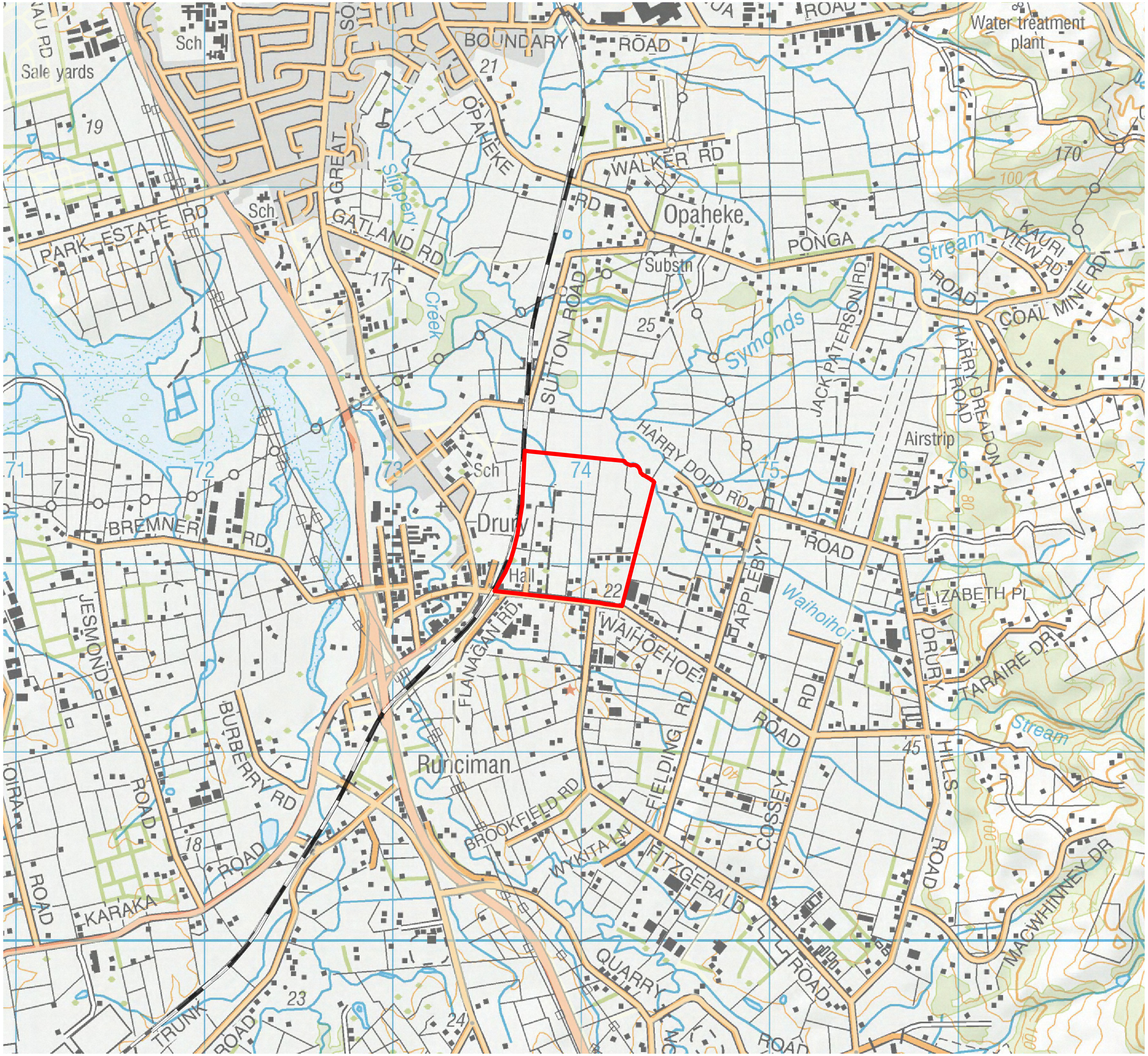
Appendix A

Figures



LEGEND

Plan Change Area

A3 SCALE: 1:20,000

0 0.2 0.4 0.6 0.8 1 Kilometers


Location Plan

Notes:

Topomap sourced from the LINZ Data Service and licensed by LINZ for re-use under the Creative Commons Attribution 3.0 New Zealand licence

DRAWN	DERI	Apr.19
CHECKED	LEAN	Apr.19
APPROVED	TSRF	Apr.19
ARCFILE	A1_PropertySetting.mxd	
SCALE (AT A3 SIZE)	1:20,000	
PROJECT No.	1008200.1000	

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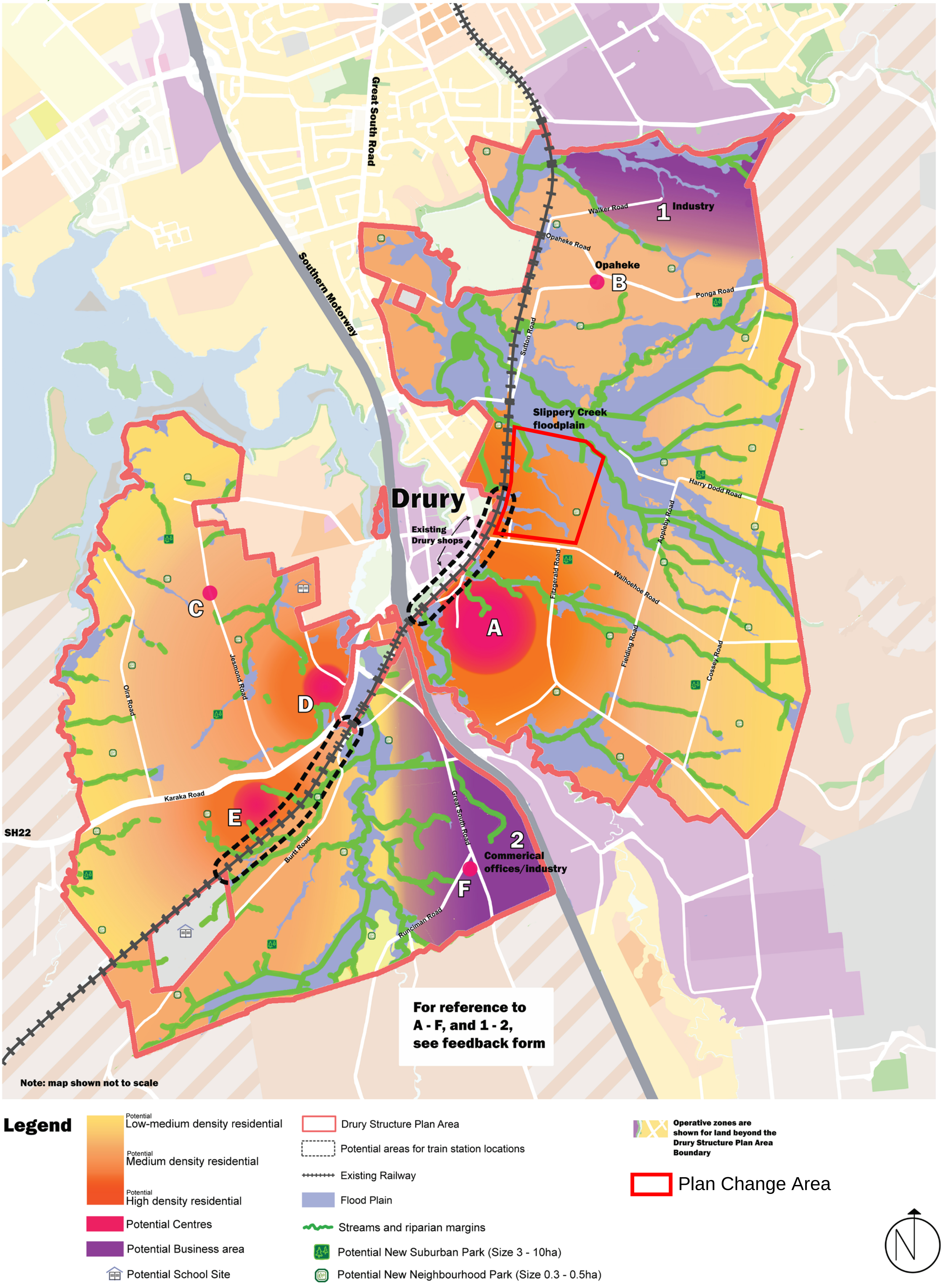
OYSTER CAPITAL
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Property Setting

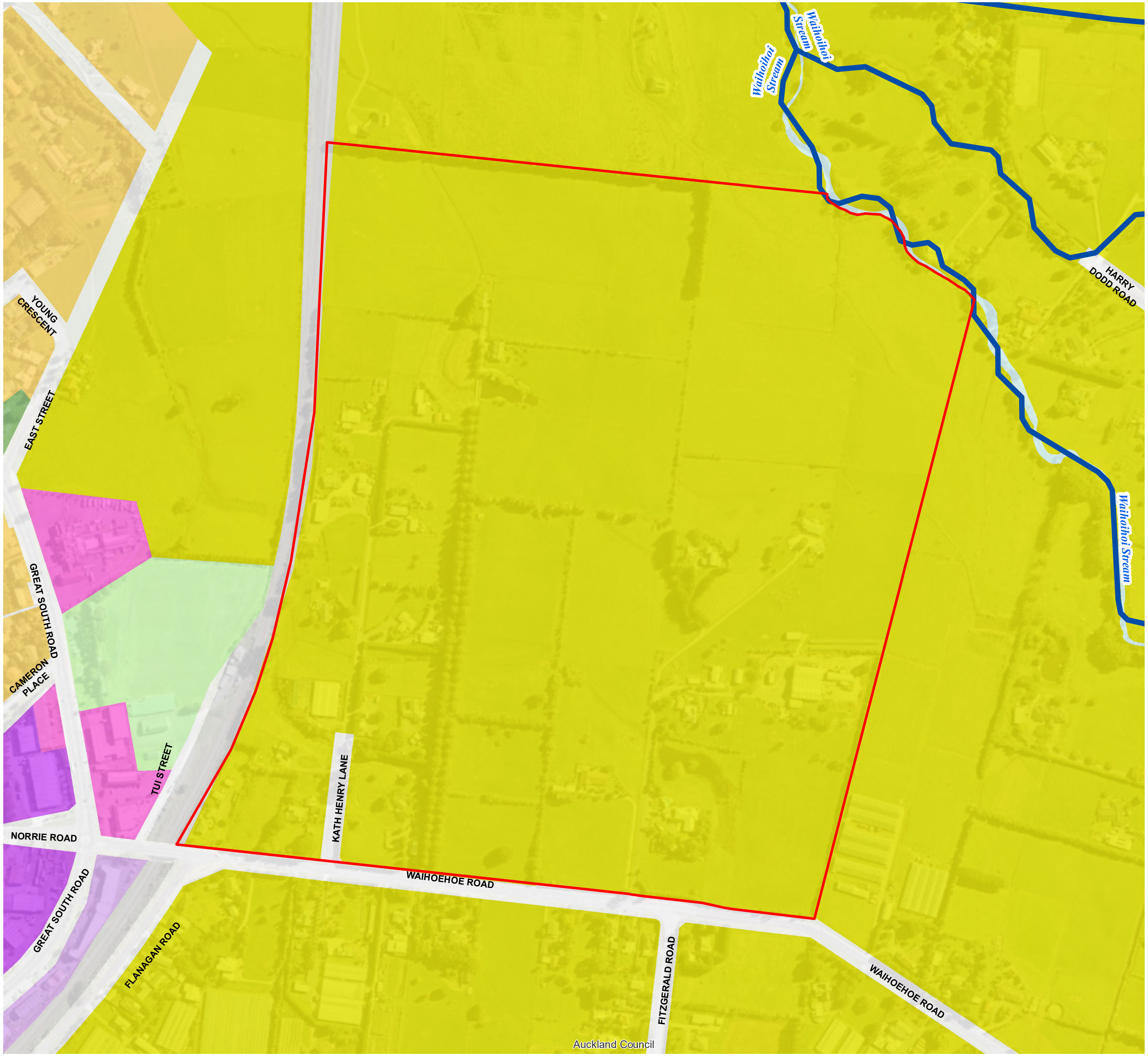
Figure A1

Drury-Opāheke Draft Land Use Plan Map

Source: Drury-Opaheke Draft Land Use Plan 2018, Summary and feedback form



A2 - Plan Change Area Location within Drury-Opaheke Draft Land Use Plan



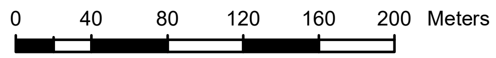
LEGEND

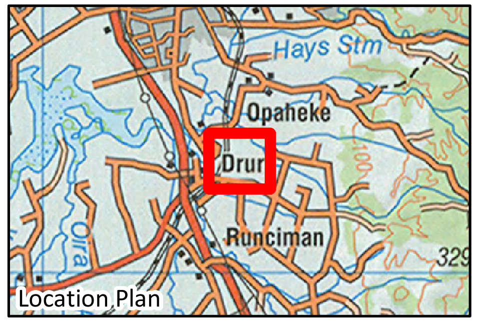
- Plan Change Area
- Streams and rivers

Unitary Plan Zones

- Residential - Mixed Housing Suburban Zone
- Open Space - Informal Recreation Zone
- Open Space - Sport and Active Recreation Zone
- Business - Local Centre Zone
- Business - Mixed Use Zone
- Business - Light Industry Zone
- Future Urban Zone
- Strategic Transport Corridor Zone
- Water [i]
- Road [i]

A3 SCALE: 1:4,000





Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Unitary Plan Zones sourced from Auckland Council GIS data.

DRAWN	DERI	Apr.19
CHECKED	LEAN	Apr.19
APPROVED	TSRF	Apr.19

ARCFILE A3_AUP-Zones.mxd

SCALE (AT A3 SIZE) 1:4,000

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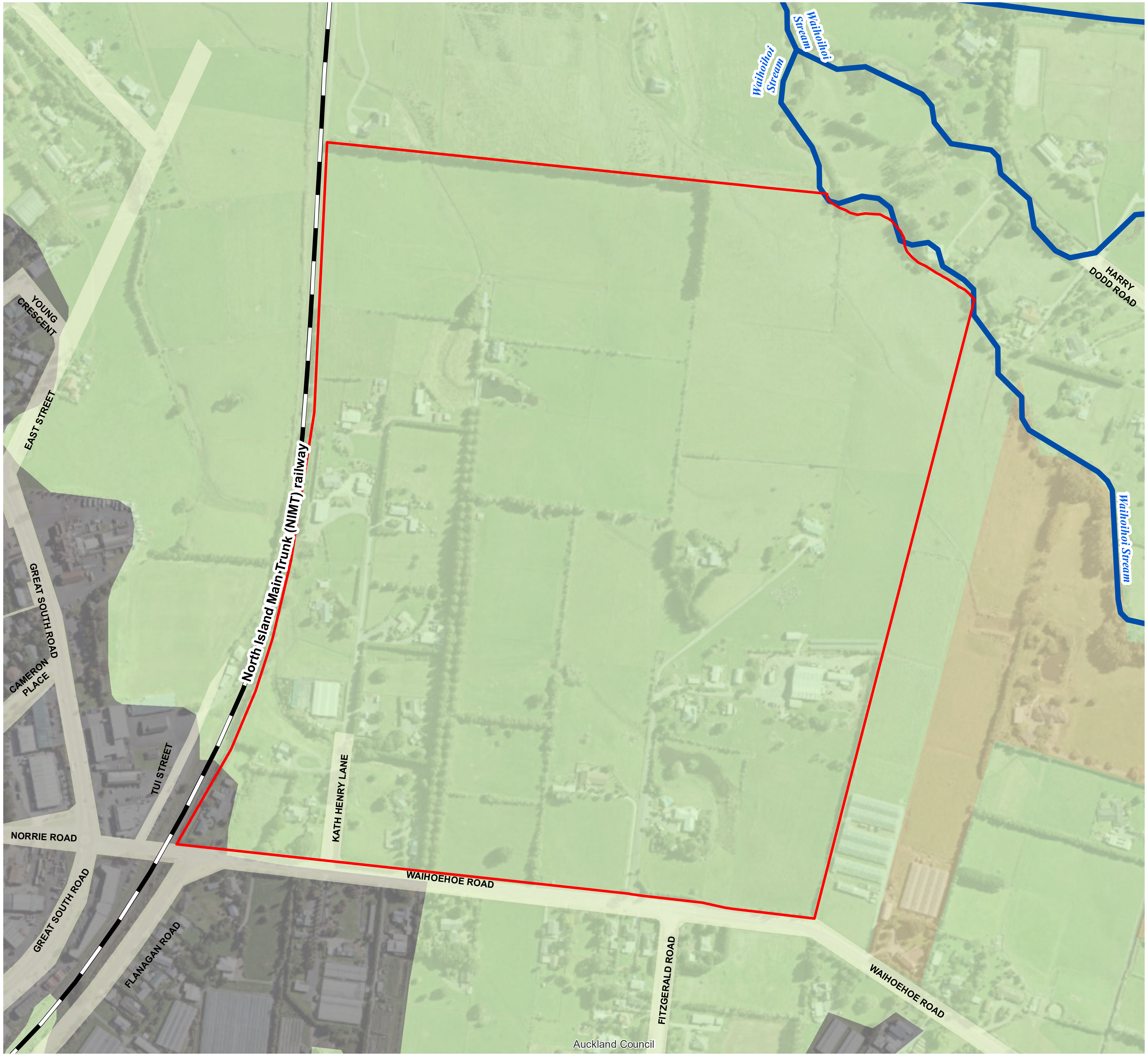
Unitary Plan Zones

Figure A3



LEGEND

Plan Change Area

Streams and rivers

Land Use (2012)

Artificial Surfaces

- Built-up Area (settlement)
- Surface Mine or Dump
- Transport Infrastructure
- Urban Parkland/Open Space

Cropland

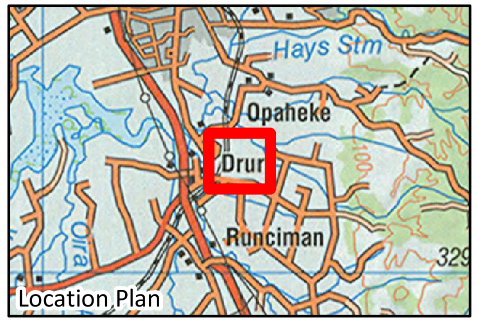
- Short-rotation Cropland

Grassland, Sedge and Saltmarsh

- High Producing Exotic Grassland

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Land Use Data as per New Zealand Land Cover Database LCDB v4.1 (July 2015).

DRAWN	DERI	Apr.19
CHECKED	LEAN	Apr.19
APPROVED	TSRF	Apr.19

ARCFILE A4_CurrentLandUse.mxd

SCALE (AT A3 SIZE) 1:4,000

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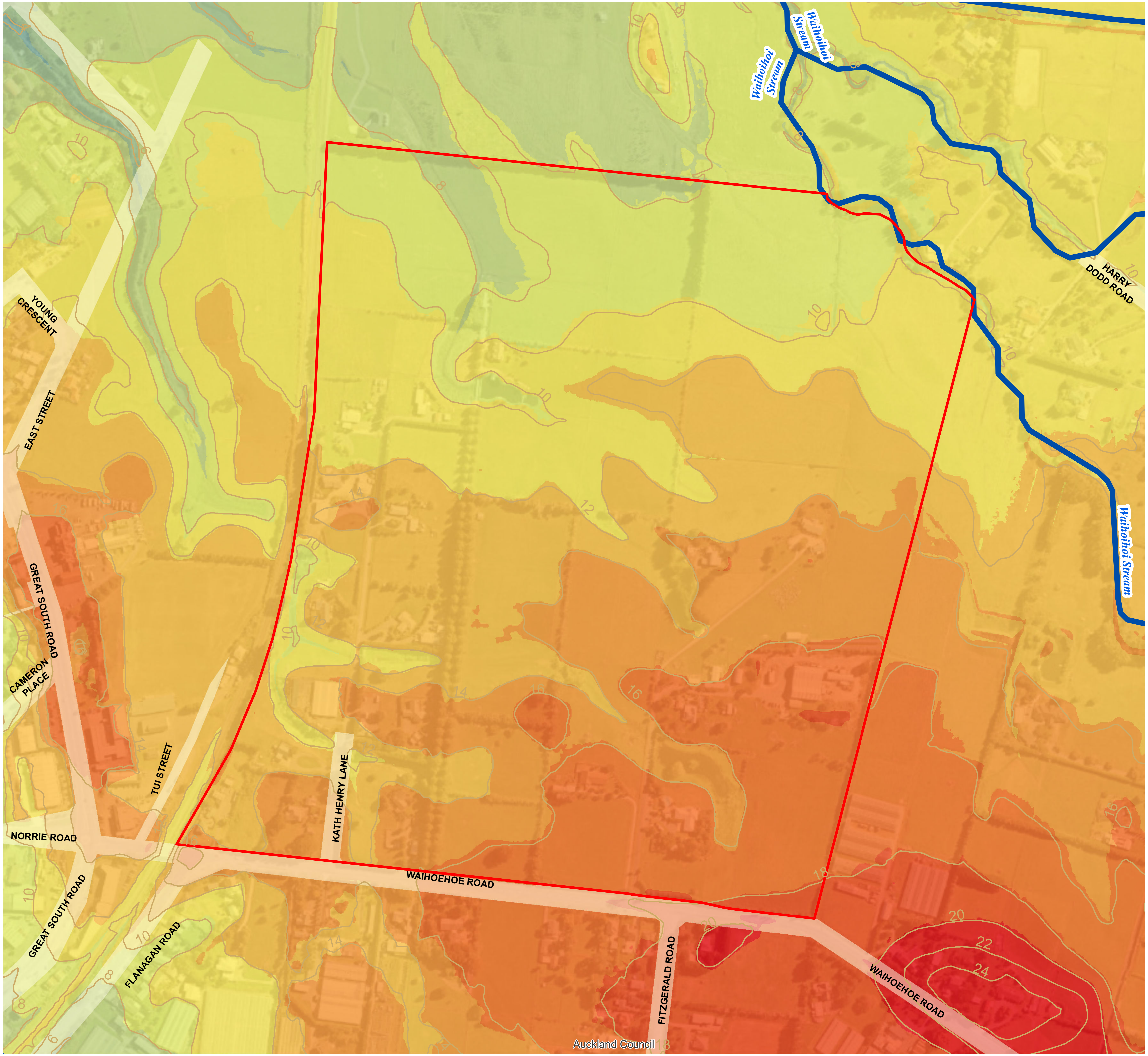
STORMWATER MANAGEMENT PLAN
Current Land Use

Figure A4



LEGEND

- Plan Change Area
- Streams and rivers
- 2 m Contours

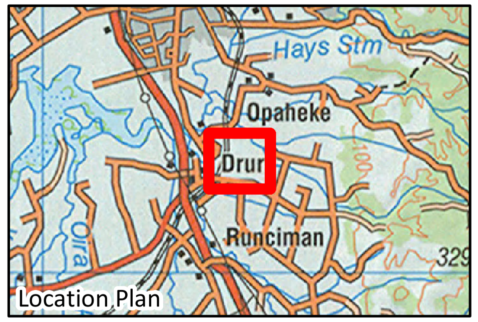
LiDAR 2013 DEM

Elevation (m RL)

- < 0
- 0 - 2.0
- 2.0 - 4.0
- 4.0 - 6.0
- 6.0 - 8.0
- 8.0 - 10.0
- 10.0 - 12.0
- 12.0 - 14.0
- 14.0 - 16.0
- 16.0 - 18.0
- 18.0 - 20.0
- > 20.0

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Elevation as per LiDAR 2013 DEM.

DRAWN	DERI	Apr.19
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APPROVED	TSRF	Apr.19

ARCFILE A5_Topography.mxd

SCALE (AT A3 SIZE) 1:4,000

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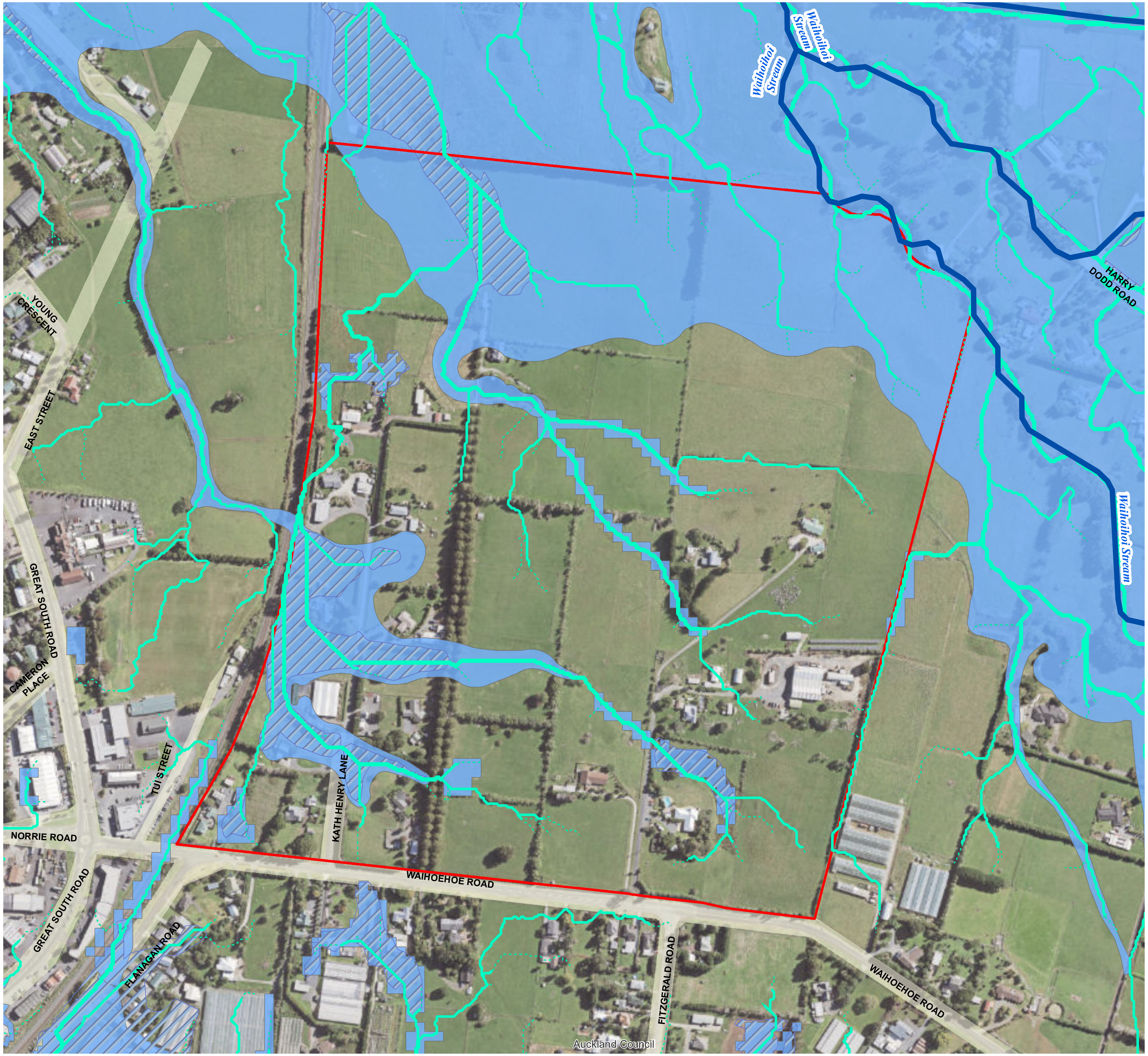
STORMWATER MANAGEMENT PLAN
Topography

Figure A5



LEGEND

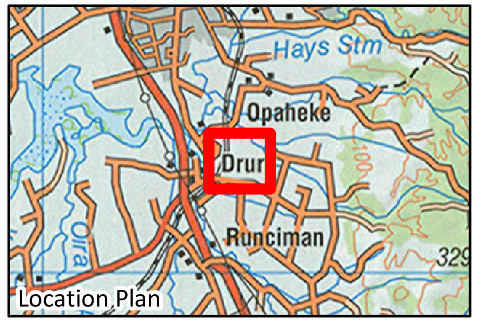
- Plan Change Area
- Streams and rivers

Overland Flow Paths

- 3ha and above
- 4000m² to 3ha
- 2000m² to 4000m²
- Flood prone area
- Flood plain

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



N

Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Flood plain, flood prone areas and overland flow paths created by the Stormwater Hydraulic Modelling Team for Auckland Council (Updated July 2013).

DRAWN	DERI	Apr.19
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APPROVED	TSRF	Apr.19

ARCFILE A6_Flooding.mxd

SCALE (AT A3 SIZE) 1:4,000

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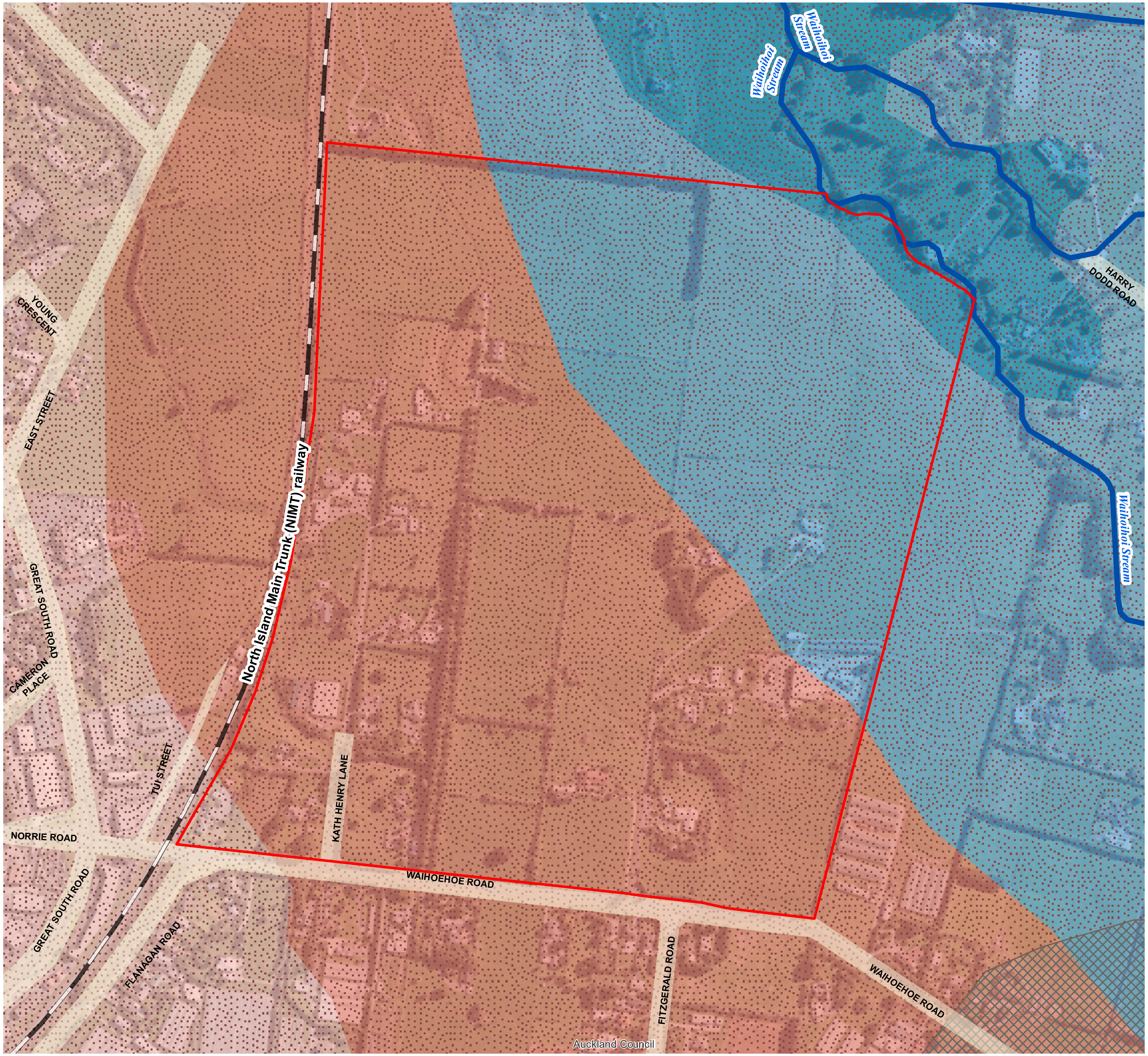
STORMWATER MANAGEMENT PLAN
Flooding

Figure A6



LEGEND

- WaihoehoeRd
- Streams and rivers

Preliminary Rock Type (GNS&Eagle)

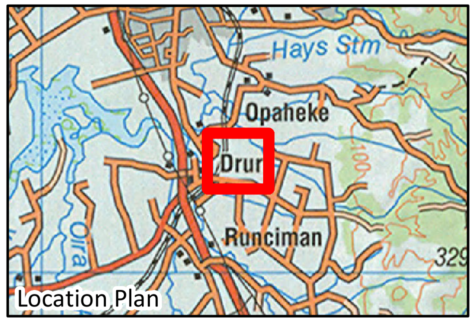
- Alluvium
- South Auckland Basalt

FSL Soil Classification

- Impeded (LI)
- Recent (GR)
- Orthic (GO)
- Orthic (NO)

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Preliminary Rock Type Layer as created by GNS.
FSL Fundamental Soil Layer as created by Landcare Research NZ Ltd (2000).

DRAWN	DERI	Apr.19
CHECKED	LEAN	Apr.19
APPROVED	TSRF	Apr.19
ARCFILE A7_Geology.mxd		
SCALE (AT A3 SIZE) 1:4,000		
PROJECT No. 1008200.1000		

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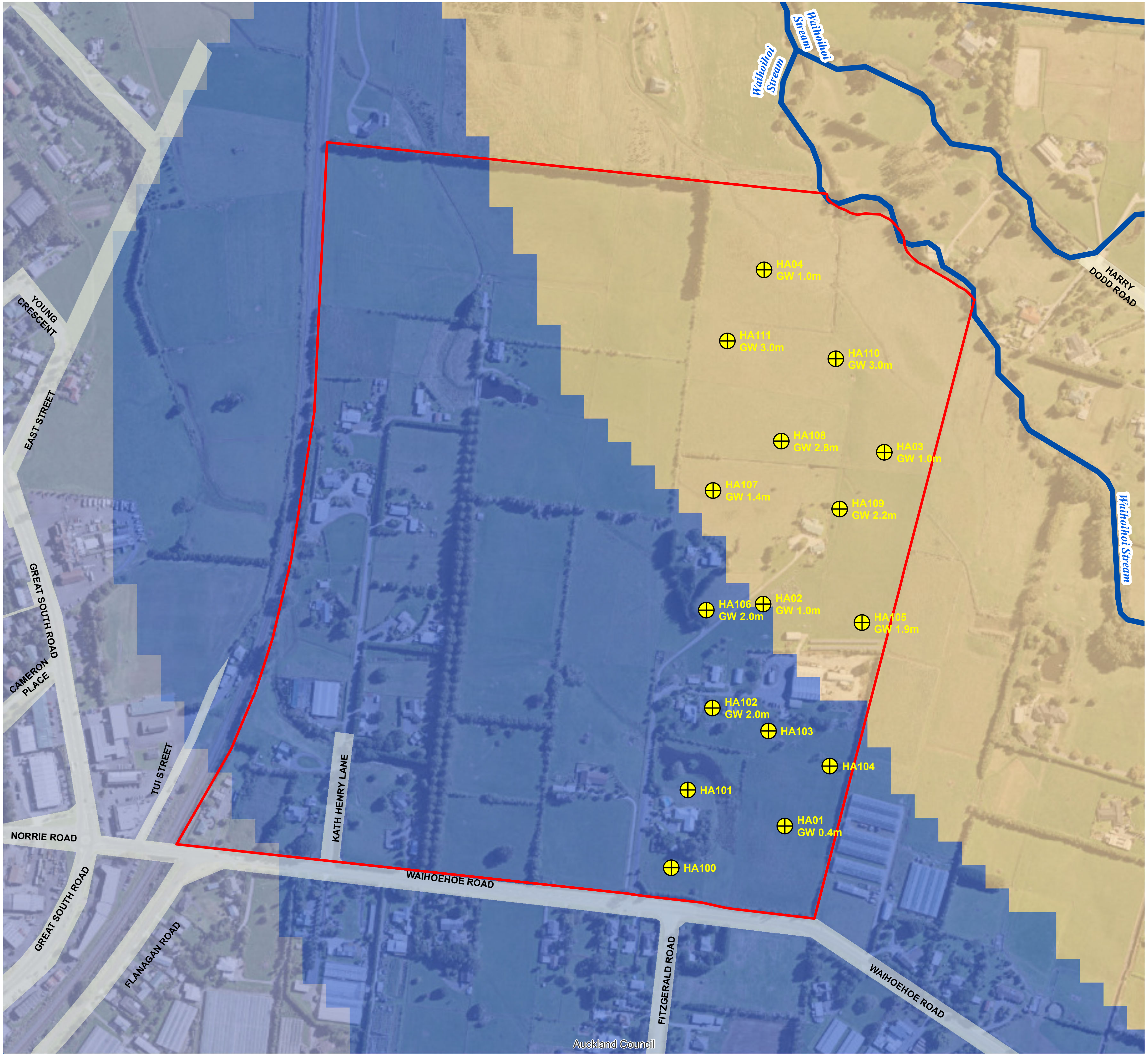
STORMWATER MANAGEMENT PLAN
Geology

Figure A7



LEGEND

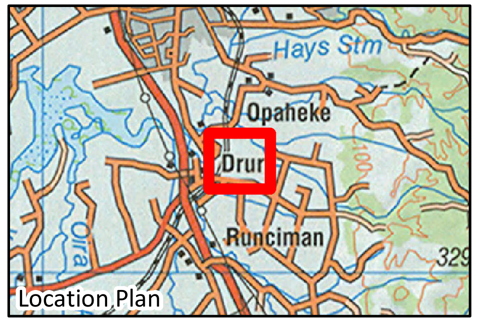
- Lander Geotechnical Hand Auger Boreholes
- Plan change area
- Streams and rivers

Soil drainage (LENZ)

- Very poor
- Poor
- Imperfect
- Moderate
- Good/Well

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
LENZ Soil drainage layer as created by Landcare Research Ltd (2003).
Borehole locations and groundwater depths sourced from Lander Geotechnical Preliminary Geotechnical Appraisal Report for Waihoehoe Plan Change Area, Drury (March 2019).

DRAWN	DERI	Apr.19
CHECKED	LEAN	Apr.19
APPROVED	TSRF	Apr.19

ARCFILE
A8_SoilDrainage-GWLevel.mxd
SCALE (AT A3 SIZE)
1:4,000
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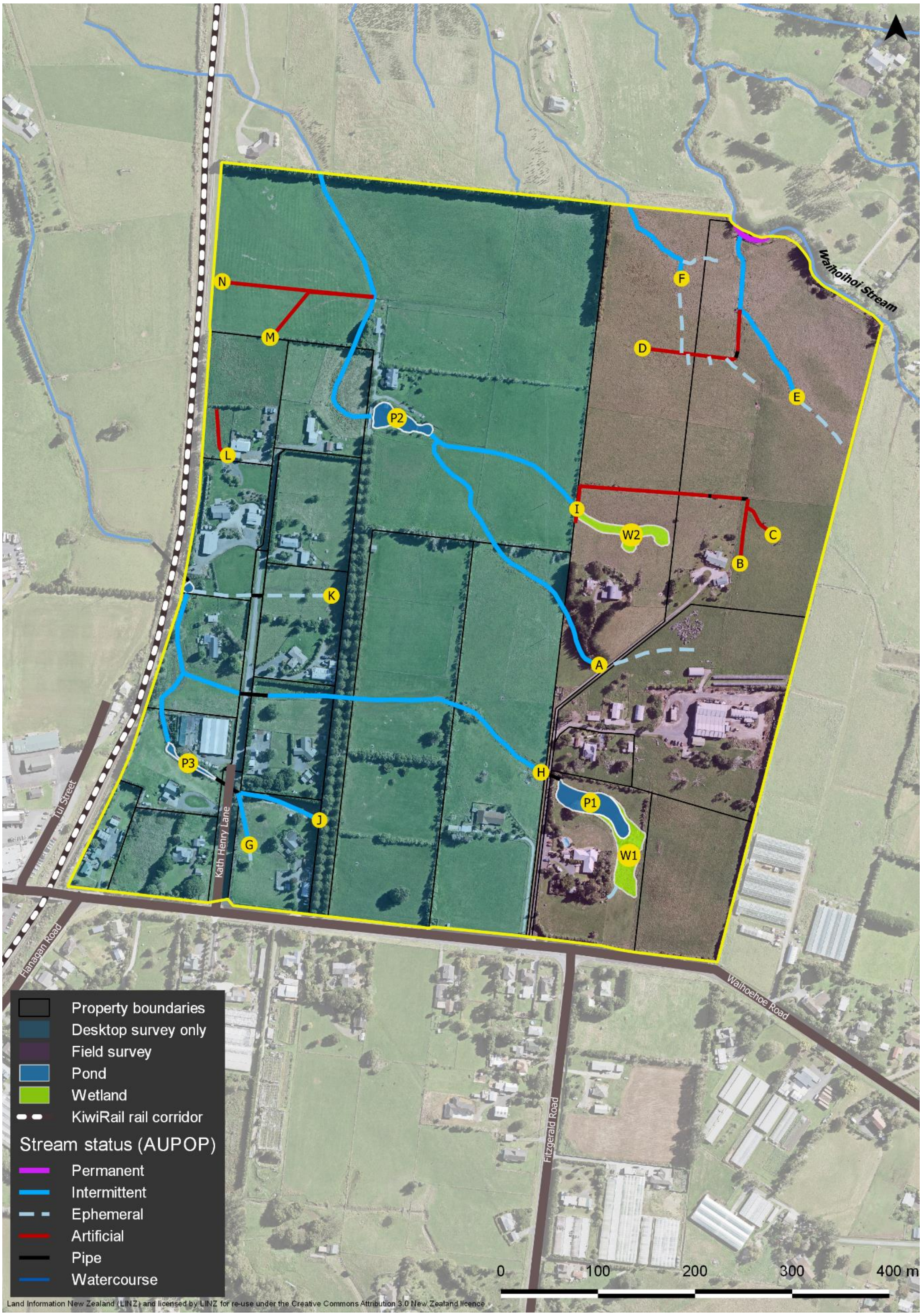
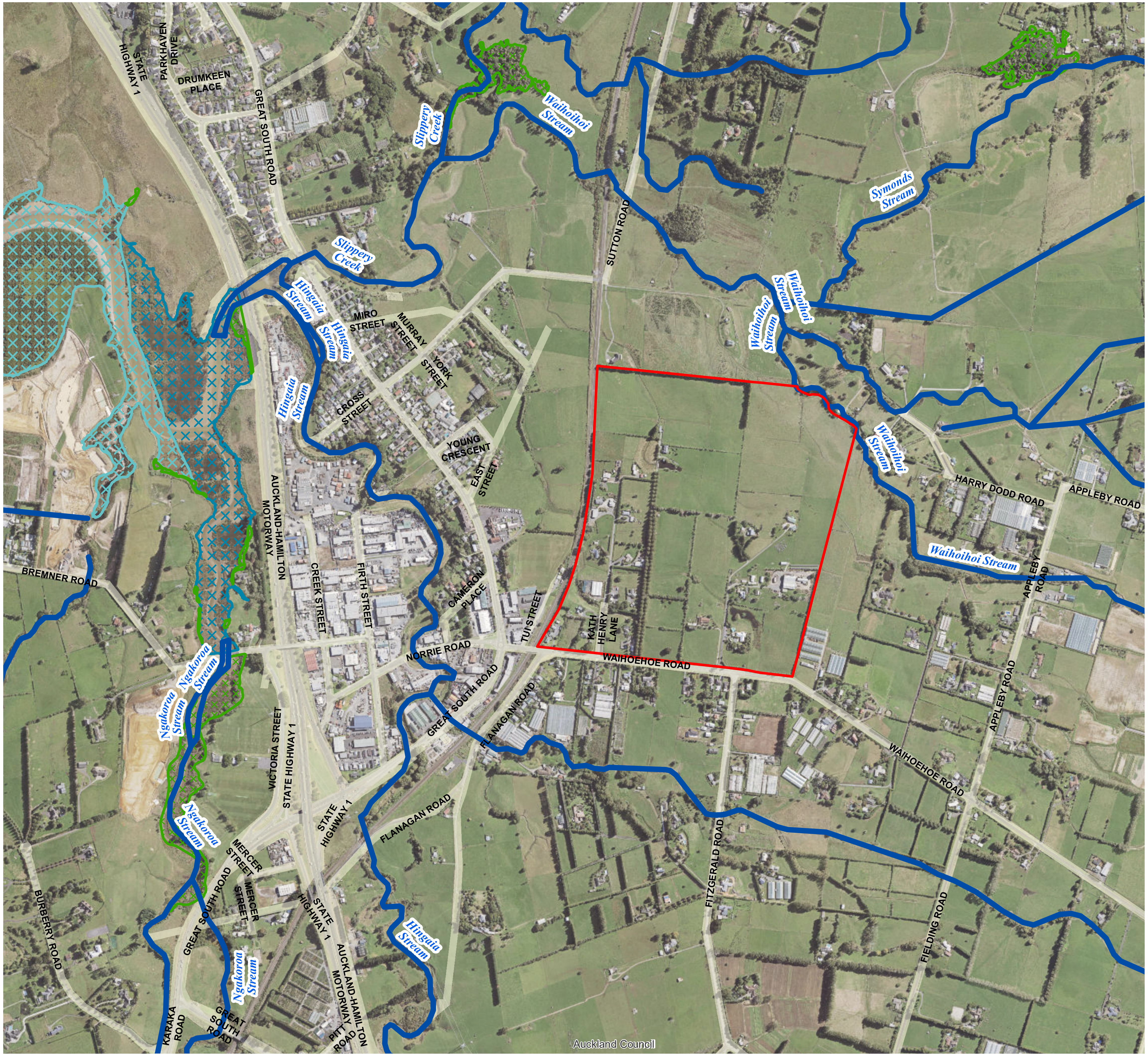
STORMWATER MANAGEMENT PLAN
Soil Drainage And Groundwater Levels

Figure A8

Source: Freshwater Solutions, Waihoehoe Road Drury Ecological Assessment Draft, March 2019



A9 - Stream classification



LEGEND

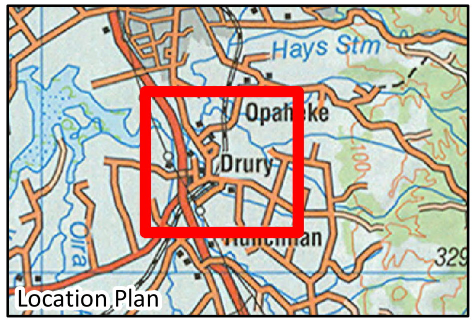
- Plan Change Area
- Streams and rivers

Significant Ecological Areas

- Terrestrial
- Marine 1
- Marine 2

A3 SCALE: 1:10,000

0 100 200 300 400 500 Meters



Location Plan

Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).

Significant Ecological Areas Overlay as per Auckland Council GIS data.

DRAWN	DERI	Apr.19
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APPROVED	TSRF	Apr.19

ARCFILE
A10_SignificantEcologicalAreas.mxd

SCALE (AT A3 SIZE)
1:10,000

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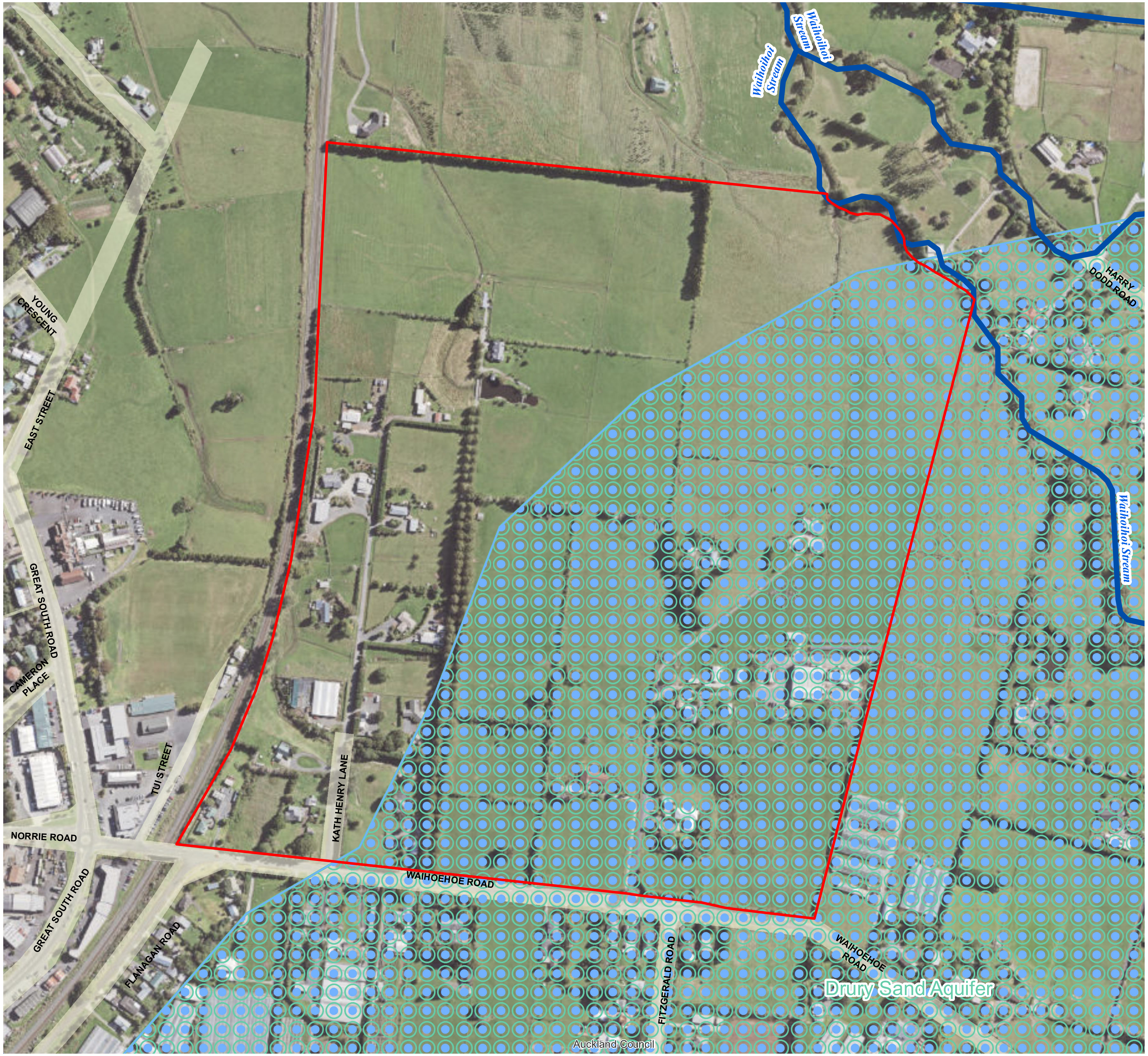
116 WAIHOEHOE ROAD AND SURROUNDS

STORMWATER MANAGEMENT PLAN

Significant Ecological Areas

Figure A10

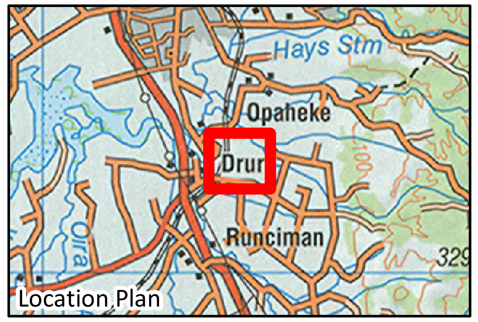


LEGEND

- Plan Change Area
- Streams and rivers
- High-Use Aquifer Management Area
- Quality Sensitive Aquifer Management Area

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).

Aquifer Management Area Overlays as per Auckland Council GIS data.

DRAWN	DERI	Apr.19
CHECKED	LEAN	Apr.19
APPROVED	TSRF	Apr.19

ARCFILE A11_AquiferManagementAreas.mxd

SCALE (AT A3 SIZE) 1:4,000

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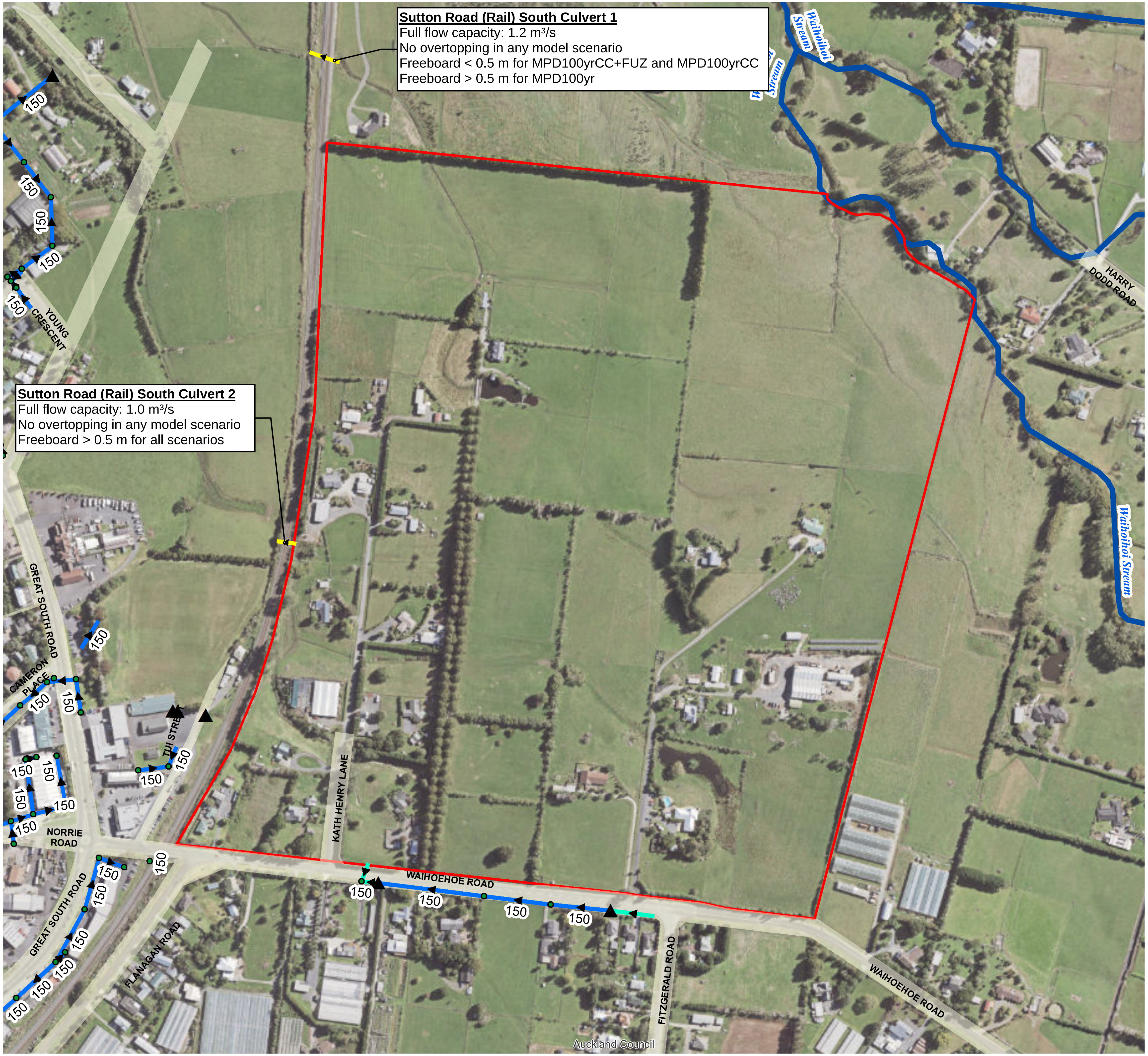
STORMWATER MANAGEMENT PLAN
Aquifer Management Areas

Figure A11



LEGEND

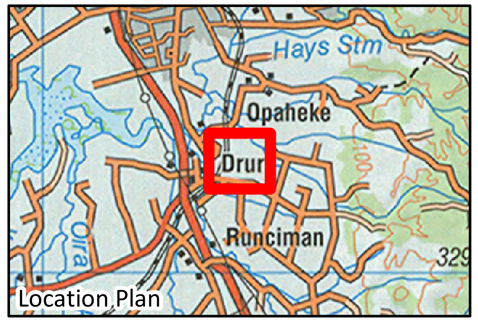
- Plan Change Area
- Streams and rivers
- Railway culverts

Stormwater assets

- SW manhole and chamber
- SW inlet and outlet
- SW channel
- SW pipe

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Stormwater asset data sourced as per Auckland Council GIS data.
Culvert locations sourced from AECOM Slippery Creek model.

DRAWN	DERI	Jun.19
CHECKED	LEAN	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE
A12_Existing-Infrastructure.mxd

SCALE (AT A3 SIZE)
1:4,000

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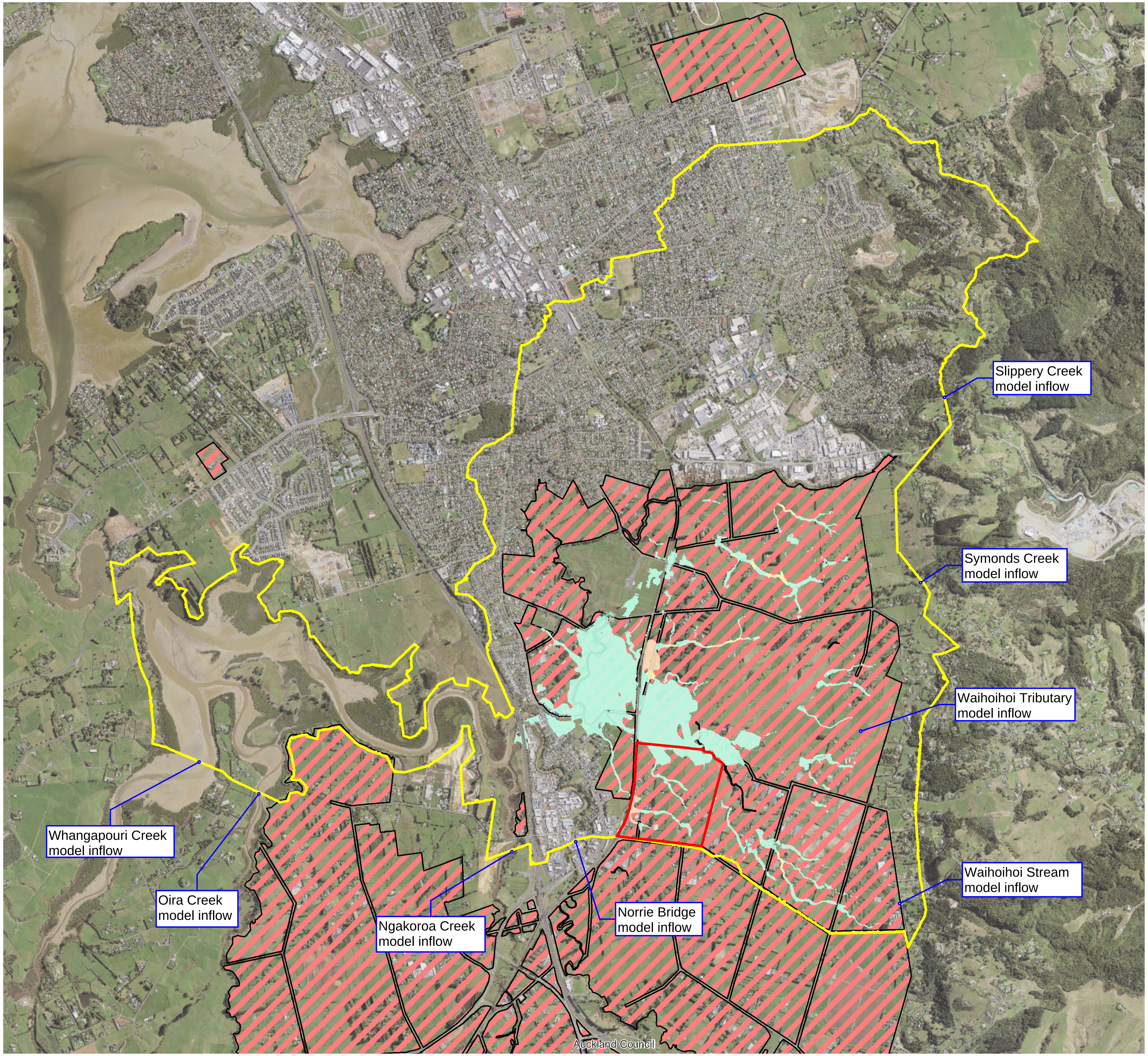
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Existing Stormwater Infrastructure

Figure A12



LEGEND

- Plan Change Area
- Approx. 2D model extent
- Future Urban Zone (FUZ)

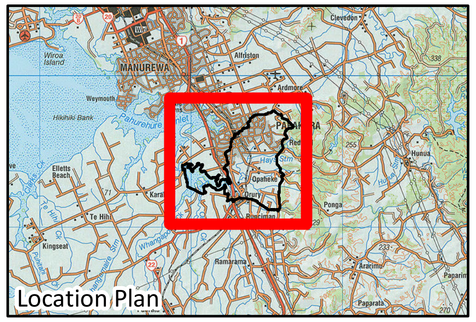
ED100yr with FUZ minus ED100yr without FUZ

Flood level difference (m)

- < 0 (ED+FUZ below ED flood level)
- 0 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.15
- 0.15 - 0.2
- 0.2 - 0.25
- 0.25 - 0.3
- 0.3 - 0.35
- 0.35 - 0.4
- > 0.4 (ED+FUZ above ED flood level)

A3 SCALE: 1:30,000

0 0.2 0.4 0.6 0.8 1 Kilometers



N

Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).

Flood level data and 2D model extent sourced from latest AECOM Slippery Creek flood model results.

Future Urban Zone (FUZ) as per Auckland Unitary Plan Operative in Part (AUP-OiP, 2016).

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE
A13_FloodLevelDiff_EDwithFUZminusEDNoFUZ.mxd

SCALE (AT A3 SIZE)
1:30,000

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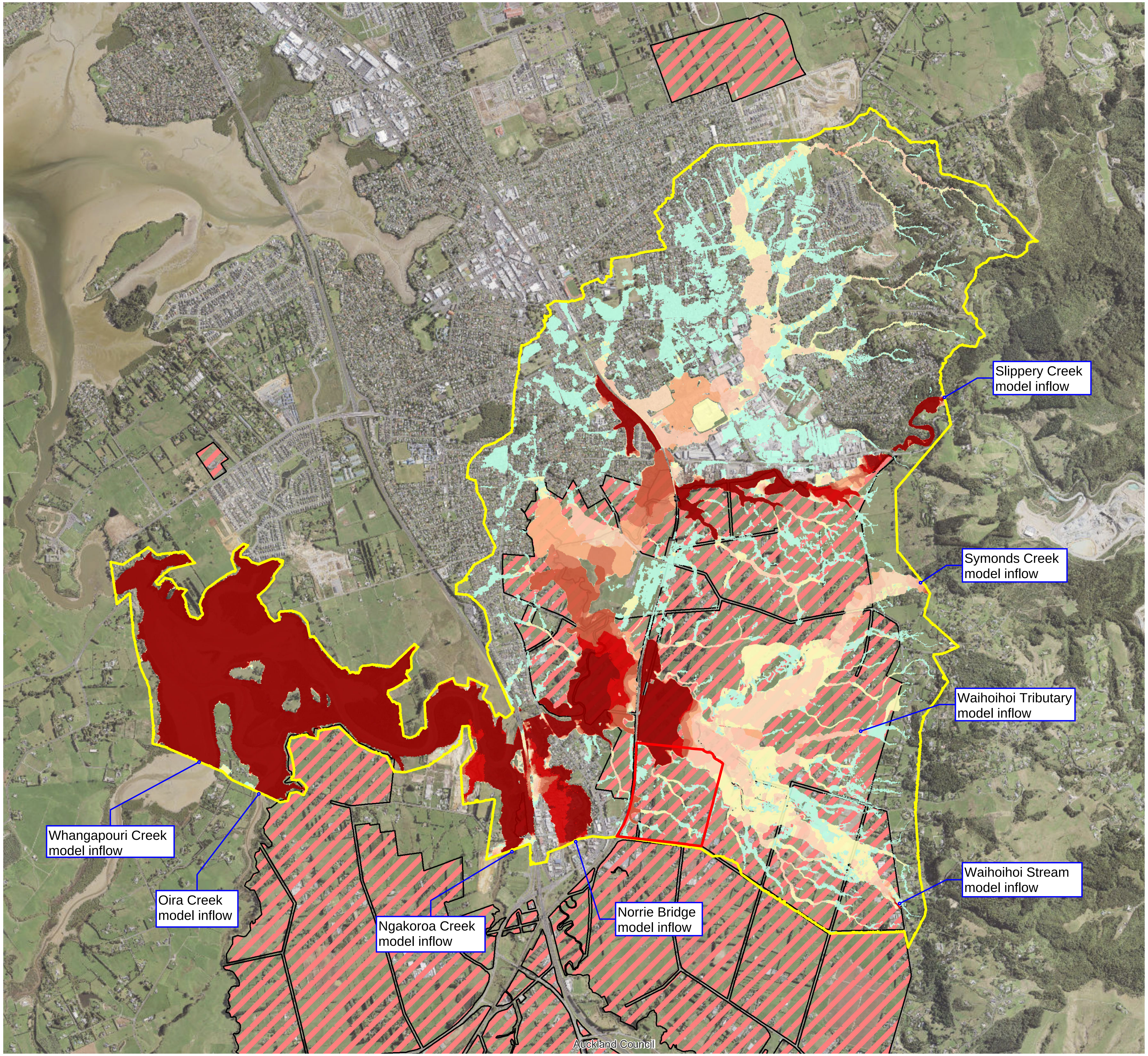
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Slippery Creek Model - Flood Level Difference
ED100yr with FUZ minus ED100yr without FUZ

Figure A13



LEGEND

- Plan Change Area
- Approx. 2D model extent
- Future Urban Zone (FUZ)

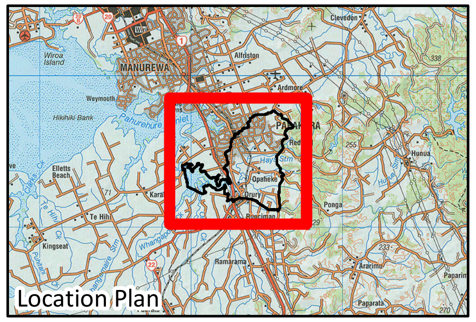
MPD100yrCC with FUZ minus ED100yr NoFUZ

Flood level difference (m)

- < 0 (MPD+CC+FUZ below ED flood level)
- 0 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.15
- 0.15 - 0.2
- 0.2 - 0.25
- 0.25 - 0.3
- 0.3 - 0.35
- 0.35 - 0.4
- > 0.4 (MPD+CC+FUZ above ED flood level)

A3 SCALE: 1:30,000

0 0.2 0.4 0.6 0.8 1 Kilometers



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).

Flood level data and 2D model extent sourced from latest AECOM Slippery Creek flood model results.

Future Urban Zone (FUZ) as per Auckland Unitary Plan Operative in Part (AUP-OiP, 2016).

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE
A14_FloodLevelDiff_MPD100yrCCFUZminusED100yr.mxd

SCALE (AT A3 SIZE)
1:30,000

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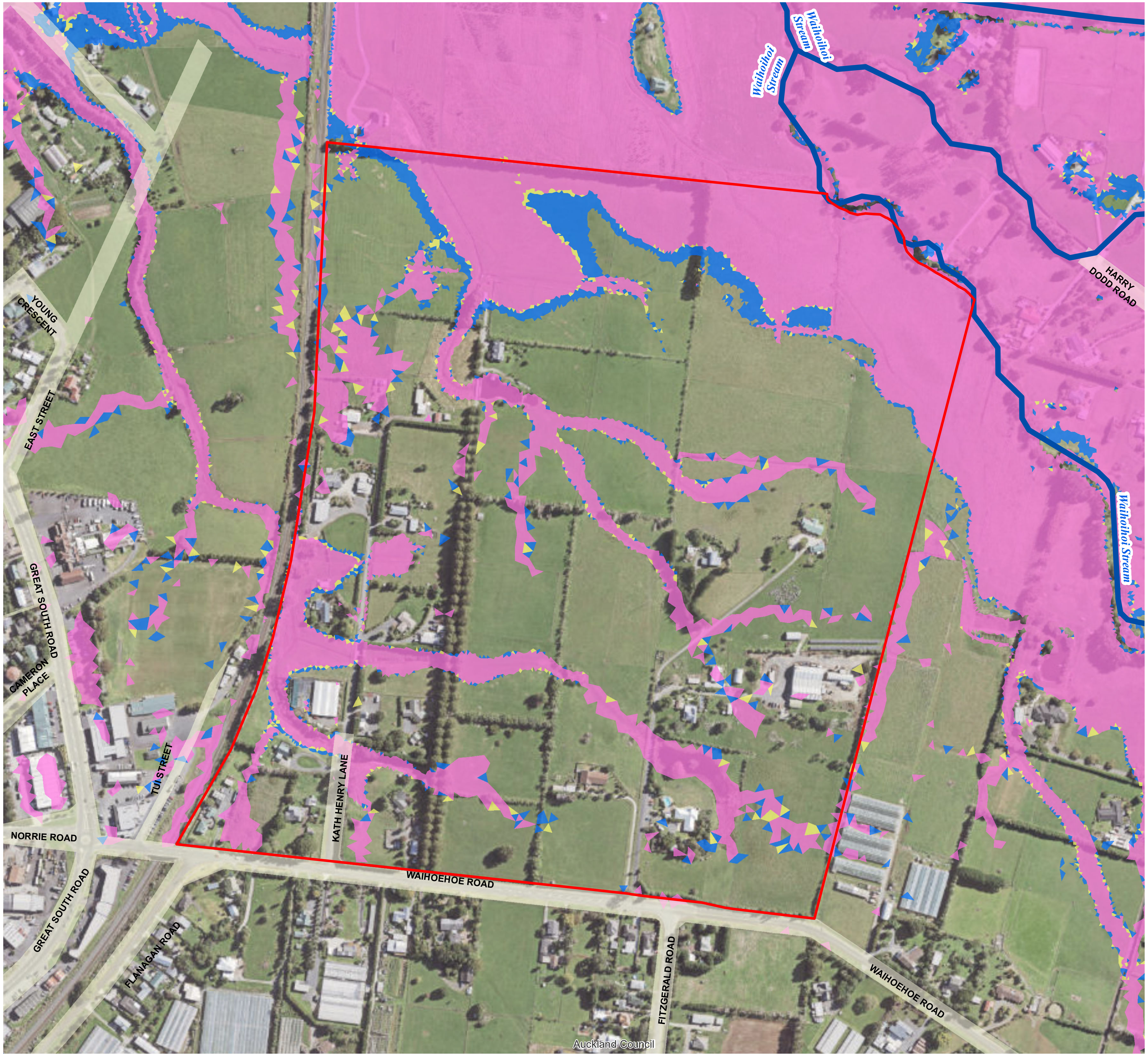
STORMWATER MANAGEMENT PLAN

Slippery Creek Model - Flood Level Difference
MPD 100yrCC with FUZ minus ED100yr without FUZ

Figure A14



LEGEND

Plan Change Area

Streams and rivers

Flood Extents

ED 100yr (no CC, no FUZ)

ED 100yr with FUZ (no CC)

MPD 100yr with CC with FUZ

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters

Location Plan

Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).

Flood extents sourced from latest AECOM Slippery Creek flood model.

Modelling results have been excluded where depth is below 0.05m.

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE A15_SlipperyCreek_FloodExtents.mxd

SCALE (AT A3 SIZE) 1:4,000

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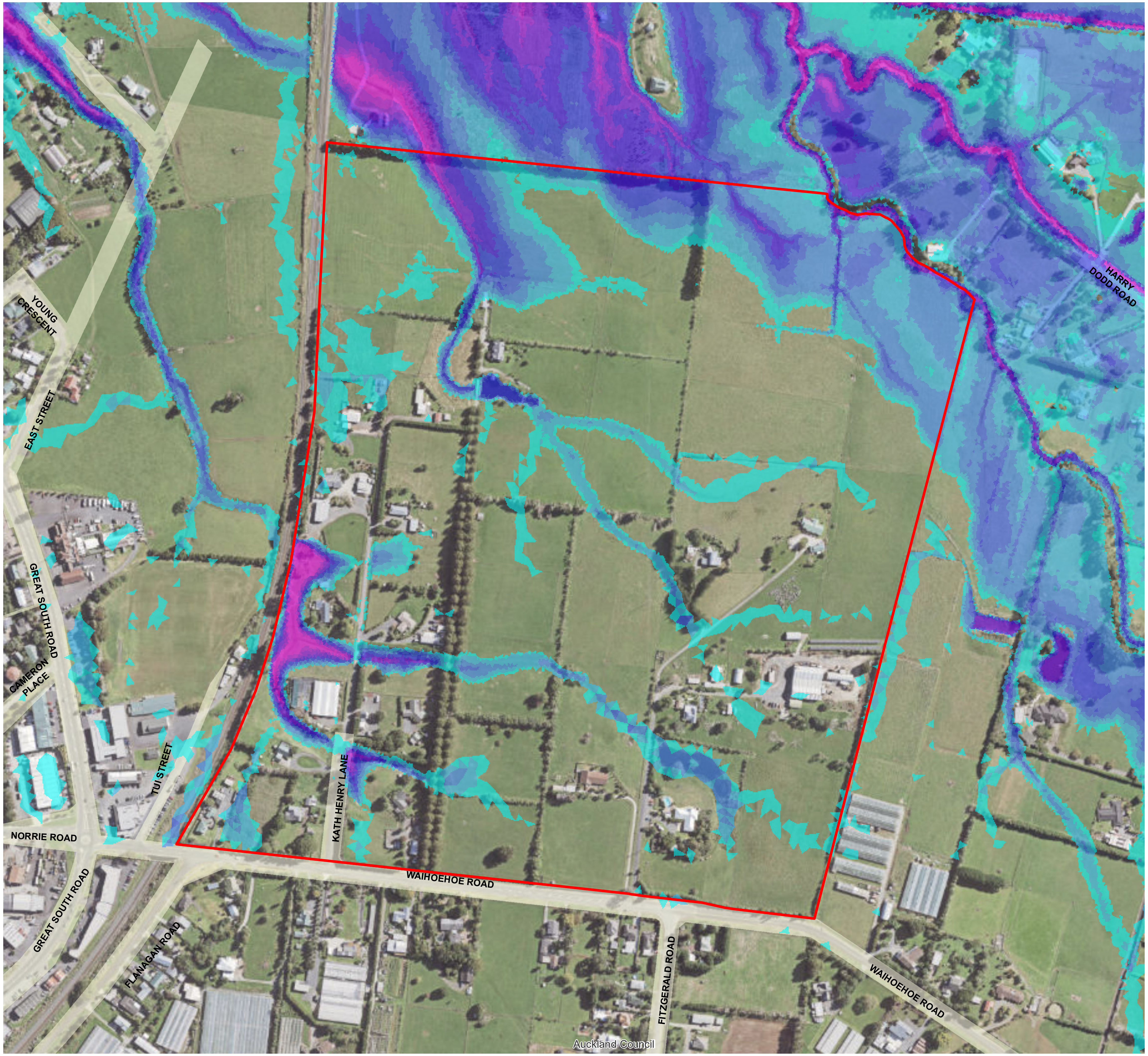
STORMWATER MANAGEMENT PLAN
Slippery Creek Model - Flood Extent Comparison
MPD100yr(CC+FUZ) to ED100yr(FUZ) to ED100yr

Figure A15



LEGEND

Plan Change Area

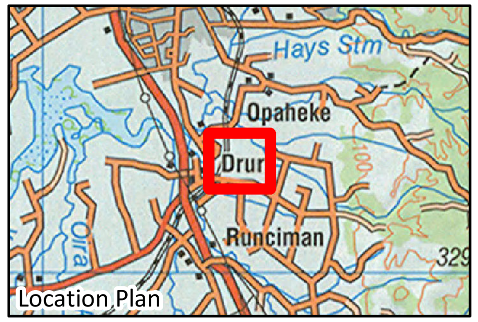
ED100yr

Flood depth (m)

- 0.05 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- 1.4 - 1.6
- 1.6 - 1.8
- > 1.8 m

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Flood depthl data sourced from latest AECOM Slippery Creek flood model results.
Modelling results excluded where depth is below 0.05m.

