team Leader of Waste and Environment for NIRC during the AECOM field activities in February 2017, undertook a water quality study in 2009/2010 to determine if there was contamination to the water quality of the island from sewage. Water samples were collected from various locations across the island, inclusive of: built-up areas, throughout the Watermill Creek and Upper Cascade Creek catchments, groundwater (bore water), and surface water. Results were assessed against the Environmental Protection Agency (EPA)'s Queensland Water Recycling Guidelines (2005) for surface and subsurface irrigation of recycled effluent to identify the suitability of the Island's waste water/sewage treatment programs to protect human health and the natural ecosystems of Norfolk Island.

Results indicated that elevated concentrations of *E.coli* were found throughout the Watermill Creek catchment and ranged from 0 colony forming units (cfu) per 100 mL (sites 9,and 11 within Watermill Creek East Branch and at the very top of Watermill Creek West Branch – site 17) to 960.6 cfu/100 mL (sites 3 and 4 in the Kingston Commons subcatchment). Kingston Commons subcatchment was found to have the highest concentrations of *E.coli* and all samples collected from this area reported *E.coli* (63.8 cfu/100 mL to 960.6 cfu/100 mL). Samples from the upper branches of Watermill Creek reported lower concentrations of *E.coli*.

Results from the Upper Cascade Creek Catchment reported generally no *E.coli* from water samples analysed with the exceptions of two locations, at the very top of the of the catchment just downgradient of the sewer line (site 19) reported 1011.2 cfu/100 m L; and, one location (site 23) reported 6.3 cfu/100 mL. The sample from site 23 was reported to have been collected after the water was passed through a filtration system and settling facilities which prevented a sample to be collected directly from the bore itself.

While the impacts were not able to be spatially delineated, the presence of raw human effluent in the waterways of Norfolk Island was confirmed. The study represents the first key data deliverable to advance the development of a Framework for Wastewater Management on Norfolk Island.

2.3.4 URS, 2013 – Norfolk Island Water Quality Study Emily Bay & Upper Cascade Creek Catchments

A limited desktop assessment and site inspection were undertaken to review water quality issues for the Watermill Creek (Emily Bay) and Upper Cascade Creek catchments of Norfolk Island in response to concerns of the former Administration of Norfolk Island (ANI) that there is human and animal pathogen contamination in surface and groundwater resources across the island. Specifically, these contaminants were in the catchment waters which discharge into Emily Bay, a very popular swimming beach with locals and tourists, considered the "jewel in the crown" for attracting tourism to the Island.

The ANI Water Assurance Scheme (WAS) officers Bacterial Analyses book which included results of microbial testing data was reviewed by URS and assessed to identify impacts and trends of *E.coli* in the water quality across these catchments in order to identify the likelihood and sources of faecal contamination on the water resources.

Available water quality data, primarily bacterial, was assessed against relevant criteria for human health (ANZECC 2000 guidelines). The results indicated consistently elevated levels of *E.coli* (ANZECC guideline value is 0 cfu/100 mL) in the lower waterways which flow through Kingston Commons subcatchment and Recreation Reserves inclusive of the Officers Bath (Town Creek Subcatchment) for the time period 2011 to 2012.

E.coli concentrations reported in the waterways that discharge into Emily Bay were reported to almost always exceed safe levels for primary contact, swimming and fishing (ANZECC, 2000) during this time frame (2111 – 2012). These waters, as a result of the *E.coli* concentrations reported, were considered only suitable for restricted uses where human contact was avoided. Trends of *E.coli* concentrations were found to generally increase after rainfall and also after significant disturbance of the creeks, i.e. dredging.

Concentrations of *E.coli* from Emily Bay itself measured from 2010 to 2012 indicated Emily Bay is generally suitable for swimming with few exceptions which include the period when Town Creek is dredged to remove weeds and mud (carried out in early May 2012), and following heavy rain events.

The long term bacterial testing maintained by the WAS officer indicated contaminant levels within surface water discharge into Emily Bay peaks substantially after rain. Watermill Creek and Town Creek water quality was considered to be significantly impacted by heavy rainfall events which have shown to increase *E.coli* levels in exceedance of 13,000 cfu/100 mL at three locations immediately after a heavy rain in August 2011. Of the locations which reported *E.coli* above 13,000 cfu/100 mL, one (Bloody Bridge) is located just east outside of the present study area where waters discharge into Cemetery Bay; one location was reported as Pier Street, located within the Kingston Commons portion of the current study area, which discharges into Emily Bay. The third sample location cannot be confirmed, it was reported as “outlet”.

Overall, the data assessed (2010 – 2013) indicated that elevated *E.coli* has been consistently detected above 100 cfu/100 mL from Watermill Creek, several areas throughout the catchment, and through Kingston Commons subcatchment. It was observed from the data that *E.coli* levels generally declined through the Kingston wetlands area within Kingston Commons, between Pier St and the Emily Bay outlet; however, the discharge into Emily Bay exceeded primary contact criteria (ANZECC, 2000) for approximately 80% of the data. The data analysed from the Emily Bay outlet also reported to exceed *E.coli* criteria for fishing for human consumption (ANZECC, 2000).

Recommendations included an audit of septic tanks, pump stations, and effluent disposal/irrigation fields in the catchment areas; stock management measures to reduce/exclude cattle from direct access to permanent waterways, dams, and wetlands; enhancement and restoration of existing wetland areas within the catchments to improve the quality of surface waters flowing into Emily Bay and the Pacific Ocean; ongoing microbiological monitoring of Emily Bay waterways inclusive of a broader suite of physical/chemical parameters to assist with interpretation and water quality improvement strategies; assessment of some samples by a NATA-accredited laboratory, and education for the community with respect to septic, sewer, and livestock management.

2.3.5 GHD, 2016 – Drinking Water & Recreational Waters Monitoring Program

GHD developed a Water Quality Monitoring Program (WQMP) for the NIRC to provide a structured and systematic approach for the management of public drinking and recreational water to ensure safety and reliability for intended uses on the Island. The WQMP provides detail in regards to the water quality parameters, sample locations, and frequency for sample procurement and analysis along with the relevant guideline values to analyse against for suitability of water quality (ANZECC 2000, ADWG). Additionally, the report includes a systematic approach for the management of results in the form of documentation and reliability, corrective responses, and a notification protocol for the detection of *E.coli* and/or coliform bacteria in waters.

It is considered this document provides a monitoring program approach to manage public drinking and recreational waters to ensure safety and reliability which, after implementation, will allow for long-term results assessment and identification of effectiveness of any preventative and remedial measures adopted.

2.3.6 Advisian, 2016 – Norfolk Island Sewerage Network Preliminary Condition Assessment Report

Advisian undertook a preliminary conditions assessment report of the Norfolk Island Sewerage Network for the former ANI (Advisian, 2016). The report provided an overview of the current condition of the reticulated sewer assets (WAS) and identified priority maintenance areas. The study included site visits, inspections, and risk assessments for the waste water treatment plant (WWTP), seven pump stations, 28 manholes, and three other sites associated with the assets.

Overall, the condition of the sewer assets was found to be very good with over 50% of items inspected were considered ‘as new’ condition; less than 5% of items inspected were identified as requiring urgent repair. Approximately 20% of items inspected were considered to require minor maintenance or additional monitoring for further degradation and 21% were reported require maintenance in the near future to prevent failure.

The risk assessment results reported that three sites were deemed to pose an extreme risk, which include the WWTP septic tanks, Manhole MH-28, and the rising main pressure relief valve. The rising main pressure relief valve and WWTP septic tanks were recommended to have further detailed inspections undertaken urgently to identify items required to be addressed to prevent failure.

Other urgent repair works were recommended as a result of this study and included:

- Repairs to concrete erosion on inlet and outlet pits at septic tanks;
- Replacement of corroded pit covers at septic tanks;
- Further investigation of valves and pumps to determine extent of corrosion;
- Clearing of blockages to manhole MH-27 and MH-28; and
- Further investigation of the rising main pressure relief valve to determine the extent of corrosion.

Several minor works were recommended for the WWTP and further works were identified to improve the reliability of the sewer system and to reduce potential future maintenance costs. These included the clearance of tree roots from manholes and pump stations, corrosion inspections on a number of valves, pipes, chians, manholes, and steel lids and frames across the assets.

2.3.7 Summary

There have been numerous studies undertaken over time with respect to investigation and assessment of the Island’s water quality, potential impacts and contamination to water resources, and the suitability of the existing wastewater treatment and management programs to protect human health and the environment. Monitoring and assessment programs, along with several small scale prevention and protection recommendations, have been developed with respect to the Island’s limited resources. Prior to the commencement of the Norfolk Island Regional Council in July 2016, it is not apparent to AECOM that many of the recommendations were implemented.

3.0 Environmental Setting

3.1 Topography

Norfolk Island is considered an erosional remnant of a volcanic complex which has been subject to deep weathering since eruptive activities ceased. The topography is dominated by elevated terrain in the northwest, which rises to a ridge where Mount Bates (318 m) and Mount Pitt (316 m) are the Island's highest points. The remainder of the Island consists of the deeply incised southern plateau, where the study area is located, which is approximately 100 m high. The higher terrain reflects the remains of the volcanic vent responsible for the Island's formation. The rugged coastline comprises cliffs up to 100 m in the Island's northwest which slope towards the southeast, where they are approximately 50 m. Kingston represents the boundary between the southern plateau and the coastal lowland, which is less than 20 m above sea level (Abell and Faulkland, 1991).

The study area comprises portions of the two largest surface water catchments on the island, Watermill Creek and Upper Cascade Creek. Topography varies where areas at the top of the catchments (e.g. Burnt Pine, Upper Cascade Creek) which are located generally in the centre of the island, just south of the highest point, Mount Bates, which slope south to the coastal lowland of Kingston. A review of Google Earth indicates the highest elevation is approximately 148 metres above Australian Height Datum (m AHD) and slopes southwards towards Emily Bay to an elevation of approximately 5 m AHD.

Figure 2 presents the topography of the study area.

3.2 Hydrology

In general, Norfolk Island has developed a drainage system considered typical of volcanic terrain which has been deeply weathered in a subtropical climate. The study area, located on the southern plateau, consists of a network of dry valleys which lead into perennial and intermittent streams. Streams which flow from the southern plateau are supported in the higher reaches by spring seepage and are maintained by groundwater baseflow (Abell and Faulkland, 1991). Most streams are active and flow in the winter months, however, in the summer months they are generally dry or reduced to localised pools.

The catchments of the study area are comprised of multiple tributaries which discharge into a primary creek. The Upper Cascade Creek catchment portion of the study area is comprised of the most upper reaches of Cascade Creek. The site visit observed that the uppermost creek beds were dry, considered a result of the extensive dry period on the island. Upper Cascade Creek catchment flows from the higher elevations of Middlegate towards the north-northeast where it meanders for approximately 2 km then discharges into Cascade Bay.

Watermill Creek Catchment is comprised of five subcatchments in the study area (West Branch, East Branch, Town Creek, Community Bore, and Kingston Commons). Each of these subcatchments discharges into Watermill Creek at various points as it flows from the higher elevation areas in the north (Burnt Pine) downgradient approximately 2.5 km where it discharges into Emily Bay.

Figure 2 depicts the catchments and subcatchment areas of the study area.

3.3 Geology

Norfolk Island, located within the Norfolk Island group is situated on the Norfolk Ridge, an elongated submarine rise, which extends from New Zealand to New Caledonia. Norfolk Island is almost completely volcanic in origin, an erosional remnant, considered the result of a number of local volcanic centres that erupted several times in the Pliocene, between 3.05 and 3.3 million years (Ma) ago.

The geology is considered to be primarily comprised of dominantly fine to medium grained olivine basaltic lavas and pyroclastic tuff (layered volcanic ash). Within the Island's lithology, there are five main geological formations, four of which comprise distinct volcanic layers generally considered the result of sheet lavas:

- Ball Bay Basalts;
- Duncombe Bay Basalts;
- Cascade Basalts; and
- Steeles Point Basalts.

The sheet lavas are typically flat, up to 30 m in thickness, and display well developed columnar jointing and occasional flow banding. The basalts weather to form spheroidal basaltic core stones and cobbles, which are often matrixes of completely weathered basalt or high plasticity residual clay (PB, 2005). Pyroclastic tuffs are interbedded with, and lie unconformably on top of, the basalts (Abell & Falkland, 1991). These weathered basalts and residual clays are recognised to include a shallow groundwater unit.

The fifth main geological formation on the Island consists of a coarse marine calcareous rock, calcaranite, (sand, coral and shell fragments cemented with lime) of late Pleistocene origin and is located near Kingston.

The study area is located on the Southern Plateau lava apron and is considered to be underlain by weathered basalt and alluvial sediments within and adjacent to creeks and tributaries. Calcaranite can be found in the southernmost portions of the Kingston Commons subcatchment.

3.4 Hydrogeology

The hydrogeological regime of Norfolk Island is considered to be a dynamic system. Two primary aquifers are recognised within the Island, a shallow water table within the alluvial sediments and weathered basalt and a deeper regional bedrock aquifer.

The shallow unconfined water table is recognised to underlie the Southern Plateau within the weathered basalt and alluvial sediments within and adjacent to creeks. Water within this unit is observed to follow topography and generally flow from the elevated recharge areas in the centre of the plateau to the discharge areas along the coastline (Abell and Faulkland, 1991). This hydrostratigraphic unit is considered to be strongly influenced by rainfall which means the shallow water table is recharged by rain and surface water (creeks); clear responses of the shallow aquifer to seasonal rainfall events have been previously observed.

A deeper, regional (bedrock) aquifer below the weathered basalt is associated with the discrete permeable zones of the volcanic sequence, specifically within the fractures of basalt and the tuff beds. Groundwater from the weathered basalt water table is considered to provide limited recharge to the bedrock aquifer through fractures. Groundwater movement within this unit is considered to be dependent on the size and extent of fractures within the bedrock aquifer.

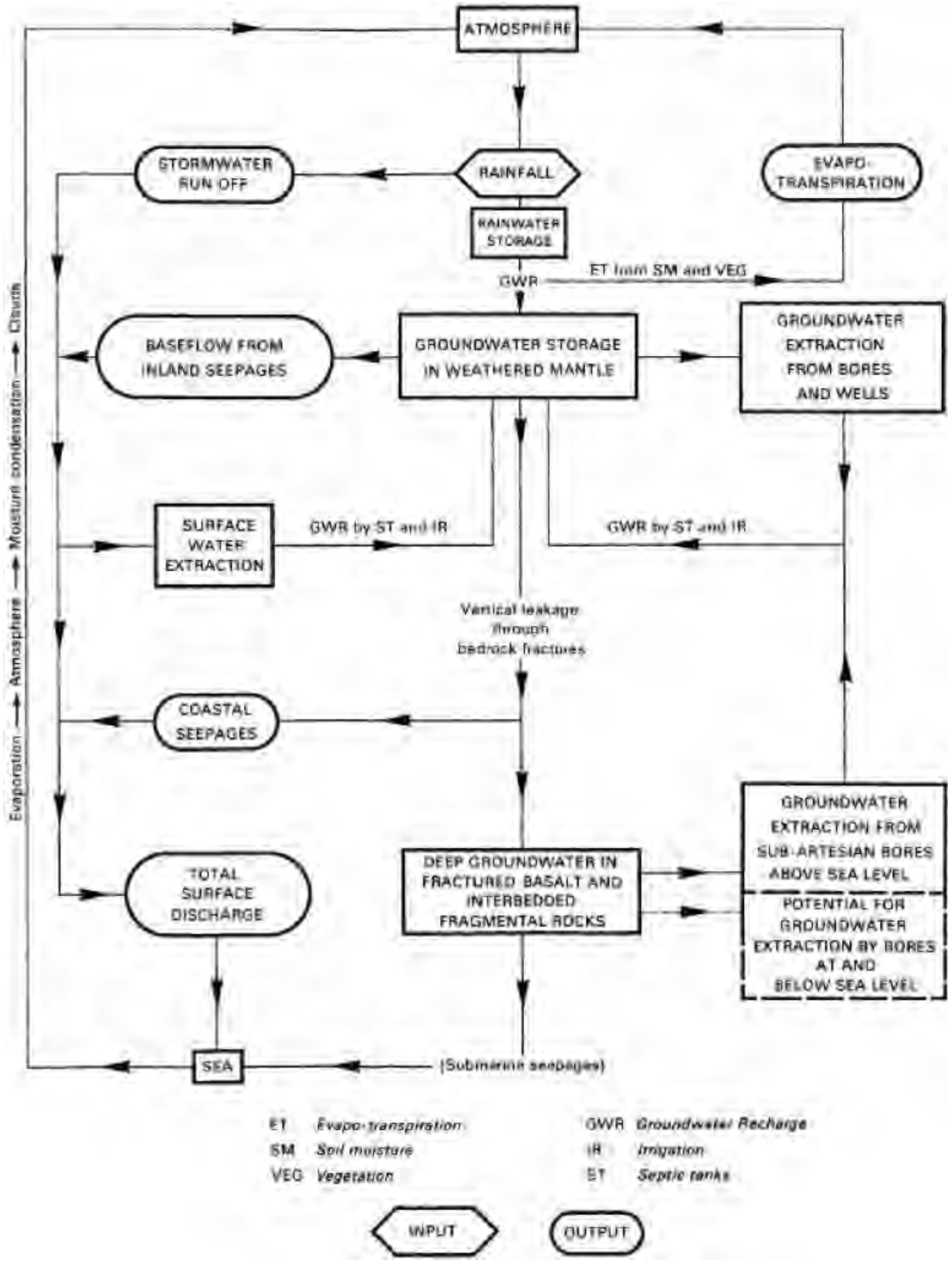
Upon review of groundwater flow patterns, geology and topography, it is considered that creeks, inclusive of Waterm ill Creek, are fed by shallow groundwater in the form of natural springs. This is exemplified by the reservoir of the Community Bore, which is likely a natural spring where groundwater discharges to surface and feeds the local creek and Community Bore.

Quality of the weathered basalt water table is generally considered suitable for domestic uses in the study area in the wet season. It is recognised that, as water levels within shallow bores increase after rainfall as the result of recharge from creeks and rainfall directly, pollution within surface water and on the ground surface itself (in the form of animal excrement, chemical/ contaminant spills, etc.) can migrate vertically into the water table and subsequently, laterally into shallow bores. In contrast, the deeper basalt aquifer, due to limited vertical connectivity with the ground surface and the overlying water table, it is apparent this aquifer may have better groundwater quality than the shallow water table.

Due to the potential seasonality of shallow groundwater, it is considered that the availability of groundwater may be limited in volume across the study area and Island. A review of the status of registered bores on the Island indicates many bores are dry and others are contaminated (see **Figure F4**). While further investigation is warranted to determine the cause of dry bores, it is considered that a lack of planning for water consumption and extraction from bores will facilitate more bores to become dry in the future. Furthermore, the available shallow water supply is considered to be vulnerable to pollution from human and livestock wastes, which is considered a likely reason for the contaminated bores identified on **Figure F4**.

Figure 1 presents the understood hydrological cycle of the Island.

Figure 1 Hydrological Cycle of Norfolk Island



4.0 Field Activities

4.1 Summary of Field Activities

4.1.1 Data Collection and Review

All available historical data in regards to water quality was provided by P.J. Wilson, the Acting Team Leader for Waste and Environment for the NIRC. It was noted that subsequent to the change in administration on 1 July 2016, most of the information collected under the previous administration in regards to bore and water quality data was not transferred over to the NIRC. A statement in regards to this loss of information is presented as **Appendix A**.

Information of relevance to this investigation that was available for this report included:

- Previous reports and associated data;
- Water quality data procured by the NIRC, from 1 July 2016 to February 2017;
- Microbial data procured by Dr Martin Goldsmith of Biotec;
- Rainfall data for the island;
- Recent (2016) population (permanent and tourist) data;
- Agricultural data estimates (number and type of livestock);
- Limited and sporadic historical microbial data procured under the former Norfolk Island Administration (ANI);
- Sewer condition assessment information and septic overflow records since 1 July 2016; and
- Water Assurance Scheme (WAS) sewer connection information.

Microbial data has been collected and analysed for the presence of *E.coli* from tourist accommodations, restaurants, and water supply facilities on the Island since the NIRC was formed in July 2016. While the sample points were not directly from creeks or bores, the water from accommodation room taps, common areas, kitchen taps, and laundries were assessed in order to identify any potential risks to human health. These data were reviewed by AECOM for this study.

4.1.2 Inspection of Wetlands and Managed Areas of Creeks

Surface water features known to have historically been dredged or actively managed, such as the wetlands and creeks, were visited. From the Duck Dam in the north following the surface water features south into and across the actively managed areas are predominantly within the Kingston and Arthurs Vale Historical Area (KAVHA) World Heritage Site to the drainage inlet to Emily Bay were examined and are presented on **Figure F2**.

The surface water features were inspected to identify potentially disturbed areas which may affect water quality downstream. It is noted that the surface water features inspected drain into Emily Bay, a popular location for water activities for locals and tourists alike. The location of wetlands/dams in proximity to Emily Bay allow for a natural or enhanced water quality filter prior to release into the Bay as predominantly all surface water runoff flows through this waterway. These features would need to be managed differently to enhance the filtration processes.

4.1.3 Inspection of Septic Tanks and Water Treatment Plant

Inspections were undertaken as component of the field works of:

- a number of septic tanks reported to have had several overflows within the last four years,
- the water treatment plant (WTP),
- WAS sewered areas, and
- pumping stations.

These inspections allowed for the identification of areas where known impacts of human waste were introduced to the receiving environment; the geographic location of the WAS with respect to densely populated areas and areas of primarily septic systems; the condition and capacity of the WTP; and the overall layout of tourist accommodations in regards to the proximity and relationship between bore placement, creeks, and septic tank/pumping station.

A review of the WAS Log and Overflow Record for incidents since July 2016 was also undertaken. This details confirmed overflows, cause, actions, and preventative measures undertaken.

The information gathered and reviewed has allowed for the identification of locations and potential sources of human waste into the environment over time.

4.1.4 Assessment of Implementation of 2013 Recommendations

The investigation included assessment of whether any of the 2013 URS recommendations have been adopted and, if so, the success or otherwise of implementation. These recommendations included:

- digitisation of data obtained in the past 4 years and scanning of historical hard copy data;
- adoption of a broader suite of analytes for water quality tests;
- conducting some water quality analysis on mainland Australia or in New Zealand to verify data for QA/QC;
- liaison with landowners of properties on septic which are within or adjacent to the WAS to connect to sewer;
- trial exclusion of livestock from areas, provision of troughs, and comparison of cattle productivity;
- waterways management (staged vegetation removal, wetlands); and
- audit of septic systems (during wet season).

4.1.5 Scope Variation – Water Quality Monitoring

Due to conditions encountered and information assessed as a component of these works, the following variations to our scope of works were adopted after discussions with P.J. Wilson and Blake Hunton (AECOM’s client) and approval from Mr Hunton:

- To procure water samples from seven selected locations, along with quality control (QC samples), throughout the catchments for analysis by a National Associated of Testing Authorities (NATA) -accredited laboratory from both bore and surface water locations; and
- To analyse the samples for water quality parameters and genetic speciation for *E.coli* results in order to identify the source of impacts, human, cattle and/or bird contributors.

Seven water samples were taken at various locations within the catchments in an effort to identify potential sources / locations of contaminants entering the waterway. Sample locations were determined based on historical results and anecdotal evidence provided by P.J. Wilson inclusive of a data set and map of bores on the Island produced in 1970 and details the known conditions of the bores, dry, contaminated, or usable. This data is presented on **Figure F4**; the AECOM sample locations are also included in this figure for reference. The map and data set of registered bores was provided to AECOM by the NIRC.

The seven sample names and corresponding locations are described in Table 1 below and are presented on Figure 2. The sample locations were selected to:

- Provide a geographic cross section through Watermill Creek Catchment that targets areas of known historic impacts,
- Highly utilised water sources (for domestic or other uses), and
- Areas before and after dams/wetlands to assess the potential impacts these areas may have on surface water quality before discharge into Emily Bay (Pacific Ocean).

Table 1 Water Sample Locations and Rationale

Sample ID	Location and Rationale
BH139	Borehole 139 was identified for sample procurement as it is located at the very top of the Watermill Creek West Branch subcatchment of the Watermill Creek Catchment and is reported to provide potable water supplies to several residences in the immediate vicinity. The bore was unable to be sampled due to a faulty pump. The sample location was then relocated from the bore to the nearby creek, at the top of the surface water catchment. It was noted that a sewage pumping station (Mildred) is located upgradient from the sample location. Due to a paucity of surface water flow, no water samples could be taken upgradient of the pump station. The decision to take a sample from the creek at this location, while just downgradient from the sewage pumping station, allows for identification of the water quality entering the catchment at this point.
BH166	Borehole 166 is located within the Governor's Lodge Resort Hotel property at the top of the Watermill Creek East Branch subcatchment. The bore sampled is located within a valley behind the hotel. Historically, microbial results from this location have indicated faecal contamination and have been identified as contaminated on the registered bore list (see **Figure F4**). This bore is reportedly used primarily for landscape water supply; however, anecdotal evidence indicates this well is used to top up the rainwater tanks (primary hotel potable water supplies) in times of extreme drought.
SW_DDInlet	This surface water sample was collected just before the inlet to the Duck Dam and after the convergence of the Watermill Creek East and West branches. The location was selected to assess the water quality entering the Duck Dam, the first dam within a series of dams and managed surface water areas and wetlands within the KAVHA.
SW_CB	This sample was collected from the Community Bore located along Country Road. The Community Bore is located within the Community Bore subcatchment of the Watermill Creek Catchment and is a well-known and utilised water source for many residents of the island in times of prolonged dry periods. The water is, per anecdotal evidence, used primarily for stock watering. However, domestic uses of this water cannot be discounted. The bore is essentially a tap constructed within a road cut which is considered to be the output from a natural spring and associated reservoir which is located approximately 100 m north (upgradient) of the tap/road cut.
BH224	Borehole 224 is located behind the Government House near the bottom of the Town Creek Subcatchment. The bore is reportedly used as a source of potable water for many residents and workers of the Government House. The bore has historically been analysed for water quality (ECG, 2008) and was selected for comparison of results over time and because it is a widely used source of water.
SW_EBInlet	This location represents the surface water sample taken from the last flowing point before the inlet to Emily Bay, a popular location for recreational water sports and fishing, utilised by both locals and tourists. The sample from this location allows for the identification of the water quality entering Emily Bay.
BH132	Borehole 132 is located within the Fletcher Christian Apartment property. The bore is reportedly predominantly used for landscape water supply and is located adjacent to a creek considered to be at the top of the Upper Cascade Creek Catchment. This sample location allows for identification of the water quality entering this catchment upgradient of numerous historical septic tank overflows.

Photographs of each of the sample locations are presented in **Appendix B**.

4.2 Water Sample Collection Methodology

4.2.1 Surface Water Sample Collection

The surface water sample collection methodology is described below in Table 2.

Table 2 Surface Water Sample Procurement Methodology

Activity/Item	Details
Date of Field Activities	22 - 28 February 2017
Surface Water Sampling method	Surface water samples were collected by grab sample methodology. Physicochemical properties were measured with a YSI water quality meter for pH, electrical conductivity (EC), redox potential (Eh), dissolved oxygen (DO) and temperature were measured. Field sheets and calibration certificates for the equipment used are presented in **Appendix C**.
Sample preservation	Water samples were placed in laboratory-supplied pre-preserved bottles. Samples for dissolved metals analysis were field filtered through a 0.45µm filter. Samples were stored on ice (<4°C) in an esky while on the island and in transit to the laboratory. Samples were transported to the laboratory on the day of sample collection to meet the analysis hold times.
Decontamination Procedures	The water quality meter was decontaminated with Decon 90 solution and rinsed with distilled water between sample locations.

4.2.2 Groundwater Sample Collection

The groundwater sample collection methodology is described below in Table 3**.**

Table 3 Groundwater Sample Procurement Methodology

Activity/Item	Details
Date of Field Activities	22 - 28 February 2017
Well Gauging	Monitoring wells were gauged for static water level (SWL) prior to sample procurement with an electronic water level meter.
Groundwater Sampling method	Monitoring wells were sampled from either a dedicated well pump or disposable Teflon bailer. Bores sampled via pump were purged for at least three well volumes or 10 minutes prior to collection to ensure representative groundwater quality from the intersected aquifer. Groundwater physicochemical properties were measured with a YSI water quality meter for pH, electrical conductivity (EC), redox potential (Eh), dissolved oxygen (DO), and temperature. Field sheets and calibration certificates for the equipment used are presented in **Appendix C**.
Sample preservation	Water samples were placed in laboratory-supplied pre-preserved bottles. Samples for dissolved metals analysis were field filtered through a 0.45µm filter. Samples were stored on ice (<4°C) in an esky while on the island and in transit to the laboratory. Samples were transported to the laboratory on the day of sample collection to meet the analysis hold times.
Decontamination Procedures	The water level meter and water quality meter were decontaminated with Decon90 solution and rinsed with distilled water between sample locations. In the instance a bailer was utilised for sample collection, a new disposable Teflon bailer and string were used for each well.
Disposal of purged water	Purged water was discharged to surface, per P.J. Wilson.

5.0 Laboratory Analysis and QA/QC

5.1 Laboratory Analysis and QA/QC

Seven primary water samples, three bore and four surface water, were submitted to ALS Environmental (ALS) in Brisbane for analysis of standard water quality parameters inclusive of physiochemical properties, metals, alkalinity, nutrients, major ions, cyanide, turbidity, and salinity.

The duplicate water sample of BH166 (QC01) was collected and submitted to ALS Brisbane who forwarded the sample to Eurofins Laboratory in Brisbane for analysis of physiochemical parameters, metals, alkalinity, major ions, cyanide, turbidity, and salinity.