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE
A16_SC_FloodDepth_ED100yr.mxd

SCALE (AT A3 SIZE)
1:4,000

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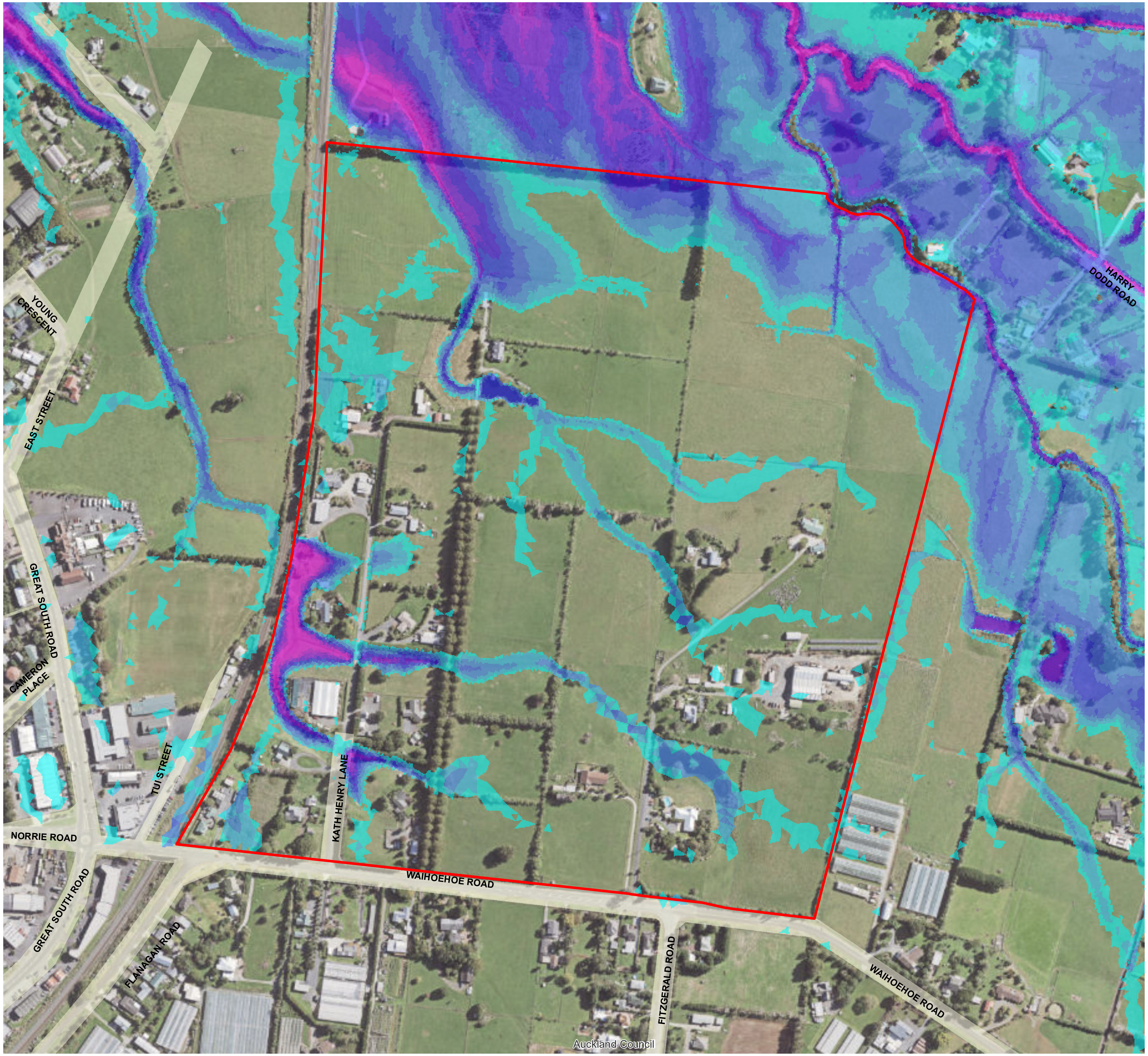
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Slippery Creek Model - Flood Depth
ED100yr

Figure A16



LEGEND

Plan Change Area

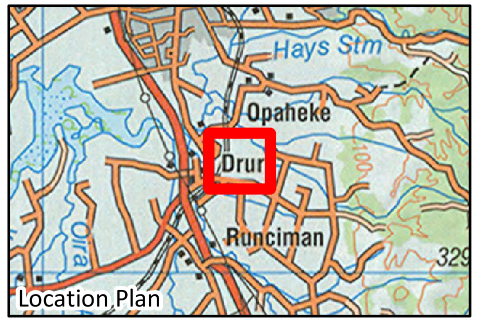
ED100yr with FUZ

Flood depth (m)

- 0.05 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- 1.4 - 1.6
- 1.6 - 1.8
- > 1.8 m

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Flood depthl data sourced from latest AECOM Slippery Creek flood model results.
Modelling results excluded where depth is below 0.05m.

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE
A17_SC_FloodDepth_ED100yrFUZ.mxd

SCALE (AT A3 SIZE)
1:4,000

PROJECT No.
1008200.1000

Tonkin+Taylor
105 Carlton Gore Road, Newmarket, Auckland
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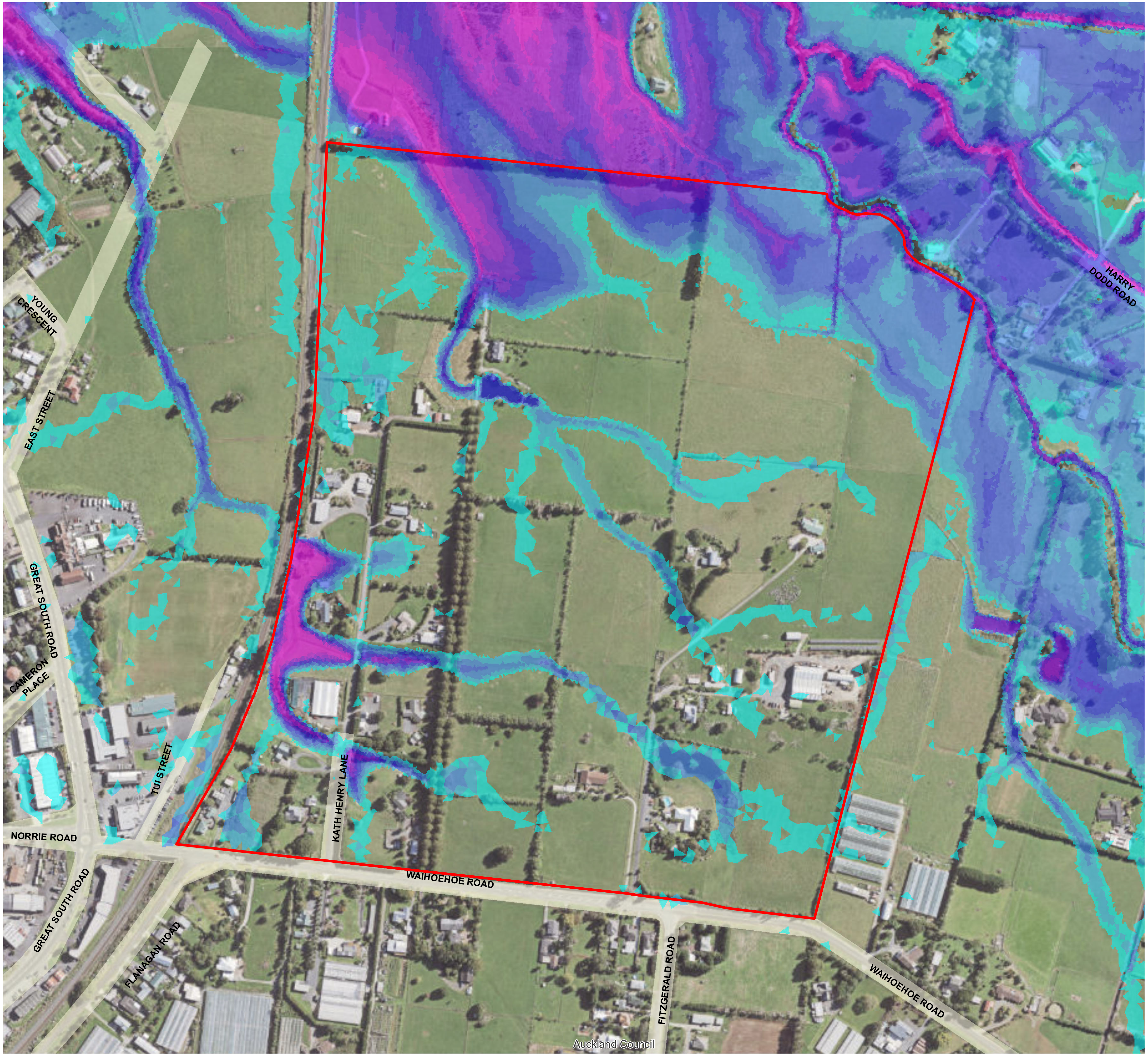
OYSTER CAPITAL
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Slippery Creek Model - Flood Depth
ED100yr with FUZ

Figure A17



LEGEND

Plan Change Area

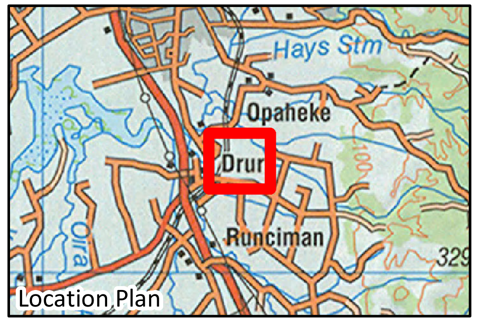
MPD100yrCC with FUZ

Flood depth (m)

- 0.05 - 0.2
- 0.2 - 0.4
- 0.4 - 0.6
- 0.6 - 0.8
- 0.8 - 1.0
- 1.0 - 1.2
- 1.2 - 1.4
- 1.4 - 1.6
- 1.6 - 1.8
- > 1.8 m

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Flood depthl data sourced from latest AECOM Slippery Creek flood model results.
Modelling results excluded where depth is below 0.05m.

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE
A18_SC_FloodDepth_MPD100yrCCwithFUZ.mxd

SCALE (AT A3 SIZE)
1:4,000

PROJECT No.
1008200.1000

Tonkin+Taylor
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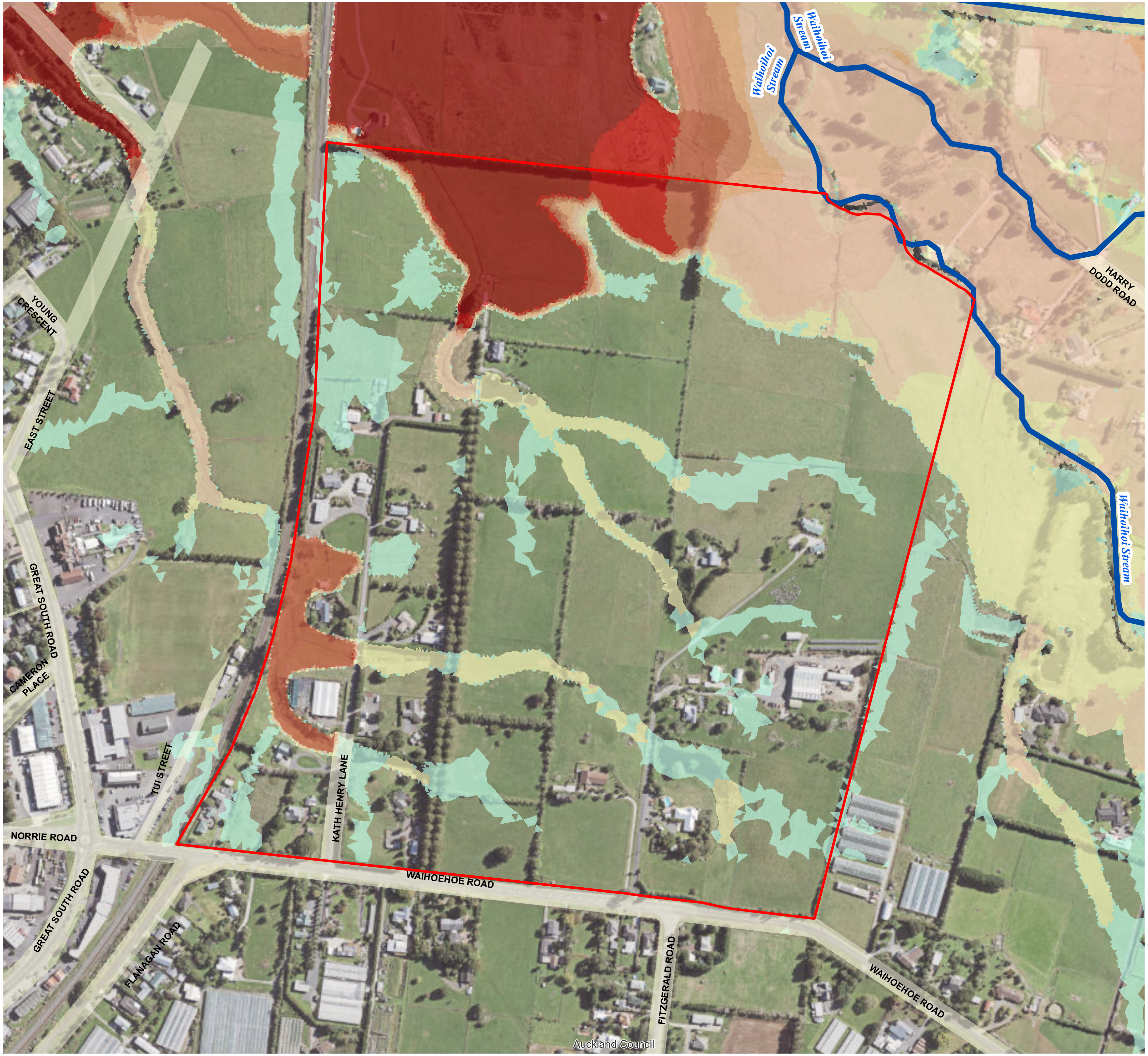
OYSTER CAPITAL
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Slippery Creek Model - Flood Depth
MPD100yrCC with FUZ

Figure A18



LEGEND

- Plan Change Area
- Streams and rivers

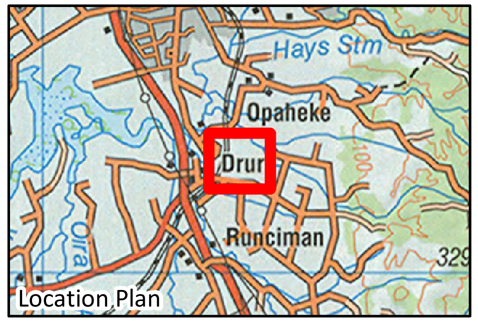
MPD100yrCC with FUZ minus ED100yr without FUZ

Flood level difference (m)

- < 0 (MPD+CC+FUZ below ED flood level)
- 0 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.15
- 0.15 - 0.2
- 0.2 - 0.25
- 0.25 - 0.3
- 0.3 - 0.35
- 0.35 - 0.4
- > 0.4 (MPD+CC+FUZ above ED flood level)

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Flood level data sourced from latest AECOM Slippery Creek flood model results.

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE
A19_SC_FloodLevelDiff.mxd

SCALE (AT A3 SIZE)
1:4,000

PROJECT No.
1008200.1000

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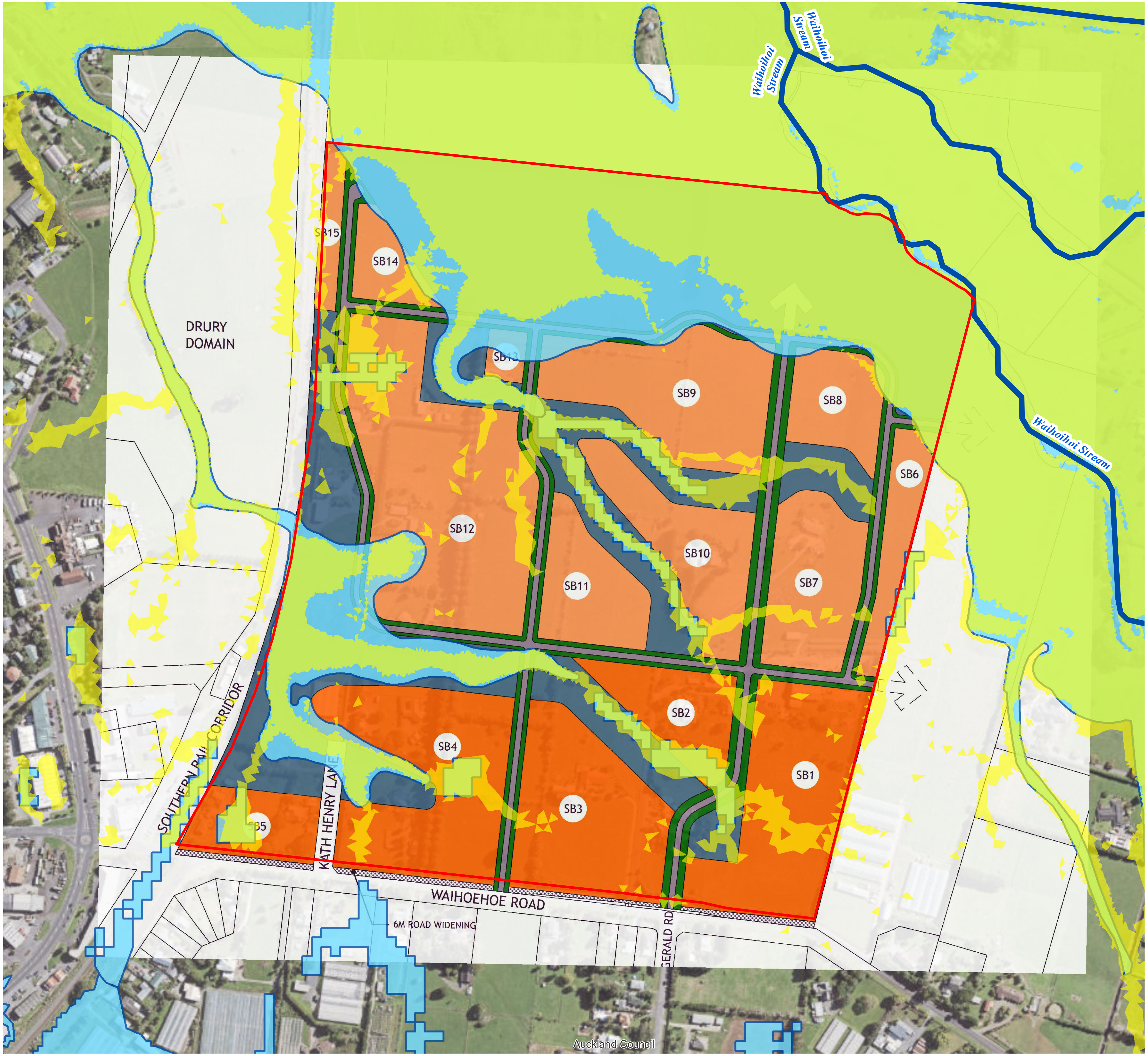
OYSTER CAPITAL
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Slippery Creek Model - Flood Level Difference
MPD 100yrCC with FUZ minus ED100yr without FUZ

Figure A19



LEGEND

Plan Change Area

Streams and rivers

Flooding

MPD 100yrARI with CC with FUZ flood extent (excluding depths below 0.05m)

Existing Auckland Council GIS 100yrARI flood plain

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters

Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).

MPD100yrCC flood extents sourced from latest AECOM Slippery Creek flood model results. Modelling results have been excluded where flood depth is below 0.05m.

AC flood plain created by the Stormwater Hydraulic Modelling Team for Auckland Council (Updated July 2013).

Concept masterplan provided by Oyster Capital.

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE A20_FloodExtent_MPD_ACfloodplain.mxd

SCALE (AT A3 SIZE) 1:4,000

PROJECT No. 1008200.1000

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OYSTER CAPITAL

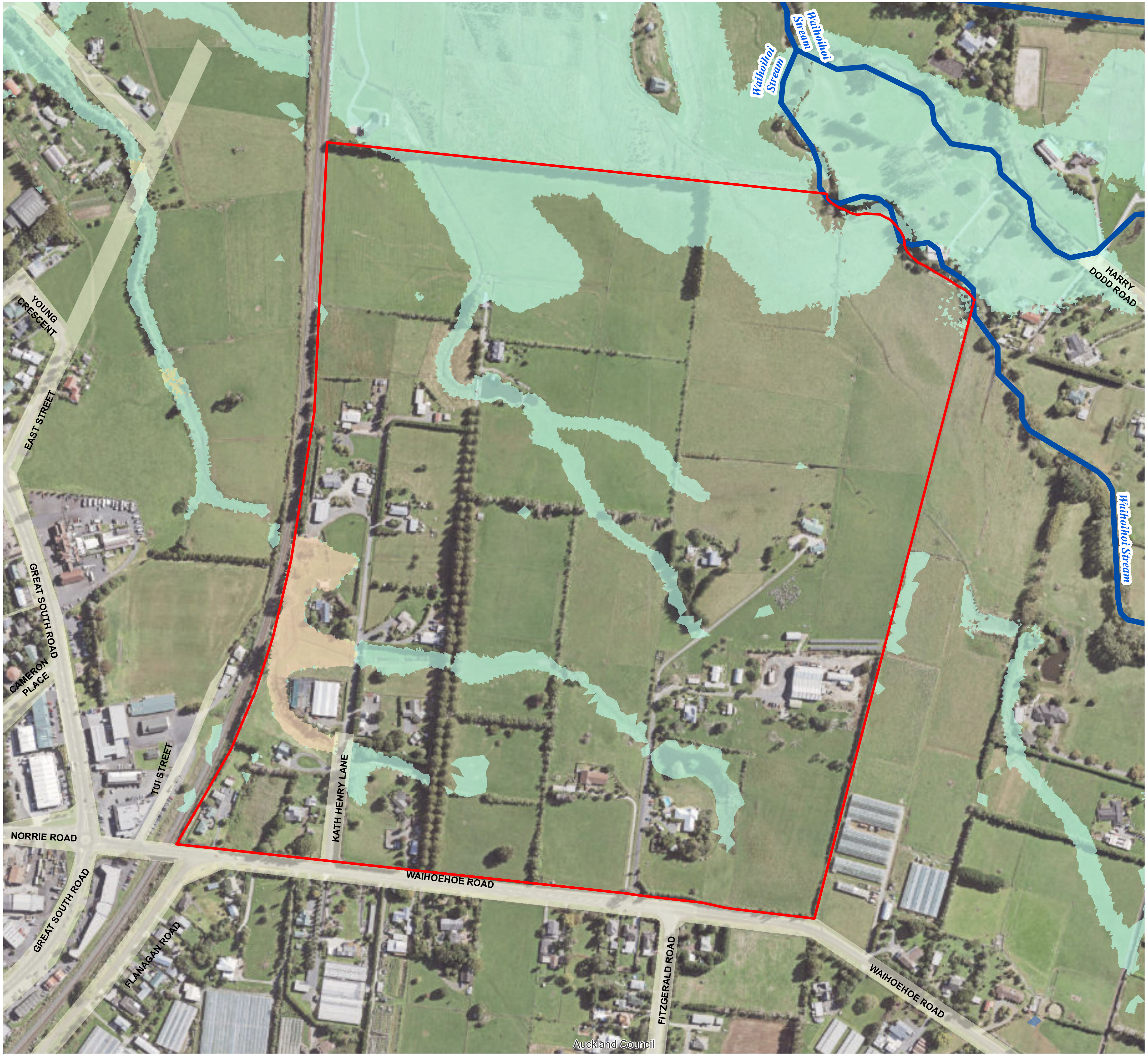
116 WAIHOEHOE ROAD AND SURROUNDS

STORMWATER MANAGEMENT PLAN

Flood Extent Comparison

MPD100yrCC to AC GIS 100yrARI flood plain

Figure A20



LEGEND

- Plan Change Area
- Streams and rivers

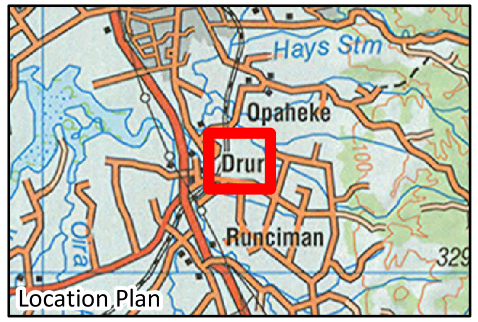
ED100yr with FUZ minus ED100yr without FUZ

Flood level difference (m)

- < 0 (ED+FUZ below ED flood level)
- 0 - 0.01
- 0.01 - 0.05
- 0.05 - 0.1
- 0.1 - 0.15
- 0.15 - 0.2
- 0.2 - 0.25
- 0.25 - 0.3
- 0.3 - 0.35
- 0.35 - 0.4
- > 0.4 (ED+FUZ above ED flood level)

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).
Flood level data sourced from latest AECOM Slippery Creek flood model results.

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19

ARCFILE
A21_SC_FloodLevelDiff_EDFUZminusED.mxd

SCALE (AT A3 SIZE)
1:4,000

PROJECT No.
1008200.1000

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OYSTER CAPITAL
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Slippery Creek Model - Flood Level Difference
ED 100yr with FUZ minus ED100yr without FUZ

Figure A21

LEGEND

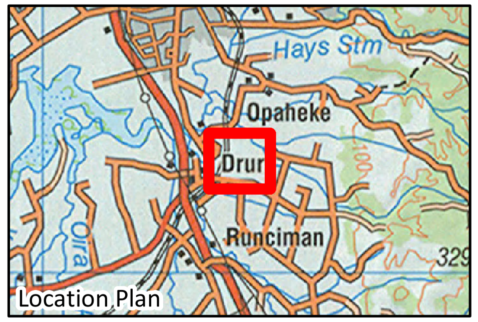
Subcatchment

Proposed SW Management Areas

- Drainage Reserve
- Residential - 116 Waihoehoe Rd - North
- Residential - 116 Waihoehoe Rd - South
- Residential - Western PPC - North
- Residential - Western PPC - South
- Road - 116 Waihoehoe Rd - North
- Road - 116 Waihoehoe Rd - South
- Road - Western PPC - North
- Road - Western PPC - South

A3 SCALE: 1:4,000

0 40 80 120 160 200 Meters



Notes:

Aerial photography sourced from Auckland Council latest aerial photography (2016/2017).

DRAWN	LEAN	Jun.19
CHECKED	BRNA	Jun.19
APPROVED	TSRF	Jun.19
ARCFILE A22_SWManagementAreas.mxd		
SCALE (AT A3 SIZE) 1:4,000		
PROJECT No. 1008200.1000		

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OYSTER CAPITAL
116 WAIHOEHOE ROAD AND SURROUNDS
STORMWATER MANAGEMENT PLAN
Proposed Stormwater Management Areas

Figure A22

Appendix B

WAHH Concept Masterplan Drawings

HUE
HOLISTIC URBAN ENVIRONMENTS

SUPER BLOCK	ZONE	DUPHA	LOW 30	MED 40	HIGH 50
		Area	UNITS	UNITS	UNITS
SB1	THAB	28,764	86	115	144
SB2	THAB	11,505	35	46	58
SB3	THAB	25,614	77	102	128
SB4	THAB	31,345	94	125	157
SB5	THAB	9,302	80	37	47
	SUB TOTALS		372	426	533

SUPER BLOCK	ZONE	DUPHA	LOW 18	MED 25	HIGH 35
		Area	UNITS	UNITS	UNITS
SB6	MHU	8,320	15	21	29
SB7	MHU	16,469	30	41	58
SB8	MHU	9,948	18	25	35
SB9	MHU	25,593	46	64	90
SB10	MHU	16,556	30	41	58
SB11	MHU	12,258	22	31	43
SB12	MHU	46,980	85	117	164
SB13	MHU	2,166	4	5	8
SB14	MHU	5,803	10	15	20
SB15	MHU	3,938	9	12	17
	SUB TOTALS		268	372	521
	TOTAL UNITS		640	798	1,054

	M^2	HA
THAB	106,533	10.7
MHU	148,036	14.8
DRAINAGE RES	181,814	18.2
ROAD RES	52,627	5.3
TOTAL AREA	489,010	48.9
Max Gross Dev Density (DUPHA)		21.55
Max Net Dev Density (DUPHA)		41.40

N

KEY
- SB# DEVELOPMENT BLOCKS
- NORTHERN STORMWATER SUB-CATCHMENTS
- SOUTHERN STORMWATER SUB-CATCHMENT
- DRIANGE RESERVE
- ROAD RESERVE & CARRIAGEWAY

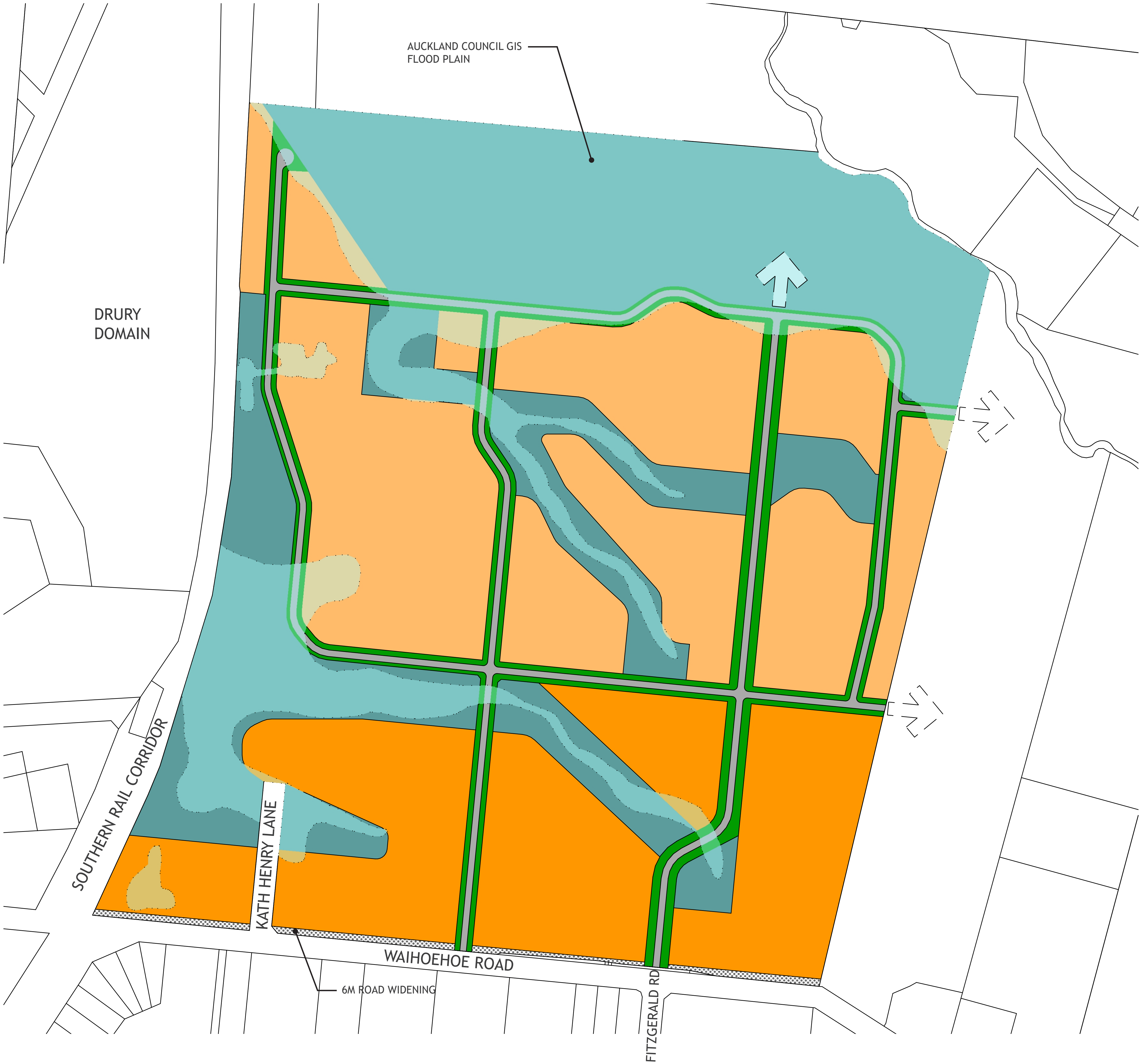
CLIENT
OYSTER CAPITAL

ADDRESS
WAIHOEHOE ROAD PLAN CHANGE

PROJECT #: 19-005_WAHH
ISSUE DATE: 03/18/19
STATUS: DRAFT
AUTHOR: MP
SCALE: 1:3,500 @ A3

DWG TITLE
CONCEPT MASTERPLAN

DWG #
CP-101-A



HOLISTIC URBAN ENVIRONMENTS

N

KEY

- SB# DEVELOPMENT BLOCKS
- NORTHERN STORMWATER SUB-CATCHMENTS
- SOUTHERN STORMWATER SUB-CATCHMENT
- DRIANGE RESERVE
- ROAD RESERVE & CARRIAGEWAY

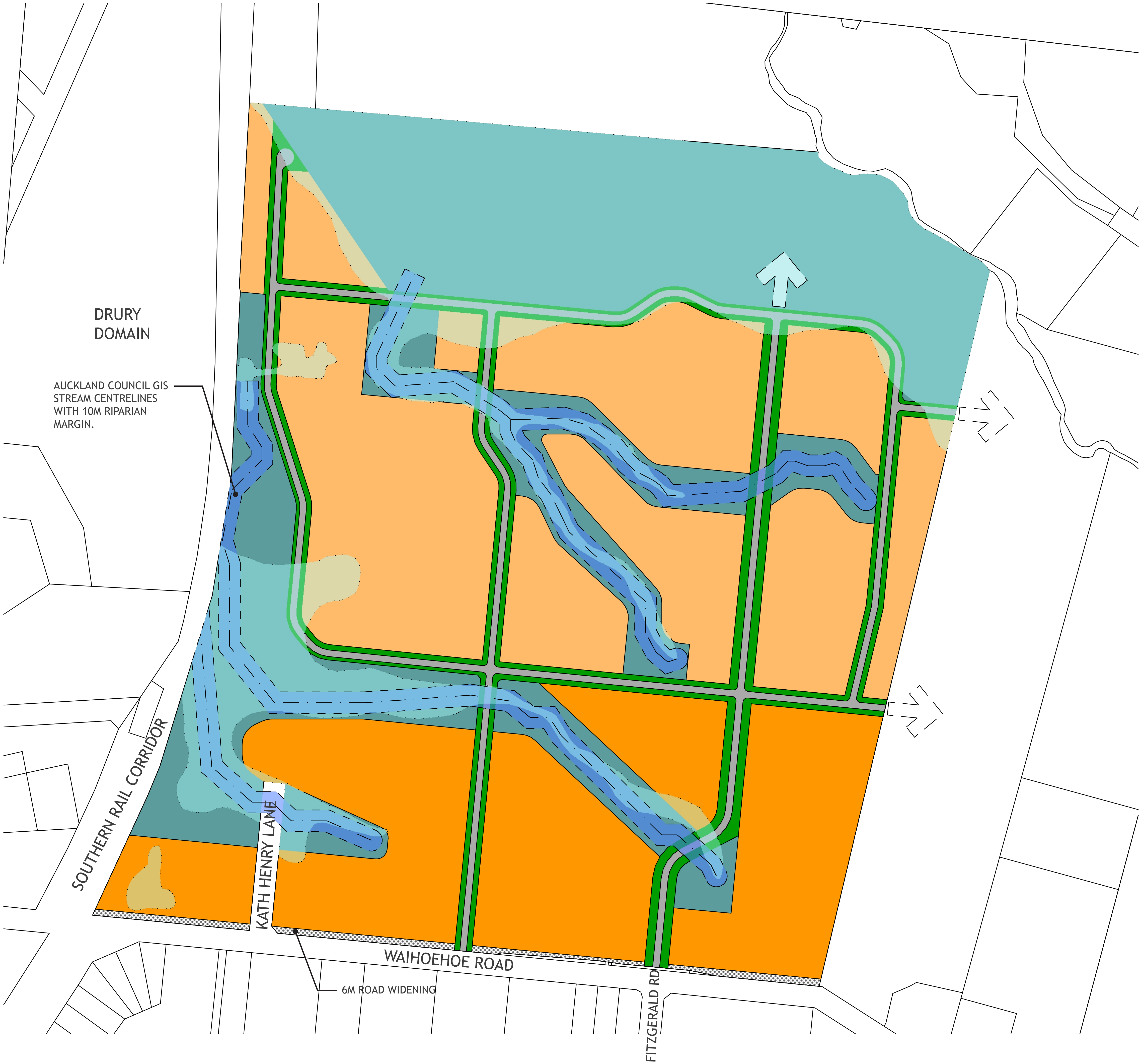
CLIENT
OYSTER CAPITAL

ADDRESS
WAIHOEHOE ROAD PLAN CHANGE

PROJECT #: 19-005_WAHH
ISSUE DATE: 03/18/19
STATUS: DRAFT
AUTHOR: MP
SCALE: 1:3,500 @ A3

DWG TITLE
CONCEPT MASTERPLAN
+ AUCKLAND COUNCIL GIS FLOOD PLAINS

DWG #
CP-102-A



KEY

- SB# DEVELOPMENT BLOCKS
- NORTHERN STORMWATER SUB-CATCHMENTS
- SOUTHERN STORMWATER SUB-CATCHMENT
- DRIANGE RESERVE
- ROAD RESERVE & CARRIAGEWAY

HUE
HOLISTIC URBAN ENVIRONMENTS

N

CLIENT
OYSTER CAPITAL

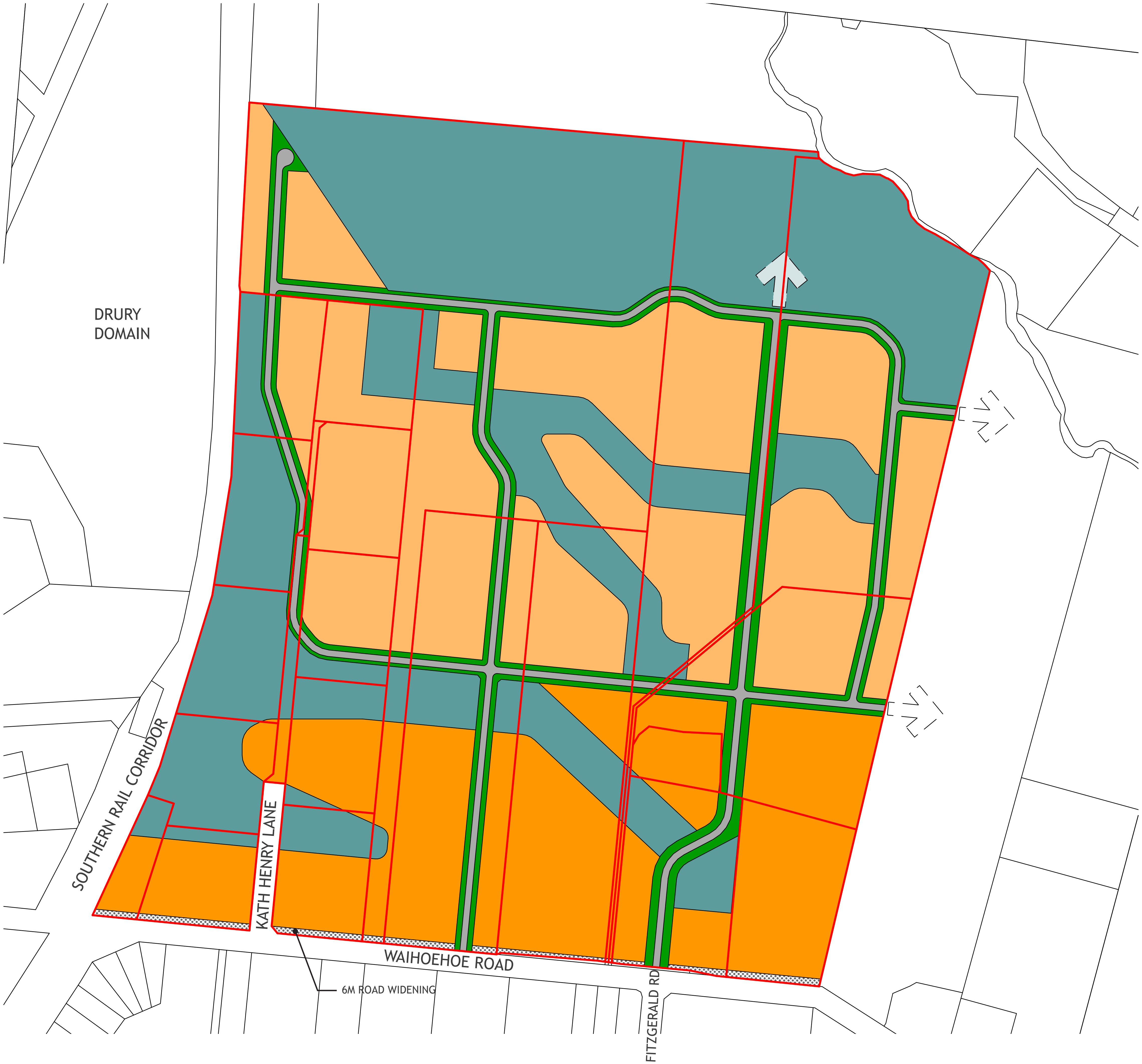
ADDRESS
WAIHOEHOE ROAD PLAN CHANGE

PROJECT #: 19-005_WAHH
ISSUE DATE: 03/18/19
STATUS: DRAFT
AUTHOR: MP
SCALE: 1:3,500 @ A3

DWG TITLE
CONCEPT MASTERPLAN
+ AUCKLAND COUNCIL GIS FLOOD PLAINS + STREAMS & RIPARIAN

DWG #
CP-103-A

HUE
HOLISTIC URBAN ENVIRONMENTS



KEY

- SB# DEVELOPMENT BLOCKS
- NORTHERN STORMWATER SUB-CATCHMENTS
- SOUTHERN STORMWATER SUB-CATCHMENT
- DRIANGE RESERVE
- ROAD RESERVE & CARRIAGEWAY

N

CLIENT
OYSTER CAPITAL

ADDRESS
WAIHOEHOE ROAD
PLAN CHANGE

PROJECT #: 19-005_WAHH
ISSUE DATE: 03/18/19
STATUS: DRAFT
AUTHOR: MP
SCALE: 1:3,500 @ A3

DWG TITLE
CONCEPT MASTERPLAN
+ PROPERTY BOUNDARIES

DWG #
CP-104-A

HOLISTIC URBAN ENVIRONMENTS

SUPER BLOCK	ZONE	DUPHA	LOW 30	MED 40	HIGH 50
		Area	UNITS	UNITS	UNITS
SB1	THAB	29,243	88	117	146
SB2	THAB	9,572	29	38	48
SB3	THAB	26,126	78	105	131
SB4	THAB	29,914	90	120	150
SB5	THAB	10,716	32	43	54
SUB TOTAL		105,571	317	422	528

SUPER BLOCK	ZONE	DUPHA	LOW 18	MED 25	HIGH 35
		Area	UNITS	UNITS	UNITS
SB6	MHU	6,579	12	16	23
SB7	MHU	15,845	29	40	55
SB8	MHU	18,115	33	45	63
SB9	MHU	27,969	50	70	98
SB10	MHU	14,419	26	36	50
SB11	MHU	13,460	24	34	47
SB12	MHU	44,068	79	110	154
SB13	MHU	2,125	4	5	7
SB14	MHU	5,682	10	14	20
SB15	MHU	14,401	26	36	50
SUB TOTAL		162,663	293	407	569
TOTAL		268,234	610	829	1,097

	M²	HA	%
THAB	105,571	10.6	22
MHU	162,663	16.3	33
DRAINAGE RES	166,431	16.6	34
ROAD RES	54,349	5.4	11

TOTAL AREA 489,014	48.9
Max Gross Dev Density (DUPHA)	22.4
Max Net Dev Density (DUPHA)	40.9

N

CLIENT
OYSTER CAPITAL

ADDRESS
WAIHOEHOE ROAD
PLAN CHANGE

PROJECT #: 19-005_WAHH
ISSUE DATE: 08/APR/2019
STATUS: DRAFT
AUTHOR: MP
SCALE: 1:3,500 @ A3

KEY
- SB# DEVELOPMENT BLOCKS
- NORTHERN STORMWATER SUB-CATCHMENTS
- SOUTHERN STORMWATER SUB-CATCHMENT
- DRAINAGE RESERVE
- ROAD RESERVE & CARRIAGEWAY

DWG TITLE
CONCEPT MASTER PLAN

DWG #
CP-101-B

HUE
HOLISTIC URBAN ENVIRONMENTS

CLIENT
OYSTER CAPITAL

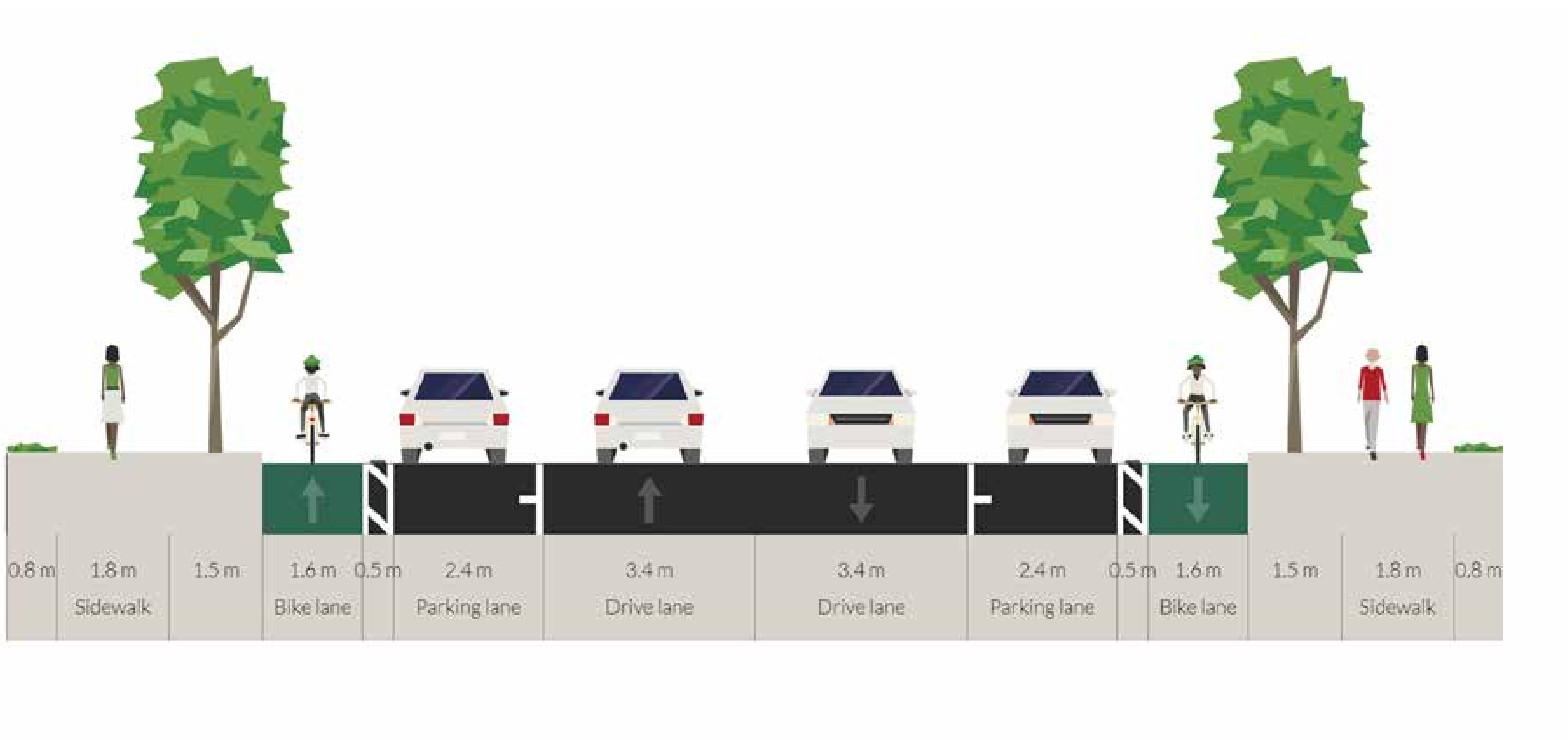
ADDRESS
WAIHOEHOE ROAD PLAN CHANGE

PROJECT #: 19-005_WAHH
ISSUE DATE: 08/APR/2019
STATUS: DRAFT
AUTHOR: MP
SCALE: 1:3,500 @ A3

DWG TITLE
PRELIMINARY ROAD HIERARCHY PLAN

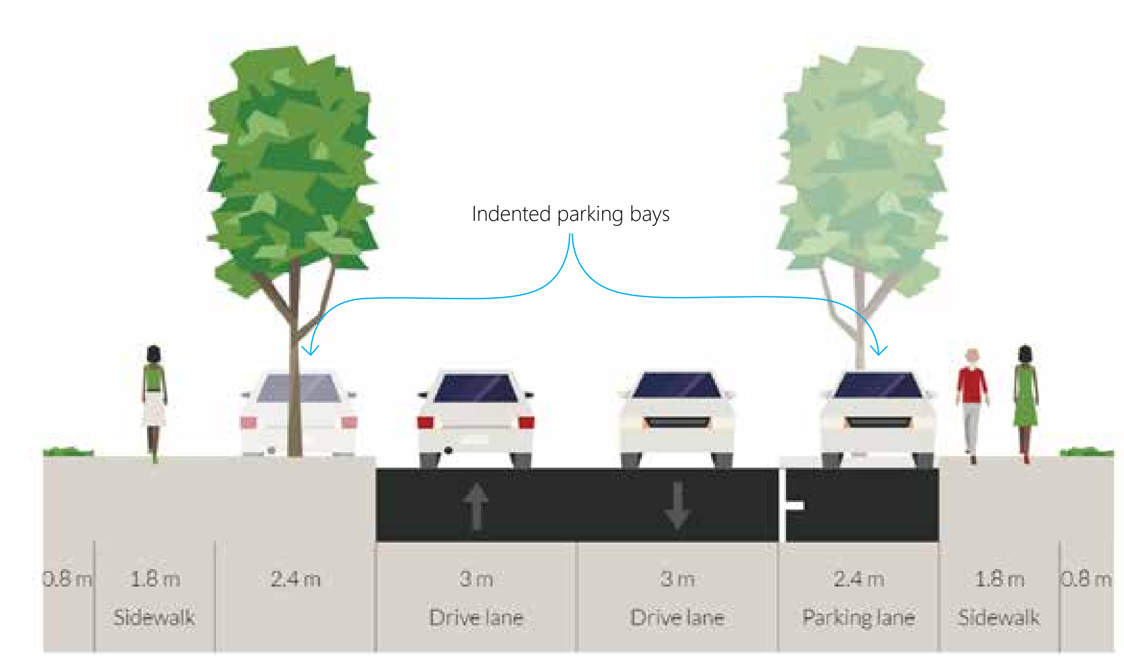
DWG #
CP-200-B

HUE
HOLISTIC URBAN ENVIRONMENTS

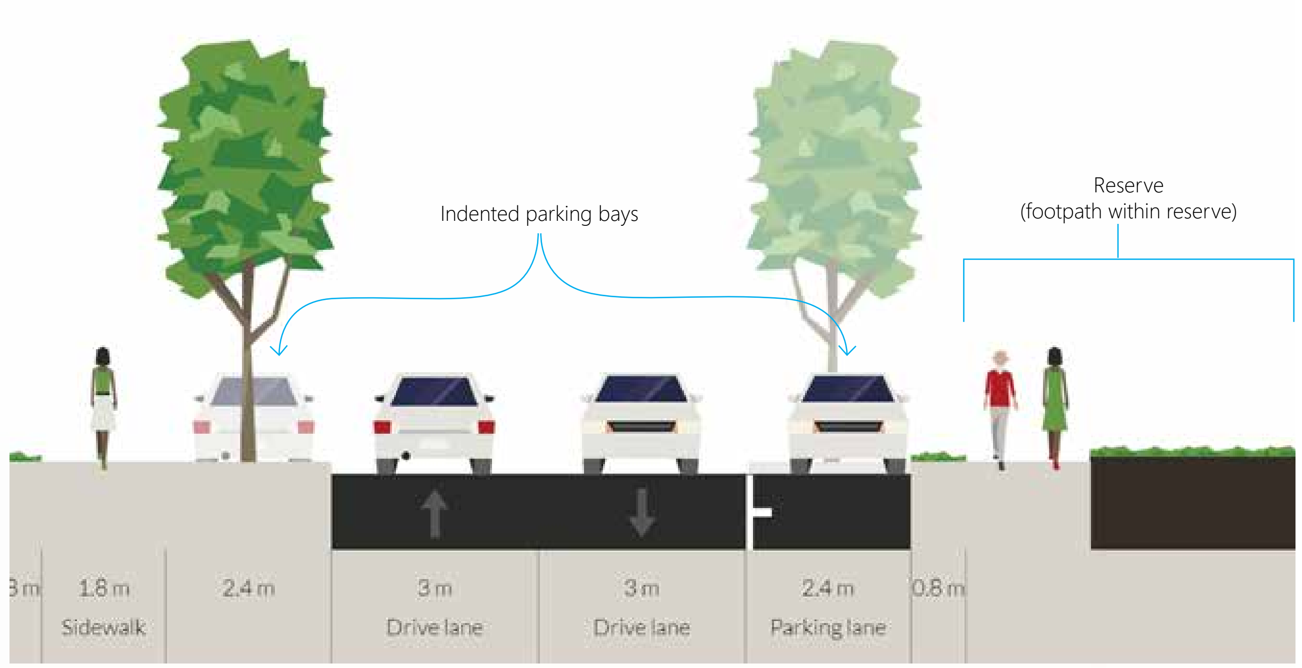


Collector Road
24m Width

(on street & seperated cycle lanes)



Standard Local Road
16m Width



Reserve Edge Road
14.2m Width

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OYSTER CAPITAL

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WAIHOEHOE ROAD PLAN CHANGE

PROJECT #: 19-005_WAHH
ISSUE DATE: 08/APR/2019
STATUS: DRAFT
AUTHOR: MP
SCALE: NOT TO SCALE

DWG TITLE
PRELIMINARY ROAD CROSS SECTIONS

DWG #
CP-201-B

Appendix C

Drury-Opaheke Stormwater Management Plan

Drury-Opaheke Structure Plan Future Urban Zone

Draft Stormwater Management Plan

12 April 2019

Mott MacDonald
Mason Bros. Building
Level 2, 139 Pakenham
Street West
Wynyard Quarter
Auckland 1010
PO Box 37525, Parnell,
1151
New Zealand

T +64 (0)9 375 2400
mottmac.com

Drury-Opaheke Structure Plan Future Urban Zone

Draft Stormwater Management Plan

12 April 2019

Mott MacDonald New Zealand Limited
Registered in New Zealand no. 3338812

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
01	21 Jan 2019	Carmel O'Sullivan			Draft for Client review
02	20 Feb 2019	Carmel O'Sullivan			Draft for Client review
03	4 March 2019	Carmel O'Sullivan			Draft for Client review
04B	2 April 2019	Carmel O'Sullivan	Paula Vincent Shaun Jones Kieren Daji		Draft
04C	12 April 2019	Carmel O'Sullivan	Paula Vincent Shaun Jones Kieren Daji		Draft

Document reference: 391951 | 001 | D

Information class: Standard

Contents

Executive summary

The Drury Structure Plan area includes about1921 hectares around Drury and Opaheke which is zoned Future Urban in the Auckland Unitary Plan Operative in Part (AUPOP).

This Stormwater Management Plan (SMP) has been prepared to support the development of the Drury Structure Plan. The SMP covers three stormwater management areas that include four stream catchments; Drury West (Oira Creek and Ngakoroa Stream), Drury East (Hingaia Stream) and Opaheke (Slippery Creek). Refer Figure ES 1. The proposed timeframes for development are identified in the 2017 Future Urban Land Supply Strategy (FULSS). Part of the Future Urban Zone will be developed from2022. The remainder is sequenced for development between 2028-2032.

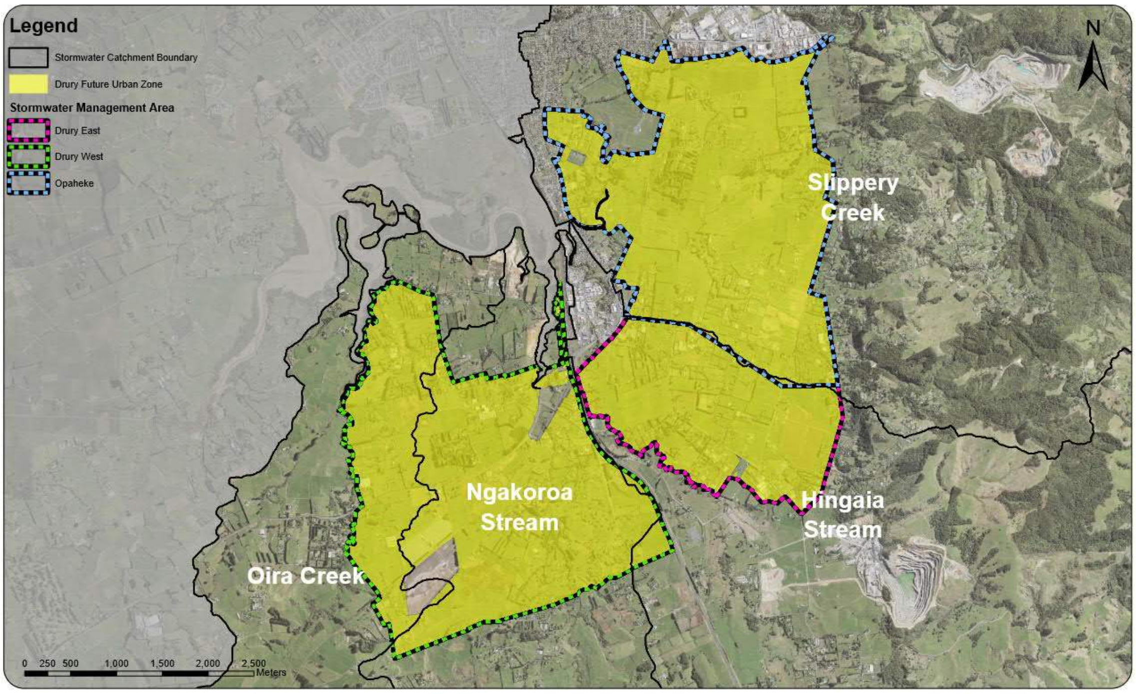


Figure ES 1 Drury Structure Plan Area - Stormwater Management Areas

Constraints and Opportunities

Identifying constraints and opportunities for development and different land uses is a key component of the Structure Plan. The following stormwater constraints, risks and opportunities relating to development of the Future Urban Zone (FUZ) have been identified in this SMP.

Key constraints include:

- Existing flooding of urban areas such as Drury township affecting private and public property. Flood modelling carried out indicates that the motorway and Great South Road will be inundated during a 100 year average recurrence interval (ARI) storm event. This modelling allows for maximum probable development (MPD) and climate change. Other roads will also be inundated. Options to address the flooding are limited as the downstream Drury Creek is a flow constraint. This means that water ponds in the creek and runoff from the contributing catchments can't discharge freely to the creek resulting in water 'backing up' the streams with a resultant rise in water levels. Hydraulic modelling is ongoing.

- Extensive flood plains particularly in the Slippery Creek Future Urban Zone (FUZ) area constraining the extent of developable land. The floodplains can be seen in Figure ES2. The Slippery Creek floodplain occupies approximately 261 ha of the 735 ha FUZ.
- Stream erosion which is a significant issue across the FUZ. As noted in E11 of the AUPOP sediment is a major contaminant. Increased sediment loads arising from human disturbance of soils are among the most significant impacts on freshwater values throughout the world, including in New Zealand (NIWA, 2015). Development of the FUZ has the potential to exacerbate erosion as the increased imperviousness associated with development can cause increased erosion from increased runoff. This can be managed by taking an integrated stormwater management approach to development (as required by the AUPOP) and requiring exemplary sediment and erosion control measures during construction.
- Capacity constraints at bridges and culvert.
- Sensitive receiving environments.

Key risks include:

- Due to the highly sensitive, low energy receiving environment of the Pahurehure Inlet, increased erosion (and associated sediment deposition) due to increased impervious areas is of particular concern.
- Decreased water quality, aquifer recharge and instream ecological values resulting from changes in land use and land development.

Key opportunities include:

- Mitigating and managing existing flood risk;
- Reduce existing stream adverse effects and enhance watercourse values;
- Implementation of stream enhancement opportunities;
- Retaining and buffering natural watercourses to improve water quality and increase numbers and diversity of instream biota;
- Reducing volumes of sediment and contaminants reaching the Pahurehure Inlet. Water quality testing found zinc and copper levels to be above ERC red and amber levels respectively within the Hingaia Stream catchment. High levels of *E.coli* (above MfE Red / Action mode) were also reported. Copper and zinc levels had also increased significantly in the Slippery Creek catchment across a nine year testing period;
- Improve the ecological functionality in currently degraded areas, along with the ability to set aside areas for public amenity value.

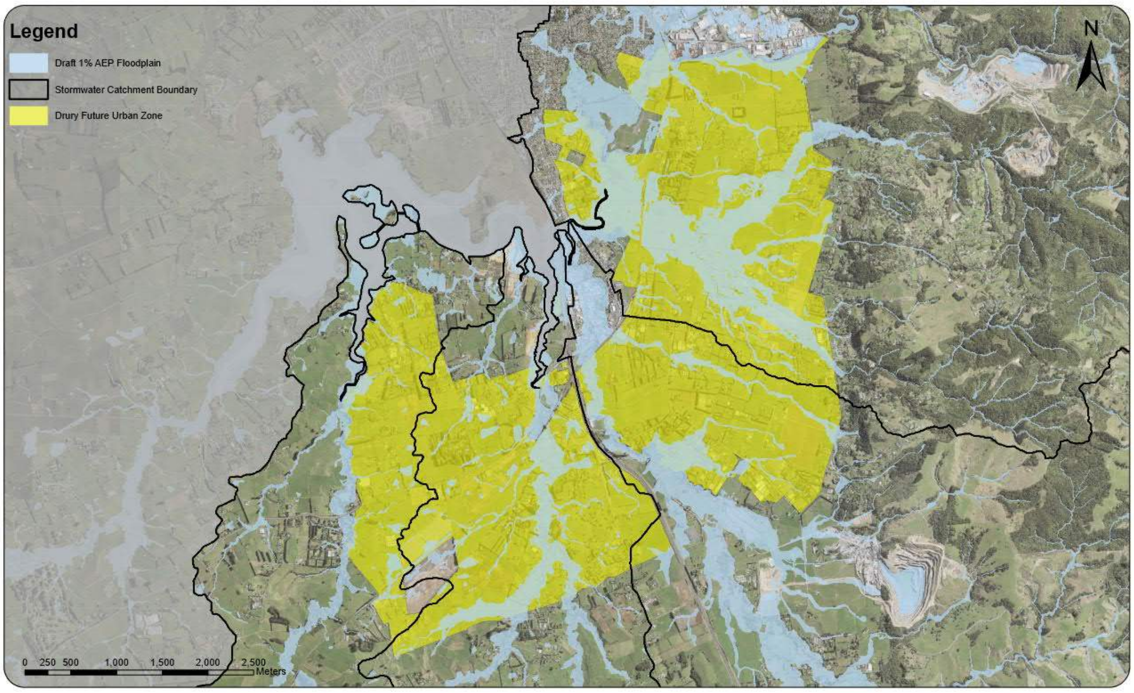


Figure ES 2 Drury Structure Plan Area Floodplains

Outcomes Sought

The key stormwater management outcomes sought for the Structure Plan Area are presented in Table ES1 below:

Table ES1: Key Stormwater Management Outcomes Sought

Outcome	Additional Information and guidance includes:
To protect and enhance the environment and to connect communities to water	B2.7.1 (2) AUPOP E1.2 AUPOP E1.3.10 AUPOP
Ecological values are maintained or enhanced Stream health is maintained or enhanced through improved baseflow	B7.3 and B7.4 of the AUPOP E1.2 AUPOP E1.3.2 AUPOP E15.2.1 AUPOP E1.3.8, AUPOP Guidance for Water Sensitive Design (GD04), Auckland Design Manual
Urban development is facilitated, key infrastructure protected and people and the environment protected from significant flooding events	E36.2 AUPOP Detailed flood hazard modelling
Stormwater is integrated with other land uses and values so that the amount of land available for development is maximised	E1.3.10 AUPOP E38.22 (f) & (g)
Sediment into sensitive receiving environments is minimised	E1.3.8 AUPOP E1.3.10 AUPOP E11.7 AUPOP D9.6.(f) AUPOP

Outcome	Additional Information and guidance includes:
	B7.4.1(4) AUPOP TP124
Contaminants into the sensitive receiving environments of the Drury Sands aquifer and Manukau harbour are minimised	D2, AUPOP B7.4.1(4) AUPOP E1.3.8 and E1.3.10 AUPOP

Stormwater Management Requirements Summary

General

Development to be carried out using an integrated stormwater management (in accordance with E1.3.8 and E1.3.10 of the AUPOP) approach i.e. water sensitive design as the design basis. This will enable the aforementioned constraints, risks and opportunities to be appropriately addressed.

Water Quality

- Freshwater and sediment quality is maintained where it is excellent or good and progressively improved over time in degraded areas in accordance with Section E1.2(1) of the AUPOP.
- Treatment of all impervious areas (excluding non-contaminant generating areas such as patios) to be provided at or near source using devices such as swales, rain gardens, tree pits. Runoff to be treated prior to discharge to the council system or directly to receiving environments (such as aquifers).
- Use inert building materials.
- Contaminant specific treatment devices are required for industrial or trade activities in accordance with E33 of the AUPOP.
- Sediment and erosion control measures, in accordance with GD05, are to be provided during earthworks and construction, including individual lot construction. This stage is a major risk of sediment contamination to the receiving environment. It is critical that permitted activity standards are applied and monitored at small sites.
- Integrated green outfalls to be used when discharging to streams. These can help to mitigate thermal pollution and erosion.

Minimising and mitigating hydrological change

- Changes in hydrology are avoided as far as practicable and any changes in hydrology are minimised or mitigated (in accordance with E1.3.8 of the AUPOP).
- The minimum requirement when hydrological mitigation is necessary is in accordance with Table E10.6.3.1.1 of the AUPOP.
- Erosion assessments are to be carried out as part of detailed SMPs. The purpose of these assessments is to determine if additional measures (such as additional detention requirements) are required to mitigate the hydrological impacts of development. If additional measures are found to be required these shall be provided. This information will be required to support Plan Change processes.
- Stream erosion management may require staging of development so that the bottom of the catchment is developed first and stream bank strengthening is carried out in tandem. Council may consider collaborating or contributing to stream works in the event of multiple developers in the same sub-catchment.

Streams

- Protect and enhance all permanent and intermittent streams as directed in the AUPOP.
- A minimum 10m planted riparian margin shall be provided either side of intermittent streams and a minimum 20m riparian margin either side of permanent streams.
- Prepare natural stream channels for future storm flows through bioengineered erosion protection works.
- Watercourse margins should be sufficiently sized to allow space for gentle sloping embankments and revegetation of riparian margins.
- Outfalls should be pulled back from the streams where possible to allow for dispersal of flows and to disconnect impervious surfaces from the receiving environment to form part of a treatment train approach.
- Provide distributed stormwater outlets into watercourses rather than single discharge points.
- Barriers to fish passage occur at perched or steeply inclined culverts. Redevelopment presents an opportunity to remediate this issue through the removal and replacement of problem culverts. Further details can be found in the relevant Water Course Assessment Reports .
- Integrate bioengineering to increase habitat values for fish.
- Improve inanga spawning habitat.
- Incorporate shared cycle/walkways along riparian corridors to improve connectivity to key recreational and transport infrastructure.
- Upgrade and install all required inlets and outlets to appropriate inlet outlet standards including: TR2013-18 (Hydraulic Energy Management Inlet Outlet Design for Treatment devices); GD2015/004 (Water Sensitive Design for Stormwater); SWCoP 2015 (Auckland Council Stormwater Code of Practice for Land Development and Subdivision.
- Retain existing stream meander patterns and reintroduce stream meanders and naturalisation where possible. Avoid any further channel straightening.
- Address erosion issues, both erosion hotspots and culvert erosion before and/or as urban development occurs. Details for each watercourse is provided in the relevant Watercourse Assessment Report.
- Carry out maintenance of existing culverts such as structural repairs, vegetation clearance and provision of erosion protection. Details are provided in the Watercourse Assessment Reports.
- For essential stream crossings, bank-to-bank bridges with minimal riparian and stream bed disturbance are preferred.
- Implement Enhancement Opportunities.
- Development of the FUZ should ensure that fish passage is maintained and where possible enhanced between the coastal marine area and natural stream management areas. This is in accordance with D4 of the AUPOP.

Slippery Creek

- Manage willows to reduce erosion from flow diversion, debris jams, and improve fish passage to upstream high value habitat. Further information can be found in Management Zone 1 of the Watercourse Assessment Report (WAR).
- Investigate lower reaches of the main channel of Slippery Creek for potential inanga spawning habitat and potential for enhancement.

- Protect and enhance areas with remnant mature indigenous trees particularly at WAI_MAIN_6, SYM_MAIN_7, SYM_MAIN_14-16. Further information can be found in Management Zone 1 of the Watercourse Assessment Report.
- Increase channel sinuosity between WAI_MAIN_12 and WAI_MAIN_18. Refer to Watercourse Assessment Report for further information
- Ensure fish passage is provided for where suitable.

Hingaia Stream

- Investigate potential point sources of faecal bacteria to urban/peri-urban streams and identify any necessary maintenance requirements. This would be Council led.
- Improve aquatic habitat in the northern tributaries by naturalising modified streams and removing potential barriers.
- Ensure ecological, amenity and stormwater management linkages are established between existing, developing and urban areas.

Ngakoroa Stream

- Progressively replace willows with native plantings where possible in order to maintain bank stability and stream shading while improving riparian vegetation condition. Refer to Management Zone 1 of the WAR for further information.
- Remove redundant farm culverts during development. Refer to Management Zone 2 of the WAR for further information.
- Investigate potential to implement esplanade reserves on Pahurehure Inlet tributary and Tributaries 3 and 8 as part of development. Refer to Management Zone 2 of the WAR for further information.

Oira Creek

- Improve access to public land around the coastal margin.
- Enhance potential inanga spawning habitats.

Flood Management

General

- Modelling has identified that a number of structures will be inundated during a 10 year and or 100 year ARI MPD CC event. Signage is to be provided at these structures indicating that the road is flood prone. Potentially a warning light when flood waters exceed a certain water level (or some other warning method) could also be implemented.
- All buildings to be outside the 100 year ARI floodplain in accordance with E36.3.17 of the AUPOP.
- Avoid locating infrastructure in the 100 year ARI floodplain unless it can be designed to be resilient to flood damage.
- Ensure all development and changes within the 100 year floodplain do not increase adverse effects or increased flood depths or velocities to other properties upstream or downstream of the site.
- Avoid increasing flood risk and flood extent upstream and downstream for all flood events up to the 100 year ARI.
- Identify overland flowpaths and ensure that they remain unobstructed and able to safely convey runoff.

- Use capacity available in riparian margins as part of the water conveyance system and enhance intermittent streams to provide capacity and conveyance as a means to manage flood waters.

Slippery Creek

Due to the significant flood plain within Slippery Creek, development should be limited to land outside the flood plain. The flooding issues within this catchment require development of a comprehensive solution to avoid effects of cumulative development.

Hingaia Stream

The general management approach (for the FUZ) will be to pass forward large storm event flows. However, existing culverts along the northern Hingaia Stream tributary will need to be upgraded to enable this management approach. Modelling indicates that passing flows forward will not impact on downstream (Drury township) flood levels for the 100 year ARI MPD CC event.

Further investigations are underway to determine the extent and timing of the required upgrades.

SH1 Bridge Upgrade – modelling indicates that increasing the flow conveyance of the bridge will result in a drop in water levels in Drury township during a 100 year ARI MPD event (including climate change). Engagement with the Supporting Growth Alliance is ongoing.

Norrie Road Bridge Upgrade - modelling indicates that increasing the flow conveyance of the bridge will result in a drop in water levels in Drury township during a 100 year ARI MPD event (including climate change).

Great South Road Bridge Upgrade - modelling indicates that increasing the flow conveyance of the bridge will result in a drop in water levels upstream of the bridge.

Drury West

The general management approach (for the FUZ) will be to pass forward large storm event flows.

1 Introduction

This document builds on the Preliminary Opaheke-Drury Stormwater Management Plan[1] (SMP) and outlines stormwater management requirements for the Drury-Opaheke Future Urban Zone (FUZ). It has been developed in conjunction with the Pukekohe-Paerata SMP prepared by WSP-OPUS and utilises text from that report.

1.1 Purpose of this Stormwater Management Plan

The purpose of this SMP is to:

- Support the Drury Opaheke Structure Planning process by providing a robust analysis of stormwater issues and management measures across the four stormwater catchments, based on current, best available information.
- Direct the stormwater management response in the context of the Drury-Opaheke catchment's receiving environments, proposed development and existing stormwater management issues and opportunities.
- Give effect to the objectives and policies of the Auckland Unitary Plan Operative in Part (AUPOP).
- Promote water sensitive design principles during development to create water sensitive communities. Inform the community of how stormwater management will be changing in the future.

1.2 Scope of this Stormwater Management Plan

This document captures the current knowledge, thinking and best practice at this time. As intended land use becomes more certain and knowledge improves, the SMP will be updated to reflect this and feedback from the community and mana whenua.

The scope of this SMP includes:

- Current state information about the catchments and receiving environments;
- Information on constraints and opportunities for development;
- Key stormwater management requirements to deliver on the AUPOP;
- Knowledge gaps and next steps.

It should be noted that this SMP identifies stormwater management requirements that are known at this time (without detailed knowledge of proposed landuses). Consideration of different types of proposed land uses will potentially change or add to stormwater management requirements. This SMP will be refined in more detail through an iterative plan change process. There are still a number of knowledge gaps that need to be filled.

1.3 Stormwater Management Outcomes Sought for the Structure Plan Area

Table 1 below highlights the key stormwater management outcomes sought for the Structure Plan Area.

[1] (AECOM New Zealand Ltd (19 September 2017))

Table 1: Key Stormwater Management Outcomes Sought

Outcome	Method	Additional information and guidance
To protect and enhance the environment and to connect communities to water	Follow integrated stormwater management guidance. Create water sensitive communities through water sensitive design and at source stormwater management and treatment	B2.7.1(2) AUPOP E1.2 AUPOP E1.3.10 AUPOP
Ecological values are maintained or enhanced. Stream health is maintained or enhanced through improved baseflow	Incorporate existing landforms (e.g. streams, floodplains, wetlands) and ecological corridors into stormwater infrastructure and urban design. Maintain pre development hydrology as directed in the Auckland Unitary Plan. Follow Water Sensitive Design guidance in designing stormwater management options	B7.3 and B7.4 of the AUPOP E1.2 AUPOP E1.3.2 AUPOP E15.2.1 AUPOP E1.3.8, AUPOP Guidance for Water Sensitive Design (GD04), Auckland Design Manual
Urban development is facilitated, key infrastructure protected and people and the environment protected from significant flooding events	Development in the Slippery Creek floodplain is avoided. Existing pre development hydrology is maintained through mechanisms such as discharge to ground, use of permanent and intermittent streams for flood management. Future climate change impacts accounted for by taking the latest guidance into consideration when planning development and associated infrastructure, including stream and floodplain capacity and associated development setbacks Undertaking works to improve drainage and flood control Control of nuisances and inappropriate interference of watercourses Development layout must consider overland flow paths The design and placement of new transport infrastructure or upgrading of existing needs to account for flooding events. Development of suitably detailed Flood Hazard Modelling to determine the above and test potential stormwater management options.	E36.2 AUPOP Detailed flood hazard modelling
Stormwater is integrated with other land uses and values so that the amount of land available for development is maximised	Complementary land uses such as passive recreation, stormwater conveyance, protection of habitats and active transport networks are identified through structure planning	E1.3.10 AUPOP E38.22 (f) & (g) AUPOP
Sediment into sensitive receiving environments is minimised	Riparian margins are planted Exemplar sediment and erosion measures are provided during construction Erosion Assessments of streams carried out to inform design of how best to address channel stability issues	E1.3.8 AUPOP E1.3.10 AUPOP E11.7 AUPOP D9.6.(f) AUPOP B7.4.1(4) AUPOP TP124

Outcome	Method	Additional information and guidance
Contaminants into the sensitive receiving environments of the Drury Sands aquifer and Manukau harbour are minimised	Require treatment prior to discharge to ground in the Drury Sands quality sensitive aquifer area. Retention of first flush similar to SMAF requirements across all development to both manage hydrology and reduce contaminants.	D2, AUPOP B7.4.1(4) AUPOP E1.3.8 and E1.3.10 AUPOP

1.4 Report Layout

The report has the following layout:

- Section 2 sets out the planning context – stormwater management in the Auckland context, water sensitivity and water sensitive design, the development context, the statutory direction (eg AUPOP), local board direction and Iwi input.
- Section 3 describes the existing catchment characteristics such as land use, topography, hydrological (i.e. stream) and stormwater network, stream ecology, erosion and water quality, receiving environments and flooding issues. In addition, constraints and opportunities associated with development of the future urban zone are identified.
- Section 4 discusses implementation of an integrated stormwater management approach for the future urban zone.
- Section 5 identifies the next steps for refining the SMP as areas are brought forward for development.

2 Planning Context

2.1 Stormwater Management – The Auckland Context

The Auckland Plan 2050 is Auckland's long-term spatial plan to ensure that Auckland grows in a way that will meet the opportunities and challenges of the future. Auckland Council has developed the Auckland Plan 2050 with, and on behalf of, all Aucklanders.

High population growth and environmental degradation are two of the three key challenges identified in the Plan. These challenges have implications for stormwater.

Six outcomes are identified in the Plan in which Auckland must make significant progress so that Auckland can continue to be a place where people want to live, work and visit. Stormwater management and protection of waterways are a component of each these outcomes. Refer Figure 1 below.

Figure 1 Auckland Plan Outcomes and Associated Alignment with Healthy and Connected Waterways

The Environment and Cultural Heritage outcome is that Aucklanders preserve, protect and care for the natural environment as our shared cultural heritage, for its intrinsic value and for the benefit of present and future generations

Direction 3 of this outcome directs to use growth and development to protect and enhance Auckland's natural environment.

The focus areas of this outcome include:

- Focusing on restoring environments as Auckland grows
- Protecting Auckland's significant natural environments from further loss
- Using green infrastructure to deliver greater resilience, long-term cost savings and quality environmental outcomes.

Urban development and climate change are two specific issues (identified in the Auckland Plan) that will continue to have the biggest effect on our environment. Increasing green infrastructure across Auckland together with moving to a low carbon economy has been identified (in the Auckland Plan) as things that can be done to reduce the impacts and costs of climate change. Increasing green infrastructure *will improve water management, reduce flood risk and deliver spaces that people want to visit and connect to*.' Green infrastructure is a component of water sensitive design.

The Auckland Plan identifies that implementing Water Sensitive Design (WSD) has benefits for freshwater and marine receiving environments.