ALS subcontracted out a portion of each sample to Dairy Technical Services (DTS) Food Assurance laboratory in North Melbourne to undertake analyses for chemicals of potential concern (COPCs) which include total coliforms, thermotolerant coliforms, Escherichia coli (*E.coli*), faecal coliforms, and heterotrophic plate counts (at 21°C and 37°C). It is noted that two methods were utilised by DTS for total coliforms and *E.coli* analyses.

Further details are provided in **Appendix D**.

5.2 Genetic Speciation Laboratory Analysis and QA/QC

Seven primary water samples and one QC sample (QC01) were submitted to the Commonwealth Scientific and Industrial Research Organisation (CSIRO) in Brisbane for genetic speciation analysis for *E.coli*. The genetic speciation included analyses for five human markers, one bovine (cattle) marker, and one avian (bird) marker. The analyses for human genetic markers included tests for human adenoviruses and polyomaviruses, *Methanobrevibacter smithii* niFH, *Bacteroides* HF183, and *E.coli* H8 markers.

Genetic speciation analysis is performed after separation of the sample into three components then each component is analysed individually. The concentrations from the three samples are then averaged to provide an overall concentration. Standard deviation (SD) between the three components of the sample was then calculated to qualify the dispersion between the resultant concentrations.

Further details are provided in **Appendix D**.

5.3 Analytical Data Validation

AECOM has undertaken a review of the laboratory analytical results for quality control purposes; the results of the data validation process are presented in **Appendix D**; laboratory quality control reports are included in **Appendix E**. Based on AECOM’s review of all QA/QC results, these data are considered acceptable for interpretative use in the context of this report.

6.0 Adopted Investigation Levels

6.1 Contaminants of Potential Concern

Based on the existing land uses, historical investigation information, and observations from this investigation, the COPCs are considered to be primarily indicator organism bacteria inclusive of total coliforms, thermotolerant coliforms, Escherichia coli (*E.coli*), faecal coliforms, and heterotrophic plate counts (at 21°C and 37°C).

6.2 Adopted Investigation Levels

The adopted investigation levels (IL) are used as an initial screening test to identify whether continued uses and practices within the study area may pose a risk to human health and/or the environment. These are presented in Table 4 below.

Table 4 Adopted Investigation Levels

Environmental Media	Adopted IL	Rationale
Groundwater and Surface Water	ANZECC guidelines for freshwater ecosystems, low reliability have been adopted: The Australian and New Zealand Environment and Conservation Council *(ANZECC & ARMCANZ) 2000 Guidelines for the protection of fresh waters (95% species protection level).*	To understand if there is any potential impacts to ecological receptors in the study area.
	ANZECC guidelines for freshwater ecosystems, low reliability have been adopted: The Australian and New Zealand Environment and Conservation Council *(ANZECC & ARMCANZ) 2000 Guidelines for the protection of marine waters (95% species protection level).*	
	Australian Drinking Water Guidelines (ADWG) for Health, developed by the Australian Government National Health and Medical Research Council (NHMRC), 2011 (updated November 2016).	To identify the suitability of waters in the study area for human consumption, and exposure, particularly during times of drought.
	Australian Drinking Water Guidelines (ADWG) for Aesthetics, developed by the NHMRC, 2011 (updated November 2016).	
	Groundwater Investigations Levels (GILs) for Freshwater developed by the NEPC and documented by NEPM, 2013	
	Groundwater Investigations Levels (GILs) for Marine water developed by the NEPC and documented by NEPM, 2013	
	Groundwater Investigations Levels (GILs) for Drinking water developed by the NEPC and documented by NEPM, 2013	
	Guidelines for Managing Risks in Recreational Waters, developed by the Australian Government National Health and Medical Research Council (NHMRC), 2008	
	ANZECC guidelines for Irrigation have been adopted for short term (STV) and long term uses (LTV): The Australian and New Zealand Environment and Conservation Council *(ANZECC & ARMCANZ) 2000 Guidelines for the protection of marine waters*	To identify the suitability of waters in the study area for irrigation and livestock watering.
	ANZECC guidelines for livestock drinking water quality: The Australian and New Zealand Environment and Conservation Council *(ANZECC & ARMCANZ) 2000 Guidelines for the protection of marine waters*	

7.0 Results

7.1 Historical Data Review

Background

The results of *E.coli* sampling in waterways were reviewed. The 2013 URS report reviewed the results of bacterial testing (*E.coli*) undertaken by the ANI in November 2011 and October 2012 and found it to be consistent with the long term bacterial analyses data collected by the former ANI Water Assurance Scheme (WAS) officer over the previous 30 years. The 2011 and 2012 results showed there are consistently elevated levels of *E.coli* in the lower waterways flowing through Kingston Commons and Recreation Reserves including the Officers Bath sample point (Town Creek subcatchment).

E.coli levels reported in the waterways which discharge into Emily Bay were found to almost always exceed safe levels for primary contact, swimming and fishing (ANZECC, 2000). These waters were only considered suitable for restricted uses where human contact was avoided. *E.coli* levels were found to increase after rainfall and also after significant disturbance of the creeks (i.e. dredging events).

E.coli test results for Emily Bay waters, as reported in the WAS Bacterial Analyses book, from 2010 to 2012 and reviewed by URS in 2013 indicated Emily Bay itself was generally suitable for swimming, with very rare exceptions which included the period after dredging of Town Creek to remove weeds and mud was carried out in early May 2012, and directly after substantial rain events. Watermill Creek and Town Creek water quality was reported to be clearly impacted by heavy rainfall events which have shown to increase *E.coli* levels to the order of 10,000 colony forming units (CFU)/100 mL (URS, 2013).

2017 Update

Upon AECOM's visit in February 2017 and discussions with the NIRC's Acting Team Leader for Waste and Environment, P.J. Wilson, it was identified that the former ANI had not provided NIRC with water quality testing data from 2012 to 1 July 2016. While some historical data was located, a data gap exists for *E.coli* and coliforms as tested by the former ANI between the data reviewed for the 2013 URS report until the NIRC was formed (July 2016).

However, water samples from various locations throughout the catchments were taken and analysed by Dr Martin Goldsmith of Biotec NI, on behalf of the Australian Government, until 1 July 2016. Microbial data was analysed from samples collected from the Duck Dam, Officers Bath, Governors House Bore, and the inlet to Emily Bay in April and May 2015 for human faecal source tracking. Results confirmed significant detection of target Human Mitochondrial DNA (faecal impacts from human sources) in the samples collected at Officers Bath and the inlet to Emily Bay. The Tweed Shire Council Laboratory Centre who undertook the analysis reported these samples "had mitochondrial signals at levels equivalent to untreated human waste entering a waste water treatment plant (influent)..." The sample from Duck Dam did not report detections of human mitochondrial signals. Samples taken from the same locations in May 2016 were reported to have *E.coli* concentrations consistent with historical values for these locations (see **Appendix F**).

Water quality samples have been taken from tourist accommodations by NIRC since October 2016 which utilise primarily bore and/or rain water, or bore water as a backup when rain supplies are limited. Results from 65 locations sampled reported twelve detections of *E.coli*. Detections ranged from 10 CFU/100 mL (Islander Lodge guest room tap) to 266 CFU/100 mL (Governors Lodge kitchen tap). Of the twelve locations with detections of *E.coli*, three are reported to have a filtration system in place; one location reports to have an ultraviolet (UV) filtration system in operation.

Total coliforms ranged from non-detect to 11,988 CFU/100 mL (Broad Leaf Villas); the kitchen tap at Christians of Bucks Point reported a total coliform concentration of 10,656 CFU/100 mL. While total coliforms are generally not considered harmful to humans, they do not occur naturally in groundwater and their presence is an indication that more harmful organisms may be present. Testing for total coliforms is used globally to determine the adequacy of water treatment and the integrity of potable water distribution systems.

It is noted these two sample location are not reported to utilise any water filters or other water treatment system (i.e. ultraviolet) whereas the other locations have such systems in place. *E.coli* was not detected at either of these locations. The water quality results for tourist accommodations are presented in **Table F1** in **Appendix F**.

Of the restaurant kitchen taps sampled, none reported detections of *E.coli* except for the Olive Café which reported an *E.coli* concentration of 133 CFU/100 mL prior to filtration. The Olive Café utilises an ultraviolet (UV) water treatment system for all of their water prior to use. A sample of water was analysed after it was subject to their UV system which reported no detections of *E.coli.*

While *E.coli* concentrations were not detected, total coliform concentrations ranged from non-detect to >17,000 CFU/100 mL (Barney Duffy's) from restaurant taps within the study area. It is considered that the detection of total coliforms but no *E.coli* warrants further investigation to the water supply system and distribution network. The water quality results for restaurants and businesses are presented in **Table F2** in **Appendix F**.

It is noted that these water samples were not analysed by a National Association of Testing Authorities (NATA) -accredited laboratory and that no QC samples were collected or analysed. However, these samples were analysed via agar plate techniques. These tests were undertaken by the pathology laboratory at the Norfolk Island hospital.

A map of registered bores on the Island was provided to AECOM, which detailed the known conditions of the bores, dry, contaminated, or usable. This information is depicted on **Figure F4**; the AECOM sample locations are also included in this figure for reference. It is noted this dataset is from a census undertaken in 1970; the information on this figure was provided to AECOM from the NIRC. It was reported that a comprehensive bore census has not been undertaken since that time.

7.2 Inspection of Wetlands and Managed Areas of Creeks

As the upper reaches of the east and west branches of Waterm ill Creek Catchment flow into the Duck Dam prior to discharge into Emily Bay, the status of these wetlands is an important feature for natural filtration of COPCs from the watercourse. Physical settling and biological filtration processes initially occur in the Duck Dam and then more substantially in the lower wetlands of the KAVHA, prior to discharge into Emily Bay. The recruited wetland plants (mostly non-native species) provide important treatment/filtration benefits to enhance the water quality throughout this area based on historical and recent water quality results from samples collected before and after the dam.

The Duck Dam was historically maintained as a water source; in the mid-1900s, the dam was breached and the floor used as a market garden. Anecdotal evidence suggests the Duck Dam was historically dredged but is no longer. The primary surface water drainage pathway through the KAVHA is reported to be dredged annually to remove overgrowth of plants in the waterway which prevent a continuous flow through the drainage system. The dredged materials are stockpiled adjacent to the waterway. Saturated soils and low lying areas with ponding water were observed west of Pier Street and south of Country Road. This suggests the waterway becomes blocked for a substantial period of time and water overtops the channel into the adjacent land.

During the site visit, the Island was considered to be in drought. The outfall to Emily Bay was dry and the last area of water before Emily Bay was observed to be stagnant and coloured with tannins from biological materials that have settled over the long dry season. There was insufficient water in the channel to discharge into Emily Bay.

Historical convict-dug wells were observed within the KAVHA area. The wells are approximately 1 m in diameter and are unprotected from the surface. It is considered these wells, while open to the surface, may act as preferential pathways at times of flood/high water in the nearby wetlands in addition to allowing other foreign matter into the groundwater (i.e. garbage, animal faecal matter, septic overflows). **Figure F5** presents these locations.

7.3 Inspection of Septic Tanks and Sewer System

AECOM inspected several septic systems, sewer connections, and pump stations reported to have a history of uncontained overflows, particularly from July 2016 to February 2017. Table 5 below summarises the confirmed overflows within the study area from July through December 2016. **Figure F6** (attached) presents the locations of the confirmed flows in addition to soakage trenches and other locations confirmed by Andrew Barnett (plumber) to have had regular/multiple failures over the past four years. The soakage trenches indicated on **Figure F6** are generally constructed within or adjacent to creeks. There are some areas of high density houses where only soakage trenches are primarily utilised, inclusive of the Short Ridge area, Quality Row, and Grassy Road. Most of these soakage trenches are reported to be released down valleys through a single above ground pipe.

While there are only four confirmed overflows from 2016, there are a number of locations considered to potentially leak and cause contamination from human sewage, namely areas with aerated wastewater treatment systems (AWTS) which, anecdotal evidence suggests are not maintained effectively or irrigated over a sufficient land area, specifically the Government House AWTS.

The soakage trenches and AWTS identified by Andrew Barnett and P.J. Wilson to be of concern are depicted on **Figure F6**.

A photographic log of locations visited and inspected by AECOM is included in **Appendix B**.

Table 5 Summary of Confirmed WAS Overflows

Date	Location	Issue	Cause	Actions	Prevention	AECOM Inspection
19/07/2016	Governor's Lodge Pump Station (Watermill Creek Catchment)	Pump station overflowing	Float switch stuck	Pump shut down manually, check pumps and fix float	Identified installation of a remote monitoring system for pump station – not actioned	Yes
9/09/2016	Sewer manhole in Richard Cottles Paddock (Watermill Creek West Catchment)	Sewer manhole regularly overflowing	Roots in sewer	Lifted lids back to the end of Mitchell's Lane and all manholes were full of roots. Cleared the roots and flushed the lines with the water blaster. Flushed the lines.	Regular maintenance of sewer lines	Yes
6/12/2016	Sewer manhole next to RSL Pump Station (Upper Cascade Creek Catchment)	Sewer manhole regularly overflowing	Pump station not working	Fixed pump station, lifted manhole lid and flushed sewer line	Regular maintenance of sewer lines and manholes	Yes
19/12/2016	Governor's Lodge Pump Station (Watermill Creek Catchment)	Pump Station not pumping	Pump Fail. Second pump only pumps for 3 days then fails	Manually pump out, replace non-return valve, water blast	Maintain regular water blasting, back flushing. Both pumps kept in automatic mode	Yes

7.4 Assessment of Implementation of 2013 Recommendations

The paucity of available data before 1 July 2016 and discussions with P.J. Wilson indicated some recommendations from the 2013 Water Quality Study Report were adopted in a limited or trial capacity. The observations in regards to the implementation of 2013 recommendations are presented below.

- The digitisation of data was observed to be of importance to the NIRC and has been implemented since 1 July 2016. However, there was no observed increase of digitised data from 2013 to 1 July 2016.
- Testing for a broader suite of analytes for water quality samples was not observed to have been implemented. The extended suite of analytes recommended included additional potential human pathogens (Adenovirus, salmonella, Polyomavirus) and physical/chemical parameters as a more comprehensive suite of human and animal sewage indicators.
- Analysis of water quality samples on mainland or in New Zealand at National Association of Testing Authority (NATA) registered laboratories to verify data for QA/QC purposes was not observed to have been implemented. However, it is noted the logistics, given the sample hold times for certain analyses, to have samples flown from the Island to mainland or New Zealand and delivery to a laboratory is a logistical challenge. Furthermore, quarantine certificates for environmental samples are required, which presents an additional challenge.
- Liaison with landowners of properties on septic systems within proximity to connect to the WAS to reduce the potential impacts of effluent on the environment was not observed to have been undertaken.
- It is noted that a trial exclusion of livestock from areas of creeks was proposed via a five stage approach to protect waterways of the Island while allowing cattle to graze through the majority of the KAVHA area but was not considered successful. The five stage approach was developed by the Norfolk Island Cattle Associated Inc. in response to the 2013 URS report with the objectives of waterway protection while allowing cattle to still graze through the majority of the KAVHA area. The five stages identified included:
    - Installation of water troughs at three locations;
    - Trial fencing between Pier and Bounty streets around the creek at a distance of five metres from the creek and add/plant appropriate plants within the enclosed area adjacent to the creek with plants recommended by a wetland expert;
    - Monitor waters at appropriate locations to determine effectiveness of the modified wetland;
    - If monitoring shows further wetlands are needed, the wetland area woult be increased to Flagstaff; and
    - Create a leaky weir system from the Duck Dam to reduce the speed of water in order to reduce erosion, further improve water quality, allow water to soak into the groundwater system and reduce flow into Emily Bay.

    It was reported that fences were constructed however; they were torn down and destroyed by unknown person(s).
- Waterways management were reported to include dredging of Watermill Creek through the wetlands within Kingston Commons on an annual basis. The dredged material was observed stockpiled on the banks, adjacent to the creeks and surface water bodies dredged.
- Undertaking audits of septic systems during the wet season was not reported to have been implemented under the former ANI; however P.J. Wilson reported this is a task recognised to provide value to the overall management of waste water and associated impacts to human health and the environment.

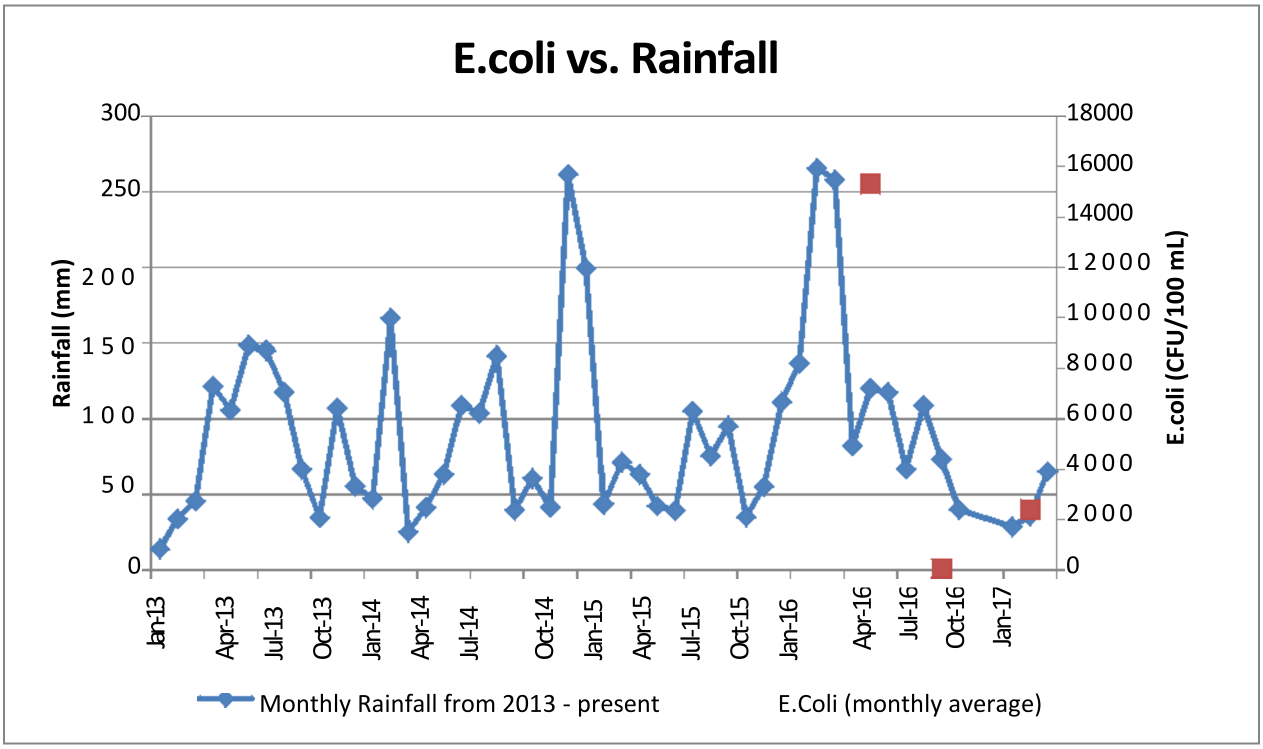
7.5 Rainfall Data

Monthly rainfall data was procured from the Bureau of Meteorology (BoM) website for weather station number 200288, which is located at the Norfolk Island International Airport. Data assessed for this study was limited to monthly rainfall data from since the 2013 URS report until February 2017.

While limited microbial data (*E.coli*, coliforms) was available for review from this time period from surface or bore water in the study area, *E.coli* concentrations available were assessed against rainfall data to determine whether there is a correlation between elevated *E.coli* results and significant rainfall events. **Figure 1** below depicts the monthly rainfall data and the available *E.coli* measurements (averaged) from 2013 to February 2017. Specifically, the data includes results from samples analysed by Biotec (2016) and the AECOM samples (2017) collected from the Watermill Creek catchment, specifically, from Duck Dam, Officers Bath, and the inlet to Emily Bay.

The graph supports historical trends that observed *E.coli* concentrations increased directly after large rainfall events and is considered to provide rationale to the variations in reported *E.coli* concentrations over time.

Figure 2 Rainfall events vs. *E.coli* measurements (2013 – February 2017)



7.6 Potential Human Sources

Data was obtained to update the number of potential human sources since the 2013 URS report. Specifically, data was procured in regards to: number of residents, tourist beds, and commercial/industrial/government connected to, or within close proximity to, the WAS.

It was reported by P.J. Wilson that, to the best of his knowledge, no properties have been added to the WAS since at least 2013. This means there are about 135 residences connected to sewer, where 47 of these properties are located within the Watermill Creek catchment. There are about 37 residences still using septic tank systems in close proximity to the sewer, with approximately 16 of these in Watermill Creek catchment.

For the upper Cascade Creek catchment, it is estimated that there is an unsewered residential population of about 35 mostly around the Middlegate subdivision and surrounds include the Settlers Village but excluding the Catholic Church. All of this is within the WAS service area and in close proximity to existing sewers.

In 2013, it was reported there were approximately 900 tourist accommodation beds plus commercial/industrial premises (retail and restaurants) with about 1130 seats/staff within the Burnt Pine and Middlegate sewered area. Roughly 50% of this development is within the Emily Bay Catchment, with the balance mostly within the upper Cascade Creek catchment. ANI advised in 2013 that only about 3 of the commercial/industrial premises are not connected to sewer.

P.J. Wilson has reported that these numbers have not changed.

7.7 Potential Agricultural Sources

P.J. Wilson organised a meeting with the local veterinarian on the Island, Candice Nobbs, who reported that, on the whole island, there are an estimated:

- 1,200 cattle on the Island, of which 213 licenses are available for purchase which allow tagged cattle to roam along and within the public spaces, inclusive of the KAVHA areas;
- 150 sheep;
- 150 pigs (understood to be at a piggery); and
- Feral chickens, ducks, and geese also inhabit the Island and have not been surveyed to estimate numbers. It is understood that several residences have a couple of chickens for eggs; however, the majority are wild and not utilised.

While it is recognised not all of these animals inhabit the study area, the total estimates on animal populations for the island were utilised as a conservative approach to estimate the animals' impact on the receiving environment. When the number of animals is calculated to Population Equivalents (PE), their contributions on the water quality and environment in general can be estimated. **Table 6** below presents the estimated number of animals and human equivalents. The PE represents the approximate human equivalent impacts on wastewater from animals; for example, one cow contributes generally the same amount of waste to the environment as 15 people.

Table 6 Person Equivalent Estimations for Animals in the Study Area

Animal	PE*	Estimated number of animals	Total PE (estimated)
Cattle	15	1,200	18,000
Pigs	1.9	150	285
Sheep	2.5	150	375
Chickens	0.14	Unknown	-

Notes: PE equivalents source Klass, 1998; and Conservation Commission of Missouri 2013

7.8 Field Sampling Results

7.8.1 Water Level Measurements

Water level measurements from the field investigation are presented in Table 7 below.

Table 7 Hydrogeological Summary

Aspect	Measurement / Observation
Depth to Groundwater	Water level measurements ranged between 1.745 metres below the top of well casing (mbtoc) (BH132) and 1.872 mbtoc (BH224); see **Table T1** (attached).
Groundwater Inferred Flow Direction	The local groundwater flow direction of the alluvial aquifer appears to follow topography and flow towards the ocean: south for the Watermill Creek catchment and flow north for the Upper Cascade Creek catchment.

7.8.2 Field Parameters and Observations

The physicochemical results collected during the field investigation are presented in **Table T1** (attached) and summarised in Table 8 below.

Table 8 Physiochemical Field Measurements

Parameter	Results and Comments
pH	The measured data indicates generally slightly acidic to neutral conditions with pH values from 5.53 (BH132) to 8.13 (EB Inlet). The slightly basic pH value of 8.13 is likely the result of remnant salt water from Emily Bay as the inlet is considered to be influenced by tidal movements.
Redox Potential (Eh)	Groundwater redox potential was measured to range from -1.00 (EB Inlet) to 140.70 mV (BH166). The average redox potential concentration was 114 mV which indicates an oxidizing environment. It is noted only EB Inlet recorded a negative value, which is considered to be the result of stagnant water which has pooled for a prolonged period of time (extended dry season).
Dissolved Oxygen (DO)	Water was generally well oxygenated with concentrations that ranged from 1.00 (EB Inlet) to 5.43 mg/L (DD Inlet). Based on the Eh and DO results, water in the project area is considered to be aerobic.
Electrical Conductivity (EC)	EC values ranged from 250.5 (BH132) to 575 µS/cm (EB Inlet). Such concentrations are considered to represent fresh water conditions.
Temperature	Groundwater temperatures ranged from 20.8 (BH166) to 22.5°C (EB Inlet).

It was observed by AECOM staff during the site visit that several of the bores installed have not been completed to Australian Standards. Specifically, it was observed that the bores had not been sealed to the surface which allows foreign material to enter the borehole and surrounding environment, inclusive of the bore's intersected aquifers. A schematic of the completion of bores observed on the Island is presented on **Figure F7**, along with a schematic of the Australian Guidelines well completion requirements.

7.9 Matters of National Environmental Significance

Upon review of data gathered from the site visit, a letter from Pendoley Environmental to the former ANI (dated 5 October 2015) was reviewed which is considered of significance to the study area and particularly, the water quality runoff into Emily Bay (see **Appendix F**). The *Environmental Protection and Biodiversity Conservation Act 1999* (the EPBC Act), lists the Booths pipefish (*Halicampus boothae*) and green turtles (*Chelonia mydas*) which have both been recorded in waters off of Norfolk Island as federally protected. This means the Commonwealth has identified these animals to be protected as a matter of national environmental significance with the objective of conservation of Australian biodiversity.

No further information was available for review in this regard.

8.0 Analytical Results

8.1 Water Quality Results

Analytical results for water quality are presented in **Table T2,** results for COPCs (coliforms, *E.coli*, etc.) are presented in **Table T3 and** laboratory reports are included in **Appendix E**. Water quality results are presented on **Figures F8** and **F9.**

8.1.1 General Water Quality Analytical Results

Physiochemical Parameters

Analysis of seven primary and one QC sample were undertaken for physiochemical parameters inclusive of total dissolved solids (TDS), EC, and pH. The laboratory results were consistent with the field measurements; pH ranged from 6.58 (BH132) to 7.68 (EB Inlet) which was slightly more neutral than the field results. TDS ranged from 135 mg/L (BH132) to 326 mg/L (CB) and EC ranged from 241 µS/cm (BH132) to 563 µS/cm (EBInlet); these concentrations are consistent with field measurements collected.

Metals

While all samples reported various metals concentrations above their respective laboratory limit of reporting (LOR), three analytes reported concentrations in exceedance of the adopted ILs for maintenance of freshwater ecosystems (ANZECC 2000), GILs for freshwater (NEPM 2013), and drinking water aesthetics (NHMRC 2016) for aluminium, iron, and manganese.

Two samples, BH166, and EB Inlet all exceeded the ANZECC 2000 maintenance of freshwater ecosystems for aluminium. In addition, the CB sample exceeded the Freshwater GILs and BH132, BH139, and DD Inlet also exceeded the drinking water aesthetic ILs for aluminium.

One sample, BH224, reported a concentration of boron (0.06 mg/L) above the LOR and the IL for long term irrigation (2 mg/L).

Copper was reported at or above the LOR in five samples. Two samples, BH139 and BH224, reported a concentration of 0.004 mg/L, which exceeds the GILs for Freshwater (0.0014 mg/L).

All samples except for BH224 reported elevated concentrations of iron above the LOR and four samples (BH139, BH166, EB Inlet, DD Inlet) reported concentrations of iron in exceedance of the adopted ILs for long term irrigation and drinking water aesthetics. BH139 reported the highest concentration of iron, 5.94 mg/L, which exceeds the long term irrigation IL (0.2 mg/L) and drinking water aesthetic IL (0.3 mg/L).

Lead was reported from one sample above the LOR: BH139 reported a concentration of 0.004 mg/L which exceeds the GIL for freshwater (0.0034 mg/L).

All samples reported concentrations of manganese above the LOR; three samples (BH139, EBInlet, and DDInlet) reported concentrations in exceedance of the adopted ILs for drinking water aesthetic (0.1 mg/L). EB Inlet and BH139 concentrations exceeded the IL for long term irrigation (0.2 mg/L) and one sample, EB Inlet also exceeded the drinking water GIL (0.5 mg/L).

Four samples (BH132, BH139, BH166, and BH224) reported zinc concentrations in exceedance of the LOR; two samples (BH132 and BH139) reported concentrations in exceedance of the GIL for Freshwater.

Given the widespread presence of the elevated metals concentrations in wells from the headwaters of the creeks to the lower reaches of the waterways, these concentrations are considered to represent background conditions and are likely to have resulted from the weathering of the underlying basaltic rock over time.

Turbidity

Three samples reported turbidity concentrations in excess of the adopted IL for drinking water aesthetics of 5 nephelometric turbidity units (NTU): EBInlet (17.2 NTU), DDInlet (18.1 NTU), and

BH139 (27.5 NTU). It is noted all of these samples were collected from surface water features and as such, elevated turbidity is not unexpected.

8.1.2 COPCs

Total Coliforms

Total coliforms were analysed via two different methods, colony forming units (cfu) and most probable number (MPN), which allowed in some instances for an exact concentration result. All seven samples reported concentrations of total coliforms. The results ranged from 36 MPN/100 mL of water (BH224) to >18,000 MPN/100 mL (BH139). While there is no guideline value for total coliforms, it is considered to be a useful indicator of other pathogens for drinking water. In general, total coliform analysis is utilised globally to determine the adequacy of water treatment and the integrity of the water distribution system.

Thermotolerant Coliforms

Thermotolerant coliforms (TtC) are those coliforms which are capable of growth at temperatures between 44 - 45°C. Five primary samples reported concentrations of TtC above the IL value of 0 per 100 mL of drinking water. Concentrations in exceedance of the IL ranged from 240/100 mL (SW_CB) to >18,000 MPN/100 mL (BH139).