The use of a WSD approach provides the strategies and tools to help support delivery of the Auckland Plan outcomes.

2.2 Water Sensitivity and Water Sensitive Design

The concept "Water Sensitivity" is a shift in the focus of stormwater management from removing or disposing of stormwater as fast as possible via built infrastructure, to recognising the value of stormwater, its close interrelationship with natural freshwater systems, and how it can enhance the liveability of our communities and cities.

Water sensitive communities are sustainable, resilient, productive and liveable (Co-operative Research Centre for Water Sensitive Cities, n.d.)

A water sensitive community will:

- Value stormwater as an essential part of our built environment and our freshwater system.
- Commit to water sensitive and low impact design during new development and redevelopment of land which promote at source treatment and mimic predevelopment hydrology.
- Maintain and enhance the health of streams, groundwater and coastal waters.
- Manage and build resilience to flood hazards with a risk based approach to flood protection and control through the protection of flood plains, overland flow paths, and appropriate land use.
- Embrace the Maori cultural and spiritual significance of water and value the mauri of water, as well as the amenity, open space and community values.
- Contribute to the integration and interaction of communities with their streams and coastal areas.
- Explore use and reuse of stormwater as part of total water cycle management, including harvesting, cleaning and reusing stormwater in public open spaces.
- Contribute to biodiversity, carbon footprint reduction and reduction of urban heat island effects through use of green infrastructure and natural systems (Harrison Grierson, 2016).

2.2.1 Water Sensitive Design

Water sensitive design (WSD) is an inter-disciplinary design approach, which considers stormwater management in parallel with the ecology of a site, best practice urban design and community values. WSD has a positive environmental impact and ensures multiple public benefits from stormwater management whilst developing a unique 'sense of place' for our communities. It also seeks to deliver low risk, higher resilience and better return on investment for land developers.

WSD approaches focus on reducing or eliminating stormwater runoff generation through source control, and utilising natural systems and processes to manage stormwater quantity and quality effects. It utilises a combination of conventional stormwater infrastructure, green infrastructure and enhanced natural systems to achieve the best practical stormwater management outcome.

In the Auckland region, WSD represents the best practice approach for stormwater management, taking into consideration whole-of life costs. WSD is Auckland Council's preferred approach to stormwater management.

Guidance on WSD is provided by Auckland Council Guideline Document 2015/004 Water Sensitive Design for Stormwater (GD04). It provides guidance for the application of WSD to land use planning and development (including device design), with a specific focus on stormwater and freshwater.

The sensitivity of the marine and freshwater receiving environments is a key consideration of Water Sensitive Design.

WSD provides an approach which will contribute to achieving the outcomes of The Auckland Plan. It is supported by rules in the AUPOP.

2.2.2 Urban Water Principles and Values

The following 10 high-level urban water principles and values, developed by an Urban Water Working Group convened by the Ministry of the Environment, reflect Auckland's Water Sensitive Design Guidance (GD04). The development of these principles is to support the creation of water sensitive urban spaces:

1. Protect and enhance ecosystem health of all receiving environments.
2. Co-design with nature an integrated and regenerative approach to urban development
3. Address pressures on waterbodies close to source.
4. Recognise and respect mana motuhake – the whakapapa and relationship that mana whenua have with water ecosystems in their rohe.
5. Identify and consider the community values for urban water and reflect them in decision-making.
6. Optimise environmental, social and cultural benefits when investing in buildings and infrastructure
7. Uphold and foster kaitiakitanga and custodianship of urban water ecosystems
8. Collect and share information to promote common understanding of urban water issues, solutions and values
9. Increase resilience to natural hazards and climate change.
10. Conserve and reuse water resources.

Further information on the above can be found on the (New Zealand) Ministry for the Environment website.

2.3 Development Context

The Auckland Plan 2050 (published in June 2018) identifies that the population of Auckland could increase by another 720,000 people within the next 30 years. An additional 313,000 dwellings would be required to accommodate the population increase.

Auckland Council's strategy for growth in Auckland includes the urbanisation of the Future Urban Zone (FUZ) around Drury and Opaheke. Approximately 1900ha around the Drury area has been zoned Future Urban Zone under the Auckland Unitary Plan Operative in Part (AUPOP). Refer Figure 2.

The Opaheke-Drury Structure Plan will outline and guide how and when development will occur within the Opaheke-Drury FUZ. Opportunities and constraints will be identified by the relevant disciplines to inform the Opaheke-Drury Structure Plan. The structure plan will inform the future pattern of land use, transport and service networks and plan changes to enable development.

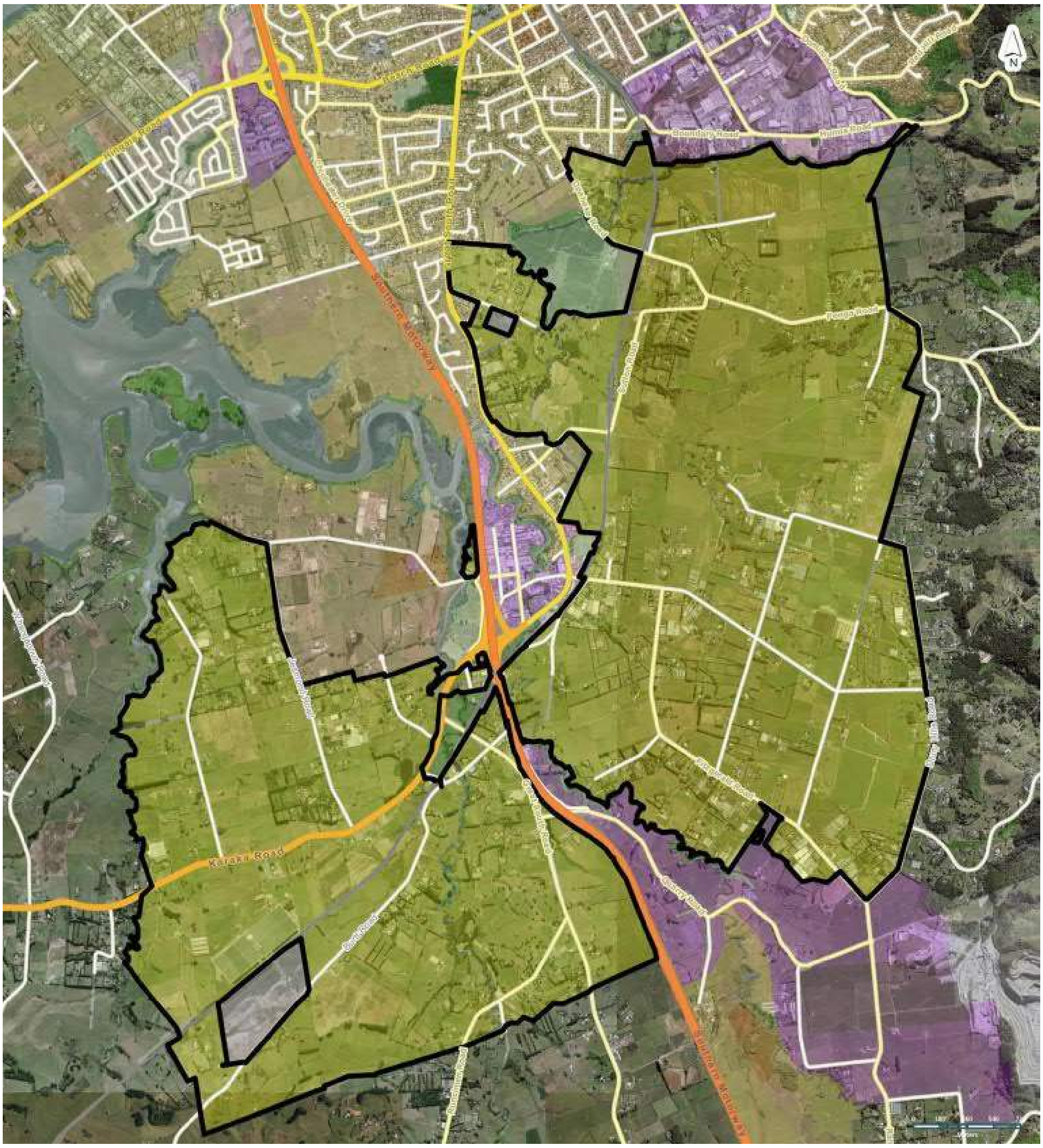


Figure 2 Drury-Opaheke Structure Plan Area

The Auckland Future Urban Land Supply Strategy (FULSS) (Auckland Council, 2017) set out a programme for sequencing future urban land development over 30 years across Auckland. The FULSS identifies three stages of development for the Drury Opaheke Future Urban area: Drury West Stage 1, Drury West Stage 2 and Opaheke-Drury. Refer Figure 3.

It should be noted that the FULSS was superceded by the Development Strategy in the 2018 Auckland Plan refresh. This has not affected the Drury Future Urban Zone extents or anticipated development timeframes.

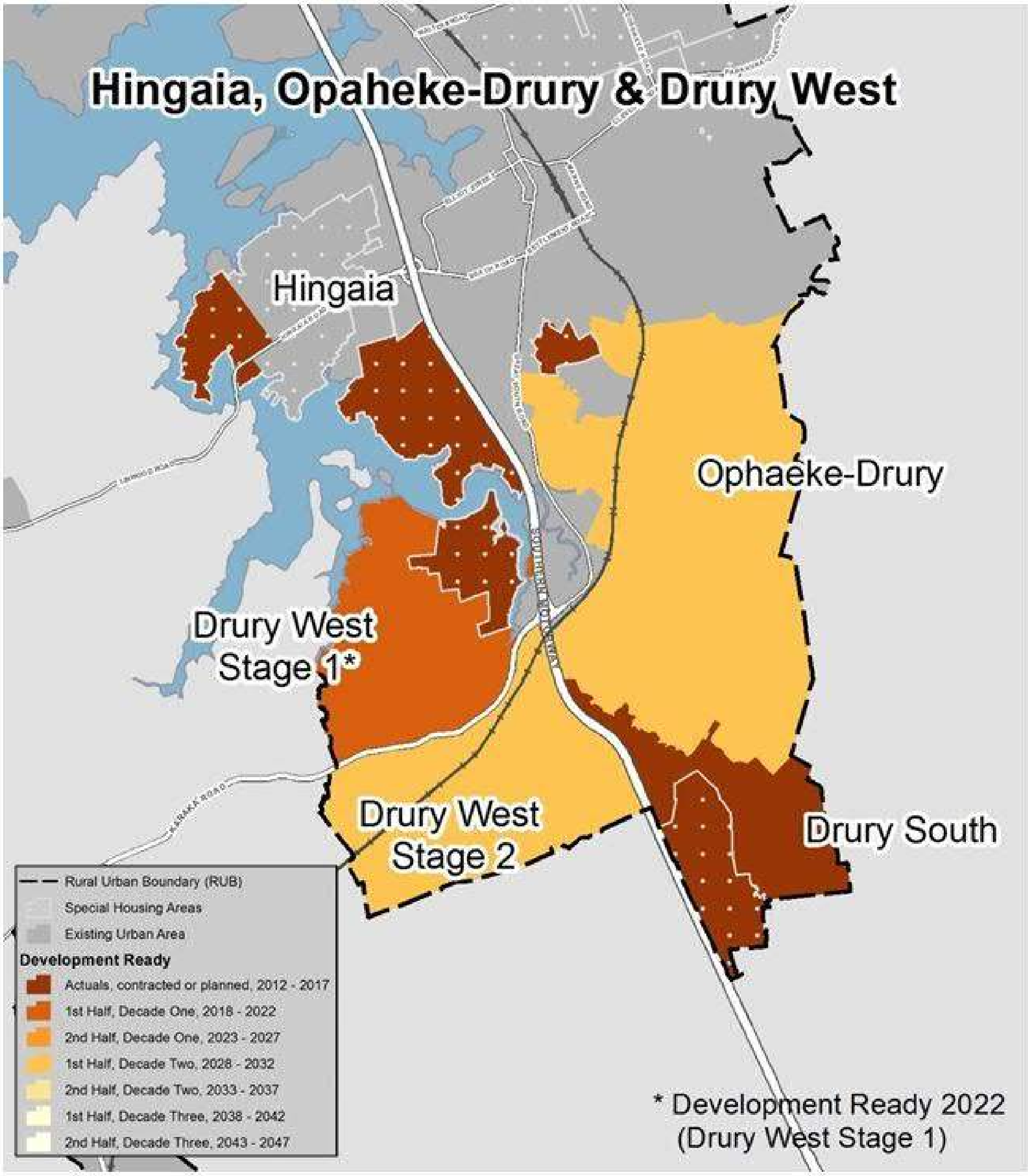


Figure 3 FULSS sequencing for Drury Structure Plan area

Drury West Stage 1 will consist of approximately 4200 dwellings across 392ha and is sequenced to be development ready from 2022.

Drury West Stage 2 will consist of approximately 5650 dwellings across 552ha and is sequenced to be development ready by 2028-2032. An industrial zone located adjacent to the motorway is proposed for the eastern part of Stage 2.

Opaheke-Drury will consist of approximately 8200 dwellings across 1149ha and is sequenced to be development ready by 2028-2032. It is sequenced later as there are significant flooding issues in the Opaheke area.

The Auranga SHA, located in the north -east corner of Drury West Stage 1, is currently under construction as is the Drury South development which is located between SH1 and the Opaheke Drury FUZ.

2.4 Statutory Direction for Integrated Stormwater Management

Stormwater Management in this SMP is guided by several statutory documents including the:

- National Policy Statement for Freshwater Management 2014 (amended 2017) (NPS-FM);
- New Zealand Coastal Policy Statement 2010 (NZCPS);
- Auckland Unitary Plan Operative in Part (AUPOP); and
- Regional Policy Statement (RPS).

The requirements of the NPS-FM relevant to this SMP include:

- Consider and recognise Te Mana o te Wai in freshwater management;
- Safeguarding fresh water's life-supporting capacity, ecosystem processes, and indigenous species;
- Taking an integrated approach to managing land use, fresh water and coastal water;
- Safeguarding the health of people who come into contact with the water;
- Protecting the significant values of wetlands and freshwater bodies;

The stormwater related objectives of the NZCPS include:

- Safeguarding the integrity, form, functioning and resilience of the coastal environment and sustain its ecosystems, including marine and intertidal areas, estuaries and land;
- Taking account of the principles of the Treaty of Waitangi, recognise the role of Tangata Whenua as Kaitiaki;
- Maintaining coastal water quality and enhancing it where it's degraded due to discharges associated with human activity;
- Enabling people and communities to provide for their social, economic and cultural wellbeing and their health and safety through subdivision, use and development.

The NPSFM, NZCPS and RPS are being implemented in Auckland through the AUPOP.

The Auckland Unitary Plan objectives require maintaining freshwater and coastal systems, where they are excellent or good, and enhancing them where they are degraded

The goal is to provide for growth in a manner that will not only prevent further degradation but improve conditions.

2.4.1 Auckland Unitary Plan Operative in Part

The Auckland Unitary Plan Operative in Part (AUPOP) is the principal statutory document for Auckland. It combines the regional policy statement, regional coastal plan, regional plans and district plans into one combined plan. The plan has a hierarchical policy framework with the regional policy statement at the top, then with regional and district plan provisions giving effect to the regional policy statement.

This SMP is guided by a number of provisions within the AUPOP. These include:

2.4.1.1 AUPOP Chapter B Regional Policy Statement (RPS)

Indigenous biodiversity (B7.2)

Parts of the Slippery Creek and Ngakoroa catchments have a Significant Ecological Areas Overlay (terrestrial). The Drury Estuary has a Marine 1 and Marine 2 Significant Ecological Areas Overlay. Refer Figure 4.

The objectives of the RPS seek to protect areas of significant indigenous biodiversity from the adverse effects of subdivision use and development and that indigenous biodiversity is maintained through protection, restoration and enhancement in areas where ecological values are degraded or where development is occurring.

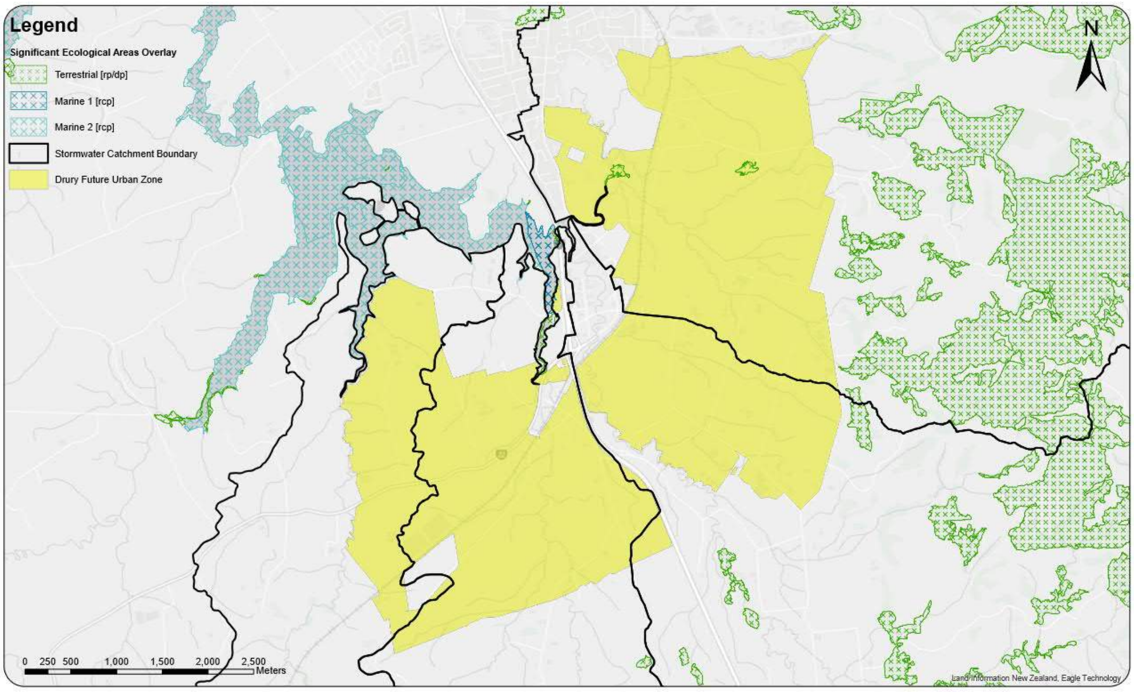


Figure 4 Significant Ecological Areas

Freshwater Systems (B7.3)

There are significant freshwater systems located within the Future Urban Zone. The objectives of the RPS seek to:

- enhance degraded freshwater systems;
- minimise loss of freshwater systems;
- avoid, remedy or mitigates the adverse effects of changes in land use on freshwater.

It should be noted that the AUPOP provides a broad definition of freshwater systems, defining them not only in terms of the freshwater body itself but also the elements that contribute to its values and functions, including riparian margins and floodplains.

Coastal water and freshwater (B7.4)

The objectives seek to:

- maintain the quality of freshwater and coastal water and improve it where it is degraded; minimise the adverse effects of stormwater runoff;
- reduce existing adverse effects;
- avoid, remedy or mitigate adverse effects from changes in land use; and
- recognise Mana Whenua, matauranga and tikanga associated with coastal water and freshwater.

The RPS identifies areas of coastal water that have been degraded by human activities. Drury Estuary is identified as being Degraded 1.

Environmental risk – natural hazards and climate change (B10)

Objectives include not increasing risks from natural hazards to existing developed areas, allowing for the effects of climate change on natural hazards, protection of floodplains from inappropriate subdivision and maintaining conveyance functions of overland flowpaths.

2.4.1.2 AUPOP Chapter E Auckland Wide

Water quality and integrated management (E1)

The focus of these provisions is to avoid adverse effects as far as practicable, particularly in greenfield developments where there are greater opportunities to do so. Where it is not practicable to avoid adverse effects, the provisions seek to minimise them and to reduce existing adverse effects when the opportunity is provided by redevelopment.

The objectives include maintaining freshwater and sediment quality where it is excellent or good and improve it in degraded areas, maintain or progressively improve the mauri of freshwater and managing stormwater networks to protect public health and safety and to prevent or minimise adverse effects of contaminants on freshwater and coastal water quality.

The (freshwater) policies to support this include managing discharges, subdivision, use and development to maintain or enhance water quality, flows, stream channels and their margins and other freshwater values where the current condition is above the relevant Macroinvertebrate Community Index (MCI) in Table E1.3.1 or enhancing water quality, flows, stream channels and their margins and other freshwater values where the current condition is below the relevant Macroinvertebrate Community Index (MCI) in Table E1.3.1.

Policy E1.3.3 requires freshwater systems to be enhanced unless existing intensive land use and development has irreversibly modified them such that it practicably precludes enhancement

Policy E1.3 (8) discusses stormwater runoff from greenfield development. It promotes avoiding as far as practicable, or otherwise minimising or mitigating adverse effects of stormwater runoff on freshwater systems, freshwater and coastal water by

- *"Taking an integrated stormwater management approach (refer to Policy E1.3.10)*
- *Minimising the generation and discharge of contaminants, particularly from high contaminant generating carparks and high use roads and into sensitive receiving environments*
- *Minimising or mitigating changes in hydrology including loss of infiltration to minimise erosion, maintain stream baseflows and support groundwater recharge*
- *Where practicable, minimising or mitigating the effects on freshwater systems arising from changes in water temperatures caused by stormwater discharges"*

An integrated stormwater management approach (Policy E1.3.10) considers all of the following:

- *"The nature and scale of the development and practical and cost considerations*."
- The location and design of site and infrastructure to protect significant site features and minimise effects on receiving environments.
- *"The nature and sensitivity of receiving environments*."
- *"Reducing stormwater flows and contaminants at source*."
- The use and enhancement of natural hydrological features and green infrastructure where practicable.

Other relevant stormwater policies include:

- avoiding as far as practicable or otherwise minimising or mitigating adverse effects of stormwater diversions and discharge (Policy E1.3.11);
- managing contaminants in stormwater runoff from high contaminant generating car parks and high use roads (Policy E1.3.12);
- requiring stormwater quality or flow management to be achieved on-site unless there is a downstream communal device (Policy E1.3.13);
- adopting the best practicable option to minimise the adverse effects of stormwater discharges (Policy E1.3.14);
- utilising stormwater discharges to ground soakage where it is possible to do so in a safe, and effective manner (Policy E1.3.15);

2.4.1.3 Lakes, rivers, streams and wetlands (E3)

The management of the beds of rivers, stream and wetlands *is important for the protection of natural ecological and biodiversity values, for the efficient passage of flood flows and the retention of high-water quality, Retaining the natural profile and course of a river or stream, keeping riparian vegetation and fish passage and avoiding sediment generation supports the retention of freshwater ecosystems.*

Rivers and streams *provide an important component for the assimilation and conveyance of stormwater and form part of the overall stormwater network.*

The Unitary Plan requires that permanent loss is minimised and significant modification or diversion of rivers, streams and wetlands are avoided.

The objectives relevant to this SMP include:

- *Auckland's lakes, rivers, streams and wetlands with high natural values are protected from degradation and permanent loss (E3.2.1).*
- *Auckland's lakes, rivers, streams and wetlands are restored, maintained or enhanced* (E3.2.2).

2.4.1.4 Natural hazards and flooding (E36)

This section sets out the objectives and policies relating to management of natural hazards and flooding. The relevant policies include:

- Avoid locating buildings in the 100 year ARI floodplain (E36.3.17)
- Requiring earthworks within the floodplain to do all of the following:

(a) "*remedy or mitigate where practicable or contribute to remedying or mitigating flood hazards in the floodplain;*

(b) not exacerbate flooding experienced by other sites upstream or downstream of the works; and

(c) not permanently reduce the conveyance function of the floodplain (E36.3.20)."

2.4.1.5 Overlays

There are a number of overlays across the FUZ which need to be considered in the design of the stormwater management approach.

High use Aquifer Management Area Overlay (D1)

This overlay applies to a significant portion of the FUZ. Refer Figure 5. The aquifers are highly allocated, providing water to users as well as being major sources of spring and stream flow. The key relevant objective of this overlay is that aquifers be managed so that "*they can continue to meet existing and future water take demands and provide base flow for surface streams*."

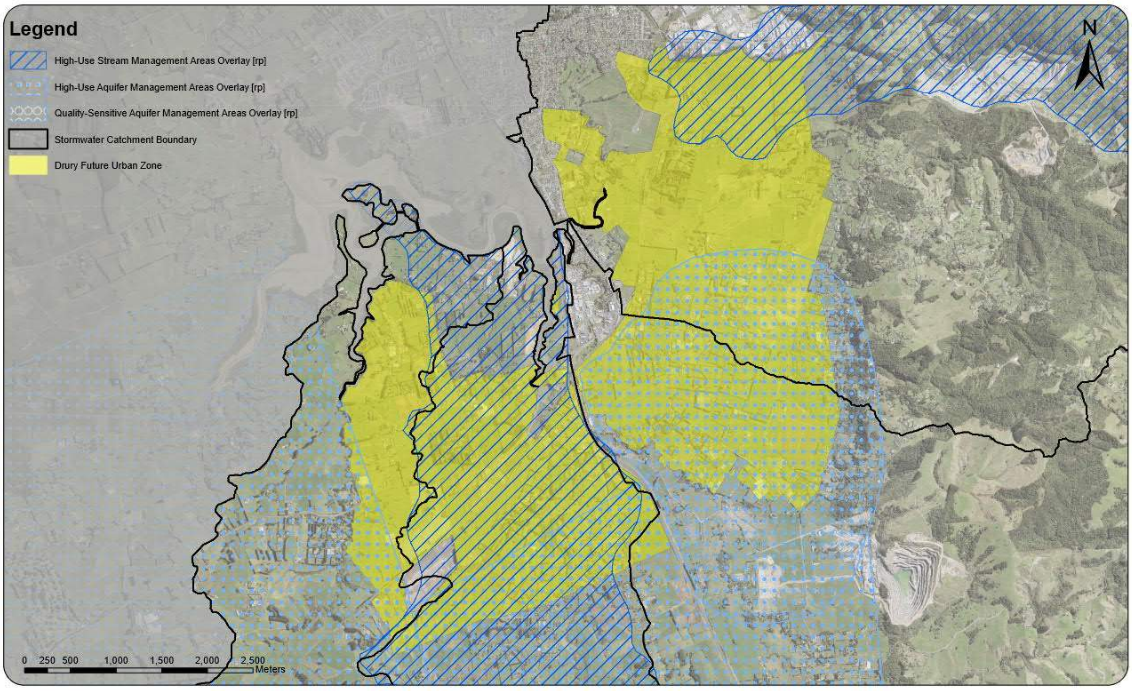


Figure 5 High Use Stream, High Use Aquifer and Quality-Sensitive Aquifer Management Areas,

Quality-sensitive Aquifer Management Area Overlay (D2)

A quality sensitive aquifer management area (Drury Sand) is located beneath part of the Hingaia Stream and Slippery Creek FUZ catchments. Refer Figure 5. It is shallow and unconfined and therefore susceptible to pollution from discharges of contaminants such as stormwater. The key objective of this overlay is that the quality and quantity of water in quality-sensitive aquifer management areas be protected from contamination. The relevant stormwater policy's are to:

- recognise the sensitivity of the Drury Sands aquifer to groundwater contamination,
- minimise the discharge of contaminants to this aquifer and
- Discourage *"the discharge of contaminants where they are likely to have significant adverse effects on groundwater quality"*.

High-use Stream Management Areas Overlay (D3)

Ngakoroa Stream and Hays Creek have a High-Use Stream Management Overlay applied to them. This is discussed further in Section 3.6. The key objective of this overlay is that "*water continues to be available from high-use streams within limits while safeguarding the life-supporting capacity and amenity of the stream.*"

Natural Stream Management Areas Overlay (D4)

Natural Stream management areas are present in the upper catchments of Slippery Creek, Hingaia and Ngakoroa Streams. Policy D4.3 (3) requires that fish passage be maintained and where possible enhanced between the coastal marine area and the upstream extent of natural stream management areas. Development of the FUZ should ensure that fish passage is maintained and enhanced between the coastal marine area and natural stream management areas.

Significant Ecological Areas Overlay (D9)

Significant Ecological Areas - Terrestrial (SEA-T) have been identified in the Slippery Creek, Hingaia Stream and Ngakoroa Stream catchments. In addition Drury Creek is a Significant Ecological Area (Marine). These are areas identified as having significant indigenous vegetation or significant habitats of indigenous fauna located in the coastal marine area.

The objectives of the AUPOP seek to:

- Protect these areas "*from the adverse effects of subdivision, use and development*";
- Enhance the indigenous biodiversity values of these areas; and
- Recognise the relationship of mana whenua.

The management of vegetation and biodiversity outside of identified significant ecological areas is subject to the provisions of E15 Vegetation management and biodiversity

2.5 Network Discharge Consent

Auckland Council has applied for a single region-wide Network Discharge Consent (NDC). Once granted the NDC will provide a comprehensive set of regionally consistent requirements to deliver the outcomes specified in the consent and will align with the Auckland Plan and Auckland Unitary Plan.

2.6 Local Boards

The Papakura and Franklin Local boards are part of the Manukau Harbour Forum, a collective of the nine local boards that border the Manukau Harbour. Strategic objectives for the Manukau Harbour Forum include raising the profile of the Manukau Harbour and its importance as a cultural, environmental and economic treasure. They also advocate for integrated management of the Manukau Harbour to be incorporated into all planning frameworks and new Manukau Harbour projects.

2.6.1 Papakura Local Board

Slippery Creek and part of the Hingaia Stream catchment are located within the Papakura District Local Board.

The Papakura Local Board Plan (2017/2018 Local Board Agreement) identifies six key outcomes including the goal that Papakura will be well-connected and easy to move around. To further this goal the Papakura Greenways Plan (Papakura Local Board, 2016) identifies the

Board's long term plan to develop a network of paths and cycleways to connect communities within the Board area. The Plan includes a pathway within the esplanade reserve along the western (true left) bank of the Hingaia Stream mouth, north of Great South Road with linkages to the coastal edge of Drury Creek and to Slippery Creek.

Another key outcome for Papakura is that the area will be treasured for its environment and heritage. To further this goal the Papakura Board will champion green drainage systems such as new wetlands with the ultimate goal of improving the health of Manukau Harbour and its catchment streams (Morphum Environmental, 2015)

Under the Auckland Council Long Term Plan, Papakura Local Board has identified the following priority projects that are relevant to this watercourse assessment report (Auckland Council, 2015):

- Development of Pahurehure Inlet cycle and walkways
- Continued development of the Opaheke Sportsfields

The Papakura Local Board objectives generally align with the direction set through this SMP.

2.6.2 Franklin Local Board

Specific aspirations of the Franklin Local Board Plan (2017) and initiatives relevant to Drury West (Ngakoroa and Oira) include:

- To enhance, protect, and maintain our diverse natural environment and make sure it's able to be enjoyed.
  – - Focus on improving water quality through working with local communities
  – - Support good pest management practices through education and help local groups with pest control initiatives
- Growth is dealt with effectively
- Communities feel ownership and connection to their area

The Franklin District Local Board recognises that the waterways within the region have significant importance to mana whenua and local residents, and are a resource to be utilised, used and enjoyed. The Local Board is committed to improving water quality within the region, and in general improving the overall state of its watercourses (Franklin Local Board, 2014). As part of its Cherished Natural Environment Outcome the Local Board is keen to support community initiatives such as plantings to enhance rivers, streams and coastlines (Franklin Local Board, 2014).

2.7 Engagement with Iwi

Mana whenua have enduring aspirations to protect and enhance te mauri o te wai (the life-supporting capacity of Auckland's waters) as kaitiaki, and activity should be undertaken to ensure a net improvement of mauri in Drury/Opaheke. This includes, but is not limited to, protecting and enhancing the environment by:

- limiting development around awa to maintain access, preserve amenity, retain views and protect water quality;
- promoting resilient and water sensitive communities through water sensitive design that encourages water conservation;
- ensuring activity allows for the recharge of aquifers with uncontaminated water (such as the use of pervious paving);

- preserving sensitive and high value areas (such as floodplains, areas of indigenous vegetation and wetlands); and
- ensuring cumulative impacts and effects have been considered and measured at all steps.

The direction provided here should be used to provide guidance on what key aspects must be addressed or considered prior to engaging with mana whenua and does not replace genuine engagement.

3 Catchment Characteristics, Constraints and Opportunities

Stormwater characteristics and constraints are described through this section, supported by mapping. Key stormwater management messages to inform the Structure Plan are **highlighted** through this section and summarised in the Executive Summary. Appendix A includes mapping at a finer scale for reference.

The key stormwater constraints, risks and opportunities for development within the Structure Plan Area are summarised below and described further in the following sections.

Constraints include:

- Existing flooding of parts of the FUZ and downstream urban areas such as Drury township;
- Extensive flood plains in the Slippery Creek Future Urban Area;
- Bellfield SHA within the Slippery Creek catchment is sensitive to increasing flows and water levels within its vicinity;
- Capacity constraints at bridges and culverts;
- Existing stream erosion issues across the FUZ. Urbanisation typically significantly exacerbates stream bank erosion (and associated impacts on water quality issues) unless carefully managed;
- Sensitive receiving environments, including aquifers.

Risks include:

- Increased erosion (and associated sedimentation) due to increased impervious areas is of particular concern due to the highly sensitive, low energy receiving environment of the Pahurehure Inlet.
- Decreased water quality, aquifer recharge and instream ecological values resulting from changes in land use and land development.

Opportunities include:

- Flood mitigation to reduce hazards and unlock development;
- Restoration and enhancement of watercourse;
- Retaining existing and increasing the vegetation buffering to natural watercourses to improve water quality and increase numbers and diversity of instream biota;
- Re-establish wetland ecosystems particularly in floodplains where wetlands would historically have occurred. Wetlands have excellent treatment and flood protection capabilities;
- Improve the water quality of stormwater reaching the Pahurehure Inlet through reducing contaminant loads (sediment, metals and nutrients);
- Improve ecological functionality in currently degraded areas, along with the ability to set aside areas for public amenity value and stormwater attenuation;
- Improve fish passage;
- Address existing erosion issues.

3.1 Land Use

The dominant land use within the four stormwater catchments is rural. This comprises grazed pasture with smaller areas of arable land and market gardens. Remnant forest stands are present in all four catchments, but these are limited in scale and distribution. The greatest extent of forest (exotic/native) is located in the Slippery Creek catchment (25% land use) and to a lesser extent, the Hingaia Stream catchment; in the foothills of the Hunua Ranges.

The catchments also include scattered residential and commercial properties and lifestyle blocks. The urban area of Drury Township is in the Hingaia Stream catchment and part of urbanised Papakura is in the Slippery Creek catchment. These towns form the most significant developed areas within the four catchments. Pukekohe is starting to expand into the upper reaches of the Oira Creek catchment. Additional notable land uses include the Stevenson quarry located within the Hingaia Stream catchment and the Winstone quarry located in the north eastern corner of the Slippery Creek catchment. Part of the Hingaia Stream catchment includes the Drury South industrial and residential areas currently under construction.

Significant infrastructure includes SH1 which runs north-south through the Hingaia catchment, and SH22 which runs approximately east-west passing through Hingaia, Ngakoroa and Oira catchments. The North Island Main Trunk (NIMT) Rail Line passes through all four catchments.

3.2 Topography and Catchments

The topography is divided into the Slippery Creek catchment, Hingaia Stream catchment, Ngakoroa Stream catchment and Oira Creek catchment.

The land within the FUZ is gently undulating with localised steep slopes typically being present adjacent to streams and the Pahurehure Inlet tidal zone (Riley Consultants, 2018). The topography across the majority of the catchments is characterised by low elevation gently undulating land. This excludes the flanks of the Hunua Ranges which extend through the headwaters of Slippery Creek and Hingaia Stream, where there is a mix of steep and gently contoured slopes.

There is a sharp change in topography from the steeper Hunua Ranges to the flatter low lying areas where the Drury Fault Line is located. The flat topography of the Future Urban Zone particularly within the Slippery Creek catchment contributes to extensive floodplains.

The topography generally falls towards Drury Creek which is the confluence of all of the streams within the Future Urban Area.

Although the catchments are largely within an area of low lying land, elevated landforms clearly separate each of the stream catchments. This is illustrated in Figure 6.

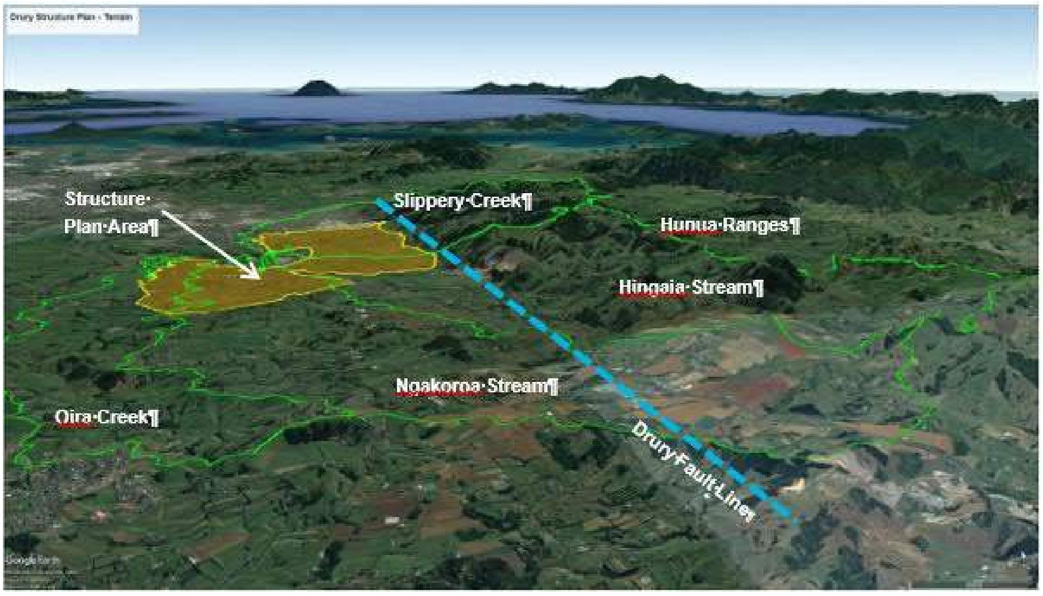


Figure 6 Drury Structure Plan Area - Terrain

3.3 Geology and Soils

The geology underlying the Structure Plan Area is illustrated in Figure 7. It is predominantly Puketoka Formation and basalt. Puketoka Formation comprises alluvial and estuarine deposits of sand, silt, clay and occasionally peat and organic topsoils. Smaller areas of mud and tuff (orange brown silty clay) are also present (Riley, 2017). The Drury Fault Line runs north to south through the Slippery Creek and Hingaia catchments and divides the flat lands from the foothills of the Hunua Ranges (Golder Associates, 2009).

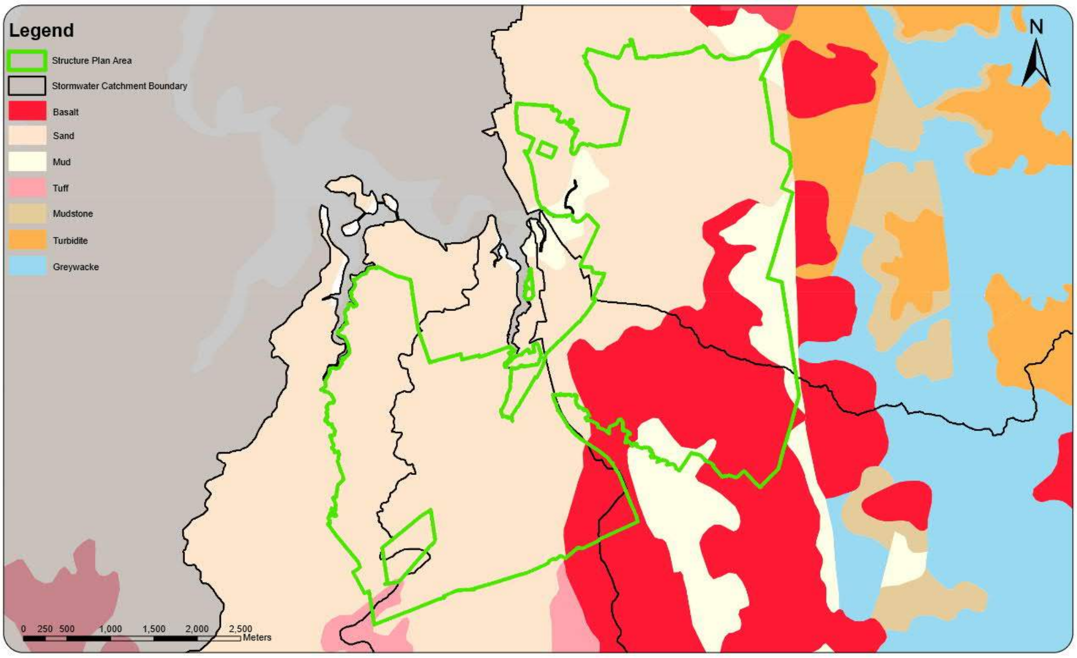


Figure 7 Opaheke-Drury Structure Plan Area - geology

The expected soil types within the FUZ can be seen in Figure 8 below.

Soil types across Auckland are classified (for hydrological modelling purposes) as hydrological soil groups A, B, C or D. Group A soils have low rainfall runoff potential and high infiltration rates whereas Group D soils have high runoff potential and very low infiltration rates. Group D soils will result in significantly more flood volumes and flows through a catchment.

The Franklin Area soils maps prepared by Landcare Research indicate that the Ngakoroa and Oira catchments are a mixture of hydrological soil groups A (granular volcanic loam), C (weathered mudstone and sandstone) and D (clay soils).

Work carried out by Landcare Research indicates that large portions of the Hingaia Stream catchment consists of group D soils.

The Slippery Creek catchment consists of Group B and C soils.

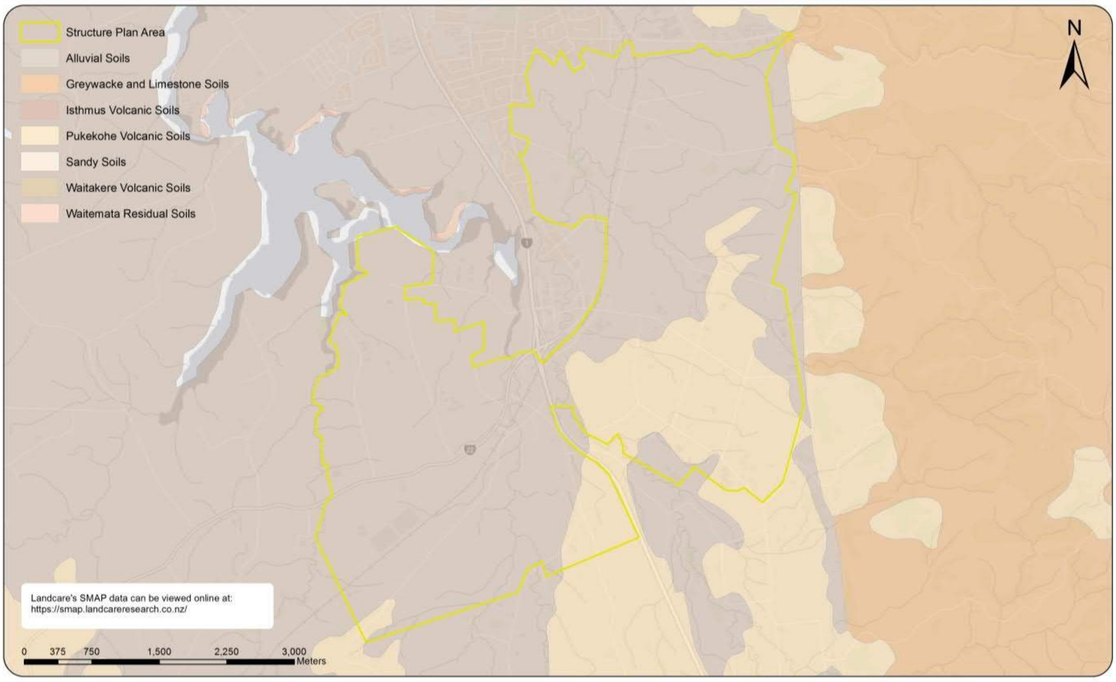
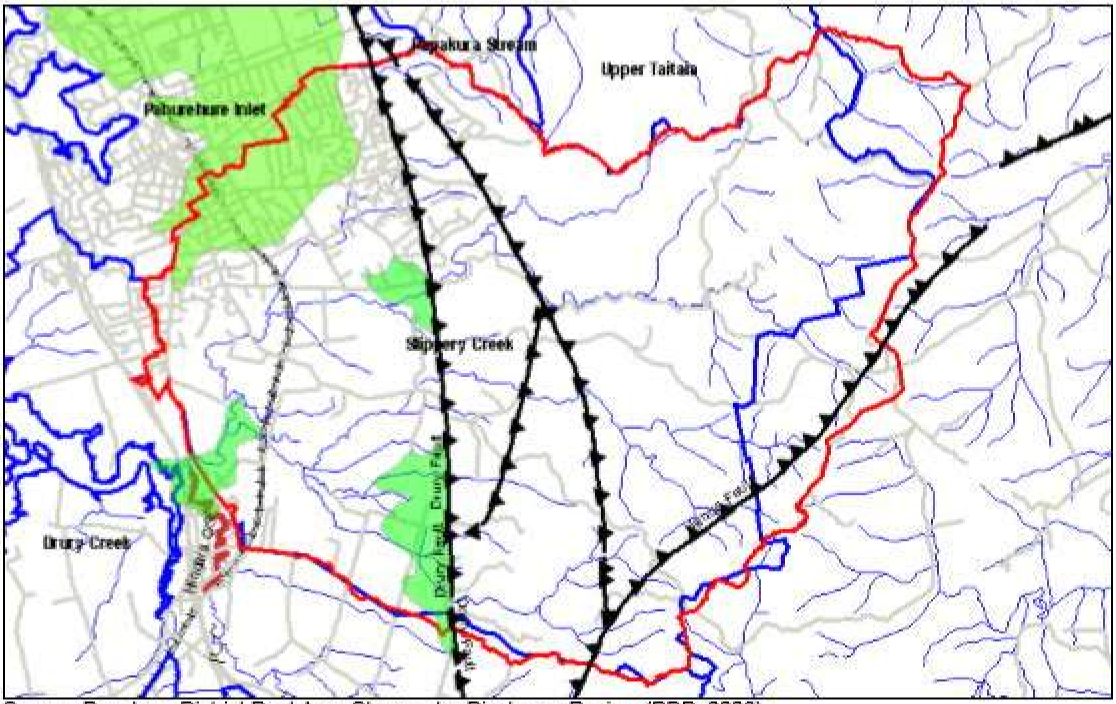


Figure 8 Opahe-Drury Structure Plan Area Soil Types

Peat soils may be present in parts of the FUZ of the Slippery Creek catchment. Figure 9 shows the indicative extent of peat soils (in green) in the Slippery Creek catchment. This figure was taken from the 2010 Slippery Creek Catchment ICMP which was prepared on behalf of Papakura District Council. It is a combination of data from the IGNS Geological Map and locally collected geotechnical data at PDC compiled by Pattle Delamore Partners Ltd (2006).



Source: Papakura District Peat Area Stormwater Discharge Review (PDP, 2006)

Figure 9 Indicative Slippery Creek Peat Soil Extent

As can be seen in Figure 7 parts of the FUZ in the Hingaia Stream and Slippery Creek catchments are underlain by basalt. These areas have been identified on Figure 9 of TR040: Stormwater Disposal via Soakage in the Auckland Region (Auckland Council, 2013) as “possible” locations for stormwater disposal via soakage.

The geotechnical report supporting the Structure Plan notes *groundwater is at variable depth across the study area. Within low-lying land, it is often near-surface in winter, whilst beneath elevated areas it can be at 10m+* (Riley Consultants, 2017).

The geological implications on stormwater management are:

- Discharge via soakage as the primary stormwater disposal method (i.e. 10% AEP storm event) in the Future Urban Zone is likely to be limited. Further investigations are required to confirm soakage disposal areas.
- Disposal of stormwater via soakage may also be limited by groundwater levels in low lying areas, such as floodplains, however, it is expected these areas will generally be kept free of development (refer Section 4.5.1).
- In addition, to limited soakage capacity in the FUZ, soakage locations will need to consider the sensitivity of the underlying aquifer (refer Section 3.6.2).
- Even if primary stormwater disposal via soakage is not practicable, infiltration of stormwater should be maximised, where practicable, to support recharge of the groundwater and underlying aquifers. This is in accordance with a Water Sensitive Design approach (refer Section 4).
- Development in areas underlain by peat soils (such as the lower Slippery Creek catchment) must allow for stormwater discharge to ground soakage to maintain underlying aquifer levels and the geotechnical stability of peat areas.

Further information on the geology and soils of the FUZ can be found in the geotechnical report supporting the Structure Plan.

Data on soakage and infiltration will be important in refining stormwater management in the Future Urban Zone as development planning and design is progressed.

3.4 Existing Hydrological and Stormwater Network

3.4.1 Hydrological Network Overview

The FUZ straddles four stormwater catchments:

1. Slippery Creek;
2. Hingaia Stream;
3. Ngakaroa Stream; and
4. Oira Creek.

These catchments can be seen in **Figure 10**.

Within this SMP the FUZ area that straddles four catchments has been amalgamated into three stormwater management areas: Drury West (Oira Creek and Ngakoroa Stream), Drury East (Hingaia Stream) and Opaheke (Slippery Creek). Refer **Figure 10**.

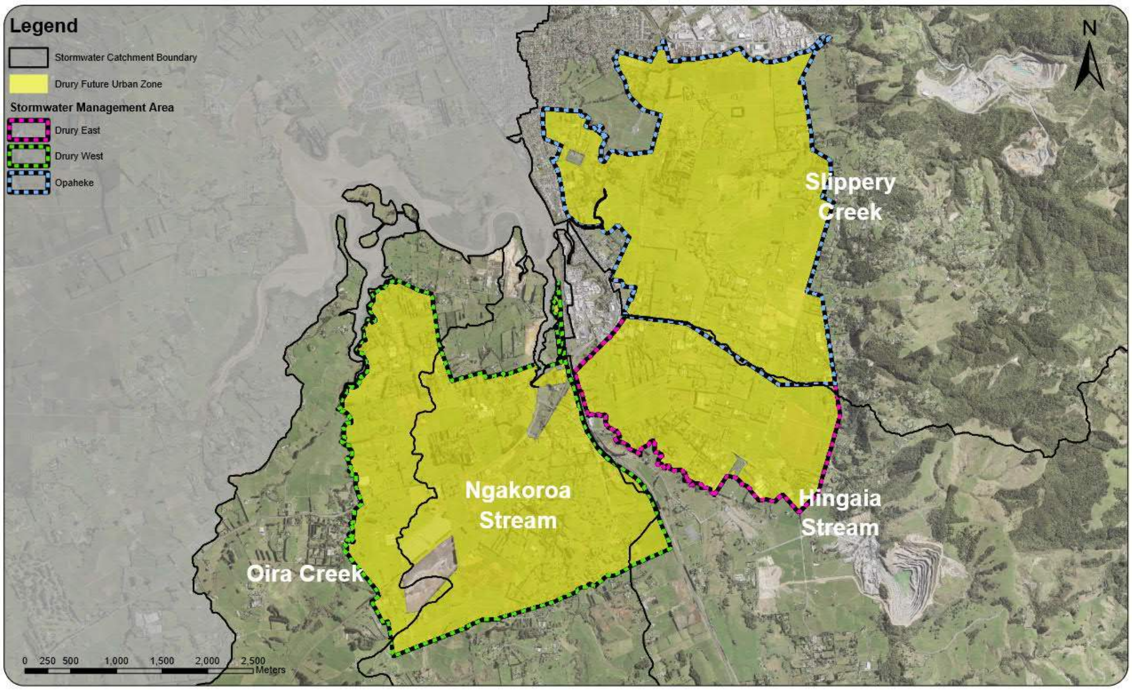


Figure 10 Drury Structure Plan Area - Stormwater Management Areas

Slippery Creek, Hingaia Stream and Ngakaroa Stream catchments are naturally hydrologically connected during high order storm events when water flows from one catchment to another upstream of the natural stream confluence. Slippery Creek overtops into Hingaia Stream upstream of Great South Road bridge. Ngakoroa Stream overtops SH1 into Hingaia Stream.

The permanent and intermittent streams within the FUZ (as identified in the Watercourse Assessments) are shown in Figure 11. Wetlands have also been shown.

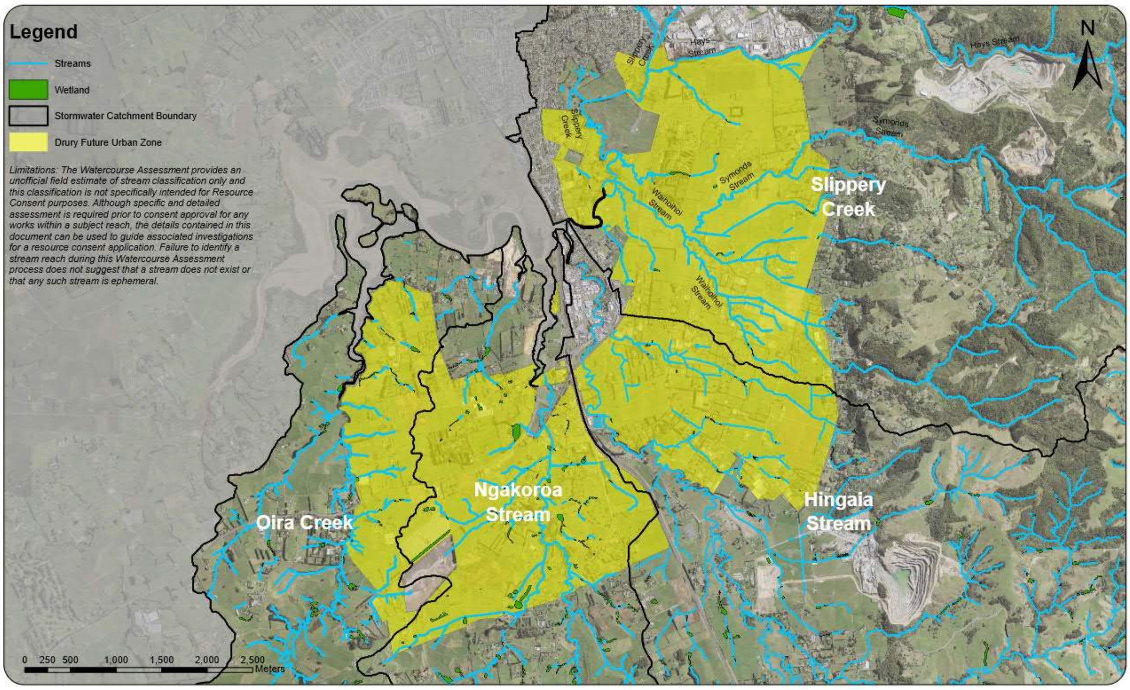


Figure 11 Drury-Opaheke Stormwater Management Plan Streams

3.4.2 Stormwater Network Overview

The public stormwater assets within the FUZ are sparse, and generally limited to road/rail crossings and stream crossings. Private stormwater structures are also present. The private structures include ponds, pipes, culverts, inlets and outfalls and serve to manage flow through agricultural land and to provide access to private properties and businesses.

3.4.3 Stormwater Catchments Descriptions

This section provides an overview of the hydrology and stormwater network for each of the catchments.

3.4.3.1 Slippery Creek Catchment

Key features of the Slippery Creek catchment include:

- Slippery Creek consists of four main tributaries - Croskery Road Drain, Hays Stream, Waihoihoi Stream and Symonds Stream. The lower reaches of the latter three tributaries are located in the FUZ. The Slippery Creek main channel starts at the confluence of the Hays Stream and the Croskery Road Drain just downstream of the Boundary Road Bridge.
- Catchment area of 46.3km², approximately 50% of which is currently pastoral, 30% forestry, 15% urban development (southern side of Papakura) and 4.4% special purposes (including the Hunua Quarry). The Future Urban Zone will increase the urban component to over 30% (with associated increase in flows).
- The stream system is the main drainage system for most of the catchment. The urban area of the catchment (southern side of Papakura) is reticulated.

- The low lying and flat downstream terrain coupled with high volumes of rainfall from the large upstream catchment results in significant areas of floodplains in the FUZ. This is discussed further in Section 3.7.1.
- A number of bridges and culverts along the watercourses that influence flooding. The railway embankment is also a flow constraint. .
- The presence of the Hays Creek Dam in the upper catchment which supplies potable water to part of Auckland. The dam impounds nearly 1 million m³ of water when operating at capacity (Jairaj, 1998). It also acts (inadvertently) as a stormwater attenuation device.

3.4.3.2 Hingaia Stream Catchment

Key features of the Hingaia Stream catchment include:

- Hingaia Stream rises at the crest of the Bombay Hills and flows northwards towards Drury township. Near its midpoint it is joined by Maketu Stream. At the northern end of Drury township, Slippery Creek meets Hingaia Stream. The two streams collectively become Drury Creek (Snelder, 1991).
- Catchment area of 57.5km², predominantly rural but with Drury township located at the bottom of the catchment and the recently consented Drury South development (which will comprise industrial and residential landuses) occupying approximately 361ha of the catchment upstream of the Future Urban Zone. Stevenson's quarry is located in the central area of the catchment.
- Waterways within the catchment include permanent streams, intermittent streams, artificial farm drains and amenity ponds, stormwater retention and treatment ponds, and natural wetlands. The streams in the eastern and southern portions of the catchment within the Hunua Ranges and foothills are higher gradient streams while the streams in the western and northern portions of the catchment are lower gradient streams (Golder 2010).
- The land within the FUZ comprises flat to gently rolling landforms, drained by two main tributary branches and bounded by the Hingaia Stream mainstem to the southwest (4Sight Consulting, 2018).
- The stream system is the main drainage system for most of the catchment. Drury Township is reticulated.
- A number of bridges and culverts along the stream and its' tributaries that influence flooding, as well as the railway embankment blocking overland flow (refer Section 3.7).

3.4.3.3 Ngakoroa Stream

Key features of the Ngakoroa Stream catchment include:

- The catchment is drained primarily by the Ngakoroa Stream which discharges to Drury Creek. The Ngakoroa Stream includes a large tributary which splits from the main branch in the Runciman area and extends south for approximately one-third of the catchment.
- Catchment area of 40.1km², predominantly rural but with the Auranga SHA located at the bottom of the catchment which is currently under construction.
- The lower 3 km of the main Ngakoroa Stream is dominated by mature willows which provide bank stability however in some areas, these have formed large debris jams and are creating back-waters and pools. In these areas, the willow canopy extends across the full width of the channel.
- Due to the gentle topography of the area, freshwater systems tend to be low order, low energy watercourses connected to large wetland areas. These waterways serve vital

drainage and flood protection functions throughout this landscape (Morphum Environmental Ltd, 2018).

- Overall the catchment is highly modified, with historical vegetation clearance resulting in only small, fragmented pockets of native vegetation remaining. Modified stream channels are evident throughout the catchment, with the most common form of modification being straightening to increase conveyance. Modified channels are more common within market gardening areas, as well as the Future Urban Zone where a number of the lower reaches of the Ngakoroa West tributary have been straightened as part of historical wetland drainage (Morphum Environmental Ltd, 2018).
- The presence of online ponds and dams throughout the catchment.
- A number of bridges and culverts along the watercourses that influence flooding as well as the railway corridor embankment blocking overland flow (refer Section 3.6).

3.4.3.4 Oira Creek

Key features of the Oira Creek catchment include:

- Comprises 61 km of watercourse, of which 81% is classified as permanent or intermittent stream.
- Catchment area of 20.3km², predominantly rural but with some development and public stormwater networks at the top of the catchment. Future urban zones are located at the top of the catchment (Pukekohe-Paerata Future Urban Zone) and at the bottom (Drury-Opaheke Future Urban Zone);
- Stream characteristics (assessed as part of a Watercourse Assessment Report – discussed in Section 3.5) were reflective of the current agricultural nature of the catchment with a limited intactness of the riparian vegetation and low stream shading, a lack of stream fencing, widespread signs of stock damage and stream bank erosion and multiple weed infestations.

3.5 Ecology, Erosion and Water Quality

There are a number of streams upstream, within and downstream of the Future Urban Zone area. These play a critical role in the conveyance of runoff as well as providing ecological, cultural and amenity value within the catchments.

A number of stream assessment studies have been undertaken for the streams within the Drury Structure Plan Area. These include the following:

- Slippery Creek Catchment Watercourse Assessment Report (Morphum Environmental for Auckland Council, 2015)
- Hingaia Stream Catchment Watercourse Assessment Report, Draft (4Sight Consulting and Urban Solutions, 2018)
- Hingaia Stream Classification Survey – 4Sight Consulting, 2018
- Ngakoroa Catchment Watercourse Assessment Report (Morphum Environmental for Auckland Council, 2018)
- Ngakoroa Watercourse Assessment Stream Classification Report (Morphum Environmental Ltd, 2017)
- Oira Catchment Watercourse Assessment Report, Draft (Kane-Sanderson et al, 2017)

The purpose of the Watercourse Assessment Reports (WAR) includes:

- providing Auckland Council with baseline information on the watercourses within the catchments, including built and natural features (such as culverts and wetlands),
- broadening the understanding of the current state of the watercourses,
- identifying key issues likely to be exacerbated by development,
- identifying enhancement opportunities and
- guiding ongoing management and enhancement of the watercourses.

A detailed description of the stream networks is provided in the Watercourse Assessment Reports (WARs). Some of the key findings of the WARs are discussed in the following sections.

Overall the watercourses within the FUZ have been heavily modified, lack riparian vegetation and suffer from bank stability issues, loss of habitat and poor water quality.

3.5.1 Ecology

This section summaries the ecology findings of the WAR's. Further information can be found in the WAR's.

Large scale land clearance and rural conversion has resulted in limited vegetation within the riparian margins of the FUZ. Pasture was the most commonly observed streamside vegetation. The average riparian width was largely less than 5 m. This severely reduces the riparian zone's ability to slow and spread overland stormwater runoff and filter out pollutants, including sediment laden runoff, before it enters the stream (4Sight Consulting, 2018).

The value of watercourses has been degraded by the removal of vegetation cover, increased sedimentation, nutrients from surrounding land use, and in some areas, channel modification and the draining of wetlands (Morphum Environmental Ltd, 2018). Hence, there are significant opportunities for stream enhancement.

A Stream Ecological Valuation (SEV), which is a method of assessing the ecological health of streams, was carried out at a number of locations within the FUZ. The SEV scores varied from 'moderate' to 'low' ecological value ranges. These low scores are reflective of modification to the riparian vegetation through agricultural land use, limited instream habitats due to lack of shading cover, sediment inputs to the streams and low biodiversity.

The Macroinvertebrate Community Index (MCI) is an index of stream health based on the type and number of macroinvertebrates (animals such as insects, crustaceans, snails and worms) that live in streams. Macroinvertebrates have been used extensively for the assessment of river health and the MCI has been adopted in the AUPOP as a guideline for freshwater ecosystem health. The MCI values (within the FUZ) tended to be below the AUPOP MCI guideline value for rural land use adopted for the Auckland region (MCI of 94). This indicates that the SEV sites were below that typically associated with rural land uses in Auckland. In the circumstance where the current stream condition is below guideline values, the AUPOP directs that water quality, flows, stream channels and their margins and other freshwater values be enhanced.

Development of the FUZ offers the opportunity to enhance stream channels and their margins.

Enhancement opportunities have been identified in the WARs and in Section 4.2 of this report. Cumulatively these projects will improve water quality and flow capacity leading to improved amenity and ecology.

Six species of native fish were observed during the site works phase of the watercourse assessments. Unidentified eels, bullies, galaxiids and fish that could not be recorded to any level were also recorded. Longfin eel and two small schools of inanga were observed in the Hingaia Stream catchment. Both species have been identified as ‘At Risk – declining’ in the most recent threat classification list. Inanga were the most abundant native fish observed in the Slippery Creek and Oira catchments. Areas of potential inanga spawning habitat (within the FUZ) that could be enhanced were identified in the WAR’s. These are discussed further in Section 4.2. Gambusia (also referred to as mosquitofish) were observed in the Oira catchment. These are an exotic species classified as an ‘unwanted organism’ by the Biosecurity Act (1993). A total of eight species of native fish, four species of exotic fish, plus the native freshwater crayfish koura have been recorded for the Ngakoroa catchment.

Fish passage barriers have been identified across the FUZ. Their locations have been identified in the WAR’s.

Development of the FUZ offers the opportunity to address fish passage barriers across the FUZ.

Two terrestrial Significant Ecological Areas (SEAs) occur within the Slippery Creek FUZ. These have been identified as priority sites for protection and enhancement under the Auckland Council Biodiversity Focus Area Ecosystem Prioritisation Framework.

Three areas of noteworthy indigenous vegetation were observed within the low land agricultural areas of the Slippery Creek catchment, a patch of kahikatea, a remnant stand of karaka, broadleaf forest and kahikatea. None of these areas are designated significant ecological areas.

Four SEA’s border (or extend into) the Future Urban Zone of the Ngakoroa catchment. Two are Terrestrial SEAs consisting of remnant forest fragments and two are Marine SEAs containing areas of coastal and riparian vegetation associated with the inner Drury- Creek and the top of Ngakoroa Stream. A terrestrial SEA is located south of Bremner Road bridge and north of SH22 which has both rare and threatened flora and fauna species.

The Ngakoroa Stream mouth has been designated ‘SEA-M1’ which means that it has been assessed to be particularly vulnerable to the negative environmental impacts of inappropriate subdivision, use and development.

Historical vegetation clearance of the Ngakoroa catchment has resulted in only small, fragmented pockets of native vegetation remaining.

Development of the FUZ offers the opportunity to protect areas of existing vegetation and plant riparian corridors to extend and connect existing Significant Ecological Areas.

These measures will enhance ecological values, improve water quality and flow conveyance, leading to improved amenity

Willows are present within the Slippery Creek and Ngakoroa Stream catchments. These can block structures (such as bridges), exacerbate erosion issues, block fish passage and obstruct stream and flood conveyance. Managing willows has been identified as a general goal and objective for these catchments.

Wetlands (predominantly artificial) are present across the FUZ. Development offers the opportunity to protect and enhance existing wetland areas of value.

3.5.2 Erosion

Bank stability and erosion is a significant issue for most of the FUZ.

Most of the streams within the FUZ (excluding the Ngakoroa Stream catchment) were assessed as having either a ‘fair’ or ‘poor’ Pfankuch bank stability score (refer Figure 12) which would indicate the potential for ongoing erosion and slumping issues. Given the existing erosion issues within the FUZ, it is considered that application of SMAF 1 will not provide adequate hydrological mitigation. Therefore, additional measures (such as additional detention requirements, floodplain management or in-stream works) may be required to minimise and / or mitigate erosion. This is discussed further in Section 4.3.

Bank stability within the FUZ of the Ngakoroa catchment was assessed to be ‘fair or ‘good’.

As can be seen in Figure 12 erosion hotspots were identified across the FUZ. These areas are actively eroding and pose a potential risk to stream health and or safety. The majority of hotspots (across the Hingaia Stream catchment) had formed as a direct response to increased water flow during flood events.

Erosion has occurred and will continue, potentially exacerbated by development within the FUZ.

Development of the FUZ presents an opportunity to enhance the stream environments to mitigate erosion and improve habitat values.

There is large-scale soil loss and erosion of cultivated land (within the Ngakoroa catchment) with the consequent sedimentation of receiving environments including streams throughout the catchment and the Pahurehure Inlet. The WAR identified the presence of a high level of deposited loose sediment along the stream reaches. In some places this loose sediment reached 0.7 m in depth and smothered the stream bed completely (Morphum Environmental Ltd, 2018).

The Ngakoroa stream mouth was recorded as a low-energy environment. Sediment load modelling by Green (2008), indicated that sediment loads are largely deposited within these low energy ‘settling zones’ in the upper sections of the Ngakoroa stream mouth. In combination with the nearby Slippery Creek and Hingaia Stream catchments, the Ngakoroa catchment is the primary source of sediment to the harbour (approximately 65% of total) (Green, 2008). These values have the potential to increase with future urban development proposed in the catchment (Morphum Environmental Ltd, 2018).

Sediment modelling reported in TR2008/058 (Green, 2008) predicted that the average sediment runoff into the Pahurehure Inlet from the Drury sub-catchment (comprising Slippery Creek, Hingaia Stream and Ngakoroa Stream catchments) would be 3,229,387 kg per year. This totalled 322,938,656 kg over the 100-year simulation. An increase in sediment runoff from urban sources within Drury sub-catchment was also predicted (Green, 2008). This modelling did not allow for additional urbanisation of the catchment (such as development of the Future Urban Zone) from what was present in 2008.

Reducing erosion and sediment discharge is a key priority for the FUZ and other catchments draining to Drury Creek.

Auckland Council are developing a continuous, process-based model for water quality contaminants including sediment (total suspended sediment), spanning the region and developed from a sub-catchment basis – the Freshwater Management Tool (FWMT). The FWMT will be able to resolve sedimentary loading by sub-catchments including Drury Creek, with expected output on current sediment loading by mid-2019, but with expectations for ongoing revisions to better resolve causes for and behaviour of contaminants across the region's waterways (e.g., improved resolution of causes for erosion and processes transforming sediment instream). This FWMT will complement earlier modelling by Green (2008) in understanding the rates of sediment loss to and delivery by Drury Creek, from which to estimate the effects instream or in-harbour on ecosystem processes and organisms.

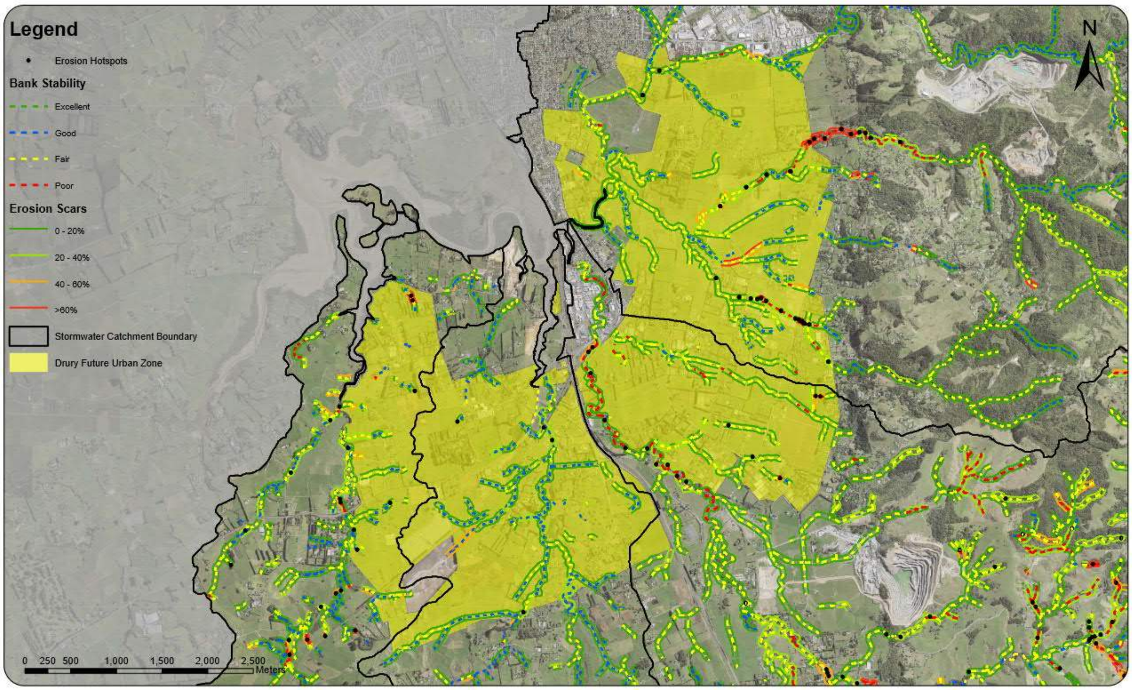


Figure 12 Erosion Issues within the FUZ

3.5.3 Water Quality

Water sampling carried out as part of the Slippery Creek Watercourses Assessment found concentrations of zinc exceeded the ISQG low threshold at a sampling site within the Future Urban Zone. This indicates that adverse biological effects could occur and provides an early warning for management intervention. The zinc concentration was nearly five times greater than when the same site was sampled in 2006. Copper concentrations had also doubled in that timeframe.

Sediment and water quality testing of one of the SEV sites within the Hingaia Stream catchment found elevated levels of zinc and copper (above ERC Red and Amber alert levels respectively).

Heavy metal concentrations appear to have increased between testing carried out by Golder in 2009 and testing carried out as part of the 2018 Hingaia Stream WAR. Total recoverable zinc was 100 mg/kg dry wt in 2009 but was 186 mg/kg dry wt at a similar location in 2018, a value that is now above the ERC Red Zone. These results are not truly comparable but may provide an indication of the trend through time in zinc concentrations (4Sight Consulting, 2018)

E. coli levels exceeded the MfE Action/Red Mode threshold at the SEV sites (within the Hingaia Stream catchment) indicating an increased risk of water-borne infection during the time of sampling.

E.coli levels (300 cfu per 100mm) at one of the SEV sites within the Ngakoroa Streams FUZ correspond to a low risk of infection from contact with water during activities with occasional immersion or ingestion of water e.g. wading and boating

The Drury sub-catchment is a significant generator of metals. It was predicted to be the third largest source of zinc to the harbour. About 25% of sediment from Whangapouri Creek, Oira Creek and the Drury sub-catchment deposits in Drury Creek. The fate of zinc and copper largely mirrors that of sediment (Green, 2008). This will result in an increase in metal concentrations in Drury Creek.

Development of the FUZ offers the opportunity to address existing contaminant issues and reduce the discharge of metals to Drury Creek.

3.6 Receiving Environment

The FUZ discharges to the local stream network which subsequently discharge to Drury Creek and then the Pahurehure Inlet of the Manukau Harbour. Runoff from the FUZ also discharges to the underlying aquifers.

The local streams as receiving environments are discussed in Section 3.5.

The Manukau Harbour and the aquifers are discussed below.

3.6.1 Manukau Harbour

Drury Creek and parts of the Pahurehure Inlet are identified as marine Significant Ecological Areas (SEA). These comprise a variety of intertidal habitats, including transitional zones from mangroves to salt marsh to freshwater and terrestrial habitats.

The area near the Hingaia Stream mouth is classified as a marine Significant Ecological Area (SEA-M1), indicating that it is a high value area that is very vulnerable to any adverse effects of inappropriate subdivision, use and development (Auckland Council, 2016).

The Oira Creek drains into the Drury Creek via a major tidal inlet. The tidal inlet servicing the Oira Creek forms part of the Drury Creek SEA-M2 which has been identified as significant due to the varied range of intertidal habitats and saline vegetation. The area is also considered as a suitable roosting site for pied stilts (AUPOP), 2016).

Additional information on the ecological values of the receiving environments can be found in the Watercourse Assessment reports.

The Pahurehure Inlet is a low energy receiving environment dominated by soft, fine sediments (Kelly, 2008) which settle out changing the structure of the sea bed and detrimentally impacting macroinvertebrate communities. Modelling indicates that the Drury sub-catchment is the primary source of sediment to the harbour. The erosion risk (and associated discharge and deposition of sediment), during earthworks and construction, associated with development is significant and has the potential to exacerbate existing sediment deposition issues both within and downstream of development.

Erosion and sediment control measures in accordance with GD05 for all scales of development are required. Small site sediment management and monitoring is critical to achieving sediment management outcomes.

Development of areas (such as the FUZ), which discharge to low energy estuarine receiving environment pose higher environmental risk to marine receiving environments because contaminants (typically sediment, trace metals, hydrocarbons and trace organics) rapidly accumulate in these zones with minimal mixing and dispersal from coastal processes, subsequently affecting marine health (Huls & Chin, 2016).

The ecological health of the Pahurehure was ranked as 'unhealthy' in a 2016 State of Auckland Marine Report card prepared for the Manukau Harbour by Auckland Council's Research and Evaluation Unit (RIMU).

The Auckland Council State of the Environment Report 2015 reported a continual decline (since the *State of the Auckland Region* report in 2009) in marine and freshwater health due to sediment and contaminants and the expanding footprint of urban Auckland.

There is concern about the long term degradation of the Manuaku Harbour as indicated by Council monitoring data with two red trigger levels (indicating relatively high levels of zinc, copper and lead), six orange trigger levels (indicating some elevation of zinc, copper and lead) and none green.

Given the sensitivity and existing degraded nature of the receiving environments exemplar water quality, hydrological, watercourse management and sediment and erosion control measures are required to be provided.

3.6.2 Aquifers

The following aquifers lie beneath the catchments:

- Kaawa aquifer - Oira Creek, Ngakoroa Stream and Hingaia Stream.
- Drury Sand Aquifer - Hingaia Stream and Slippery Creek.
- Bombay Volcanic Aquifer - Ngakoroa Stream and Hingaia Stream.
- Clevedon West Waimata Aquifer - Slippery Creek.

These aquifers are within a High-Use Aquifer Management Area and Quality Sensitive Aquifer Management Area as shown in the AUPOP overlays D1 and D2. Refer Figure 5. Oira Creek, Ngakoroa Steam and Hingaia Stream catchments are likely to be aquifer fed and could be affected by a reduction in aquifer recharge if not managed appropriately when development is undertaken.

The Drury Sand Aquifer is a 'Quality-Sensitive Aquifer Management' area. It is shallow and unconfined and therefore susceptible to pollution from surface sources such as excess fertiliser application or discharges of contaminants such as stormwater or sewage (4Sight Consulting, 2018). It is an important sources of water for rural and industrial purposes, as well as providing base flow to surface streams (Auckland Council, 2016). Therefore, aquifer recharge is important.

Development of the FUZ will require that treatment of stormwater runoff be provided prior to discharge to aquifers.

Part of the FUZ sits atop a High-Use Aquifer Management Area. Aquifers are an important contributor to the base flow of many streams, particularly in the southern parts of Auckland and provide important inputs into the overall quality and diversity of surface waterbodies (AUPOP), 2016). Aquifer recharge is reliant on rainwater infiltration and an increase in impervious surfaces, due to urban development may result in increased surface water runoff, and reduced infiltration that would ultimately contribute to aquifer recharge.

Development of the FUZ must consider aquifer recharge.

The Oira Creek is considered to be sensitive to changes in the amount of imperviousness within the catchment and an increase in imperviousness is likely to have a significant negative effect on the groundwater contribution to base flows within the creek (Pattle Delamore Partners Ltd, 2012).

3.7 Flooding and Coastal Inundation

3.7.1 Flooding

3.7.1.1 Historical Flooding

The Slippery Creek and Hingaia Stream catchments (including the Future Urban Zoned areas) have historically suffered from significant flooding. Drury Township and urban Papakura have also historically flooded.

The most recent flooding in the Slippery Creek and Hingaia Stream catchments occurred in March - April 2017. Prior to that significant flooding occurred in both catchments in 1966 and 1988. Storm events in other years have also been reported but they were not as significant as the events noted above.

The 1966 flooding destroyed the motorway bridge and resulted in both Great South Road bridges (over Slippery Creek and Hingaia Stream) being almost overtopped. The Norrie Road Bridge in Drury Township was also almost overtopped. It was assumed at the time that the 1966 flood was in the vicinity of a 50-year storm event (Snelder, 1991). At the time of the 1966 storm event most of the floodplain of the Hingaia Stream was used for pastoral farming. A report to the Franklin County Council in 1978 indicated that, prior to the area being zoned for development a number of floods had occurred. Because these did not impact greatly on landuse or properties, records had not been taken (Snelder, 1991).

The 1988 storm event was estimated to be a 40 year storm event. Considerable damage was caused to the industrial area of Drury township. In addition, houses in Miro Street (located at the bottom of the Slippery Creek catchment) were flooded and floodwater from Slippery Creek was reported to have flowed over Great South Road and through industrial properties on the opposite side of Great South Road.

During the 2017 storm event a large water tank was swept downstream in the upstream rural Hingaia catchment before getting stuck at a bridge (and so reducing the bridge conveyance capacity). Willow trees (and other exotic species) are currently planted in the rural area floodplains. These are easily knocked down during storm events and can block bridges andculverts. Future development of the FUZ should aim to remove tree species from floodplains that are prone to storm effects and debris production. This is discussed in the Watercourse Assessment Reports and in Section 4.2 of this report.

Catchment Interactions

The catchments have a complex hydrological relationship. The interconnectedness of the catchments can be summarised as follows:

- Slippery Creek and Hingaia Stream combine upstream of SH1 Bridge.
- Flood overflows occur from Slippery Creek into Hingaia Stream over Great South Road in larger flood events.

- Modelling of the 100 year ARI storm event (including climate change) indicates that Ngakoroa Stream will overtop SH1 (in the vicinity of Drury Township – between Great South Road Intersection with SH1 and the SH1 bridge) into Hingaia Stream followed by overtopping of Hingaia Stream into Ngakoroa Stream.

3.7.1.2 Hydrological and Hydraulic Modelling

Extensive hydrological and hydraulic modelling of the stormwater catchments has been carried out. The purpose of the modelling includes:

- Identifying the extent of the 100 year ARI floodplains;
- Identifying major infrastructure such as bridges and culverts which may be undersized and require upgrading;
- Assisting in identifying options to mitigate flooding.

Three stormwater models were used. These are the:

- Hingaia Stream model;
- Slippery Creek model; and
- Ngakoroa Stream and Oira Creek Hydraulic Model.

The models were developed in accordance with Auckland Council's Stormwater modelling Specification (2011) and consider maximum probable development land use scenarios and allow for a 2.1^{o}C rise in temperature and 1m sea level rise due to climate change in the future scenario. Importantly, the climate change allowances are based on the Ministry for the Environment 2008 Climate Change and Effects and Impacts Assessment. Consideration will need to be given to the latest climate change prediction allowances from Auckland Council, as development is brought forward.

The Slippery Creek and Ngakoroa - Oira models are Rapid Flood Hazard Assessment's (RFHA's).

The Hingaia Stream model is a detailed model. It is also the base model for the SMP and extends down to the Pahurehure Inlet. Outputs from the other models (such as flows) were inputs into the Hingaia Stream model. This model thus provides a very good understanding of flooding in areas such as Drury Township which is generally at the confluence of these stream networks.

Figure 13 shows the floodplains within the Future Urban Zone. This figure has also been provided at a larger scale in Appendix A. It should be noted that the floodplains are draft and awaiting final sign off prior to being finalised and published on Auckland Council GEOMAPS.

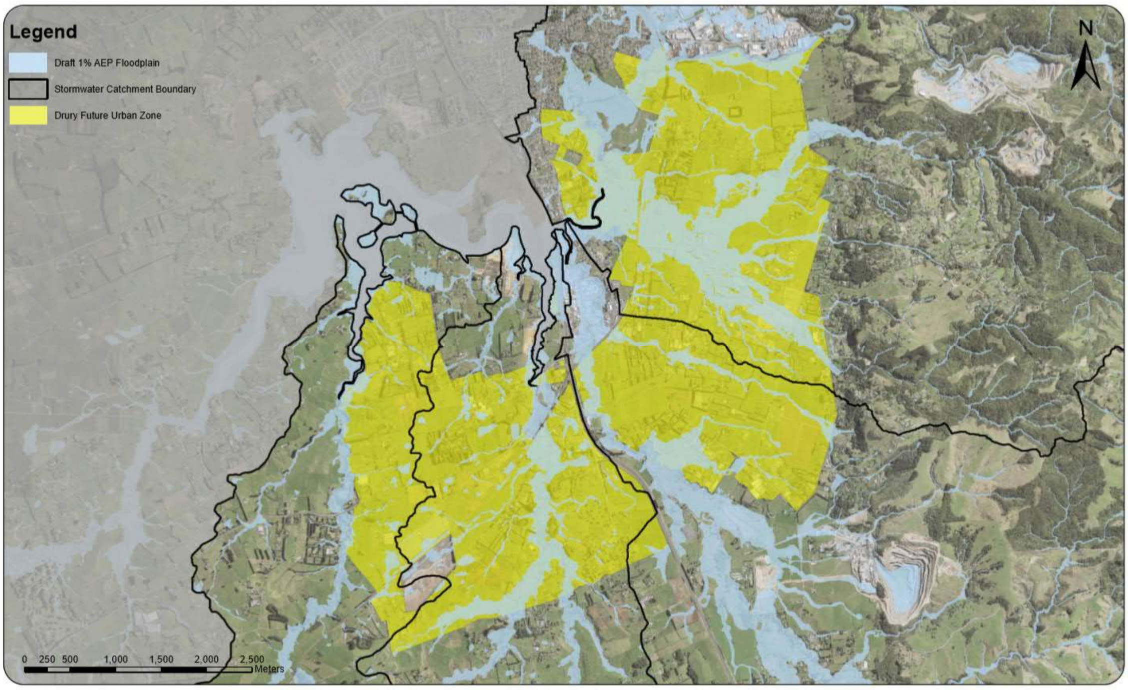


Figure 13 Drury-Opaheke Stormwater Management Plan – Predicted 100 year ARI Floodplains

3.7.1.3 Floodplains

Slippery Creek

The flat terrain of the FUZ and flow constraints through some road and rail crossings coupled with the high volumes of runoff from the large upstream area, results in extensive predicted areas of floodplain. Approximately 735 hectares (Ha) of the Slippery Creek catchment falls within the Drury Structure Plan area, of which approximately 261 ha is predicted to be floodplain.

Although the urbanisation of the FUZ is expected to have minimal effects on current flood hazards, the floodplain within the Slippery Creek FUZ has been identified as a significant hazard (in accordance with the Auckland Council modelling specifications).

Figure 14 below shows the floodplain depths thematically.

The modelling indicates that the railway line at the northern end of the Future Urban Zone (in the vicinity of the Boundary Road rail bridge) will be overtopped during a 100 year ARI Maximum Probable Development (MPD) with Climate Change (CC) storm event.

Sutton Road is predicted to overtop during a 10 year ARI Existing Development (ED) scenario (without climate change). The approach road to Sutton Road bridge is 0.2m lower than the bridge deck. During a 10 year ARI event the modelled depth of flow over the approach road is 0.38m and 0.18m over the bridge deck. The downstream railway bridge is a flow constraint although even with the downstream railway bridge opened up this road still floods. Any measures to increase the flow capacity of Sutton Road bridge (as a means of addressing flooding) must also include increasing the flow capacity of the downstream rail bridge as the rail bridge is a flow constraint.

The approach road to Opaheke Road bridge is predicted to overtop by 0.47m during a 100 year ARI MPD CC storm event. Bellfied SHA is located downstream of this bridge. The SHA is sensitive to an increase in flows and associated increases in water levels. The habitable floor levels have been set with respect to modelled flows which did not consider increased flows as a result of opening up structures.

Great South Road (at the bottom of the catchment) is predicted to be overtopped during a 100 year ARI MPD CC event.

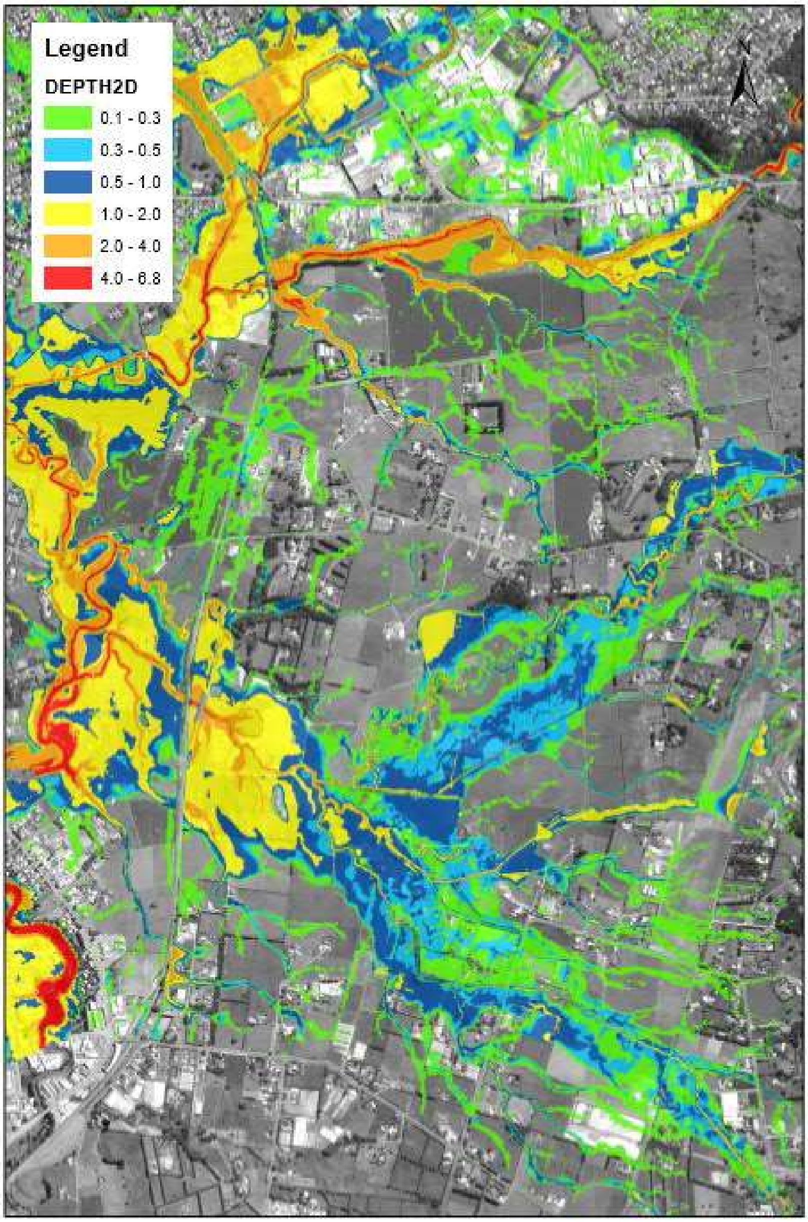


Figure 14 Slippery Creek Flood Depths

Hingaia Stream Catchment

The predominantly rural 57.5 km² Hingaia Stream catchment is predicted to produce over 10,500,000m^3 of runoff in a future 100 year ARI rainfall event with climate change and contains one of the deepest floodplains in the Auckland Region. Approximately 366 Ha of the Hingaia Stream catchment falls within the Structure Plan Area. Approximately 54ha or 15% of the structure plan area within this catchment is predicted to be within the floodplain.

Due to past development within the floodplain the stream channel is highly constrained through the urbanised Drury Township at the downstream end of the catchment. Drury Township suffers from frequent and extensive flooding. The Future Urban Zone is also subject to flooding. Bridge and culvert infrastructure capacity is limited in places, resulting in overtopping of roads during large order events. Future development must consider the management of flooding, effects on other property and critical infrastructure, such as the North Island Main Trunk railway, Great South Road and SH 1.

The modelling indicates that the motorway will not flood in the existing development scenario. This scenario does not allow for climate change. However, flooding of the motorway is predicted to occur as a result of climate change i.e. increased rainfall depths.

During a 100 year ARI MPD CC rainfall event approximately 900m of the motorway adjacent to Drury Township is predicted to be inundated to depths of over 1m in places. Great South Road will be overtopped by the main Hingaia Stream. This water will then flow down Firth Street before re-entering the Hingaia Stream. The railway will not be overtopped.

Great South Road is also predicted to be overtopped during a 100 year ARI MPD CC event.

The northern tributary of the Hingaia Stream is located north of the main Hingaia Stream adjacent to Waihoehoe Road. Modelling indicates that flows from the catchment discharging to the northern tributary can be passed forward without impacting on predicted flood levels in Drury Township. However, if the Pass Forward option is selected the upstream effects need to be considered. To pass flows forward all of the culverts along the tributary would need to be upsized.

Drury West

Ngakoroa Stream and Oira Creek are rural catchments with generally constrained floodplains. The soils are predominately silty that allow for recharge of the underlying Kaawa Aquifer. Ngakoroa Stream currently receives flood waters from Hingaia Stream in larger events that occur over SH1 upstream of the natural confluence. Current floodplain mapping suggests some road infrastructure forms a barrier to flows resulting in more extensive floodplain areas upstream of these features. Opening up these structures however could worsen downstream flood levels.

The Ngakoroa floodplain is generally channelised however the channel has insufficient capacity to convey the 100 year ARI flow. Structures along the channel also impact the floodplain extent. There are some properties within the predicted floodplain.

The modelling indicates that the railway will not be overtopped during a 100 year ARI MPD CC storm event.

However Runciman Road, Pitt Road and Bremner Road bridges will all be overtopped during a 100 year ARI MPD CC storm event. These structures currently hold back flows which impact on the extent of the floodplain.

3.7.1.4 Structures Assessment

A hydraulic assessment of the major structures (bridges and major culverts) within and downstream of the FUZ has been carried out. One of the purposes of the assessment was to determine how structures would 'cope' under different land uses and storm events. The structures were assessed for the following scenarios:

1. 100 year ARI Maximum Probable Development (MPD) with climate change (CC) with FUZ (tidal boundary of MHWS + 1m sea level rise used)
2. 100 year ARI MPD CC without FUZ (in order to determine the impact of the proposed FUZ on structures) FUZ was modelled at 10% impervious for this option
3. 100 year ARI MPD (no CC or FUZ)
4. 10 year ARI Existing permitted development (ED) for both Slippery + Drury West (Ngakoroa and Oira). Hingaia Stream was assessed for 10 year ARI MPD (Hingaia) - in order to determine how structures would cope in a 10 year event
5. 100 year ED CC (in order to determine impact of development (ie 100 year MPD CC) on flooding of Drury Township. This reflects the existing risk of a do nothing scenario into the future.

Figure 15 shows most of the structures that were assessed.

There is minimal difference in flows and water levels at the major structures within the FUZ between Scenarios 1 and 2. This is probably because the peak flow from the FUZ will have passed these structures by the time the overcall catchment peak arrives at the structures and the FUZ area is so small in comparison to the upstream rural catchments.

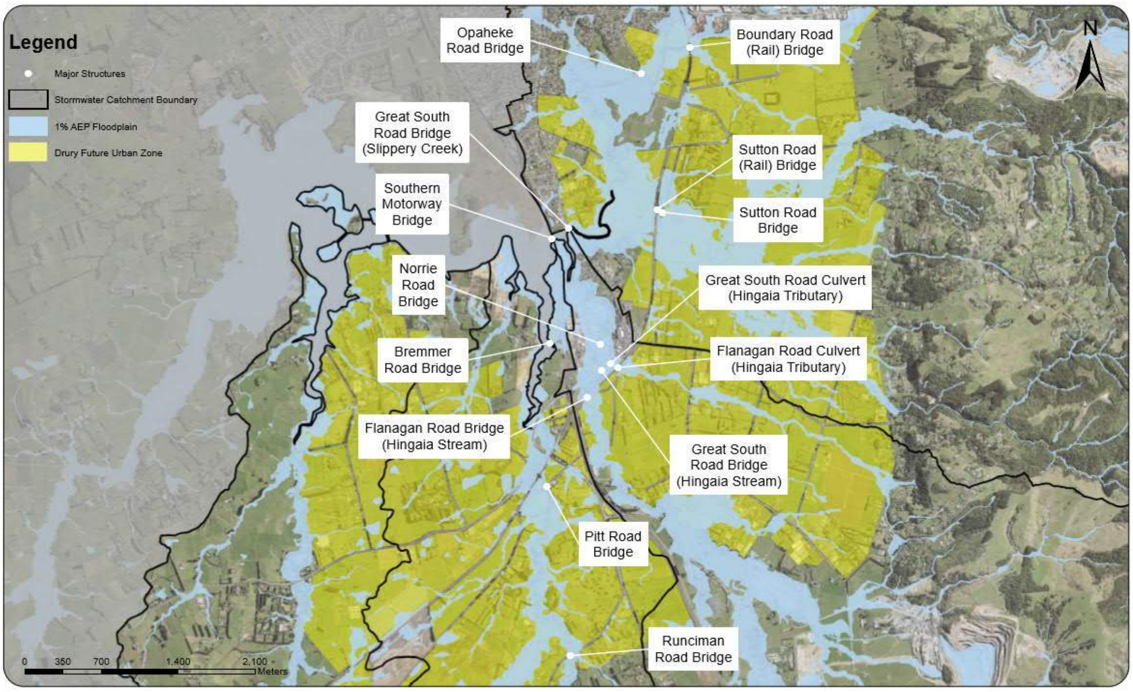


Figure 15 Structures Assessed within FUZ

The structures were also assessed in order to determine if they meet the levels of service for local roads, arterials or collector roads. The level of service for each road type is identified in **Table 2** below.

Table 2: Level of Service for Local, Collector and Arterial Roads

Road Designation	Level of Service
Local	Must not overtop in a 10 year ARI MPD CC event

Road Designation	Level of Service
Collector	Must not overtop in a 100 year ARI MPD CC event
Arterial	Must not overtop in a 100 year ARI MPD CC event

Table 3 below identifies if the structures meet their level of service.

Table 3: Level of Service of Structures

Structure Name	Designation	Meeting Level of Service
Railway in vicinity of Hays Stream (Slippery Creek catchment)		No
Opaheke Road (Slippery Creek catchment)	Local Road	Yes - as a local road but not as an arterial)*
Sutton Road (Slippery Creek catchment)	Local Road	No
Great South Road (Slippery Creek catchment)	Arterial	No
Great South Road (Hingaia Stream catchment)	Arterial	No
Norrie Road Bridge (Hingaia Stream catchment)	Local Road	No
Southern Motorway	Arterial	No
Bremner Road (Ngakoroa Stream catchment)	Local Road	Yes - as a local road but not as an arterial*
Pitt Road Bridge (Ngakoroa Stream catchment)	Local Road	Yes
Runciman Road (Ngakoroa Stream catchment)	Local Road	No

* This road has been identified as a potential future arterial.

3.7.1.5 Impact of development of the FUZ on Flows and Water Levels

The impact of development of the Future Urban Zone on downstream flows and water levels at key locations has been considered. The key findings are as follows:

- In the Slippery Creek catchment peak flows (for a 100 year ARI MPD CC event) increase from 358 to 362m3/s resulting in flood levels increasing by 10 to 50mm. These increases are considered to be minor. In the vicinity of Kath Henry Lane (off Waihoehoe Road and immediately upstream of the railway) the modelling indicates that flood levels may increase by 0.05-0.1m.
- In the Hingaia Stream catchment the 100 year ARI MPD CC flows and levels do not increase as a result of urbanisation in the FUZ.
- In the Drury West catchment there is minimal increase in 100 year ARI MPD CC flows as a result of urbanisation of the FUZ.

3.7.1.6 Flood Prone Areas

Flood prone areas are topographical depressions that can fill rapidly during a storm event due to a lack of capacity or blockage. They can be natural low points or man-made (e.g due to embankments). Auckland Council has mapped flood prone areas using LiDAR data across the region.

Resilient development should avoid flood prone areas, providing a buffer to flooding hazards as described in the Auckland Unitary Plan E36 objectives.

Where this is not practicable, design must consider how to manage this residual risk in accordance with the Building Code.

3.7.1.7 Overland Flowpaths

Overland flowpaths (like streams) are a natural component of the stormwater conveyance system. They convey stormwater from the point of inception to a discharge point such as a stream. Auckland Council have mapped overland flow paths across the region using LiDAR data.

Overland flowpaths should be aligned with natural flow paths as much as possible.

Overland flowpaths need to be integrated as part of the development proposals in accordance with the AUPOP, Stormwater Code of Practice and Building Code.

3.7.1.8 Drury Estuary as a Flow Constraint

It is now understood that there are a number of locations within Drury Estuary which are a constraint to flow. This had not previously been identified. The total catchment area draining to the estuary is in excess of 200km². Some of the catchments draining to the estuary have similar times of concentration (i.e. the peak runoff from these catchments arrives in the estuary at similar times). The water is unable to drain away and so it 'sits' there resulting in the water level in the estuary rising. The water in the estuary hinders / prevents additional runoff from the catchments draining to it resulting in a backwater effect in the streams which contributes to flooding. Widening of the estuary was explored as an option. However, it became apparent that the cost of widening the estuary would be significant but with no significant benefit such as a reduction in flooding at Drury Township or freeing up additional land for development. In addition there would be significant consenting issues. Carrying out works in the estuary would be contrary to current policy direction which directs retreat in coastal inundation areas and restoration and enhancement of the coastal environment.

3.7.2 Coastal Inundation

Extreme water levels are also influenced by coastal inundation and the tidal influence of the Pahurehure Inlet and the Drury Creek. Coastal inundation is particularly likely when high tides, storm surges and/or large waves occur at the same time. At these times, areas where rivers or creeks meet the sea are more vulnerable because high seas can cause the rivers to back up inland.

The area predicted to be influenced by coastal inundation is illustrated in Figure 16. This shows the predicted area affected by the 100 year ARI event with a 1m sea level rise added.

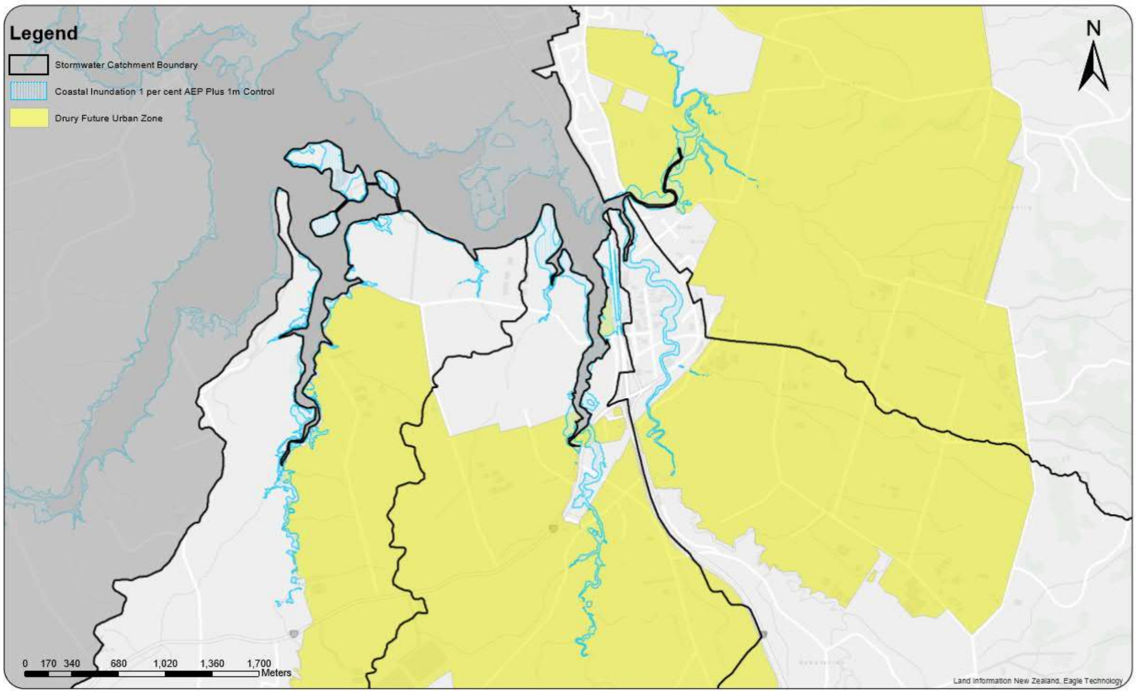


Figure 16 Drury-Opaheke Structure Plan Area - Coastal Inundation (1% AEP plus 1m control)

3.7.3 Hays Creek Dam

The Hays Creek water supply dam is located in the Hunua Ranges upstream of the Slippery Creek Future Urban Zone. In the unlikely event of failure of the dam, water would travel down the 5 km Hunua Gorge before overtopping Hunua Road bridge, be conveyed in the floodplain of the Hays Stream, overtop the railway embankment and then be conveyed in the Slippery Creek floodplain to the Drury Estuary. The dam break floodplain can be seen in Figure 17. The predicted dam break flood extent in the vicinity of the Hays Stream extends beyond the 100 year ARI floodplain.

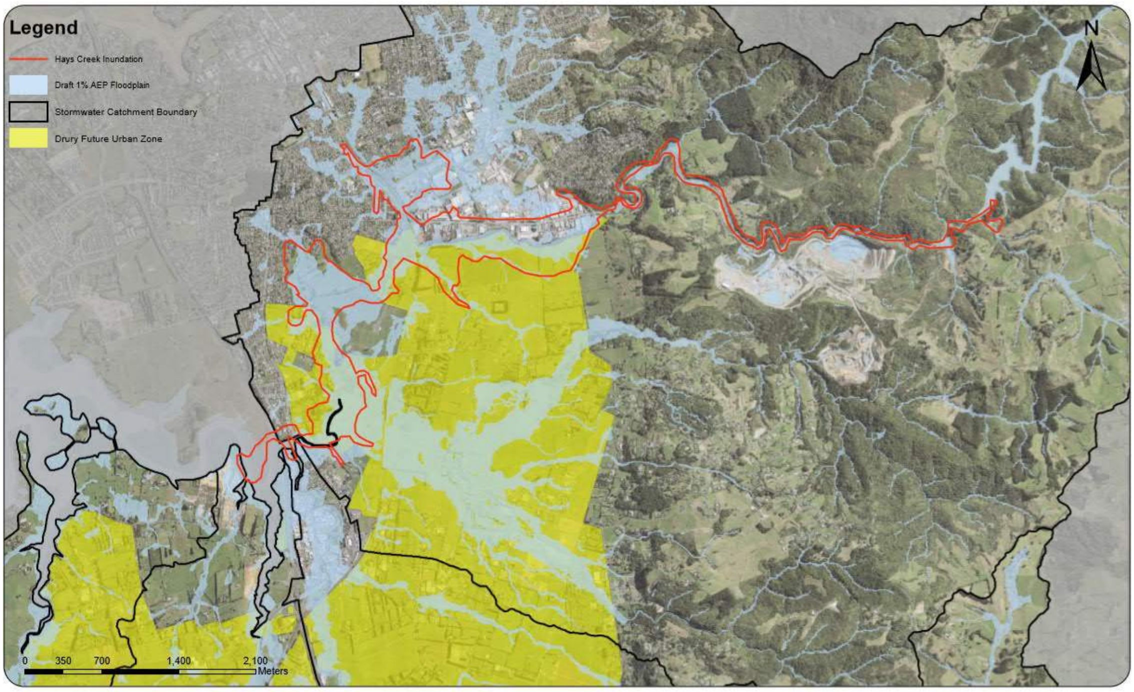


Figure 17 Hays Creek Dam Inundation Floodplain

3.8 Knowledge Gaps

Hydrological and hydraulic modelling is still ongoing to confirm flood mitigation options. The draft outputs indicate that for the 100 year ARI MPD CC scenario the “pass forward” option for each of the four sub-catchments provides the best solution for releasing land for development.

Erosion risk assessments will need to be carried out (as part of detailed SMPs) in order to determine if additional measures are required to minimise and mitigate erosion. This information will be required to support Plan Change processes. This information will be used to determine what rules need to be added to the plan change so that the issues can be mitigated.

4 Implementing Integrated Stormwater Management

4.1 Introduction

The National Policy Statement for Freshwater Management, the New Zealand Coastal Policy Statement and the AUPOP seek to improve the integrated management of freshwater and the use and development of land. Policy E1.3.8(a) of the AUPOP requires that greenfield development be carried out using an integrated stormwater management approach. This can be achieved using Water Sensitive Design (WSD) which is defined in GD04 as

"***An approach to freshwater management, it is applied to land use planning and development at complementary scales including region, catchment, development and site. Water sensitive design seeks to protect and enhance natural freshwater systems, sustainably manage water resources, and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities."***

Integrated approaches such as WSD are important to minimise the adverse effects of growth and development on freshwater systems and coastal waters. In addition, WSD provides more resilience (to flooding, for example) than traditional approaches. It is also Auckland Council's preferred stormwater management approach.

The stormwater management approach recommended for the FUZ takes into account:

- The sensitivity of the receiving environments to further contaminants;
- The planning requirements discussed in Section 2;
- The FUZ characteristics and constraints (such as existing flooding and erosion issues) discussed in Section 3;
- The enhancement opportunities offered as a result of development of the FUZ;
- The use of Water Sensitive Design as a tool to achieve integrated stormwater management as directed in policies E1.3(8) and (10) of the AUPOP.

The stormwater management requirements for development of the FUZ are discussed in this report.

It should be noted that the WSD approach to stormwater and flood management used in Auckland encourages green infrastructure responses and at-source management of stormwater. Green infrastructure is described in the Auckland Plan as *'natural and engineered ecological systems which integrate with the built environment to provide the widest possible range of ecological, community and infrastructure services.*'

Implementation of green infrastructure allows stormwater management to be incorporated into the urban design of developments to provide amenity, hydrological and environmental benefits. Green infrastructure, such as swales for flow conveyance, should be considered instead of hard engineering solutions.

WSD can minimise the need for large scale communal stormwater devices and pipework. The retention and protection of streams avoids engineered flood management approaches because stream corridors can be designed to allow flood flows to be conveyed safely.

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4.2 Stream Management and Enhancement

The proposed change in land use, from rural to urban, offers significant opportunity to reduce existing adverse effects and enhance currently degraded environments. The Watercourse Assessment Reports (WARs) for the Slippery Creek, Hingaia Stream, Ngakoroa Stream and Oira Creek catchments identified management responses to address existing adverse effects and minimise potential future adverse effects caused by development of the FUZ.

Management responses have been provided for Management Zones (areas) and stream Enhancement Opportunities (EOs) in the watercourse assessment reports. The Management Zones generally reflect large areas whereas the EO’s are specific locations. The FUZ component of the Ngakoroa catchment, for example, has two management zones and nine enhancement opportunities located across the two Management Zones.

In each of the WARs, Stream Enhancement Opportunities (EOs) were identified for opportunities with the greatest potential benefit to amenity, ecology and conveyance. The EOs have been summarised in tables in this section. The locations of the EOs can be seen in Figure 18. It should be noted that the EOs are indicative only based on overall catchment assessments and do not exclude areas of enhancement not currently identified. Other enhancement opportunities may arise through development or redevelopment.

Management zones (MZs) were identified in each WAR based on stream reaches with similar characteristics and land use pressures (such as the FUZ). Specific goals and objectives (such as erosion remediation and stream naturalisation) were identified for each MZ. These goals and objective are identified in tables in this section. The areal extent of the management zones can be seen in the relevant WAR.

Specific maintenance issues (such as erosion hotspots and culverts requiring repair) are also identified in the Management Zones of each WAR. Please refer to the WAR for further information.

Generic goals and objectives identified in the WAR’s for the Management Zones include:

- Upgrading and installing all required inlets and outlets to appropriate inlet outlet standards;
- Future proofing channels through erosion susceptibility mitigation works;

Other goals and objectives are identified the following tables and in the WAR’s.

Only the EO’s and management zones relevant to the FUZ have been discussed in this SMP. Their numbering is as per the numbering in the WAR.

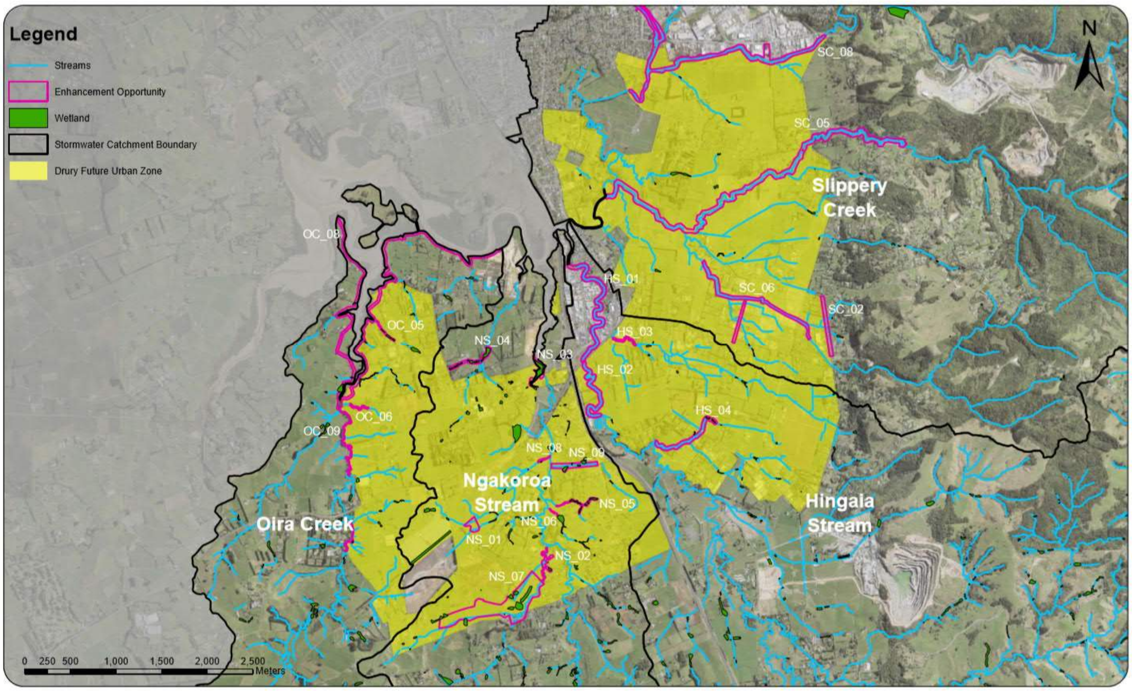

Figure 18 Enhancement Opportunities

4.2.1 Slippery Creek

The WAR identified three Management Zones (1, 2 and 4) within the FUZ.

Specific goals and objectives identified in the WAR for these Management Zones are identified in Table 4 below.

Table 4: Goals and Objectives of the Slippery Creek Management Zones

Management Zone	Goals and Objectives
1	• Contact landowners to provide education regarding management of waterways, landowner responsibilities, and supporting programmes and funding such as the Environment Initiatives Fund, Waterways Protection Fund or Trees for Survival. (Council led) • Manage willows to reduce erosion from flow diversion, debris jams, and improve fish passage to upstream high value habitat • Investigate lower reaches of the main channel of Slippery Creek for potential inanga spawning habitat and potential for enhancement • Protect and enhance areas with remnant mature indigenous trees particularly at WAI_MAIN_6, SYM_MAIN_7, SYM_MAIN_14-16 • Retain existing stream meander patterns and avoid any further channel straightening • Engage landowners to fence watercourses where moderate to severe stock damage has occurred to reduce further damage and ongoing sediment and faecal pollution downstream (Council led) • Establish 40 m wide riparian corridors with a minimum width of 10 m on each bank on the main channels of Symonds Stream and Waihoihoi Stream, and tributary 5 of Waihoihoi Stream. Planting

Management Zone	Goals and Objectives
	should be conducted on stream margins, banks and floodplains • Integrate bioengineering to increase habitat values for fish • Increase channel sinuosity between WAI_MAIN_12 and WAI_MAIN_18 • Incorporate shared cycle/walkways along riparian corridors to improve connectivity to key recreational and transport infrastructure such as the Opaheke Sports Park and the Papakura Park and Ride • Integrate stormwater wetlands, rain gardens, or other water treatment systems with open space planning to detain additional flow and manage stormwater contaminants • Involve the community in ongoing weed control and enhancement planting of riparian margins(Council led)
2	• Support watercourse enhancement opportunities (Council led)
4	• Remove willows and establish a riparian corridor with a minimum width of 15m on the TLB and 5m on the TRB • Improve access to the esplanade reserve through Walker Park from Boundary Road. • Investigate options to develop shared pedestrian/cycleway linkages along riparian corridors to connect to proposed pathways within this management zone. • Engage with the industrial sector to implement operational procedures and water treatment systems to manage heavy metal contaminants. (Council led)

Source: Slippery Creek Watercourse Assessment Report

Three EO's were identified within the FUZ.

Table 5: Slippery Creek Enhancement Opportunities

Enhancement Opportunity	Description
5	• Remedial works are required to prevent further erosion and slumping of the stream banks as well as any subsequent sediment deposition. • A cost effective remediation option could be to regrade the banks to a more stable gradient such as a 1:1 batter. Erosion protection such as rock could be installed at the toe of the banks. It is also recommended that the sections of stream that are easily accessible to stock are adequately fenced off to prevent access. Following bank regrading, planting a riparian buffer would further improve bank stability and provide additional ecological benefits such as shading, filtration, and habitat provision. • Further investigations are required to assess the options available and their associated costs to ensure the most appropriate solutions are implemented.
6	• Remedial works are required to prevent further erosion and slumping of the stream banks as well as any subsequent sediment deposition. • A cost effective remediation option could be to regrade the banks to a more stable gradient such as a 1:1 batter. Erosion protection such as rock could be installed at the toe of the banks. Naturalisation of the stream to incorporate meanders could also help mitigate against

Enhancement Opportunity	Description
	erosion. Following bank regrading, planting a riparian buffer would further improve bank stability and provide additional ecological benefits such as shading, filtration, and habitat provision. A 40 m riparian corridor with a minimum of 10 m on each bank is recommended. It is also recommended that the sections of stream that are easily accessible to stock are adequately fenced off to prevent access. • Sections where erosion is more severe and where there is higher risk to dwellings may require retaining structures. Further investigations are required to assess the options available.
8	• The reaches upstream of Opaheke Sports Park have been identified as an enhancement opportunity to increase connectivity of public spaces, provide riparian planting initiatives and erosion control, willow removal projects, and general maintenance concerns. This enhancement opportunity also forms part of a proposed cycleway and pathway that was identified in the Watercourse Assessment Report. • A public asset (ID 1115547) should be fitted for erosion protection and undergo structural repair). Re-contouring and regrading of the banks within the reach will help to restore stability and planting will increase the resistance of the banks against further erosion.

Source: Slippery Creek Watercourse Assessment Report

4.2.2 Hingaia Stream

Management Zone (MZ) 1 is located within the FUZ.

Specific goals and objectives identified in the WAR for this Management Zone are identified in Table 6 below.

Table 6: Goals and Objectives of the Hingaia Stream Management Zone

Management Zone	Goals and Objectives
1	• Establish ownership of assets with unknown ownership. If they are council owned, incorporate them into Council GIS. (Council led) • Investigate and remedy all assets with flooding issues on public and private land. (Council and landowner led) • Address erosions issues, both erosion hotspots and culvert erosion before and/or as urban development occurs. • Futureproof stormwater conveyance capacity in areas that may be put under pressure by further development. Remove unnecessary culverts and replace undersized culverts before land development occurs. • Investigate potential point sources of faecal bacteria to urban/peri-urban streams and identify any necessary maintenance requirements. (Council led) • Encourage landowners and/or developers to restore, enhance and/or protect riparian zones. (Council led) • Improve aquatic habitat in the northern tributaries by naturalising modified streams and removing potential fish barriers. • Ensure ecological, amenity and stormwater management linkages are established between existing, developing and future urban zones

Management Zone	Goals and Objectives
	• Look to create a continuous riparian corridor from the Hingaia Stream mouth to Ararimu Road, integrating with proposed riparian improvements within the Drury South developments. • Improve the amenity value of the stream network by incorporating walkways/cycleways into the design of new public open spaces, particularly within Esplanade Reserves. have a continuous walkway/cycleway from the Hingaia Stream mouth to Ararimu Road. • Involve iwi, community groups, schools and local residents in riparian restoration or habitat improvement projects on public land. • Take advantage of greenfield development to leverage stream enhancement outcomes (improving ecological, amenity and stormwater functions).

Source: Hingaia Stream Watercourse Assessment Report

Three Enhancement Opportunities were identified within the FUZ.

Table 7: Hingaia Stream Enhancement Opportunities

Enhancement Opportunity	Description
2	• Enhancement should focus on providing both ecological and amenity linkages between Drury Township and Drury South. • Improving riparian vegetation through weed control and riparian planting of native vegetation. If the riparian margins within this section of stream were restored, along with riparian improvements through Drury township and that which will be undertaken as part of the Drury South developments, it would result in a continuous 10 km riparian corridor along the Hingaia Stream. Riparian planting would also contribute to the AUP objective of improving riparian vegetation throughout the region.
3	• Naturalisation (bank recontouring) of this section of stream (for approximately 350m) would enhance the habitat available for fish (and associated spawning) and macroinvertebrates. Naturalisation could include instream improvements, as well as improvements to the current state of riparian vegetation. Restoring native shade providing riparian plantings would d significantly improve stream health, through increasing shade, organic input and habitat, and through its ability to trap and diffuse contaminants before they enter the watercourse. Riparian vegetation may also help to alleviate some of the flooding issues associated with this area.
4	• Naturalise stream channels (including reintroducing natural meanders) to improve habitat for aquatic fauna and also to improve the natural flow regime. Fencing and reinstatement of riparian vegetation should be prioritised as a key initiative in helping to restore stream health. Shading riparian cover will help reduce excessive growth of aquatic plants and reduce sediment inputs to the stream (4Sight Consulting, 2018).

Source: Hingaia Stream Watercourse Assessment Report

4.2.3 Ngakoroa Stream

Two management zones are located within the FUZ. Management Zone 1 encompasses the main stem of the Ngakoroa Stream. Management Zone 2 includes all of the tributaries off the main stem of the Ngakoroa Stream within the Future Urban Zone, as well as the Pahurehure Inlet Tributary to the north-west of the Ngakoroa Stream.

The goals and objectives identified in the WAR for the management zones are outlined in the following table.

Table 8: Goals and Objectives of the Ngakoroa Stream Management Zones

Management Zone	Goals and Objectives
1	Progressively replace willows with native plantings where possible in order to maintain bank stability and stream shading while improving riparian vegetation condition.
1	Implement esplanade reserves along both banks of the main Ngakoroa Stream as part of the provisions for subdivision consenting.
2	Re-meandering of modified watercourses, consider daylighting options and formation of contiguous green corridors See EO1, EO2, EO6, EO7, EO8, EO9
2	Expected limitations on development within floodplains provide opportunities for the creation of public open space for passive recreational use combined with stormwater management. This could include detention basins, integrated with naturalised stream corridors to increase sinuosity with consideration of conveyance capacity. See EO7
2	Removal of the redundant farm culverts through development
2	Advocate for the fencing and planting of riparian margins through the development process. (Council led)
2	Remove/remediate ponds to address associated impacts on water quality and freshwater ecology. See EO5 and EO6
2	Remediate fish passage barriers (identified in WAR).

Source: Ngakoroa Watercourse Assessment Report

Nine Enhancement Opportunities (EOs) have been identified within the Ngakoroa catchment of the FUZ. These are identified in the following table.

Table 9: Ngakoroa Stream Enhancement Opportunities

Enhancement Opportunity	Description
1	Restoration of an historic wetland. This could provide stormwater treatment / attenuation and or enhance ecological values and diversity
2	Relates to a straightened channel with historic high sinuosity and a wetland on the true right bank. There is the opportunity to restore hydrology, channel morphology and floodplain engagement. In addition there is a culvert which is forming a partial barrier to fish passage
3	Coastal wetland enhancement and management interventions to support potential inanga spawning.

Enhancement Opportunity	Description
4	Opportunity to remove a series of ponds to address associated impacts on water quality and freshwater ecology. Potential to create an offline wetland
5	Opportunity to remove a series of online ponds to address associated impacts on water quality and freshwater ecology. Approximately 800m of potential habitat enhancement for fish communities could be created
6	100m length (approx.) daylighting opportunity downstream of pond. Potential habitat enhancement for fish communities
7	Opportunity to create public open space for passive recreational use combined with stormwater management
8	Opportunity to restore hydrology and channel morphology and floodplain engagement and potentially remove culvert
9	Opportunity to naturalise straightened channel and adjacent wetlands to reintroduce meanders and habitat heterogeneity and floodplain engagement

Source: Ngakoroa Watercourse Assessment Report

4.2.4 Oira Creek

Management Zone 1 is located within the FUZ.

Suggested goals and objectives identified in the WAR for this Management Zone are identified in the following table.

Table 10: Goals and Objectives of the Oira Creek Management Zone

Management Zone	Goals and Objectives
1	• Engage with landowners to install or repair fencing around moderately or severely damaged watercourses, thus minimising further damage, erosion and pollution issues. (Council led) • Address inlet/outlet erosion issues before land becomes developed. • Involve community groups in the protection and enhancement of the public conservation land along the coastal margins of the catchment. (Council led) • Encourage landowners to restore, enhance or protect riparian zones. (Council led) • Improve access to public land around the coastal margin. • Enhance potential inanga spawning habitats. • Take advantage of greenfield development to leverage stream enhancement outcomes (improving ecological, amenity and stormwater functions) (Council led)

Source: Oira Catchment Watercourse Assessment Report

Four Enhancement Opportunities (EOs) have been identified within the FUZ.

Table 11: Oira Creek Enhancement Opportunities

Enhancement Opportunity	Description
5	Relates to improving fish passage, daylighting a section of piped stream and improving the inanga spawning habitat at the downstream end of the EO. Address existing erosion issues around culverts. Future proof culverts to facilitate development of the FUZ.
6	Address erosion issues and fish passage restrictions. Habitat enhancement, including weed removal, riparian plantings and adding additional rough elements would be beneficial to the stream, as would fencing. Replace existing culverts with suitably sized ones.
8	Improving public access would increase the amenity value of this area, allowing it to be observed and enjoyed by more than just the immediate landowners. Improvements to low growing bank vegetation would increase the potential inanga spawning habitat of the small stream mouths along this coastal edge within the Oira Creek Catchment.
9	Riparian plants, removal of weed species and fencing (where stock may remain) would all be beneficial and help to improve the state of the stream.

Source: Oira Creek Watercourse Management Report

4.2.5 Riparian Planting

Riparian vegetation provides a range of ecosystem services which improve the ecological values of a stream and its terrestrial margins. An established vegetation zone along the stream edge can help control stream temperature and light levels, provide additional habitat, both terrestrial and aquatic, increase organic inputs into the stream and reduce contaminant loads reaching the watercourse, all of which can be beneficial to water quality and biodiversity (Collier et al., 1995; Vigiak et al., 2016). Even relatively small increases in the amount of riparian cover can have a significant impact on stream health (Chase et al., 2016).

Stream margins and associated riparian strips can also form important linkage corridors and pathways of biodiversity linking fragments of remaining native vegetation and ecosystem types that may still be intact within the catchment. Using a green infrastructure and water sensitive design approach, these biodiversity corridors can also be used to provide connections for urban centres and their associated communities by incorporating walkways and cycleways following these same routes. These then provide valuable greenspace for development areas that serve a very concentrated and diverse range of ecosystem services ranging from biodiversity and ecology through to resilience (floodplains, water supply) and human health and wellbeing (recreational, amenity, sports, sense of place).

Modern best practice water sensitive design development approach management of stream corridors and overland flow paths by incorporating their form and function into developmental designs at the very early stage of the development process. A clear plan established at an early stage allows these corridors to be designed to maximise their value to both future urban communities and its supporting natural environment. Once the values are defined and accounted for, intensification and urban development of the surrounding urban developments can strategically take place on the land surrounding these corridors. These approaches are outlined in the Auckland Council GD04 Water Sensitive Design Manual.

Riparian vegetation plays an important role in many functional aspects of streams including hydrodynamics, flood management and conveyance, water quality improvement, sediment retention, erosion control and biodiversity. These corridors also provide valuable functions from a social, cultural and amenity perspective, ranging from provision of a sense of place for wellbeing, air quality and local climate management (particularly heat effects), supply of materials of traditional cultural value, sight lines and visual breaks.

While it is widely understood and acknowledged that riparian vegetation plays a vital role in a wide variety of catchment functions, these are very rarely considered at the design phase. There are significant benefits to be gained from having more consideration of the functional role of these corridors in future land forms. For example, reducing above ground biomass and roughness would be a desirable outcome in areas where flood risk and maximising conveyance is necessary. From an urban community perspective, similar vegetation types can be incorporated into areas where maintenance of sight lines is desirable where visual amenity or reduced crime risk are important factors.

Riparian planting should also be considered for its potential impact on reducing conveyance related issues.

Riparian planting in the Future Urban Zone is primarily required in order to mitigate the effects of development by improving the ecological value of the streams and improve marine and fresh water quality.

Incorporating these other design considerations into developments will further enhance their function and increase the overall value of the development itself. Stream corridors should be left free of development to enable safe conveyance of flows.

4.3 Minimising and Mitigating Hydrological Change

Stream channel erosion contributes significantly to sedimentation and is a key water quality issue in the Manukau Harbour. As identified in Section 3.5 of this report, erosion is a significant issue across the FUZ. Section E1.2 of the AUPOP requires that water bodies identified as degraded are progressively improved over time. Section E1.2 also requires that erosion not be worsened. The NPS-FM requires that aquatic habitats are maintained and improved as opposed to allowing further degradation.

In addition, the Pahurehure Inlet, which is a low energy system, is known to be receiving fine sediment inflows from Drury Creek. These sediments are settling out in the inlet and detrimentally impacting ecological values (Golder Associates, 2009).

Prevention or minimisation of erosion is therefore necessary to meet legislative requirements.

For some existing urban areas this is addressed using the SMAF overlay of the AUPOP which requires hydrology mitigation consisting of retention (of flow on-site therefore reducing flow volumes) and detention (temporary storage and drain down over 24 hours). Hydrology mitigation is applied subtly differently in the stormwater management area – Flow 1 and Flow 2 (SMAF) areas. These areas contain high value rivers, streams and aquatic biodiversity which require protection from further adverse effects associated with stormwater runoff from urban development. The provisions also impose a “clawback” which seeks to improve water quality by requiring mitigation where more than 50% of the site is being redeveloped. In this way, flows from the existing development is managed, as well as that from new development.

During the Unitary Plan process the future urban areas were excluded from the SMAF management layer on the basis that during structure plan and plan change processes the most appropriate method of hydrology mitigation could be applied because greenfield development presents a greater opportunity to achieve higher standards than small-scale brownfield development. The AUPOP also sets a policy expectation that large scale brownfield redevelopment offers greater opportunity and this is reflected in the discharge rules which require hydrology mitigation (not specifically SMAF volumes) for large extents of impervious surface.

Section E10 of the AUPOP sets out controls for SMAF areas. SMAF 1 requires:

- retention of the first 5mm of runoff from impervious surfaces
- detention (temporary storage) and a drain down period of 24 hours for the difference between the pre-development and post-development runoff volumes from the 95th percentile 24 hour rainfall event minus the achieved retention volume.

The effect of this retention is to encourage infiltration and soakage of stormwater to ground to recharge groundwater systems, support stream baseflows and reduce erosive flows during small storm events. Detention is used to store and release of flows slowly over an extended period of time to reduce peak (erosive) flows. Peak flow management is also an important tool for reducing water levels and overall flood risk to lower catchment areas but the detention volume for this approach is applied to much larger storm event: typically the 10 and/or 100 year ARI. It should be noted that the 5mm was derived with respect to clay soils and that a different value may be more appropriate for the alluvial and volcanic soils within the Structure Plan area which have different infiltration rates.

Application of SMAF 1 requirements will be the minimum requirement for development within the Structure Plan area.

Given the existing erosion and stream stability issues within the structure plan area the use of infiltration and detention alone may not fully address the hydrological impacts of development. Additional measures (such as additional detention requirements, floodplain management or in stream works) may be required to manage erosion. Erosion risk assessments will need to be carried out (as part of detailed SMPs) in order to determine if additional measures are required to minimise and mitigate erosion. These assessments will be required to support plan change processes.

Erosion risk assessments to be carried out to determine if additional measures are required to minimise and mitigate erosion.

Erosion risk assessments to understand the strengths of natural bed materials (shear stresses) will be required. These can inform modelling and/or engineering design that consider the site-specific nature of the Drury-Opaheke Future Urban Zone will be required to determine what additional measures are required to mitigate the effects of changes in hydrology.

Bank stability and erosion is a significant existing issue for the FUZ and urbanisation typically significantly exacerbates stream bank erosion unless carefully managed. Auckland Council seeks to avoid, minimise and / or mitigate stream bank erosion. Means of achieving this could include:

- avoiding development in areas of particularly high risk from erosion (such as steep slopes, weak soils);
- setting limits on impervious surfaces;
- on-site retention/detention;
- communal detention/activated flood plains/ dry detention basins;
- storm flow bypass direct to coast;
- natural channel modification including channel geometry and slope;
- riparian planting;
- battering of banks;
- increase erosion resistance by increasing the strength of bed materials through provision of a rock toe along the bottom of the stream bank or other instream materials (such as logs) protection.

Riparian planting is used to address erosion issues. However, it should be noted that riparian planting on its own is more successful in the headwaters of a stream. As the FUZ is located at the bottom of large catchments stream management measures including altered channel geometry or increased critical shear strength may be required in addition to riparian planting. Erosion management measures should be considered as a hierarchy of potential responses, with the preferred approach always deferring to methods with the least degree of disturbance to natural systems as outlined in the avoid, remedy, mitigate hierarchy of the RMA.

Stream erosion management may require staging of development so that the bottom of the catchment is developed first and stream bank strengthening is carried out in tandem with the development.

Council may collaborate or contribute to stream works in the event of multiple developers in the same sub-catchment via Development Contributions and Infrastructure Funding Agreements. This will enable stream works to be carried out prior to the introduction of new impervious surfaces in the catchment to prevent stream bank erosion. Note this work will need to be in tandem with other stormwater management methods and is not intended to direct stream channelization, lining or straightening.

4.3.1 Ongoing Auckland Council Stream Erosion Studies

Auckland Council (AC) are currently carrying out a number of stream erosion studies across the region. Once these studies are complete AC will issue a technical report outlining the findings and recommendations to reduce the risk of stream bank erosion downstream of development. These studies include:

- A region wide GIS assessment to identify streams that may be prone to stream erosion (due to hydraulic forces only) from additional impervious surfaces. This study will help to determine if a stream bank will / is likely to start eroding.
- A quantitative evaluation of how potential changes in the magnitude and duration of flows associated with future growth scenarios affect erosion rates and channel instabilities in the developmental and downstream receiving environments. A second key objective of this study is to provide quantifiable evidence of how cost-effective measures can be used to create a stable, natural river system that is capable of supporting the altered catchment hydrology and associated channel hydraulics.
- An assessment of channel and bank stability along reaches of the Omaru Creek which is located in the Tamaki North catchment. Modelling of the effectiveness and cost-effectiveness

of potential erosion mitigation measures were carried out using the Bank Stability and Toe-Erosion Model (BSTEM). A concept design for reaches of the Creek was developed. This design was based on achieving / addressing channel stability, protection and enhancement of cultural and ecological resources and provision of a community accessible stream corridor with aesthetic benefits.

- An assessment of root tensile strength and erosion resistance of native vegetation to support stream banks.

The outcome of the aforementioned studies will be used by Auckland Council as an input to guide erosion management responses across the region.

4.4 Stormwater Treatment

Development provides an opportunity to improve the water quality discharging into the sensitive receiving environments. Stormwater treatment measures in accordance with the guideline documents set out in Section 4.6 is required to be provided.

A treatment train approach is desirable. This is the combination of sequential stormwater management responses that collectively deliver stormwater quality and quantity objectives for a site. A treatment train is based on a logical sequence of stormwater flowing through a catchment, beginning with stormwater runoff controls at-source, followed by capture and treatment of overland flows, and finally the enhancement of receiving environments to enhance their stormwater management function

Industrial and trade activities will be required to meet the requirements of E33 in the AUPOP.

Given the sensitive receiving environments, treatment of all impervious areas (excluding non-contaminant generating areas) and use of inert building materials must be provided

Temperature can be a thermal pollutant. From an ecological perspective the objective for upland streams should be to have water temperatures < 20ºC at all times and the objective for lowland streams should be to have water temperatures < 25ºC at all times (Auckland Council, 2013). The Proposed Auckland Unitary Plan adopted a maximum temperature of 25ºC for discharges to a river or stream.

To mitigate any potential temperature issues impervious surfaces should be disconnected from the receiving environment by using bioinfiltration devices such as green outfalls when discharging to streams.

Green outfalls consist of a length of naturalised open channel (vegetated swale) which can be located within the riparian margins of a stream..

4.5 Flood Risk Management

An Integrated stormwater management approach means flood risk should be managed through applying the hierarchy in Table 12. This hierarchy is reflected within the Unitary Plan, which directs that in greenfield areas and large scale brownfield redevelopment building in the floodplain should be avoided and flood tolerant activities only occur if there are no downstream or upstream effects. The flood risk management hierarchy should be considered through the structure planning process as well as when development areas are brought forward.

Table 12 Flood Risk Management Hierarchy

Step	Approach	Description	Example
1	Avoid	Locate development in areas at least risk of flooding	Set aside floodplains free from any development
2	Substitute	Where development has to be located in the floodplain, located the least vulnerable land uses there	Prioritise public open space, or similar, within the floodplain
3	Control	Implement interventions to reduce the impact of flooding. Where the need for vulnerable land uses or critical infrastructure outweighs flooding, engineering interventions could be brought forward to reduce flood extents.	Culvert/bridge upgrades Channel widening Land raising Flood storage
4	Mitigate	Implement interventions to reduce the residual risk of flooding	Property level flood protection or flood resilience measures

Source: Planning Policy Statement 25 Practice Guide, CLG, December 2009

The flood risk management hierarchy will be applied through the structure planning process for the Drury Future Urban Zone and as development is brought forward.

Because the Drury Estuary is a constraint to flow, flood mitigation options (such as passing flows forward) proposed for one stormwater catchment, must consider the impact those options may have on the other catchments discharging to the Drury Estuary.

4.5.1 General

- Modelling has identified that a number of structures will be inundated during a 10 year and or 100 year ARI MPD CC event. Signage is to be provided at these structures indicating that the road is flood prone. Potentially a warning light when flood waters exceed a certain water level (or some other warning method) could also be implemented.
- Avoid locating buildings within the 100 year ARI floodplain.
- Avoid locating infrastructure in the 100 year ARI floodplain unless it can be designed to be resilient to flood damage.
- Ensure all development and changes within the 100 year floodplain do not increase adverse effects or increased flood depths or velocities to other properties upstream or downstream of the site.
- Avoid increasing flood risk and flood extent upstream and downstream for all flood events.
- Identify overland flowpaths and ensure that they remain unobstructed and able to safely convey runoff.
- Use capacity available in riparian margins as part of the water conveyance system and enhance intermittent streams to provide capacity and conveyance as a means to manage flood waters.

4.5.2 Slippery Creek Catchment

Due to the significant floodplain within Slippery Creek, development should be limited to land outside the floodplain. The flooding issues within this catchment require development of a comprehensive solution. Ad hoc development within the floodplain will not be considered due to the high risk of cumulative effects on downstream property and infrastructure.

4.5.2.1 Potential Interventions

Potential interventions in the Slippery Creek Catchment to control the floodplain in the Future Urban Zone could include:

Sutton Road Bridge Upgrade – Section 3.7.1.3 identified that the bridge and approach road are predicted to be overtopped during a 10 year storm event. Therefore they do not meet AT levels of service for a local road. Any works to address the overtopping (such as raising the bridge and approach road and increasing the flow conveyance of the bridge) must be carried out in tandem with upsizing the downstream railway bridge which is a constraint to flow. No flow mitigation benefit (such as lowering water levels) will be obtained if work is not also carried out on the downstream railway bridge.

Opaheke Road Bridge Upgrade - Section 3.7.1.3 identified that the existing approach road to the bridge is predicted to overtop by 0.47m depth of water during a 100 year ARI MPD CC storm event. We understand that this is a future arterial. Therefore it would not meet AT levels of service should it become an arterial road. Any flood mitigation works on this road will need to consider the downstream Bellfield SHA.

Great South Road Bridge Upgrade - the existing bridge and approach road is predicted to overtop by 0.2m and 0.3m depth of water (respectively) during a 100 year ARI MPD CC storm event. Modelling indicates that enlarging the conveyance capacity of the bridge results in a drop in water levels.

4.5.3 Hingaia Stream Catchment

The general management approach will be to pass flows forward.

However, existing culverts along the northern Hingaia Stream tributary will need to be upgraded to enable this management approach.

Further investigations are underway to determine the extent and timing of the required upgrades.

4.5.3.1 Potential Interventions

SH1 Bridge Upgrade – modelling indicates that increasing the flow conveyance of the bridge will result in a drop in water levels in Drury township during a 100 year ARI MPD CC event. Engagement with the Supporting Growth Alliance is ongoing.

Norrie Road Bridge Upgrade - modelling indicates that increasing the flow conveyance of the bridge will result in a drop in water levels in Drury township during a 100 year ARI MP CC event.

Great South Road Bridge Upgrade - modelling indicates that increasing the flow conveyance of the bridge will result in a drop in water levels upstream of the bridge.

4.5.4 Drury West

The general management approach will be to pass forward large storm event flows.

4.6 Applying Water Sensitive Design in the Future Urban Zone

Table 13 provides a ‘toolbox’ of options that can be applied by development to help meet the stormwater management requirements described in this section. For primary and secondary conveyance, priority is given in Table 13 to the order in which options must be applied. For example, for secondary stormwater conveyance the preferred option is to retain and enhance permanent and intermittent streams and maintain as much as practical overland flowpaths. If it can be demonstrated that there are practical reasons why this cannot be achieved, then swales and open channels (or other overland flow redirecting methods) can be considered. Finally, if swales are not practical, the road network can then be considered for secondary conveyance.

As development plans are brought forward the appropriateness of particular devices or approaches can be refined.

Guidance on applying water sensitive design at the development level can be found in the following documents:

- GD04: Water Sensitive Design for Stormwater, March 2015
- GD05: Erosion and Sediment Control Guide for Land Disturbing Activities in the Auckland Region, June 2016.
- SW CoP: Code of Practice for Land Development and Subdivision, Chapter 4 – Stormwater, November 2015
- GD01: Stormwater Management Devices in the Auckland Region.
- TR035: Auckland Unitary Plan stormwater management provisions: Technical basis of contaminant and volume management

Table 13: Water Sensitive Design Toolbox

Key Principles

Working with the existing landform - minimising cutting and filling that effects infiltration and changes the natural flowpaths, as far as practicable.

Minimise impervious surfaces and land disturbance thereby retaining the natural infiltration capacity of the soil

Apply exemplar erosion and sediment control measures (including small site development) to minimise the impact on the downstream receiving environment

Disconnection of impervious surfaces from the receiving environment to encourage infiltration and attenuation prior to discharge to the stormwater system

Utilise soakage into basaltic soils – directly via pervious surfaces or using soakage devices coupled with stormwater treatment.

Utilise soakage into peat soils

Utilise soakage in high use aquifer managements areas and high use stream management areas.

Avoid soil compaction or undertake cultivation to include organics and restore damage to maximise permeability

Re-vegetation/planting to reduce runoff and erosion and maximise biodiversity

Use inert building materials

Capture and reuse of rainwater for buildings and landscapes – the reuse component diverts stormwater first flush to wastewater (toilet flushing) or to ground for infiltration.

Land Use	Requirements	Options	Auckland Council Guidance Documents (refer Section 4.6 above)
Residential	Hydrological Mitigation – Retention and Detention	Above ground rainwater storage/re-use tanks Rain gardens/planter boxes Underground storage tanks, structural cells Permeable pavement and porous concrete Filter trenches/trench drains Note: Infiltration for retention is preferred.	TR035 GD04 GD01
	Primary Stormwater Conveyance	In order of preference: Soakholes (where practicable, and subject to testing) Retain and enhance permanent and intermittent streams Swales Pipe network	GD04 SW CoP GD01
	Secondary Stormwater Conveyance	In order of preference: Retain and enhance permanent and intermittent streams Swales and open channels Road corridors	GD04 SW CoP

Key Principles

	Flood Risk Attenuation (where required)	‘At source’ storage, e.g. underground storage Wetlands. ‘Dry’ basins with multi-purpose functionality	GD04 SW CoP GD01
All roads/ carparking	Hydrological Mitigation - Retention and Detention	Rain gardens Tree pits Filter trenches/trench drains Permeable pavement and porous concrete Note: Infiltration for retention is preferred.	TR035 GD04 GD01
	Stormwater Treatment	Rain gardens Tree pits Filter strips/swales Wetlands	GD01
	Primary Stormwater Conveyance	In order of preference: Soakholes (where practicable, and subject to testing) Retain and enhance permanent and intermittent streams Swales Pipe network	GD04 SW CoP GD01
	Secondary Stormwater Conveyance	In order of preference: Retain and enhance permanent and intermittent streams Swales and open channels Road corridors	GD04 SW CoP
	Flood Risk Attenuation (where required)	‘At source’ storage, e.g. underground storage Wetlands ‘Dry’ basins with multi-purpose functionality	GD04 SW CoP GD01
Business	Hydrological Mitigation - Retention and Detention	Above ground rainwater storage tanks Rain gardens/planter boxes Underground storage tanks, structural	TR035 GD04 GD01

Key Principles

		cells Permeable pavement and porous concrete Filter trenches/trench drains Detention basins Note: Infiltration for retention is preferred. Where retention is not achieved then treatment of impervious surfaces is required prior to discharge	
	Stormwater Treatment	Rain gardens Tree pits Filter strips/swales Proprietary treatment devices Wetlands Contaminant specific treatment devices are required for industrial or trade activities	GD01
	Primary Stormwater Conveyance	In order of preference: Soakholes (where practicable, and subject to testing) Retain and enhance permanent and intermittent streams Swales Pipe network	GD04 SW CoP GD01
	Secondary Stormwater Conveyance	In order of preference: Retain and enhance permanent and intermittent streams Swales and open channels Road corridors	GD04 SW CoP
	Flood Risk Attenuation (where required)	‘At source’ storage, e.g. underground storage Wetlands ‘Dry’ basins with multi-purpose functionality	GD04 SW CoP GD01
Special Purpose	Hydrological Mitigation - Retention and Detention	To be confirmed	

Key Principles

	Primary Stormwater Conveyance
	Secondary Stormwater Conveyance

5 Next Steps

This Stormwater Management Plan provides guidance on how development can be delivered in accordance with the objectives of national and regional policy and guidelines. It has considered the stormwater constraints within the Future Urban Zone, as well as how to manage potential impacts on the downstream receiving environment. Delivered following a water sensitive design approach, development offers a significant opportunity to enhance the local water environment and address a number of existing stormwater issues.

This Stormwater Management Plan is a high level document, reflecting the start of the development process. As development plans are brought forward and knowledge gaps outlined in section 3.8 are filled it is expected that either this Stormwater Management Plan is updated, or more detailed Plans are prepared that comply with the requirements set out in Section 4.This SMP will need to be revised in greater detail as part of an iterative process or a new more detailed SMP developed to support any plan change process. This SMP is very high level at this stage and only highlights areas to be considered.

Key next steps for informing the refinement of this stormwater management plan as specific areas are brought forward include:

1. Apply Water Sensitive Design as the basis for development planning.

2. Engage early with Healthy Waters for large scale development to align expectations.

3. Development layout considers the extent of floodplain, flood prone, and overland flowpaths so these areas are free from vulnerable land uses.

4. Undertake baseline water quality testing within the Structure Plan Area to determine the current water quality.

5. Site specific geotechnical investigations, including infiltration testing to inform the potential for soakage and/or retention of stormwater to ground.

6. Ensure watercourse enhancement opportunities are co-ordinated and integrated from the start of development planning to maximum benefits. Work with landowners in a collaborative manner to ensure sufficient land is set aside for greenways or riparian buffer zones, as appropriate.

8. Work with landowners in a collaborative manner to ensure multiple benefits (social, cultural and environmental) are achieved based on the need for flood risk attenuation (where required).