Escherichia coli (*E.coli*)

E.coli were analysed via two different methods, similar to total coliforms, CFU and MPN, which allowed in some instances for an exact concentration result. For the CFU analysis methodology, all samples except for deep bore BH224 reported concentrations in exceedance of the IL (0/100 mL of drinking water). Reported concentrations from all samples except BH224 exceeded the maximum method detection limit of 80 cfu/100 mL.

In an attempt to identify a more precise estimate of *E.coli* present per 100 mL of water, the MPN analysis method was utilised. As a result, five samples reported concentrations above the LOR (BH132, BH139, SW_CB, SW_DDInlet, and SW_EBInlet) that range from 240/100 mL (SW_CB) to >18,000/ 100 mL (BH139).

The presence of *E.coli* is considered an indicator of faecal contamination of the water source.

Faecal Coliforms

All samples except for deep bore BH224 reported concentrations of faecal coliforms in exceedance of the LOR. The CFU analysis method was utilised which reported all results in excess of 80 cfu/100 mL.

While there is no guideline value for faecal coliforms, their presence is considered an indicator of other bacterial pathogens and confirmation of faecal contamination of the water source.

Heterotrophic Plate Count

Heterotrophic plate count (HPC) analysis is a test to detect microorganisms that grow over a specified incubation period at a defined temperature inclusive of vegetative bacteria (coliforms and other Enterobacteriaceae which are sensitive to disinfectants), fungi, and bacteria that form disinfectant-resistant spores, and bacteria and fungi that grow in water. HPCs are one of the simplest tests to monitor water quality.

Two analyses were undertaken, one at a low incubation temperature for a longer time (21°C for 72 hours) and one at a higher incubation temperature for a shorter time (37°C for 48 hours). Typically, elevated HPC concentrations as a result of the high temperature and short incubation time favour the growth of bacteria specifically from animals and humans.

All samples analysed for HPC reported detections above the LOR for both analytical methods. The sample from BH224 (deep bore) reported the lowest concentration (10 cfu/100 mL) while the sample from location BH139 reported the highest concentration (>30000 cfu/100 mL at 21°C/ 72 hours). In general, concentrations reported for the analysis undertaken at 21°C for 72 hours were higher than the analysis at 37°C for 48 hours for all samples except BH166 which reported a higher concentration of HPC at 37°C for 48 hours.

8.2 Genetic Speciation

Samples collected were analysed by CSIRO to genetically identify the source of impacts: five human markers, cattle, and bird markers were assessed. The results are presented in **Table T4** (attached) and on **Figure F9**.

Human Markers

Five human markers were analysed for in each of the water samples. One sample, SW_DDinlet, reported positive for human marker *Bacteroides* HF183 at a concentration of 1298±421 genomic units (GU) per 500 mL of water. *Bacteroides* HF183 is a recognised human genetic marker specific to human sewage.

No other samples reported concentrations of the human genetic markers analysed

for. **Bird Markers**

The genetic marker for birds was analysed for all of the samples. Four of the seven primary samples reported concentrations of the bird marker analysed for, which ranged from 148±113 (BH139) to 572,102±11,623 (SW-EBInlet).

Cattle Markers

One genetic marker for cattle was analysed for all of the samples. None of the samples reported detectable concentrations of the cattle genetic marker.

8.3 Discussion

Water quality samples were taken from various locations across the Watermill Creek and the Upper Cascade Creek catchments from both surface water and bores. The locations for sample collection and analysis were selected to assess potential risks to human health and the environment and to allow for comparison with previous results to establish if trends are apparent.

All samples except for deep bore (BH224) reported elevated concentrations of aluminium, iron, and manganese above the LOR and in most cases, in exceedance of the adopted investigation levels (NHMRC drinking water aesthetics, ANZECC 2000 for maintenance of freshwater ecosystems, and NEPM drinking water GILs). The elevated concentrations reported for aluminium and iron are considered to be representative of the background geology and primary matrix of the aquifers (basalt). Chemical weathering of basalt over time has produced decomposed volcanic material with clays rich in iron and aluminium oxides (Abell & Falkland, 1991). Iron is widely distributed within the weathered mantle stratigraphic unit and is released into the chemical breakdown of minerals in basalt. Manganese has been reported in elevated concentrations from bores across the Island over time; while the concentrations are above the LOR and in exceedance of the adopted ILs from two samples (SW_DDInlet and SW_EBInlet); the concentrations reported are not considered to impact on human health. Given the geology of the island and the historical data reviewed, the elevated iron, aluminium, and manganese concentrations are considered to be representative of natural background conditions.

Turbidity were reported in exceedance of the ILs for drinking water aesthetics in two samples (SW_EBInlet, SW_DDinlet); these samples were collected from surface water features in time of extreme drought and are not considered to impact on human health.

E.coli was detected above the LOR and adopted ILs in all samples except for the sample from well BH224. There are several potential reasons why this well did not report a detectable concentration of *E.coli*, which include potential for this well to intersect the lower portion of the shallow aquifer or the deeper basalt aquifer, or it is in an area of the aquifer where there are limited fractures which prevent the vertical migration of contaminants from the upper aquifer. However, more information is needed to determine the local geometry and connectivity of this well within the overall groundwater regime.

Elevated concentrations of *E.coli* were reported from the top of both catchments (BH139 and BH132), which indicates contamination is entering the waterways at these locations and likely flowing downgradient where there is potential to impact on various environmental and human receptors. It is noted that the reported concentrations of *E.coli* and other COPCs downgradient of the Duck Dam and wetland features across the Kingston Commons (SW_EBInlet) were less than those from the upper portions of the catchment. This suggests the wetlands and dams are providing physical settling and biological filtration processes, initially occurring in Duck Dam and then more substantially in the lower wetlands of Kingston Commons prior to discharge into Emily Bay. The recruited wetland plants (mostly non-native species) are considered to be providing important treatment benefits to surface water through these areas.

The sample from location BH139, was collected from the uppermost flowing section of the western branch of Waterm ill Creek, generally reported the highest concentrations of total coliforms, thermotolerant coliforms, *E.coli*, and HPC. A large sewage pump station is located approximately 100 m upstream from the sample location adjacent to the creek channel, which based on the results, suggests that releases from the pump station itself or associated pipework is impacting the water quality at the top of the catchment. The *E.coli* results from this investigation were compared to those collected previously (Biotec in 2016 where soil and surface water were analysed) and are considered to be consistent and even slightly higher. This is likely the result of dry season limited flows where the impacts have been accumulating and not yet been flushed/washed down gradient due to a lack of water in the creek at this point in the catchment.

Water samples analysed for genetic markers resulted in the confirmation of bird markers from four of seven primary samples. The highest concentration of bird markers was reported from the inlet to Emily Bay and was two orders of magnitude greater than the next highest concentration (Duck Dam Inlet). The impact of bird faeces within the water supplies is considered to contribute to gastroenteritis.

One sample, Duck Dam Inlet, reported confirmation of the human marker *Bacteroides* HF183, which is a specific marker for human sewage. As this marker was not detected in the samples upgradient, specifically at BH139 which is adjacent to a sewer pump station, it is considered there is a contamination source impacting the catchment in the vicinity of the Duck Dam. An additional sample event and analyses for human enteric viruses may be warranted to comprehensively identify the potential risk to human health as a result of water quality.

No cattle markers were detected as a result of genetic speciation analysis. This was not expected as cattle were observed by AECOM to defecate in the waterways while samples were being collected, specifically at the Duck Dam. Additionally, the carcass of one cow was observed to be decaying adjacent to the reservoir for the Community Bore. Upon discussions with Dr Warish Ahmed of CSIRO, who undertook the speciation analyses, it was identified that the cattle marker is not present in the faeces of all cattle and that it is likely the cattle do not carry the marker. This is further supported by anecdotal evidence from the President of the Norfolk Island Cattle Association Inc. that the cattle on Norfolk Island are of a unique breed, Norfolk Blue.

While no speciation test for rodents is available, it was reported that the Island has a large rat population. During the field activities, rats were observed to be in the reservoir for the Community Bore and numerous rat traps were observed across the Island. It is considered that rodents are also a potential risk to human health as disease can be easily infect humans through contact with rodent urine and faecal matter, specifically Leptospirosis, Hantavirus, Rat-bite Fever, and Salmonellosis.

9.0 Conceptual Site Model

A conceptual site model is the qualitative description of all plausible mechanisms by which receptors (human health and/or the environment) may be exposed to an impact, such as contaminated water. For exposure to be considered possible, some mechanism (pathway) must exist by which impact from a given source can reach a given receptor.

Potential exposure pathways are evaluated for completeness based on the existence of:

- An identified source of impact (sewage);
- A mechanism for release of identified sources (septic overflow, animal faecal contributions to water source);
- A transport/migration pathway (e.g. creek flow into bores, vertical migration into aquifer);
- Potential sensitive receptors in the vicinity of site (recreational areas, water bores); and
- A mechanism for chemical intake by the receptor at the point of exposure (e.g. skin contact for human health).

Whenever one or more of the above elements is missing, the exposure pathway is incomplete and the linkage not realised. An exposure pathway can either be direct, where the receptor comes into direct contact with the affected environmental media (e.g. groundwater ingestion) or indirect, where exposure occurs at different location or in a different medium than the source (e.g. swimming in Emily Bay after heavy rains deposited contaminated runoff into the Bay or irrigation of a garden with impacted creek water).

Based on the information presented in this report, the sections below present a summary of potential sources / areas, exposure mechanisms and receptors to provide a context in which to qualitatively assess the significance of any source-pathway-receptor linkages identified and to identify potential risk drivers. A graphical illustration of the conceptual site model, updated with the current data, is shown in **Figure F10.**

9.1 Sources of Impacts

Based on the data available, sources of impacts/contaminants to the overall water quality of the island include animal and human faecal contributions to water supplies through various exposure mechanisms. Specific sources of impact identified include:

- Human sewage (septic systems, wastewater pump stations, soakage trenches, sewer lines);
- Animal faecal matter from livestock (cattle, pigs, sheep) and undomesticated (rats, chickens); and
- Decaying animal matter.

9.2 Contaminants of Potential Concern

The primary COPC identified are indicator organism bacteria inclusive of E. coli, faecal coliforms, total coliforms, thermotolerant coliforms, and HPC.

9.3 Migration Pathways

The main migration pathways from sources of impacts of COPCs into the water supplies are considered to include:

- Direct source/contact from faeces and carcasses of animals (cattle, sheep, pigs, rats, chickens) into watercourses (dams, creeks, reservoirs, etc.);
- Leaking/overflows of sewage waste from septic systems, waste water pump stations, soakage trenches and/or sewer lines into watercourses;

- Surface runoff (contaminated or not) from upgradient areas downhill over faecal deposits which discharges into watercourses;
- Vertical migration of impacted surface water through soils into the underlying shallow aquifer;
- Extraction of water from bores (surface or shallow groundwater) for use as irrigation water, stock water, and/or to top up rainwater tanks for potable use in times of drought;
- Surface water flow into Emily Bay; and
- Poorly constructed / unsealed bores which act as a vertical pathways for surface contaminants into the shallow aquifer.

Water supply bores were observed to have been constructed improperly across the Island. Such incorrect construction allows for surface contaminants to enter the bore and subsequently, into the water supplies. Several bores were identified to be either dry or no longer utilised; however, these boreholes are reported to remain open to the surrounding environment. These boreholes are considered to act as a preferential pathway for surface runoff and any entrained/suspended contaminants into water supplies which have potential to impact on the water quality.

9.4 Potential Receptors

The potential receptors for contamination from identified sources and migration pathways include:

- Extraction and use of impacted water (bore or creek water) for drinking water, household water supply (shower, washing dishes/laundry, etc.), for irrigation of food crops and stock watering;
- Recreational users of surface water bodies (Emily Bay);
- Consumption of food sources from contaminated waterways (fish, crustaceans, shore shellfish) and
- Aquatic ecosystems in freshwater and marine environments of surface water bodies (all creeks, Emily Bay, Pacific Ocean).

9.5 Exposure Pathways

The potential transport mechanisms and exposure pathways and an assessment of the likelihood of exposure are presented in **Table 9**.

Table 9 Transport Mechanism and Exposure Pathways

Source	Transport Mechanism	Exposure Pathway	Likely / Unlikely	Justification
Faecal impacted surface water	Contact with impacted surface water	Dermal contact and ingestion of impacted surface water by users of creek water (recreational users)	Likely	Faecal contamination was detected in all surface water samples collected throughout the study area. Any persons who enter the creeks can be exposed / impacted.
	Migration of impacted surface water (discharge into downgradient surface waters)	Discharge downstream, into Emily Bay (dermal contact by recreational users) Ingestion / dermal contact with impacted surface water if extracted for use (irrigation, stock watering).	Likely	Faecal contamination was detected in the upper areas of each catchment and at each surface water sample downgradient including the inlet to Emily Bay. At many locations, shallow bores are installed to intersect the creek water which can be extracted for various uses, particularly during dry seasons when rainwater supplies have been exhausted. It is considered that contaminated water is likely pumped from the creeks and used for various irrigation, stock watering and/or domestic uses, inclusive of topping up rainwater tanks in dry periods.
	Impacted surface water enters ecosystem	Ingestion / dermal contact with impacted surface water for ecosystems (flora and fauna)	Likely	Faecal contamination was detected in all surface water samples collected throughout the study area. Aquatic ecosystems, fresh and marine waters, inclusive of fish, shell fish, crustaceans, and birds (amongst flora and others) which rely on surface water can be contaminated and/or become sick due to impacts.
Faecal impacted groundwater	Vertical migration of impacts from surface water or via preferential pathways (open wells) into groundwater.	Ingestion / dermal contact with impacted groundwater if extracted for drinking water, domestic use, stock watering or irrigation	Likely	At many locations, shallow bores are installed to intersect the alluvial aquifer within and adjacent to creek beds. During dry seasons when rainwater supplies have been exhausted, creek water is extracted. It is considered that contaminated water is likely pumped from the shallow wells and used for various household, irrigation, stock watering and/or as drinking

Source	Transport Mechanism	Exposure Pathway	Likely / Unlikely	Justification
				water (rain water tanks are reportedly replenished with bore water when dry).
	Migration of impacted groundwater	Discharge to surface water bodies to impact on ecosystems (flora and fauna); Dermal and ingestion of contaminated water by recreational users of Emily Bay	Likely	The detections of faecal coliforms at the inlet to Emily Bay suggest the Bay and, the South Pacific Ocean are being impacted by contaminated creeks discharging into these features. Particularly, after heavy rainfall events and after the wetland areas have been dredged, flora, fauna and humans can be exposed to impacts

10.0 Conclusions and Recommendations

The findings of this investigation were consistent with the results and recommendations of previous investigations and reports. Surface water bodies and shallow aquifers are contaminated with COPCs from animal and human sources via multiple pathways.

It is considered that the contamination of surface and shallow groundwater presents a risk to human health through the exposure pathways of secondary contact such as swimming in Emily Bay, and primary contact from ingestion as water supply, irrigation of food crops, stock watering, and consumption of impacted food sources (shell fish, etc.). Additionally, fresh and marine ecosystems are considered to be impacted with contamination.

Based on the results of the water quality study presented in this report, the primary recommendations are recognised to reflect previous report recommendations and include:

- The results of this investigation have identified impacts to human health and the environment, particularly drinking water sources. Given the broad scale issues identified across the study area, a holistic approach to addressing the issues is warranted. A holistic approach is considered to include short and long term goals to remedy issues based on a priority ranking of potential risks and sources. A Drinking Water Quality Management Plan (DWQMP) developed based on the information included in this report, in conjunction with previous reports, will allow for the identification of priorities to be addressed from which solutions can be developed and implemented over time which consider the limitations of the Island (resources and financial). NSW has developed a program available through a public website, the Community Water Planner (CWP), which is designed to assist and provide a management program for communities with limited resources and/or those located in regional areas. The CWP is a joint initiative of the NMRC and the National Water Commission (NWC) to allow the generation of one comprehensive, integrated water safety plan.

  The Drinking Water Quality Management Plan is considered a living document which includes, but is not limited to, a community specific program which includes:

    - Commitment to drinking water quality management,
    - Assessment of the drinking water supply system(s),
    - Water quality assessment guidelines,
    - Risk assessment for drinking water supply system(s).
    - Preventative measures for drinking water management,
    - Operational procedures,
    - Stakeholder engagement programs, and
    - Community involvement in awareness and education programs.

  The DWQMP provides a roadmap for the best management of drinking water supplies to assure safety of customers at points of supply. The scope of the DWQMP is to identify water quality issues and procedures from the water supply source to consumer tap which have the potential to compromise the provision of safe, potable water to the community.

  Furthermore, the DWQMP provides a basis for short term and long term water quality monitoring and preventative actions which may include small scale programs to limit surface impacts from entering the primary water supply sources. The DWQMP identifies mechanisms and criteria for water quality monitoring to assess the implementation of the plan and allows for continued improvement.

  It is considered that the development of a DWQMP will identify additional recommendations to address contamination issues, inclusive of those which require significant resources (e.g. upgrade to the water treatment plant to allow for incorporation of more households onto the WAS and training programs for workers).

- Confirmation of the various aquifers that bores intersect will allow for the identification of which bores intersect the shallow impacted aquifer and those which intersect the deeper aquifer. Furthermore, this will provide an understanding of suitable volumes of water for extraction without impacting on other wells and the resource itself, i.e. ensure no salt water intrusion from over pumping, particular in times of drought when large volumes are required to be extracted. This will identify bores suitable for use during dry seasons which will limit potential risks to human health and the environment. Identification and implementation of protections measures for the aquifers will ensure safe water supplies for the Island, particularly in times of drought when rainwater resources have been depleted.
- Identification and implementation of protection measures for the shallow and deep aquifers are recommended and include adequate sealing of existing extraction bores from the surface as per Australian Guidelines and decommissioning of disused wells to prevent unnecessary impacts to groundwater from surface contaminants.
- Identification and implementation of protection measures for the surface water resources are recommended and include controlling stock access to surface water (providing alternate stock watering vessels and fencing), identifying and minimising direct seepage of contamination into waterways and revegetation or extension of planted riparian zones along creeks to act as a natural filter for surface water run-off entering waterways.
- Engage NSW Health to commence dialog and discussions that provide guidance, resources, and assist with monitoring and compliance programs to ensure human health protection.
- Further investigation into the apparent positive impact of wetland areas in the lower catchment areas is warranted and extension of these areas may improve water quality discharging into Emily Bay.
- Conduct monitoring of water quality in Emily Bay to assess whether potential risks to recreational users and marine habitats are likely to be realised, and if so, management procedures that can be employed to reduce risks to human health and the environment.
- Critical to the success of water quality management on Norfolk Island is the involvement of the general community to understand the issues that affect their health and livelihoods, what can be done to improve it and the benefits for all. This can be achieved by undertaking regular community sessions and educational forums to initiate and maintain an open dialogue, to ensure management measures are practical and able to be implemented, to provide information for safe water use, maintenance of septic and rainwater tanks via workshops and outdoor classrooms, and to gain support, ownership and involvement in management strategies such as revegetation of creek lines.

11.0 References

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12.0 Limitations

12.1

A

Transition from ANI to NIRC

Appendix B

Photographic Log

Calibration Certificates

Appendix D

Analytical Data Validation

QA/QC Sampling Program

Analytical data validation is the process of assessing whether the data are in compliance with method requirements and project specifications. The primary objective of this process is to ensure that data of known quality are reported, and to identify if data can be used to fulfil the overall project objectives. Data validation guidelines adopted for the project are based on guidance published by the United States Environmental Protection Agency (US EPA, 2002). The validation process involves the checking of analytical procedure compliance and an assessment of the accuracy and precision of analytical data from a range of quality control measurements generated from both the field sampling and the laboratory analytical programs.

Specific Quality Assurance/Quality Control (QA/QC) elements that have been checked and assessed for this project include:

- Preservation and storage of samples upon collection and during transport to the laboratory;
- Sample holding times;
- Use of appropriate analytical and field sampling procedures;
- Required limits of reporting;
- Frequency of conducting quality control measurements;
- Field/equipment blank, trip blank and trip spike results;
- Laboratory blank results;
- Field duplicate results;
- Laboratory duplicate results, and;
- Occurrence of apparently unusual or anomalous results (e.g., laboratory results that appear to be inconsistent with field observations and/or measurements).

Definitions of the QA/QC samples collected are provided in the table below.

Quality Sample Definitions

Quality Sample	Description
Trip blank	Used to assess if contamination is introduced during shipping and field handling procedures. A sample of analyte-free media is taken from the laboratory to the sampling site and returned to the laboratory without being exposed to the sampling procedures. Only analysed for volatile compounds.
Field blank	A deionized water sample that is prepared prior to field sampling, carried to the sampling site, and exposed to site atmosphere during sampling. Field blank results are used to screen for field volatile contaminants that might not travel through the septum of a travel blank, but might contaminate samples on-site.
Trip spike	Used to assess if volatiles analytes are lost during shipping and field handling procedures. A sample spiked with a known aliquot is taken from the laboratory to the sampling site and returned to laboratory. The amount of volatiles recovered is compared to a laboratory control sample to assess if recovery is within acceptable limits.
Duplicate	Used to document the precision of the sampling process. Independent samples which are sampled as close as possible to the primary sample in space and time. They are separate samples taken from the same source and stored in separate containers and analysed independently.
Triplicate	Used to document inter-laboratory precision. Independent samples which are sampled as close as possible to the primary sample in space and time. They are separate samples taken from the same source and stored in separate containers and analysed at the secondary laboratory.

Quality Sample	Description
Rinsate	Used to assess the adequacy of the decontamination of the sampling equipment. A sample of analyte-free water supplied by the laboratory was poured over the decontaminated equipment prior to the collection of the next sample. The sample was analysed for the same suite as the primary samples.

QA/QC Analytical Data Validation

Water QA/QC samples

The water duplicate sample of BH166 (QC01) was collected and submitted for physiochemical properties, metals, alkalinity, nutrients major ions and various other analyses (cyanide, turbidity, salinity) to ALS Laboratory in Brisbane.

Additionally, QC01 and primary sample BH166 were analysed for coliforms, *E.coli*, faecal coliforms, and heterotrophic plate counts to Dairy Technical Services (DTS) Food Assurance laboratory in North Melbourne on behalf of ALS.

Furthermore, these samples were also submitted to CSIRO for genetic speciation analysis.

The frequency of this quality control sampling exceeds the frequency of 5% recommended by Australian Standard AS4482.

QA/QC Sample Results

The results of the QA/QC review and data validation are discussed below. Supporting QA/QC documentation is provided on laboratory certificates of analysis in **Appendix E**.

The ALS laboratory quality control results for the water analyses (ALS laboratory report EB1703885) demonstrated adequate reproducibility in terms of the analytical techniques adopted in the laboratory. The laboratory's Interpretative Quality Report indicated there were no quality control non-conformances except for one hold time exceedance for pH analysis. It is noted the hold time for pH is six hours. AECOM has taken field measurements for pH from all water samples at the time of collection to compensate for the limited hold time and subsequent analysis.

The ALS laboratory quality control results for the water analyses (EB1703885) demonstrated adequate reproducibility in terms of the analytical techniques adopted in the laboratory.

Evaluation of RPD calculations for water samples indicates greater than acceptable RPD limits between the analytical results for ammonia of the sample set for BH166 (refer to **Table D1**). Unacceptable RPDs are attributable to heterogeneity associated with distributing the water sample between several containers for each field duplicate. Although the analytical results for BH166 are variable, they tend to be uniformly above the LOR and the applicable guidelines and hence do not alter the conclusions of the report.

Primary and duplicate water samples analysed by CSIRO for speciation reported no difference between samples.

Summary

Overall the laboratory quality control results demonstrate adequate reproducibility in terms of field sampling and the analytical techniques adopted in the laboratory and sample integrity in the field, transport and handling in the laboratory.

Appendix E

Laboratory Reports

Historical Microbial Data (2013-2016)

Appendix C – Correspondence - Disposal of Sewage into the Ocean at Headstone

Australian Government

Director of National Parks

The Hon Gary Hardgrave
Administrator
Office of the Administrator
PO Box 201
NORFOLK ISLAND NSW 2899

Dear Mr Hardgrave

I am writing in relation to waste disposal practices from Headstone Reserve into the marine environment and the implications of this practice under a new management plan for the Norfolk Commonwealth Marine Reserve. I understand that you have discussed this issue in some detail with Jason Mundy, Assistant Secretary, Marine Protected Areas Branch, and you are aware of our concerns and responsibilities under the *Environment Protection and Biodiversity Conservation Act 1999.*

Disposal of solid industrial and domestic waste into the ocean

I have previously written to Mr Ron Ward, (then Minister for the Environment, Government of Norfolk Island) on this matter (see attached letter) This correspondence explained my concerns that the disposal of solid waste from Headstone Reserve into the ocean was not consistent with the objectives of marine reserves.

As you would be aware from discussion with Mr Mundy, the Government has recently received a major independent review of Commonwealth marine reserves and is considering its findings and recommendations. This report will inform next steps, including the commencement of a formal process to develop new management plans. Subject to agreement by Government, I expect this process will proceed within 12 months.

In advance of this process, you should be aware my intention is that disposal of waste into the Norfolk Commonwealth Marine Reserve from Headstone Reserve, an activity that is prohibited by the *Environment Protection and Biodiversity Conservation* (EPBC) *Regulations 2000*, should cease when the management plan comes into effect (noting the final content of the plan is subject to public consultation and approval by the Minister for the Environment).

I acknowledge and understand that waste management on a remote island is a complex issue, especially during a time of significant governmental reform with other priorities and infrastructure challenges. Consequently, to allow a period of transition to alternative waste disposal arrangements by the newly appointed Norfolk Island Regional Council, I propose that the activity would be permitted for a period of 12 months after the management plan comes into effect.

Timing for the commencement of the management plan will depend on the duration of necessary statutory consultation periods. Indicatively, if the new management plan enters into effect by mid 2017, the 12 month transition period permitting disposal of waste would cease in mid 2018. I intend to work collaboratively and constructively with the Norfolk Island Regional Council and Department of Infrastructure and Regional Development on the details of this arrangement.

It is my understanding that this approach, which would ultimately result in the ceasing of waste disposal from Headstone Reserve, is consistent with the vision of the draft Waste Management Strategic Plan of the Norfolk Island Administration. I also understand the community of Norfolk Island is strongly supportive of implementing sustainable waste management practices, as highlighted in the draft Community Strategic Plan.

Disposal of sewage into the ocean

A separate but related issue is the disposal of sewage into the ocean. I understand that sewage currently collected from Norfolk Island's central sewer system undergoes a level of treatment, prior to being discharged into the ocean in the vicinity of Headstone Reserve. Under the EPBC Regulations, the discharge of sewage into a Commonwealth reserve is a prohibited activity, if it is likely that the waste will pollute the environment, be harmful to native species or be harmful or offensive to another person.

The management of sewage has implications with other health and safety legislation, and I understand discussions have commenced on this subject between the Norfolk Island Administration and the New South Wales Ministry of Health. As with the issue of solid waste disposal, I have significant concerns about the impacts of sewage discharge on the marine environment of the Norfolk Commonwealth Marine Reserve. I am willing to work collaboratively with other agencies during the broader reform process, to ensure marine environment considerations are taken into account in relation to sewage management.

Officers from Parks Australia will be in touch with the Norfolk Island Regional Council when the review of Commonwealth marine reserves is released, to discuss the consultation process to develop a new management plan. Please contact Jason Mundy, Assistant Secretary, Marine Protected Areas Branch on 03 6208 2922 if you have any further questions.

Yours sincerely

Sally Barnes

Sally Barnes
Director of National Parks

2 June 2016

Enc . Letter to Mr Ron Ward (18 July 2014)

Australian Government

Director of National Parks

Ref: 2013/10768

Mr Ron Ward
Minister for the Environment
The Government of Norfolk Island
Old Military Barracks
KINGSTON NORFOLK ISLAND 2899
SOUTH PACIFIC

Dear Mr Ward

I refer to your letter of 26 June 2014 concerning submersible waste from Headstone Reserve into the marine environment of the Norfolk Commonwealth Marine Reserve.

You seek a determination under regulation 12.14B of the Environment Protection and Biodiversity Conservation (EPBC) Regulations 2000 to allow for the discharge, disposal of, release or leaving of industrial or domestic waste of Norfolk Island into the marine area adjacent to Headstone Reserve that is within the proclaimed boundary of the Norfolk Commonwealth Marine Reserve.

The Australian Government has committed to review the management arrangements for all Commonwealth marine reserves proclaimed in November 2012. Consequently, the draft management plan for the Temperate East Commonwealth marine reserves, which was scheduled to come into effect on 1 July 2014, has been set aside. Transitional arrangements remain in place to ensure that there are no changes on the ground as a consequence of the marine reserve proclamations. Accordingly, until such time as a new management plan takes effect, there is no requirement for authorisation to undertake activities in the Norfolk Commonwealth Marine Reserve.

The review of the Commonwealth marine reserves, which is to commence shortly and is expected to take approximately six months, will inform the preparation of a new management plan for the Temperate East network, of which the Norfolk Commonwealth Marine Reserve is part. The new management plan will be developed in further consultation with stakeholders. Information on both the review process and the subsequent development of the new management plan, and opportunities to be involved, will be available on the website of the Department of the Environment (www.environment.gov.au).

In respect to the waste issue on Norfolk Island, I note that the Department of Infrastructure and Regional Development is working closely with the Norfolk Island Government on a range of waste disposal projects. I understand that the intention is to develop a more contemporary and sustainable waste management framework and system that would minimise impacts on the environment and in time replace the current discharge and disposal method. It is my hope that this work will lead to a lasting and suitable alternative to the current discharge and disposal of waste by the time the Temperate East Network Management Plan is completed and in effect. Should this not be the case, I must flag with you in advance that, as the current arrangements are not consistent with the objectives of marine reserves in the longer term, any approval issued under the plan to continue disposal of waste in the marine reserve, could only be temporary and contingent upon a clear and timed commitment to cease the practice Parks Australia would be looking to work alongside the Department of Infrastructure and Regional Development with you on the path forward to ensure the best longer term outcomes for both the marine reserve and the community.