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Appendices

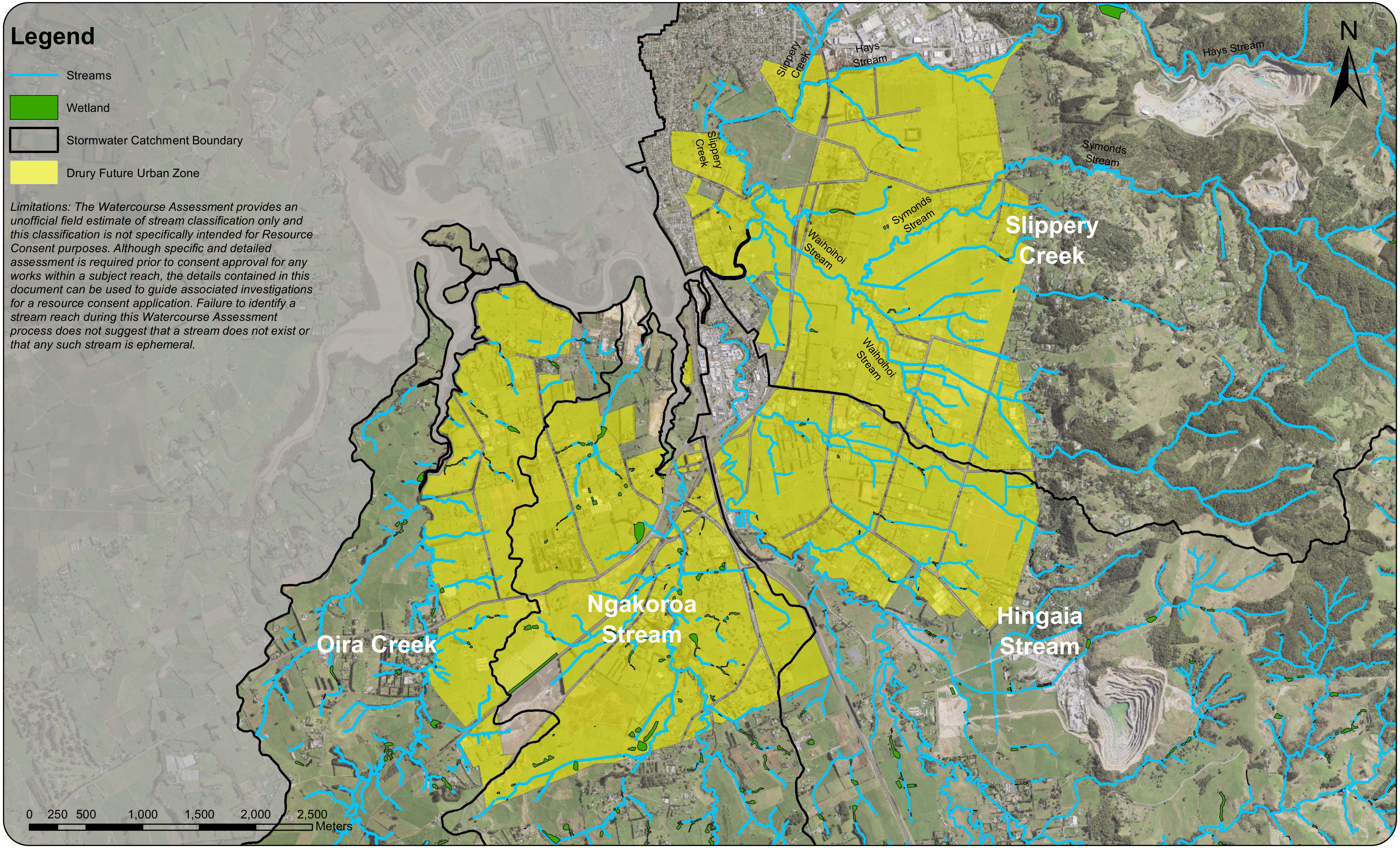
A. Catchment Characteristics and Constraints Mapping

A.1 Figure 11: Streams

A.2 Figure 12: Ecology, Erosion and Water Quality

A.3 Figure 13: Flooding

A.4 Figure 19: Enhancement Opportunities



Opaheke-Drury Stormwater Management Plan

Figure 11: Streams

Issue: Draft
Date: 20/03/2019

Drawn: HJL
Checked: COS

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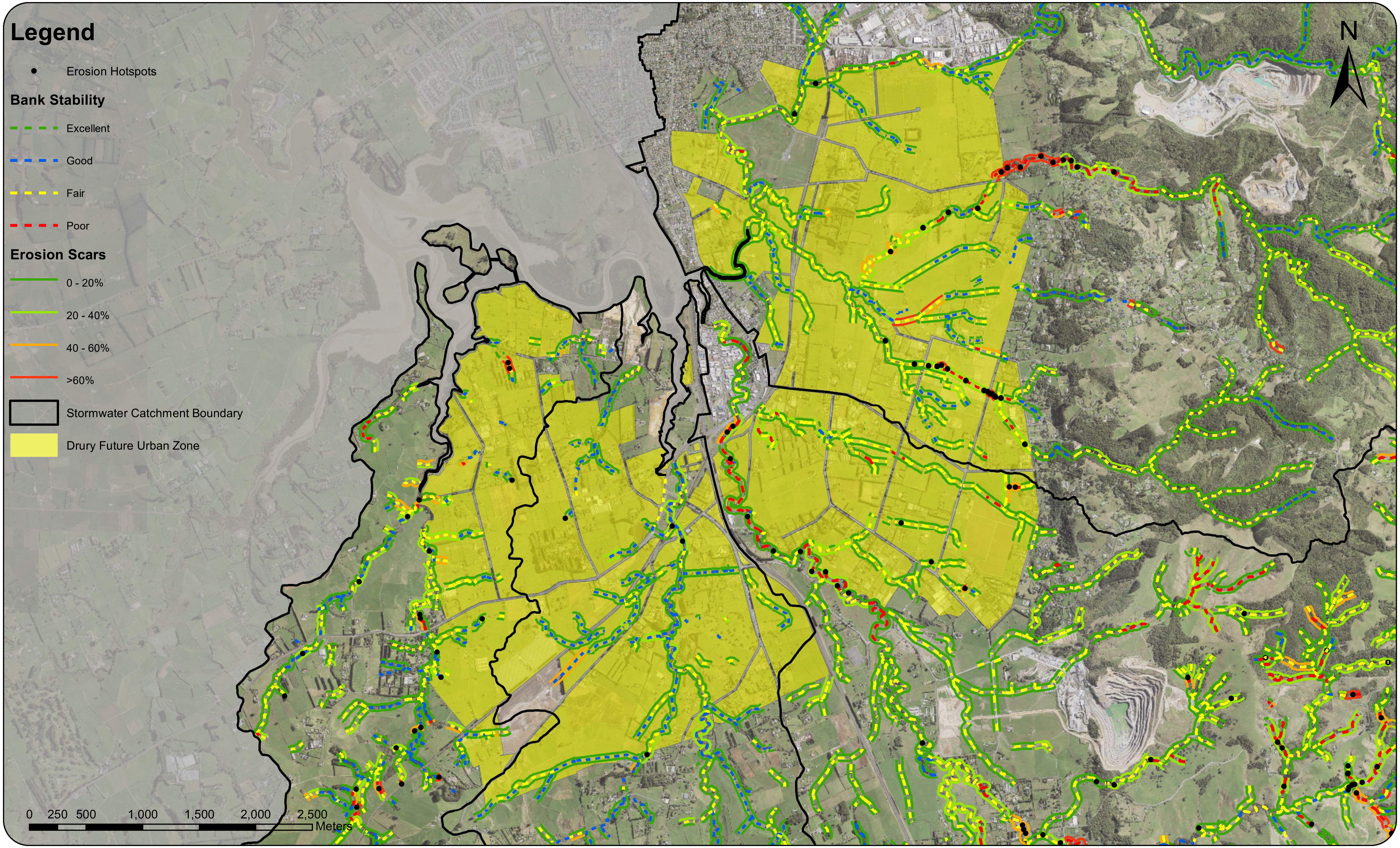

Opaheke-Drury Stormwater Management Plan

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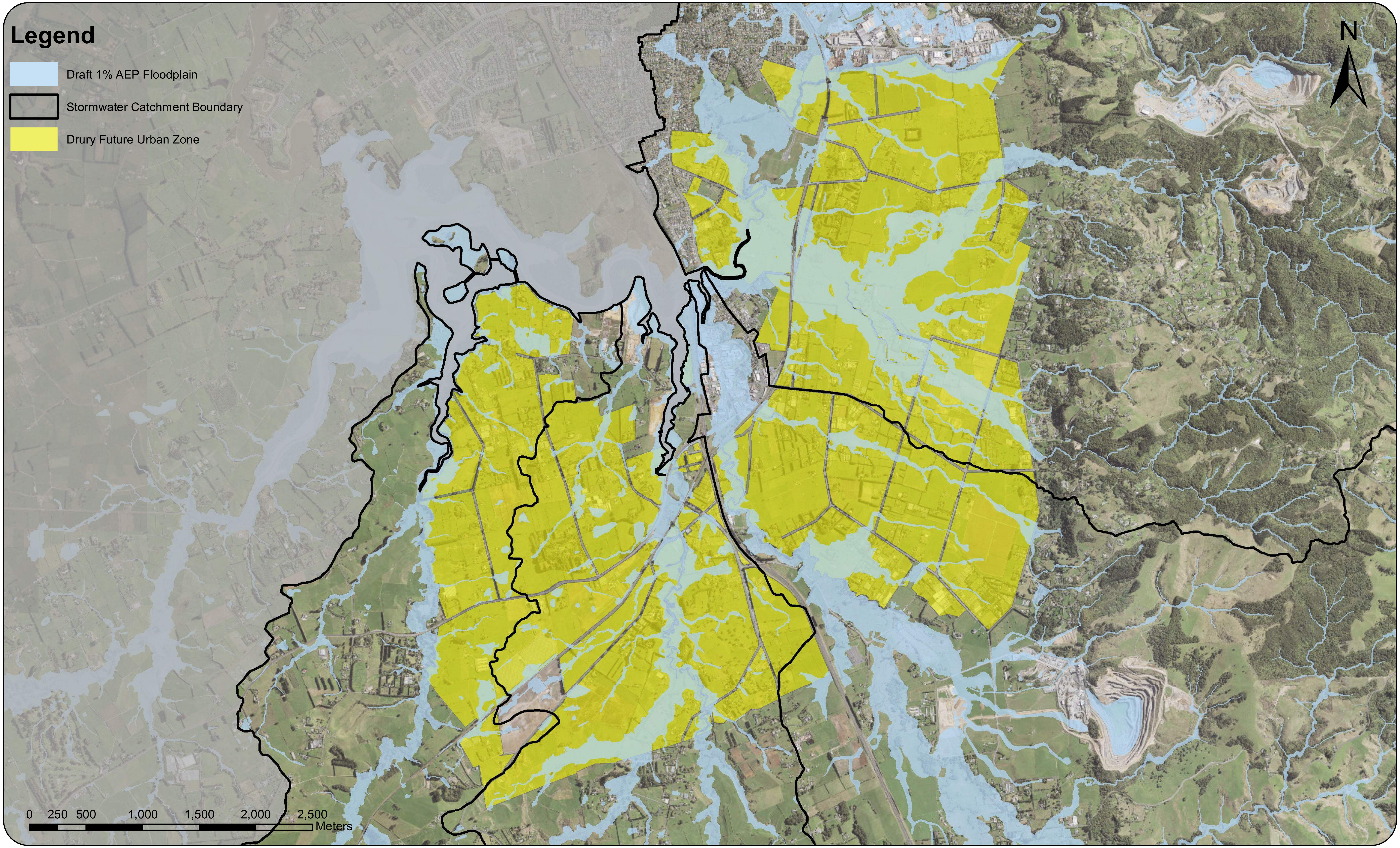
Figure 12: Ecology, Erosion and Water Quality



Opaheke-Drury Stormwater Management Plan

Figure 13: Flooding

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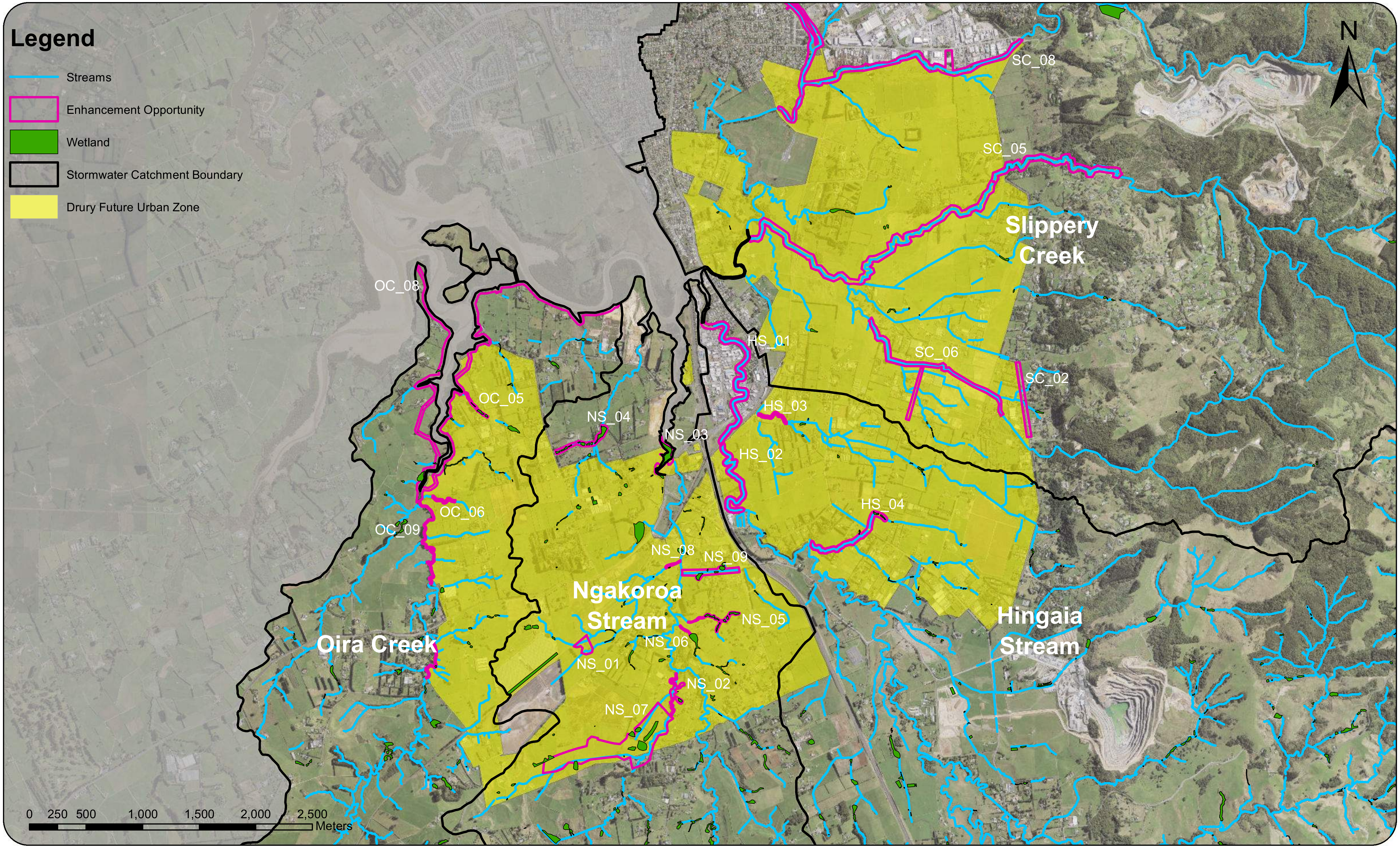
Checked: COS



Opaheke-Drury Stormwater Management Plan

Figure 18: Enhancement Opportunities

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Checked: COS

Appendix D

Opaheke-Drury Stormwater Management Plan

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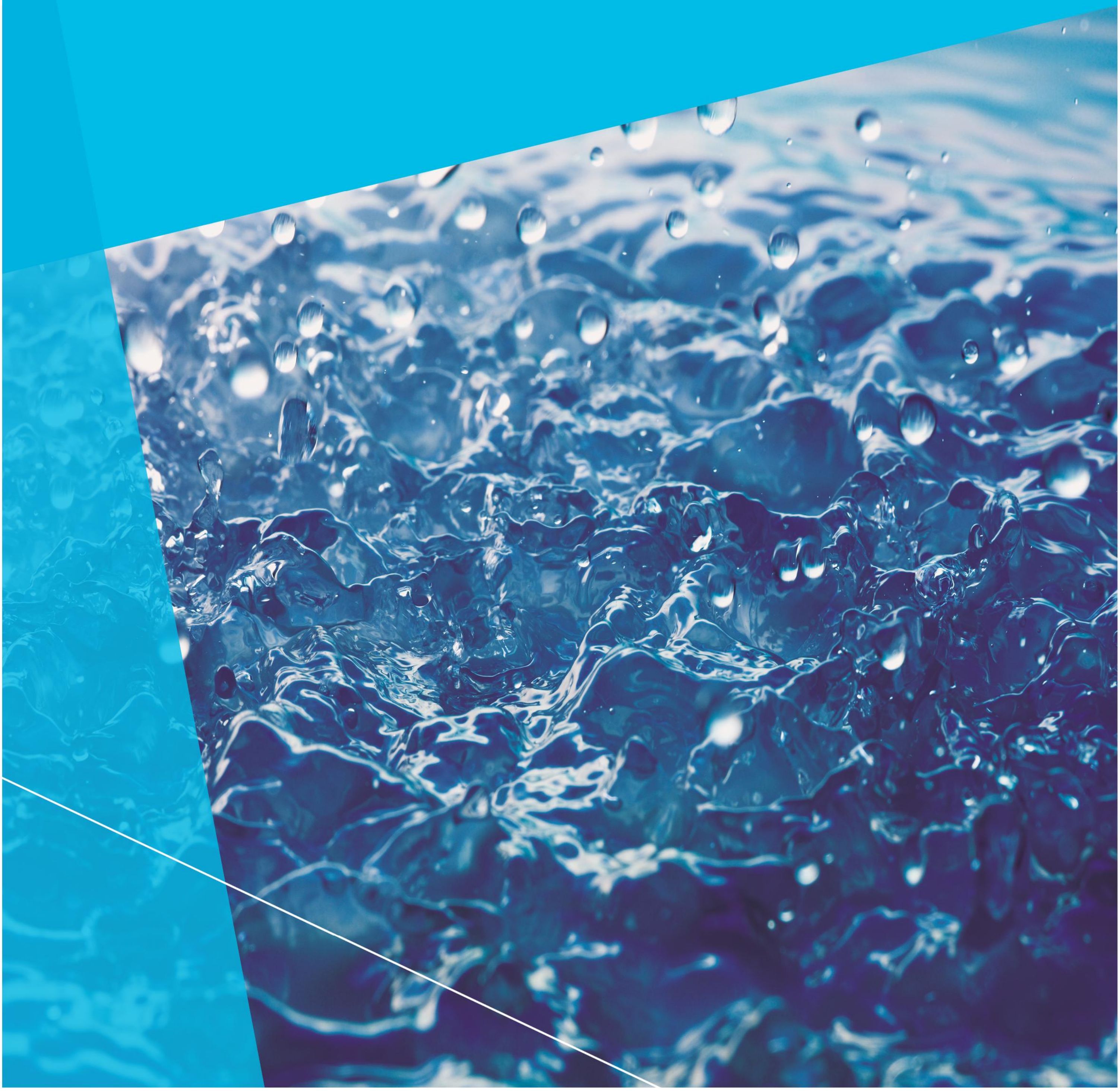
Opaheke-Drury Stormwater Management Plan

Preliminary Plan



Opaheke-Drury Stormwater Management Plan

Client: Auckland Council

Co No.: N/A

Prepared by

AECOM New Zealand Limited
8 Mahuhu Crescent, Auckland 1010, PO Box 4241, Auckland 1140, New Zealand
T +64 9 967 9200 F +64 9 967 9201 www.aecom.com

19-Sep-2017

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Quality Information

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Date	19-Sep-2017
Prepared by	Lyndsey Smith
Reviewed by	Kristina Healy

Revision History

Rev	Revision Date	Details	Authorised	
			Name/Position	Signature
1	3-Aug-2017	For submission to Structure Plan Team for Council review	Justine Bennett Associate Director - Environment	JA Bennett
2	7-Aug-2017	Further Council and Structure Plan Team review	Justine Bennett Associate Director - Environment	JA Bennett
3	15-Aug-2017	For submission to Structure Plan Team	Justine Bennett Associate Director - Environment	JA Bennett
4	19-Sep-2017	Inclusion of updated maps for final submission	Justine Bennett Associate Director - Environment	JA Bennett

Table of Contents

Glossary and Abbreviations

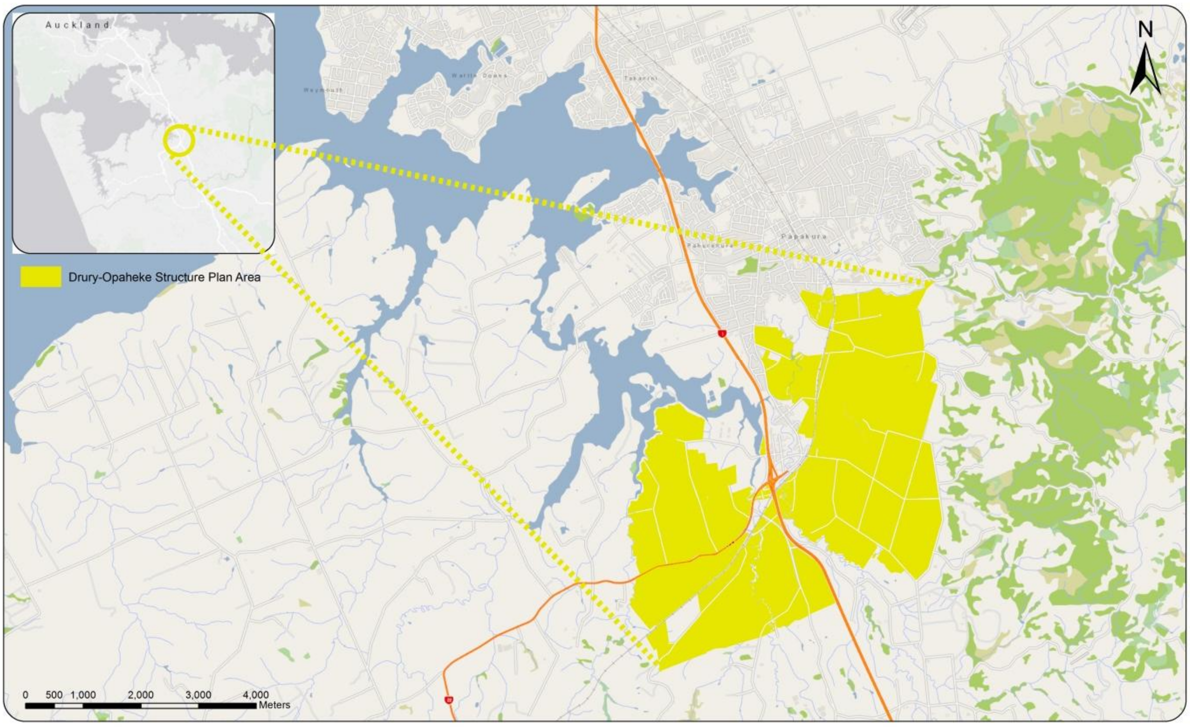
AC	Auckland Council
AEE	Assessment of Environmental Effects
AEP	Annual Exceedance Probability
ARC	Legacy Auckland Regional Council (now Auckland Council)
ARI	Average Recurrence Interval
AUP(OiP)	Auckland Unitary Plan (Operative in Part)
CMA	Coastal Marine Area
FULSS	Future Urban Land Supply Strategy
FUZ	Future Urban Zone
GD	Guideline Document
HSG	Hydrological Soil Groups
ITA	Industrial Trade Activity
NIMT	North Island Main Trunk Rail Line
RPS	Regional Policy Statement
SH	State Highway
SMAF	Stormwater Management Area – Flow
SMP	Stormwater Management Plan
TP	Technical Publication
TR	Technical Report
WSD	Water Sensitive Design

Executive Summary

The Unitary Plan has zoned extensive areas of rural land in the southern Auckland Region as “Future Urban”. The sequencing of development of the Future Urban Zone (FUZ) is set out in the recently updated Future Urban Land Supply Strategy (FULSS).

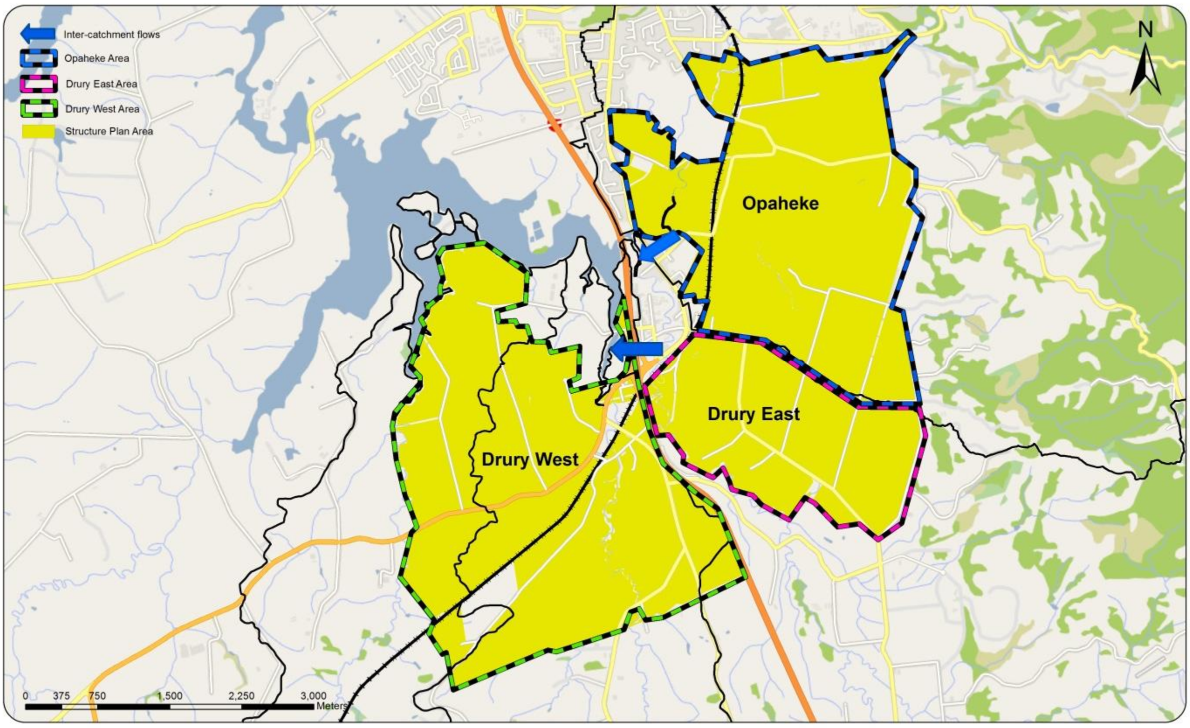
The Opaheke-Drury Structure Plan area covers the FUZ around Drury Township and encompasses the area south of Papakura and north of Pukekohe, as shown in Figure 1 below.

Figure 1 Opaheke-Drury Structure Plan Area – General Location Plan



The Opaheke-Drury Stormwater Management Plan (SMP) has been produced to support the Drury component of the Structure Plan South. The SMP covers three stormwater management areas that include four stream catchments; Drury West (Oira Creek and Ngakoroa Stream), Drury East (Hingaia Stream) and Opaheke (Slippery Creek). The structure plan extents within the Oira Creek and Ngakaroa Stream catchments have been grouped into a single stormwater management area due to the many similarities shared between these catchments.

Figure 2 Opaheke-Drury Structure Plan Area – Stormwater Management Areas



This SMP has been prepared to support Structure Planning of the Opaheke-Drury FUZ and inform development. It identifies the key constraints, risks and opportunities for stormwater management within the three stormwater management areas. The SMP also identifies where there are synergies with stormwater management with other outcomes, such as passive recreation, maintaining ecological values and respecting natural land forms.

The three stormwater management areas are naturally hydrologically connected (e.g. Slippery Creek drains into Hingaia Stream) during high order flood events when flood flows move from one catchment to another upstream of the natural stream confluence (e.g. Hingaia Stream overflows to Ngakoroa Stream via State Highway 1 (SH1) during high order events).

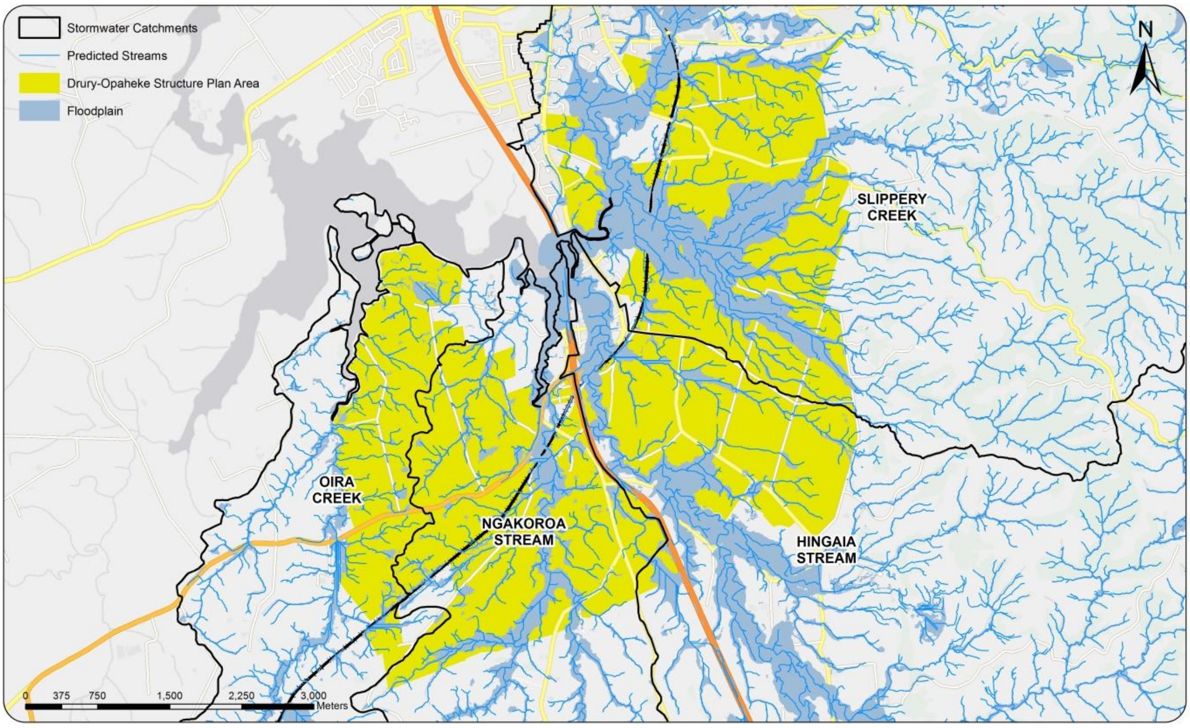
Drury and Papakura townships are the only significant development areas in proximity to the structure plan area. The stormwater management areas are rural (greenfields) in nature.

State Highway 1 and the North Island Main Trunk Rail Line cross the structure plan area.

Flooding has occurred within Drury and Papakura townships. Drury Township is within the natural floodplain of the Hingaia Stream. Because the land is steeper and the soils are of low permeability in Opaheke and Drury East, the velocity of water traveling through the system is expected to be higher than in Drury West. This is also Auckland's deepest flood plain.

Fine sediments from these stormwater management areas are impacting on the health of the streams and the Pahurehure Inlet, which is forms a part of the Manukau Harbour.

Figure 3 Opaheke-Drury Structure Plan Area - Floodplains



The key risk for the structure plan area is flood risk. The floodplains are extensive and deep with high velocity flows. They represent a real risk to human health and safety if not managed appropriately.

The Unitary Plan anticipates that water quality will be improved as a consequence of stormwater management approaches for new development where the receiving environment is degraded. The Pahurehure Inlet is shown as Degraded 1 in Figure B7.4.2.1 of the Regional Policy Statement. Degraded areas have been identified based on assessments of water quality, sediment contamination and benthic health.

Stormwater management options have been provided in this preliminary SMP for each of the Structure Plan's stormwater management areas which take into account the existing constraints and risks and the receiving environment. Three possible management approaches have been identified for the mitigation of flooding; which reflects the connectivity of the four catchments. The first is to delay live zoning until up to date, detailed catchment modelling and stormwater management options work is complete. The second is described as Adequate Floodplain Allowance which indicates a route where conveyance and storage functions must be provided. The cumulative effects of development on these areas must also be considered. The third is described as Pass Flows Forward which entails improving conveyance to expedite the drainage of flood flows. This approach is subject to achieving an adequate downstream conveyance capacity and management of geotechnical constraints.

The complexity of the relationship between the four stream catchments is reflected in the proposed staged release of land for development (FULSS, 2017). This will require coordination and funding of studies, assessments of receiving environments, hydrological modelling and geotechnical investigations to better inform decision makers prior to development commencing. This is a significant body of work that will necessitate compliance with the staging in the FULSS to provide adequate time for it to be completed.

The Opaheke stormwater management area (Slippery Creek) is perhaps the most hydrologically complex of the catchments requiring a significant amount of investigation and modelling prior to development commencing. The risk of ad-hoc early development could result in flood and stormwater management mitigation measures being unable to be implemented. The interconnected relationship of all four catchments requires integrated solutions that address site specific and cumulative effects from land development. Flood management approaches are best managed at a catchment scale because there are no practical options to manage flooding on individual lots. Flood management at a development scale is feasible but will likely lead to piecemeal, inefficient solutions that may represent a high operational (ratepayer) expense.

The Auckland Unitary Plan Operative in Part (AUP(OiP)) requires development in Greenfield areas to avoid as far as practicable, or otherwise minimise or mitigate, adverse effects of stormwater runoff on freshwater systems, freshwater and coastal water by taking an integrated stormwater approach (E1.3 , AUP(OiP)) and to progressively reduce existing adverse effects where practical. An integrated stormwater management approach is described in Policy 10 in E1.3 which is aligned with Water Sensitive Design as described in Auckland Council's Guidance Document 04 (GD04). The policy recognises that there is greater opportunity in Greenfields development to achieve good stormwater outcomes. It requires protection of hydrological features, ecology and hydrology and consideration of the sensitivity of the receiving environment; and expresses a preference for stormwater management at source and the use of green infrastructure.

1.0 Introduction

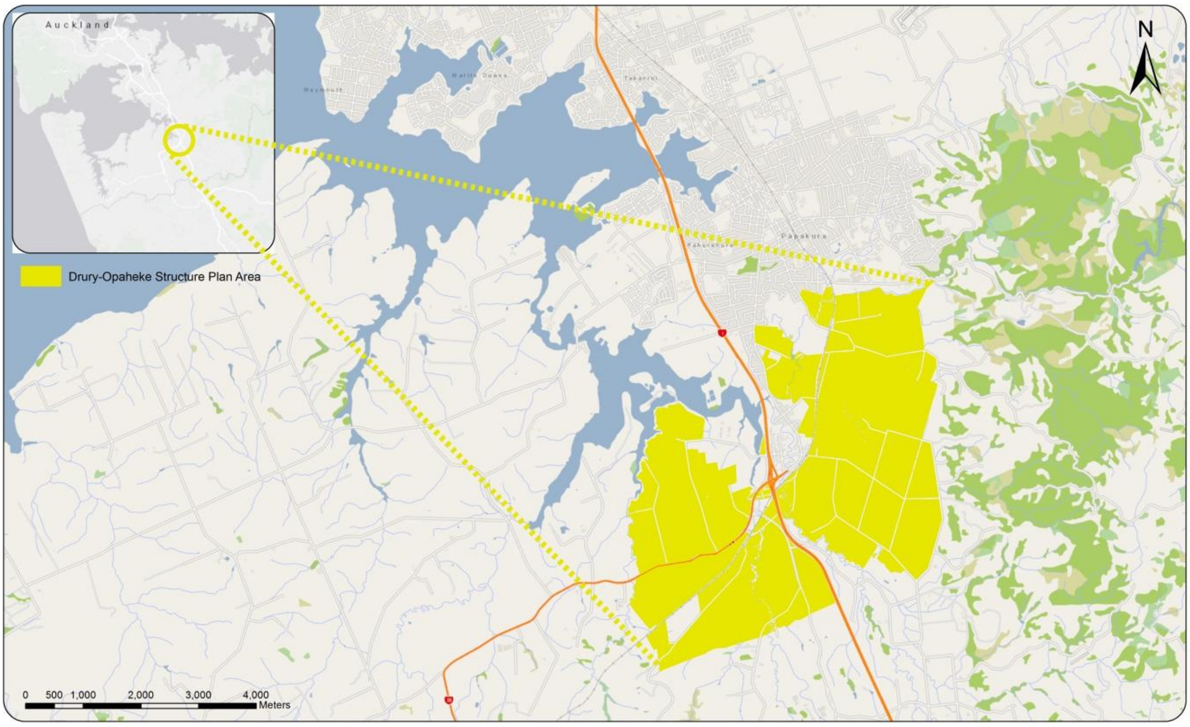
1.1 Stormwater management – the Auckland context

Auckland Council has commissioned AECOM New Zealand Limited (AECOM) to produce the Opaheke-Drury Stormwater Management Plan (SMP), to support the Opaheke-Drury Structure Plan process.

The Drury area has been identified by Auckland Council as suitable for future urban growth and has been zoned as Future Urban Zone (FUZ) under the Auckland Unitary Plan (Operative in Part) (AUP(OiP)).

The Opaheke-Drury Structure Plan will outline and guide how and when development will occur within the Opaheke-Drury FUZ. Opportunities and constraints will be identified by the relevant disciplines to inform the Opaheke-Drury Structure Plan. The structure plan will inform the future pattern of land use, transport and service networks and plan changes to enable development. Figure 4 shows the location of the Opaheke-Drury Structure Plan area.

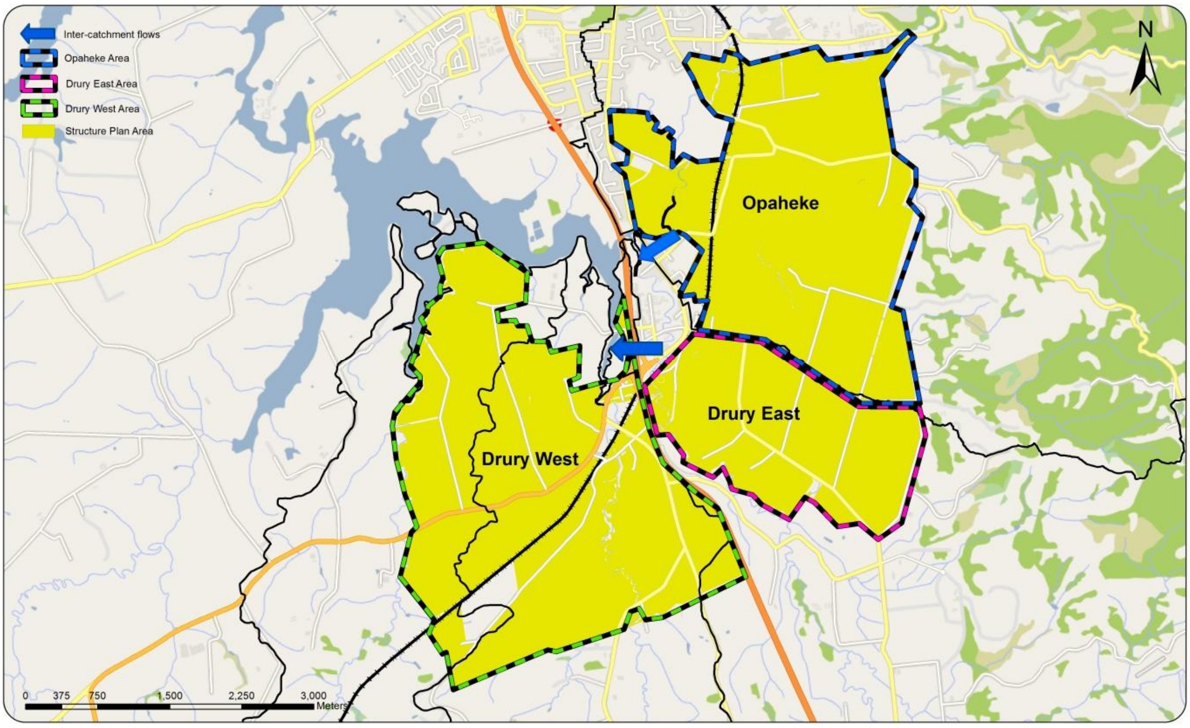
Figure 4 Opaheke-Drury structure plan area – general location plan.



This SMP covers three stormwater management areas within the Opaheke-Drury Structure Plan area that include four stream catchments that drain into Drury Creek which discharges to the Pahurehure Inlet, part of the Manukau Harbour. These areas are defined below and the stormwater management areas and stream catchments are illustrated in Figure 5 and Appendix A.

- Drury West – includes parts of Oira Creek and Ngakoroa Stream catchment.
- Drury East – includes part of the Hingaia Stream catchment.
- Opaheke – includes part of the Slippery Creek catchment.

Figure 5 Opaheke-Drury structure plan area – stormwater management areas



The dominant land use in these catchments is currently rural with low levels of imperviousness. It is anticipated that when fully developed, imperviousness within the FUZ will increase up to 70%. The Future Urban Land Supply Strategy (FULSS) (2017) details the level of development within these four catchments, and is summarised in Table 1. The FULSS sets out a programme for sequencing future urban land development over 30 years across Auckland. As shown in Table 1, the sequencing for development within the Opaheke-Drury Structure Plan area starts with the Drury West stormwater management area.

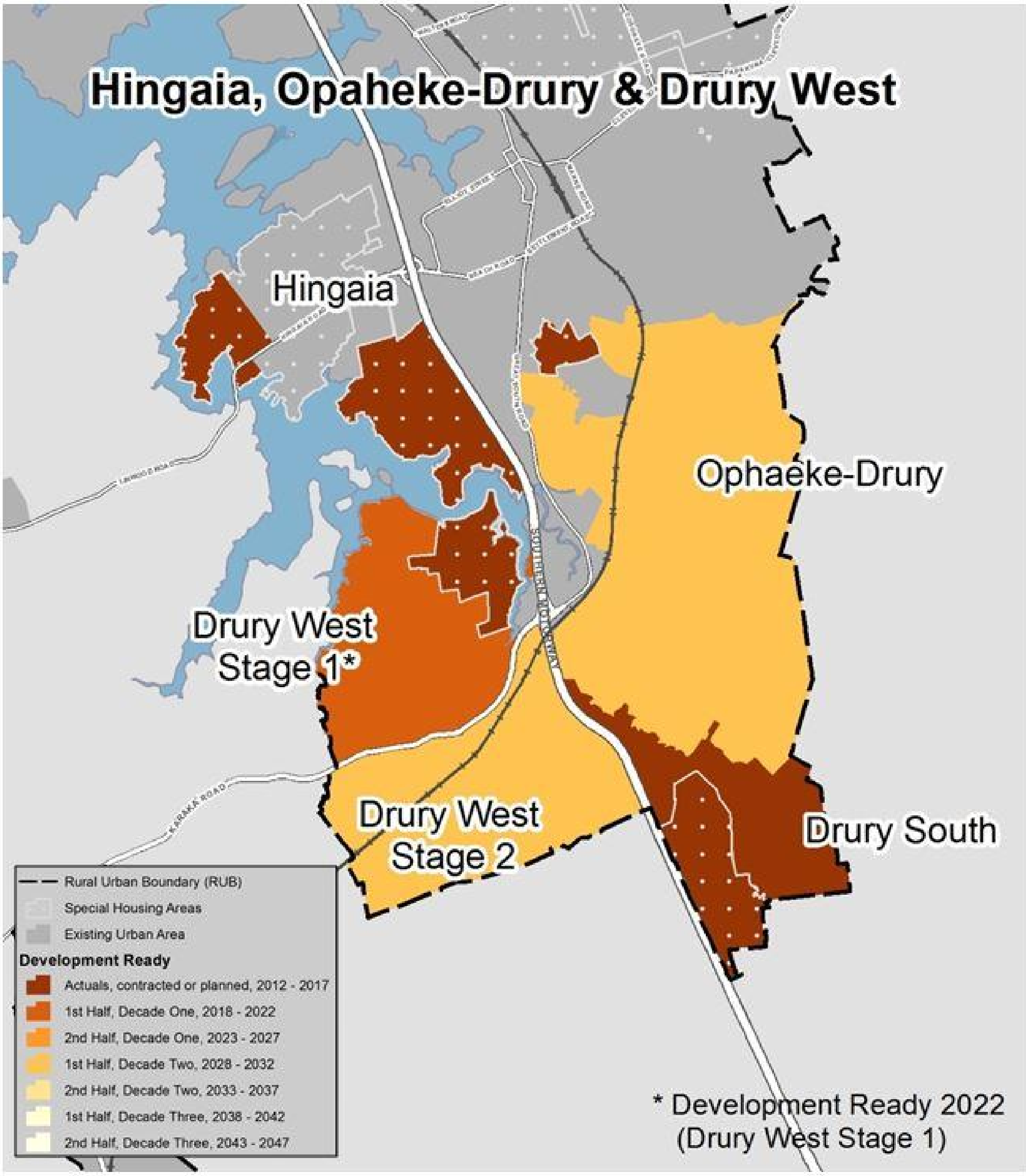
Figure 6 shows the timing for development for different areas of the Opaheke-Drury Structure Plan area (sourced from the FULSS, 2017).

Table 1 Proposed Future Urban Zone – Future Urban Land Supply Strategy (2017)

Drury West (comprises Drury West Stormwater Management Area)	Drury (comprises Drury East and Opaheke Stormwater Management Areas)
Live zone – 87ha, 1350 dwellings. **Stage 1** – 392ha, approx. 4,200 dwellings. **Stage 2** – 552ha approx. 5,650 dwellings.	1, 149ha. Approx. 8,200 dwellings. 1 town and 2 local centres.
Timing - Stage 1 2018-2022 and Stage 2 2028-2032	2028-2032

NOTE: Actual development yields may differ from these estimates.

Figure 6 FULSS development sequence for Opaheke-Drury Structure Plan area



Integrated stormwater management is woven into the AUP (OiP) with the expectation that land use is controlled to manage stormwater effects. The key policies related to water quality and integrated management are presented in Chapter E1 of the AUP(OiP).

A Water Sensitive Design (WSD) Guidance Document (GD04) has been produced and forms a part of the Auckland Design Manual. It describes the process set out in the integrated stormwater management policies within the AUP(OiP). WSD is an inter-disciplinary design approach, which considers stormwater management in parallel with the ecology of the site, best practice urban design, and community values.

Auckland Council is responsible, under the Local Government Act 2002 (amended 2010), for stormwater management and flood protection within the Auckland region. Auckland Council's priorities in relation to stormwater management, relevant to the SMP, include:

- Growth: supporting and servicing the Auckland Plan's growth strategy demonstrating innovation and best practice.
- Flooding: progressively reducing existing flood risk across the region.
- Environmental Improvement: reducing existing negative effects on the environment, particularly streams and coastal areas.

1.2 Purpose and scope of the SMP

It is envisaged that the stormwater management approach for the Opaheke-Drury SMP will be addressed in three stages due to the availability of necessary technical information. The stages are set out below:

1. Preliminary SMP to highlight issues and constraints, the implications for development and knowledge gaps that require further technical work. Potential mitigation and management approaches will be identified. The SMP addresses immediate needs for guiding appropriate land use in accordance with the staging and timing identified in the FULSS. Further investigations for subsequent development is programmed to occur but cannot be delivered prior to the development of the structure plan.
2. Catchment Scale SMP which is a stormwater management philosophy and a tool box of stormwater management approaches will be identified at a later stage. These will be incorporated into an updated SMP. This can occur once catchment investigations, detailed catchment modelling and stormwater management options work is completed. This update can support precinct plans/plan changes.
3. Developer led SMPs will be produced for larger scale developments to support development proposals. Specific stormwater management options and devices with design details will be provided. The stormwater management approach should respond to land use, urban design and roading requirements for a specific development area. These plans should be consistent with the approach identified in the Catchment scale SMP discussed above to avoid piecemeal development that implements inefficient stormwater infrastructure and that contributes to cumulative flooding effects. Should developers apply to develop in the absence of appropriate zoning they will need to carry out detailed stormwater catchment modelling to demonstrate they can develop without adversely affecting other landholdings in the catchment and achieve betterment to avoid cumulative flooding effects.

The purpose of this preliminary Opaheke-Drury SMP is to:

- Identify opportunities within the four catchments/ three development areas to realise additional benefits during development.
- Identify constraints within the catchment such as:
  - Areas that could be particularly sensitive to development and identify measures to protect these.
  - Areas that should not be developed, such as flood plains and their margins where current models are known to be inaccurate.
  - Natural features which will be protected and enhanced
- Identify possible infrastructure projects that could manage flooding in an efficient manner.

The modelling being undertaken to support this work will take into account the effects of climate change, however some existing (older) models do not currently incorporate climate change. In these cases this document applies a buffer to the flood plain in some areas to ensure a resilient flood plain extent is provided. In time this will be updated with new models and revised flood extents at which point, development can respond to the updated modelled flood plain extents.

All figures in the SMP report text are provided in Appendix A as A3 maps.

1.3 Objectives of the SMP

The objective of the SMP is to describe a range of possible stormwater management approaches/methods within the four catchments/ three stormwater management areas covered by the Opaheke-Drury SMP to enable sustainable development within the FUZ.

These suggested management approaches will be developed based on knowledge of the existing stormwater infrastructure, environmental conditions, flooding issues, soil and topographic conditions.

1.4 Outcomes

- Permanent and intermittent streams will be retained as directed in the AUP(OiP).
- Development will not significantly impede natural overland flow paths through the catchment.
- All development must match pre-development hydrology in terms of flows, volumes and frequency of runoff. Stormwater Management Area Flow (SMAF) 1 may be an appropriate mechanism to achieve this, however, subject to soil characteristics, an amended hydrology mitigation approach could be applied (different retention and detention volumes). SMAF1 has been developed to work in clay soils of low permeability and therefore its application without further assessment would achieve the desired hydrological mitigation and good environmental outcomes.
- Development will be staged to accommodate the technical work needed to identify catchment scale solutions and any necessary construction programme for flood mitigation devices.

1.5 Limitations

- The assessment has been based on the flood models completed to date for each of the catchments. It is known that the quality of these models is variable, therefore, a buffer around the modelled floodplain extents has been applied in some locations to account for climate change and possible modelling limitations and to better identify potential development constraints and opportunities in this SMP.
- The soil conditions throughout the structure plan area are variable and have been assessed based on a desktop analysis. Soil type will influence how stormwater is managed, particularly hydrology mitigation, and final design solutions in specific locations will require further analysis of soil type (refer to Section 2.6).

1.6 Assumptions

The old flood models available in three of the four stormwater catchments in the structure plan area represent a reasonable indication of the location of flood plains if a buffer is applied to represent the revised flood plain once climate change is applied.

2.0 Catchment Description

This SMP includes three stormwater management areas; Drury West, Drury East and Opaheke. These three stormwater management areas cover four stream catchments that discharge into Drury Creek and then the Pahurehure Inlet of Manukau Harbour. These stream catchments are naturally interconnected as flood flows from one may influence adjoining catchments. In addition, high order flood overflows occur between the catchments upstream of the natural confluences. For example, Hingaia Stream overflows (via the SH1 motorway) into the Ngakaroa Stream and Slippery Creek overflows (via Great South Road) into the Hingaia Stream catchment in high order flood events. In flood events these overflows impact significant public infrastructure, such as SH1 and Great South Road. Because the catchments' response to flood events is affected by flooding in the neighbouring catchments, there is a high degree of complexity to developing flood management approaches in the structure plan area. Hydrology mitigation and management of stormwater quality outcomes can be managed with typical stormwater devices.

This section presents a summary of the physical, chemical and biological characteristics of the stream catchments and how these affect the way in which stormwater is conveyed through the catchments and consequently the Opaheke-Drury Structure Plan area. Potential constraints and risks to development are presented in Section 3.0 of this report, which will guide options for the stormwater management approaches presented in Section 4.0.

2.1 Land use

The dominant land use within the four stream catchments is rural. This comprises grazed pasture with smaller areas of arable land and market gardens. Remnant forest stands are present in all four catchments, but these are limited in scale and distribution. The greatest extent of forest (exotic/native) is located in the Slippery Creek catchment (25% land use) and to a lesser extent, the Hingaia Stream catchment; in the foothills of the Hunua Ranges.

The catchments also include scattered residential and commercial properties and lifestyle blocks. The urban area of Drury Township is in the Hingaia Stream catchment and part of urbanised Papakura is in the Slippery Creek catchment. These towns form the most significant developed areas within the four catchments. Pukekohe is starting to expand into the upper reaches of the Oira Creek catchment. Additional notable land uses include the Stevenson quarry located within the Hingaia Stream catchment and the Winstone quarry located in the north eastern corner of the Slippery Creek catchment.

Significant infrastructure includes SH1 which runs north-south through the Hingaia catchment, and SH22 which runs approximately east-west passing through Hingaia, Ngakoroa and Oira catchments. The North Island Main Trunk (NIMT) Rail Line passes through all four catchments.

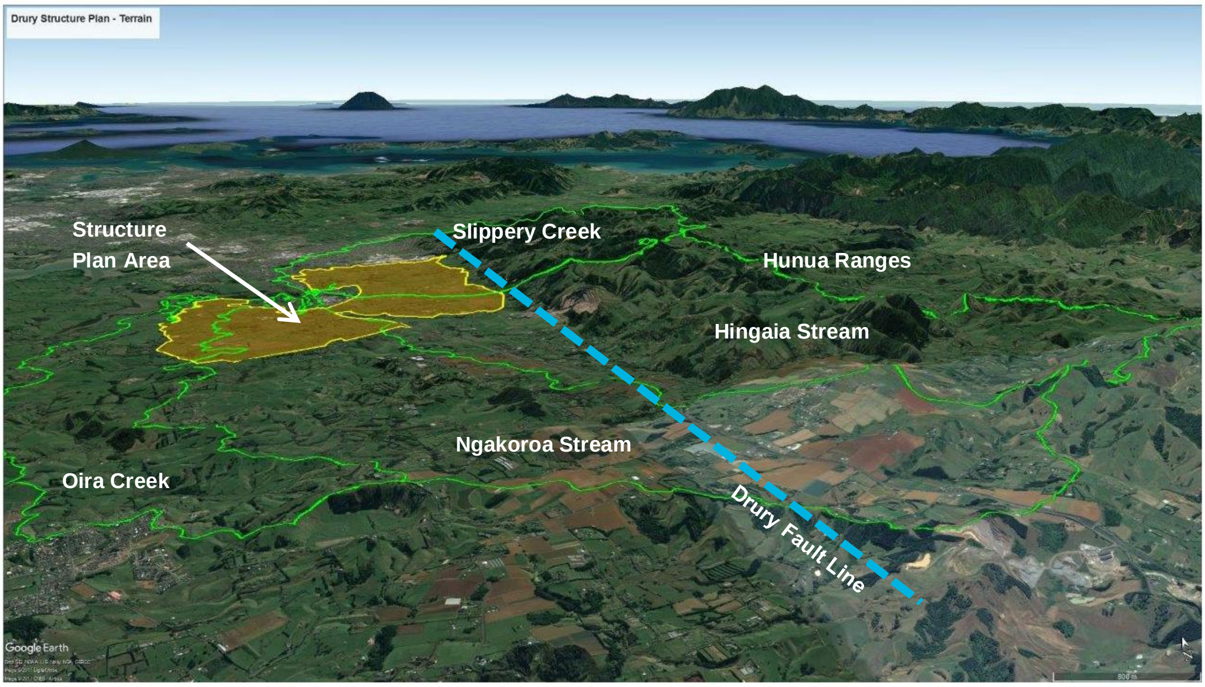
2.2 Topography

The topography across the majority of the catchments is characterised by low elevation gently undulating land. This excludes the flanks of the Hunua Ranges which extend through the headwaters of Slippery Creek and Hingaia Stream, where there is a mix of steep and gently contoured slopes.

There is a sharp change in topography from the steeper Hunua Ranges to the flatter low lying areas where the Drury Fault Line is located.

Although the catchments are largely within an area of low lying land, elevated landforms clearly separate each of the stream catchments. This is illustrated in Figure 7 Appendix A.

Figure 7 Opaheke-Drury structure plan area - Terrain



2.3 Geology and soils

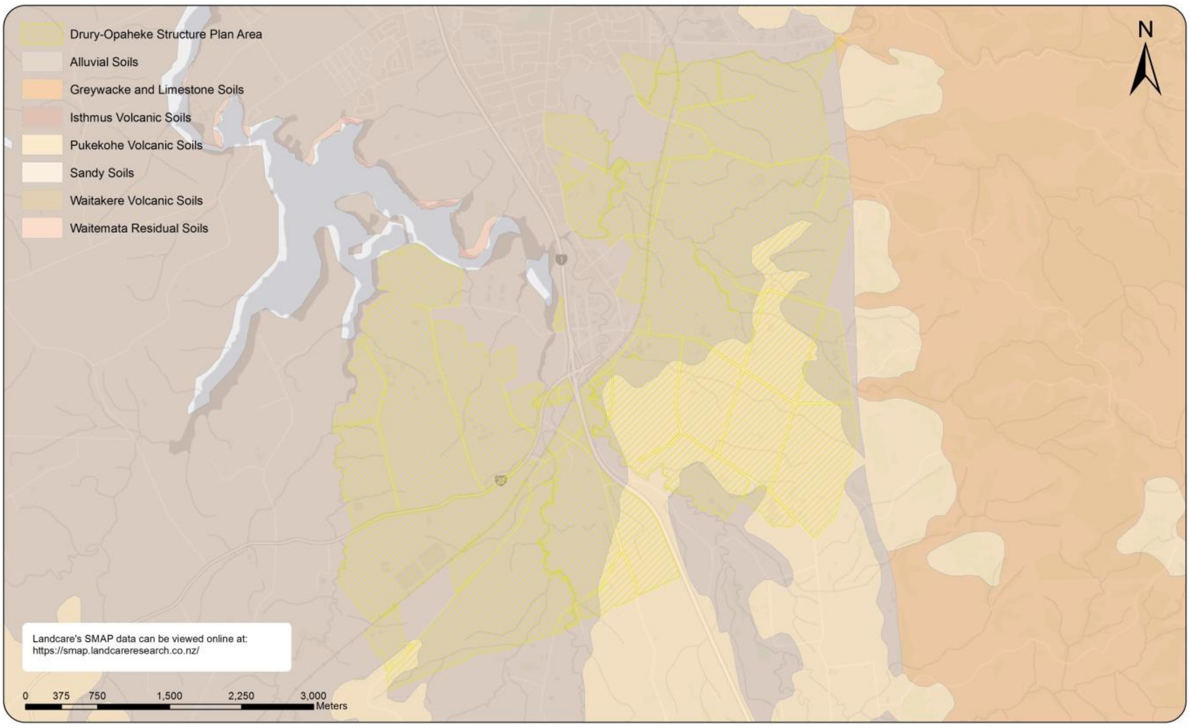
The geology underlying the Structure Plan Area and FUZ is illustrated in Figure 8. It is predominantly Puketoka Formation and basalt. Puketoka Formation comprises alluvial and estuarine deposits of sand, silt, clay and occasionally peat and organic topsoils. Smaller areas of mud and tuff (orange brown silty clay) are also present (Riley, 2017). The Drury Fault Line runs north to south through the Slippery Creek and Hingaia catchments and divides the flat lands from the foothills of the Hunua Ranges (Golder Associates, 2009).

Figure 8 Opaheke-Drury structure plan area – geology (grey channel demarks Pahurehure Inlet of Manukau Harbour)

The four catchments have deep soils (>100cm), which comprise clay on the foothills of the Hunua Ranges with areas of loam surrounding the watercourses within all four catchments, while silts dominate the Oira and Ngakoroa catchments (Figure 9). The loam surrounding the Hingaia Stream and Slippery Creek extends significantly from these watercourses which reflect the extent of natural flooding that would have historically occurred in these catchments, prior to human influences. This high level soil information is insufficient to determine the ability of these soils to infiltrate 5mm of runoff in all locations. Further on site soil investigation work will be required to determine site specific soil infiltration rates.

The streams are typically soft bottomed comprised of sand and silt, albeit that the headwaters of Hingaia Stream and Slippery Creek in the Hunua Ranges are a mix of gravels and sands (Auckland, 2015).

Figure 9 Opaheke-Drury structure plan area - soil type



2.4 Streams

2.4.1 Ecology

Ecological values across all four catchments have been degraded by the removal of vegetation from the landscape (Ecology Assessment, Opaheke-Drury Structure Plan). Very little remnant native vegetation still exists across the four catchments, excluding the foothills of the Hunua Ranges which extend across Slippery Creek and Hingaia Stream catchments. The remaining native vegetation is comprised of small and isolated areas. Consequently, the occurrence and abundance of native fauna is impacted by the limited availability of habitat. The values of watercourses have been degraded as a consequence of the removal of vegetation cover, inputs of sediment and nutrients from surrounding land use, channel modification, and draining or infilling of wetlands/swamps. Instream and wetland fauna has severely declined as a result of this modification and degradation (Auckland Council, 2017a).

Four terrestrial Significant Ecological Areas (SEAs) occur within the structure plan area; two remnant forest fragments and two areas of coastal and riparian vegetation associated with the inner Drury Creek and the top of Ngakoroa Stream. The one marine SEA within the structure plan area is discussed in Section 2.10 Receiving Environments.

The two remnant forest fragments are both stands of kahikatea (*Dacrycarpus dacrydioides*) forest which have been identified as priority sites for protection and enhancement under the Auckland Council Biodiversity Focus Area Ecosystem Prioritisation Framework (SEA_T_77 and SEA_T_545). In addition, several areas of coastal edge vegetation on Drury Creek just north of the Bremner Road bridge has been collectively identified as SEA (SEA_T_530). South of Bremner Road bridge and north of SH22 is an area identified as SEA_T_530b which borders and extends slightly into the FUZ. SEA_T_530b has both rare and threatened flora and fauna species.

2.4.2 Erosion and Water Quality

Watercourse assessments have been carried out which identified erosion hotspots within Oira Creek and Slippery Creek. The modification of watercourses (both direct and as a consequence of land use and development) has led to the development of steep embankments (Auckland Council, 2015 & 2017b). This could be due to the stream bed clearing, placement of structures, pugging from cattle or erosion/scouring due to the absence of riparian vegetation; which slows flows and provides bank stabilisation. Slippery Creek is considered to be the greatest contributor of sediments and heavy metals to the Pahurehure Inlet due to existing land uses in their catchments (Green, 2008).

Where the dominant surrounding land use is agricultural, heavy metal concentrations were found to be low in the water column for the Oira Creek, Hingaia Stream and Slippery Creek. (Phillips *et al*. 2006, Auckland Council, 2015). However, elevated levels of waterbourne sediment are commonly observed in rural areas as indicated in the Slippery Creek watercourse assessment report. The Slippery Creek catchment is predicted to be the greatest contributor of sediments to the Pahurehure Inlet and one of the second greatest contributors of heavy metal contaminants (Green, 2008).These sediment loads typically reduce once development has occurred but levels of copper, zinc and lead typically increase and elevated levels were recorded in the industrial and residential areas of the Hingaia Stream and Slippery Creek catchments (Phillips *et al*. 2006, Auckland Council, 2015). E.coli levels were found to be elevated at some of the monitoring sites within Oira Creek, Hingaia Stream and Slippery Creek, which reflects the agricultural land use of the catchments (Phillips *et al*. 2006, Golders Associates, 2009 & Auckland Council, 2015).

Macroinvertebrate sampling in the four catchments has been limited but where it has been sampled it has indicated that there are low levels of taxa sensitive to pollution, however this did not apply in the headwaters of Slippery Creek. This suggests that some of the streams are partially degraded (Phillips *et al*. 2006, Auckland Council, 2015). The macroinvertebrate sampling in the headwaters of Slippery Creek and Hingaia Stream identified pollution sensitive species where the habitat has not been modified. Species were present at levels that reflect the higher quality of the habitat (Golder Associates, 2009 & Auckland Council, 2015).

Native fish are present within Oira Creek, Hingaia Stream and Slippery Creek (Ngakoroa has not been studied), albeit species diversity does vary. Inanga spawning habitat was identified within the lower reaches of Oira Creek, Hingaia Stream and Slippery Creek typically within habitat that had not been significantly modified (Auckland Council 2015 & 2017b & Golder Associates, 2009).

Hingaia Stream has a constrained channel in Drury Township, and the watercourse vegetation is regularly cleared to maximise the conveyance capacity of the channel to manage flood risk. Any works close to the stream channels are an opportunity to improve conveyance sufficiently so that the streams can also be enhanced through replanting without the associated flood risk implications.

During development and redevelopment watercourse margins should provide space for gentle sloping embankments and revegetation of riparian margins. Outfalls should be pulled back from the stream where possible to allow for the dispersal of flows, and to disconnect impervious surfaces from the receiving environment to form part of a treatment train approach. Outfalls are prone to erosion because the increased speed and channelization of water can erode outfalls, contributing to sedimentation, undermining them and causing them to become perched (which inhibits fish passage).

2.5 Existing surface hydrology

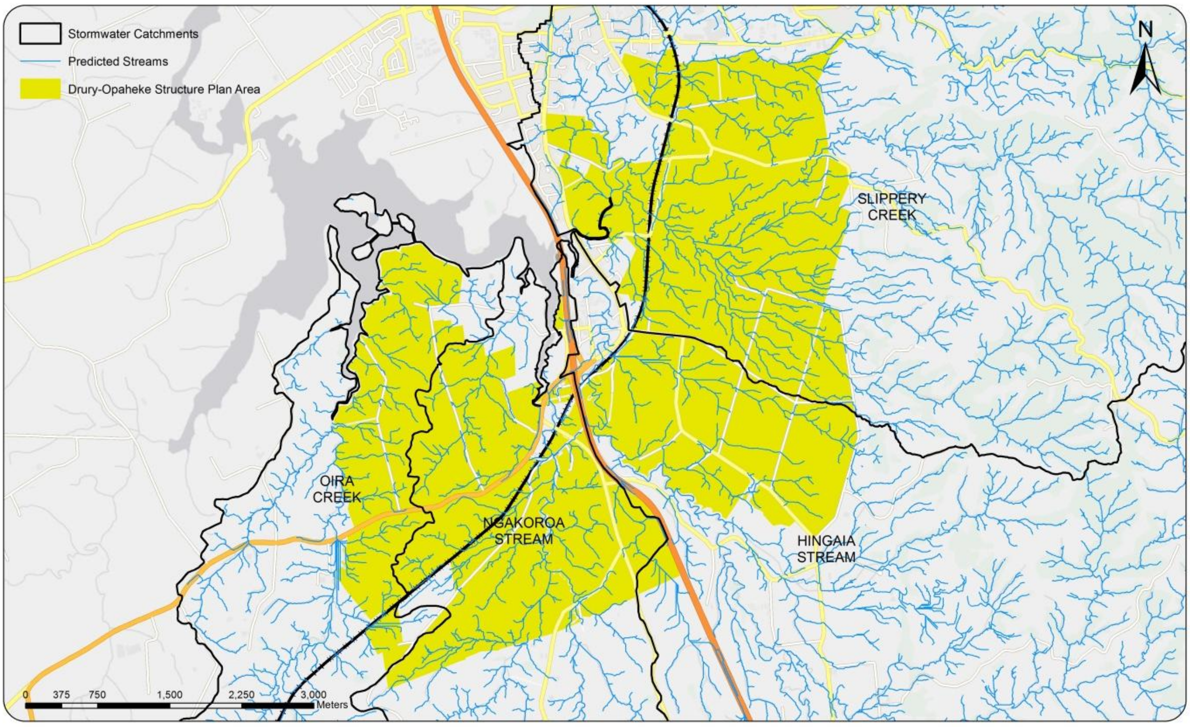
This SMP covers four adjacent stormwater catchments that are interconnected. This includes:

- Oira Creek – catchment size 20.3km^2
- Ngakoroa Stream – catchment size 40.1km^2
- Hingaia Stream – catchment size 57.5km^2
- Slippery Creek – catchment size 46.3km^2

Slippery Creek is comprised of four main watercourses; Croskery Road Drain, Hays Stream, Waihoihoi Stream and Symonds Stream. At the northern end of Drury Township Slippery Creek meets Hingaia Stream and these two streams form the tidal Drury Creek. Oira Creek and Ngakoroa Stream drain separately into Drury Creek before it reaches Pahurehure Inlet and discharges into the upper Manukau Harbour. There are several small streams at the bottom of the Oira and Ngakoroa catchments that drain independently into the Pahurehure Inlet creating several smaller stream mouths. Figure 10 Appendix A shows the network of predicted streams (based on high level terrain modelling) throughout all four catchments within the Structure Plan Area.

The Hingaia Stream and Slippery Creek catchments generate peak flows in the order of 330m^3/s for the 100 year AEP event.

Figure 10 Opaheke-Drury structure plan area – predicted streams



2.6 Soil Type and Hydrological Soil Groups

Figure 11 and Table 2 show that there are a range of soil families and Hydrological Soil Groups (HSG) in the Structure Plan area. The nature of the soils will impact the infiltration rate of stormwater runoff and the volume of stormwater runs off.

Soil type and infiltration rates will need to be considered when assessing the ability of the soil to infiltrate 5mm of runoff (or amended depth) to achieve hydrological mitigation. Hydrological mitigation, through the application of SMAF1 or other approaches, reduces the detrimental impact development (and associated reduction in permeability) may potentially have on groundwater recharge, stream baseflows and erosion rates in the small, frequent rain events (0-2 year ARI). In a brownfields scenario the AUP(OiP) does not expect infiltration for soils that has soil infiltration rates of less than 2mm/hr but this is very unlikely and would require site specific testing to avoid applying the AUP(OiP) requirements.

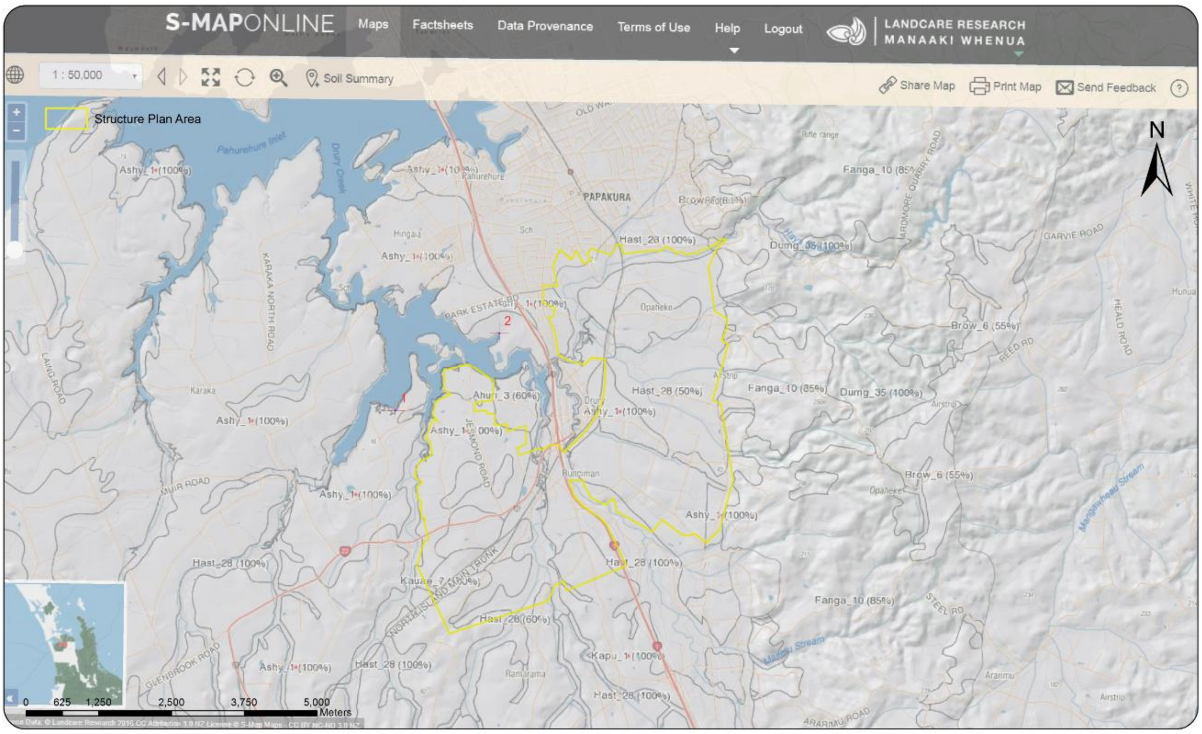
In terms of flood risk, the variability in soil families across the structure plan area and their associated HSGs will also impact on overall runoff volumes generated. For example, HSG A soils generate lower volumes of runoff for the same rainfall depths as soils with an HSG of D. Increases in runoff volume due to development increasing impervious area are likely to be greater in areas with soils of HSG A or B, and therefore flood mitigation measures in HSG A and HSG B areas may be required to accommodate greater volumes of runoff to ensure there is no increase in flood risk (2-100 year ARI).

Where the ground has geotechnical limitations that would make infiltration unsuitable due to instability, reuse and living roofs could be used to achieve volume loss. Detention could be applied where re-use is not practical, such as in the road corridor.

Table 2 Soil Families and hydrological soil groups

Soil Family	S-Map Family Name	Soil Series Name	Likely Hydrological Soil Group (HSG)[1]
Ahuri_3	Ahuriri	Takahiwai or Te Hihi	D
Ashy_1	Ashy		C
Brow_6	Browns	Patumahoe clay loam	B
Hast_28	Hastings	Whangamaire	B/D
Kauae_7	Kauaeranga	Hamilton	B
Kapu_1	Kapu	Kapu or Karaka	A
Fanga_10	Whangaripo	Aponga clay or Aponga hill soil	C
Dumg_35	Dumgree	Haldon	A
Wark_3	Warkworth	Warkworth clay and silty clay loam , part of hill soil part	C

Figure 11 Opaheke-Drury structure plan area - soil siblings (Landcare Research Land Resource Information System (LRIS))



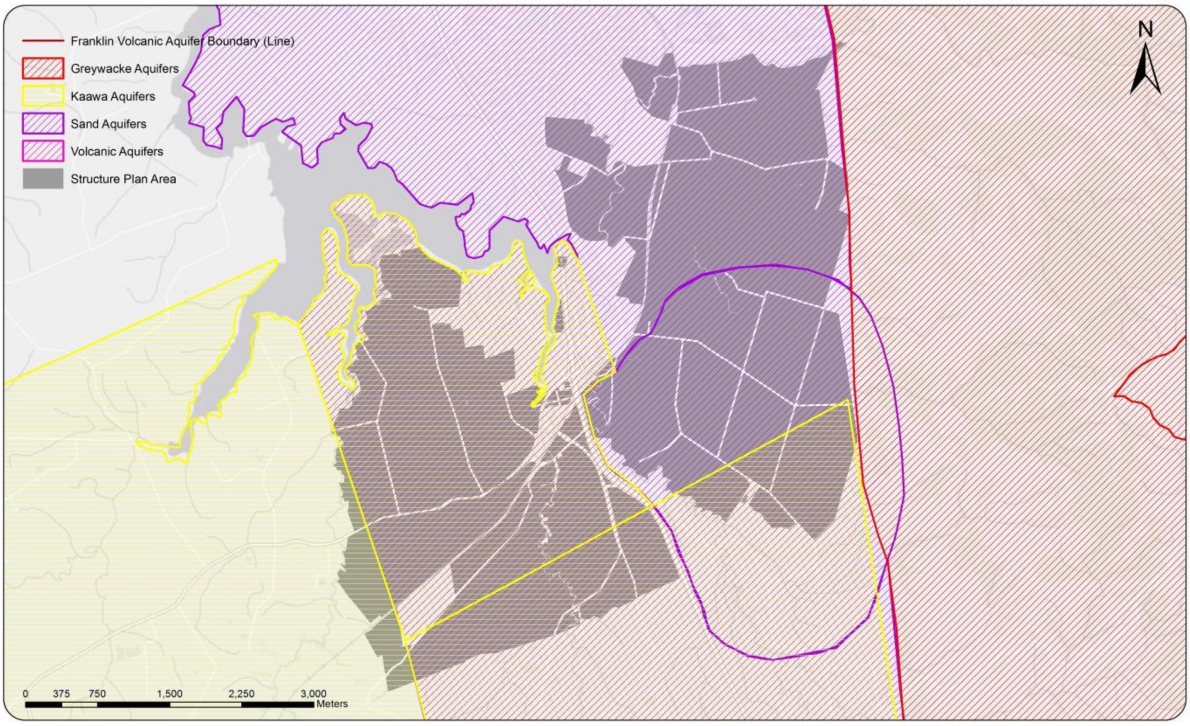
[1] Soil group A has high infiltration rates, and D low; with B C falling on the spectrum between the A and D.

2.7 Groundwater

The aquifers that lie beneath the catchments are detailed below and shown in Figure 12 Appendix A.

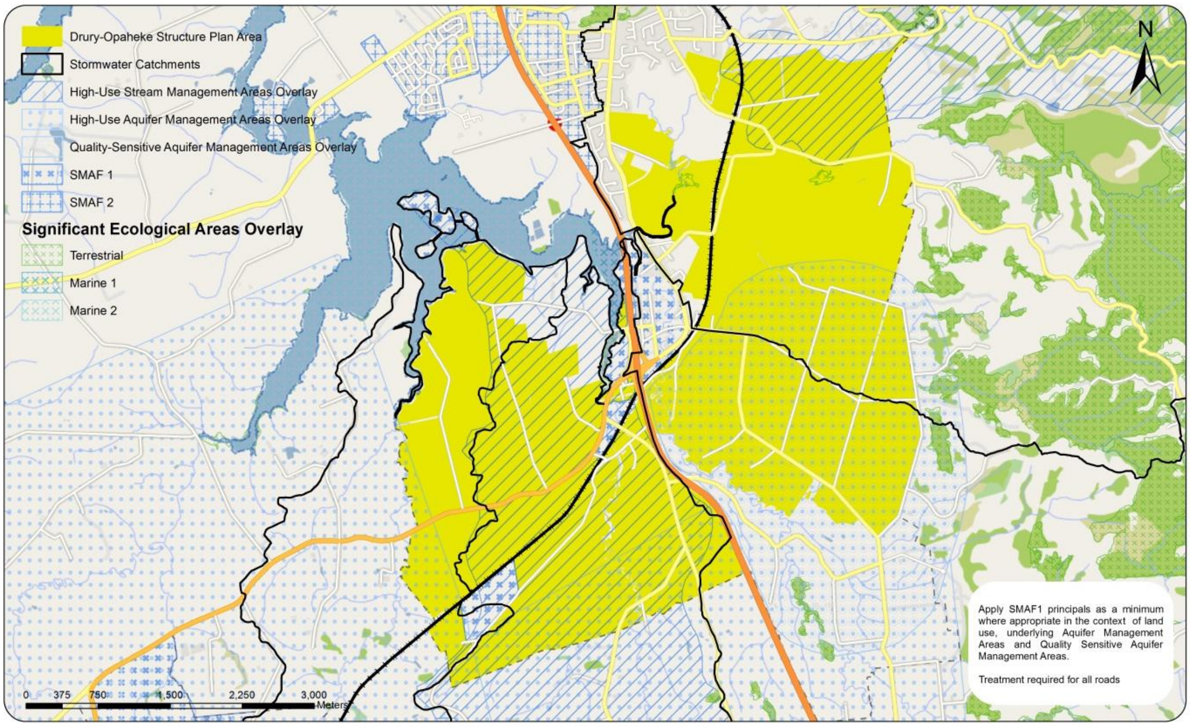
- Kaawa aquifer - Oira Creek, Ngakoroa Stream and Hingaia Stream.
- Drury Sand Aquifer - Hingaia Stream and Slippery Creek.
- Bombay Volcanic Aquifer - Ngakoroa Stream and Hingaia Stream.
- Clevedon West Waimata Aquifer - Slippery Creek.

Figure 12 Opaheke-Drury structure plan area – aquifers



These aquifers are within a High-Use Aquifer Management Area and Quality Sensitive Aquifer Management Area as shown in the AUP(OiP) (see Figure 13 Appendix A). Oira Creek, Ngakoroa Steam and Hingaia Stream catchments are likely to be aquifer fed and could be affected by a reduction in aquifer recharge if not managed appropriately when development is undertaken.

Figure 13 Opaheke-Drury structure plan area – high-use aquifer management areas & quality-sensitive aquifer management areas.



2.8 Existing stormwater network

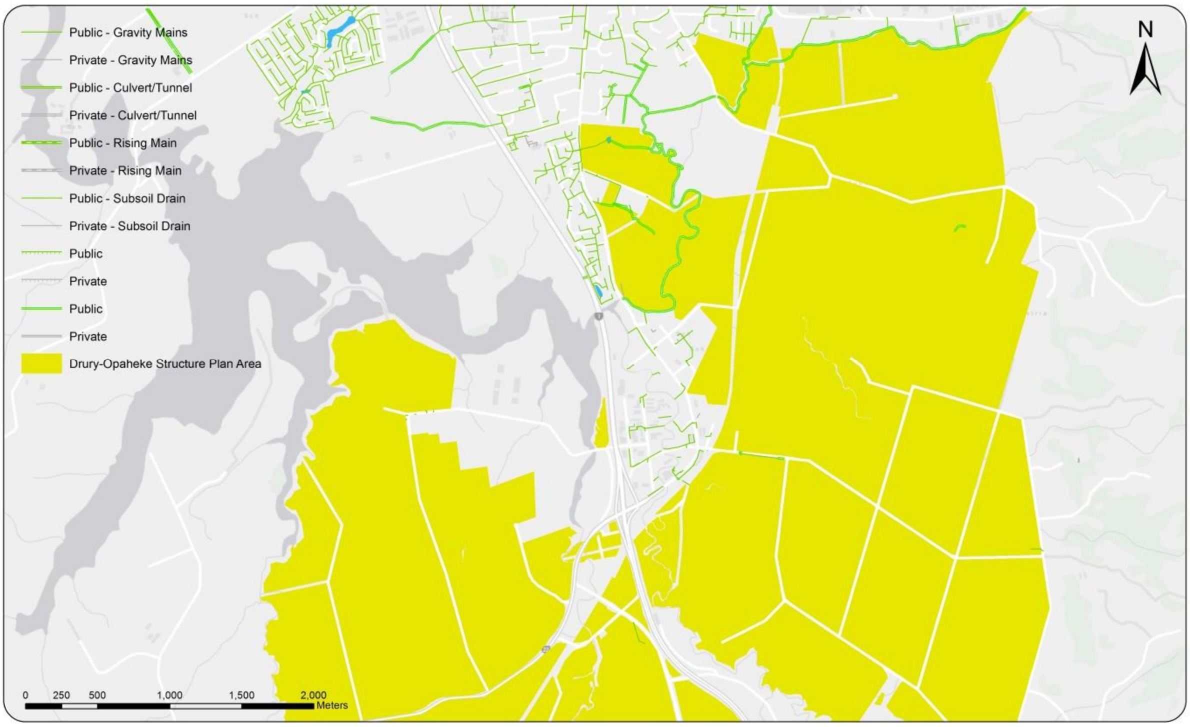
Drury and Papakura have existing stormwater networks which are illustrated in Figure 14 Appendix A. The stormwater network from Pukehoke also extends into the upper reaches of Oira catchment. Otherwise, the public stormwater assets are sparse, and generally limited to road/rail crossings and streams. Private stormwater structures are also present. The private structures include ponds, pipes, culverts, inlets and outfalls and serve to manage flow through agricultural land and to provide access to private properties and businesses.

The largest constructed stormwater attenuation device is the Hays Creek Dam in the Slippery Creek catchment. It attenuates water from approximately 18.2ha. Smaller constructed wetlands are also present within all four catchments.

While constructed ponds are designed to attenuate flows or collect sediment, they can detrimentally affect ecology by raising in stream water temperatures through the release of warmer water than occurs in the streams.

Within Drury township some works have been undertaken to mitigate flooding impacts including vegetation clearing in the stream channel and constructing flood training gabions at the confluence with Slippery Creek.

Figure 14 Opaheke-Drury structure plan area -existing stormwater network



2.9 Flooding and coastal inundation

Development of land can increase the risk of flooding due to the increase in imperviousness which reduces the area available to infiltrate rainfall. When no mitigation measures are put in place, development results an increase in the velocity, flow and volume of runoff.

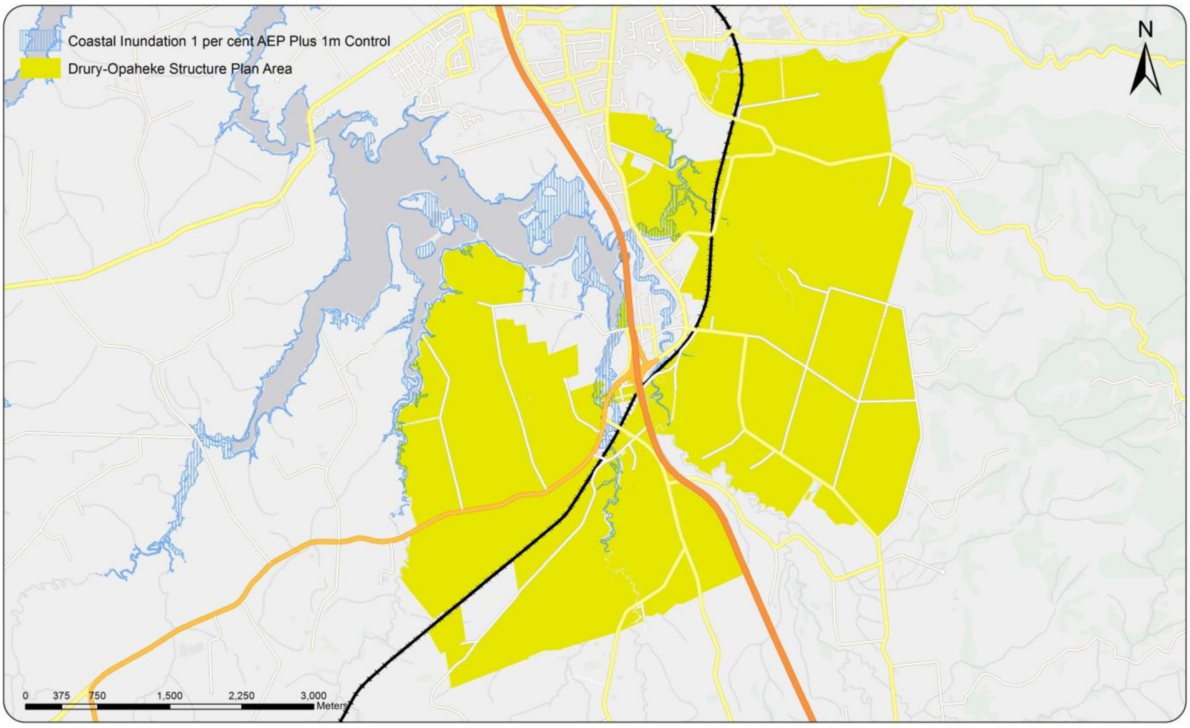
Historically, as development has occurred in Auckland, watercourses (intermittent and permanent) have been straightened, narrowed, piped or culverted to make room for development. This further exacerbates flooding by reducing flood capacity. The AUP (OiP) expects that development in the floodplain is avoided during greenfields development and it is a key premise of WSD to maintain natural floodplain function to provide for a resilient stormwater network. Past development has led to the loss of intermittent streams which contributes to localised flooding.

Within all four catchments the streams typically have good connectivity to the floodplain because the surrounding land use is predominantly agricultural with an absence of features such as levees that would inhibit flood flows. The streams have been highly modified in places, which has altered the natural hydrology and flood plains. This is especially true in the Slippery Creek catchment. The absence of riparian vegetation typically results in a reduced stream channel roughness, which increases flow velocities and can affect flood levels and extents downstream.

There are existing flooding issues in the urban areas of Papakura (Slippery Creek catchment) and Drury Township (Hingaia Stream catchment) due to development within the flood plain, piping and modification of streams diversion of overland flow paths and stream flood flows. While some flood mitigation works have been completed including culvert upgrades, stormwater diversion pipes, the elevation of properties, bunding and detention ponds, additional mitigation works are required to effectively manage flooding within the existing urban areas. This may require mitigation be provided in adjacent rural areas, including within the structure plan area.

Flood levels are also influenced by the interaction of flood flows with the coastal inundation area and the tidal influence of the Pahurehure Inlet and the Drury Creek. The effects of flooding can be exacerbated by periods of extreme high tides. The area influenced by coastal inundation is illustrated in Figure 15 Appendix A, which illustrates a 1 in 100 year event with a 1m control added to mean high water spring tide.

Figure 15 Opaheke-Drury structure plan area – coastal inundation (1% AEP plus 1m control)



The flood models for the catchments have variable levels of confidence, complexity and age. Figure 16 Appendix A illustrates the current understanding of the floodplain within the four catchments, while Figure 17 Appendix A highlights the limitations of the information currently available.

Figure 16 Opaheke-Drury structure plan area - floodplains

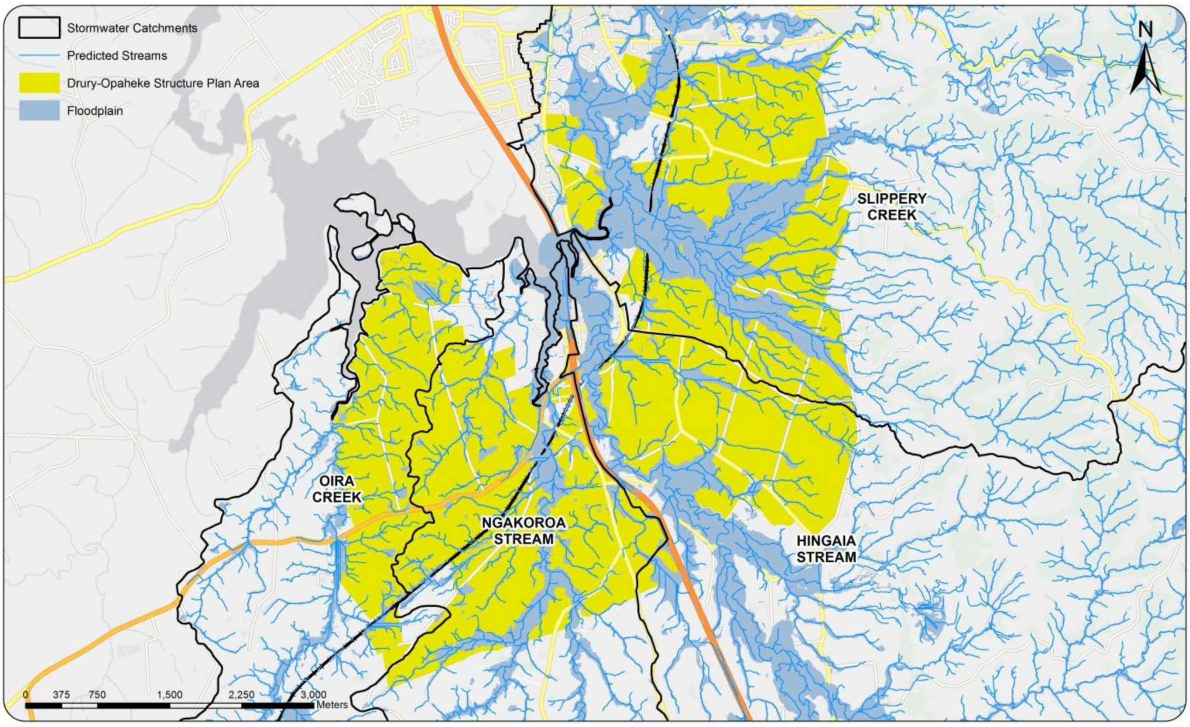
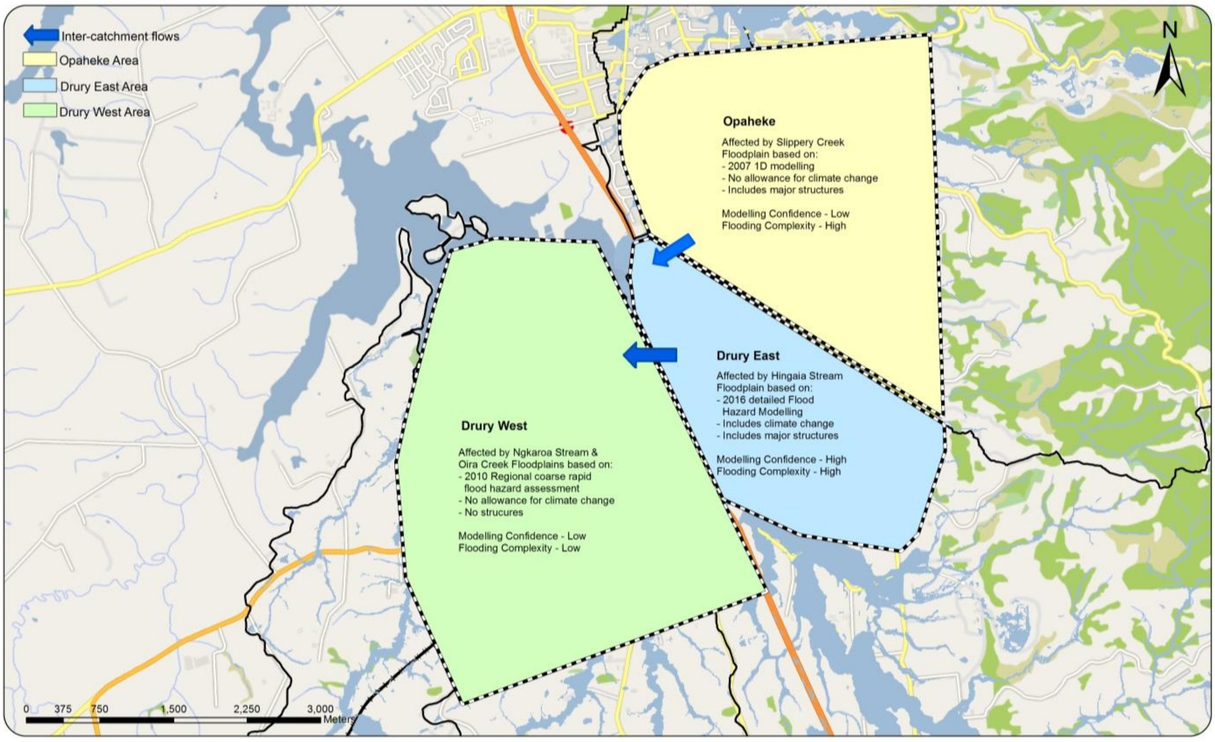


Figure 17 Opaheke-Drury structure plan area – flood modelling limitations.



2.10 Receiving environment

The Health of Auckland's Natural Environment (2015) highlights that, the degradation of the region's watercourse ecological values has occurred in stages. Streams in areas dominated by native forest are typically found to be of high quality, areas dominated by agriculture are of moderate quality and in urban areas the streams are typically of low quality. This is due to a gradual removal of vegetation which, when present, provides instream shade, nutrient inputs and bank stabilisation. Modifications to stream structure, including the reduction in length and volume of these watercourses, can lead to a reduction in a stream's capacity to convey flood flows. Urbanisation leads to an increase of contaminants including hydrocarbons, sediments and heavy metals. Urban streams macroinvertebrate populations are therefore typically represented by groups that are tolerant of pollution and fish diversity and abundance declines.

The four catchments discharge into Drury Creek and then Pahurehure Inlet of the Manukau Harbour. Pahurehure Inlet is a low energy receiving environment dominated by soft, fine sediments and expansive mangrove forests (Kelly, 2008). Drury Creek and parts of the Pahurehure Inlet are identified as marine SEA. These comprise a variety of intertidal habitats, including transitional zones from mangroves to salt marsh to freshwater and terrestrial habitats. The creek provides valuable habitat for wading birds including pied stilt (*Himantopus himantopus leucocephalus*).

The system is known to be receiving fine sediment inflows from Drury Creek. The sediments are settling out in the inlet and detrimentally impacting ecological values (Auckland Council, 2009).

The terrestrial coastal edge has been cleared of its native vegetation and is now vegetated with weeds, reducing the quality of ecological connections between land and sea (Auckland Council, 2017a).

Figure 15 illustrates the predicted level of coastal inundation, which could influence the effects of flooding during a storm event.

Fine sediments are impacting the Pahurehure Inlet, which is a low energy system. The sediments settle out changing the structure of the sea bed and detrimentally impacting macroinvertebrate communities.

2.11 Summary of specific stormwater management area characteristics

The three stormwater management areas within the Opaheke-Drury Structure Plan area covers approximately 833ha, with an estimated 139ha of existing modelled floodplain (excluding floodplain buffer) which is 17% of the entire structure plan area.

2.11.1 Drury West

Ngakoroa Stream and Oira Creek are rural catchments with generally constrained floodplains. Urban development is limited to agricultural properties excluding the expansion of Pukekohe (upper reaches of Oira Creek catchment). The soils are predominately silty that allow for recharge of the underlying Kaawa Aquifer. Ngakoroa Stream currently receives flood overflows from Hingaia Stream in high order events that occur over SH1 upstream of the natural confluence. Current floodplain mapping suggests some road infrastructure forms a barrier to flows resulting in more extensive floodplain areas upstream of these features. Future detailed modelling updates should include road structures, culverts and bridges to assess structure capacity and map the floodplain extents upstream of these features correctly.

2.11.2 Drury East

The predominantly rural Hingaia Stream catchment is 57.5km^2 in area, produces over 10,500,000m^3 of runoff in a 1% AEP event and contains one of the deepest floodplains in the Auckland Region. Approximately 366ha of the Hingaia Stream catchment falls within the Structure Plan Area. Approximately 51ha or 14% of the structure plan area within this catchment is within the floodplain (based on the current published floodplain which excludes climate change). This figure will increase slightly when reassessed under the recently completed 2017 Hingaia Stream Flood Hazard Model.

Due to past development within the floodplain the stream channel is highly constrained through the urbanised Drury Township at the downstream end of the catchment. As a result, Drury Township suffers from frequent and extensive flooding. The Opaheke-Drury Structure Plan area falling within this catchment is also subject to flooding. Bridge and culvert infrastructure capacity is limited in places, resulting in overtopping of roads during large order events. Detailed flood hazard modelling shows the Hingaia Stream overflows into the Ngakoroa Stream via SH1 in high order events. Future development must consider the management of flooding, effects on other property and critical infrastructure, such as the North Island Main Trunk railway, Great South Road and SH 1.

2.11.3 Opaheke

Slippery Creek (46.3km^2) is predominately rural with 25% of the catchment comprised of native and exotic forest. 735ha of the catchment falls within the Opaheke-Drury Structure Plan area, of which 292ha comprises floodplain (excluding climate change).

Papakura Township in the upstream reaches of the northern part of catchment suffers from flooding due in part to piped sections of watercourses, structures affecting overland flow paths and floodplains and due to the catchment characteristics. In the Opaheke-Drury Structure Plan area, the flat terrain and constraints to flow through some road and rail crossings coupled with the high volumes of runoff from the large upstream area, results in extensive areas of floodplain.

2.11.4 Catchment interactions

The catchments have a complex hydrological relationship. The interconnectedness of the catchments can be summarised as follows:

- Slippery Creek and Hingaia Stream confluence upstream of SH1 Bridge.
- Flood overflows occur from Slippery Creek into Hingaia Stream over Great South Road in high order flood events.
- Hingaia Stream flood overflows into Ngakoroa Stream over SH1 at Drury Township during high flow events.

2.12 Knowledge gaps

As part of the SMP development a comprehensive collation and review of available data has been undertaken. The reports referenced are presented in the reference list of this plan. There is an inherent risk with using historic documents to provide a comprehensive representation of the study area, particularly where piecemeal studies have been completed on a specific area or catchment. Studies are not always commissioned to meet the same objectives, assumptions can differ, definitions of features can change and seasonal variations may affect the reporting outcomes. All of the above factors may impact on the validity of data and its use to inform this SMP.

The data set that has been reviewed as part of this SMP provides an adequate baseline of the catchments to support the development of this preliminary stormwater management plan. It will, however, be necessary to carry out additional work to support future plan changes and for developers to undertake adequate site specific investigations as part of their projects. Known gaps in the information include;

- The absence of a detailed watercourse assessment for Ngakoroa Stream and Hingaia Stream. These assessments have been completed for Oira Creek and Slippery Creek. Watercourse assessments are being commissioned for Ngakoroa Stream and Hingaia Stream. The Slippery Creek watercourse assessment is out of date and a more up to date assessment is required.
- The flood models for the four catchments are variable in quality/confidence, due to the age of the models, software used and the approach to the modelling. To compensate for information gaps a buffer has been applied to the floodplains shown on Figures 16 and 18 in some areas to show where land may be at risk of flooding and shouldn't be developed. These buffers are shown on the potential options maps for each stormwater management area. Accurate, detailed models that take account of climate change will provide up to date floodplain extents.
- A comprehensive assessment to develop stormwater management options has not been completed. Once all four catchment flood models are updated and the flood mechanisms are understood, development scenarios can be used to develop specific stormwater management options which also consider cumulative effects and the complex interactions across all four catchments. These options will be more refined and applicable to specific areas within the catchment than those presented in Section 4 of this SMP. The approaches and options discussed in Section 4 are conceptual only and reflect the level of information and understanding of the complex relationships between stormwater management areas. These concepts may change significantly as the SMP work progresses.
- Information relating to coastal erosion is not available for the study area.

3.0 Catchment Constraints and Risks

The key constraints and risks to development within the three stormwater management areas beyond typical stormwater effects associated with development are summarised below and described in Table 3 for each of the catchments. Where applicable it has been highlighted where the interconnections between the catchments could exacerbate the issues identified.

Constraints:

- Flooding of existing urban areas.
- Extensive flood plains in future urban areas.

Risks:

- Increased erosion due to high velocity flows is of particular concern due to the highly sensitive, low energy receiving environment of the Pahurehure Inlet.
- Decreased water quality, aquifer recharge and instream ecological values resulting to changes in land use and land development.

Table 3 Catchment constraints and risks

Risk	Implications for Development without Mitigation	Assessment of Area Sensitivity/Risk
Flooding (including overland flow and coastal inundation) – **Existing risk**	**Drury West (Oira Creek and Ngakoroa Stream catchments)** – - There are currently no significant flooding issues associated with overland flows or tidal inundation within Drury West - Predominantly rural with limited buildings and structures that can be impacted by flooding. - Pukekohe is subject to some existing flooding, however it is located in the catchment headwaters and is therefore less at risk Therefore, based on the current level of understanding (and low confidence in the flood model) we have assessed that the level of risk of flooding in the current situation is likely to be **Low**. The risk/ sensitivity may be reviewed upon completion of updated flood modelling.	**Drury West - Moderate risk**
	Drury East (Hingaia Stream catchment) - Predominantly rural - The top of the catchment is steep (Hunua Ranges foothills) which will increase the rate at which water is travelling through the system (a steeper hydrograph). - Historical flooding in Drury township due to undersized stream culverts and impeded surface flow (Figure 16) which could be exacerbated by high tides in coastal inundation areas (Figure 15). Therefore, we have assessed that the level of risk of flooding in the current situation is **High**.	**Drury East - High risk**
	Drury East and **Drury West** (Ngakoroa Stream) catchments can become connected during flood events as impeded overland flows overtop SH1. This connectivity of stormwater continues as **Opaheke** is connected to **Drury East** through overland flow that over top Great South Road and through its natural connections (Slippery Creek drains into Hingaia Stream before discharging into Drury Creek). These stormwater network linkages mean that post development flood levels within **Drury West** could be influenced	**Opaheke - High risk**

Risk	Implications for Development without Mitigation	Assessment of Area Sensitivity/Risk
	not only by the development itself but also through its interconnectivity with its neighbouring catchments. **Opaheke (Slippery Creek)** - This area includes parts of Papakura (residential and industrial), the forested foothills of the Hunua Ranges and areas of agricultural land. - Flooding has occurred due to undersized culverts, under capacity pipes and the watercourse being constrained/ diverted/straightened in places throughout the catchment. - Steep headwaters result in a high rate of runoff through the catchment (Figure 16). - There is the potential for flooding to be exacerbated by high tides in those areas affected by tidal inundation in Drury East (Figure 15). Therefore, we have assessed that the level of risk of flooding in the current situation is **High**. Significant additional works will be required to fully mitigate the flood risk in Papakura and to facilitate the proposed development within the Structure Plan Area.	
Erosion – ground instability	**Drury West** - The Oira Catchment Watercourse Assessment Report (2017) identified that there were 54 erosion hotspots along the streams in the catchment which occur in areas where the embankments are steep and un-vegetated. It is anticipated that the Ngakoroa catchment would be similar as land use and bank profiles are similar. **Opaheke**- The Slippery Creek catchment Watercourse Assessment Report (2015) identified that there were 33 erosion hotspots within Slippery Creek. The cause of these erosion hotspots is the same as detailed in the Oira catchment, but has been exacerbated in areas by constructed structures. It is considered that the Hingaia catchment will also be in a similar condition, impacted in rural areas by vegetation loss and cleaning out of watercourses and in urban areas; and due to steep embankments as a consequence of urban stream syndrome. We consider that the risk of the development increasing ground instability in the catchments is **Moderate** for all three stormwater management areas. Localised risk will be greater where land is steeper or soils are less strong.	**Drury West - Moderate risk** **Drury East - Moderate risk** **Opaheke - Moderate risk**
Erosion – sedimentation	**Drury East, West and Opaheke** are currently predominantly agricultural which typically leads to a continuous release of fine sediment. During development there is the risk that ground disturbance can lead to large releases of sediment into the surrounding receiving environments. It is anticipated that the mobilised sediment would settle in the bed of the watercourses and also in the Pahurehure Inlet. As only part of the catchments is to be developed the remainder would continue to release sediment that is under agricultural production (continuous slower release). Removal of vegetation during development will have a similar level of impact, due to the location of development on low lying land. Localised risk will be greater where land is steeper and dominated	**Drury West - high risk** **Drury East - high risk** **Opaheke - high risk**

Risk	Implications for Development without Mitigation	Assessment of Area Sensitivity/Risk
	by fine sediments. The risk of the development increasing sedimentation in the catchments is **Moderate** for all three stormwater management areas. However, the receiving environment is very sensitive therefore the risk of sediment impacting the receiving environment is high.	
Water quality – heavy metals / hydrocarbons	**Drury West** does not include any significant urban centres. The catchments are characterised by agricultural buildings, with a small area of Pukehoke in the upper reaches of the Oira catchment Water quality sampling has shown that levels of heavy metals are low in the Oira catchment (Phillips et al. 2006) Monitoring completed in the **Drury East** and **Opaheke** shows elevated levels of zinc, lead and copper. The sources of these contaminants include existing industry, road runoff and unpainted metal roofs (residential and commercial). Therefore, it is assumed that without treatment that the concentrations of heavy metals would increase in the watercourses located within all three stormwater management areas and within the receiving environment. The risk in all management areas has been assessed to be **High**. Taking into account the effects of past land use localised impacts could be higher in areas dominated by industry or crossed by roads.	**Drury West - High risk** **Drury East - High risk** **Opaheke - High risk**
Water quality – Pathogens	Water quality monitoring in **Drury East, West and Opaheke** identified that *E.coli* levels were elevated, likely a result of stock being present within and adjacent to the watercourses. The urbanisation of the FUZ will lead to a decrease in the amount of land available for grazing stock. Therefore, it could be assumed that this would lead to a decrease in *E.coli* input into the streams. The risk of high *E.coli* levels in all three storm water management areas is considered to be **Moderate**, as the inputs from agriculture are likely to decline, but each catchment will still include a significant area of agricultural land.	**Drury West - Moderate risk** **Drury East - Moderate risk** **Opaheke - Moderate risk**
Aquifer recharge	**Opaheke, Drury East** and **Drury West** comprise a mix of Hydrological Soil Groups (HSG). Therefore, the rate of soil infiltration will vary across the catchments. **Opaheke** catchment includes only small areas of aquifer in relation to its overall surface area and the soils have a low infiltration rate, therefore, development in this area is considered to be less likely to impact on aquifer recharge, and the risk was classified as **Low**. In **Drury East** the aquifer extends for a greater area under the management area, but soil infiltration is still likely to be low so the risk to aquifer recharge was considered to be **Low**. However, in **Drury West** where soil infiltration rates are higher and the management area is underlain by a major aquifer the risk was considered high in relation to aquifer recharge. Development will be focused at the bottom of the catchment therefore the risk was assessed to be **Moderate**.	**Drury West - H risk** **Drury East - Low risk** **Opaheke – Low risk**

Risk	Implications for Development without Mitigation	Assessment of Area Sensitivity/Risk
Instream and marine ecological values	The receiving environment of Pahurehure Inlet is very sensitive If appropriate stormwater mitigation is not applied in **Drury East, West and Opaheke** the quality of the instream and marine environments would significantly decline. This impact was assessed to be **High**	**Drury West - High risk** **Drury East - High risk** **Opaheke - High risk**

4.0 Stormwater Management Approach

4.1 Management approach

This section sets out a broad, high level management approach due the knowledge gaps that currently exist and the early stage of land use planning for this area. It has been developed in accordance with the principles of Water Sensitive Design and the integrated stormwater management approach in the AUP (OiP).

WSD is considered the best practice stormwater management approach in the Auckland region and is defined in the AUP(OiP) and GD04 as:

> "*An approach to freshwater management, it is applied to land use planning and development at complementary scales including region, catchment, development and site. Water sensitive design seeks to protect and enhance natural freshwater systems, sustainably manage water resources, and mimic natural processes to achieve enhanced outcomes for ecosystems and our communities*."

The WSD principles and approach to stormwater management are defined in Auckland Council's GD04 (Lewis *et al*, 2015) as:

1. Promote inter-disciplinary planning and design.
2. Protect and enhance the values and functions of natural ecosystems.
3. Address stormwater effects as close to source as possible.
4. Mimic natural systems and processes for stormwater management.

Ad hoc development is likely to result in cumulative effects and an overall increase in flood risk. In addition, ad-hoc development that has not considered all constraints and risks represents a risk to coordinated flood mitigation options that enable wider development, and could represent high infrastructure costs in the long term.

The complexity of the relationship between the four catchments is reflected in the proposed staged release of land for development.

4.1.1 Flood management mitigation approach

The 100 year ARI (1% AEP) floodplain extent must be kept free of structures and development in order to retain their conveyance function and retain storage capacity. The exact location and extent of floodplains is currently being developed by the council though refined hydraulic and hydrological modelling.

Figures 18 to 20 show existing indicative information on floodplains but this information may change as a result of the modelling work. In in some areas the existing floodplain information does not allow for climate change as required by AUP B10.2. Also the effect of future change to land use has not been modelled in some areas. Therefore as an interim step, an additional "potential climate change allowance" has been included in figures 18 and 20 for some floodplains.

As part of the interim approach it is proposed that if a developer wishes to pursue land development prior to public release of the floodplain modelled extents the developer will need to develop outside of the floodplain potential climate change allowance shown in these figures (18 to 20). They must also consider Maximum Probable Development in the surrounding catchments in accordance with the Auckland Council Code of Practice (Stormwater). Due to the interaction between catchments the flood management approach is not straight forward and it would be undesirable and also unlikely to be cost efficient to develop or zone land prior to the appropriate modelling and flood management strategy being developed for these connected catchments.

4.1.2 Hydrological mitigation approach

All development must ensure pre-development hydrology for the wider catchment area is maintained. Pre-development hydrology must be matched in terms of flows, levels, volumes and frequency of runoff. Soil infiltration rates have been assumed based on the soil group described in Section 2.3.

Hydrology mitigation volumes (retention and detention) could be tailored to more closely match the pre-development hydrology. In the interim the application of SMAF1 (designed for clay soils) will achieve good stormwater outcomes should zoning occur before more detailed information is available.

SMAF 1 is designed for clay soils so should work in most circumstances in Auckland. It seeks to protect and enhance Auckland's rivers, streams and aquatic biodiversity by managing smaller and more frequent storms up to the 2 year ARI event. The SMAF 1 hydrology mitigation measures defined in Table E10.6.3.1.1 (AUP(OiP)) are copied below.

Stormwater management area – Flow 1

a. *provide retention (volume reduction) of at least 5mm runoff depth for the impervious area for which hydrology mitigation is required; and*
b. *provide detention (temporary storage) and a drain down period of 24 hours for the difference between the predevelopment and post-development runoff volumes from the 95th percentile, 24 hour rainfall event minus the 5 mm retention volume or any greater retention volume that is achieved, over the impervious area for which hydrology mitigation is required.*

Additional assessment work will be undertaken to determine if altered retention and detention volumes are needed.

4.1.3 Water quality mitigation approach

Runoff is to be treated prior to discharge to the council system or directly to receiving environments. Treatment is to be provided to all new impervious surfaces unless they are known not to generate contaminants (e.g. patio areas).

Industrial and Trade Activities (ITA) pose an increased risk of discharging contaminants to the stormwater system and receiving environment due to the use, storage and handling of environmentally hazardous substances on a regular basis. We do not propose any additional management to those set out in the AUP (OiP). During earthworks and construction the risk of reducing water quality through sedimentation and impacting aquatic habitats is significant. TP90 (Auckland Council, 2007), or subsequent guidelines (e.g. Draft GD05 (Leersnyder et al, 2016)) may not be adequate. Erosion and sediment control measures may need to exceed the standards and methods set out in TP90.

4.1.4 Stream and wetland management

To protect the receiving environment the following is required:

- Protection and enhancement of permanent and intermittent streams and wetlands during Greenfields development is required by AUP(OiP). Indicative stream locations are provided in Figure 10, these are both based on watercourse assessments and modelled stream extents. Developers will need to confirm stream classification and exact extents to inform development proposals however, the current stream locations can usefully inform development patterns and yield. Wetland locations are not available.
- Riparian planting is to be progressively restored or enhanced to a minimum of 10m either side of the watercourse or wetland. The riparian margin width should be assessed by an ecologist to determine if an amended width is required. Riparian restoration or enhancement will also need to consider flow rates and conveyance of flood waters to ensure flood waters are discharged quickly in areas where conveyance is required.
- Construction of erosion protection measures where erosion is currently an issue. Green infrastructure and soft engineering approaches should be considered in preference to engineered protection works.
- Diffuse flows from smaller distributed stormwater outlets to the receiving environment better mimic natural drainage paths and reduce the risk of erosion that can result from single large point discharges. Additional controls to disperse flows should be considered through setting back of stormwater outlets within the riparian margin or at the coastal edge and allowing sheet flow to enter the waterway. The encouragement of sheet flow through the vegetated riparian margins will also provide additional treatment, providing a more resilient stormwater network.

- The addition of fish passage where necessary and removal of existing barriers.
- Natural wetlands should be protected and restored and a 10m margin applied as for streams. They should not be used for stormwater treatment; rather they are a part of the receiving environment to be protected.
- Applying hydrology mitigation will assist in maintaining stream base flows, and reduce peak flows and stream erosion.

4.1.5 Stormwater device and Infrastructure design

The Auckland Design Manual is a practical guide that provides support through the design concept and development phase. It sits alongside the AUP(OiP). The Auckland Design Manual provides tools that can be applied in the Opaheke-Drury Structure Plan area.

Stormwater devices to achieve hydrological mitigation (SMAF1) and stormwater quality as set out in GD01 are considered adequate to achieve good stormwater outcomes in these catchments. A palette of devices can be used, with some examples provided below.

Table 4 Example of potential stormwater devices as per GD01

Device	SMAF Detention	SMAF Retention	Quality	Flooding	Note
Pervious paving	P	P	O	O	Avoid impervious surfaces At source
Living Roof	P	P	O	O	
Bioretention (Unlined)	P	P	P	O	Mitigate for impervious surfaces created at source
Bioretention (Lined)	P	O	P	O	
Reuse	P	P	O	O	
Wetlands	P	O	P	P	Communal device

4.2 Potential stormwater management options

Table 3 in Section 3.0 provides the catchment constraints/ risks and assessment of the risk sensitivity. Three key high risks dominate across the entire structure plan area:

1. Existing and future flooding risk
2. Water quality degradation from an increase in urban source contaminants
3. Degradation of instream and marine ecological values

Due to the hydrological link between the catchments three possible management approaches have been identified in specific areas for mitigation of flooding: –

- Opaheke - defer zoning until hydrological modelling and flood management options have been developed to protect existing and future development.
- Drury West and parts of Drury East - Adequate Floodplain Allowance - a route where conveyance and storage functions must be provided for and the cumulative effects of development on these functions are considered.
- Parts of Drury East - Pass Flows Forward to expedite the drainage of potential flood waters subject to adequate downstream conveyance.

Potential stormwater management options based on existing constraints and risks have been identified in the subsequent sections for each of the FUZ management-areas.

4.2.1 Drury West

Drury West, consisting of the Ngakoroa and Oira catchments is dominated by rural land uses and constrained flood plains (refer to Figure 18). Oira Creek, Ngakoroa Stream, Drury Creek and their tributaries have been identified as a potential adequate floodplain allowance management areas, subject to:

- Development of setbacks to allow space for floodplains and conveyance.
- Utilisation of stream corridors for multiple benefits including stormwater management.
- Assessment and design to be based on assumptions that the entire contributing catchments are fully developed to 70% imperviousness.
- Maintenance of the existing floodplain function.

The development of Drury West provides a significant opportunity to enhance stream and biodiversity values by promoting restoration and WSD to minimise stream erosion and further reduction in water quality. WSD should be guided by the information presented in GD04.

As defined in Sections 4.1.3 and 4.1.4 this may include riparian vegetation restoration or enhancement that is reflective of the stream size, water quality and desired biodiversity outcomes.

4.2.2 Drury East

The southern boundary of the Drury East area (along Hingaia Stream and selected tributaries), parallel to SH1 has been identified as a potential adequate floodplain allowance management area, subject to:

- Confirmation of suitable geotechnical conditions.
- Utilisation of existing stream corridors.
- Maintenance of the existing floodplain function.
- Ability to prioritise the reduction of flood extents in the Drury township.
- Known conveyance constraints in existing stormwater infrastructure and stream channel.

The more north eastern reaches of the Hingaia Stream catchment have been identified as areas where flows could potentially be passed forward allowing runoff to discharge faster than the wider catchment area and surrounding catchments. This could separate the interconnecting hydrographs from the adjacent areas and relieve peak flow pressures.

Identified opportunities within Drury East include:

- Facilitation of stream enhancement and riparian planting to reduce erosion and improve ecological values.
- Reduction of flooding in Drury township and Great South Road with an approach that may include asset upgrade.
- Reduction of flood risk to SH1 through possible design changes at Drury SH1 interchange.
- Removal/ reduction of flow constraints caused by existing infrastructure.
- Improved stream conveyance through Drury Township.
- Application of WSD as set out in GD04.
- Mitigation of existing flooding in brownfield areas.

These areas are depicted on Figure 19**Error! Reference source not found.**.

4.2.3 Opaheke

The Opaheke area of the Structure Plan is represented by a significant floodplain that when considered in conjunction with climate change projections creates high risk development areas where flood mitigation is a primary driver in stormwater management (refer to Figure 20). The area upstream of the SH1 Bridge is a Comprehensive Flood Management Area requiring a comprehensive flood management strategy prior to development progressing. This area should not be zoned until updated modelling and stormwater management options work has been completed.

The following are considerations and constraints likely to form part of the overall strategy.

- Development setbacks to allow for controlled flooding.
- Utilisation of existing stream corridors.
- Maintenance of the existing floodplain function.
- Protection and enhancement of all permanent and intermittent streams.
- Primary drainage through existing permanent and intermittent streams.
- Wetland restoration.
- Need for large scale attenuation in selected areas.
- Solutions that consider catchment wide and multi-catchment interactions.
- Promotion of integrated, deliberate development.
- Consideration of flooding in existing brownfield areas, specifically Papakura and Drury townships.

The opportunities that land development within the FUZ poses for the Opaheke area include:

- Enhanced stream protection and restoration.
- Application of WSD as set out in GD04.
- Wetland restoration.
- Mitigation of cumulative effects defined in a comprehensive stormwater management plan.
- Mitigation of existing flooding in brownfield areas.

Should developers apply to develop in the absence of appropriate zoning, they will need to carry out stormwater detailed catchment modelling to demonstrate they can develop without adversely affecting other landholdings in the catchment and achieve betterment to avoid cumulative flooding effects.

4.3 Future Work

To better enable development of stormwater management options and supporting growth in prioritised areas, Healthy Waters are committed to:

- The preparation of stormwater management plans for the Opaheke-Drury stormwater catchments. Time frames for Structure Plans will not provide time for final solutions to be included in stormwater management plans. Further research will be required either by Council or developers. Stormwater management plans will cover the existing constraints (floodplains and streams), identify treatment principles, and specific projects/interventions). Stormwater management plans must consider the Structure Plan area as a whole due to the inter-catchment interactions and the complex flooding mechanisms in some locations.
- Defining floodplains accurately and investigate works/options to reduce floodable area/increase yield desirable where feasible and without prohibiting development in other areas. Various options to be considered. Floodplain requires comprehensive solution for whole area (not piecemeal) which also accounts for cumulative effects of ad hoc development.
- Defining accurate stream extents (permanent, intermittent watercourses to be protected).

- Improving soil information (particularly permeability).
- Investigating receiving environment condition (sedimentation in the harbour), and infrastructure required (e.g. culvert upgrades).

Figure 18 Drury west potential stormwater management options

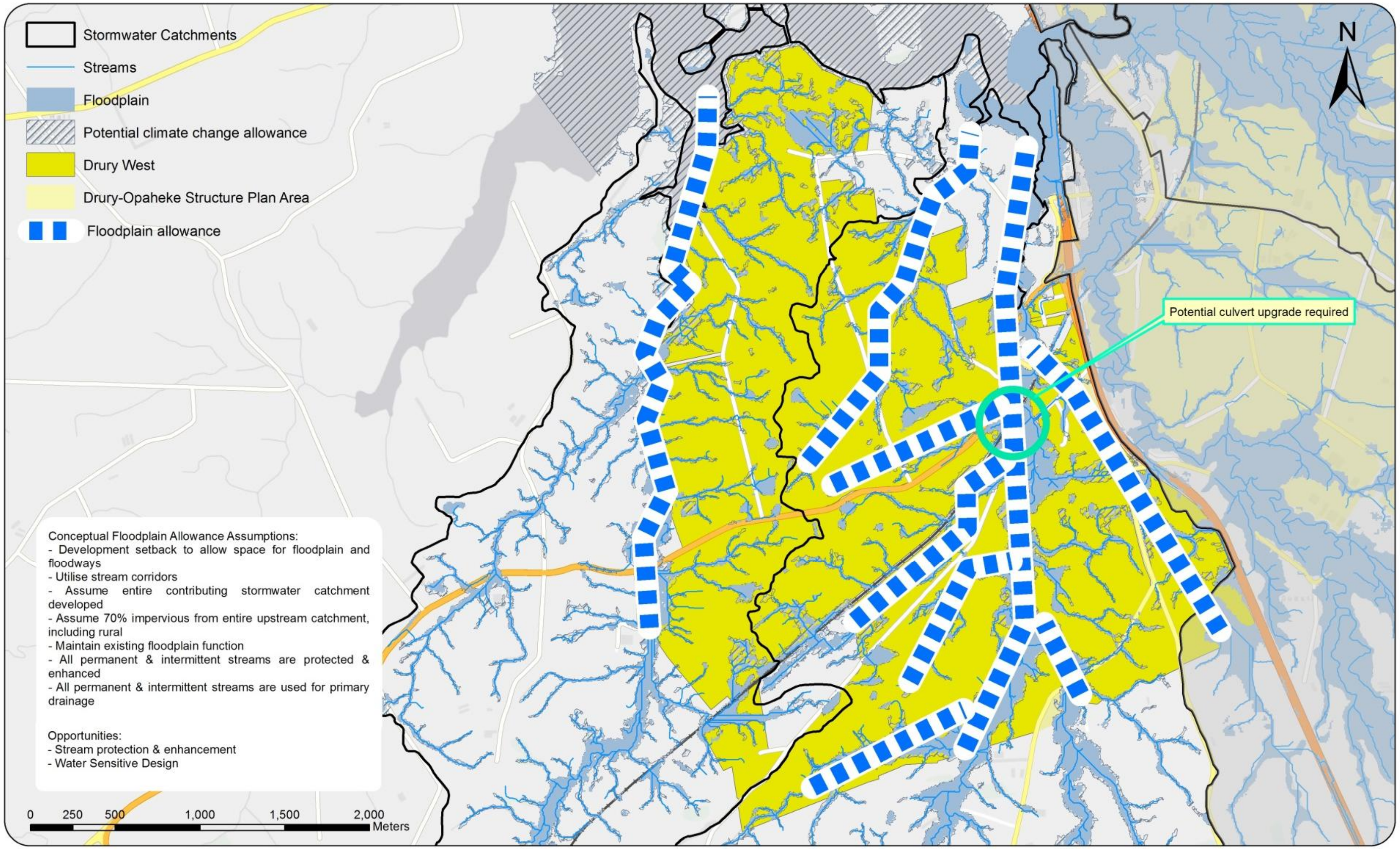


Figure 19 Drury east potential stormwater management options

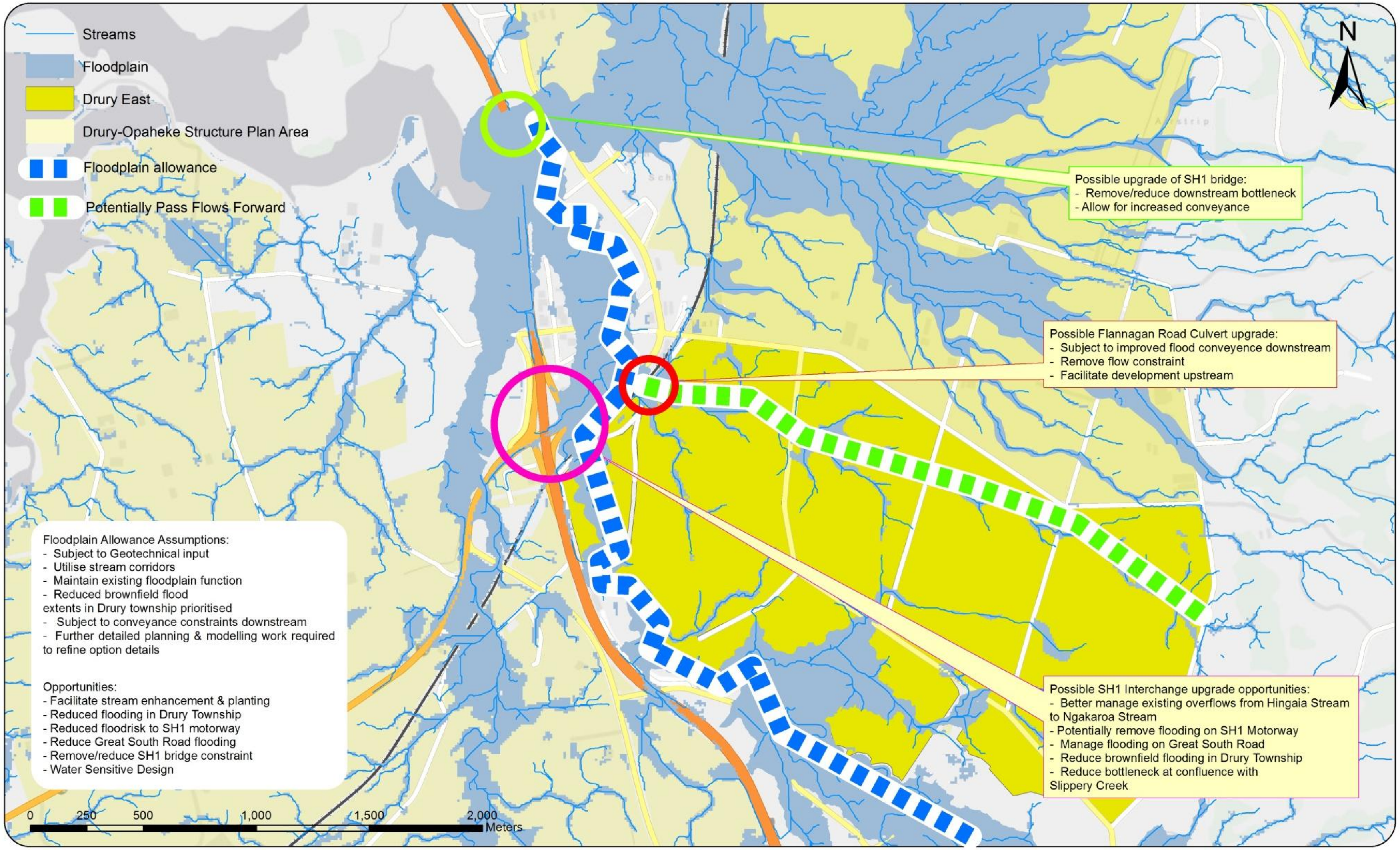
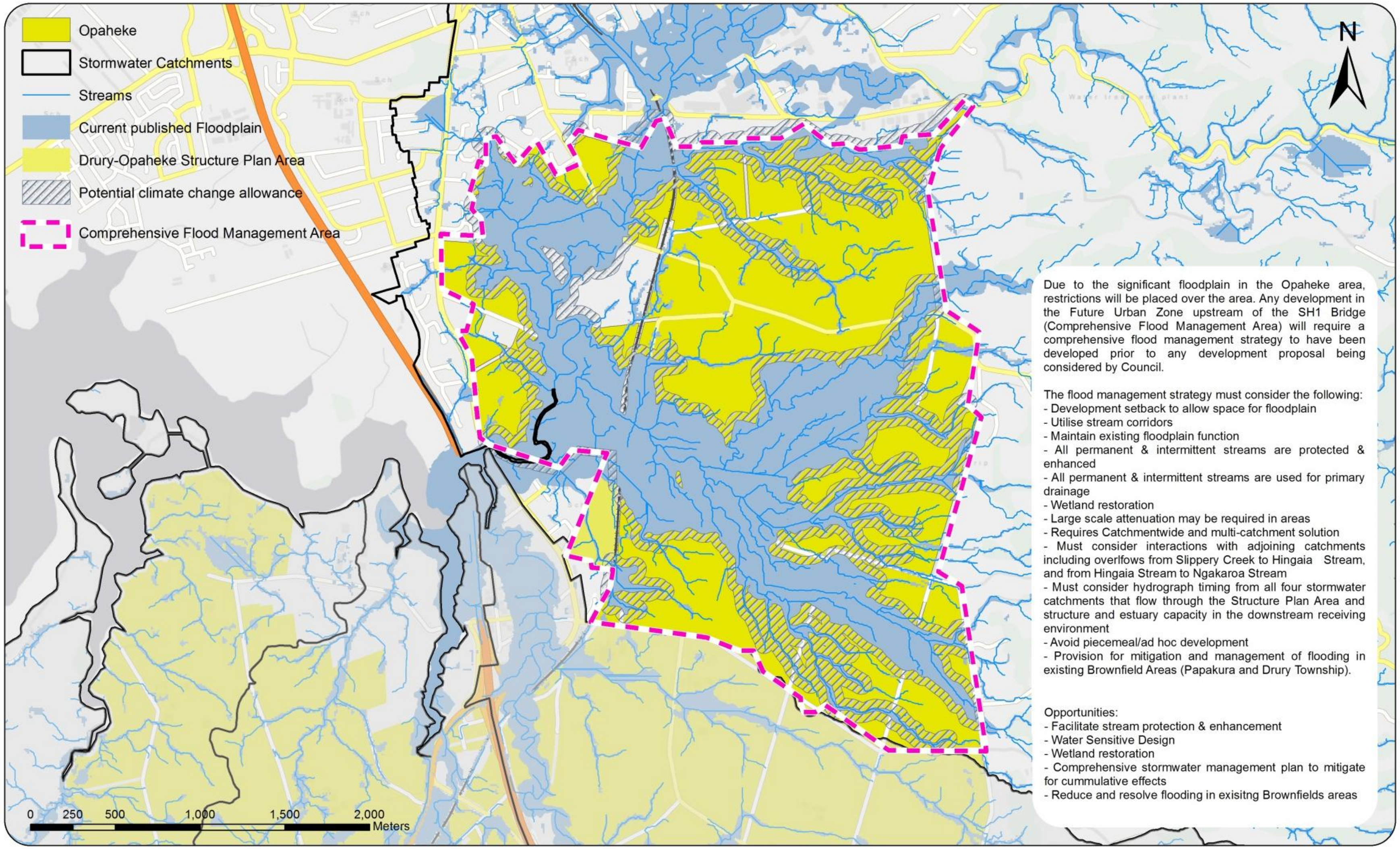


Figure 20 Opaheke potential stormwater management options



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Lewis, M., James, J., Shaver, E., Blackbourn, S., Leahy, A., Seyb, R., Simcock, R., Wihongi, P., Sides, E., & Coste, C. (2015). Water sensitive design for stormwater. Auckland Council Guideline Document GD2015/004. Prepared by Boffa Miskell for Auckland Council.

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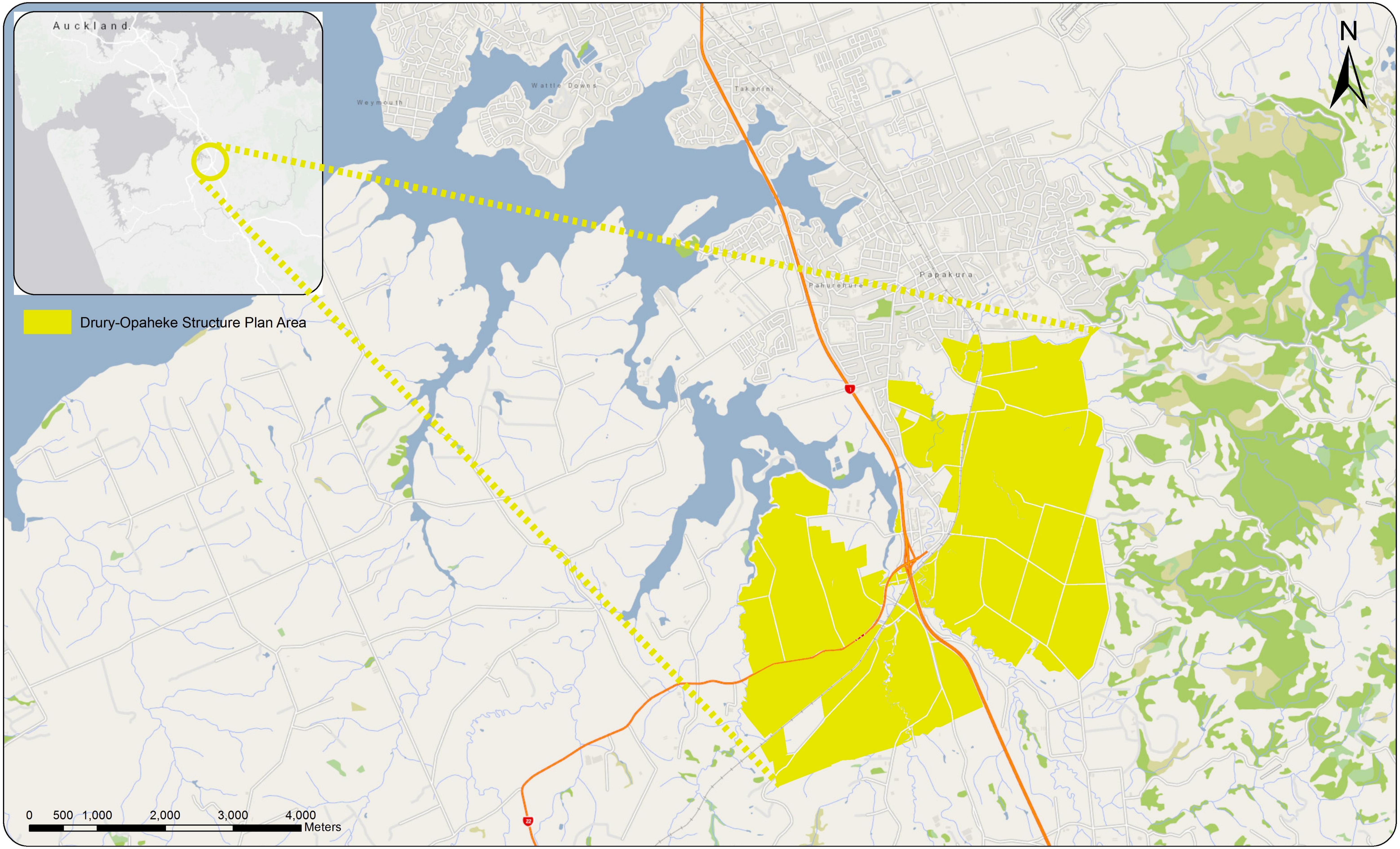
Appendix A

SMP Maps - A3 Size



Drury Structure Plan Area - General Location Plan

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 06-09-2017

Indicative concepts only
Not to scale

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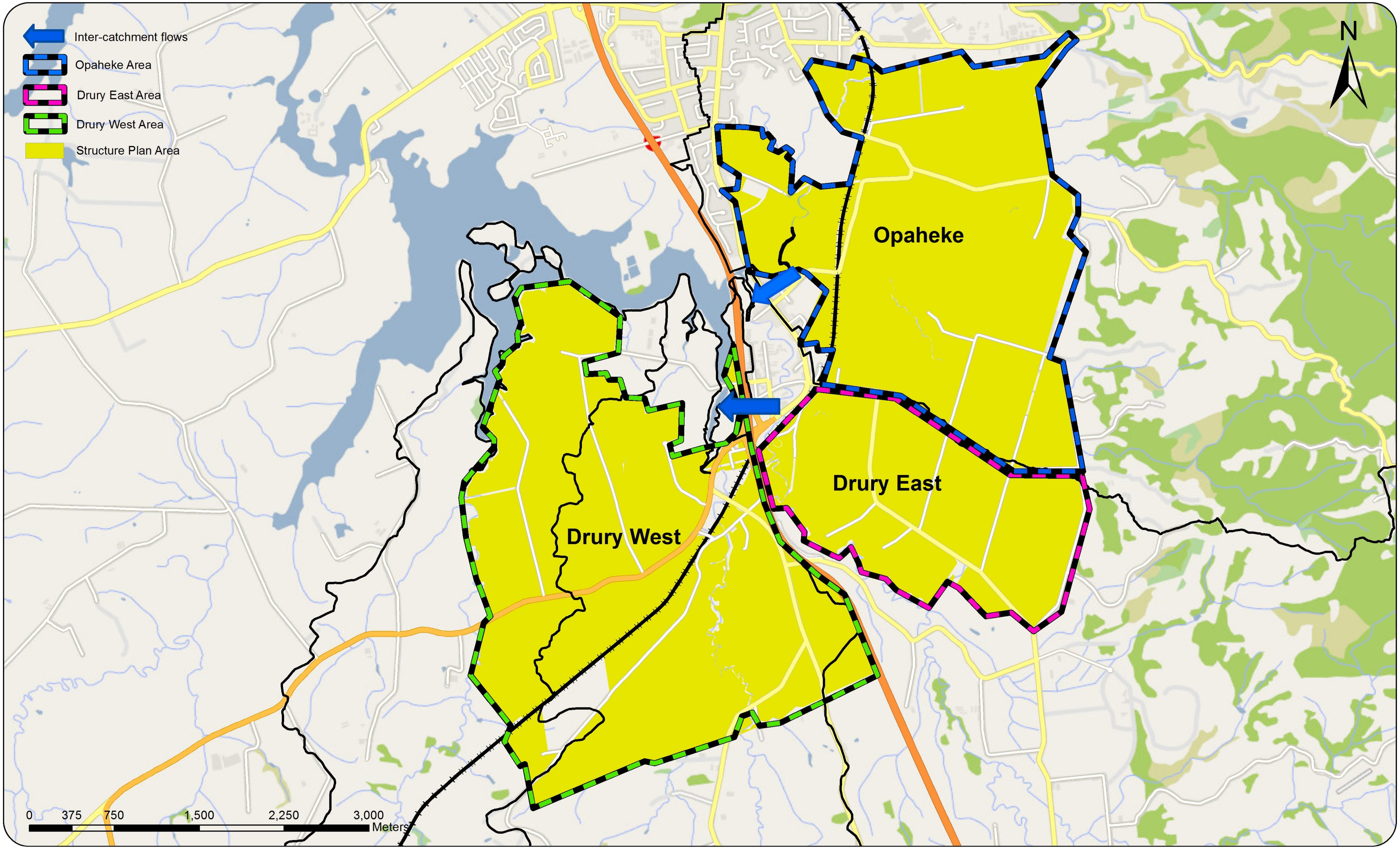

Drury-Opaheke Structure Plan Area - Stormwater Management Areas

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

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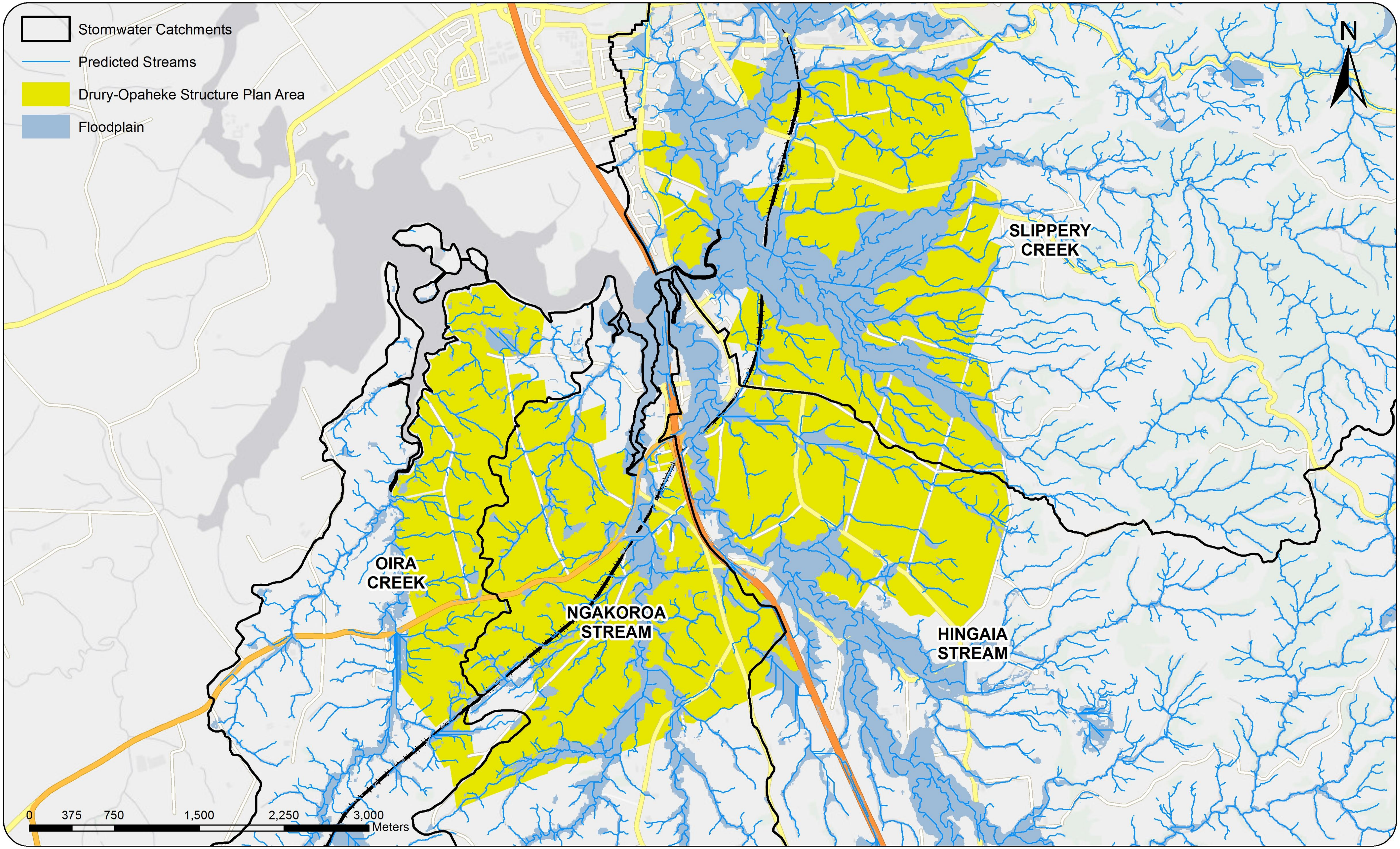

Drury-Opaheke Structure Plan Area - Floodplains

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

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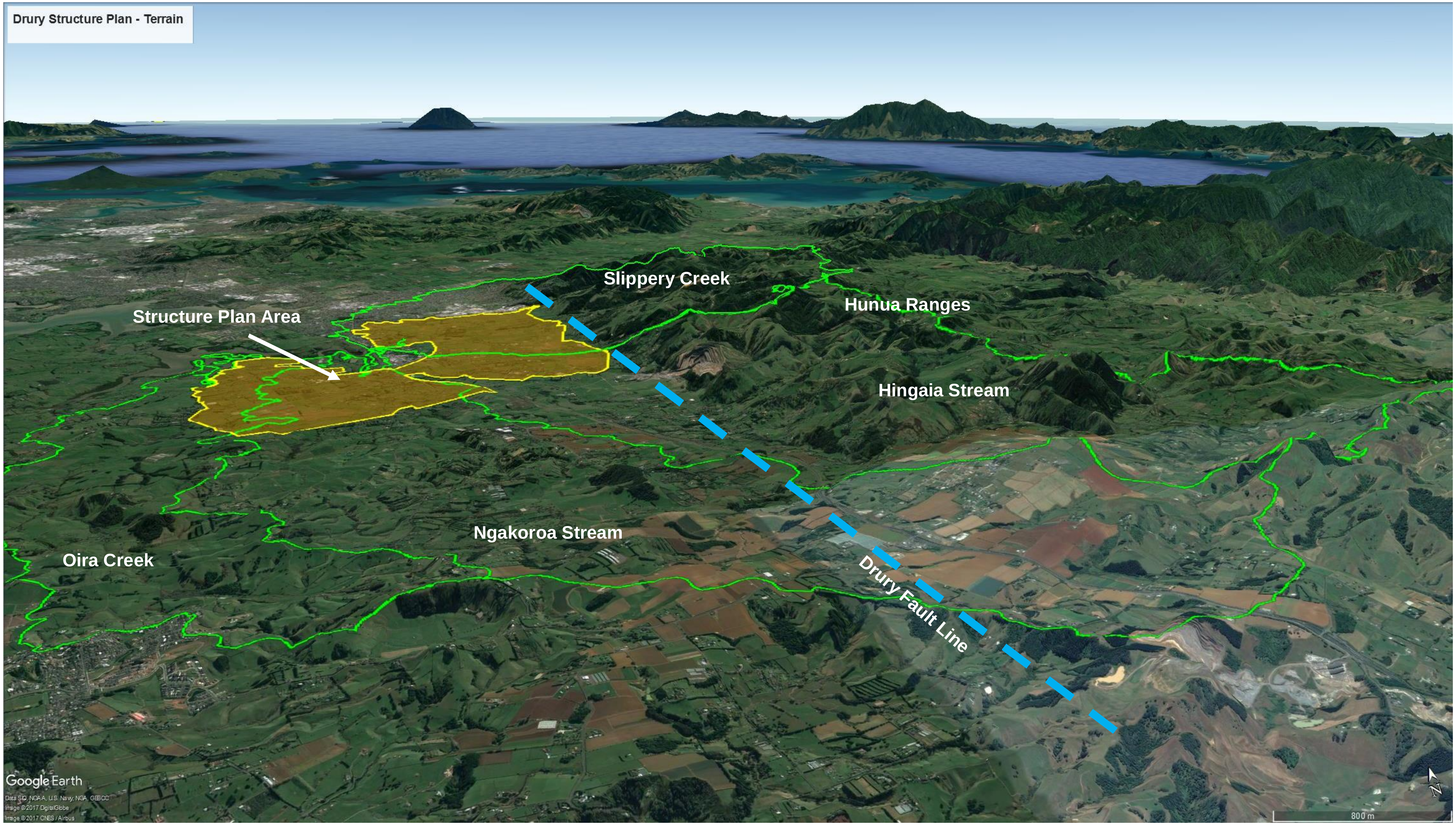
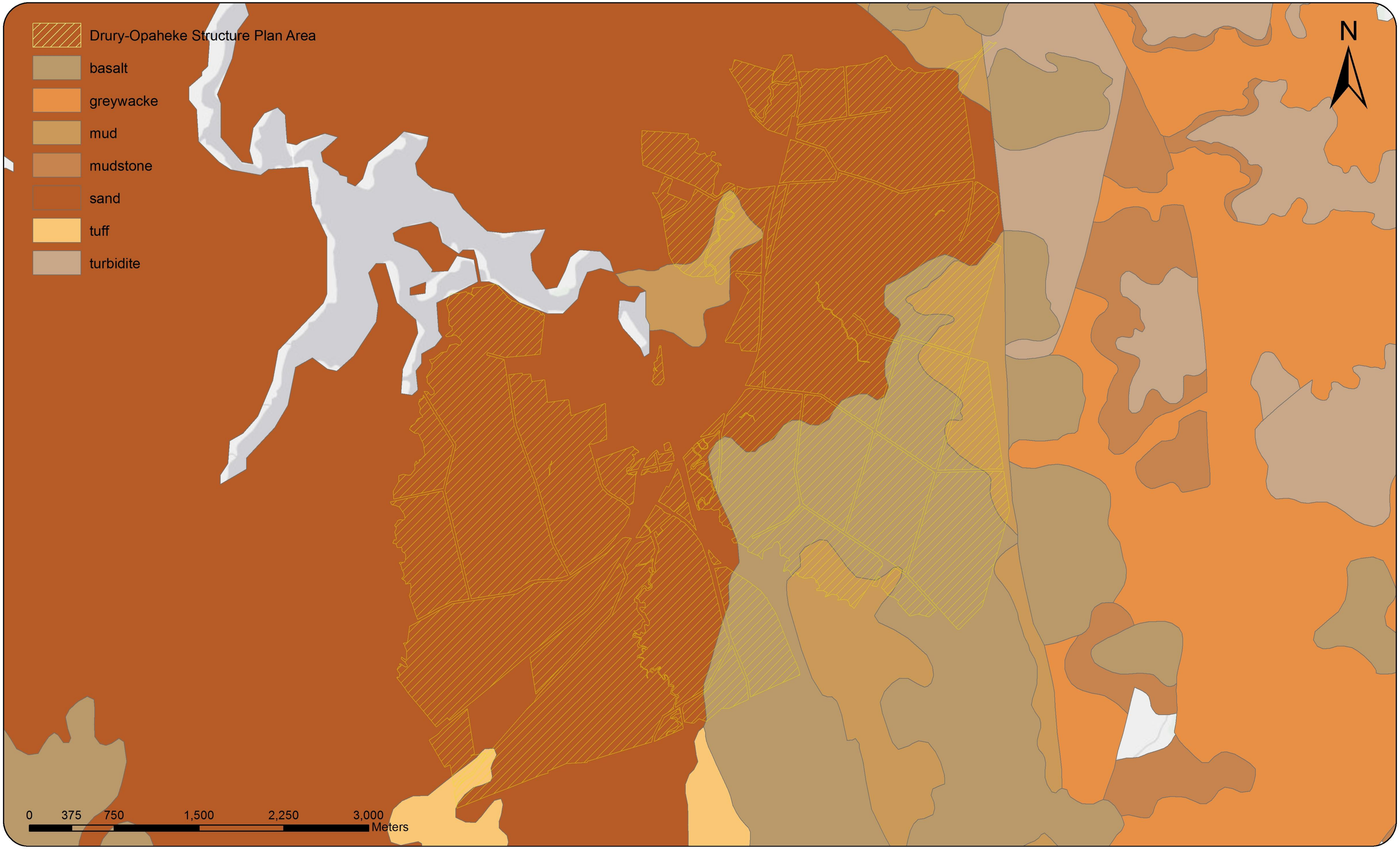

Drury Structure Plan - Terrain
Slippery Creek
Structure Plan Area
Hunua Ranges
Hingaia Stream
Ngakoroa Stream
Oira Creek
Drury Fault Line
Google Earth
800 m



Drury-Opaheke Structure Plan Area - Geology - Main Rock Types

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

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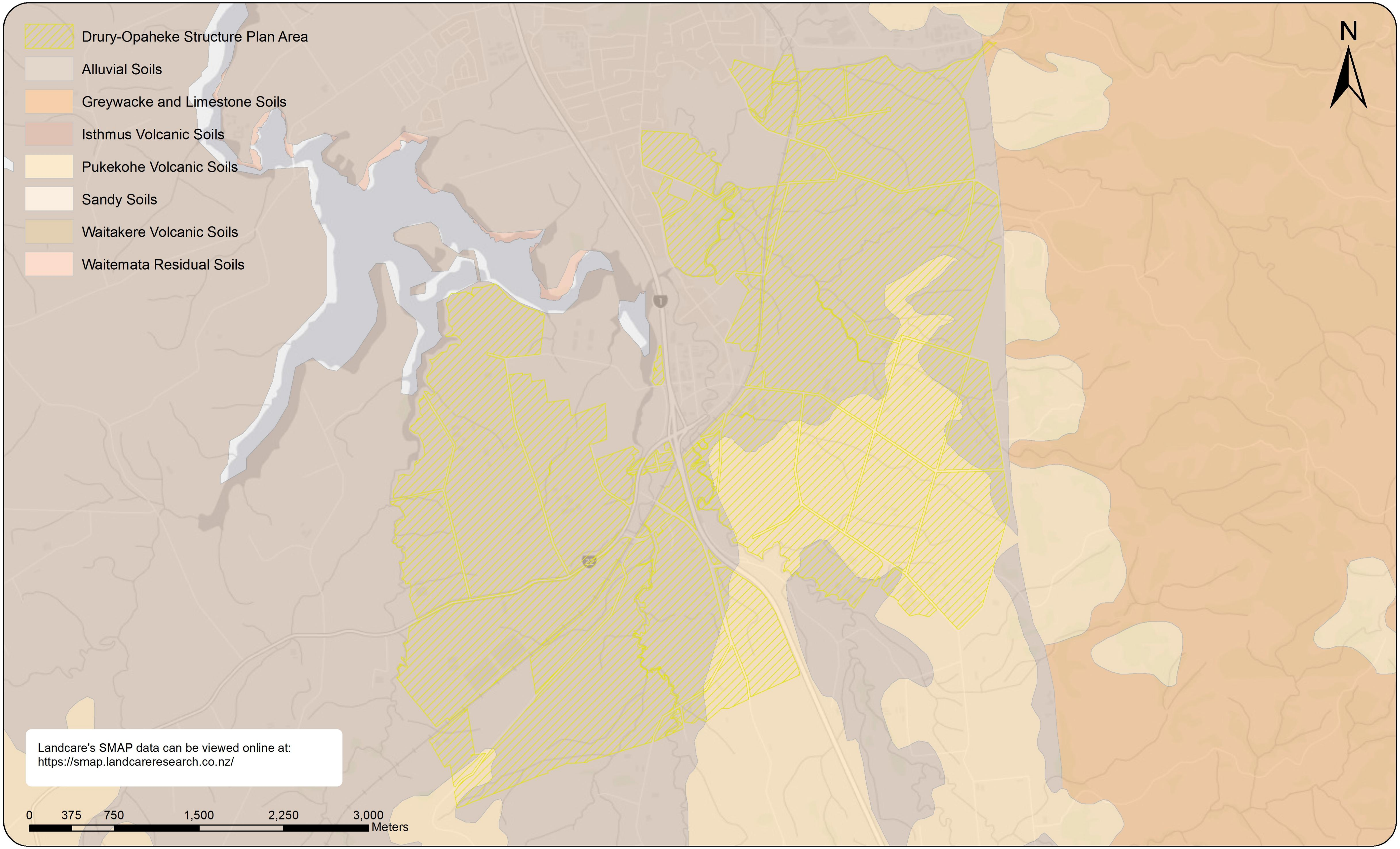

Drury-Opaheke Structure Plan Area - Soils - Generalised Soil Type (GNS)

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

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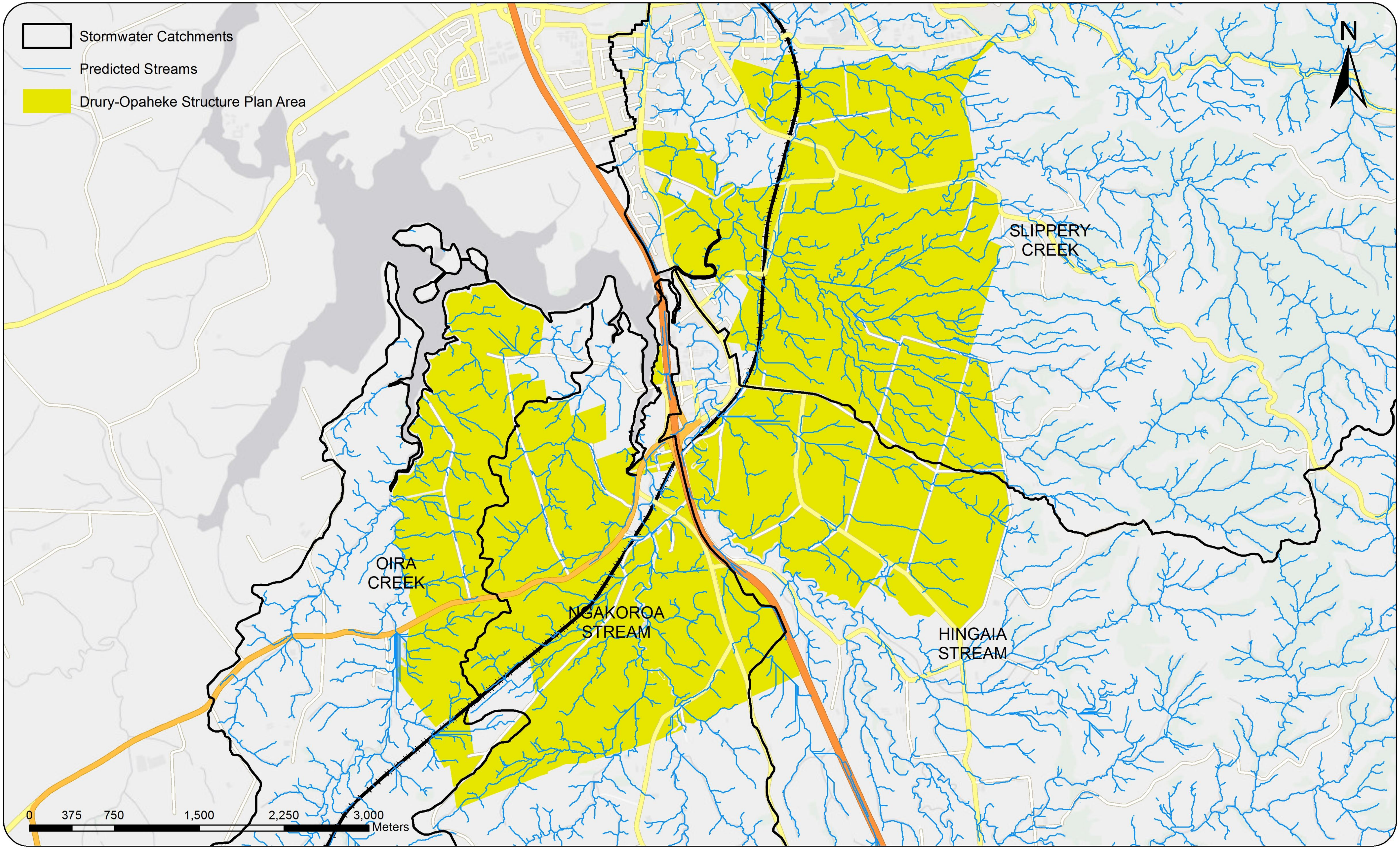

Drury-Opaheke Structure Plan Area - Predicted Streams

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

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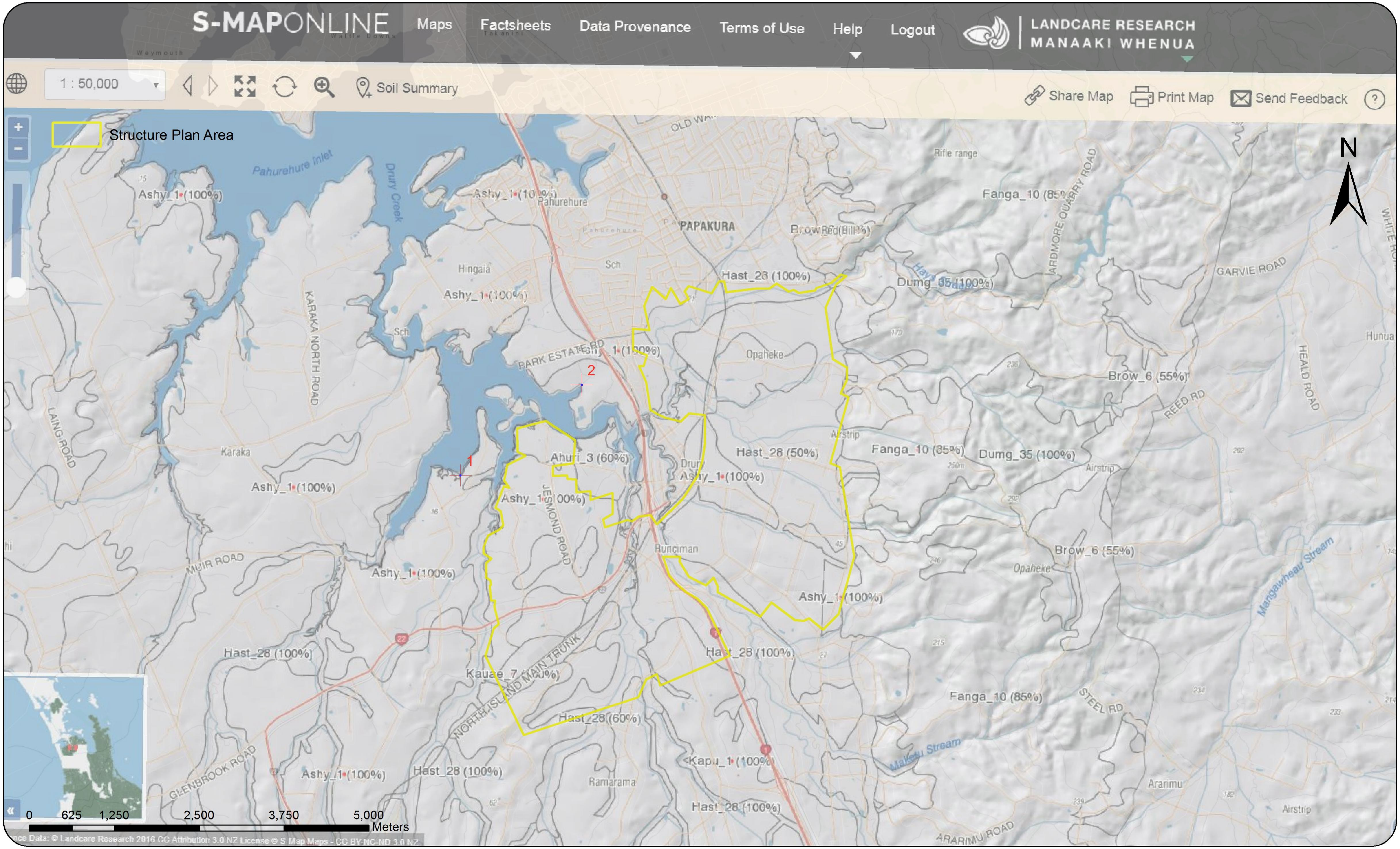