I trust this information clarifies the transitional arrangements applicable to activities in the Norfolk Commonwealth Marine Reserve and the future requirements that may apply once a management plan is in place. Please contact Barbara Musso (acting Assistant Secretary, Commonwealth Marine Reserves Branch on 03 6208 2924) or Andrew Read (Director, Southern Marine Reserves Management Section on 02 6275 9766) if you have any further questions.

Yours sincerely

Sally Barnes
Director of National Parks
18 July 2014

Appendix D – Norfolk Island Geotechnical Soils Investigation

Norfolk Island

Report on Geotechnical Soils Investigation

June 2005

Norfolk Island Administration

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Approved by: Doug Graham ....

Signed: ....

Date: ....

Distribution: 3 Hard copy and 1 CD (including DPF copy and GIS layer) NIA, 1 copy PB file, 1 copy PB library

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1. Introduction

This report presents the results of a geotechnical soils investigation carried out by Parsons Brinckerhoff (PB) for the Norfolk Island Administration (NIA). The investigation was commissioned by Nicole Diatloff on behalf of NIA on 26 October 2004.

The purpose of the investigation was to provide advice with respect to several aspects of Geotechnical Site Classification in accordance with AS 2870 – 1996 on the island, including:

- What areas of the island, if any, are likely to be classified as Class H, E or P sites (as defined by AS 2870):
- The relationship between these sites and the topography; and
- The relationship between these site classifications and the structures that may be constructed upon these soils.

We have also provided some broad comments with regard to development adjacent to coastal cliff areas and land instability.

We note that the Australian Standard AS2870 – 1996 “Residential slabs and footings – Construction” is applicable to the design and construction of footings for single dwelling houses and townhouses and other forms of construction (e.g. light industrial, commercial and institutional buildings) if they are similar to houses in size, loading and superstructure flexibility.

As part of the study we have produced a new layer for the NIA GIS system that generally applies a broad soil Site Classification Zoning in accordance with AS2870-1996 – Residential Slabs and Footings. Based on this map layer, it is possible for the NIA to assess the likely Site Classification for any area within the island.

2. Desktop Study and Review of Existing Information

2.1 Location and Setting

Norfolk Island is located approximately 1600 km ENE of Sydney in the South Pacific Ocean at latitude 29° 3' 45" South and longitude 167° 56' 29" East, as shown in *Figure 1* (Abell and Falkland, 1991). The island is approximately square, less a truncated north eastern corner, and is about 8km long (measured northeast-southwest) and 7km wide in maximum dimension, and has an area of about 3450Ha, as shown in *Figure 2*.

2.2 Topography

Norfolk Island is an extinct remnant of a volcanic cone which has been considerably modified by weathering and stream dissection. The dominant features of the Island are the dual peaks of Mt Pitt and Mt Bates which are located in the interior of the north west. These peaks rise to about 318m and 313m respectively. From these peaks, the ground surface generally falls moderately to steeply down to a plateaux that rings the peaks, which has an elevation typically of about 120m. The plateau is widest to the south of the peaks (about 2km to 4km wide), almost pinches out to the west and northeast, and is about 1km wide to the northwest. The plateau is heavily dissected by creek lines that generally run radially from the dual peaks. This dissection, along with uplift and coastal erosion has resulted in Norfolk Island having a coastline which consists mainly of cliffs, which vary between 30m and 80m in height. Nearly all the creek lines of Norfolk Island enter the sea by rapids and falls over the cliffs. Occasional swamp conditions can be found along stream paths at the flatter grades. A coastal low land is located on the southern side of the island at the township of Kingston. This lowland is about 1.5km long and 0.5km wide, with a typical elevation of about 20m,

2.3 Climate

The climate of Norfolk Island is typically sub-tropical, with mild temperatures and a well distributed rainfall pattern precipitating about 1300mm of rainfall annually. The meteorological station located at the Islands' airport collects rainfall and temperature data. A summary of the climatic conditions from Abel and Falkland 1991 is provided below.

Based on climatological readings taken up to 1987, the mean annual rainfall was 1326mm, with maximum rainfall occurring in winter (June and July) and the minimum occurring in summer (November and January). The average number of rain days per month varied between 23 in June to 12 in November. The humidity through out the year is fairly constant, with monthly averages varying between 77% and 82% (Stephens and

Hutton, 1954), and a yearly average of 79%. Winds typically blow from the east in the summer and west in the winter, with average velocities of between 11km/hr or 20km/hr.

2.4 Geology

Norfolk Island lies on the eastern edge of the Australian lithospheric plate, and is located on the pronounced Norfolk Rise, a north south trending continental ridge between New Zealand and New Caledonia. The island is an erosional remnant of a number of volcanic centres that were constructed during several volcanic episodes from about 3 million years ago to about 2.3 million years ago.

Norfolk Island is almost completely volcanic in origin, with the rocks dominantly comprising fine to medium grained olivine basaltic lavas and pyroclastic tuff (layered volcanic ash). The basalts constitute a wide variety of volcanic lithofacies related to variations in the physical condition of lava at the time of eruption, its mode of eruption, and environments of eruption and emplacement (Jones and McDougal, 1973). Within the island there are five main geological formations, four of which comprise distinct volcanic layers, as follows:

- The Ball Bay Basalts (formed approximately three million years ago);
- The Duncombe Bay Basalts (formed approximately 2.6-2.7 million years ago);
- The Cascade Basalts (formed approximately 2.4 million years ago); and
- The Steele’s Point Basalts (formed approximately 2.3-2.4 million years ago).

Basaltic sheet lavas are the most common rock type. The flows are generally flat lying are up to 30m in thickness, and often display well developed columnar jointing and occasional flow banding. The basalts typically weather to form spheroidal basaltic core stones, often in a matrix of completely weathered basalt or high plasticity residual clay.

The pyroclastic tuff rocks are typically interbedded with and lie unconformably on the basalts. They range in thickness from a few metres up to 15m. The tuff typically weathers to form well structured high plasticity residual clay soils.

The basaltic lavas and tuffs are often highly weathered to great depths, commonly as much as 45m.

Each lava flow and tuff layer represents a new period of volcanic activity that has occurred after a period quiescence, during which time weathering and erosion has occurred. As a result, subsequent volcanic events are often laid down over a weathered surface consisting of weathered rock or residual soils (see Plate 1).

The fifth main geological formation within the island consists of a coarse marine calcareous rock, calcaranite, (sand, coral and shell fragments cemented with lime) of late Pleistocene origin and is located near Kingston. The rock was in part deposited by on-shore winds during a period of low sea level, and subsequently lithified and cemented with lime. The soils formed on this material are dominantly sandy in nature.

2.5 Soils

The soils that have developed on the island have a strong relationship with geology and topography. Based on the Soil Map of Norfolk Island and the associated paper by Stephens and Hutton, 1954, it appears that the majority of the island soils are clayey soils that have developed over the basalt flows. The thickness of these soils appears to be dependent on the slopes upon which they have developed – generally speaking, the steeper the slope the thinner the soil profile. In the southern part of the island, a pocket of sandy soils exist near the township of Kingston, which have developed over a small pocket of Calcaranite. We note that the 1954 study classified the island's soils in terms of great soil groups, which is more suited to agricultural studies, rather than engineering studies.

A summary of the mapped soils from the Stephens and Hutton study is reproduced in *Table 2.1* below:

Table 2.1: Summary of Norfolk Island Soils

Soil Series	Topography and Drainage	Parent Material	Soil Grading		
			Clay	Silt	Sand
Palm Glen Clay	Steep to moderate slopes – unrestricted drainage	Basalt	77	15	2
Mt Pitt Clay	Moderate slopes – unrestricted drainage	Basalt	82	11	2
Rooty Hill Clay	Steep to moderate convex slopes and ridge tops – unrestricted drainage	Basalt	76	10	10
Steel's Point Clay	Gently undulating to flat – unrestricted drainage	Probably Tuff	77	12	9
Middlegate Gravelly Clay	Gently undulating drainage divide – unrestricted drainage	Basalt	85	5	3
Selwyn Clay	Gently undulating areas on cliff tops – unrestricted drainage	Basalt	71	16	7
Emily Bay Calcareous Sand	Undulating – restricted drainage	Calcarenite	-	-	-
Unnamed Shallow Stony Soils	Steep slopes – unrestricted drainage	Basalt	-	-	-
Unnamed Alluvial Soils	Gently sloping to flat – unrestricted drainage	Basaltic Alluvium	-	-	-
Unnamed Swamp Soils	Valley floors with restricted drainage (acid sulfate potential)	Basaltic Alluvium	-	-	-

The results of the Stephens and Hutton study of 1954 indicated that the clayey soils on the island derived from the basalts are typically silty clays with a minor sand fraction.

3. Investigation Methodology

3.1 Desk Study

A desktop study was undertaken that comprised a review of our previous environmental study (reference 2110309A_PR_7657, dated October 2003), the existing Norfolk Island Geographic Information System (GIS), and soils, geological and topographical information made available to and researched by PB.

As a result of the study, contour, slope and soils maps were produced by PB's GIS operators to provide a base onto which the field investigation locations and notes were annotated.

3.2 Field Investigation

The field investigation was conducted between 1 February and 5 February 2005 and comprised field mapping of exposed rock and soil out crop, followed by borehole drilling at selected locations across the island.

3.2.1 Field Mapping

The field mapping was undertaken over a period of two days by an experienced senior engineering geologist, to regionally ground truth the desktop study, and establish a preliminary borehole drilling and sampling plan. A total of 16 sites were visited during the mapping, where records were taken as to the soil composition, and samples collected for office assessment and laboratory testing. The locations of the mapping sites are shown in *Figure 3*.

A summary of the soil and rock conditions encountered during the mapping is presented in *Appendix A*.

3.2.2 Borehole Drilling

Following the mapping, 17 boreholes were drilled over a period of two days using a Bobcat mounted drilling rig. The boreholes were drilled to depths ranging between 1.5m and 2.6m, using a 300mm diameter posthole auger. U50 push tubes were collected using a device attached to the auger that was fabricated on the island. Pocket penetrometer tests were conducted in the ends of the U50 push tubes, while disturbed soil samples were collected from the auger for office assessment and laboratory testing.

The subsurface investigation was observed on a full time basis by a senior engineering geologist, who was responsible for locating the boreholes, logging the subsurface profile, monitoring the drilling and collecting the soil samples. The boreholes were located using a hand held GPS unit, the coordinates of which appear on the borehole logs. The reduced levels shown on the borehole logs were interpolated from spot heights on the contour plans. The locations of the borehole sites are shown in *Figure 3*.

Engineering logs of the boreholes are attached to the rear of this report in *Appendix B* along with a set of Explanatory Notes that define the terms and symbols used in their preparation.

3.3 Laboratory Testing

Selected soil samples from the boreholes and mapping sites were dispatched to a NATA accredited laboratory in Sydney under PB's standard Chain of Custody conditions and an Australian Quarantine Inspection Service (AQIS) permit, for laboratory testing as follows:

- 5 Shrink Swell tests;
- 19 Atterberg Limits tests; and
- 19 linear shrinkage test;

The results of the laboratory tests are presented in *Appendix C* and summarised in *Section 4.3*.

4. Results of the Investigation

4.1 Geology

Based on the results of the desk top study, the majority of the Norfolk Island geology generally comprises a series of Tertiary age Basalts flows, with a minor pocket of coarse marine calcareous rock (Calcaranite) of late Pleistocene origin.

The results of the investigation were essentially consistent with the results of the desk top study.

4.2 Field Mapping and Borehole Drilling

For a detailed description of the subsurface conditions encountered during the mapping and drilling, reference to the attached mapping summary and borehole logs in *Appendices A and B* respectively is recommended.

In general terms the subsurface conditions encountered generally comprised a layer of topsoil, overlying a high plasticity clay residual soil profile of varying depth, beneath which variably weathered basalt was encountered. Sandy and clayey fill materials of varying depth were also encountered at several locations.

The pertinent aspects of the encountered subsurface conditions are summarised below:

Fill Materials

Encountered in boreholes BH1, BH2, BH5, BH6, BH7, BH16 and BH17, comprising clayey sand, silty sand, silty clay and silty gravely clay generally of medium plasticity. The fill ranged in depth between 0.3m to 1.6m and is considered to be uncontrolled fill. As the majority of the boreholes were drilled adjacent to road ways, we have assumed that most of the fill materials are associated with the road construction.

Topsoil

Encountered in all boreholes except BH2, BH5, BH6, BH9, BH16, and BH17 either from the ground surface or beneath fill materials, generally comprising either silty sand or silty clay of low and low to medium plasticity. The thickness of the topsoil generally ranged between 0.4m and 0.6m, with one location (BH10) where the topsoil was up to 1.2m thick.

Residual Soil

Residual soils were encountered in all boreholes and at each of the mapping sites, either beneath fill materials or topsoils. The residual soils generally comprised silty clay, silty gravely clay or clayey silt and were typically of high plasticity, with moisture contents generally estimated to be close to or above the plastic limit.

Weathered Basalt

Weathered basalt was encountered in boreholes BH4, BH6 and BH9, at all mapping sites except Sites 1, 7, 10, 14, 15 and 16, and generally consisted of extremely to highly weathered basalt of very low to low strength. In the road cuttings, the basalt was often vesicular, displayed spheroidal weathering patterns forming core stones up to about 1m in diameter, and occasionally flow banded.

Groundwater inflows were not observed in any of the boreholes or at any of the mapping sites. We note that climatic conditions and precipitation may influence groundwater levels.

4.3 Laboratory Testing

Nineteen samples of the residual clay collected from both the boreholes and mapping sites were subject to Atterberg Limits, moisture content and linear shrinkage tests conducted at a NATA accredited laboratory located in Sydney. The results of the Atterberg Limits tests are plotted in a plasticity chart in *Figure 4*, summarised in *Table 4.1* below along with the moisture content and linear shrinkage test results, and presented in full in *Appendix C*. The test results in *Table 4.1* below have also been listed against the mapped soil unit from which they were sampled (Stephens and Hutton, 1954).

Table 4.1: Summary of Atterberg Limits, Moisture Content and Linear Shrinkage Test Results

Test Location	Moisture Content (%)	Liquid Limit (%)	Plastic Limit (%)	Plasticity Index (%)	Linear Shrinkage (%)	Mapped Soil Unit (after Stephens et al 1954)
BH2	25.1	54	32	22	13	Steels Point Clay
BH3	32.9	63	28	35	15.5	Steels Point Clay
BH5	28	53	28	25	13.5	Rooty Hill Clay
BH7	40.1	70	40	30	14.5	Rooty Hill Clay
BH8	38	89	40	49	19.5	Mt Pitt Clay
BH10	38	70	33	37	17.5	Selwyn Clay
BH11	40.8	84	36	48	19.5	Selwyn Clay
BH13	31.4	57	30	27	16.5	Rooty Hill Clay
BH14	31.5	44	29	15	9.5	Middlegate Gravelly Clay
BH15	33.9	61	34	27	15	Rooty Hill Clay
BH16	36.1	56	34	22	11.5	Steels Point Clay
BH17	37	69	34	35	16	Rooty Hill Clay
Site 2	44.6	72	34	38	17.5	Rooty Hill Clay
Site 5	35.5	68	41	27	15	Rooty Hill Clay
Site 5	50.1	109	46	63	23.5	Rooty Hill Clay
Site 7	51.7	79	50	29	19	Unnamed Stony Soils
Site 11	33.3	60	32	28	15.5	Rooty Hill Clay
Site 14	39.5	84	38	46	20.5	Selwyn Clay
Site 16	53.9	104	44	60	19.5	Palm Glen Clay

As indicated in *Figure 4*, all the results of the Atterberg Limits tests (except one – BH14 from the Middlegate Gravelly Clay unit), indicate that the soils tested are high plasticity silty clays or clayey silts. The sample from BH14 is a medium plasticity silty clay.

Five samples of the residual clay collected from the boreholes were subject to Shrink-Swell Index (I_{SS}) testing to assess the shrinkage index (I_{ps}) of the soils, with the tests conducted at a NATA accredited laboratory located in Sydney. The results of the tests are summarised in *Table 4.2* below and presented in full in *Appendix C*.

Table 4.2: Summary of Shrink-Swell Index Tests Results

Test Location	Shrink-swell Index (I_{SS})	Moisture Content (%)
BH3	2.1	29
BH4	2.2	34
BH11	3.5	40.7
BH12	3.2	37.7
BH15	2.6	31.8

As indicated in *Table 4.2* the shrink-swell index test results are very similar for each of the residual soil samples tested.

5. Comments and Recommendations

5.1 Purpose of Site Classification

Most natural clay soils derived from the weathering of parent rock have sufficient bearing capacity to support typical residential loads. Most distress to residential and light commercial structures commonly occurs due to reactive soil movements due to changes in soil moisture. Site classification is a method adopted in residential and light commercial development for quantifying the anticipated ground movements that may occur on a site principally due to soil reactivity.

AS 2870 – Residential Slabs and Footings – 1996 and Supplement 1 1996, establishes a classification system whereby reactive clay sites are classified based on the reactive clay movements anticipated. Other foundation conditions such as the presence of fill material or the depth to rock, may affect the site classification. The purpose of the classification is to allow the design of an economical footing system, which will limit cracking of footings, floor slabs and masonry walls to an extent normally considered acceptable (the performance expectations are defined in AS2870 Clause 1.3.1), due to reactive movements of the clay foundation.

5.2 Basis of Site Classification

The Australian Standard AS 2870 – Residential Slabs and Footings provides the basis for Site Classification, and three procedures are offered as follows:

1. prior performance;

2. profile Identification; and

3. movement Estimates.

In this study we have adopted a combination of procedures 2 and 3, that is, we have identified the subsurface profile through a site visit involving mapping and borehole drilling, and made estimates of the Characteristic Surface Movement (y_s) based on laboratory soil classification and shrink-swell tests carried out on samples of residual soil collected during the field work.

Procedure 1 was not used as PB has no previous geotechnical experience on the island, nor knowledge of the type and style of footings typically used.

The Characteristic Surface Movement (y_s) is the vertical movement range expected during the life of the house from a reasonable estimate of dry conditions to a similar reasonable estimate of wet conditions and does not take into account the moderating effect of the footing system (AS2870 Supp1 – 1996).

AS 2870 – 1996 defines the various site classifications in terms of y_s as follows:

S	Slightly reactive	$y_s < 20mm$
M	Moderately reactive	$20mm < y_s < 40mm$
H	Highly reactive	$40mm < y_s < 70mm$
E	Extremely reactive	$y_s > 70mm$

Based on the results of the laboratory testing i.e. Atterberg Limits, Linear Shrinkage and Shrink-Swell index tests, estimates of the Characteristic Surface Movement were made and the various areas investigated were classified accordingly.

Appendix D of AS 2870 – 1996 also provides a ready guide to the expected level of site classification in areas where sufficient data have been collected such that relationships between the typical soil profile and site classification have been established. As such, Appendix D of AS 2870 – 1996 can be used to check the calculated classification. Furthermore, the classification of sites for areas other than those provided in Appendix D of the standard may be based on an appropriate Table, provided the climates and soil types and soil profiles are similar between the areas. This comparison technique was also used in assessing the site classification of Norfolk Island.

5.3 Relationship between the Mapped Soils and Geotechnical Properties

The intent of this investigation was to map, sample and analyse typical soils of Norfolk Island in order to apply general site classifications to various parts of the island. As discussed in *Section 2.5*, the soils of the island were mapped in 1954 by Stephens and Hutton from a pedalogical stance in terms of great soil groups. This classification scheme is more suited to agricultural purposes, rather than engineering purposes. With a soil map already in place, the field investigation therefore targeted the various soils mapped in 1954 in an effort to compare how the various units relate to an engineering classification.

As can be seen in *Tables 4.1.* and *4.2*, and *Figure 4*, the vast majority of the soils are high plasticity clays or silts, and also have a very similar Shrink Swell Index value. On this basis, we have concluded that the soils formed on the basalts of Norfolk Island are very similar with respect to their geotechnical properties, and are likely to give rise to similar classifications across the island.

5.4 Assessment of Site Classification

5.4.1 Profile Identification and Movement Estimates

In assessing site classification for the island, we have calculated the Characteristic Surface Movement (y_s) at each of the boreholes sites. This calculation was based on the profile identified during the drilling and the results of the laboratory testing, including the Linear Shrinkage and Shrink-Swell Index tests.

Each of the borehole sites have been classified in accordance with AS2870 "Residential Slabs and Footings", as detailed in *Table 5.1* below.

Table 5.1: Site Classifications

Test Location	Characteristic Surface Movement (y_s)	Site Classification	Mapped Soil Unit (after Stephens et al 1954)
BH1	35mm	**M**	Middlegate Gravelly Clay
BH2	40mm	**M**	Steels Point Clay
BH3	50mm	**H**	Steels Point Clay
BH4	35mm	**M**	Middlegate Gravelly Clay
BH5	40mm	**M**	Rooty Hill Clay
BH6	45mm	**H**	Rooty Hill Clay
BH7	60mm	**H**	Rooty Hill Clay
BH8	70mm	**H**	Mt Pitt Clay
BH9	55mm	**H**	Rooty Hill Clay
BH10	60mm	**H**	Selwyn Clay
BH11	70mm	**H**	Selwyn Clay
BH12	50mm	**H**	Steels Point Clay
BH13	55mm	**H**	Rooty Hill Clay
BH14	20mm	**S**	Middlegate Gravelly Clay
BH15	50mm	**H**	Rooty Hill Clay
BH16	40mm	**H**	Steels Point Clay
BH17	55mm	**H**	Rooty Hill Clay

These classifications generally assume that:

- prior to building any fill materials and organic matter have been stripped, and that any encountered topsoils are treated in accordance with the requirements of Section 6 of AS2870; and

- up to 500mm of reactive clay soils have been placed as engineered fill to level a building site.

In some areas fill materials were encountered to depths of greater than 400mm. If we had not adopted the assumption that the fill materials were stripped, these sites would have been classed as Class P sites. As these fill sites are likely to be isolated, it would not be sensible to apply a P classification in a broad zoning study such as this.

As indicated in table nearly all of the profiles identified during the drilling are classified as **Class H** sites. The exceptions are:

- Boreholes BH1, BH4 and BH14 located in the Middlegate Gravelly Clay unit, which, based on the movement estimate method, is classified as a Class M unit. This unit is likely to be less reactive than the other clayey units due to the gravel content. However given its limited coverage over the island in small pockets and its high range Class M movement in boreholes BH1 and BH4, it would be prudent to classify this unit as **Class H** also.

- Boreholes BH8 and BH11, located in the Mt Pitt Clay and Selwyn Clay units respectively. The calculated Characteristic Surface Movement (y_s) for both these profiles was on the boarder between Class H and Class E. On this basis, and given the consistent classifications calculated elsewhere and its high range Class H movement, we have elected to classify both these profiles as **Class H** also.

- Boreholes BH2 and BH5, located in the Steels Point Clay and Rooty Hill Clay units respectively. The calculated Characteristic Surface Movement (y_s) for both these profiles was on the boarder between Class M and Class H. On this basis, and given the consistent classifications calculated elsewhere and its high range Class M movement, we have elected to classify both these profiles as **Class H** also.

This investigation targeted clayey soils, in an effort to establish their reactivity. For this reason, boreholes were not drilled in the sandy soils located on the southern side of the island in the Kingston region. The area mapped by Stephens and Hutton as “Emily Bay Calcareous Sand”, has provisionally been classified as **Class S**, while the area mapped as “Basaltic Colluvium mixed with Calcareous Sand” has provisionally been classified as a **Class M** area.

The results of the site classification assessment are presented on a layer within the Norfolk Island GIS system. This has been reproduced as *Figure 5* in this report.

These site classifications assume that site maintenance complies with *Appendix B* of AS 2870 – 1996.

5.4.2 Comparison with Similar Areas

Appendix D of AS 2870 – 1996 allows for site classification based on typical profiles. In order for this style of assessment to be used, there must be a strong correlation between the site being classified and the tables in the appendix with respect to soil profile and climatological conditions.

After viewing the tables in the Appendix, Table D2 – Victoria provided the closest match with respect to the subsurface profile, and allowed for a range of climatological conditions to be compared.

Using Table D2 we assumed the following:

- climatic Zone 2 – wet temperate, and
- basaltic Clays between 0.6 and 1.8m deep.

On this basis, the typical profile is classified as **Class H**, which is in concurrence with our classifications based on the calculated Characteristic Surface Movement (y_s)

5.5 Site Classification in Relation to Topography

Based on the results of the borehole drilling, the residual soil profile over the majority of the island appears to be greater than 0.6m in thickness. On this basis, we expect the there is unlikely to be a change in the Site Classification of an area due to steeper ground.

5.6 Site Preparation

Prior to construction of footings, ground slabs or filling, any fill materials and organic matter should be stripped, and any encountered topsoils should be treated in accordance with the requirements of Section 6 of AS2870. Areas to be filled should be proof rolled and any soft or heaving materials removed. Areas exposing bedrock will not require proof rolling.

Evidence of fill was observed in several boreholes, however its extent is considered to be limited over the island. Any fill that is encountered on a site should be considered to be uncontrolled fill, and should be removed from areas to support high-level footings.

Any proposed site regrading should take into account the guidelines provided in *Appendix D Table 3* - "Good Hillside Construction Practice".

5.7 Footing Design and Construction

In general, flexible structures such as brick veneer or clad frames are preferred for residential development on reactive clay sites. Footings should be designed by a practising structural engineer in accordance with AS2870 - 1996 for the classifications provided in *Section 5.4* above and presented in *Figure 5*.

Strip/pad footings, raft slabs and pier and beam systems would be suitable footing types.

Any future cut and fill earthworks may effect the site classifications provided in this report. We recommend that the site classifications be reassessed if excavations in excess of 0.4 m or filling in excess of 0.5 m thick are proposed.

Footings should be excavated, cleaned out and poured with minimum delay. If footing excavations are to be left open for an extended period of time, a concrete blinding layer should be provided to protect the foundation material. Should any uncompacted fill or locally deep topsoil be encountered during footing excavation, these materials should be penetrated and the footings founded in accordance with the requirements of Section 6 of AS2870. A geotechnical engineer should be consulted if these conditions are encountered. We note that deep fill materials and topsoil were encountered in boreholes BH6, BH7 and BH10.

Where footing excavations are partially on rock, the whole footing should be taken to rock to achieve uniform bearing and foundation conditions. Alternatively structures may be articulated over changes in founding conditions, in accordance with AS2870.

Where footings are to be piered to rock, reclassification of the site and amendment to footing sizes may be appropriate, and both a geotechnical and structural engineer should be consulted prior to construction of the footing.

5.8 Drainage Maintenance

Adequate site drainage should be installed to prevent ponding of surface water adjacent to structures. Surface flows should be directed away from structures and into the stormwater disposal system. All roof run off should be collected and piped to the stormwater system.

Subsoil drains from any retaining walls should be connected to the stormwater system. Surface dish drains should be provided at the crest of all cut or fill batters and retaining walls.

Classification of the subject lots has been assessed based on moisture variations caused by normal climatic and garden conditions. More severe moisture variations can be caused by other common, but controllable factors. Reactive soil notes included in Appendix E are intended as a summary to those provided in CSIRO 10 - 91 “A guide to Home Owners on Foundation Maintenance and Footing Performance” and should be regarded as ‘recommendations’. Future owners should be advised of these maintenance procedures, as it is commonly accepted that most damage to residential type structures on reactive sites is due to poor site maintenance.

5.9 General Comments Relating to Development Adjacent to Cliff Lines and on Slopes

The majority of Norfolk Island is surrounded by cliffs that range in height from 30m to 80m, and as such, present desirable locations with respect to residential development.

The vast majority of the island is made up of olivine rich basalt, which was laid down in four volcanic episodes over a period of about 700,000 years commencing three million years ago. Each episode was about 150,000 to 200,000 years apart. As such, basalt rock is dominantly exposed in the cliff lines. Areas where the dominant rock type is basalt are renowned for their association with land instability. This instability typically occurs for several reasons, as follows:

1. The layered nature in which basalt is typically laid down often provides for preferential sub-horizontal ground water flow paths. As groundwater accumulates along these flow paths, pore pressures build and contribute to land instability.

2. If basalt flows occur with significant amounts of time between each flow, the ground surface has time to weather and form a soil horizon. This means that for each successive volcanic event, the basalt will flow over a previously developed soil profile. Such geological occurrences are prone to land sliding as a defined layer of weakness exists within the profile. These ancient buried land surfaces also provide a preferential path for groundwater flow and become prone to land instability. During the mapping carried out on the island, ancient land surfaces buried by basalt flows were observed at several locations, as shown in *Plate 1*.

3. The mineral olivine is particularly susceptible to weathering and once weathered, forms various clay minerals. As the basalt rock mass weathers, its shear strength is

gradually reduced. The presence of the weathered olivine further reduces the shear strength, promoting land instability.

While major cliff instability events are unlikely to occur frequently in a human lifetime, they are significant coastal forming processes that are likely to be frequent occurrences in a geological time frame. Therefore, for the reasons outlined above, it is important that a suitable offset be provided between a cliff line and any residential development. Without a detailed study of such land forming events on the island, it is difficult to provide a definitive offset. However, such on offset would likely be set to a minimum distance up to a certain cliff height, and then scaled up as the height of the cliff increases. For the purposes of this section of the report, we would expect that the minimum offset could be 20m for cliffs less than 20m in height, and then equal the height of the cliff for cliffs greater than 20m in height.

With regard to developments on slopes, the guidelines provided in *Appendix D* should be followed. These guidelines are particularly relevant to the slopes on Norfolk Island, where there is likely to be a significant risk of land instability initialled by developments with poor hill side practice, given the steep slopes, basaltic geology, high plasticity residual clay soils, and the relatively high rainfall.