Drury-Opaheke Structure Plan Area - S-Map Soil Families

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 01-08-2017

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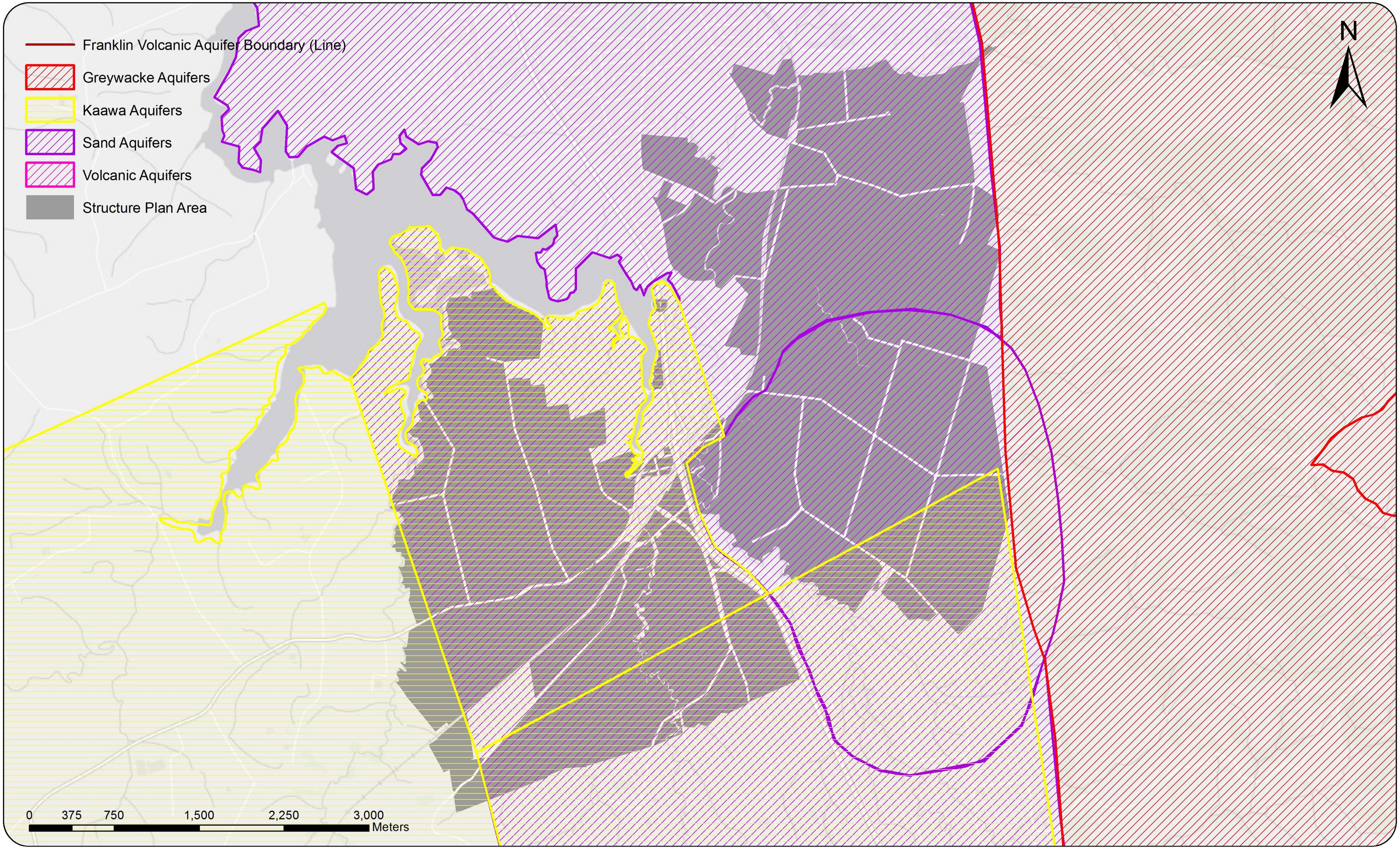

Drury Structure Plan Area - Aquifers

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 06-09-2017

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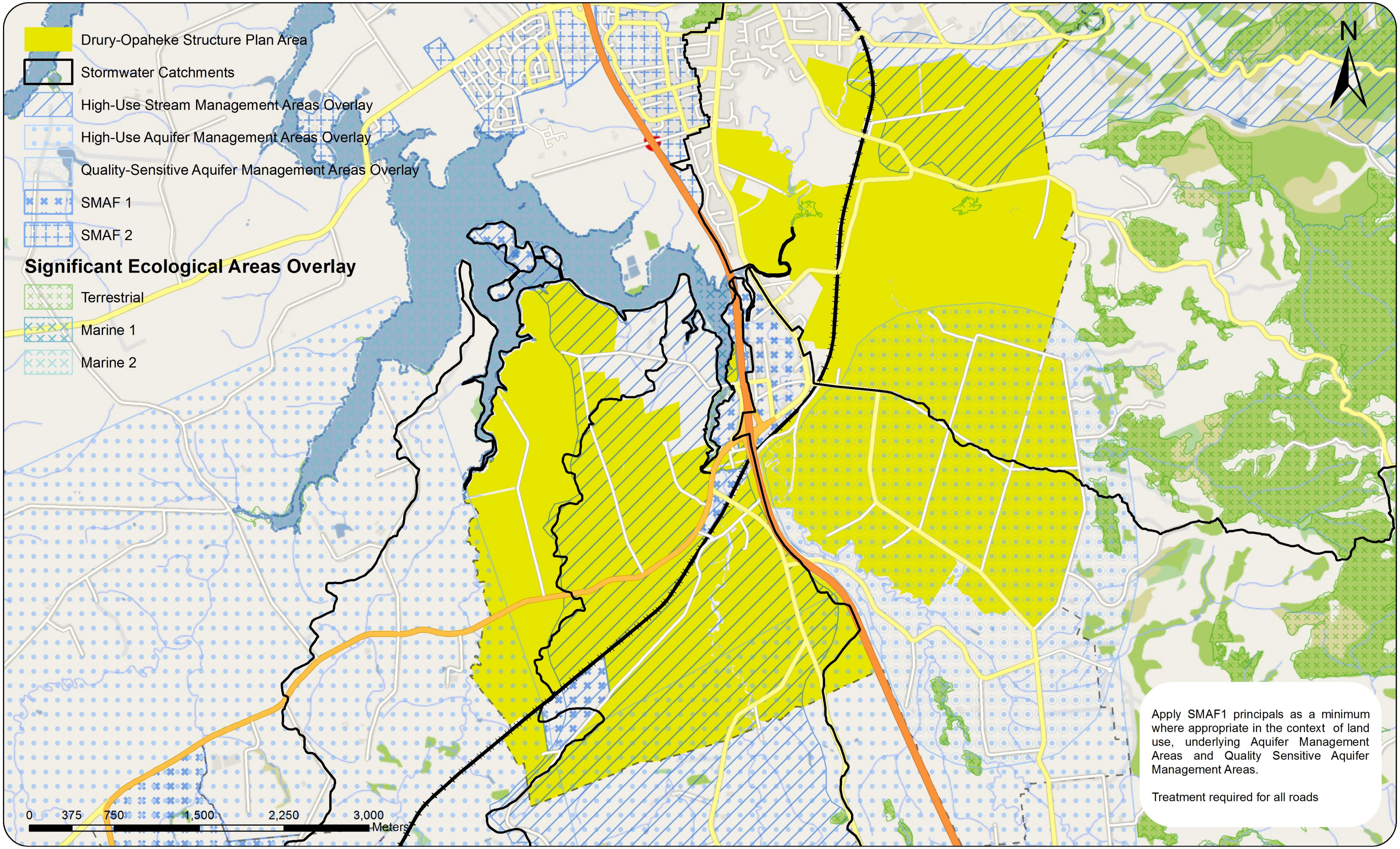

Drury-Opaheke Structure Plan Area - Natural Resource Overlays & Stormwater Management Controls

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

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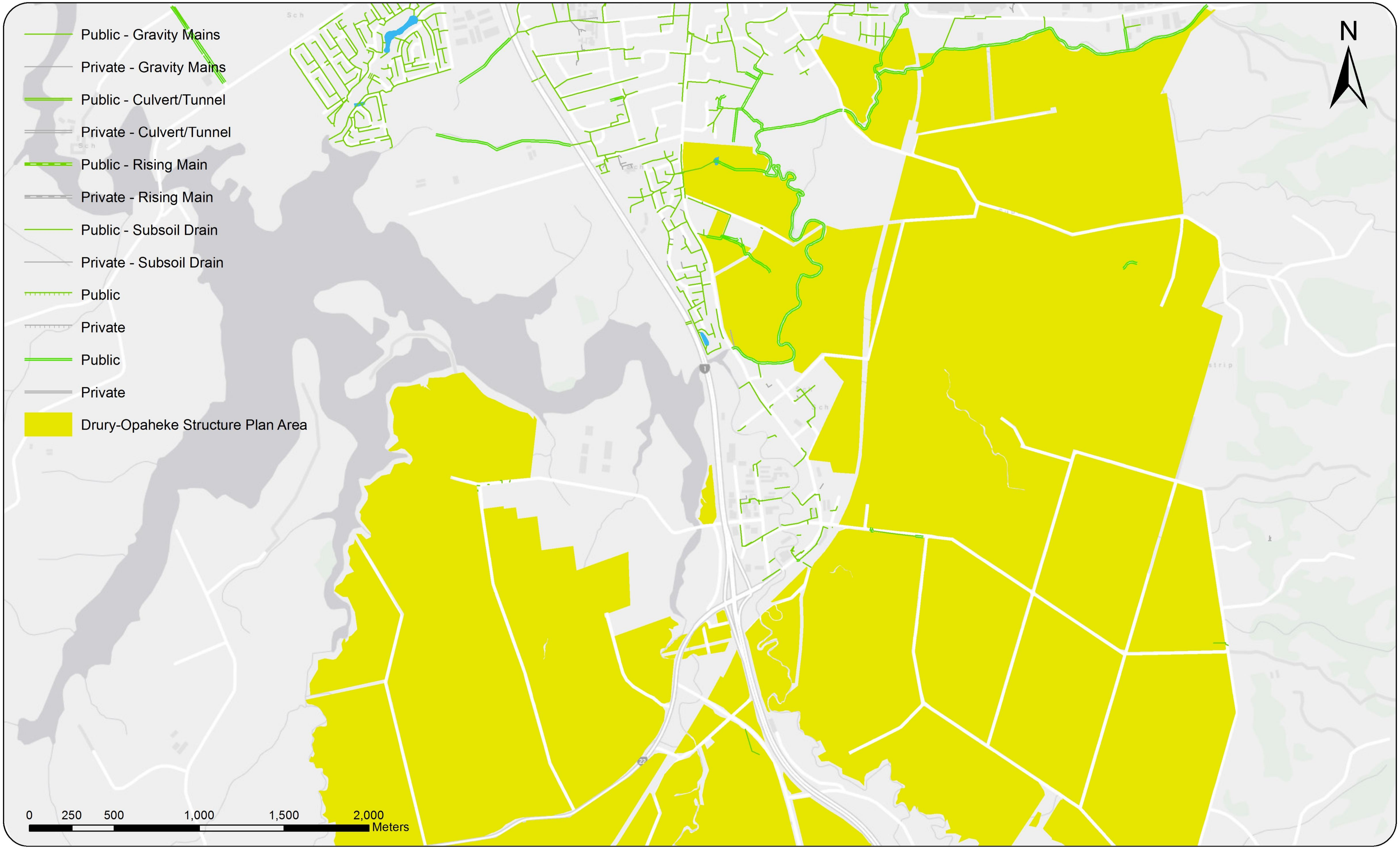

Drury-Opaheke Structure Plan Area - Stormwater Assets

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 06-09-2017

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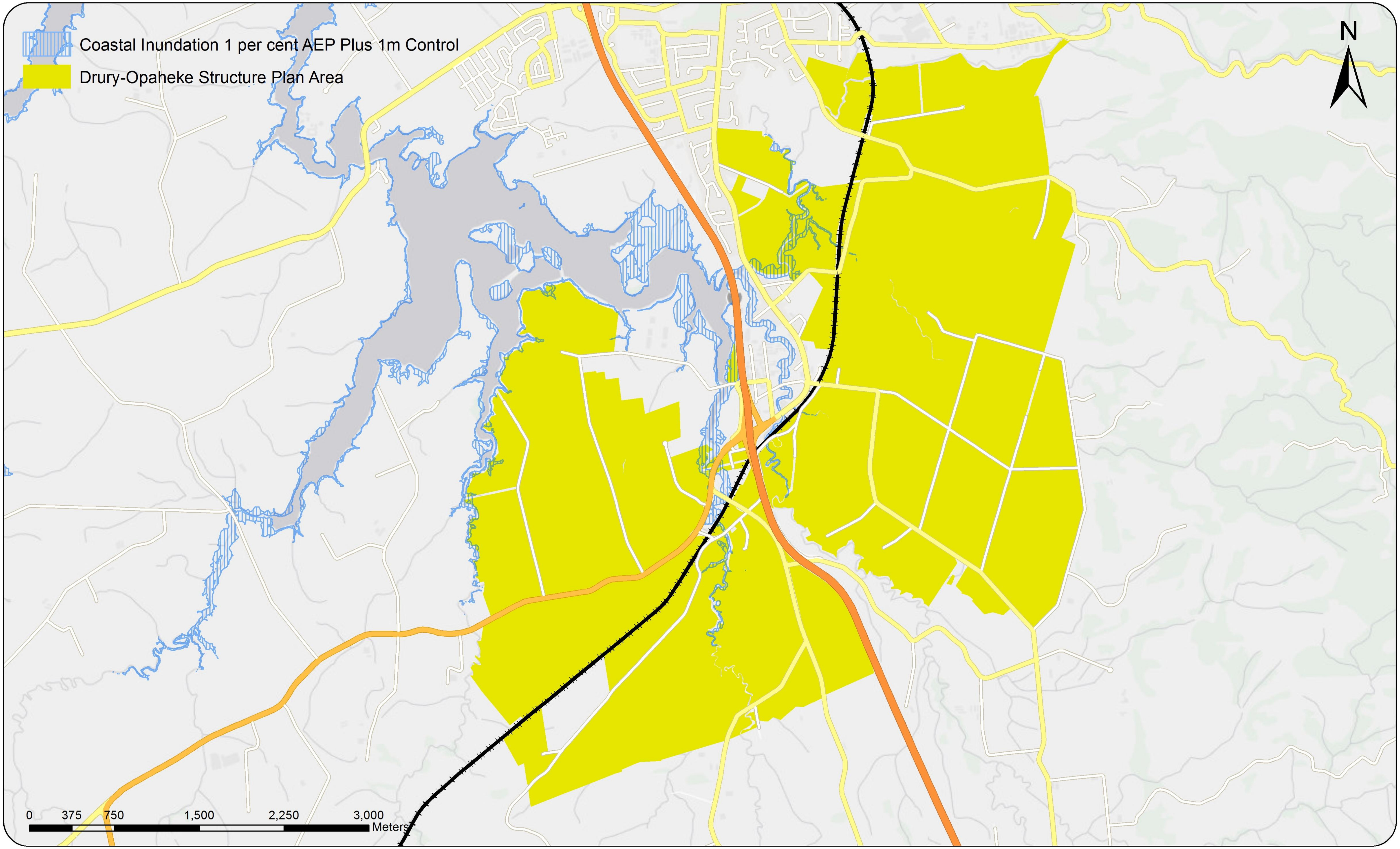

Drury-Opaheke Structure Plan Area - Coastal Inundation (1% AEP plus 1m control)

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

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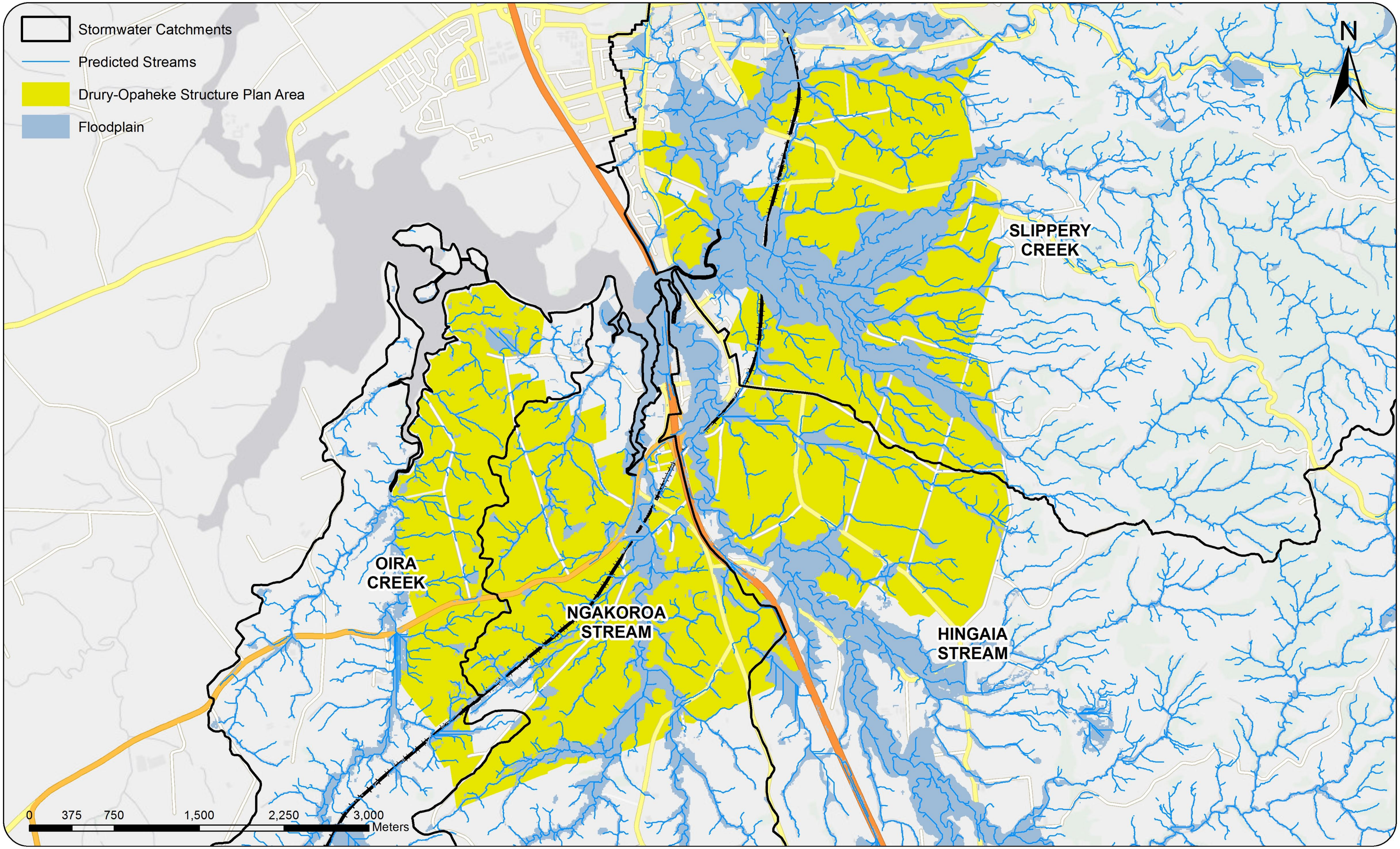

Drury-Opaheke Structure Plan Area - Floodplains

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

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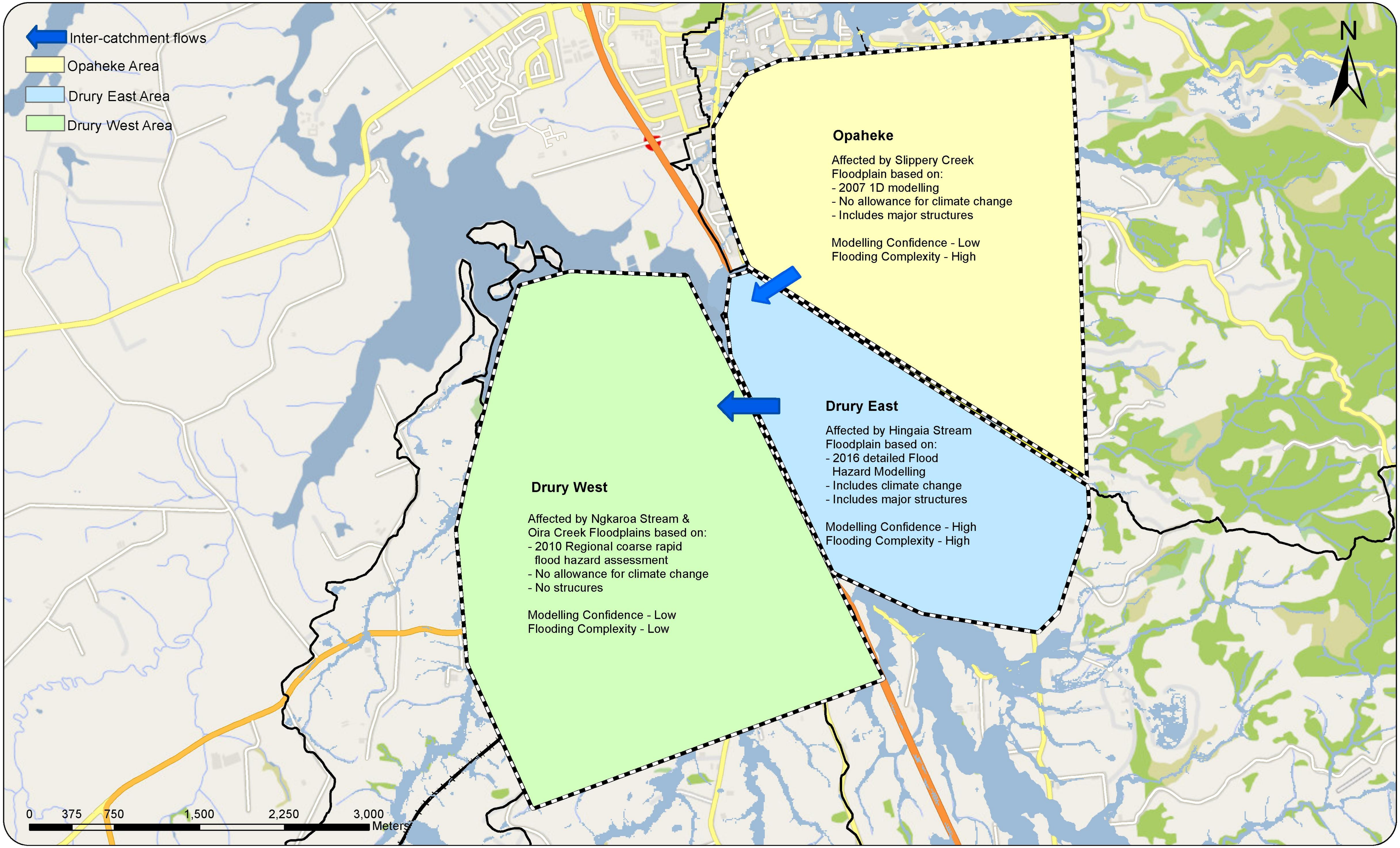

Drury-Opaheke Structure Plan Area - Floodplain Limitations

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 01-08-2017

Indicative concepts only
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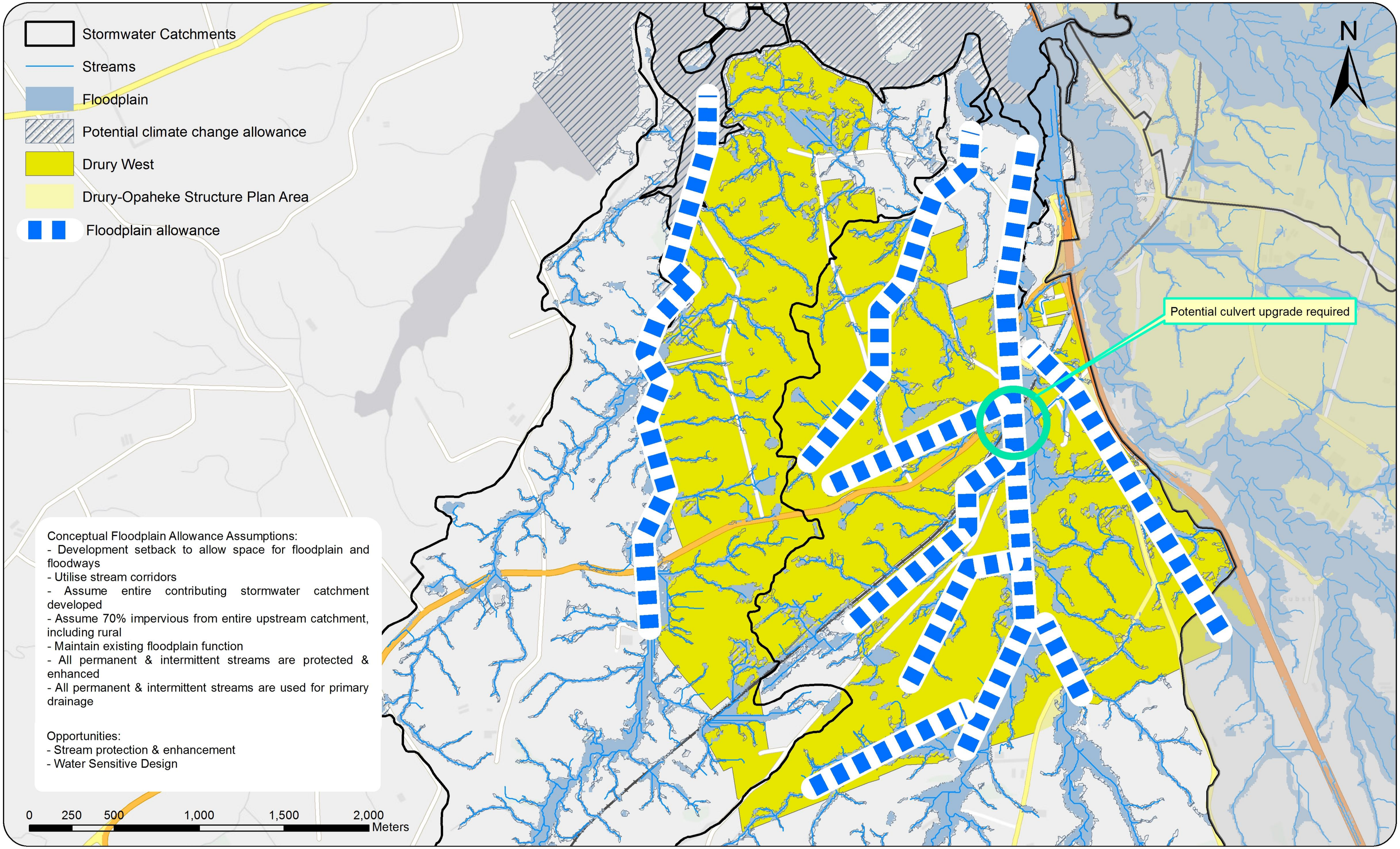

Drury West - Potential Stormwater Management Options

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

Indicative concepts only
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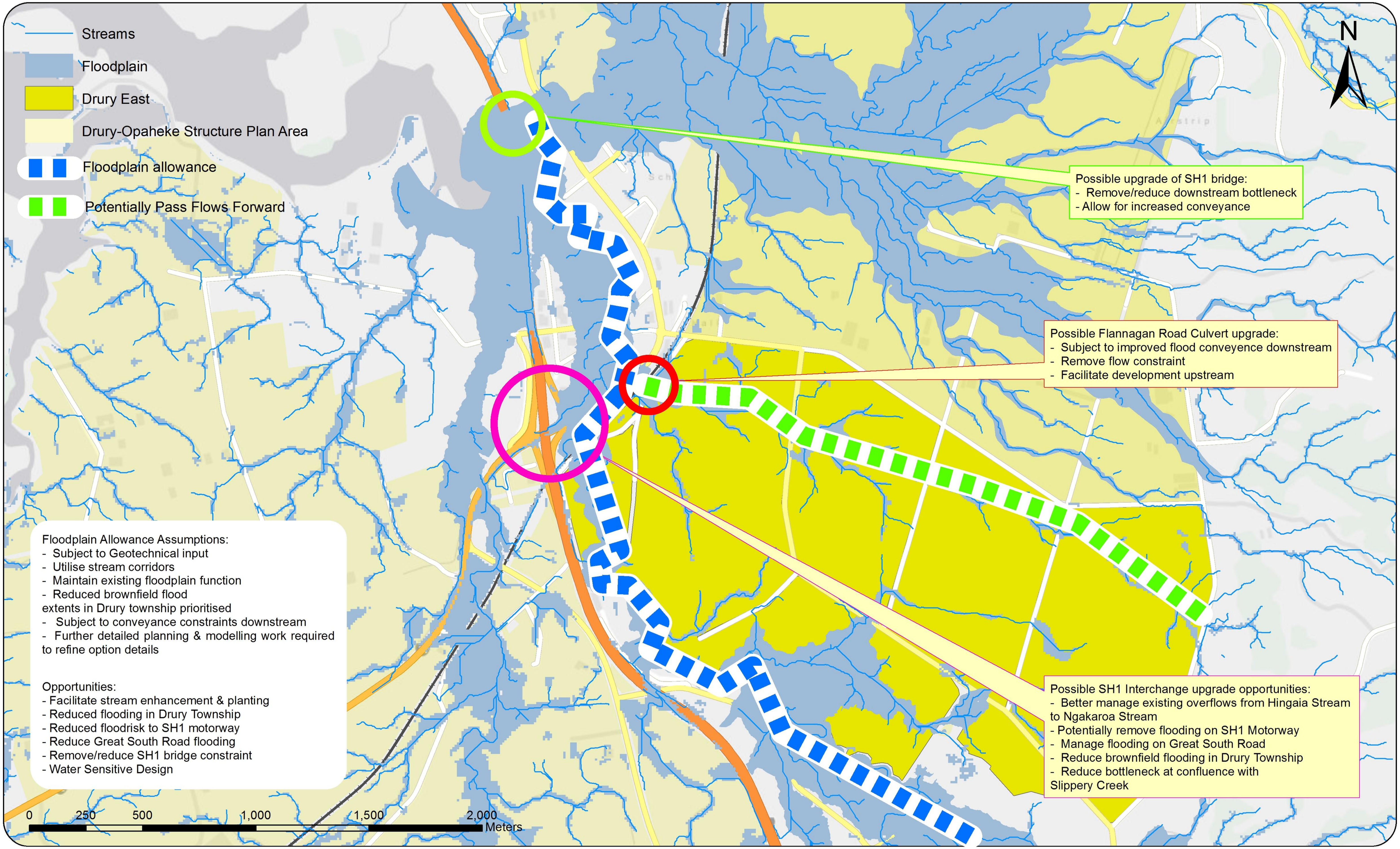
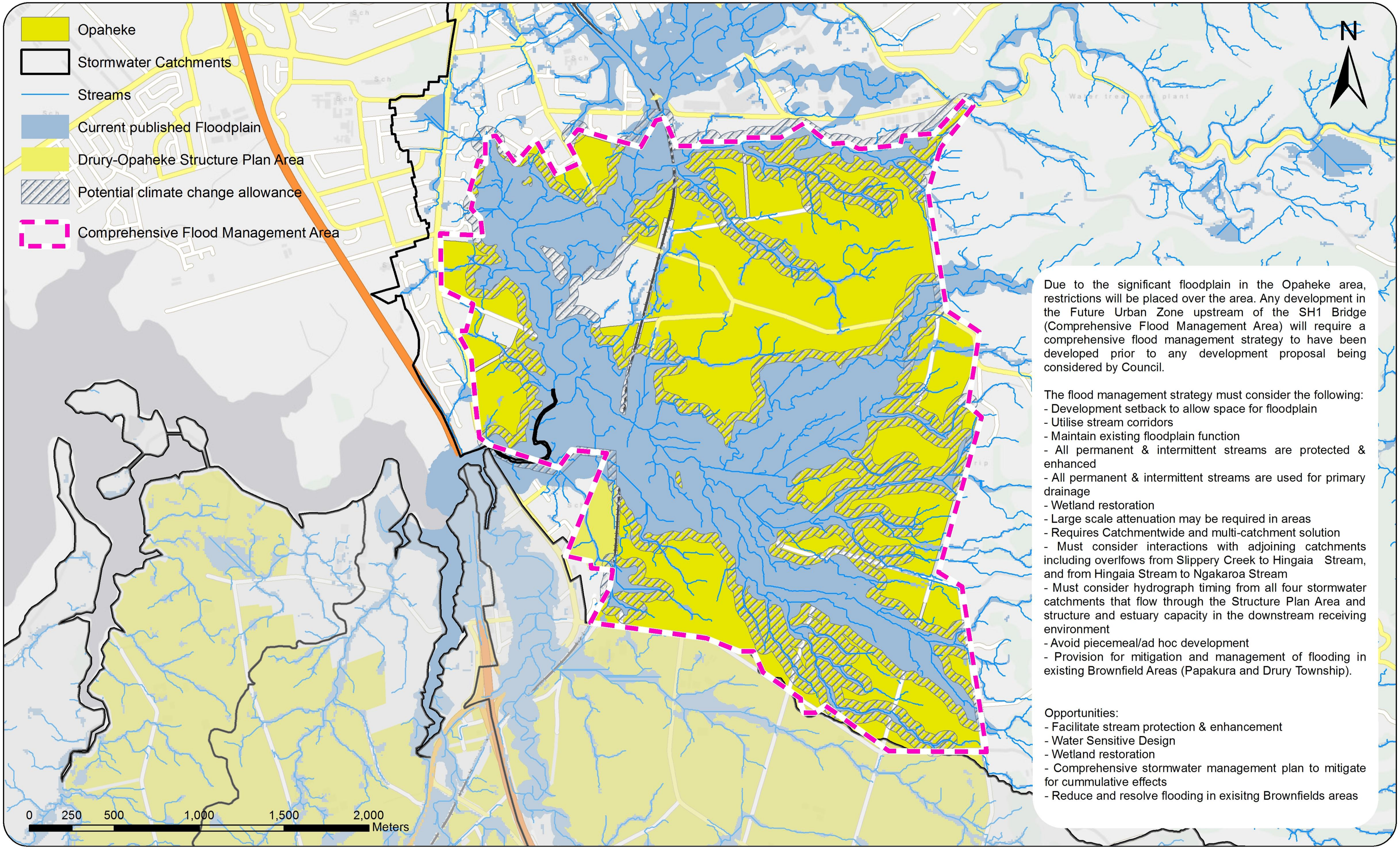


Drury East - Potential Stormwater Management Options

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

Indicative concepts only
Not to scale

Auckland Council
Te Kaunihera o Tāmaki Makaurau



Due to the significant floodplain in the Opaheke area, restrictions will be placed over the area. Any development in the Future Urban Zone upstream of the SH1 Bridge (Comprehensive Flood Management Area) will require a comprehensive flood management strategy to have been developed prior to any development proposal being considered by Council.

The flood management strategy must consider the following:
- Development setback to allow space for floodplain
- Utilise stream corridors
- Maintain existing floodplain function
- All permanent & intermittent streams are protected & enhanced
- All permanent & intermittent streams are used for primary drainage
- Wetland restoration
- Large scale attenuation may be required in areas
- Requires Catchmentwide and multi-catchment solution
- Must consider interactions with adjoining catchments including overlfows from Slippery Creek to Hingaia Stream, and from Hingaia Stream to Ngakaroa Stream
- Must consider hydrograph timing from all four stormwater catchments that flow through the Structure Plan Area and structure and estuary capacity in the downstream receiving environment
- Avoid piecemeal/ad hoc development
- Provision for mitigation and management of flooding in existing Brownfield Areas (Papakura and Drury Township).

Opportunities:
- Facilitate stream protection & enhancement
- Water Sensitive Design
- Wetland restoration
- Comprehensive stormwater management plan to mitigate for cummulative effects
- Reduce and resolve flooding in exisitng Brownfields areas

Opaheke - Potential Stormwater Management Options

Conceptual Drury Stormwater Management Plan
Stage 1 - high level constraints and concepts
Date Produced: 07-09-2017

Indicative concepts only
Not to scale

Auckland Council
Te Kaunihera o Tāmaki Makaurau

Appendix E

Drury Stormwater Management Summary

REPORT

Tonkin+Taylor

Drury Stormwater Management Summary

Final

Prepared for

Kiwi Property Group Ltd., Karaka and Drury Ltd., Fulton Hogan Land Development Company, Drury South Ltd.

Prepared by

Tonkin & Taylor Ltd

Date

April 2018

Job Number

1003297

Exceptional thinking together

www.tonkintaylor.co.nz

Document Control

Title: Drury Stormwater Management Summary					
Date	**Version**	**Description**	**Prepared by:**	**Reviewed by:**	**Authorised by:**
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Distribution:

Kiwi Property Group Ltd., Karaka and Drury Ltd., Fulton Hogan Land Development Company, Drury South Ltd. 1 copy

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Table of contents

Executive summary

The Drury Structure Plan Area (DSPA) is defined as the Drury-Opaheke Future Urban zoned land as well as the Drury South and Drury West operative zoned land. This area has been identified as an area of future growth by Auckland Council. T+T have been engaged by the four major developers that currently have land interests in the area (Kiwi Property Group Ltd., Karaka and Drury Ltd., Fulton Hogan Land Development Company and Drury South Ltd.) to develop a stormwater and flood management framework for the DSPA. This was derived by summarising the stormwater and flood management approaches for the first tranche of developments within the DSPA and identifying a common approach that could be used as a blueprint the Auckland Council structure plan for Drury. The proposed stormwater and flood management framework for Drury Structure Plan is summarised in the table below.

Water quality	• Avoiding the use of high contaminant yielding building materials to minimise contaminant generation • Provision of at-source water quality treatment of roads and carparks using multi-functional devices such as tree pits, raingardens, vegetated swales and/or filter strips. These devices also serve a hydrological mitigation function as well as providing amenity value. • Provision of contaminant specific treatment for individual lots that are classified as industrial/trade activities
Hydrology	• Retention for first 5 mm of runoff from impervious surfaces where practical • Detention of the difference in impervious surface runoff volumes from a pre-development and post-development for the 95th percentile, 24 hour rainfall event minus the retention volume • Provision of hydrological mitigation (detention and retention) for residential roof areas using water reuse tanks • Provision of hydrological mitigation (detention and retention) for driveways associated with residential lots and laneways using permeable paving and/or retention/detention tanks • Provision of hydrological mitigation (detention and retention) for roads and/or carparks using multi-functional devices such as raingardens, tree pits, swales and filter strips for roads/carparks. These devices also serve a water quality treatment function as discussed for water quality as well as providing amenity value. • Green outfalls for stormwater outfalls to streams
Flood management	• Exclude development from the 100 year ARI floodplain • Not worsen flooding on land outside the DSPA areas or on properties not owned by the developer • Flood management by “passing flows forward” in the lower catchment. Passing flows forward is where runoff from development in the lower catchment is released without attenuation as a delayed release of local floodwater can make the flood peak from the larger flood from the upper catchment worst • For upper catchments use a combination of dry basins, wetlands and online flood storage (stream or floodplain modification) to attenuate peak flows in the upper catchment
WSD	• Retain and enhance streams as much as practicable • Green corridors for stream protection and flood management.

1 Introduction

The Drury Structure Plan Area (DSPA) is located between Papakura and Pukekohoe, approximately 35 km south-east of Auckland CBD. The DSPA is defined as the Drury-Opaheke Future Urban zoned land as well as the Drury South and Drury West operative zoned land (refer Figure 1.1). This area has been identified as an area of future growth by Auckland Council.

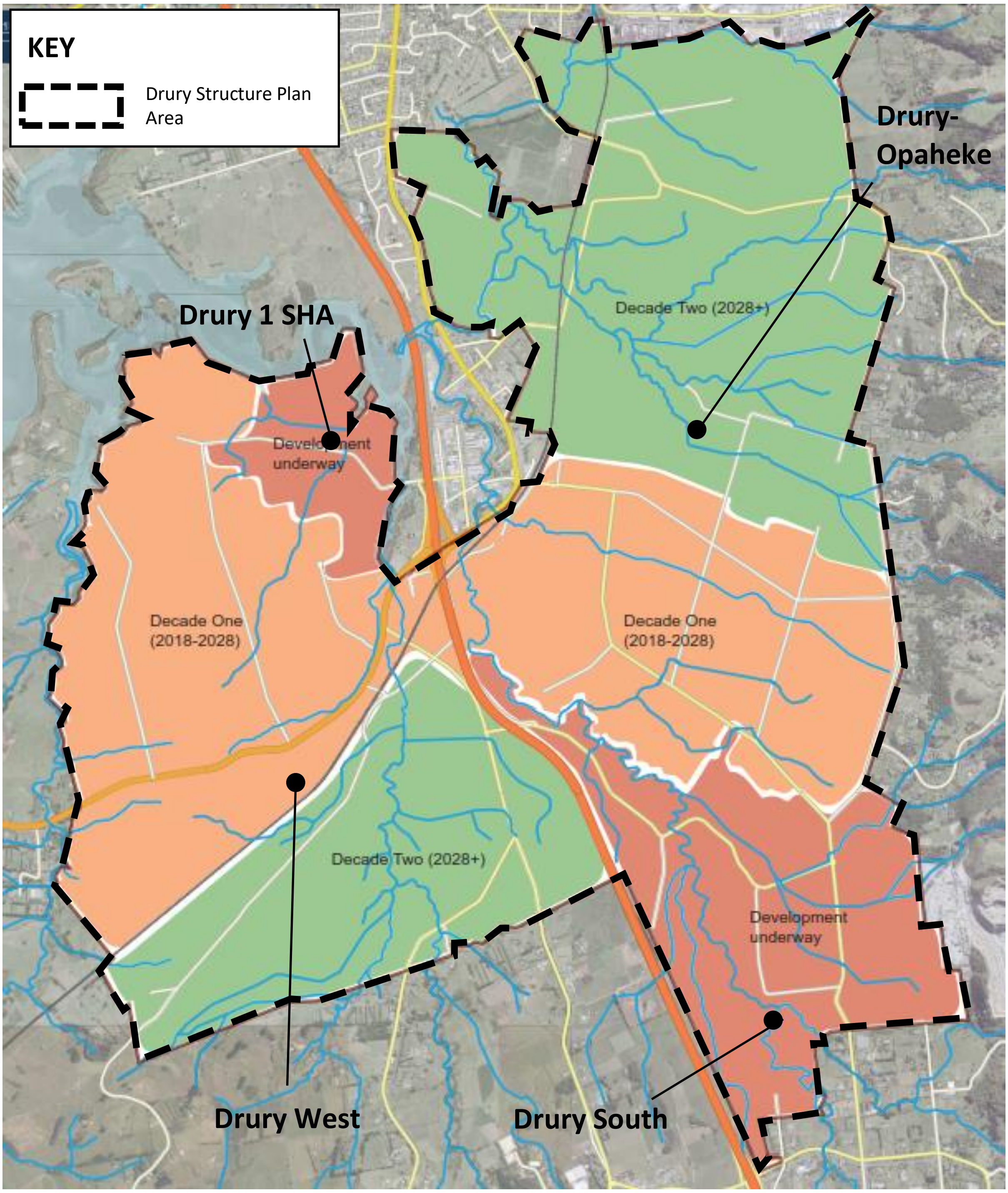

Figure 1.1: Drury Structure Plan Area (Source – Barkers and Associates)

1.1 Background

Auckland Council's strategic direction for growth in Auckland includes the urbanisation of the Future Urban Zone around Drury. A structure plan guides the future urban development of an area. The purpose of a structure plan is to ensure that an integrated approach to land use, transport, infrastructure and community facilities is achieved. The strategic approach to growth enables development to contribute to a quality built environment, and also achieves efficiencies in infrastructure provision. Plan Changes to the Auckland Unitary Plan (AUP) to rezone land within the Drury Structure Plan area will be required to be generally consistent with the Drury Structure Plan.

Four major land developers have land interests within the Drury Structure Plan area: Kiwi Property Group Ltd., Karaka and Drury Ltd., Fulton Hogan Land Development Company and Drury South Ltd. These developers will have a key role in delivering the first stages of the Drury Structure Plan. The developers have worked together to prepare a draft Drury Structure Plan that achieves the objectives of the Auckland Plan and AUP, responds to the opportunities and constraints of the area, and also recognises their development aspirations. A copy of the draft Drury Structure Plan is included as Appendix A.

The structure plan also responds to work already undertaken by the developers, including:

- Drury South Ltd: Drury South has operative zones and precincts under the AUP to enable industrial and residential development (in the Quarry Road Special Housing Area).
- Karaka and Drury Ltd (Drury West): Drury West incorporates the Bremner Road Special Housing Area (Drury 1 Precinct), which has operative zones to enable residential development. Karaka and Drury Ltd is currently also seeking a Plan Change to extend the operative residentially zoned area. As part of the Plan Change, Karaka and Drury Ltd prepared a structure plan for Drury West, which provides for an integrated approach to development of residential and commercial land, with a centre providing for the retail and community facilities needs of the Drury West residential population.
- Kiwi Property and Fulton Hogan (Drury East)*:* Each of Kiwi Property and Fulton Hogan prepared detailed submissions on the Future Urban Land Supply Strategy refresh in April 2017. These submissions included a high-level identification of constraints and opportunities, and potential framework for development.

Auckland Council have also commissioned a Drury-Opaheke stormwater management plan to support the Drury Structure Plan[1]. This report identifies the key constraints, risks and opportunities for stormwater management within the DSPA.

1.2 Purpose and scope

T+T have been engaged by the four major developers that currently have land interest in the area (Kiwi Property Group Ltd., Karaka and Drury Ltd., Fulton Hogan Land Development Company and Drury South Ltd.) to develop a stormwater and flood management framework for the DSPA. This will be derived by summarising the stormwater and flood management approaches for the first tranche of developments within the DSPA with a view to identifying a common approach that can be used as a blueprint for the Auckland Council structure plan for Drury. The scope of the report is as follows:

- Section 2 – summarises the relevant stormwater and flood management policies within the AUP that development in the DSPA needs to give effect to
- Section 3 – discusses the catchment-specific stormwater and flood management issues identified by Auckland Council and in the planning regulations

[1] AECOM report 'Opaheke-Drury Stormwater Management Plan: Preliminary Plan' dated 19 September 2017

- Section 4 – describes the development areas that are currently proposed, their current development status and any local stormwater and flood management issues
- Section 5 – presents the integrated stormwater and flood management approach for the DSPA
- Section 6 – summarises the findings of this report.

1.3 Acknowledgements

Woods has contributed to this report by briefing T+T on the Fulton Hogan (Drury East) development activities and the proposed approaches to stormwater management in that area. Woods assisted with the stormwater management plan approach summary table in Appendix B and in the meeting with Auckland Council. The approaches applied to Drury South Precinct and Auranga have also be used in this report and we acknowledge Drury South Limited and Karaka and Drury Limited.

Auckland Council has contributed to this report by meeting with T+T and Woods on 17 November 2017. In this meeting the catchment issues, requirements and proposed approaches were discussed.

Iwi have contributed to our understanding of the catchment and the development of stormwater management approaches. The minutes from a hui held on 21 February 2018 are included in Appendix B.

2 Auckland Unitary Plan (AUP) policies

The AUP is the planning document for Auckland that replace the former Regional Policy Statement and the 13 regional and district plans. The AUP became 'operative in part' on 15 November 2016. The AUP sets out objectives, policies and rules for development on both a city-wide scale and in some cases on a site-specific scale for areas that have been designated as 'precincts' The general AUP policies for management of stormwater and flooding are covered in Section E – Auckland Wide rules, namely:

- Section E1 – Water quality and integrated management
- Section E10 – Stormwater management area – Flow 1 and Flow 2
- Section E36 - Natural hazards and flooding.

The following subsections summarise the policies in the AUP that development in the DSPA needs to give effect to.

2.1 General

Policy 8 in Section E1 (Policy E1.3.8) sets out the following policies for management of stormwater runoff from greenfield development:

Avoid as far as practicable, or otherwise minimise or mitigate, adverse effects of stormwater runoff from greenfield development on freshwater systems, freshwater and coastal water by:

- *taking an integrated stormwater management approach (refer to Policy E1.3.10);*
- *minimising the generation and discharge of contaminants, particularly from high contaminant generating car parks and high use roads and into sensitive receiving environments;*
- *minimising or mitigating changes in hydrology, including loss of infiltration, to:*
  - *minimise erosion and associated effects on stream health and values;*
  - *maintain stream baseflows; and*
  - *support groundwater recharge;*
- *where practicable, minimising or mitigating the effects on freshwater systems arising from changes in water temperature caused by stormwater discharges; and*
- *providing for the management of gross stormwater pollutants, such as litter, in areas where the generation of these may be an issue.*

The other relevant policies from Section E1 are summarised briefly below:

- Maintain or enhance water quality, flows, stream channels and their margins where MCI scores for the existing streams are above the guidelines in Table E1.3.1 or Enhance water quality, flows, stream channels and their margins where MCI scores for the existing streams are below the guidelines in Table E1.3.1 (Policy E1.3.2a, Policy E1.3.2b and Policy E1.3.3).
- Discharges must avoid contamination that will have an adverse effect on the life supporting capacity of freshwater (Policy E1.3.4).
- Discharges must avoid contamination that will have an adverse effect on health of people and communities (Policy E1.3.5).
- An integrated stormwater management approach (Policy E1.3.10) must have regard to all of the following:
  - The nature and scale of the development and practical and cost considerations.
  - The location and design of site and infrastructure to protect significant site features and minimise effects on receiving environments.

- The nature and sensitivity of receiving environments.
- Reducing stormwater flows and contaminants at source.
- The use and enhancement of natural hydrological features and green infrastructure where practicable.

- Avoid, minimise or mitigate adverse effects of stormwater diversions and discharges (Policy E1.3.11).
- Manage contaminants in stormwater runoff from high contaminant generating carparks (> 30 cars) and high use roads (>5000 vehicles per day) to minimise adverse effects on water and sediment quality (Policy E1.3.12).
- Require Stormwater quality or flow management to be achieved on-site unless there is a downstream communal device (Policy E1.3.13).
- Adopt the best practicable option to minimise the adverse effects of stormwater discharges (Policy E1.3.14).
- Utilise stormwater discharge to ground soakage where it is possible to do so in a safe, and effective manner (Policy E1.3.15).

2.2 Natural hazards and flooding

Section E36 sets out the policies relating to management of natural hazards and flooding. The relevant policies are summarised briefly below:

- Identify land subject to natural hazards, taking into account the likely effects of climate change (Policy E36.3.1).
- Avoid development in greenfield areas which would result in an increased risk of adverse effects from coastal hazards, taking account of a longer term rise in sea level in areas subject to coastal hazard (Policy E36.3.5).
- Avoid locating buildings in the 100 year ARI floodplain (Policy E36.3.17).
- Earthworks within the 100 year ARI floodplain should not permanently reduce floodplain conveyance or exacerbate flooding experienced by other sites upstream or downstream (Policy E36.3.20).
- Ensure all development in the 100 year floodplain does not increase adverse effects or increased flood depths or velocities to other properties upstream or downstream of the site (Policy E36.3.21).
- Maintain the function and capacity of overland flowpaths to convey stormwater runoff safely and without damage to the receiving environment (Policy E36.3.29) and Policy E36.3.30).

2.3 Hydrological Mitigation

Section E10 sets out additional controls for sites identified in the Stormwater management area control – Flow 1 and Flow 2. These additional controls are referred to as 'hydrological mitigation' as they seek to minimise the change in hydrology, namely runoff volumes and flow rate, as a result of development. Hydrological mitigation is aimed at protecting rivers and streams that are particularly susceptible to the effects of development or have relatively high values. Hydrological mitigation controls are apply to the DSP site as it is located upstream of a Stormwater Management Area control - Flow 1 (SMAF 1) overlay and is a greenfield development where Policy E1.3.8 requires "*…minimising or mitigating changes in hydrology…*".

The SMAF 1 hydrological mitigation requirements are given in Table E10.6.3.1.1 in the AUP and are as follows:

- Retention (volume reduction) of at least 5mm of runoff depth from impervious surfaces.
- Detention (temporary storage) and a drain down period of 24 hours for the difference between the pre-development and post-development runoff volumes from impervious surfaces in the 95th percentile, 24 hour rainfall event minus the achieved retention volume.

Exceptions for providing retention can be made in cases where soil infiltration rates preclude disposal to groundwater and rainwater reuse is not possible.

2.4 Precinct rules

The DSPA contains three designated AUP precincts which have additional sets of planning rules. These three precincts within the DSPA are the Drury South Industrial Precinct, the Drury South Residential Precinct and Drury 1 Precinct.

2.4.1 Drury South Precincts

The relevant objectives and policies for the Drury South Industrial Precinct and the Drury South Residential Precinct are set out in Section I410 and I451of the AUP and are summarised below:

- Avoid or mitigate adverse effects on surface or groundwater quality from stormwater runoff through on-site stormwater management and containment and the provision of catchment based wetlands (Policies I410.3.21 and I451.3.21).
- Use wetlands for stormwater treatment and detention that also provide reserve and visual amenity opportunities (Policies I410.3.7 and I451.3.10).
- Make provision to detain the 100 year ARI event without adverse effects on the extent of flooding upstream and downstream (Policies I410.3.15 and I451.3.15).
- Provide sufficient floodplain storage to avoid increasing flood risk upstream and downstream, and manage the increased flood risk within the precinct, to habitable rooms for all flood events from the 2 year ARI to 100 year ARI (Policies I410.3.16 and I451.3.16).
- Undertake earthworks to form the modified floodplain in a manner which ensures upstream and downstream flood effects are not exacerbated (Policies I410.3.17 and I451.3.17).
- Avoid locating buildings within the 100 year ARI modified floodplain (Policies I410.3.18 and I451.3.18) or otherwise mitigate the risk.
- Avoid locating infrastructure in the 100 year ARI modified floodplain unless it can be designed to be resilient to flood related damage and does not exacerbate flood risks for upstream or downstream activities (Policies I410.3.19 and I451.3.19).
- Identify overland flowpaths in a SMP and ensure that they remain unobstructed and able to safely convey runoff to the reticulated stormwater network (Policies I410.3.20 and I451.3.20).
- Mitigate any diversion or piping of watercourses by ecological enhancement of existing natural and diverted watercourses within and immediately adjacent to the DSP (Policies I410.3.22 and I451.3.6).
- Consider opportunities to recharge the aquifer using treated stormwater where permeable soils are available (Assessment criteria 1.e.iv, Section I410.8.2 and 1.c.iv, Section I451.7.2).
- Provide for stormwater retention in the Residential Precinct through water reuse tanks (Assessment criteria 1.h.ix, Section I451.7.2).
- Provide for stormwater detention in the Residential Precinct through catchment based SW devices, on-site SW devices or a combination of both (Assessment criteria 1.h.viii, Section I451.7.2).

2.4.2 Drury 1 Precinct

Drury 1 is a Special Housing Area (SHA) with an area of 84.62 ha and is bordered by Drury Creek in the north, the southern motorway to the east, Karaka road to the south and Jesmond road to the west. The relevant objectives and policies for Drury 1 are set out in Section I6.35 and are summarised below:

- Require on-site management or, for higher density development, private communal management of stormwater runoff from impervious areas. Stormwater from roads should generally be managed within the road corridors (Policy 8).
- Require native riparian planting along waterways (Policy 9).
- Provide retention (volume reduction) and detention (temporary storage) in accordance with SMAF 1 requirements. Exceptions for providing retention can be made in cases where soil infiltration rates preclude disposal to groundwater and rainwater reuse is not possible (Development Control I6.35.3.1).

3 Catchment-specific issues

The DSPA covers four adjacent, inter-connected stormwater catchments: Oira Creek (20.3 km^2), Ngakoroa Stream (40.1 km^2), Hingaia Stream (57.5 km^2) and Slippery Creek (46.3 km^2) (refer Figure 3.1). All these catchments discharge into Drury Creek, which is an estuary of the Pahurehure Inlet and Manukau harbour.

The development of the Drury Structure Plan requires consideration of the potential effects (including cumulative effects) of development on freshwater systems and the estuary. Several key stormwater and flood management issues have been identified for development of the DSPA through discussions with Auckland Council and in the Drury Structure Planning Overview[2]. These are as follows:

- Provision of enhanced water quality treatment to protect stream health, quality-sensitive aquifers and the downstream marine habitats
- Implementation of hydrological mitigation to protect the health of existing streams and maintain aquifers
- A floodplain management approach that minimises flood risk to people and property recognising catchment-wide, and potentially cross-catchment flood constraints
- Adoption of water sensitive design (WSD) principles including avoiding or minimising impacts to streams as much as practicable

The following subsections provide further discussion on each of these issues.

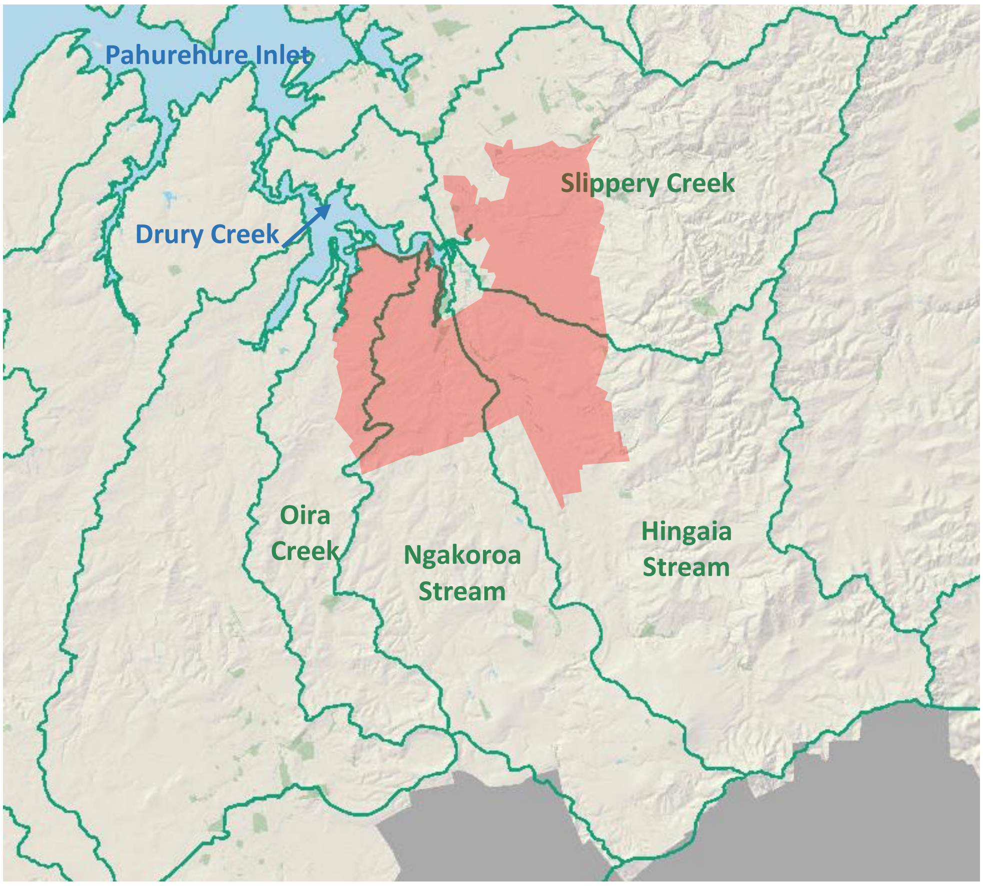

Figure 3.1: Catchment boundaries (DPSA shown in red)

[2] Auckland Council report 'Drury Structure Planning Overview' dated September 2017

3.1 Water quality

The DSPA discharges into the Pahurehure Inlet within the eastern Manukau Harbour via Drury Creek. The upper reaches of Drury Creek are classified as a Significant Ecological Area (SEA) – Marine 1 under the AUP due to the presence of marshes and because it is a migration path between the marine and freshwater habitats for a number of native freshwater fishes. The remaining intertidal habitats of Drury Creek, Whangapouri Creek and Oira Creek are classified as a SEA – Marine 2 under the AUP because of their sand-mud intertidal and rocky reef habitats and excellent examples of saltmarsh vegetation transitioning into mangroves. Figure 3.2 below shows the spatial extent of the areas classified as SEAs. The Pahurehure Inlet is also classified as a 'Degraded 1' coastal water area under Section B7 –Natural Resources of the Regional Policy Statement in the AUP (refer Figure B7.4.2.1)

While the AUP rules generally focus on targeting high contaminant generating surfaces such as high use roads and large carparks (refer Section 2.1), Auckland Council have expressed that development within the DSPA may warrant a wider application of water quality treatment for impervious surfaces. This approach recognizes the sensitive nature of the downstream receiving environment, the possible impact of cumulative effects within the catchment, and the direction in the AUP Policy E1.3.8 to *"…avoid as far as practicable, or otherwise minimise or mitigate, adverse effects of stormwater runoff…" and to* enhance water quality where it is degraded (Objective E1.2.1). Provision of hydrological mitigation of impervious surfaces (discussed in Section 5.2) also provides opportunity for treatment of additional surfaces using multifunctional stormwater devices.

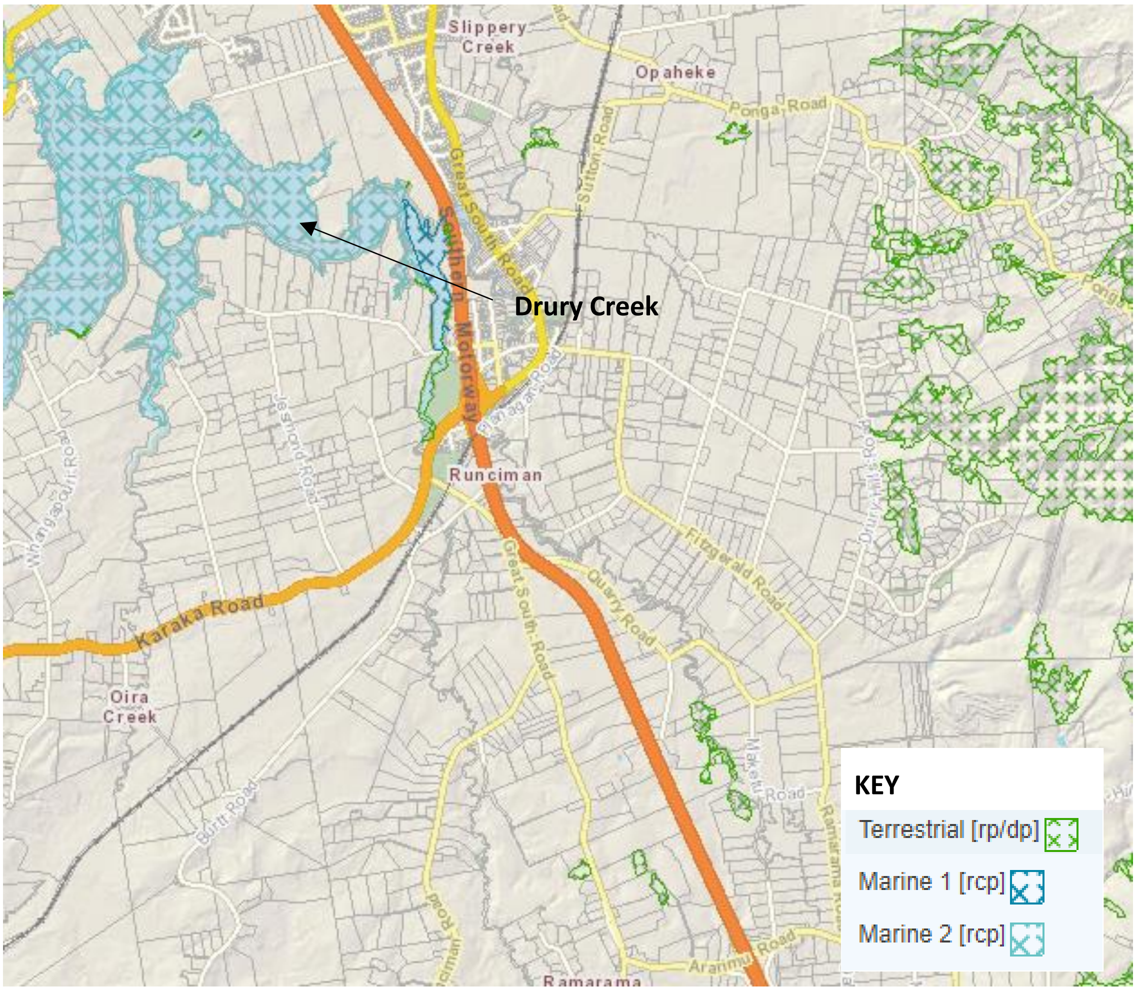

Figure 3.2: Areas classified as Significant Ecological Areas (SEAs) under the AUP (Source – Auckland Council Geomaps)

3.2 Hydrological mitigation

Auckland Council have identified hydrological mitigation as a key consideration for stormwater management in the DSPA due to the greenfield nature of the site. Urbanisation results in large amounts of land becoming impervious, the result being less infiltration into ground, shorter runoff response times, higher runoff rates and greater runoff volumes. Greenfield development offers the greatest opportunity to implement hydrological mitigation of the effects of development. Minimising or mitigating changes in hydrology is identified as a requirement for greenfield development in the AUP (refer Section 2.3). Hydrological mitigation is beneficial for maintaining stream baseflows and supporting groundwater recharge, in addition to protecting receiving streams from erosive velocities.

3.3 Flooding

The DSPA covers four adjacent, inter-connected stormwater catchments: Oira Creek, Ngakoroa Stream, Hingaia Stream and Slippery Creek. These stream catchments are interconnected as flood flows from one catchment have the ability to influence adjoining catchment due to their common confluence and cross-catchment flows can occur in larger storm events. For example the Hingaia stream overflows SH1 into the Ngakaroa Stream and Slippery Creek overflows Great South Road into the Hingaia Stream catchment in large storm events. These complex inter-catchment floodplain interactions require that all four affected stormwater catchments are considered together for flood management to ensure that early development in one area does not preclude development elsewhere in the DSPA. Currently the existing urban areas of Papakura and Drury Township are subject to flood hazard during storm events. The AUP requires that development of the DSPA minimise flood risk to people and property (refer Section 2.2). The design of stormwater infrastructure will also have to be design to be resilient for the effects of climate change. Auranga developments are unique in that there is not existing development downstream, so flood effects on downstream neighbours do not need to be considered.

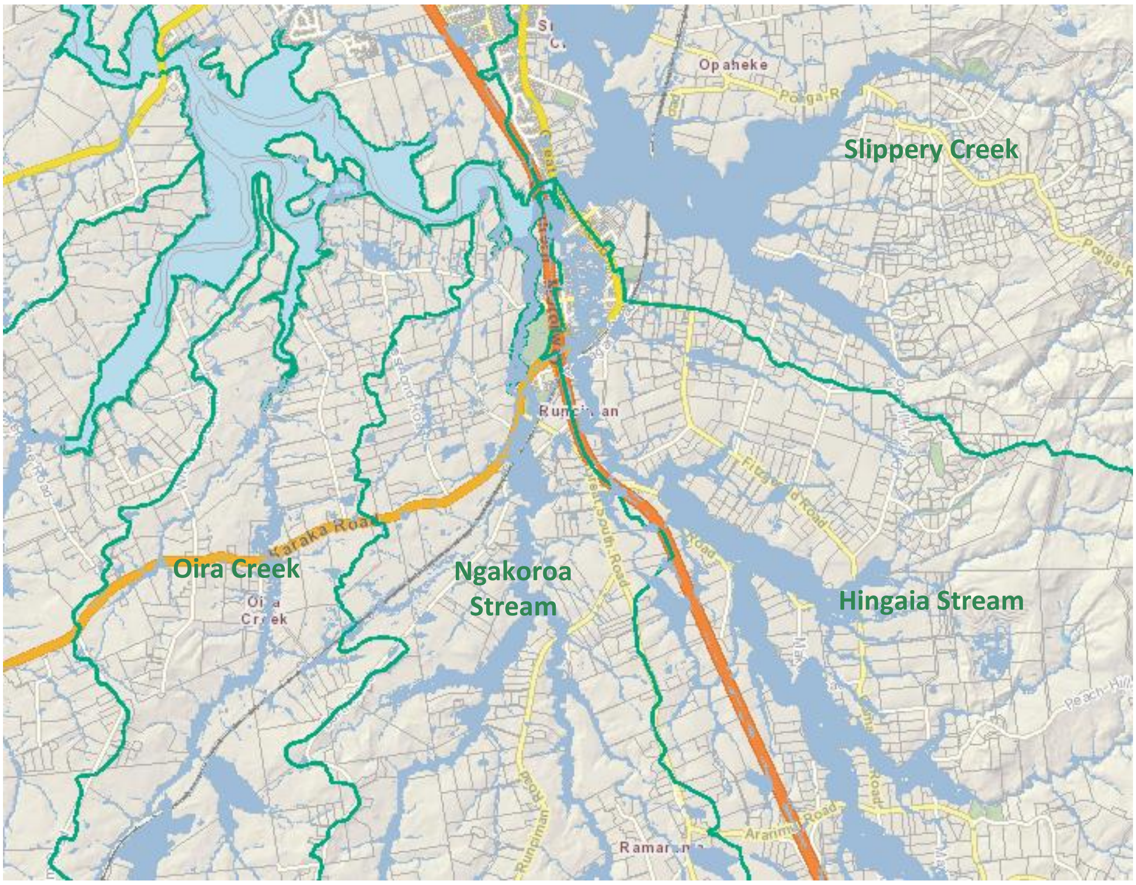

Figure 3.3: 100 year ARI floodplain (Source – Auckland Council Geomaps)

3.4 Water sensitive design

It is important that greenfield development considers WSD on a whole of development basis to more comprehensively protect and enhance stream systems and natural hydrology while achieving pre-development flow conditions. Water Sensitive Design for Stormwater (GD04) is a guideline document produced by Auckland Council to introduce practitioners to the principles and objectives for WSD in Auckland. The WSD principles from GD04 are summarised below:

- Promote inter-disciplinary planning and design
- Protect and enhance the values and functions of natural ecosystems
- Address stormwater effects as close to the source as possible
- Mimic natural systems and processes for stormwater management.

These WSD approaches are written into the policies of the AUP as integrated stormwater management, namely Policy 10 of Section E1 (refer Section 2.1). Loss of permanent and intermittent streams should be avoided as much as practicable as reclamation is non-complying activity in the AUP (see AUP Chapter E3).

4 Development areas

Four major land developers have land interests within the Drury Structure Plan Area: Kiwi Property Group Ltd., Karaka and Drury Ltd., Fulton Hogan Land Development Company and Drury South Ltd. These developers will have a key role in delivering the first stages of the Drury Structure Plan. Stormwater and flood management approaches have been developed to different stages for their respective development areas within the DSPA. They are shown in Figure 4.1 below and are as follows:

- Drury East (to be developed by Fulton Hogan Land Development Company)
- Drury Centre (to be developed by Kiwi Property Group Ltd.)
- Auranga A (under development by Karaka and Drury Ltd.)
- Auranga B1 (to be developed by Karaka and Drury Ltd.)
- Drury South (under development by Drury South Ltd.)

Beyond these developments which form the first stage of development within the DSPA there are additional future development areas for which stormwater and flood management approaches have not yet been considered. These are also shown on Figure 4.1 and are as follows:

- Drury West (Decade One)
- Remainder of Drury West (Decade Two)
- Drury-Opaheke (Decade Two)

The following subsections describe each of the development areas, their current development status and the local stormwater and flood management issues where they have been assessed.

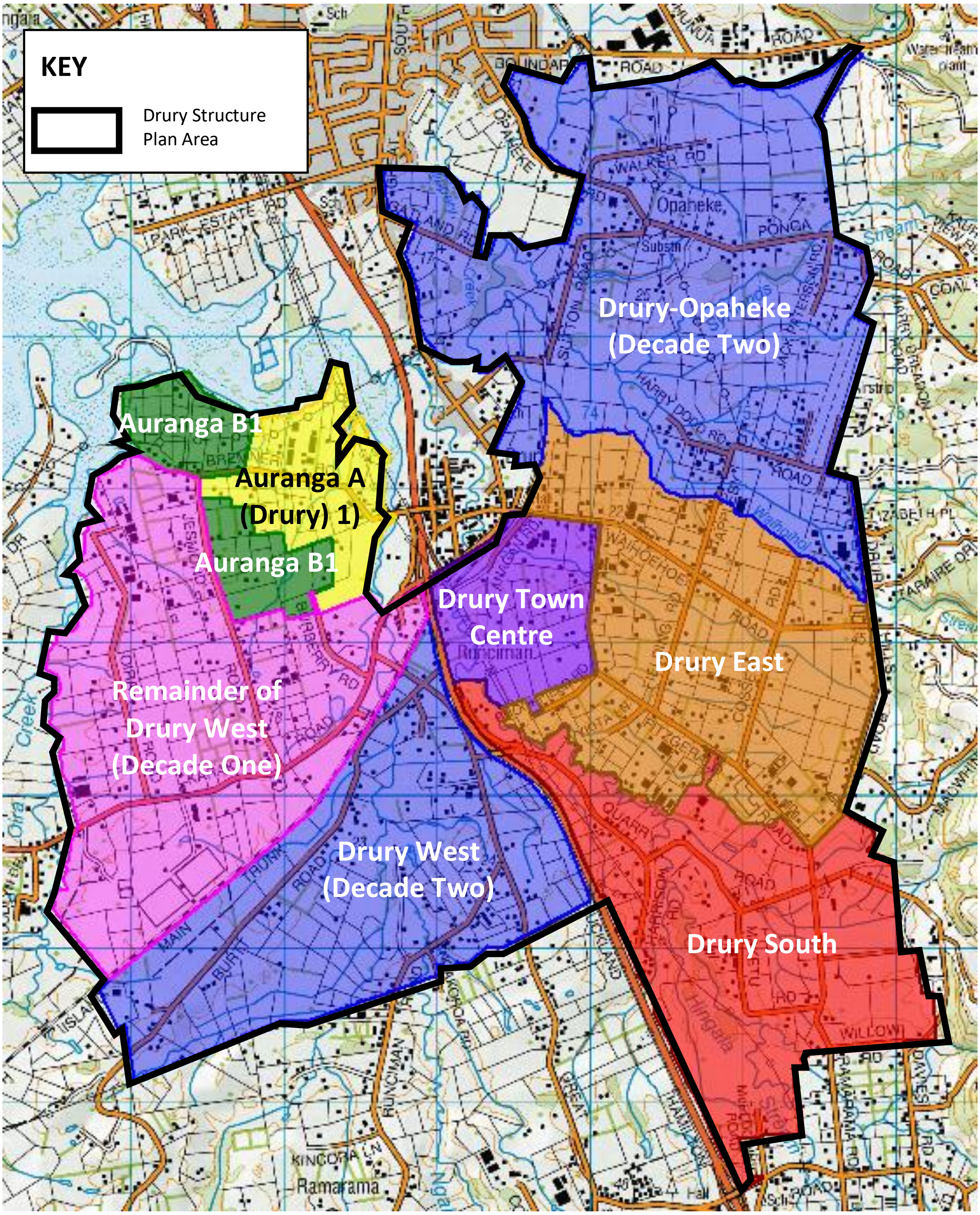

Figure 4.1: development areas

4.1 Drury East

Drury East is the area located to the east of the SH1/Great South Road interchange in Drury. It is approximately 317 hectares in size, generally bound by the Hingaia Stream to the South, Fitzgerald Road to the west, the Waihoihoi Stream to the North and Drury Hills Road to the east (refer Figure 4.1). The site is currently zoned as 'Future Urban' but Fulton Hogan intends to seek a private plan change to develop the area as residential and commercial land once the Auckland Council structure planning process is complete. It is anticipated that the plan change process will take between 12-18 months. Once complete it is estimated that the Fulton Hogan site will contain approximately 4470 dwellings and 0.5 ha of commercial land use.

A key stormwater feature of the site is the fact that it straddles two catchments (the Hingaia Stream Catchment and Slippery Creek Catchment). Therefore the site has been divided into different stormwater management areas. This concept is discussed further in Woods' Drury East –Stormwater Management Options report[3].

4.2 Drury Centre

Kiwi Property Group Ltd. are looking to develop a Drury Centre, located to the south-east of the SH1/Great South Road interchange in Drury. The site is 88 ha and is generally bound by Brookfield Road to the south, the Hingaia Stream to the west, Waihoehoe Road to the north and Fitzgerald Road to the east (refer Figure 4.1). The site is currently zoned as 'Future Urban' but Kiwi Property intends to seek a plan change to establish a new Drury Centre on the site with complementary residential development planned for the wider area. Currently Kiwi Property are working with Auckland Council through the structure plan process for the DSPA and will subsequently prepare a private plan change application. A stormwater and flooding constraints assessment has been undertaken by Tonkin + Taylor which included a high level assessment of stormwater and flood management required to develop the site[4]. A key stormwater feature of this site is the underlying basalt geology which has provides potential for soakage to ground.

4.3 Auranga A and Auranga B1

Karaka and Drury Ltd. are developing two areas known collectively as the Auranga Development, located to the west of the Ngakoroa Stream (refer Figure 4.1). Auranga A (the Drury 1 Precinct in the Unitary Plan) totals 84.6 ha and will consist of approximately 1350 dwellings. Auranga B1 totals 83.1 ha and will consist of a further 1300 dwellings (approximately).

Auranga A is designated SHA under the Auckland Unitary Plan (refer Section 2.4.2). Earthworks for Auranga A began in late 2016 with the first titles expected to be issued in late 2018 or beginning of 2019. The SHA was supported by a stormwater management plan prepared by Tonkin + Taylor[5]

Karaka and Drury Ltd's private plan change application for Auranga B1 (Proposed Private Plan Change 6) has been accepted by Auckland Council and was publically notified on 19 October 2017 for public submissions. The plan change application is supported by a stormwater management plan prepared by Tonkin + Taylor[6]. The approaches to stormwater management for Auranga B1 are proposed to be the same as Auranga A.

The proposed stormwater management approach for Auranga recognises that some areas discharge to streams while others will discharge directly to the coast. Some of the land within Auranga is within the coastal erosion hazard zone (CEHZ).

4.4 Drury South

Drury South Ltd. are developing the Drury South Precinct, located on the eastern side of State Highway 1 (SH1), just south of the Drury Interchange (refer Figure 4.1). The Drury South Precinct is approximately 361 ha and is split into the Drury South Industrial Precinct and the Drury South

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[3] Woods report 'Drury East – Stormwater Management Options' dated 17 November 2017

[4] Tonkin + Taylor report 'Drury Town Centre Development – Stormwater and Flooding Constraints' dated 21 April 2017. Reference 1002251.