6. Limitations

It is possible that the subsurface conditions encountered during construction may vary from those identified by this report. Should such variations or differences become apparent we recommend that this office should be immediately contacted for further geotechnical advice. This report should be read in conjunction with the appended notes that explain the limitations of the geotechnical investigations (*Appendix F*).

7. References

1. Abell, R.S. and Falkland, A.C., (1991), *The Hydrogeology of Norfolk Island, South Pacific Ocean*, Department of Primary Industries and Energy, Bureau of Mineral Resources, Geology and Geophysics, Bulletin 234.

2. C.G. Stephens and J.T. Hutton, (1954), *A Soil and Landuse Study of the Australian Territory of Norfolk Island, South Pacific Ocean*, Division of Soils, Commonwealth Scientific and Industrial Research Organisation, Australia, Melbourne.

3. J.G. Jones and I. McDougal, (1973), *Geological History of Norfolk and Philip Islands, South West Pacific Ocean*, Journal of the Geological Society of Australia, Volume 20, Pt.3, pp 239 – 257

4. Australian Standard, AS 2870 – 1996: Residential Slabs and Footings (Incorporating Amendments Nos 1, 2, 3 and 4), Standards Australia International, Sydney, Australia

5. Australian Standard, AS 2870 Supplement 1 – 1996: Residential Slabs and Footings – Construction – Commentary, Standards Australia International, Sydney, Australia

Figures

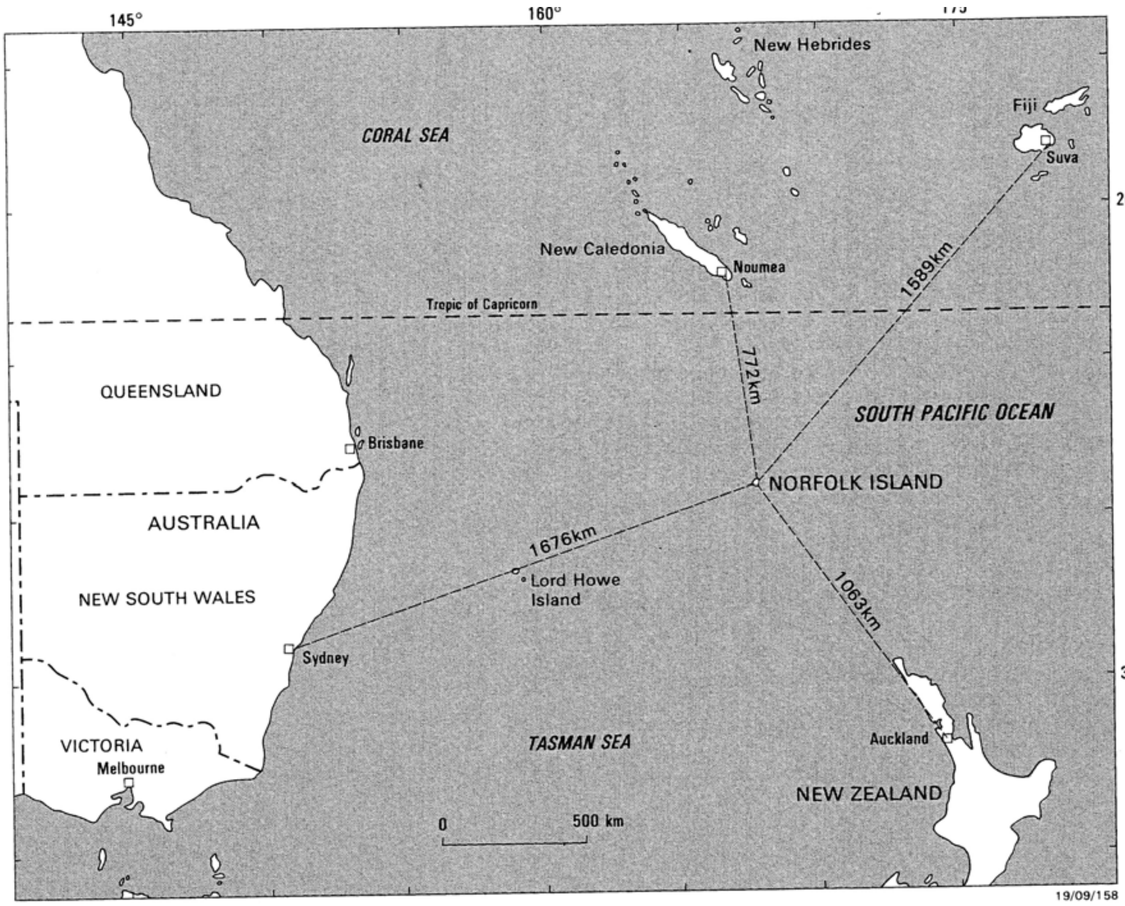
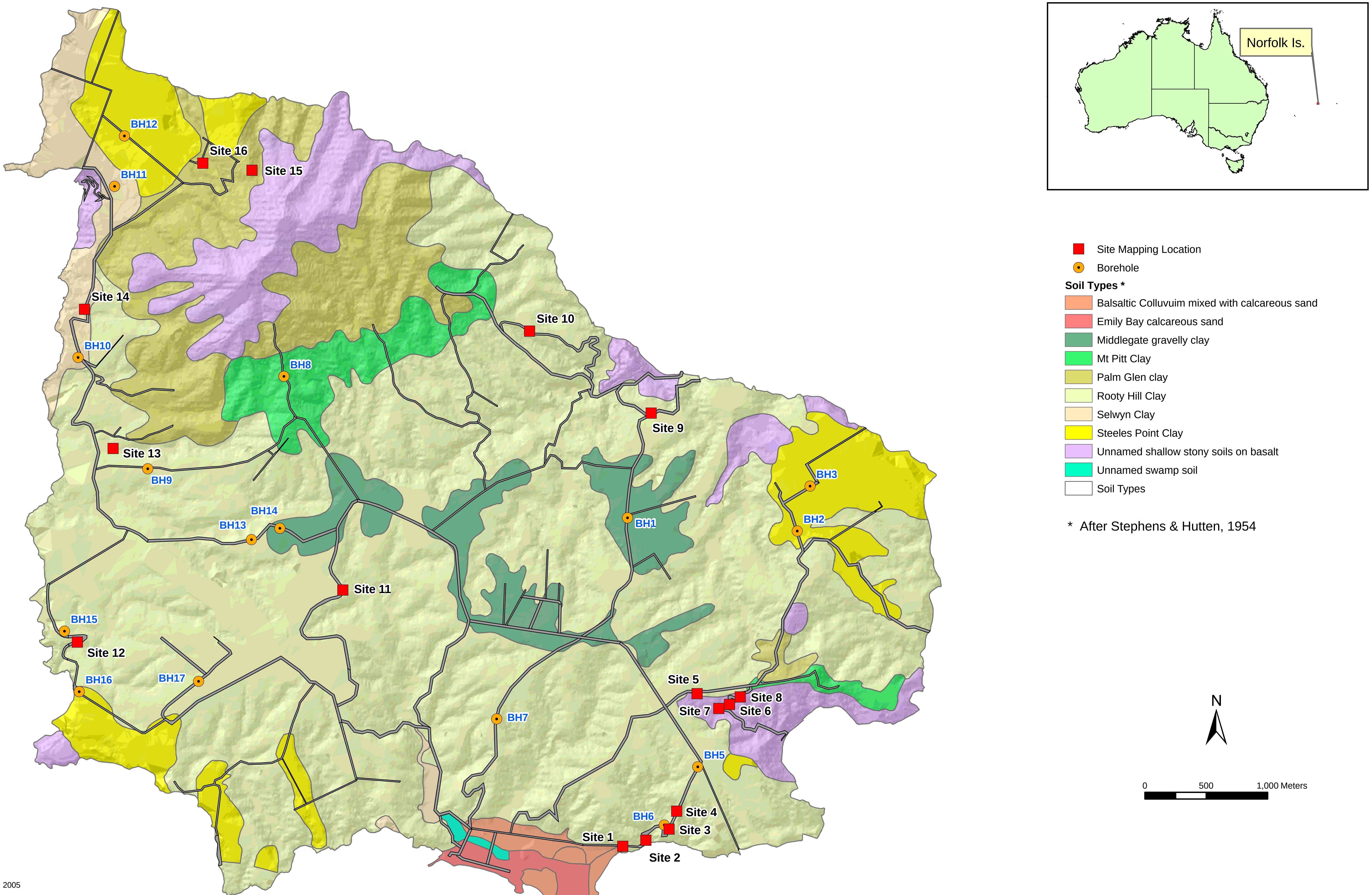


Figure 1: **Norfolk Island Location Map (Able and Falkland, 1991)**

Figure 2: **Map of Norfolk Island**

Norfolk Island Geotechnical Zoning for Site Classification

Figure 3: Borehole and Site Mapping Locality Plan



SWD - 10 Jun, 2005

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2110268A_2002_Soil_and_Site_Mapping.mxd

PARSONS BRINCKERHOFF

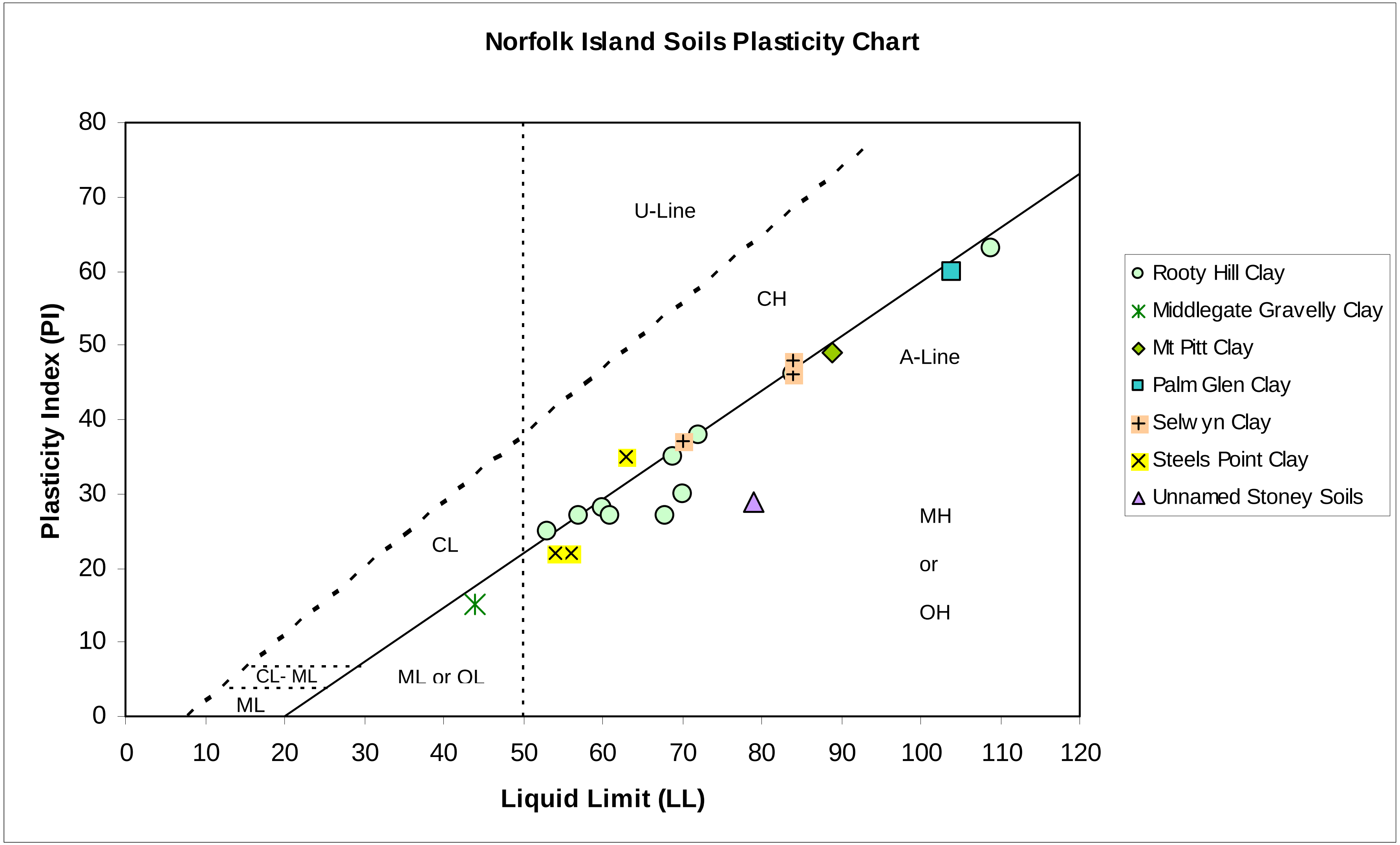
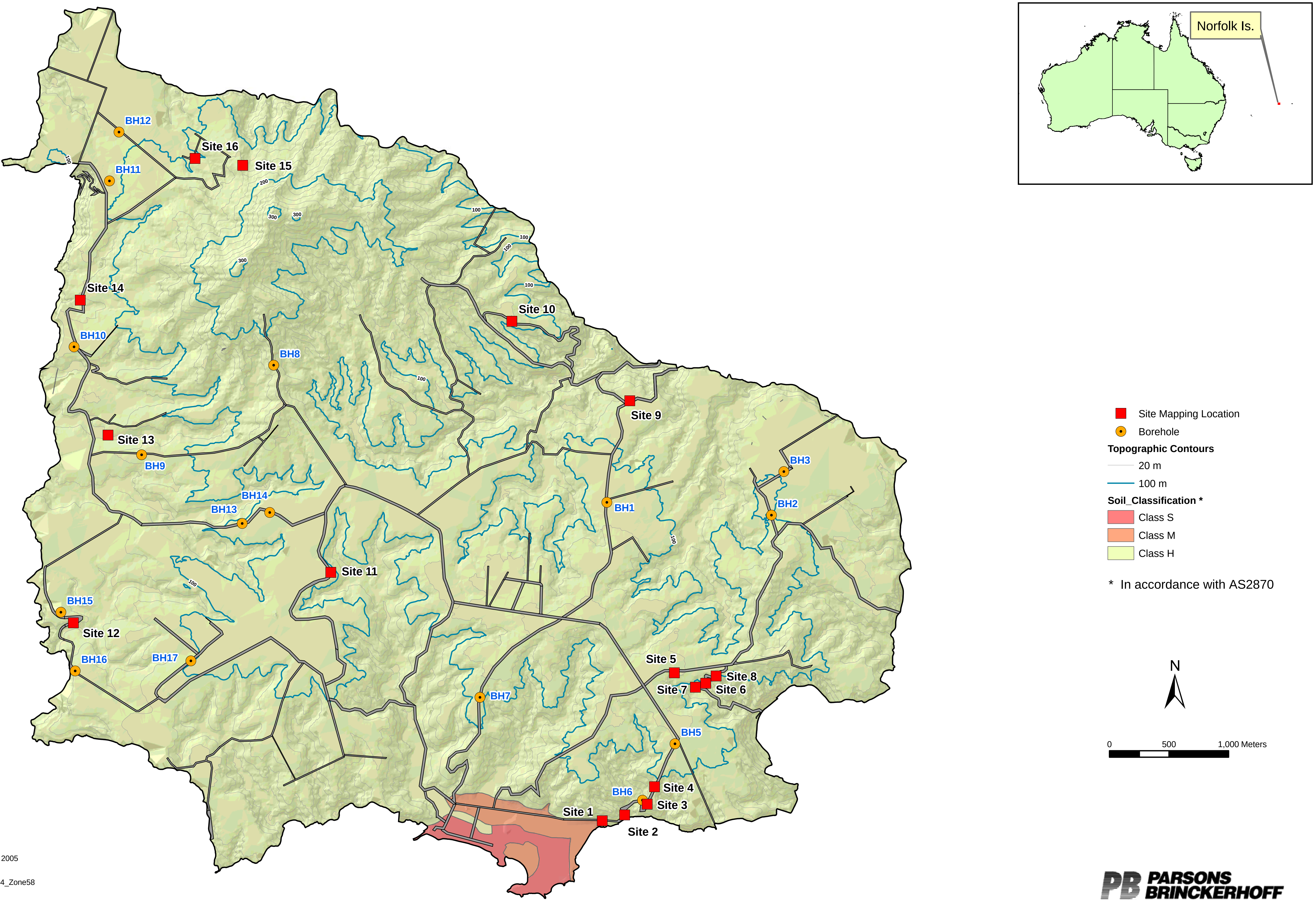


Figure 4: **Plasticity Chart**

Norfolk Island Geotechnical Zoning for Site Classification

Figure 5: Site Classification of Norfolk Island Soils



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2110268A_2003_Soil_Classification.mxd

PARSONS BRINCKERHOFF

Plates

Plate 1: Basalt flow overlying a residual soil formed by a previous basalt flow.

Appendix A

Summary of Mapping Results

Table A1: Summary of Conditions Encountered During Mapping

Site: 1

Location: Quality Row, Kingston

Coordinates: E: 58 789142 N: 6782091

Description: Timber post and panel retaining walls stepped on the slope. Posts are tilting down slope, due to soil creep movements and erosion. The retaining walls are possible supporting a previous erosion feature, or an old surface slump.

The slope above falls at 30° to 35°, and displays regular terracing/stepping of the ground surface, indicating surface creep. This is likely to be exasperated by stock contouring around the steep slopes. Fresh basalt boulders are evident scattered thinly over the slope.

Photograph:

Site: 2	**Location:**	Quality Row,
	Coordinates:	E: 58 789330 N: 6782140

Description: Layered weathered basalt/tuff exposed in a road cutting, which falls at 60° to 80°.

Basalt/Tuff is extremely weathered to highly weathered, very low strength, light brown and grey brown, vesicular, generally massive but also displaying flow contacts.

Photograph:

Site: 3

Location: Driver Christian Road

Coordinates: E: 58 789519 N: 6782231

Description: Driver Christian Road rises steeply from the southern side of the island up to the island plateau. Exposed in the road cuttings about 2m to 3m high is a thin (about 0.5m thick) well structured residual profile of high plasticity silty clay, overlying extremely weathered to highly weathered basalt of very low to low strength, vesicular, typically weathering to form spheroidal core stones up to 0.8m in diameter.

Photograph:

Site: 4	**Location:**	Driver Christian Road
	Coordinates:	E: 58 789581 N: 67 82376
Description:	Road cutting 2m to 3m high exposing a residual profile of well structured high plasticity silty clay overlying extremely weathered basalt. Erosion of the soil and basalt has left fence posts hanging, suspended by the fence wire.	
Photograph:		

Site: 5	**Location:**	Stock Yard Road, cutting in Crushing Plant site
	Coordinates:	E: 58 789747 N: 67 83332

Description: As part of the development of a crushing plant facility, an excavation into the side of a hill was completed to provide access to the crushing plant shed. The cutting was formed at an angle of about 45° to a depth of about 8m. The cutting exposed a deeply weathered profile consisting of two overlying basalt flows. The upper flow has weathered to produce a residual soil of brown, well structured, high plasticity silty clay overlying extremely weathered basalt. This upper flow has been laid down over an older ground surface profile, consisting of orange brown mottled purple brown, well structured, high plasticity silty clay overlying extremely weathered basalt.

Photograph:

Site: 6 **Location:** Marsh’s Road

Coordinates: E: 58 790011 N: 67 83244

Description: Near vertical road cutting up to about 5m high exposing highly weathered Tuff/Basalt, low strength, grey, fine grained, vesicular, highly fractured and jointed. A thin (about 0.5m thick) residual soil of high plasticity silty clay overlies the rock.

Photograph:

Site: 7	**Location:**	Marsh’s Road
	Coordinates:	E: 58 789924 N: 67 83211

Description: Road cutting falling at about 50°, about 5m to 6m high, exposing well structured, residual silty clay, high plasticity, dark orange brown to red brown,

Photograph:

Site: 8 **Location:** Marsh's Road

Coordinates: E: 58 790098 N: 67 83305

Description: Near vertical road cutting about 4m high exposing a 1.0m to 1.5m weathered basalt flow overlying an older ground surface. The younger (upper) flow consists of a thin residual silty clay overlying extremely to highly weathered basalt. This flow in-turn overlies another weathered basalt flow consisting of a thin topsoil beneath which occurs a deeper weathered profile of well structured high plasticity orange brown silty clay overlying weathered basalt at the toe of the cutting.

Photograph:

Site: 9 **Location:** Cascade Road

Coordinates: E: 58 789373 N: 67 85613

Description: A road cutting about 3m deep through a ridge line exposing residual soils overlying weathered basalt. The residual soil is about 1.0m to 1.5m deep and consists of well structured high plasticity orange brown silty clay this is well structured. The basalt is highly weathered, very low to low strength, vesicular, light grey to grey, with some spheroidally weathered core stones.

Photograph:

Site: 10

Location: Prince Phillip Drive

Coordinates: E: 58 788384 N: 67 86279

Description: A road cutting about 1.5m deep, exposing well structured high plasticity residual silty clay that is dark red brown and well structured.

Photograph:

Site: 11	**Location:**	Ferry Lane
	Coordinates:	E: 58 786864 N: 67 84174

Description: A road cutting a 3m deep through a broad shallow ridge exposing residual soil over weathered basalt. The residual soils are about 1.2m deep consisting of well structured silty clay, high plasticity, orange brown and well structured with some basalt gravel. The basalt is extremely to highly weathered, very low to low strength, pale grey and highly fractured, often displaying spheroidally weathered core stones.

Photograph:

Site: 12	**Location:**	Headstone Road
	Coordinates:	E: 58 784704 N: 67 83751

Description: A road cutting a 3m deep on the side of a hill exposing residual soil over weathered basalt. The residual soils are about 1.2m deep consisting of well structured silty clay, high plasticity, orange brown and well structured with some basalt gravel. The basalt/tuff is extremely to highly weathered, very low to low strength, pale grey and highly fractured.

Photograph:

Site: 13 **Location:** Mission Road

Coordinates: E: 58 784995 N: 67 85325

Description: A road cutting a 2.5m deep through a broad shallow ridge exposing residual soil over weathered basalt. The residual soils are about 0.5m deep consisting of silty clay, high plasticity, orange brown and well structured with some basalt gravel. The basalt is highly weathered, very low to low strength, pale grey and highly fractured.

Photograph:

Site: 14

Location: Anson Bay Road

Coordinates: E: 58 784762 N: 67 86457

Description: A shallow road cutting about 1.0m deep exposing well structured red brown high plasticity residual silty clay.

Photograph:

Site: 15 **Location:**

Coordinates: E: 58 786125 N: 67 87587

Description: A road cutting about 3.5m deep through a steep ridge line, exposing well structured red brown high plasticity silty clay over the full depth of the cutting.

Photograph:

Site: 16 **Location:** Anson Bay Road

Coordinates: E: 58 785725 N: 67 87644

Description: A 1.5m deep road cutting exposing orange brown, high plasticity, well structured silty clay over the full depth of cutting.

Photograph:

Appendix B

Engineering Borehole Logs and Explanatory Notes

Explanatory Notes - Soil Description

In engineering terms soil includes every type of uncemented or partially cemented inorganic material found in the ground. In practice, if the material can be remoulded by hand in its field condition or in water it is described as a soil. The dominant soil constituent is given in capital letters, with secondary textures in lower case. The dominant feature is assessed from the Unified Soil Classification system and a soil symbol is used to define a soil layer .

METHOD

Method	Description
AS	Auger Screwing
BH	Backhoe
CT	Cable Tool Rig
EE	Existing Excavation/Cutting
EX	Excavator
HA	Hand Auger
HQ	Diamond Core-63mm
JET	Jetting
NMLC	Diamond Core –52mm
NQ	Diamond Core –47mm
PT	Push Tube
RAB	Rotary Air Blast
RB	Rotary Blade
RT	Rotary Tricone Bit
TC	Auger TC Bit
V	Auger V Bit
WB	Washbore
DT	Diatube

WATER

▽ Water level at date shown

◁ Partial water loss

▷ Water inflow

◀ Complete water loss

NFGWO: The observation of groundwater, whether present or not, was not possible due to drilling water, surface seepage or cave in of the borehole/test pit.

NFGWE: The borehole/test pit was dry soon after excavation. Inflow may have been observed had the borehole/test pit been left open for a longer period.

SAMPLING

Sample	Description
B	Bulk Disturbed Sample
D	Disturbed Sample
Jar	Jar Sample
SPT	Standard Penetration Test
U50	Undisturbed Sample –50mm
U75	Undisturbed Sample –75mm

UNIFIED SOIL CLASSIFICATION

The appropriate symbols are selected on the result of visual examination, field tests and available laboratory tests, such as, sieve analysis, liquid limit and plasticity index.

USC Symbol	Description
GW	Well graded gravel
GP	Poorly graded gravel
GM	Silty gravel
GC	Clayey gravel
SW	Well graded sand
SP	Poorly graded sand
SM	Silty sand
SC	Clayey sand
ML	Silt of low plasticity
CL	Clay of low plasticity
OL	Organic soil of low plasticity
MH	Silt of high plasticity
CH	Clay of high plasticity
OH	Organic soil of high plasticity
Pt	Peaty Soil

MOISTURE CONDITION

Dry	-	Cohesive soils are friable or powdery Cohesionless soil grains are free-running
Moist	-	Soil feels cool, darkened in colour Cohesive soils can be moulded Cohesionless soil grains tend to adhere
Wet	-	Cohesive soils usually weakened Free water forms on hands when handling

For cohesive soils the following codes may also be used:

MC>PL	Moisture Content greater than the Plastic Limit.
MC~PL	Moisture Content near the Plastic Limit.
MC<PL	Moisture Content less than the Plastic Limit.

PLASTICITY

The potential for soil to undergo change in volume with moisture change is assessed from its degree of plasticity. The classification of the degree of plasticity in terms of the Liquid Limit (LL) is as follows:

Description of Plasticity	LL (%)
Low	<35
Medium	35 to 50
High	>50

COHESIVE SOILS - CONSISTENCY

The consistency of a cohesive soil is defined by descriptive terminology such as very soft, soft, firm, stiff, very stiff and hard. These terms are assessed by the shear strength of the soil as observed visually, by hand penetrometer values and by resistance to deformation to hand moulding.

A Hand Penetrometer may be used in the field or the laboratory to provide an approximate assessment of the unconfined compressive strength (UCS) of cohesive soils. The undrained shear strength of cohesive soils is approximately half the UCS. The values are recorded in kPa as follows:

Strength	Symbol	Undrained Shear Strength, C_u (kPa)
Very Soft	VS	< 12
Soft	S	12 to 25
Firm	F	25 to 50
Stiff	St	50 to 100
Very Stiff	VSt	100 to 200
Hard	H	> 200

COHESIONLESS SOILS - RELATIVE DENSITY

Relative density terms such as very loose, loose, medium, dense and very dense are used to describe silty and sandy material, and these are usually based on resistance to drilling penetration or the Standard Penetration Test (SPT) 'N' values. Other condition terms, such as friable, powdery or crumbly may also be used.

Term	Symbol	Density Index	N Value (blows/0.3 m)
Very Loose	VL	0 to 15	0 to 4
Loose	L	15 to 35	4 to 10
Medium Dense	MD	35 to 65	10 to 30
Dense	D	65 to 85	30 to 50
Very Dense	VD	>85	>50

COHESIONLESS SOILS PARTICLE SIZE DESCRIPTIVE TERMS

Name	Subdivision	Size
Boulders		>200 mm
Cobbles		63 mm to 200 mm
Gravel	coarse	20 mm to 63 mm
	medium	6 mm to 20 mm
	fine	2.36 mm to 6 mm
Sand	coarse	600 µm to 2.36 mm
	medium	200 µm to 600 µm
	fine	75 µm to 200 µm

Rock Description

The rock is described with strength and weathering symbols as shown below. Other features such as bedding and dip angle are given.

METHOD

Refer soil description sheet

WATER

Refer soil description sheet

ROCK QUALITY

The fracture spacing is shown where applicable and the Rock Quality Designation (RQD) or Total Core Recovery (TCR) is given where:

$$TCR\ (\%) = \frac{\text{length of core recovered}}{\text{length of core run}}$$

$$RQD\ (\%) = \frac{\text{Sum of Axial lengths of core > 100mm long}}{\text{length of core run}}$$

ROCK MATERIAL WEATHERING

Rock weathering is described using the abbreviations and definitions used in AS1726. AS1726 suggests the term "Distinctly Weathered" (DW) to cover the range of substance weathering conditions between (but not including) XW and SW. For projects where it is not practical to delineate between HW and MW or it is deemed that there is no advantage in making such a distinction, DW may be used with the definition given in AS1726.

Symbol	Term	Definition
RS	Residual Soil	Soil definition on extremely weathered rock; the mass structure and substance are no longer evident; there is a large change in volume but the soil has not been significantly transported
XW	Extremely Weathered	Rock is weathered to such an extent that it has 'soil' properties, ie. It either disintegrates or can be remoulded in water
HW	Highly Weathered	The rock substance is affected by weathering to the extent that limonite staining or bleaching affects the whole rock substance and other signs of chemical or physical decomposition are evident. Porosity and strength is usually decreased compared to the fresh rock. The colour and strength of the fresh rock is no longer recognisable.
DW	*Distinctly Weathered (see AS1726 Definition below)*	
MW	Moderately Weathered	The whole of the rock substance is discoloured, usually by iron staining or bleaching, to the extent that the colour of the fresh rock is no longer recognisable
SW	Slightly Weathered	Rock is slightly discoloured but shows little or no change of strength from fresh rock
FR	Fresh	Rock shows no sign of decomposition or staining

"Distinctly Weathered: Rock strength usually changed by weathering. The rock may be highly discoloured, usually by iron staining. Porosity may be increased by leaching, or may be decreased due to the deposition of weathering products in pores." (AS1726)

ROCK STRENGTH

Rock strength is described using AS1726 and ISRM - Commission on Standardisation of Laboratory and Field Tests, "Suggested method of determining the Uniaxial Compressive Strength of Rock materials and the Point Load Index", as follows:

Term	Symbol	Point Load Index $Is_{(50)}$ (MPa)
Extremely Low	EL	<0.03
Very Low	VL	0.03 to 0.1
Low	L	0.1 to 0.3
Medium	M	0.3 to 1
High	H	1 to 3
Very High	VH	3 to 10
Extremely High	EH	>10

● Diametral Point Load Index test

■ Axial Point Load Index test

DEFECT SPACING/BEDDING THICKNESS

Measured at right angles to defects of same set or bedding.

Term	Defect Spacing	Bedding
Extremely closely spaced	<6 mm	Thinly Laminated
	6 to 20 mm	Laminated
Very closely spaced	20 to 60 mm	Very Thin
Closely spaced	0.06 to 0.2 m	Thin
Moderately widely spaced	0.2 to 0.6 m	Medium
Widely spaced	0.6 to 2 m	Thick
Very widely spaced	>2 m	Very Thick

DEFECT DESCRIPTION

Type:	Definition:
B	Bedding
BP	Bedding Parting
F	Fault
C	Cleavage
J	Joint
SZ	Shear Zone
CZ	Crushed Zone
DB	Drill Break

Planarity:	Roughness:
P – Planar	R – Rough
Ir – Irregular	S – Smooth
St – Stepped	Sl – Slickensides
U – Undulating	Po – Polished

Coating or Infill:	Description
Clean	No visible coating or infilling
Stain	No visible coating or infilling but surfaces are discoloured by mineral staining
Veneer	A visible coating or infilling of soil or mineral substance but usually unable to be measured (<1mm). If discontinuous over the plane, patchy veneer
Coating	A visible coating or infilling of soil or mineral substance, >1mm thick. Describe composition and thickness

The inclinations of defects are measured from perpendicular to the core axis.

Graphic Symbols for Soil and Rock

Graphic symbols used on borehole and test pit reports for soil and rock are as follows. Combinations of these symbols may be used to indicate mixed materials such as clayey sand.

Soil Symbols

Main Components

- CLAY
- SILT
- SAND
- GRAVEL
- BOULDERS / COBBLES
- PEAT (Organic)

Minor Components

- Clayey
- Silty
- Sandy
- Gravelly

Other Symbols

- TOPSOIL
- FILL
- ASPHALT
- CONCRETE
- NO CORE

Rock Symbols

Sedimentary Rocks

- SANDSTONE
- SILTSTONE
- CLAYSTONE, MUDSTONE
- SHALE
- LAMINITE
- CONGLOMERATE
- BRECCIA
- TILL
- COAL
- LIMESTONE

Igneous Rocks

- PLUTONIC IGNEOUS (eg: Granite)
- VOLCANIC IGNEOUS (eg: Basalt)
- PYROCLASTIC IGNEOUS (eg: Ignimbrite)

Metamorphic Rocks

- SLATE, PHYLLITE, SCHIST
- GNEISS
- QUARTZITE

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH1

SHEET 1 OF 1

Client: **Norfolk Island Administration**
Project: **Geotechnical Soils Investigation, Norfolk Island**
Borehole Location: **Intersection Cascade and Mill Roads**
Project Number: **2110268A**

Date Commenced: **04/02/05**
Date Completed: **04/02/05**
Recorded By: **EDG**
Log Checked By:

Drill Model/Mounting: **BOB CAT 709**
Borehole Diameter: **300 mm**
Hole Angle: **90°**
Bearing: **---**
Surface RL: **115 m AHD**
Co-ords: **E 58789181 N 6784761 AMG**

Borehole Information							Field Material Description						
1	2	3	4	4	5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS S F ST VST H FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE							FILL: Clayey SAND; fine to coarse grained, brown,clay low to meduim plasticity, some fine to medium grarined gravel	MC~PL			FILL
				0.45				SM	TOPSOIL: Silty SAND, fine to coarse grained, dark brown, silt low plasticity	MC>PL	MD	300	TOPSOIL
				0.80				CH	silty CLAY: medium to high palsticity, dark orange brown, silt low plasticity, some fine to medium grained	MC>PL	H	>600	RESIDUAL SOIL
			114	1									
									END OF BOREHOLE AT 1.50 m				
			113	2									
			112	3									
			111	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH2

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**04/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**04/02/05**
Borehole Location:	**John Adams Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**97 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58790562 N 6784654 AMG**

Borehole Information							Field Material Description						
1	2	3	4	4	5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS S F ST VST H FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE					▨		FILL: Silty SAND, fine coarse grained, dark brown, gravelly, gravel fine to medium grained	MC~PL	▨		FILL
				0.60			▨	CH	Silty CLAY: high plasticity, orange brown, silt low pasticity, well structed soil	MC>PL	▨	>600	RESIDUAL SOIL
			96	1		D						600	
									END OF BOREHOLE AT 1.60 m				
			95	2									
			94	3									
			93	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH3

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**04/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**04/02/05**
Borehole Location:	**Stockyard Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**107 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58790666 N 6785019 AMG**

Borehole Information							Field Material Description						
1	2	3	4		5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB S VL F L ST MD VST D H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NGWE						SM	TOPSOIL: silty SAND; fine to coarse grained, dark brown, silt low plasticity	MC~PL	ST		TOPSOIL
				0.50				CH	Silty CLAY: high plasticity, brown, silt low plasticity	MC>PL	VST	400	RESIDUAL SOIL
			106	1		U50					H		
						D						>600	
				1.40				CH	Silty CLAY: high plasticity, dark orange brown, silty low plasticity		H		
									END OF BOREHOLE AT 1.60 m				
			105	2									
			104	3									
			103	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH4

SHEET 1 OF 1

Client: **Norfolk Island Administration**
Project: **Geotechnical Soils Investigation, Norfolk Island**
Borehole Location: **Stockyard Road**
Project Number: **2110268A**

Date Commenced: **04/02/05**
Date Completed: **04/02/05**
Recorded By: **EDG**
Log Checked By:

Drill Model/Mounting: **BOB CAT 709**
Borehole Diameter: **300 mm**
Hole Angle: **90°**
Bearing: **---**
Surface RL: **133 m AHD**
Co-ords: **E 58799456 N 6783960 AMG**

Borehole Information							Field Material Description											
1	2	3	4	4	5	6	7	8	9	10	11						12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB	S VL	F L	ST MD	VST D	H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE						SM	TOPSOIL: silty SAND, fine to coarse grained, dark brown	MC~PL				▨				TOPSOIL
				0.40				CH	Silty CLAY: high plasticity, orange brown, silty low palsticity	MC>PL						▨		RESIDUAL SOIL
			132	0.80 1		U50		CH	Silty CLAY: high plasticity, orange brown, silt low plasticity, some highly weathered basalt gravel							▨	>600	
				1.60					Basalt: extremely weathered, very low stregth, pale grey									WEATHERED ROCK
			131 130 129	2 3 4					END OF BOREHOLE AT 1.90 m									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH5

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**04/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**04/02/05**
Borehole Location:	**Driver Christian Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**129 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58789752 N 6782737 AMG**

Borehole Information							Field Material Description											
1	2	3	4	4	5	6	7	8	9	10	11						12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB	S VL	F L	ST MD	VST D	H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	N T G W E					▨		FILL: Silty CLAY, orange brown, medium plasticity, silt low plasticity, some fien to medium grained basalt gravel.	MC~PL					▨			FILL
				0.50		D		CH	Silty CLAY: high plasticity, orange brown, silty low plasticity	MC>PL						▨	>600	RESIDUAL SOIL
			128	1														
				1.60				CH	Silty gravel CLAY: orange plasticity, dark brown, silt low plasticity, gravel fine to medium grained	MC>PL						▨		
			127	2					END OF BOREHOLE AT 2.00 m									
			126	3														
			125	4														

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH6

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**04/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**04/02/05**
Borehole Location:	**Driver Christian Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**40 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58789480 N 6782264 AMG**

Borehole Information							Field Material Description						
1	2	3	4		5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS S F ST VST H FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NGWE	39	1					FILL: Silty gravel CLAY, medium plasticity, brown, dark brown and dark orange brown, silt low plasticitiy, gravel fine to medium grained	MC~PL	ST		FILL
				1.60				CH	Silty CLAY: medium plasticity, orange brown and dark orange brown, silt low plasticity, gravel fine to medium grained	MC>PL	H		RESIDUAL SOIL
			38	2.00 2					BASALT: extremely weathered, very low strength, pale grey, purple grey, apperant as clayey gravel	MC>PL	H		WEATHERED ROCK
			37	3					END OF BOREHOLE AT 2.60 m				
			36	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

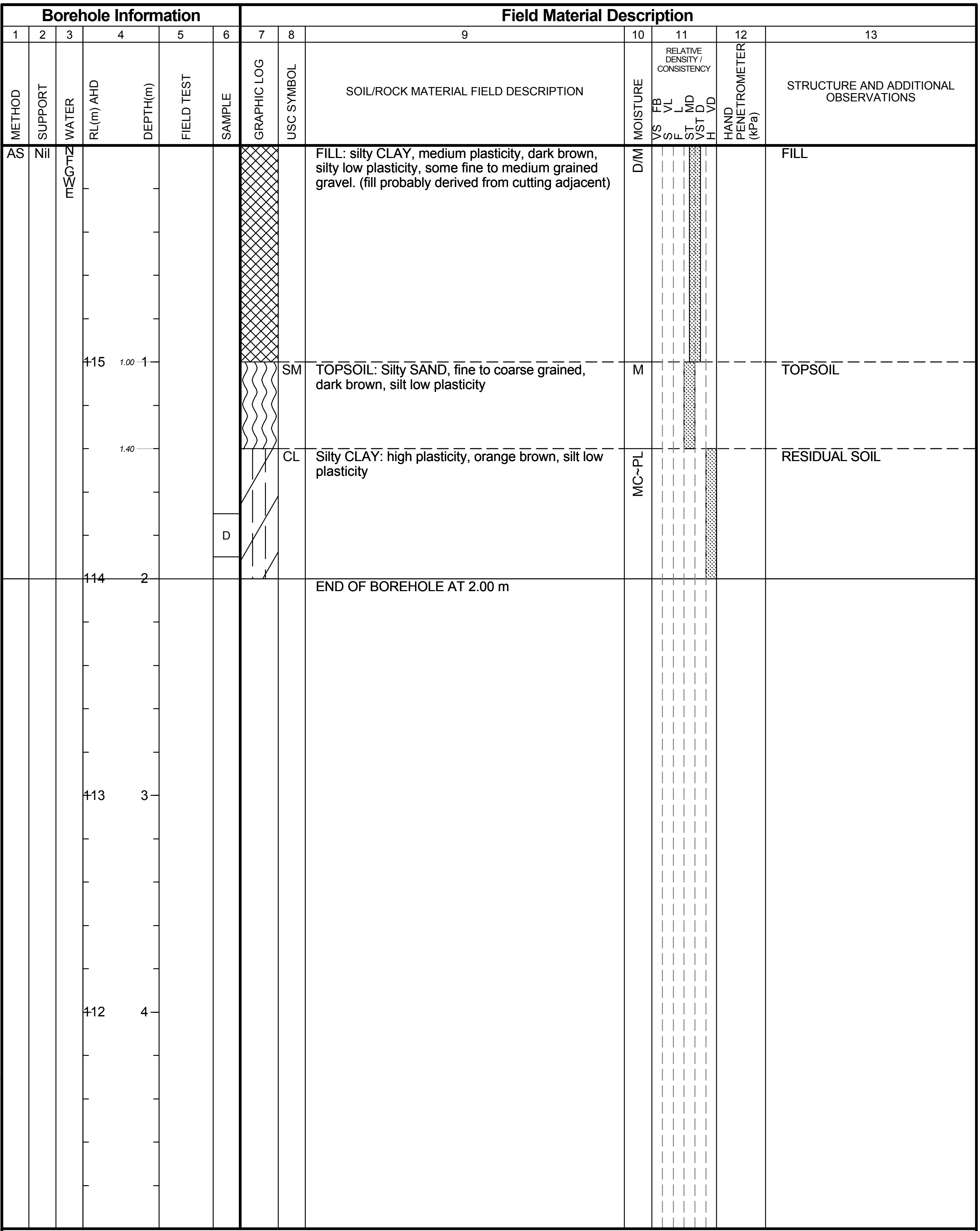
BOREHOLE NO.

BH7

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**04/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**04/02/05**
Borehole Location:	**Middlegate Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**116 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58788116 N 6783126 AMG**



Borehole Information							Field Material Description						
1	2	3	4		5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB S VL F L ST MD VST D H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE							FILL: silty CLAY, medium plasticity, dark brown, silty low plasticity, some fine to medium grained gravel. (fill probably derived from cutting adjacent)	D/M			FILL
			115	1.00 1				SM	TOPSOIL: Silty SAND, fine to coarse grained, dark brown, silt low plasticity	M			TOPSOIL
				1.40		D		CL	Silty CLAY: high plasticity, orange brown, silt low plasticity	MC~PL			RESIDUAL SOIL
			114	2					END OF BOREHOLE AT 2.00 m				
			113	3									
			112	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH8

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**05/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**05/02/05**
Borehole Location:	**Mt Pitt Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**179 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58786385 N 6785911 AMG**

Borehole Information							Field Material Description						
1	2	3	4		5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS S F ST VST H FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE						CL	TOPSOIL: silty CLAY, low plasticity, dark brown, silt low plasticity	M	VST		TOPSOIL
				0.40				CH	Silty CLAY: high plasticity, brown, silt low plasticity	M	H		RESIDUAL SOIL
						D							
			178	1									
				1.40				CH	Silty gravel CLAY: high plasticity, pale orange brown, silt low plasticity,	M	H		
			177	2					END OF BOREHOLE AT 2.00 m				
			176	3									
			175	4									

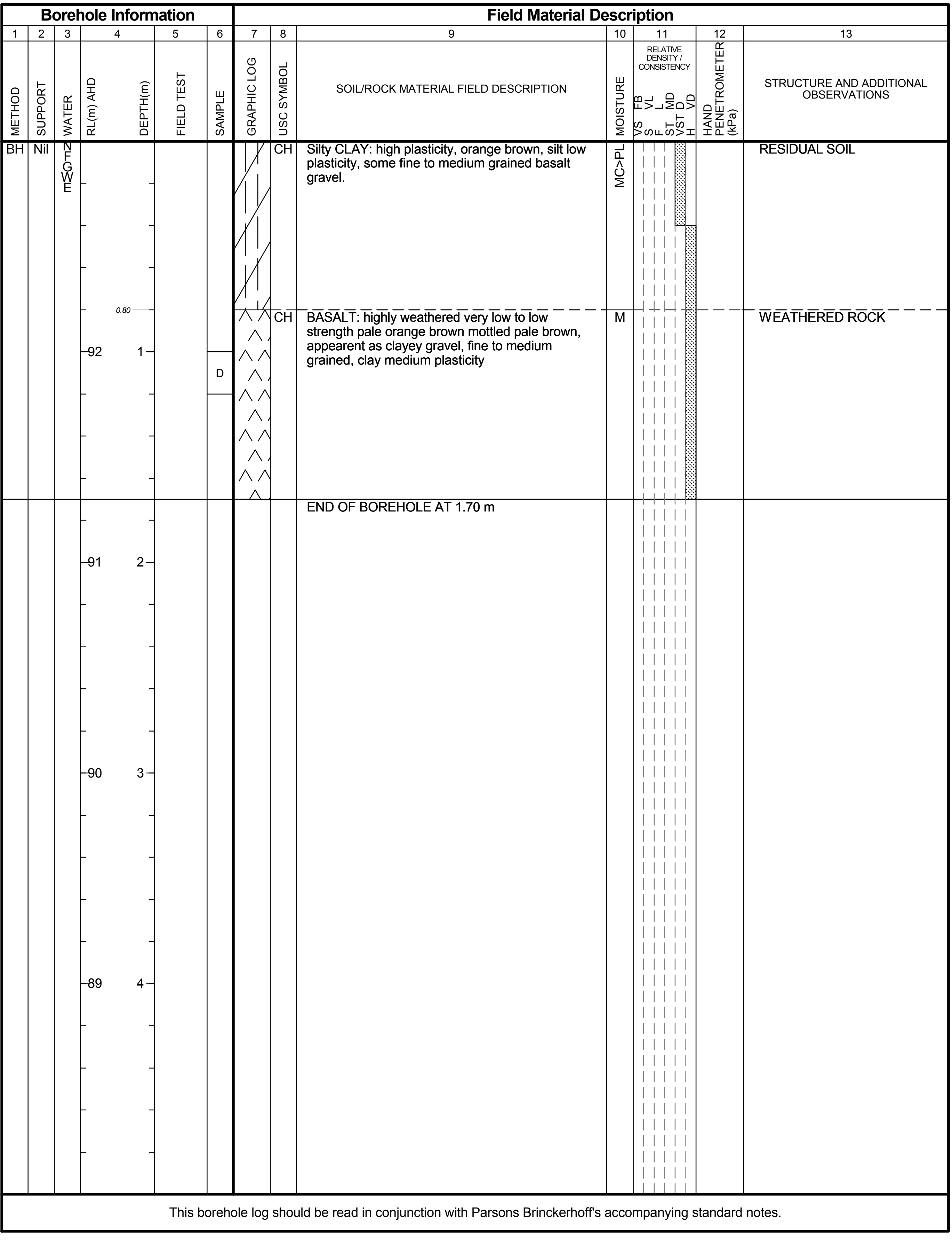
This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH9
SHEET 1 OF 1

Client: **Norfolk Island Administration**
Project: **Geotechnical Soils Investigation, Norfolk Island**
Borehole Location: **Mission Road**
Project Number: **2110268A**
Date Commenced: **05/02/05**
Date Completed: **05/02/05**
Recorded By: **EDG**
Log Checked By:

Drill Model/Mounting: **BOB CAT 709**
Borehole Diameter: **300 mm**
Hole Angle: **90°**
Bearing: **---**
Surface RL: **93 m AHD**
Co-ords: **E 58785277 N 6785160 AMG**



Borehole Information						Field Material Description						
1	2	3	4	5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD / DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS S F ST VST H FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
BH	Nil	NGWE					CH	Silty CLAY: high plasticity, orange brown, silt low plasticity, some fine to medium grained basalt gravel.	MC>PL	VST H		RESIDUAL SOIL
			0.80 92 1		D		CH	BASALT: highly weathered very low to low strength pale orange brown mottled pale brown, appearent as clayey gravel, fine to medium grained, clay medium plasticity	M	H		WEATHERED ROCK
			91 2 90 3 89 4					END OF BOREHOLE AT 1.70 m				

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH10

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**05/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**05/02/05**
Borehole Location:	**Anson Bay Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**84 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58784710 N 6786065 AMG**

Borehole Information							Field Material Description						
1	2	3	4		5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS S F ST VST H FB VL L MD D VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE						SM	TOPSOIL: silty SAND, fine to medium grained, dark brown, silt loe plasticity	M			TOPSOIL
			83	1		D						300	
				1.20				CH	Silty CLAY: high plasticity, dark orange brown, pale brown, silt low plasticity, trace fine to medium grained gravel of highly weathered basalt	M			RESIDUAL SOIL
						D							
			82	2									
									END OF BOREHOLE AT 2.60 m				
			81	3									
			80	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH11
SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**05/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**05/02/05**
Borehole Location:	**Anson Bay Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**99 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58785007 N 6787456 AMG**

Borehole Information							Field Material Description											
1	2	3	4		5	6	7	8	9	10	11						12	13
											RELATIVE DENSITY / CONSISTENCY							
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	VS FB	S VL	F L	ST MD	VST D	H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE						CL	TOPSOIL: silty CLAY, dark orange brown, clay low to medium plasticity	MC>PL				▨				TOPSOIL
				0.40				CH	Silty CLAY: high plasticity, orange brown, silt low plasticity	MC>PL						▨		RESIDUAL SOIL
						U50												
			98	1		D											>600	
				1.40				CH	Silty CLAY: high plasticity, orange brown mottled pale brown, silt low plasticity, some fine to medium grained highly weathered basalt	MC>PL						▨		
				1.80				CH	Silty gravelly CLAY: high plasticity, orange brown mottled pale brown, silt low plasticity, gravel fine to medium grained HW Basalt	MC>PL						▨		
			97	2														
									END OF BOREHOLE AT 2.20 m									
			96	3														
			95	4														

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH12

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**05/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**05/02/05**
Borehole Location:	**Bullocks Hut Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**99 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58785087 N 6787866 AMG**

Borehole Information							Field Material Description											
1	2	3	4	4	5	6	7	8	9	10	11						12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB	S VL	F L	ST MD	VST D	H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE						CL	TOPSOIL: silty CLAY, dark orange brown, clay low to medium plasticity, silt low plasticity	MC~PL					▨			TOPSOIL
				0.50		U50		CH	Silty CLAY: high plasticity, orange brown, silt low plasticity	MC~PL						▨	>600	RESIDUAL SOIL
			98	1														
				1.80				CH	Silty gravelly CLAY: high plasticity, orange brown, mottled grey and pale grey, silt low plasticity, gravel fine to medium grained							▨		
			97	2					END OF BOREHOLE AT 2.00 m									
			96	3														
			95	4														

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH13
SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**05/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**05/02/05**
Borehole Location:	**Douglas Drive**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**109 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58786121 N 6784584 AMG**

Borehole Information							Field Material Description						
1	2	3	4	4	5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB S VL F L ST MD VST D H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE						SM	TOPSOIL: silty SAND, fine to coarse grained, brown and dark brown, silt low plasticity	M	MD		TOPSOIL
				0.60				CH	Silty CLAY: high plasticity, orange brown, silt low plasticity	M	H		RESIDUAL SOIL
			108	1		D							
				1.60				CH	Silty CLAY: high plasticity, orange brown, silt low plasticity, some highly weathered fine to medium grained basalt gravel	M	H		
			107	2					END OF BOREHOLE AT 2.00 m				
			106	3									
			105	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.
BH14
SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**05/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**05/02/05**
Borehole Location:	**Douglas Drive**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**116 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58786352 N 6784676 AMG**

Borehole Information						Field Material Description						
1	2	3	4	4	5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB / S VL / F L / ST MD / VST D / H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE						SM	Silty SAND: fine to coarse grained, dark brown, silt low plasticity	M	MD		TOPSOIL
				0.40				CH	Silty CLAY: high plasticity, orange brown, silt low plasticity	M	H	>600	RESIDUAL SOIL
						D							
			115	1									
				1.60				CH	Silty CLAY: high plasticity, orange brown, silt medium plasticity, some fine to medium grained highly weathered Basalt	M	H		
									END OF BOREHOLE AT 1.80 m				
			114	2									
			113	3									
			112	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH15

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**04/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**04/02/05**
Borehole Location:	**Headstone Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**71 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58784599 N 6783840 AMG**

Borehole Information							Field Material Description						
1	2	3	4	4	5	6	7	8	9	10	11	12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB S VL F L ST MD VST D H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE							TOPSOIL: silty SAND, fine to coarse grained, dark brown, silt low plasticity	M	MD		TOPSOIL
				0.40				CH	Silty CLAY: high plasticity, orange brown, silt low plasticity, trace fine gravel	MC~PL	H	>600	RESIDUAL SOIL
						U50							
			70	1									
				1.40				CH	Silty CLAY: medium to high plasticity, red brown, silt low plasticity.				
						D							
									Some highly weathered basalt gravel at base of hole				
			69	2					END OF BOREHOLE AT 2.00 m				
			68	3									
			67	4									

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH16

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**04/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**04/02/05**
Borehole Location:	**Headstone Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**84 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58784719 N 6783348 AMG**

Borehole Information							Field Material Description												
1	2	3	4		5	6	7	8	9	10	11						12	13
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	RELATIVE DENSITY / CONSISTENCY VS FB	S VL	F L	ST MD	VST D	H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE		0.60					FILL: silty gravel CLAY: low to medium plasticity, dark orange brown, dark yellow brown, dark brown, silt low plasticity, gravel fine to medium grained.	MC~PL					▨			FILL
			83	1.30		D		CH	Silty CLAY: high plasticity, dark yellow brown, silt low plasticity	MC>PL						▨		RESIDUAL SOIL
			82	2		D		CH	Silty CLAY: high plasticity, orange brown, red brown, silt low plasticity, trace greavel, fine to medium grained (highly weathered basalt)	MC~PL						▨		
									END OF BOREHOLE AT 2.00 m									
			81	3														
			80	4														

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

BOREHOLE ENGINEERING LOG

BOREHOLE NO.

BH17

SHEET 1 OF 1

Client:	**Norfolk Island Administration**	Date Commenced:	**04/02/05**
Project:	**Geotechnical Soils Investigation, Norfolk Island**	Date Completed:	**04/02/05**
Borehole Location:	**Captian Quintal Road**	Recorded By:	**EDG**
Project Number:	**2110268A**	Log Checked By:	

Drill Model/Mounting:	**BOB CAT 709**	Hole Angle:	**90°**	Surface RL:	**96 m AHD**
Borehole Diameter:	**300 mm**	Bearing:	**---**	Co-ords:	**E 58785690 N 6783432 AMG**

Borehole Information							Field Material Description											
1	2	3	4		5	6	7	8	9	10	11						12	13
											RELATIVE DENSITY / CONSISTENCY							
METHOD	SUPPORT	WATER	RL(m) AHD	DEPTH(m)	FIELD TEST	SAMPLE	GRAPHIC LOG	USC SYMBOL	SOIL/ROCK MATERIAL FIELD DESCRIPTION	MOISTURE	VS	S FB	F VL	ST L	VST MD D	H VD	HAND PENETROMETER (kPa)	STRUCTURE AND ADDITIONAL OBSERVATIONS
AS	Nil	NFGWE		0.30			▩		FILL: silty gravel CLAY, medium plasticity, orange brown, silt low plasticity, gravel fine to medium grained	MC~PL					▨			FILL
			95	1 1.30		D	▧	CH	Silty CLAY: high plasticity, orange brown, silt low plasticity	MC>PL						▨		RESIDUAL SOIL
			94	2 2.20		D	▧	CH	Silty CLAY: high plasticity, red brown, silt low plasticity	MC~PL						▨		
							▧	CH	Silty CLAY: medium to high plasticity, red brown, some basalt gravel, (weathered Basalt) silt low plasticity	MC~PL						▨		
									END OF BOREHOLE AT 2.40 m									
			93	3														
			92	4														

This borehole log should be read in conjunction with Parsons Brinckerhoff's accompanying standard notes.

Appendix C

Laboratory Test Results

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

SOIL CLASSIFICATION TEST DATA

CLIENT: **Parsons Brinckerhoff Australia Pty Ltd**
Locked Bag 248 Rhodes NSW 2138
PROJECT: **Norfolk Island**

LAB. NO.	SAMPLE SOURCE	SAMPLE DESCRIPTION	MOISTURE CONTENT (%) 1	DRY DENSITY (t/m^3)	LIQUID LIMIT 2	PLASTIC INDEX 3	LINEAR SHRINKAG (%) 4
33562	TP2 1.0-1.2m	CLAYEY SILT: brown, high plasiticity, trace of fine to coarse sand, trace of fine gravel.	25.1	-	*54	22	13.0
33564	TP3 1.4-16m	SILTY CLAY: brown, high plasticity, trace of fine to coarse sand, trace of fine to medium gravel.	32.9	-	*63	35	15.5
33566	TP5 0.8-1.0m	SILTY CLAY: brown, high plasticity, trace of fine to coarse sand, trace of fine to medium gravel.	28.0	-	*53	25	*13.5
33567	TP7 1.7-1.9m	CLAYEY SILT: brown, high plasiticity, trace of fine to coarse sand, trace of fine gravel.	40.1	-	*70	30	14.5
33568	TP8 0.8-1.0m	CLAYEY SILT: brown, high plasiticity, trace of fine to coarse sand.	38.0	-	*89	49	19.5
33570	TP10 1.8-2.0m	SILTY CLAY: brown, high plasticity, trace of fine to coarse sand, trace of fine to medium gravel.	38.0	-	70	37	17.5
33572	TP11 1.0-1.1m	SILTY CLAY: brown, high plasticity, trace of fine to coarse sand, trace of fine gravel.	40.8	-	84	48	19.5
33574	TP13 0.9-1.1m	CLAYEY SILT: brown, high plasiticity, trace of fine to coarse sand, trace of fine to coarse gravel.	31.4	-	57	27	16.5
33575	TP14 0.8-1.0m	CLAYEY SILT: brown, medium plasticity, trace of fine to coarse sand, trace of fine to medium gravel.	31.5	-	44	15	9.5
33577	TP15 1.6-1.8m	CLAYEY SILT: brown, high plasticity, trace of fine to coarse sand, trace of fine to medium gravel.	33.9	-	61	27	15.0
33578	TP16 1.6-1.8m	GRAVELLY SILT: brown, high plasticity, fine to coarse gravel, with clay, trace of fine to coarse sand.	36.1	-	56	22	11.5

NOTES TO TESTING

1. Test method: AS 1289 2.1.1-1992
2. Test Method: AS 1289 3.1.2
   Preparation: dry sieved, *natural state with no sieving.
   Sample History: air dried, *natural state as received
3. Test Method: AS 1289 3.2.1, 3.3.1
   Preparation and sample history as 2.
4. Test Method: AS 1289 3.4.1
   Sample history and preparation as 2.
   Mould size: 125mm
   Dry state: *curling, linear.

Sampled by:	Client
Job Number:	006-011
Date Tested:	4/04/2005

Form C01 excel issue 4 Jan 1997 CWS

NATA Accredited Laboratory Number: 1459
NATA endorsed test report. This document shall not be reproduced, except in full.

Signed:
Name: G Stubbs
Title: Manager
Date: 19/4/05

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

SOIL CLASSIFICATION TEST DATA

CLIENT: **Parsons Brinckerhoff Australia Pty Ltd**
Locked Bag 248 Rhodes NSW 2138
PROJECT: **Norfolk Island**

LAB. NO.	SAMPLE SOURCE	SAMPLE DESCRIPTION	MOISTURE CONTENT (%) 1	DRY DENSITY (t/m^3)	LIQUID LIMIT 2	PLASTIC INDEX 3	LINEAR SHRINKAGE (%) 4
33579	TP17 0.7-0.9m	CLAYEY SILT: brown, high plasticity, trace of fine to coarse sand, trace of fine gravel.	37.0	-	69	35	16.0
33580	Site 2	SILTY CLAY: grey, high plasticity, trace of fine to medium sand.	44.6	-	72	38	17.5
33581	Site 5 -1	CLAYEY SILY: grey, high plasticity, trace of fine to medium sand.	35.5	-	68	27	15.0
33582	Site 5 - 2	CLAYEY SILT: purple-brown, high plasticity, trace of fine to coarse sand.	50.1	-	109	63	23.5
33583	Site 7	CLAYEY SILT: purple-brown, high plasticity, trace of fine to medium sand.	51.7	-	79	29	19.0
33584	Site 11	CLAYEY SILT: brown, high plasticity, trace of fine to medium sand.	33.3	-	60	28	15.5
33585	Site 14	CLAYEY SILT: brown, high plasticity, trace of fine sand.	39.5	-	84	46	20.5
33586	Site 16	CLAYEY SILT: brown, high plasiticity, trace of fine to coarse sand, trace of fine to medium gravel with fine roots.	53.9	-	104	60	19.5

NOTES TO TESTING

1 Test method: AS 1289 2.1.1-1992
2 Test Method: AS 1289 3.1.2
Preparation: dry sieved.
Sample History: air dried.
3 Test Method: AS 1289 3.2.1, 3.3.1
Preparation and sample history as 2.
4 Test Method: AS 1289 3.4.1
Sample history and preparation as 2.
Mould size: 125mm
Dry state: linear.

Sampled by: Client
Job Number: 006-011
Date Tested: 6/04/2005

Form C01 excel issue 4 Jan 1997 CWS

Signed: ....
Name: C Stabb
Title: Manager
Date: 19/4/05

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

SHRINK-SWELL INDEX TEST REPORT

CLIENT	**Parsons Brinckerhoff** Locked Bag 248 Rhodes NSW 2138
PROJECT	**Norfolk Island**

SAMPLE SOURCE:	TP3 0.9-1.15m	
SAMPLE DESCRIPTION:	SANDY CLAY: brown, medium plasticity, fine to medium sand, trace of roots.	
LABORATORY NUMBER:	33563	
SHRINK-SWELL INDEX (I_{ss}):	**2.1**	

SAMPLE DATA

Total Shrinkage (E_{sh}):	3.9	%
Total Swell (E_{sw}):	0.0	%
Shrink Specimen		
Measured Moisture Content (w_3)	29.0	%
Dry Density:	1.52	t/m^3
Inert Inclusions:	0	
Crumbling:	Mild	
Cracking:	Moderate	
Swell Specimen		
Initial Moisture Content (w_1):	28.8	%
After Test Moisture Content (w_2):	36.8	%
Date Tested:	08.04.05	
Sampled By:	Client	
Job Number:	006-011	

Tested in Accordance with AS 1289 7.1.1 - 2003 Determination of the shrinkage index of a soil - Shrink-swell Index

Form c02 File c02 Issue 4 July 2001

NATA Accredited Laboratory Number: 1459
NATA endorsed test report. This document shall not be reproduced, except in full.

Signed: ....
Title: Manager
Name: C Stubbs
Date: 19/4/05

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

SHRINK-SWELL INDEX TEST REPORT

CLIENT **Parsons Brinckerhoff**
Locked Bag 248 Rhodes NSW 2138

PROJECT **Norfolk Island**

SAMPLE SOURCE: TP4 0.8 to 0.95m

SAMPLE DESCRIPTION: SANDY CLAY: brown, medium plasticity, fine to medium sand, trace of roots.

LABORATORY NUMBER: 33565

SHRINK-SWELL INDEX (I_{ss}): **2.2**

SAMPLE DATA

Total Shrinkage (E_{sh}):	4.0	%	
Total Swell (E_{sw}):	0.0	%	Sample consolidated
Shrink Specimen			
Measured Moisture Content (w_3)	34.0	%	
Dry Density:	1.36	t/m^3	
Inert Inclusions:	0		
Crumbling:	Mild		
Cracking:	Moderate		
Swell Specimen			
Initial Moisture Content (w_1):	38.5	%	
After Test Moisture Content (w_2):	45.3	%	
Date Tested:	08.04.05		
Sampled By:	Client		
Job Number:	066-011		

Tested in Accordance with AS 1289 7.1.1 - 2003 Determination of the shrinkage index of a soil - Shrink-swell Index

Form c02 File c02 Issue 4 July 2001

NATA Accredited Laboratory Number: 1459
NATA endorsed test report. This document shall not be reproduced, except in full.

Signed: ....
Name: C Stabbs
Title: Manage
Date: 19/4/05

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

SHRINK-SWELL INDEX TEST REPORT

CLIENT **Parsons Brinckerhoff**
Locked Bag 248 Rhodes NSW 2138
PROJECT **Norfolk Island**

SAMPLE SOURCE: TP11 0.87 to 1.0m

SAMPLE DESCRIPTION: SANDY CLAY: brown, medium plasticity, fine to medium sand, trace of roots.

LABORATORY NUMBER: 33571

SHRINK-SWELL INDEX (I_{ss}): **3.5**

SAMPLE DATA

Total Shrinkage (E_{sh}): 6.2 %

Total Swell (E_{sw}): 0.0 % Sample consolidated

Shrink Specimen

Measured Moisture Content (w_3) 40.7 %

Dry Density: 1.35 t/m^3

Inert Inclusions: 0

Crumbling: Mild

Cracking: Moderate

Swell Specimen

Initial Moisture Content (w_1): 39.1 %

After Test Moisture Content (w_2): 52.4 %

Date Tested: 08.04.05
Sampled By: Client
Job Number: 066-011

Tested in Accordance with AS 1289 7.1.1 - 2003 Determination of the shrinkage index of a soil - Shrink-swell Index

Form c02 File c02 Issue 4 July 2001

NATA Accredited Laboratory Number: 1459
NATA endorsed test report. This document shall not be reproduced, except in full.

Signed: ....
Title: Manager
Name: C Stubbs
Date: 19/4/05

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: auststt@bigpond.com

SHRINK-SWELL INDEX TEST REPORT

CLIENT **Parsons Brinckerhoff**
Locked Bag 248 Rhodes NSW 2138

PROJECT **Norfolk Island**

SAMPLE SOURCE: TP12 0.7 to 0.8m

SAMPLE DESCRIPTION: SANDY CLAY: brown, medium plasticity, fine to medium sand, trace of roots.

LABORATORY NUMBER: 33573

SHRINK-SWELL INDEX (I_{ss}): **3.2**

SAMPLE DATA

Total Shrinkage (E_{sh}):	5.8	%	
Total Swell (E_{sw}):	0.0	%	Sample consolidated
Shrink Specimen			
Measured Moisture Content (w_3)	37.7	%	
Dry Density:	1.47	t/m^3	
Inert Inclusions:	0		
Crumbling:	none		
Cracking:	None		
Swell Specimen			
Initial Moisture Content (w_1):	37.4	%	
After Test Moisture Content (w_2):	50.1	%	

Date Tested: 08.04.05
Sampled By: Client
Job Number: 066-011

Tested in Accordance with AS 1289 7.1.1 - 2003 Determination of the shrinkage index of a soil - Shrink-swell Index

Form c02 File c02 Issue 4 July 2001

NATA Accredited Laboratory Number: 1459
NATA endorsed test report. This document shall not be reproduced, except in full.

Signed: ....
Name: [illegible]
Title: Manager
Date: 19/4/05

AUSTRALIAN SOIL TESTING PTY LTD. A.B.N. 79 003 493 623
19 Bermill Street, Rockdale, NSW, 2216 P.O. Box 2014, Rockdale D.C. NSW 2216
Tel: 9597 5599, 9597 3286 Fax: 9597 3442 Email: austst@bigpond.com

SHRINK-SWELL INDEX TEST REPORT

CLIENT **Parsons Brinckerhoff**
Locked Bag 248 Rhodes NSW 2138

PROJECT **Norfolk Island**

SAMPLE SOURCE: TP15 0.7 to 0.85m

SAMPLE DESCRIPTION: SANDY CLAY: brown, medium plasticity, fine to medium sand, trace of roots.

LABORATORY NUMBER: 33576

SHRINK-SWELL INDEX (I_{ss}): **2.6**

SAMPLE DATA

Total Shrinkage (E_{sh}):	4.6	%
Total Swell (E_{sw}):	0.2	%
Shrink Specimen		
Measured Moisture Content (w_3)	31.8	%
Dry Density:	1.37	t/m^3
Inert Inclusions:	0	
Crumbling:	moderate	
Cracking:	Mild	
Swell Specimen		
Initial Moisture Content (w_1):	29.5	%
After Test Moisture Content (w_2):	44.7	%

Date Tested: 08.04.05
Sampled By: Client
Job Number: 066-011

Tested in Accordance with AS 1289 7.1.1 - 2003 Determination of the shrinkage index of a soil - Shrink-swell Index

Form c02 File c02 Issue 4 July 2001

NATA Accredited Laboratory Number: 1459
NATA endorsed test report. This document shall not be reproduced, except in full.

Signed: ....
Title: Manager
Name: aShubb
Date: 19/4/05

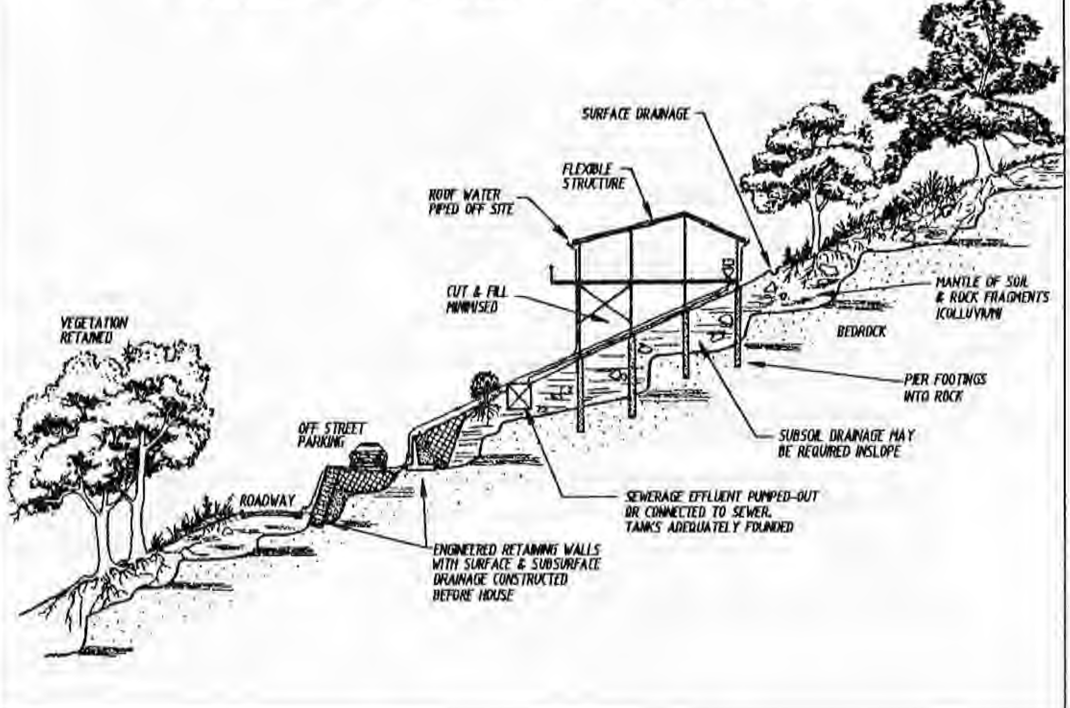
Appendix D

Good Hill Side Practice

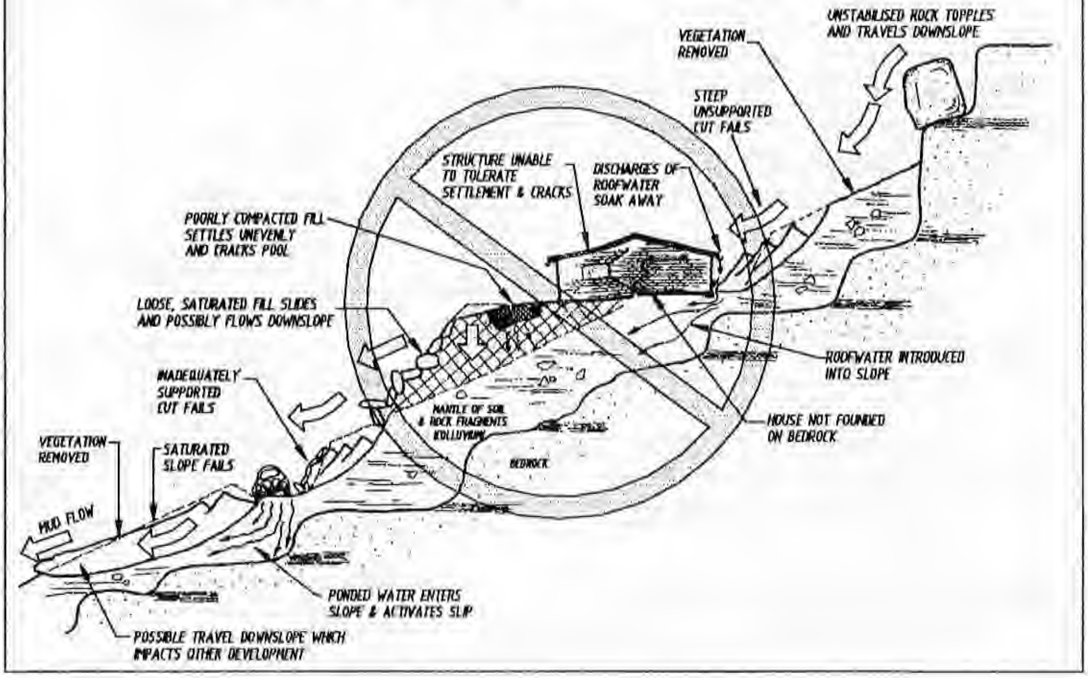
SOME GUIDELINES FOR HILLSIDE CONSTRUCTION

	GOOD ENGINEERING PRACTICE	*POOR ENGINEERING PRACTICE*
ADVICE		
GEOTECHNICAL ASSESSMENT	Obtain advice from a qualified, experienced geotechnical consultant at early stage of planning and before site works.	Prepare detailed plan and start site works before geotechnical advice.
PLANNING		
SITE PLANNING	Having obtained geotechnical advice, plan the development with the risk arising from the identified hazards and consequences in mind.	Plan development without regard for the Risk.
DESIGN AND CONSTRUCTION		
HOUSE DESIGN	Use flexible structures which incorporate properly designed brickwork, timber or steel frames, timber or panel cladding. Consider use of split levels. Use decks for recreational areas where appropriate.	Floor plans which require extensive cutting and filling. Movement intolerant structures.
SITE CLEARING	Retain natural vegetation wherever practicable.	Indiscriminately clear the site.
ACCESS & DRIVEWAYS	Satisfy requirements below for cuts, fills, retaining walls and drainage. Council specifications for grades may need to be modified. Driveways and parking areas may need to be fully supported on piers.	Excavate and fill for site access before geotechnical advice.
EARTHWORKS	Retain natural contours wherever possible.	Indiscriminant bulk earthworks.
CUTS	Minimise depth. Support with engineered retaining walls or batter to appropriate slope. Provide drainage measures and erosion control.	Large scale cuts and benching. Unsupported cuts. Ignore drainage requirements
FILLS	Minimise height. Strip vegetation and topsoil and key into natural slopes prior to filling. Use clean fill materials and compact to engineering standards. Batter to appropriate slope or support with engineered retaining wall. Provide surface drainage and appropriate subsurface drainage.	Loose or poorly compacted fill, which if it fails, may flow a considerable distance including onto property below. Block natural drainage lines. Fill over existing vegetation and topsoil. Include stumps, trees, vegetation, topsoil, boulders, building rubble etc in fill.
ROCK OUTCROPS & BOULDERS	Remove or stabilise boulders which may have unacceptable risk. Support rock faces where necessary.	Disturb or undercut detached blocks or boulders.
RETAINING WALLS	Engineer design to resist applied soil and water forces. Found on rock where practicable. Provide subsurface drainage within wall backfill and surface drainage on slope above. Construct wall as soon as possible after cut/fill operation.	Construct a structurally inadequate wall such as sandstone flagging, brick or unreinforced blockwork. Lack of subsurface drains and weepholes.
FOOTINGS	Found within rock where practicable. Use rows of piers or strip footings oriented up and down slope. Design for lateral creep pressures if necessary. Backfill footing excavations to exclude ingress of surface water.	Found on topsoil, loose fill, detached boulders or undercut cliffs.
SWIMMING POOLS	Engineer designed. Support on piers to rock where practicable. Provide with under-drainage and gravity drain outlet where practicable. Design for high soil pressures which may develop on uphill side whilst there may be little or no lateral support on downhill side.	
DRAINAGE SURFACE	Provide at tops of cut and fill slopes. Discharge to street drainage or natural water courses. Provide general falls to prevent blockage by siltation and incorporate silt traps. Line to minimise infiltration and make flexible where possible. Special structures to dissipate energy at changes of slope and/or direction.	Discharge at top of fills and cuts. Allow water to pond on bench areas.
SUBSURFACE	Provide filter around subsurface drain. Provide drain behind retaining walls. Use flexible pipelines with access for maintenance. Prevent inflow of surface water.	Discharge roof runoff into absorption trenches.
SEPTIC & SULLAGE	Usually requires pump-out or mains sewer systems; absorption trenches may be possible in some areas if risk is acceptable. Storage tanks should be water-tight and adequately founded.	Discharge sullage directly onto and into slopes. Use absorption trenches without consideration of landslide risk.
EROSION CONTROL & LANDSCAPING	Control erosion as this may lead to instability. Revegetate cleared area.	Failure to observe earthworks and drainage recommendations when landscaping.
DRAWINGS AND SITE VISITS DURING CONSTRUCTION		
DRAWINGS	Building Application drawings should be viewed by geotechnical consultant	
SITE VISITS	Site Visits by consultant may be appropriate during construction/	
INSPECTION AND MAINTENANCE BY OWNER		
OWNER'S RESPONSIBILITY	Clean drainage systems; repair broken joints in drains and leaks in supply pipes. Where structural distress is evident see advice. If seepage observed, determine causes or seek advice on consequences.	

EXAMPLES OF GOOD HILLSIDE PRACTICE



EXAMPLES OF POOR HILLSIDE PRACTICE



Appendix E

General Design Precautions for Construction on Reactive Clay Soils

Reactive Soils – General Design Precautions

These procedures generally apply to masonry residential buildings founded on reactive clay soils. Such soils are prone to shrink/swell movements due to moisture variations (either by natural or artificial causes). It must be accepted that some degree of structural cracking is likely for structures founded on these soils. The basic design philosophy is to minimise any cracking and provide a serviceable structure. It is thus a compromise between economy and performance.

The following procedures are supplementary to the foundation recommendations given in the attached report.

- All surface water runoff must be directed away from the building by appropriate grading in order to prevent ponding near foundations. Site drainage should form part of the building contract.

- Peripheral pathways, with impermeable underliner, should be provided around the building to improve site drainage and assist in the stabilisation of moisture conditions near foundations.

- All brickwork should be suitably articulated into discrete units to accommodate the expected movements. Brickwork over doors and windows should be avoided.

- Internal and external walls should be arranged along straight lines, where possible.

- All house drains and water pipes should be provided with sufficient flexibility to accommodate the expected differential movements (between foundation and uncovered outside area) at the level of the service.

- The extension of services through slabs should be avoided where possible in order to prevent hidden leaks under the slab area. Most plumbing fixtures can be arranged to exit through outside walls.

- Septic systems should be located so as not to influence the house or neighbouring foundations.

- Subgrades beneath elevated and well ventilated floors should be covered with an impermeable liner (with protective soil blanket) to minimise excessive desiccation.

In addition, certain other 'site management' precautions must be adhered to during the life of the structure. These precautions generally relate to the control of abnormal moisture variations due to the effects of drainage and vegetation. Recommendations on site management precautions are contained in the following section.

Reactive Soils – Site Management Precautions

These precautions are considered supplementary to any structural and/or foundation design measures for the subject building, and are intended for distribution to the prospective house owner.

Reactive clays are prone to heave/shrink movements with changes in soil moisture content due to natural or artificial means. The basic design philosophy employed for the dwelling is to provide a foundation/superstructure adequate to accommodate ground movements due to extreme seasonal moisture changes only. The possibility of other abnormal and/or localised moisture changes (the cause of most housing distress) has been assumed to be controlled by the following 'site management' procedures.

Leaking plumbing or blocked drains should be repaired promptly and site grading maintained to prevent ponding near foundations. Garden watering, particularly by fixed systems, should be controlled to avoid over-watering. Proper garden maintenance should produce year round uniform moisture conditions.

Trees and some shrubs can cause a substantial drying and shrinking of reactive clays, additional to that experienced in a drought or a long dry spell. This effect is most likely to result in damage when added to the drying effects from a drought or a long dry spell. Trees should be planted at a substantial distance from the house. The distance depends upon the species and soil conditions, but generally a distance equal to 75% of the mature height is a minimum.

Problems during a drought can be minimised by extensive pruning (thus reducing water demand) and/or providing trees with adequate water. Frequent moderate watering during dry periods should minimise the risk of the tree extracting excessive moisture from beneath the foundation of the house. This action should also be immediately undertaken by the owner if brickwork cracking due to tree drying is noticed. Most reactive clay failures can be minimised by controlling the combined drying effects of trees and drought.

The owner should appreciate that on reactive clays it is virtually impossible to design an economic foundation system that will totally prevent movement. Some minor aesthetic cracking, while undesirable, is likely to occur in a significant proportion of houses. In addition some minor problems should be expected with jamming of windows and doors especially during the settling period or following a major drought and any repairs should be regarded as part of normal house maintenance. Even significant masonry cracking with widths over 3 mm usually has no influence on the function of the wall and only presents an aesthetic problem. Just as it is difficult to design an immovable footing system, it is almost impossible to provide remedial measures that will prevent further movement if distress does occur. Consequently, extreme remedial measures should not be undertaken for minor problems, without further engineering advice.

Reference should be made to Appendix A of AS2870-1996 "Residential Slabs and Footings" and CSIRO 10-91 "A Guide to Home Owners on Foundation Maintenance and Footing Performance" for more detailed recommendations regarding Design and Site management precautions.

Appendix F

Limitations of Geotechnical Investigations

Limitations of Geotechnical Site Investigation

Scope of Services

This geotechnical site assessment report ("the report") has been prepared in accordance with the scope of services set out in the contract, or as otherwise agreed, between the Client and Parsons Brinckerhoff (PB) ("scope of services"). In some circumstances the scope of services may have been limited by a range of factors such as time, budget, access and/or site disturbance constraints.

Reliance on Data

In preparing the report, PB has relied upon data, surveys, analyses, designs, plans and other information provided by the Client and other individuals and organisations, most of which are referred to in the report ("the data"). Except as otherwise stated in the report, PB has not verified the accuracy or completeness of the data. To the extent that the statements, opinions, facts, information, conclusions and/or recommendations in the report ("conclusions") are based in whole or part on the data, those conclusions are contingent upon the accuracy and completeness of the data. PB will not be liable in relation to incorrect conclusions should any data, information or condition be incorrect or have been concealed, withheld, misrepresented or otherwise not fully disclosed to PB.

Geotechnical Investigation

Geotechnical engineering is based extensively on judgment and opinion. It is far less exact than other engineering disciplines. Geotechnical engineering reports are prepared to meet the specific needs of individuals. A report prepared for a consulting civil engineer may not be adequate for a construction contractor or even some other consulting civil engineer. This report was prepared expressly for the Client and expressly for purposes indicated by the Client or his representative. Use by any other persons for any purpose, or by the Client for a different purpose, might result in problems. The Client should not use this report for other than its intended purpose without seeking additional geotechnical advice.

This Geotechnical Report is Based on Project-specific Factors

This geotechnical engineering report is based on a subsurface investigation which was designed for project-specification factors, including the nature of any development, its size and configuration, the location of any development on the site and its orientation, and the location of access roads and parking areas. Unless further geotechnical advice is obtained this geotechnical engineering report cannot be used:

- when the nature of any proposed development is changed; or
- when the size, configuration location or orientation of any proposed development is modified.

This geotechnical engineering report cannot be applied to an adjacent site.

The Limitations of Site Investigation

In making an assessment of a site from a limited number of boreholes or test pits there is the possibility that variations may occur between test locations. Site exploration identifies specific subsurface conditions only at those points from which samples have been taken. The risk that variations will not be detected can be reduced by increasing the frequency of test locations; however this often does not result in any overall cost savings for the project. The investigation programme undertaken is a professional estimate of the scope of investigation required to provide a general profile of the subsurface conditions. The data derived from the site investigation programme and subsequent laboratory testing are extrapolated across the site to form an inferred geological model and an engineering opinion is rendered about overall subsurface conditions and their likely behaviour with regard to the proposed development. Despite investigation the actual conditions at the site might differ from those inferred to exist, since no subsurface exploration programme, no matter how comprehensive, can reveal all subsurface details and anomalies.

The borehole logs are the subjective interpretation of subsurface conditions at a particular location, made by trained personnel. The interpretation may be limited by the method of investigation, and can not always be definitive. For example, inspection of an excavation or test pit allows a greater area of the subsurface profile to be inspected than borehole investigation, however, such methods are limited by depth and site disturbance restrictions. In borehole investigation, the actual interface between materials may be more gradual or abrupt than a report indicates.

Subsurface Conditions are Time Dependent

Subsurface conditions may be modified by changing natural forces or man-made influences. A geotechnical engineering report is based on conditions which existed at the time of subsurface exploration.

Construction operations at or adjacent to the site, and natural events such as floods, or groundwater fluctuations, may also affect subsurface conditions, and thus the continuing adequacy of a geotechnical report. The geotechnical engineer should be kept appraised of any such events, and should be consulted to determine if additional tests are necessary.

Avoid Misinterpretation

A geotechnical engineer should be retained to work with other appropriate design professionals explaining relevant geotechnical findings and in reviewing the adequacy of their plans and specifications relative to geotechnical issues.

Bore/Profile Logs Should Not Be Separated from the Engineering Report

Final bore/profile logs are developed by geotechnical engineers based upon their interpretation of field logs and laboratory evaluation of field samples. Customarily, only the final bore/profile logs are included in geotechnical engineering reports. These logs should not under any circumstances be redrawn for inclusion in architectural or other design drawings. To minimise the likelihood of bore/profile log misinterpretation, contractors should be given access to the complete geotechnical engineering report prepared or authorised for their use. Providing the best available information to contractors helps prevent costly construction problems. For further information on this matter reference should be made to "Guidelines for the Provision of Geotechnical Information in Construction Contracts" published by the Institution of Engineers Australia, National Headquarters. Canberra 1987.

Geotechnical Involvement During Construction

During construction, excavation is frequently undertaken which exposes the actual subsurface conditions. For this reason geotechnical consultants should be retained through the construction stage, to identify variations if they are exposed and to conduct additional tests which may be required and to deal quickly with geotechnical problems if they arise.

Report for Benefit of Client

The report has been prepared for the benefit of the Client and no other party. PB assumes no responsibility and will not be liable to any other person or organisation for or in relation to any matter dealt with or conclusions expressed in the report, or for any loss or damage suffered by any other person or organisation arising from matters dealt with or conclusions expressed in the report (including without limitation matters arising from any negligent act or omission of PB or for any loss or damage suffered by any other party relying upon the matters dealt with or conclusions expressed in the report). Other parties should not rely upon the report or the accuracy or completeness of any conclusions and should make their own enquiries and obtain independent advice in relation to such matters.

Other Limitations

PB will not be liable to update or revise the report to take into account any events or emergent circumstances or facts occurring or becoming apparent after the date of the report.

Appendix E – Archaeological Fieldwork on Norfolk Island

Records of the Australian Museum, Supplement 27 (2001): 11–32. ISBN 0 7347 2305 9

Archaeological Fieldwork on Norfolk Island

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ABSTRACT. Exploratory excavations in Cemetery, Emily and Slaughter Bays in search of a prehistoric settlement site are outlined, along with small scale researches elsewhere on Norfolk Island and on adjacent islands. The archaeological excavations at the settlement site discovered in Emily Bay are described in detail and the taphonomy of the site discussed.

ANDERSON, ATHOLL, IAN SMITH AND PETER WHITE, 2001. Archaeological fieldwork on Norfolk Island. In *The Prehistoric Archaeology of Norfolk Island, Southwest Pacific*, ed. Atholl Anderson and Peter White, pp. 11–32. *Records of the Australian Museum, Supplement* 27. Sydney: Australian Museum.

The Norfolk Island Prehistory Project (NIPP) programme was divided into four field seasons. These were in December 1995 (directed by Atholl Anderson and Geoff Hope), in April 1996 (directed by Atholl Anderson and Ian Smith), in November 1997 (directed by Atholl Anderson and Peter White) and in February 1999 (directed by Peter White). It is convenient to describe the fieldwork and the characteristics of the sites investigated in this framework.

Fieldwork in 1995

Cemetery Bay. The first focus of fieldwork on Norfolk Island was upon the fauna-rich localities previously recorded in Cemetery Bay. It was considered that further investigation of these might divulge clues to a greater cultural influence in the evidence than was then known, essentially the existence of rat bone and charcoal. Local resident Jack Anderson took us to a place located 78 m south of the southern end of the Cemetery Bay sand beach ("Jack's site"). There are similar exposures, many disclosing faunal material, to either side, but this one had the deepest stratigraphy. At the top of the low cliffs (about 5 m above high tide level) were two sedimentary units resting in holes and crevices of the underlying calcarenite basement. The upper consisted of about 0.5 m of coarse yellow-brown sand, containing scattered pebbles, calcarenite rubble, landsnails and bones, while the lower consisted of up to 0.5 m of compacted brown sand and clay, full of calcarenite rubble, and with very little bone. Most of the bone came from a band 0.1–0.5 m below the surface. A small excavation of the exposed face and of material slumped from it was carried out, and the faunal remains retained for analysis. There was nothing about them to suggest a cultural origin.

Trench CB95:01. The "Old Quarry" site ("Area 1" of Varman, 1990) at Cemetery Bay was chosen for investigation because it was the locality in which unit C4 (a band of charcoal enriched sand, and bird, fish and rat bones) had been most extensively investigated (Anderson and White, *Approaching the Prehistory*, this vol.). A large shell adze had been found in the northwest corner of the "Old Quarry" during sand mining. A 3 m^2 trench (CB95:01) was excavated in undisturbed ground near the edge of the quarry, some 5–8 m away from where the adze had been picked up (Fig. 1, further details in Anderson, 1996).

The stratigraphy at this site consisted of layers of carbonate sand interleaved with layers of sand or silt-enriched clay (Fig. 2). The upper of these latter formed part of the current soil horizon (included for archaeological recording purposes in layer 1), and the others were designated layers 2, 4 and 6. The important point to note about these layers is that they are not palaeosols. There is no evidence of soil development. Rather the material appears to have been washed into the site where it makes a sharp contact with the sand beneath (except for some subsequent worm activity, especially at the base of layer 6), and lifts away from it cleanly. In each case, the clay and silt has also carried pumice, which is found particularly in the upper parts, and on top of, each clay layer. The probable source of the clay is slope wash from the nearby hills.

The discovery of a concentration of rusted iron nails in layer 4 indicates that the top 0.65 m of the site, including the upper three clay layers at least, are European. The sand in layer 7 contained an irregular depression in the upper surface, filled with layer 6 clay, which might be an old root

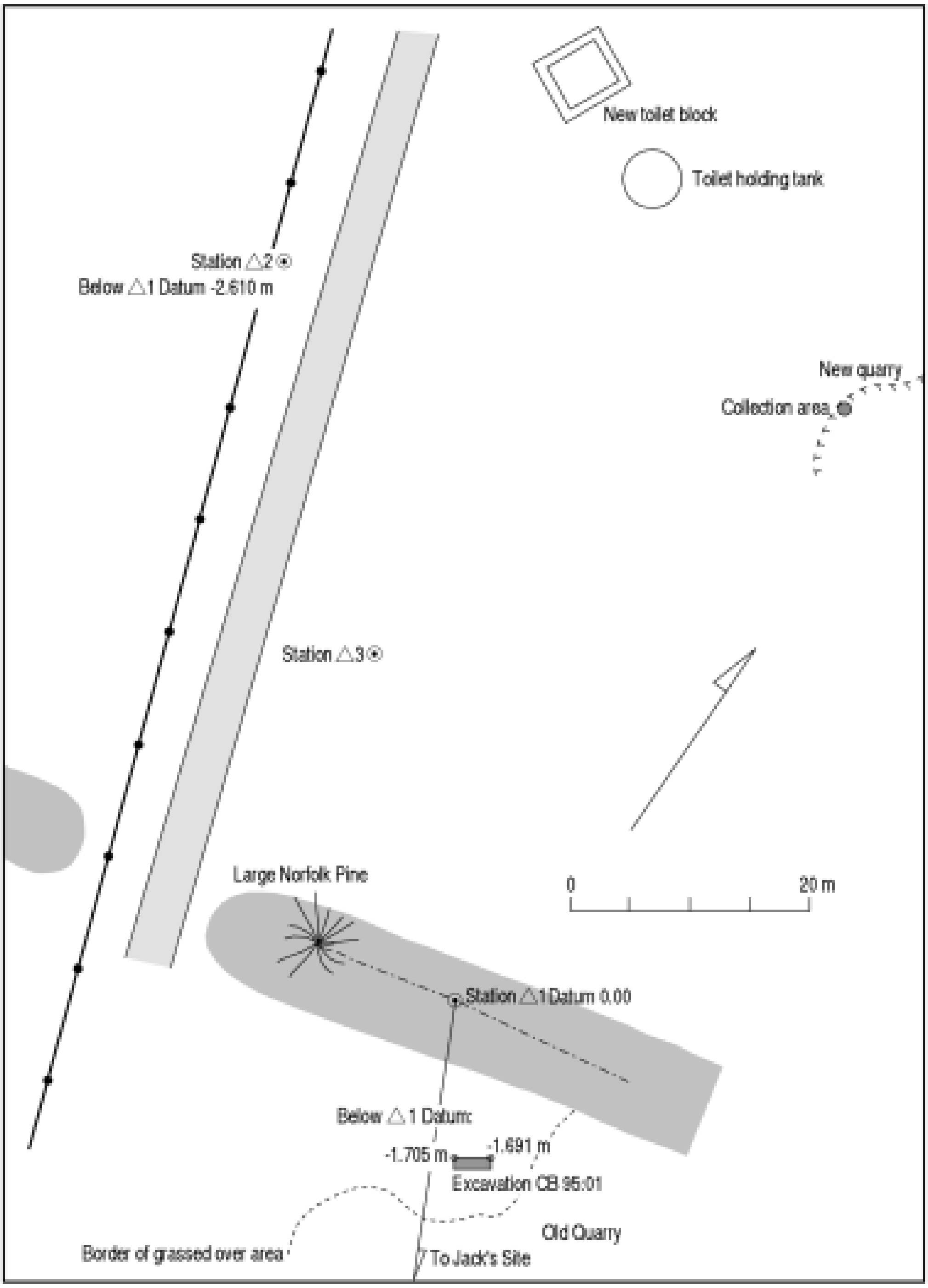

Figure 1. Location of trench CB95:01 in Cemetery Bay.

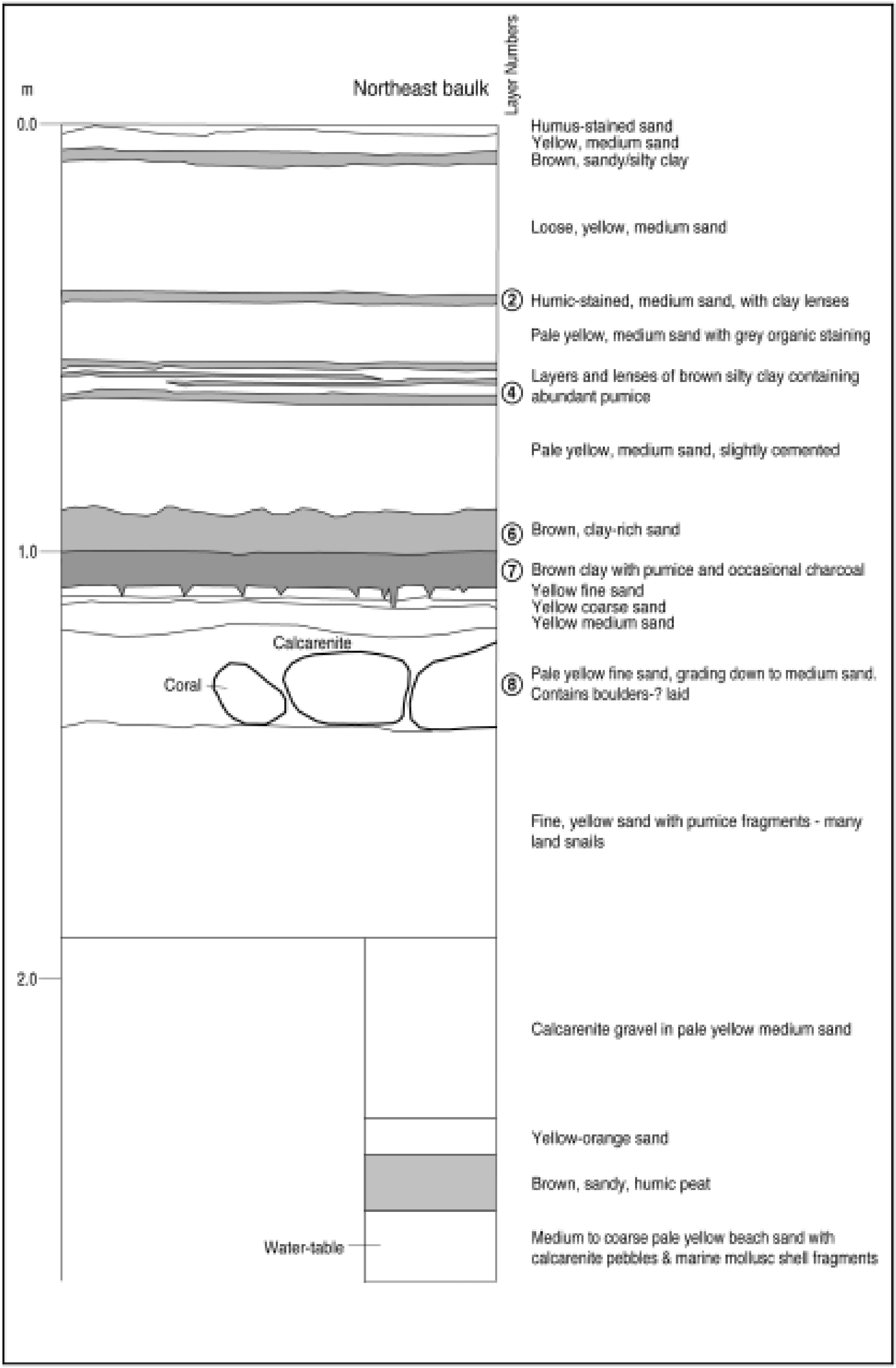

Figure 2. Stratigraphy of trench CB95:01 in Cemetery Bay.

channel, or possibly a procellariid burrow, but neither need be prehistoric. There was a noticeable increase in the abundance of charcoal and fish, bird and rat bones in layer 7, which appears in this respect, and in depth, to correspond with unit C4 (Meredith *et al*., 1985), but the layer of calcarenite and coral boulders in layer 8 seems to have been laid by hand. It may form the edge of a coastal road known to have run through Cemetery Bay during the convict era. In that case, all of the stratigraphy down to at least 1.40 m is European in age.

This has important implications for the discovery of an adze nearby, "… the only artefact found on Norfolk for which a sub-surface context has been proposed" (Specht, 1993: 153). The adze, of *Tridacna gigas* shell, does not appear to be of Polynesian provenance and might have been imported from Melanesia, possibly in the nineteenth century, after the establishment of the Melanesian Mission in 1866. It was associated with a beer-barrel conch shell, a local species, when found by Ted Clampett and Matti Nola in December 1984. Information in the Norfolk Island Museum (Bag with conch shell, labelled ARNI 7), indicates that the findspot was 1.5 m below the surface (Specht, 1993: 150, quotes Varman as indicating a depth of 1.25–1.5 m), in clean yellow, sand. This would put it in the upper part of our layer 8 which is possibly very late prehistoric or European in age. It would then follow that the stratigraphy in our trench and its vicinity, possibly through European disturbance, is not the same as that which Meredith *et al*. (1985), excavated approximately 100 m away and dated to 800–700 B.P.

A sample of *Rattus exulans* bone collected by Charles Meredith from 140–155 cm in unit C4 was provided by the Museum of Victoria and we submitted it to the Oxford Radiocarbon Accelerator Unit. A sample of *Rattus exulans* bone from 130–150 cm depth in CB95:01 was submitted for radiocarbon dating at the Rafter Laboratory, Institute of Geological and Nuclear Sciences, Lower Hutt. The results, respectively OxA5781 and NZA6635, are presented in Anderson, Higham and Wallace, this vol., Table 8.

Trench CB95:02. At the request of the Kingston and Arthur's Vale Heritage Association and the Norfolk Island Administration, the excavation of a pit, about 5 m in diameter, for the toilet holding tank at Cemetery Bay was monitored and faunal material recovered as it became exposed by hand digging. The stratigraphy was as follows: 1.0 m of buff dune sand, then 0.45 m of medium-coarse, yellow-brown calcareous sand, containing an occasional bird bone. Below this was 0.7 m of brown sandy clay containing some bird bones and fragments of pumice, overlying 0.3 m of a coarse pale-yellow to white sand. This graded down into a white sand with many lumps of calcarenite, water-rolled marine shells and some fossil wood. Left to stand, the pit filled with fresh water to the top of the pale-yellow sand.

Cemetery Bay Stratigraphy. The previous excavations in this area leave little doubt that at least some of the material has a cultural origin (Anderson and White, *Approaching the prehistory…*, this vol.). While our research did not uncover any more conclusive evidence than that already established, we think that the wide distribution of charcoal, including a burnt stump, and its stratigraphic correspondence with *Rattus exulans* bone, define an horizon which is essentially cultural. Quite probably it is either on the periphery of a settlement site or it was an area of forest clearance.

Emily Bay. Attention turned to Emily Bay because it has produced a quantity of adzes and waste flakes over the years (Anderson and White, *Approaching the prehistory…*, this vol.) and it is inherently more suitable for prehistoric settlement than anywhere else on Norfolk Island. It provides the most sheltered anchorage for small craft and the best beach from which to launch and recover canoes. It is at the centre of the broad band of intertidal reef which runs from Cemetery Bay to Slaughter Bay, and at the broadest end of the lagoon, providing unparalleled access to inshore marine resources. Small vessels, including canoes, can cross the reef at high tide and, prior to the construction of the Kingston jetty, it was possible to sail into the western end of the lagoon and along to Emily Bay (Figs. 3, 4).

Figure 3. Emily Bay sheltered by a Norfolk pine plantation, with Slaughter Bay to the right. The main excavations occurred towards the right hand end of the main plantation of Norfolk pines. Nepean and Philip Islands in the background.

Figure 4. The reef in Slaughter Bay at low tide. Emily Bay is in the background, behind the limekiln chimney.

Search procedure. After inspecting the exposures in the drain and road cuttings, some auger holes were drilled and two road sections cleaned down in the Eastern end of Emily Bay, without discovering any archaeological remains. It was then decided to employ a small mechanical digger to explore the sand dune stratigraphy in greater depth. The first trench (EB95:01) was dug 115 m east of the toilet block and 5 m south (i.e. seaward) of the present road. It was located 8 m east of the exposed remains of an historical (A.D. 1835) road. A trench of 1.5×1 m, narrowing to about 1.0×0.5 m at the bottom (2.5 m, about the level of the modern road surface) was taken out in approximately 0.2 m spits. The stratigraphy consisted of medium to fine, yellow, carbonate sand, slightly compacted. There were occasional pieces of water-rolled pumice, but none in bands. (All sands in this and other trenches were described by ANU geomorphologist, Prof. G. Hope). No sign of cultural material was noted.

Directly inland across the road, there is a sand quarry area which has been scraped down to the level of the road surface. It is now partly used as a gravel dump and parking area. In this area, 13 m north of Trench EB95:01 a second trench (Trench EB95:02), was dug in the same way and of the same dimensions. At the top of it was a 0.15 m thick brown clay packed with road gravel, and evidently the edge of the modern road base. Beneath it, was a 0.7 m deep unit of yellow carbonate sand as in Trench EB95:01, lying above 0.1 m of bright yellow-orange sand and then fine white sand saturated with fresh water. The water table stood at the junction of the latter two units and along it was found matted roots of *Araucaria*. No sign of cultural material was noted. Another trench (EB95:03) was dug approximately 36 m northeast of Trench EB95:02. This disclosed the same stratigraphy as in Trench EB95:01, that is medium to fine yellow carbonate sands containing occasional small pieces of water-rolled pumice. No cultural material was noted.

The digger was then moved to the western end of Emily Bay within a fenced-in Norfolk pine plantation (Figs. 3, 5). Local historians believe that there may be some early historical burials in this general area, and particular attention was paid to any signs of those (none were observed, and some evidence suggests that the burial area was seaward of the present road (Specht, 1984: 32)). An auger hole revealed no cultural material, and the digger was employed. In order to get a shallower scrape of 0.1 m per time, a trench 2.5×1.0 m at the top, narrowing to 1.8×0.7 m on a sloping base (Trench EB95:04), was excavated. The sand below the pine duff was as in Trench EB95:01, but with occasional brown mottles. At 0.7 m, in the western end of the trench a sand of the same type, but light grey in colour appeared. A surface of grey sand was then exposed by trowel, the sterile overburden being cleared periodically by the digger. The surface proved to slope steeply to the east and was discontinuous in plan (Fig. 6). Excavation of part of this feature by trowel disclosed a broken cobble of basalt, several small fragments of charcoal and two large fish spines. This was taken as being the remains of an Oceanic type of cooking area and thus *prima facie* evidence of a prehistoric settlement site.

Nicolai records. Our discovery prompted local resident and archaeologist Mr Bevan Nicolai to produce a sample of bone collected from West Emily Bay in which some material appeared to be of cultural origin (remains of large fish, broken bones of large birds, a dog mandible). It is apparent, in fact, that Mr Nicolai (n.d.) had come very close to deducing the existence of a prehistoric site in Emily Bay. In November 1986 the Norfolk Island Administration dug a longdrop toilet hole (subsequently unused) just outside the seaward plantation fence in Emily Bay, about 15 m west of the gate. This produced the material noted above, plus some rat bones and basalt flakes. In his field notes (26 November 1986) Mr Nicolai observed that the fish bone was too big to have been washed up or brought by birds and he was curious about the dog bone. He concluded that only some radiocarbon determinations might solve the puzzle.

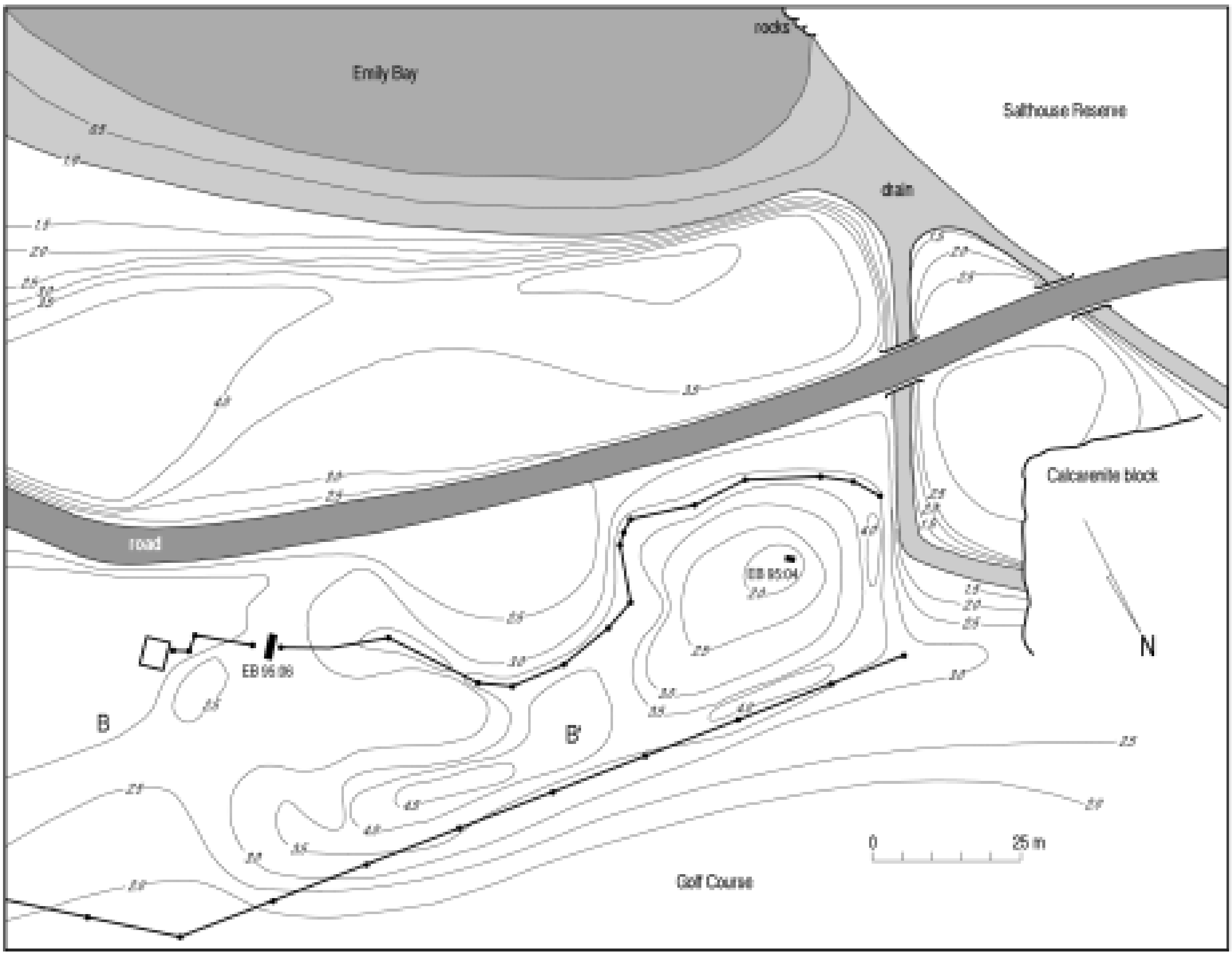

Figure 5. Location of Trenches EB95:04 and EB95:06 (incorporating EB95:05) at Emily Bay in 1995.

Similarly, in April 1987, Mr Nicolai (n.d.) recorded the existence of bird, rat and fish bones eroding from the sand face under the old convict road at the extreme eastern corner of Slaughter Bay, noting again that the fish bone must have come from individuals too large to have been carried by birds. He excavated about 0.5 m into the face and collected some faunal material. In 1995, he found an adze in the sand near this place.

While inspecting the ground surface in the vicinity of the Emily Bay toilet block, bird bone fragments and some fish bones were noted around the base of fence posts near the gate, at the gate posts, and on the sand road surface near the toilets. An auger hole near the fence (Fig. 8, Auger hole 3) encountered a brown clay soil at about 0.7 m and then some grey sand. No faunal or cultural remains were recovered, but the sand looked like that in EB95:04, so it was decided to concentrate attention in the vicinity. A test-pit of 0.4×0.4 m (Trench EB95:05) was then excavated, which disclosed cultural stratigraphy (Fig. 7), a broken and apparently burnt piece of a basalt cobble and a struck basalt flake. Some bird, fish and rat bone was recovered, along with small pieces of charcoal.

Trench E95:05 was then enlarged to an excavation of 4.0×1.0 m (Figs. 8, 9), called Trench EB95:06, which was set out across the gate opening. The digger was employed to remove loose dune sand and roots from above the clay—the latter, tough and sticky, was chipped off by hand. Underneath the clay was a surface of dark grey sand. Excavation showed that this dark grey sand formed a single layer and the material was taken out in four spits. All material was passed through 4 mm sieves. Initially we tried 2 mm mesh but found that it collected too much extraneous material, even when washed through, particularly rootlets which were abundant in the sand. Collection of material passing through the 4 mm mesh showed that some small pieces of broken bone and small landsnail shells (very common in all sand deposits on the island) were being lost, but not identifiable material of cultural origin (this was checked regularly by palaeontologist, Richard Holdaway, who took samples).

Two earth ovens were found, each consisting of a shallow scoop in which were packed burnt and broken fragments of basalt cobbles, charcoal pieces and bird, rat and fish bones, often broken and some burnt. One oven lay somewhat higher than the other in the same layer, and some material had spilled from each into the surrounding area. Six flakes of struck basalt were recovered, several of them of distinctive forms created in the fashioning of adze preforms. No other structures or artefacts were noted. The stratigraphy suggests a single cultural phase, probably of limited duration (Anderson, 1996).

Judging by our auger holes (Fig. 8, Auger holes 1–4), there is one edge of the Emily Bay site between the gateway and the northern wall of the toilet block, although the recovery of bones during the digging of the toilet pit indicates that the site extends that far. The stratigraphy in

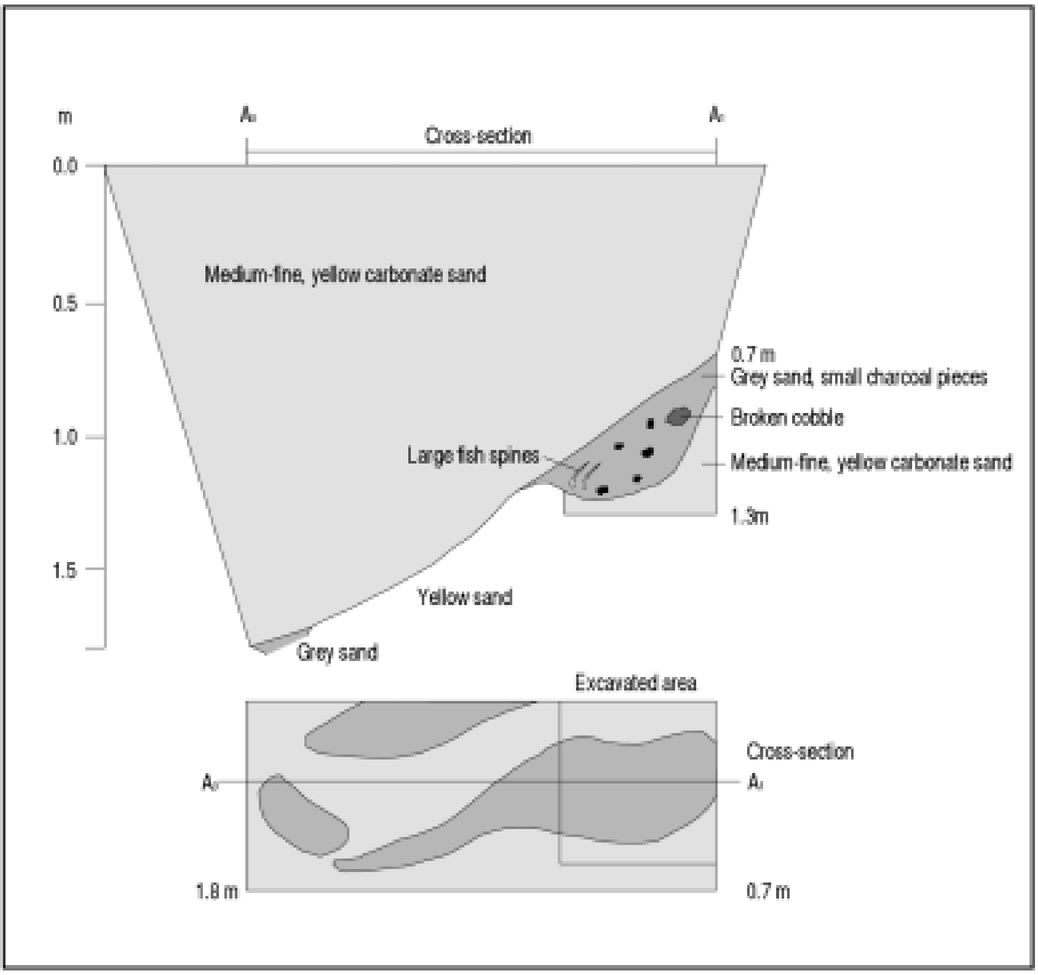

Figure 6. Stratigraphy and cross-section of Trench EB95:04.

Trench EB95:06 shallows towards the south, possibly indicating that there is another margin to the site between the gateway and the sealed road.

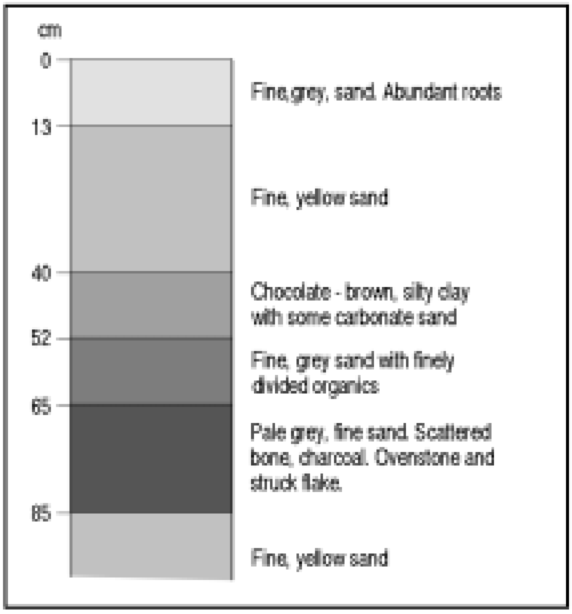

Figure 7. Stratigraphy of Trench EB95:05.

Fieldwork in 1996

Slaughter Bay. Investigations were confined to the eastern end of the bay, on the assumption that, since this was the end nearest to the known site in Emily Bay, and also the locality in which most of the adzes and adze pieces of Polynesian type had been found (Specht, 1984), it was the most likely area to produce prehistoric archaeological stratigraphy.

Search procedure. A series of holes was drilled with the sand auger along the northern side of the road at about 15 m intervals between the calcarenite massif and the western end of the stand of pines, and then north–south between the drain and the sea wall. Many of these holes bottomed out at 30–60 cm on coral rubble and were thus inconclusive. Those which disclosed greater depth and diversity of stratigraphy were noted for further reference and are shown in Fig. 10 (Auger holes a–e).

Test-pits were dug by spade at SB96:01 and SB96:02, but these also encountered difficulty in shifting calcarenite and coral rubble. Consequently, the backhoe was employed to excavate four small trenches: SB96:03 (which incorporated test-pit SB96:01), SB96:04, SB96:05 (which incorporated test-pit SB96:02) and SB96:06. Each trench was approximately 1.5×0.8 m in area at the top, narrowing to about 0.7×0.5 m at the bottom of the reach on the hydraulic arm. The sand auger was used in the base of three trenches to investigate the lower sediments. In trench