[5] Tonkin + Taylor report 'Auranga (Bremner Special Housing Area) – Stormwater Management Plan' dated May 2016. Reference 30935.003.v1

[6] Tonkin + Taylor report 'Auranga B1 – Stormwater Management Plan' dated May 2017. Reference 1001534v1.

Residential Precinct, which is a designated Special Housing Area (SHA) under the AUP. The SHA will comprise approximately 1000 dwellings.

The earthworks and streamworks consent application was submitted in October and the network discharge consent (NDC) application is being finalised and is due to be submitted in December. Earthworks have started on a qualifying development and will widen when earthworks consents are obtained. The stormwater and flooding aspects of the consent applications are being supported by a Stormwater Management Plan prepared by Tonkin + Taylor[7].

When Drury South first gained planning approvals for industrial landuse in 2013 as part of a private plan change, wetlands in the floodplain were identified as the BPO for stormwater and flood management[8]. The requirement for using wetlands was built into the Precinct Rules in the AUP (refer Section 2.4). Also embedded into the Precinct Rules are large modifications to the floodplains to achieve more developable land while mitigating effects on others outside the Drury South boundaries. Another unique constraint for stormwater management in the Drury South precinct is the very large lot sizes for industrial landuse (super lots).

4.5 Remainder of Drury West (Decade One)

The centre and higher density residential areas proposed for the remainder of Drury West- Decade One will need to be located outside of the 100 year flood plain, and further design can ensure these areas are avoided in accordance with Unitary Plan policies. Flood management and stormwater management is anticipated to generally follow the approach for the current Auranga Development (refer Section 4.3). Subject to appropriate design, there are no fundamental constraints to enabling development in this area within Decade One.

4.6 Drury West (Decade Two) and Drury-Opaheke (Decade Two)

These areas are subject to additional, complex flooding hazards with interrelated catchments. Additional flood modelling is required to determine appropriate development areas and areas required to be set aside for flood management. It is therefore appropriate that development of these areas is deferred until 2028+ or until this additional work is undertaken.

[7] Tonkin + Taylor report 'Drury South Precinct - Stormwater Management Plan (Final)' dated November 2017. Reference 31559.2000.

[8] Beca Infrastructure Ltd report 'DSBP Stormwater Management Report' dated February 2011.

5 Integrated stormwater management approach

This section presents the proposed stormwater and flood management approach that has been identified as the best practical option (BPO) to address the catchment-specific issues identified for the DSPA (refer Figure 1.1 for extent). This approach has been derived by identifying commonalities across the proposed approaches for each of the different developments described in Section 4, which in general show good agreement. A summary of the specific approaches for each development area is presented in tabulated format in Appendix C.

The presented approach is a high level blueprint for stormwater and flood management for the wider DSPA, specifically areas for which development will not occur for some time such as the wider Drury West area and Drury-Opaheke to the north-east. In some cases the approach recommends a toolbox of devices to provide flexibility for developer preferences and local site constraints. This approach is not intended to be prescriptive, but provides a starting point for the Drury structure plan. The focus is on outcomes rather than specificity of stormwater management tool. The discussion in the subsections below highlight instances where particular developments which are already underway diverge from this common approach and site-specific reasons for these differences.

5.1 Water quality

The proposed approach for managing water quality in the DSPA is as follows:

- Avoiding the use of high contaminant yielding building materials to minimise contaminant generation
- Provision of at-source water quality treatment of roads and carparks using multi-functional devices such as tree pits, raingardens, vegetated swales and filter strips. These devices also serve a hydrological mitigation function as discussed in Section 5.2 as well as providing amenity value.
- Provision of contaminant specific treatment for individual lots that are classified as industrial/trade activities.

For the Drury South Industrial Precinct centralised wetlands located in the floodplain are to be used for water quality treatment in addition to at-source devices for high-use roads. These wetlands also provide for hydrological mitigation. This approach has been adopted for the Drury South Industrial Precinct as it was identified as the BPO at the time of the plan change and are required as part of the Precinct rules of the AUP (refer Section 2.4).

5.2 Hydrological mitigation

The proposed hydrological mitigation approach in the DSPA is as follows:

- Retention for first 5 mm of runoff from impervious surfaces where practical
- Detention of the difference in impervious surface runoff volumes from a pre-development and post-development for the 95th percentile, 24 hour rainfall event minus the retention volume
- Provision of hydrological mitigation (detention and retention) for residential roof areas using water reuse tanks
- Provision of hydrological mitigation (detention and retention) for driveways associated with residential lots and laneways using permeable paving and/or retention/detention tanks
- Provision of hydrological mitigation (detention and retention) for roads and carparks using multi-functional devices such as raingardens, tree pits, swales and filter strips for

roads/carparks. These devices also serve a water quality treatment function as discussed in 5 as well as providing amenity value.

- Green outfalls for stormwater outfalls to streams.

As discussed in Section 5, centralised wetlands will be used for hydrological mitigation in the Drury South Industrial Area as these are required under the AUP Precinct Rules (refer Section 2.4). No detention will be provided for areas within Auranga B1 that discharge directly to estuary. This is because hydrological mitigation deals only with impacts that affect streams. Hydrological mitigation for roofs within the Drury Centre site may be able to be achieved with soakage/infiltration pits. The feasibility of this solution would need to be confirmed by soakage testing in the location of any proposed soakage pits. The requirement to provide detention within the Drury East site is yet to be assessed. If this assessment finds that the proposed stream enhancement (e.g. stream widening, riparian planting, armouring selected areas) is sufficient in mitigating stream effects then detention may not be provided.

5.3 Flood management

The proposed approach for flood management in the DSPA is as follows:

- Exclude development from the 100 year ARI floodplain
- Not worsen flooding on land outside the DSPA areas or on properties not owned by the developer.
- Flood management by "passing flows forward" in the lower catchment. Passing flows forward is where runoff from development in the lower catchment is released without attenuation as a delayed release of local floodwater can make the flood peak from the larger flood from the upper catchment worst. This solution is proposed for the Drury Centre site, Auranga B1, Drury South and the portion of the Drury East site within the Hingaia Stream Catchment.
- For upper catchments, such as for the portion of the Drury East site within the Slippery Creek Catchment, use a combination of dry basins, wetlands and online flood storage (stream or floodplain modification) to attenuate peak flows in the upper catchment.

Further assessment is required as part of the private plan change applications to test whether the solution of passing flows forward is appropriate for the Drury Centre site and the portion of the Drury East site within the Hingaia Stream Catchment. If this solution is not appropriate then the 'upper catchment' solution of attenuating peak flows will be adopted for these developments. It should be noted that the flood management solution of locating wetlands within the floodplain in the Drury South Industrial Precinct is due to the rules in the Precinct Plans and the legacy around the project. This concept is not intended to be an example for other developments in the DSPA.

5.4 Water sensitive design

The proposed approach for water sensitive design in the DSPA in addition to the measures detailed above is to:

- Retain and enhance streams as much as practicable
- Green corridors for stream protection and flood management.

6 Summary

A summary of the specific approaches for each development area is presented in tabulated format in Appendix C. The common approach to stormwater and flood management is summarised in Table 6.1 below. This approach can be used as a blueprint for the Auckland Council structure plan for Drury.

Table 6.1: Summary of recommended stormwater and flood management approach for the DSPA

Water quality	• Avoiding the use of high contaminant yielding building materials to minimise contaminant generation • Provision of at-source water quality treatment of roads and carparks using multi-functional devices such as tree pits, raingardens, vegetated swales and filter strips. These devices also serve a hydrological mitigation function as well as providing amenity value. • Provision of contaminant specific treatment for individual lots that are classified as industrial/trade activities
Hydrology	• Retention for first 5 mm of runoff from impervious surfaces where practical • Detention of the difference in impervious surface runoff volumes from a pre-development and post-development for the 95th percentile, 24 hour rainfall event minus the retention volume • Provision of hydrological mitigation (detention and retention) for residential roof areas using water reuse tanks • Provision of hydrological mitigation (detention and retention) for driveways associated with residential lots and laneways using permeable paving and/or retention/detention tanks • Provision of hydrological mitigation (detention and retention) for roads and carparks using multi-functional devices such as raingardens, tree pits, swales and filter strips for roads/carparks. These devices also serve a water quality treatment function as discussed for water quality as well as providing amenity value. • Green outfalls for stormwater outfalls to streams
Flood management	• Exclude development from the 100 year ARI floodplain • Not worsen flooding on land outside the DSPA areas or on properties not owned by the developer. • Flood management by “passing flows forward” in the lower catchment. Passing flows forward is where runoff from development in the lower catchment is released without attenuation as a delayed release of local floodwater can make the flood peak from the larger flood from the upper catchment worst • For upper catchments use a combination of dry basins, wetlands and online flood storage (stream or floodplain modification) to attenuate peak flows in the upper catchment
WSD	• Retain and enhance streams as much as practicable • Green corridors for stream protection and flood management.

7 Applicability

This report has been prepared for the exclusive use of our clients Kiwi Property Group Ltd., Karaka and Drury Ltd., Fulton Hogan Land Development Company, Drury South Ltd., with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose, or by any person other than our client, without our prior written agreement.

Tonkin & Taylor Ltd

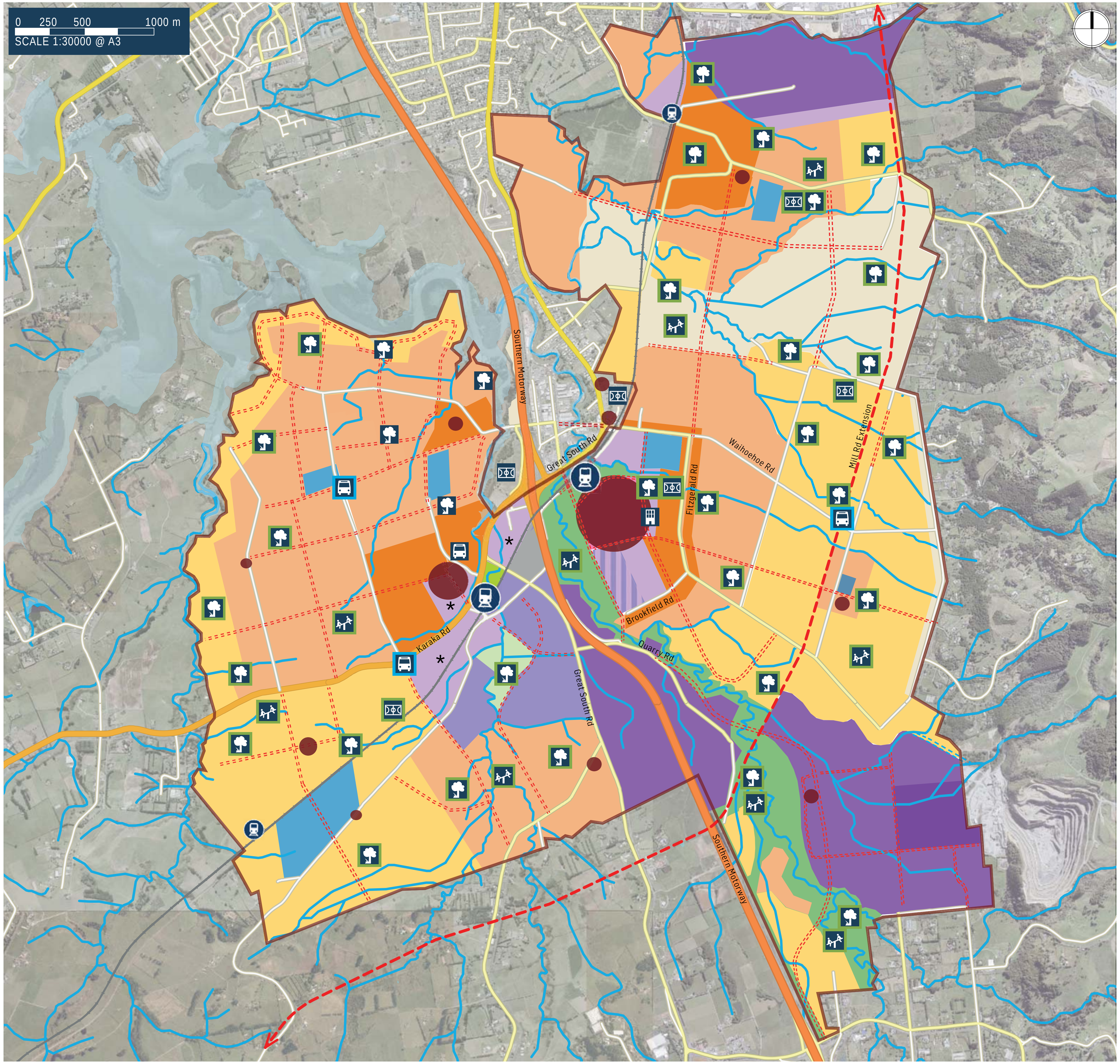
Report prepared by:	Authorised for Tonkin & Taylor Ltd by:
....	....
Joshua Hodson	Tim Fisher
Water Resource Engineer	Project Director

JTIH
t:\tauranga\projects\1003297\issueddocuments\20170418 drury sw management summary report final v3\20180418 drury stormwater management summary report.docx

Appendix A: Drury Structure Plan

Structure Plan Map

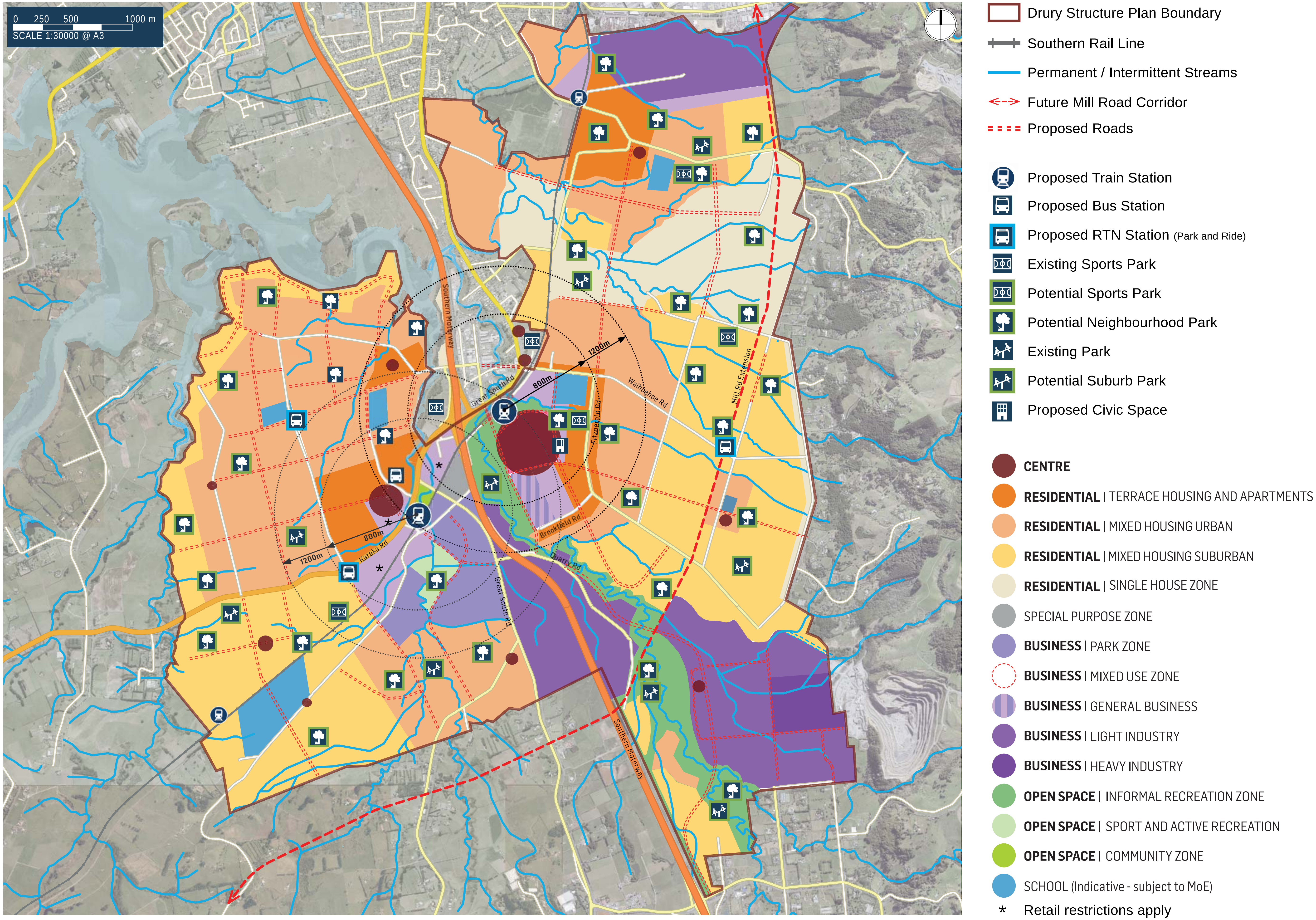
Structure plan map



- Drury Structure Plan Boundary
- Southern Rail Line
- Permanent / Intermittent Streams
- Future Mill Road Corridor
- Proposed Roads
- Proposed Train Station
- Proposed Bus Station
- Proposed RTN Station (Park and Ride)
- Existing Sports Park
- Potential Sports Park
- Potential Neighbourhood Park
- Existing Park
- Potential Suburb Park
- Proposed Civic Space
- **CENTRE**
- **RESIDENTIAL** | TERRACE HOUSING AND APARTMENTS
- **RESIDENTIAL** | MIXED HOUSING URBAN
- **RESIDENTIAL** | MIXED HOUSING SUBURBAN
- **RESIDENTIAL** | SINGLE HOUSE ZONE
- SPECIAL PURPOSE ZONE
- **BUSINESS** | PARK ZONE
- **BUSINESS** | MIXED USE ZONE
- **BUSINESS** | GENERAL BUSINESS
- **BUSINESS** | LIGHT INDUSTRY
- **BUSINESS** | HEAVY INDUSTRY
- **OPEN SPACE** | INFORMAL RECREATION ZONE
- **OPEN SPACE** | SPORT AND ACTIVE RECREATION
- **OPEN SPACE** | COMMUNITY ZONE
- SCHOOL (Indicative - subject to MoE)
- * Retail restrictions apply

Structure Plan Map

Structure plan map



Appendix B: Meeting minutes from iwi consultation

MEETING MINUTES

B&A Urban & Environmental

Project: Drury Structure Plan

Date: 21/2/18

Time: 10am

Location: Papakura Library

Attendees:

Karl Flavell	Ngāti Te Ata Waiohua	KF
Lucie Rutherfurd	Ngāti Tamaoho	LR
Elizabeth Davidson	Kiwi Property	ED
Nick Roberts	B&A	NR
Nick Mitchell	B&A	NM
Euan Williams	Woods	EW
Pranil Wadan	Woods	PW
Tim Fisher	Tonkin + Taylor	TF
Josh Hodson	Tonkin + Taylor	JH

Item	Detail	Action	Date
1	Apologies for Nigel Denny and Mark Tollemache being absent.	-	-
2	NR introduced the draft structure plan, including any updates since last hui. Key points include the connected town centres, a central railway station, a park n ride, and a connected green and blue cycle and walking network. LR would like a large 4-5 storey park n ride, as currently park n rides that service rural environments such as Pukekohe and Papakura are full before 6:30am.	-	-
3	KF query about how process fits with that of council. NR identified that the process is currently running parallel to council and will provide an alternative structure plan option to council in the future. Also reiterated that the town centre will not be a traditional shopping mall, however it will be an interactive engaged space for the community.	-	-
4	Raised that Ngai Tai representative Jonathon Billington has been attending the council meetings, and may be worth extending an invite to the next DDG Hui	NM	22/2/18
5	NR introduced the draft principle statements, explanation that they had predominantly been taken from the Auckland Unitary plan. LR stated that the treatment train approach was desirable, with final device prior to green outfall, such as a "dry basin" or a small man made wetland. TF/JH said treatment trains will be provided consisting of source control rain garden (or alternate treatment) and a green outflow. TF mentioned that within the treatment train we will design for extra resilience such as areas swales prior to treepits (as used in Drury South for Spine Road).	-	-

6	KF addressing the cultural principles identified that Cultural Values Assessments had been completed for many developments in the surrounding area. Obtain copies and check for knowledge gaps before next Hui.	NM	8/3/18
7	Point raised that council is only doing a desktop archaeology study. Council and Mana Whenua would like to see the developers reports once complete	-	-
8	KF asked which streams hold the most significant significant value – LR reaffirmed that any stream or intermittent stream should be treated the same. EW clarified that the structure plan is still at a high level stage and not every stream has been walked/studied. There is a commitment to caring for the streams and improving there ecological value.	-	-
9	KF would like to see a one or two-line overarching vision statement from the DDG	DDG	8/3/18
10	T+T presentation on stormwater. Please refer to attached presentation for key points. Discussion points: o LR asks about using reuse of water for industrial areas too – TF clarified some business would not have the capacity to reuse such as a large logistics warehouse with few operators o Infiltration may be possible in some location such as under the Kiwi site where there is Basalt (still under geological investigation). Discharges to ground would be treated first. o KF would like to know which aquifers and how big they are o LR would like to see native planting in swales o Discussion around providing resilient water treatment devices that will be able to be easily maintained by council o LR asked for secondary treatment devices such as Stormwater360 filters because the maintenance of raingardens was not well done. TF replied that duplication of stormwater treatment was costly and not likely to be accepted by Auckland Council as extra maintenance for them. TF said that clear operation and maintenance requirements needed to be included in consents and transferred to Council. o KF mentioned the possible use of permapave as a type of permeable paving	-	-
11	Both LR and KF expressed a desire to get council, DDG and themselves together for a discussion in order to get better outcomes for everyone	-	-
12	KF to send through letter of agreement between Ngāti Te Ata and DDG	KF	8/3/18

Appendix C: Stormwater management approach summary table

<table>
<tr><th colspan="2" rowspan="2">Development Area</th><th colspan="2">Hydrological mitigation/Stream protection</th><th rowspan="2">Water quality</th><th rowspan="2">Flood management</th></tr>
<tr><th>Retention</th><th>Detention</th></tr>
<tr><td rowspan="4">Drury East</td><td rowspan="2">Hingaia Catchment</td><td>Requirement:
-Retention for first 5mm of runoff from impervious surfaces.</td><td>Requirement:
-Detention of the difference in impervious surface runoff volumes from a pre-development and post-development for the 95th percentile, 24 hour rainfall event minus the retention volume.</td><td rowspan="2">Proposed solution:
-Provided by bioretention devices such as raingardens, swales and filter strips. Proprietary devices such as StormFilters are also available if no other practical solution is available.
-Inert buidling materials</td><td>Requirement:
-Is dependent on the flooding effects on the Drury Township. Attenuation can be provided for up to the 100 year storm event to pre-development peak flows if required.</td></tr>
<tr><td>Proposed solution:
-Rain tanks to capture roof runoff, bioretention devices such as raingardens or swales, filter strips or permeable pavement.</td><td>Proposed solution:
-The requirement for detention is to be assessed on the basis that riparian margin planting and stream enhancement will be able to mitigate stream scour and erosion.</td><td>Proposed solution:
-Preference would be to pass flows forward for the overland flow path that drains the area between Waihoehoe Road and Fitzgerald Road. Attenuation can be provided in dry basins, wetlands or online flood storage (stream or floodplain modification).</td></tr>
<tr><td rowspan="2">Slippery Creek Catchment</td><td>Proposed solution:
-Rain tanks to capture roof runoff, bioretention devices such as raingardens or swales, filter strips or permeable pavement.</td><td>Proposed solution:
-The requirement for detention is to be assessed on the basis that riparian margin planting and stream enhancement will be able to mitigate stream scour and erosion.</td><td rowspan="2">Proposed solution:
-Provided by bioretention devices such as raingardens, swales and filter strips. Proprietary devices such as StormFilters are also available if no other practical solution is available.
-Inert buidling materials</td><td>Proposed solution:
-Is dependent on the flooding effects on the Drury Township and Auckland Council's Flood Management Strategy for the Opaheke SMA.Attenuation can be provided for up to the 100 year storm event to pre-development peak flows if required.</td></tr>
<tr><td>Proposed solution:
-Rain tanks to capture roof runoff, bioretention devices such as raingardens or swales, filter strips or permeable pavement.</td><td>Proposed solution:
-The requirement for detention is to be assessed on the basis that riparian margin planting and stream enhancement will be able to mitigate stream scour and erosion.</td><td>Proposed solution:
-Attenuation can be provided in dry basins, wetlands or online flood storage (stream or floodplain modification).</td></tr>
<tr><td rowspan="2">Drury Town Centre*</td><td rowspan="2">All areas</td><td>Requirement:
-Retention for first 5mm of runoff from impervious surfaces.</td><td>Requirement:
-Detention of the difference in impervious surface runoff volumes from a pre-development and post-development for the 95th percentile, 24 hour rainfall event minus the retention volume.</td><td>Requirement:
-Provide water quality treatment of runoff from high use roads and high contaminant carparks.</td><td>Requirement:
-Avoid locating buildings within the 100 year ARI modified floodplain
-Ensure that any development within the floodplain does not exacerbate flood hazard to other properties upstream or downstream.</td></tr>
<tr><td colspan="2">Proposed solution:
-Raingardens or infiltration/soakage pits where water quality treatment is not required (i.e. roof areas which have inert building materials)</td><td>Proposed solution:
-Raingardens for all roads and high contaminant generating carparks.
-Inert building materials</td><td>Proposed solution:
-Maintain the 100 year ARI floodplain as a green corridor and avoid locating buildings within it.
-Pass flows forward rather than detaining to prevent coincidence of peak flows with the wider catchment</td></tr>
<tr><td rowspan="3">Auranga B1</td><td>All areas</td><td>Requirement:
-Retention for first 5mm of runoff from impervious surfaces.</td><td>Requirement:
-Detention of the difference in impervious surface runoff volumes from a pre-development and post-development for the 95th percentile, 24 hour rainfall event minus the retention volume.</td><td>Requirement:
-Provide water quality treatment of runoff from high use roads and high contaminant carparks.
-Treatment of roads discharging to estuary using raingardens (or equivalent) sized to 2% of the contributing catchment</td><td>Requirement:
-New residential buildings are required to be outside the 1% AEP floodplain (including the effects of climate change over a 100 year timeframe and a 1 m sea level rise).</td></tr>
<tr><td>Areas discharging to estuary</td><td colspan="2">Proposed solution:
-Green outfalls</td><td>Proposed solution:
-Raingardens for all roads and high contaminant carparks.
-Permeable pavements for private driveways laneways
-Inert building materials</td><td rowspan="2">Proposed solution:
-Exclude development (housing, some exceptions necessary for infrastructure) from the floodplain.
-The floodplains will be managed within the stream corridors, with the residential areas outside of the floodplains. It may be necessary to shape the floodplain within the corridors, but the main channel of the streams will not be modified.</td></tr>
<tr><td>Areas discharging to stream</td><td colspan="2">Proposed solution:
-Residential lots served by a combination of rain tanks for roof water, permeable paving for driveways and laneways, communal retention/detention devices located in rear service lanes (in applicable lots) and raingardens if practicable
-Raingardens for road areas
-Green outfalls for stormwater outfalls to streams</td><td>Proposed solution:
-Raingardens for all roads and high contaminant generating carparks.
-Inert building materials</td></tr>
<tr><td rowspan="3">Drury South Precinct</td><td>All areas</td><td>Requirement:
-Retention for first 5mm of runoff from impervious surfaces.</td><td>Requirement:
-Detention of the difference in impervious surface runoff volumes from a pre-development and post-development for the 95th percentile, 24 hour rainfall event minus the retention volume.</td><td>Requirement:
-Provide water quality treatment of runoff from high use roads (>5000 vehicles per day).
-Use wetlands for stormwater treatment and detention</td><td>Requirement:
-Provide sufficient floodplain storage to avoid increasing flood risk upstream and downstream, and manage the increased flood risk within the precinct.
-Avoid locating buildings within the 100 year ARI modified floodplain or infrastructure unless it can be design to be resilient to flood related damage.</td></tr>
<tr><td>Drury South Industrial Precinct</td><td>Proposed solution:
-Rain tanks on industrial lots (where practical)</td><td>Proposed solution:
-Temporary storage and release in centralised stormwater wetlands</td><td>Proposed solution:
-At-source pre-treatment of runoff from High Use Roads using a combination of vegetated swales, tree pits and raingardens
-Catchment-wide capture and treatment of runoff from all other impervious areas in centralised stormwater wetlands.
-Contaminant specific treatment devices for ITAs
-Inert building materials</td><td rowspan="2">Proposed solution:
-Attenuation of smaller storm events in wetlands (for Industrial Precinct)
-Modifications to the floodplain to retain flood storage and conveyance so flood risk outside of the site is not increased.
-Locating development outside/above the 100 year ARI modified flood extent</td></tr>
<tr><td>Drury South Residential Precinct</td><td colspan="2">Proposed solution:
-Rain tanks on residential lots
-Raingardens, vegetated swales and tree pit for road areas
-Permeable paving driveways for residential lots
-Green outfalls for stormwater outfalls to streams</td><td>Proposed solution:
-At-source treatment of runoff from roads using a combination of raingardens, vegetated swales and tree pits
-Inert building materials for residential lots</td></tr>
</table>

*The described stormwater management approach only applies to the Drury Town Centre site. Stormwater management solutions for other areas within the Kiwi Property site have not been identified at this stage.

Appendix F

Preliminary Geotechnical Appraisal

4 March 2019 Ref No: J00784 (Rev 1)

Oyster Capital
C/- Mr A McCarthy

Dear Andrew

RE: Preliminary Geotechnical Appraisal Report for the Waihoehoe Plan Change Area, Drury

1 INTRODUCTION

Lander Geotechnical Consultants Limited have been engaged by Oyster Capital to undertake a reasonably comprehensive desktop and preliminary field investigation of geotechnical conditions of the above site as delineated on the attached Geology Overview Plan (Figure 01) and Site Investigation Plan (Figure 2) respectively.

2 SCOPE AND OBJECTIVES

Our brief principally relates to the preparation of a Preliminary Geotechnical Appraisal Report (PGAR), in order to support a comprehensive structure planning process and subsequent private plan change application for the area define on Figure 1.

More specifically, our scope of work for the PGAR comprises:

- Desktop review of geology in beneath the Waihoehoe Plan Change area.
- Summary of the main topographical feature present, soil types and underlying geology, areas of obvious historic land modification (e.g. fill), and potential constraints to future urban development.
- The results of the Lander Geotechnical preliminary geotechnical field investigation in No. 116 Waihoehoe Road to assess the nature, bearing qualities, liquefaction potential and relative uniformity of the subsoils to the depths likely to be affected by any future land development works and future building loads;
- Preparation of a PGAR presenting the findings of this preliminary work.

In preparing this report, Lander Geotechnical have reviewed the following previous report:

- Lander Geotechnical Consultants Limited, Preliminary Geotechnical Appraisal Report for 116, 122, 128, 132, 136 and 140 Waihoehoe Road, Drury, reference J00784, dated 19 October 2017

Lander Geotechnical Consultants Limited
Level 3, 3 Osterley Way, P O Box 97 385, Manukau, Auckland 2241
Phone: (09) 262 1528; (09) 262 1526
Email: contactus@landergeotechnical.co.nz www.landergeotechnical.co.nz

3 SITE SPECIFIC APPRAISAL

3.1 Site Description

3.1.1 General

Our study area ("the site") comprises a number of separate properties, the legal descriptions and respective areas of each are able to be ascertained from Council's GIS database if required. The site is bound by Waihoehoe Road to the south and neighbouring rural properties / farmlands on all other boundaries and it's approximately outlined by the blue line depicted on the attached Figure 01.

Physical site investigations have been undertaken in the property of 116 Waihoehoe Road which is within the Plan Change area, as per Figure 02 attached. The majority of No.116 is in pasture and partially (towards the front portion) used for forging factory. There are also numerous dwellings across the site mainly to wards the southern portion.

The geomorphology of the area is defined as featureless alluvial plains, apart from shallow manmade farm drains / drainage ditches. Except where hand auger HA104 has drilled, a up to 2.2m topsoil stockpile was identified, there were no obvious signs of large-scale instability or land modifications as a result our preliminary work.

3.2 Geology

Online GNS Geology Maps indicate that the underlying geology unit is Puketoka Formation sedimentary lithology which is best described as comminuted bed of alluvial clays, silts and sands with occasional decayed organics and localised peat peds.

3.3 Preliminary Borehole Findings

Our fieldwork was undertaken in No 116 Waihoehoe Road on 21 and 22 January 2019 and involved the drilling of 12 hand auger boreholes to depths of up to 5 metres. In-situ shear vane tests were taken at 0.5m intervals to assess the vane shear strengths of the underlying soil. Hand augers 01 to 04 from October 2017 as also appended as supplementary information. The positions are shown on the attached Figure 01. A summary of findings is as follows:

- Topsoil was encountered at all borehole locations and ranged between 100mm and 300mm in thickness (expect HA104 where topsoil encountered up to 2.2m thick in a localised stockpile);
- Existing filling was encountered in HA101 and HA107 to a depth of 1.0m and 0.7m respectively. Topsoil stockpile was identified in vicinity of hand auger borehole HA104;
- The natural subsoils investigated by our boreholes predominantly consisted of inorganic orange, brown, green and grey silts, clays and sands with organic inclusions and staining in majority of our boreholes. Vane shear strengths measured within these deposits were typically returned readings between 51kPa to in excess of 205kPa indicating they were stiff to hard. Sensitivities to disturbance were typically in the range of 1.6 to 5.9 (insensitive to sensitive);
- Standing groundwater was encountered and measured at the completion of the drilling in HA102, HA105, HA106, HA107, HA108, HA109, HA110 and HA111 at 2.0m, 1.9m, 2.0m, 1.4m, 2.8m, 2.2m, 3.0m and 3.0m depth respectively. Groundwater was not encountered in our other borehole locations during the time of our investigation. Hand augers HA01 to 04 from 2017 showed the water table encountered at 0.4m, 1.0m and 1.0m respectively at the completion of the drilling;

- CPT testings refused on dense materials at between 11.0m and 14.0m depth below existing ground level.

3.4 Geotechnical Considerations

Published geology maps show that Puketoka Formation soils are present beneath the entire study area and it is sensible to conclude that ground conditions identified via the site investigations in No. 116 Waihoehoe Road will persist across the study area. Therefore, the considerations presented below are deemed to be relevant to the entire Waihoehoe Plan Change area.

3.4.1 Foundation for Buildings

Where inorganic natural ground is present, bearing capacity is expected to be in accordance with the limitations imposed by NZS 3604 where 300kPa geotechnical ultimate bearing capacity should be adopted. However, as is evident from the borehole findings to date the natural soils can contain pockets of weaker ground and/ or lenses of organics.

- Softer ground or lenses of organics can pose constraints to NZS3604 building foundations and residential end use, necessitating remediation during earthworks construction or specifically designed foundation solutions (i.e. "raft" foundations). Lander Geotechnical's experience in the delivery of hundreds of building platforms to the north-west (Hingaia Peninsular area) and west (Auranga Development area) indicates only a small proportion of lots may be affected by soft ground or organic soils, but in due course more intensive physical site investigation associated with a subdivision development scheme will substantiate this risk;
- The soils are likely to fall within AS2870 Class M to H expansive Site Class, and this is subject to laboratory testing of soil samples collected during later more intensive investigation for the Resource Consent phase(s) to support a specified subdivision scheme. Foundation design for end user will need to mitigate adverse effects from expansive soils;

3.4.2 Liquefaction Assessment

3.4.2.1 Earthquake Risk and Liquefaction Potential

A seismic liquefaction assessment has been carried out in accordance with the guidelines of MBIE module 3. Assessments were carried out using CLiq version 1.7 software. The Boulanger and Idriss (2014) method was applied to the CPT data that we have retrieved from site. This analysis has allowed for clays to soften and sands to liquefy under seismic loadings. A groundwater table of 1m below the surface has been adopted.

Peak ground Acceleration (PGA) were determined for both Serviceability Limit State (SLS) and Ultimate Limit State (ULS) criteria for each assessment. PGA was determined in accordance with NZS 1170.5 – 2004, assuming Class C soils across the site (based on our investigation). Calculations also take account for the seismic reduction factor of 0.65. Building Importance Level 2 has been assumed and based on this, a SLS (1/25yr return period) and ULS (1/500yr return period) PGA have been calculated as 0.03g and 0.12g respectively.

Based on the results presented in the outputs (attached), this analysis confirms that under an ULS earthquake the calculated maximum vertical settlements are up to 140mm. The maximum Liquefaction Potential Index (LPI) and Liquefaction Severity Number (LSN) are up to 1.546 and 20.416 respectively. These LPI and LSN figures indicate that a performance level of L2 can be assumed (based on Module 3 Guidelines, Table 5.1) and thus liquefaction effects can be considered to be moderate.

The zone of liquefaction is beyond 4m depth. It is considered likely the liquefaction induced settlement will occur relatively uncommonly (i.e. in a total fashion) across the landform, and according excessive differential settlements are unlikely to be a cause for concern, as indicated by the SLS results. However, because of the potential for total settlements any subdivision will need to be designed with this in mind, with regard to overland flows and flood plains.

No lateral displacements have been calculated as the landform of our study area is a featureless alluvial plan (which is overall flat).

3.4.2.2 Compositional Criterial of Soils

In soils consisting of greater than 30% fines (classified as dry mass passing through a 0.075mm sieve consistent with the particle site distribution tests carried out), liquefaction susceptibility can be classified as follows:

- Plasticity Index < 7: Susceptible to liquefaction;
- 7 < Plasticity Index < 12: Potentially susceptible to liquefaction;
- Plasticity Index > 12: Not susceptible to liquefaction.

The Atterberg classification results from the near surface soils indicate that the sample taken from HA100 at 0.5m to 1.0m with a PI of 56 indicating that is not susceptible to liquefaction, and the sample taken from HA110 at 0.5m to 1.0m with PI of 41 is also not susceptible to liquefaction.

3.4.3 Earthworks and Infrastructure

The natural deposits encountered across the site are typically of high strength and have good engineering characteristics for foundations and earthworks handling. Largely inorganic soils of relatively stiff to very stiff strength will be identified, although organic lenses and weaker sensitive layers are apparent in these materials.

- The natural soils may be prone to piping (internal) soil erosion particularly if they are found to contain high pumice content, however very little (if any) pumice was identified in our preliminary investigations for this report. Further geotechnical investigation should therefore assess this risk, especially if on-site stormwater management systems (e.g. rain gardens, attenuation ponds, etc.) are proposed.
- The identified materials can be sensitive to disturbance during earthworks and repetitive trafficking from heavy machinery, and some boreholes displayed isolated lenses that would have these characteristics. Careful site management and/ or subsoil drainage have been effective in minimising subgrade degradation issues on recent large residential developments in similar geology at the Drury area (i.e. Auranga). The deeper deposits in particular is likely to require conditioning prior to placement as filling as in-situ moisture consents will likely be higher than those required for optimum compaction.
- Deep trenches are prone to collapse especially where ground water conditions change rapidly and the materials are less cohesive, but this risk can be minimised by appropriate shoring or battering as required by legislation and safe construction practices.

- Road subgrades are prone to degradation once exposed to the elements but is normally dealt with by engineering design (e.g. subgrade improvement via undercutting and replacement, or lime stabilising, construction sequencing to reduce subgrade exposure time, etc.).
- Underfill drainage is usually adopted to control natural groundwater springs in the various drainage features that may be modified during development. They generally pose no constraints to end use if they are buried deep within engineered fills, or if this is not possible, they can be aligned to site boundaries to avoid future building platforms.

4 CONCLUSIONS

The site comprises topography and ground conditions that are reasonably well understood geotechnically. Precedence in this type of geology has been set via the large residential development in similar geology (e.g. Auranga & the Hingaia Peninsular). Provided there is due consideration to prevailing or perceived geotechnical issues during detailed site investigation for Resource Consent to support a subdivision scheme, then the study area as defined by Figure 01 herein is considered suitable for re-zoning to future urban use.

5 RECOMMENDATIONS

The assessments presented in this report are based on a desktop review and visual inspections, plus a limited umber of shallow borehole tests on the prevailing landform.

It is recommended that:

- To support future development (i.e. Resource Consent / Subdivision design), further physical geotechnical site investigation that are commensurate with subdivision and earthworks scheme(s) should be undertaken to substantiate ground conditions and address any geotechnical constraints. Such investigations are expected to comprise (but are not limited to) further hand auger boreholes, trial pits using a hydraulic excavator, and soil sampling.
- Appropriate laboratory soil testing is undertaken to characterise engineering and earthworks handling properties, compressibility, permeability and susceptibility to erosion or dispersion.

6 LIMITATIONS

This report has been prepared solely for the sue of our client, Oyster Capital, its professional advisers and the relevant Territorial Authorities in relation to the specific project described herein. No liability is accepted in respect of its use for any other purpose or by another person or entity. All future owner of this property should seek professional geotechnical advice to satisfy themselves as to its on-going suitability for their intended use.

For and on behalf of Lander Geotechnical Consultants Limited

Prepared By:

Alex

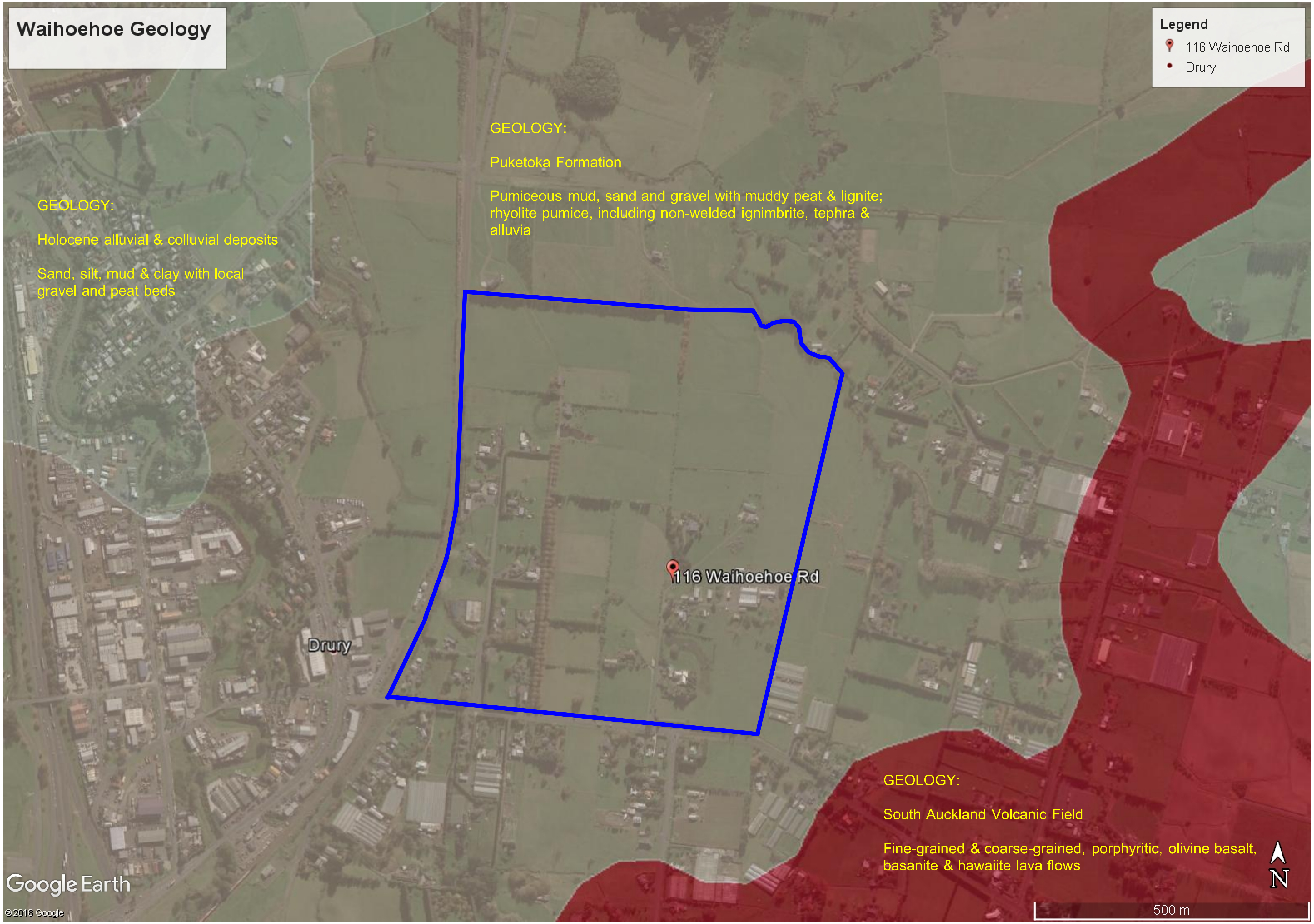
Alex Bu
Geotechnical Project Engineer
NZDE(Civil)

Reviewed and Authorised By:

Shane Lander
Principal Geotechnical Engineer
CMEngNZ, CPEng, IntPE(NZ)

Encl.

Legend and/or Notes:



Approximate Extent of Waihoehoe Road Plan Change area

BASE PLAN SOURCE: GOGGLE EARTH

revision	description	drawn	approved	date

drawn	SL
approved	SGL
date	04/03/19
scale	refer drawing
original size	A3

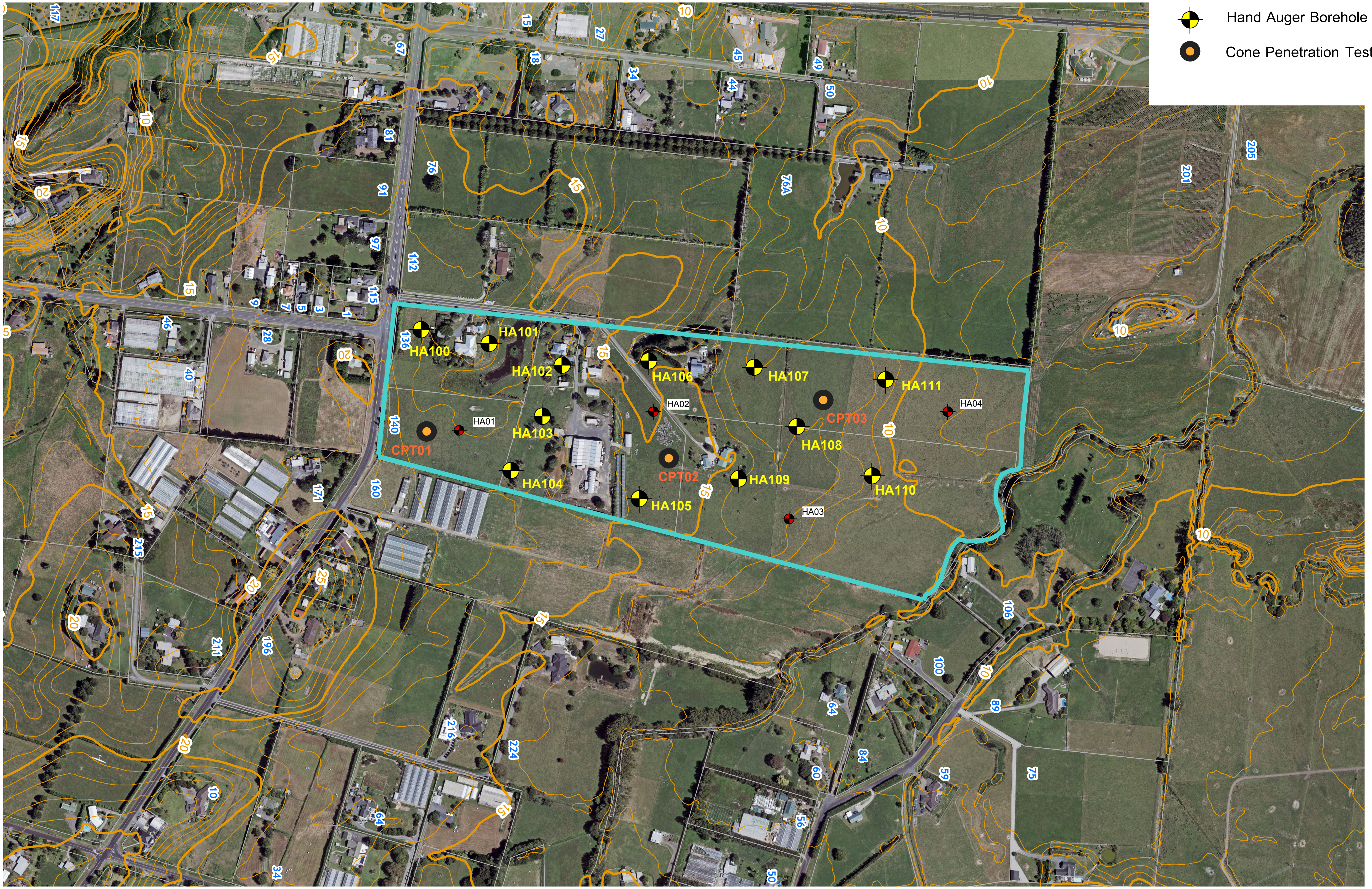
LANDER geotechnical

client:	OYSTER CAPITAL
project:	116 WAIHOEHOE ROAD, DRURY
title:	GEOLOGY OVERVIEW PLAN
project no:	J 00784
figure no:	01

Template revision: 1:2000 (10/12/14)

Legend and/or Notes:

- Hand Auger Borehole (October 2017)
- Hand Auger Borehole
- Cone Penetration Test



BASE PLAN SOURCE: AUCKLAND COUNCIL GEOMAPS DATABASE

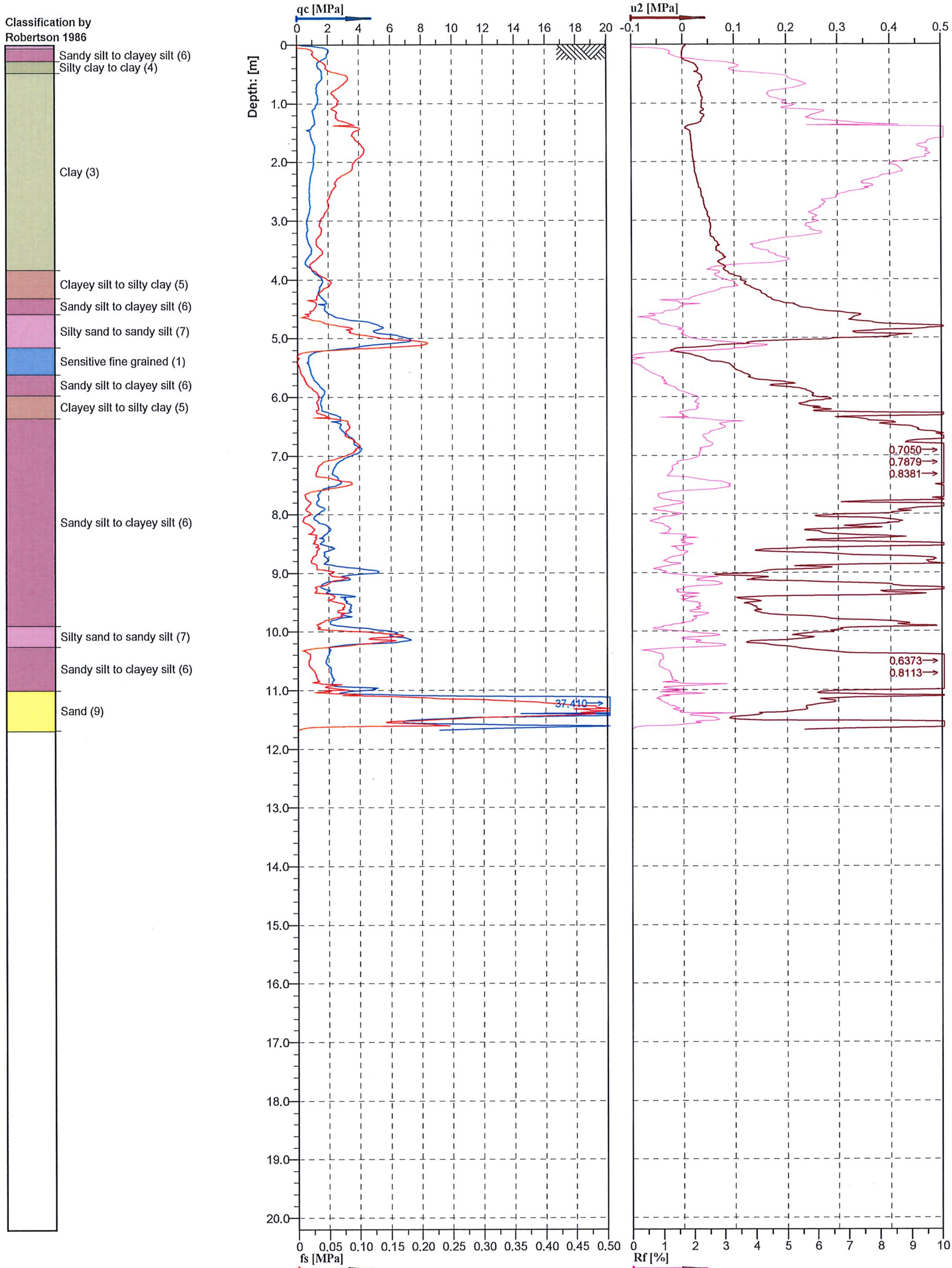
revision	description	drawn	approved	date
	Rev A - site plan figure number relabelled	SL	sl	4/03/19

drawn	SL
approved	SGL
date	17.01.19
scale	1:5000
original size	A3

LANDER geotechnical

client:	OYSTER CAPITAL
project:	116 WAIHOEHOE ROAD, DRURY
title:	SITE INVESTIGATION PLAN
project no: J 00784	figure no: 02

Template revision: 1:2000 (10/12/14)



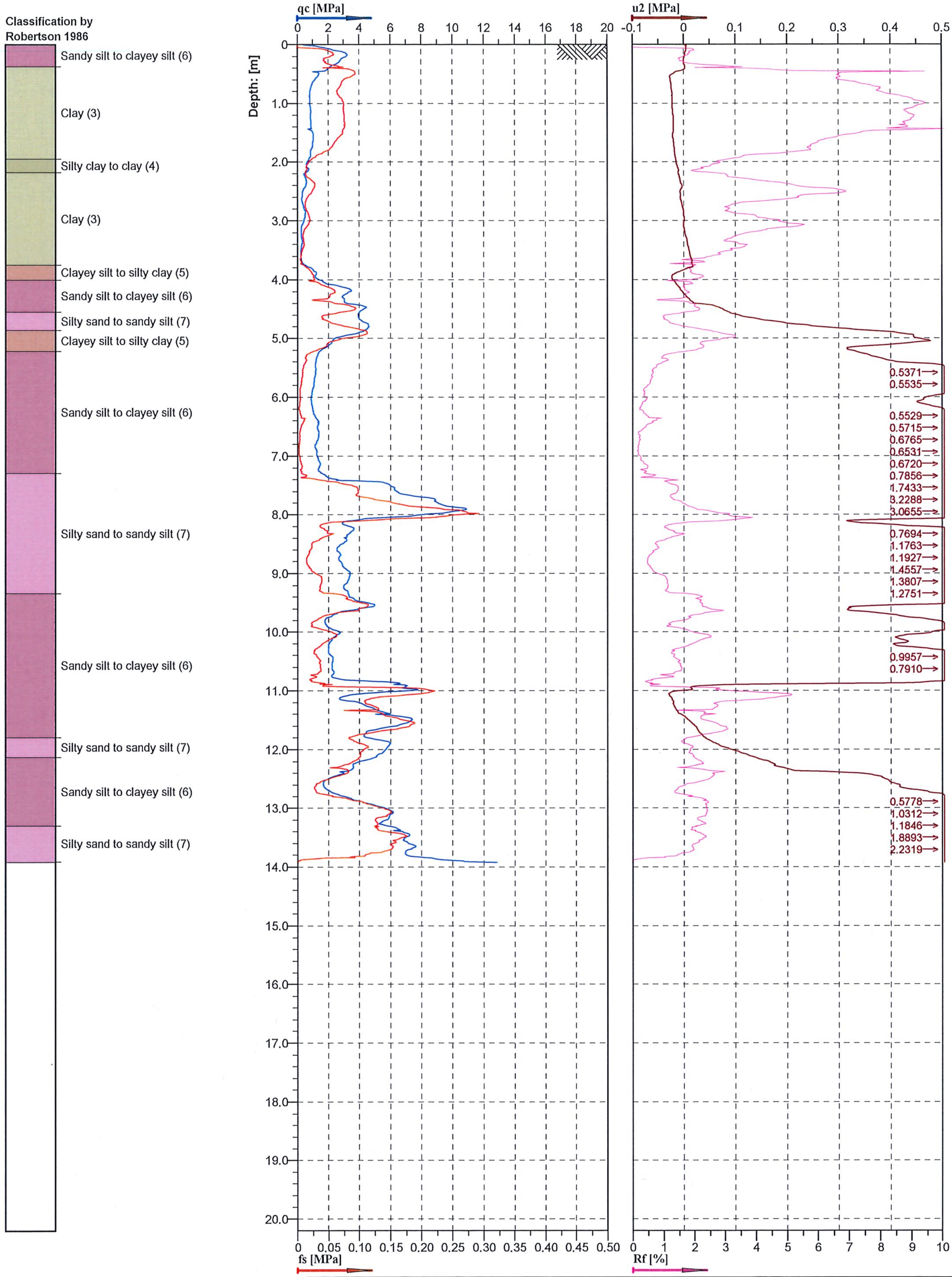
PRO-DRILL

SPECIALIST DRILLING ENGINEERS

u2

Cone No: S10CFIIP.1734
Tip area [cm2]: 10
Sleeve area [cm2]: 150

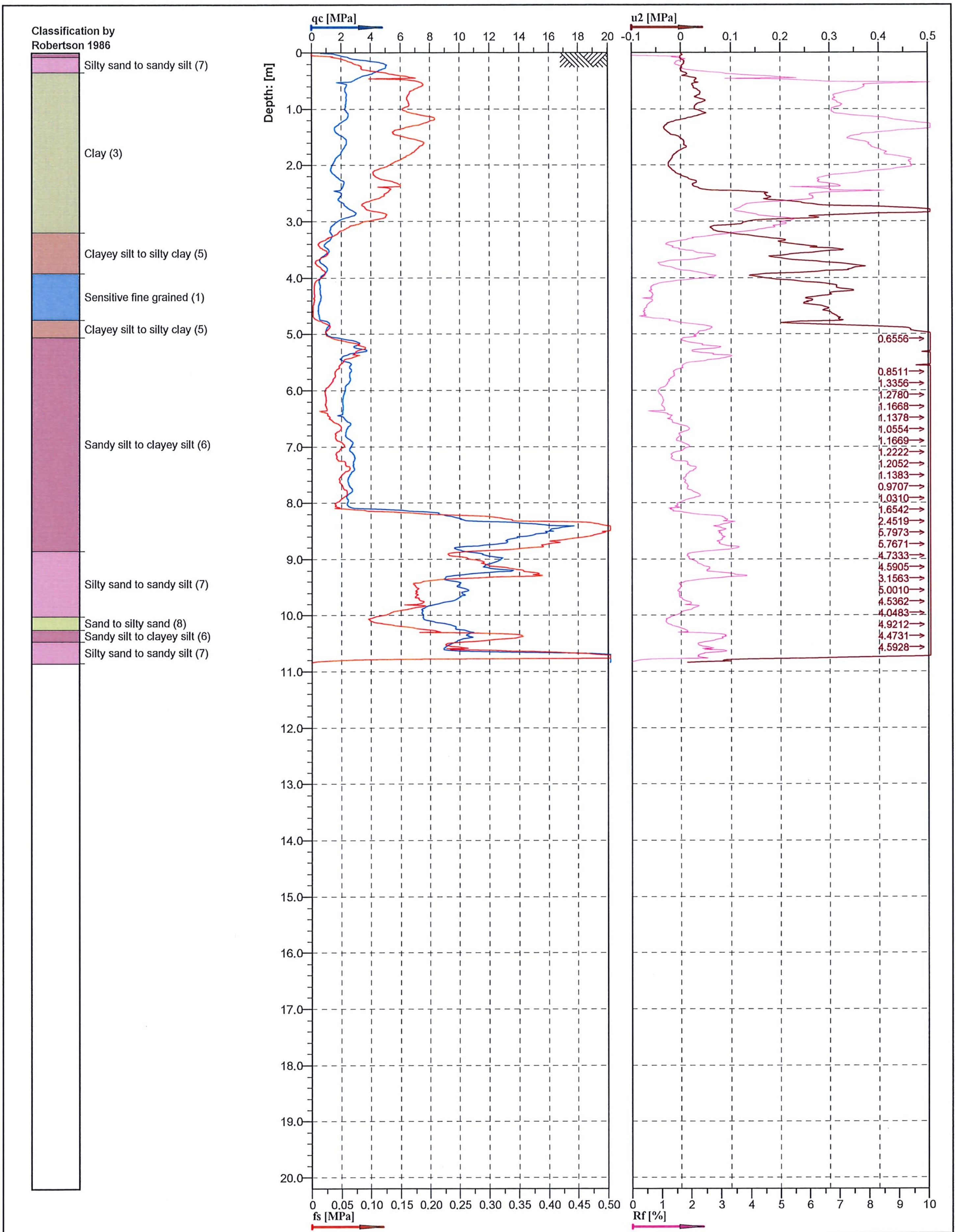
Location: 116 Waihoehoe rd Drury	Position: X: 0 m, Y: 0 m	Ground level: 0.000	Test No.: CPT01
Project ID: Lander 116 Waihoehoe rd	Client: Landers	Date: 22/01/2019	Scale: 1 : 85
Project: Lander 116 Waihoehoe rd		Page: 1/1	Fig.:
		File: Lander 116 Waihoehoe rd_CPT01.GEF	



PRO-DRILL
SPECIALIST DRILLING ENGINEERS

Cone No: S10CFIIP.1734
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: 116 Waihoehoe rd Drury	Position: X: 0 m, Y: 0 m	Ground level: 0.000	Test No.: CPT02
Project ID: Lander 116 Waihoehoe rd	Client: Landers	Date: 22/01/2019	Scale: 1 : 85
Project: Lander 116 Waihoehoe rd		Page: 1/1	Fig.:
		File: Lander 116 Waihoehoe rd_CPT02.GEF	



PRO-DRILL
SPECIALIST DRILLING ENGINEERS

Cone No: S10CFIIP.1734
Tip area [cm2]: 10
Sleeve area [cm2]: 150

Location: 116 Waihoehoe rd Drury	Position: X: 0 m, Y: 0 m	Ground level: 0.000	Test No.: CPT03
Project ID: Lander 116 Waihoehoe rd	Client: Landers	Date: 22/01/2019	Scale: 1 : 85
Project: Lander 116 Waihoehoe rd		Page: 1/1	Fig.:
		File: Lander 116 Waihoehoe rd_CPT03.GEF	

Client :	MATIRA TRUST	Auger Borehole No.	HA01
Project Location :	116, 122, 128, 132, 136, 140 WAIHOEHOE RD, DRURY	Sheet 1 of 4	
Job Number:	J00784		

Vane Head:	Logged By:	Processor :	Date:
1900	MVC	LJ	10.10.17

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Legend	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL						
clayey SILT, yellow/brown. Stiff, moist, medium plasticity, sensitive, with minor manganese oxidate inclusions [ALLUVIUM]			▽			
		0.5		66/11	6.0	
becoming orange/grey						
becoming very stiff, moderately sensitive		1.0		150/51	2.9	
silty CLAY, light grey streaked orange. Very stiff, moist to wet, medium to high plasticity, sensitive						
		1.5		120/24	5.0	
becoming slightly silty CLAY, orange and red flecked light grey, wet						
becoming insensitive		2.0		195/103	1.9	
becoming moderately sensitive		2.5		137/69	2.0	
EOB at 3.0m. Target Depth.		3.0		137/57	2.4	
		3.5				
		4.0				
		4.5				
		5.0				
		5.5				
		6.0				

LANDER geotechnical

Comments:
Groundwater encountered 0.5m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: AB

Topsoil		Sand		Sandstone		Plutonic			
Fill		Gravel		Siltstone		No Core			
Clay		Organic		Limestone					
Silt		Pumice		Volcanic					

Client :	MATIRA TRUST	**Auger Borehole No.**	HA02
Project Location :	116, 122, 128, 132, 136, 140 WAIHOEHOE RD, DRURY	Sheet 2 of 4	
Job Number:	J00784		

Vane Head:	Logged By:	Processor :	Date:
1900	MVC	LJ	10.10.17

Borehole Location: mN | mE | Ground R.L.

Description: Refer to site plan

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
clayey SILT, yellow/brown mottled grey. Very stiff, moist, medium plasticity, sensitive, with minor topsoil leaching [ALLUVIUM]	0.5		116/28	4.1	
silty CLAY, orange mottled light grey. Very stiff, moist, high plasticity, with minor rootlets					
becoming slightly silty CLAY, orange streaked light grey, moderately sensitive, with minor limonite	1.0	▽	120/54	2.2	
becoming silty CLAY					
becoming slightly silty CLAY, light grey mottled yellow/brown, wet, without limonite	1.5		116/34	3.4	
becoming stiff	2.0		84/31	2.7	
becoming silty CLAY, dark orange/brown flecked light blue/grey, with minor limonite					
becoming very stiff	2.5		133/50	2.7	
with minor organic inclusion					
EOB at 3.0m. Target Depth.	3.0		116/43	2.7	
	3.5				
	4.0				
	4.5				
	5.0				
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater encountered 1.5m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: AB

Legend				
Topsoil	Sand	Sandstone	Plutonic	
Fill	Gravel	Siltstone	No Core	
Clay	Organic	Limestone		
Silt	Pumice	Volcanic		

Client :	MATIRA TRUST	**Auger Borehole No.**	HA03
Project Location :	116, 122, 128, 132, 136, 140 WAIHOEHOE RD, DRURY	Sheet 3 of 4	
Job Number:	J00784		

Vane Head:	Logged By:	Processor :	Date:
1900	MVC	LJ	10.10.17

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
silty CLAY, yellow/brown. Very stiff, moist, medium to high plasticity, moderately sensitive [ALLUVIUM]	0.5		162/81	2.0	
becoming yellow/brown mottled grey, with minor limonite weathering	1.0		182/78	2.3	
	1.5		192/120	1.6	
becoming orange/brown streaked light grey, insensitive					
clayey SILT, light grey mottled orange/brown. Very stiff, moist, medium plasticity, moderately sensitive, with some limonite	2.0		223/106	2.1	
becoming hard	2.5		239+		
at 3.0m, becoming very stiff	3.0		137/63	2.2	
EOB at 3.0m. Target Depth.					
	3.5				
	4.0				
	4.5				
	5.0				
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater not encountered.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: AB

Legend			
Topsoil	Sand	Sandstone	Plutonic
Fill	Gravel	Siltstone	No Core
Clay	Organic	Limestone	
Silt	Pumice	Volcanic	

Client : MATIRA TRUST

Project Location : 116, 122, 128, 132, 136, 140 WAIHOEHOE RD, DRURY

Job Number: J00784

Auger Borehole No. HA04

Sheet 4 of 4

Vane Head:	Logged By:	Processor :	Date:
1900	MVC	LJ	10.10.17

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Legend	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL	Topsoil					
clayey SILT, orange/brown mottled grey. Very stiff, moist to wet, low plasticity, moderately sensitive, with some limonite [ALLUVIUM]	Silt					
		0.5		100/43	2.3	
becoming medium plasticity						
becoming stiff, grey, saturated, with some fine sand, with trace organic inclusions, without limonite		1.0	▽	97/43	2.3	
becoming sensitive		1.5		84/21	4.0	
with some decomposed roots						
fine sandy SILT with trace clay, blue/green. Medium dense, moist, no plasticity	Silt	2.0		UTP		
		2.5		UTP		
EOB at 3.0m. Target Depth.		3.0		UTP		
		3.5				
		4.0				
		4.5				
		5.0				
		5.5				
		6.0				

LANDER geotechnical

Comments:
Groundwater encountered 1.5m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter:								
50mm	Topsoil		Sand		Sandstone		Plutonic	
Checked:	Fill		Gravel		Siltstone		No Core	
AB	Clay		Organic		Limestone			
	Silt		Pumice		Volcanic			

Client :	OYSTER CAPITAL	**Auger Borehole No.**	HA100
Project Location :	116 WAIHOEHOE ROAD, DRURY	Sheet 1 of 12	
Job Number:	J00784		

Vane Head:	Logged By:	Processor :	Date:
2153	AB	AB	21.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
clayey SILT, orange/ brown. Very stiff, dry, low plasticity, moderately sensitive [NATURAL]	0.5		165/ 57	2.9	
becoming yellow/ brown mottled orange/ brown, moist	1.0		157/ 76	2.1	
silty CLAY, light grey streaked orange/ brown. Very stiff, moist, high plasticity, moderately sensitive	1.5		159/ 62	2.6	
becoming pink and orange/ brown streaked light grey	2.0		146/ 62	2.4	
	2.5		137/ 51	2.7	
becoming grey and light yellow speckled pink	3.0		128/ 46	2.8	
	3.5		134/ 46	2.9	
becoming purple and dark brown mottled brown/ grey, with some organic inclusions and staining					
becoming stiff	4.0		99/ 40	2.5	
becoming brown/ grey, without organic inclusions					
becoming very stiff	4.5		139/ 71	2.0	
	5.0		161/ 76	2.1	
EOB at 5.0m. Target Depth.					
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater not encountered.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: Km

Topsoil	Sand	Sandstone	Plutonic
Fill	Gravel	Siltstone	No Core
Clay	Organic	Limestone	
Silt	Pumice	Volcanic	

Client : OYSTER CAPITAL

Project Location : 116 WAIHOEHOE ROAD, DRURY

Job Number: J00784

Auger Borehole No. HA101

Sheet 2 of 12

Vane Head:	Logged By:	Processor :	Date:
2153	AB	AB	22.01.19

Borehole Location: mN | mE | Ground R.L.

Description: Refer to site plan

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
slightly clayey SILT with topsoil intermixed, dark brown. Stiff, moist, low to no plasticity, moderately sensitive [FILL]	0.5		66/ 25	2.6	
becoming mottled dark brown and light grey					
clayey SILT, orange/ brown. Very stiff, moist, low to no plasticity, moderately sensitive [NATURAL]	1.0		130/ 49	2.7	
	1.5		155/ 71	2.2	
silty CLAY, yellow/ brown streaked grey. Very stiff, moist, high plasticity, moderately sensitive	2.0		181/ 85	2.1	
with occasional pink streaks					
	2.5		159/ 65	2.4	
becoming mottled yellow/ brown and light grey					
	3.0		137/ 49	2.8	
	3.5		128/ 51	2.5	
becoming moist to wet					
	4.0		122/ 37	3.3	
becoming streaked pink, yellow/ brown and grey					
	4.5		134/ 57	2.4	
at 5.0m, becoming insensitive					
EOB at 5.0m. Target Depth.	5.0		155/ 81	1.9	
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater not encountered.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: KM

Legend: Topsoil, Fill, Clay, Silt, Sand, Gravel, Organic, Pumice, Sandstone, Siltstone, Limestone, Volcanic, Plutonic, No Core

Client : OYSTER CAPITAL

Project Location : 116 WAIHOEHOE ROAD, DRURY

Job Number: J00784

Auger Borehole No. HA102

Sheet 3 of 12

Vane Head:	Logged By:	Processor :	Date:
2153	AB	AB	21.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
clayey SILT, orange/ brown. Hard, dry, low to medium plasticity [NATURAL]					
	0.5		205+		
becoming yellow/ brown mottled orange/ brown, moist, medium plasticity					
	1.0		205+		
silty CLAY, grey and yellow/ brown mottled orange/ brown. Very stiff, moist, high plasticity, moderately sensitive					
	1.5		114/ 57	2.0	
becoming yellow/ brown and orange/ brown streaked light grey					
becoming insensitive	2.0	▽	102/ 57	1.8	
becoming brown/ grey					
becoming stiff, moist to wet, moderately sensitive	2.5		85/ 39	2.2	
becoming saturated					
becoming very stiff	3.0		105/ 34	3.1	
	3.5		109/ 39	3.8	
becoming orange speckled brown/ grey, limited sample recovery due to groundwater suction					
becoming stiff	4.0		96/ 46	2.1	
becoming insensitive	4.5		73/ 43	1.7	
at 5.0m, becoming moderately sensitive					
EOB at 5.0m. Target Depth.	5.0		90/ 43	2.1	
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater encountered 2.9m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: KM

Topsoil	Sand	Sandstone	Plutonic
Fill	Gravel	Siltstone	No Core
Clay	Organic	Limestone	
Silt	Pumice	Volcanic	

Client :	OYSTER CAPITAL	Auger Borehole No.	HA103
Project Location :	116 WAIHOEHOE ROAD, DRURY		Sheet 4 of 12
Job Number:	J00784		

Vane Head:	Logged By:	Processor :	Date:
1900	TK	AB	21.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Depth (m)	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL				
slightly clayey SILT, dark orange/ brown. Very stiff, moist, low plasticity, moderately sensitive, with trace organic staining [NATURAL]				
	0.5	136/ 60	2.3	Sample 1 Disturbed 0.5-1.0m
without organic staining				
with some fine sand	1.0	142/ 66	2.3	
becoming mottled grey/ orange and brown, with some limonite staining				
without limonite staining				
silty CLAY, light brown/ grey streaked orange/ brown and grey. Very stiff, moist, low to medium plasticity, moderately sensitive, with some organic inclusions	1.5	149/ 62	2.4	
becoming streaked light brown/ grey and red/ orange				
	2.0	157/ 79	2.0	
	2.5	175/ 86	2.0	
becoming orange/ brown				
becoming moist to wet, insensitive	3.0	127/ 67	1.9	
clayey SILT, streaked light grey/ brown and orange/ brown. Very stiff, moist to wet, medium plasticity, insensitive, with trace rootlets	3.5	111/ 57	1.9	
at 3.5m, becoming orange/ brown mottled light brown/ grey, without rootlets				
silty CLAY, grey. Very stiff, wet, medium to high plasticity, moderately sensitive	4.0	140/ 60	2.3	
becoming wet				
becoming stiff, insensitive, with trace fine sand	4.5	79/ 48	1.6	
at 4.9m, becoming high plasticity				
at 5.0m, becoming moderately sensitive	5.0	94/ 36	2.6	
EOB at 5.0m. Target Depth.				
	5.5			
	6.0			

LANDER geotechnical

Comments:
Groundwater not encountered.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter:	50mm
Checked:	KM

Topsoil		Sand		Sandstone		Plutonic	
Fill		Gravel		Siltstone		No Core	
Clay		Organic		Limestone			
Silt		Pumice		Volcanic			

Client :	OYSTER CAPITAL	Auger Borehole No.	HA104
Project Location :	116 WAIHOEHOE ROAD, DRURY	Sheet 5 of 12	
Job Number:	J00784		

Vane Head:	Logged By:	Processor :	Date:
1900	TK	AB	21.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Legend	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL	Topsoil					
		0.5		60/ 23	2.6	
with trace fine sand						
		1.0		43/ 17	2.5	
		1.5		73/ 14	5.2	
with some rootlets						
		2.0		179/ 64	2.6	
clayey SILT with topsoil intermixed, orange mottled brown. Very stiff, moist, low to medium plasticity, moderately sensitive [NATURAL]	Silt					
		2.5		175/ 57	3.1	
		3.0		175/ 99	1.8	
silty CLAY with trace fine sand, orange/ brown streaked brown. Very stiff, moist, medium plasticity, insensitive	Clay					
becoming streaked red and grey, with some limonite staining						
		3.5		119/ 70	1.7	
becoming light grey, with some organic inclusions						
becoming moderately sensitive		4.0		164/ 76	2.2	
becoming moist to wet						
becoming insensitive		4.5		179/ 99	1.8	
becoming brown streaked grey						
becoming orange/ brown, moderately sensitive, with trace organic inclusions						
		5.0		157/ 67	2.3	
EOB at 5.0. Target Depth.						
		5.5				
		6.0				

LANDER geotechnical

Comments:
Groundwater not encountered.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter:	Legend			
50mm	Topsoil	Sand	Sandstone	Plutonic
Checked: KM	Fill	Gravel	Siltstone	No Core
	Clay	Organic	Limestone	
	Silt	Pumice	Volcanic	

Client : OYSTER CAPITAL

Project Location : 116 WAIHOEHOE ROAD, DRURY

Job Number: J00784

Auger Borehole No. HA105

Vane Head:	Logged By:	Processor :	Date:
1900	TK	AB	21.01.19

Borehole Location: mN | mE | Ground R.L.

Description: Refer to site plan

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
slightly clayey SILT, dark brown mottled light brown/ grey. Very stiff, moist, low plasticity, moderately sensitive [NATURAL]					
with trace limonite staining	0.5		172/ 67	2.6	
becoming mottled dark orange, brown and grey, with trace organic inclusions					
becoming orange streaked grey	1.0		149/ 64	2.3	
becoming orange mottled grey					
	1.5		115/ 54	2.1	
		▽			
pumiceous fine sandy CLAY, grey. Stiff, moist, low plasticity, insensitive	2.0		73/ 47	1.6	
becoming wet					
silty CLAY, orange mottled light brown/ grey. Stiff, moist, medium plasticity, moderately sensitive, with some limonite staining	2.5		64/ 20	3.2	
becoming saturated					
with limited sample recovery due to groundwater suction	3.0		60/ 17	3.5	
	3.5		67/ 18	3.7	
	4.0		51/ 20	2.6	
becoming very stiff	4.5		144/ 37	3.9	
EOB at 5.0m. Target Depth.	5.0		127/ 56	2.3	
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater encountered 2.8m
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: KM

Legend: Topsoil, Fill, Clay, Silt, Sand, Gravel, Organic, Pumice, Sandstone, Siltstone, Limestone, Volcanic, Plutonic, No Core

Client :	OYSTER CAPITAL		**Auger Borehole No.**	HA106			
Project Location :	116 WAIHOEHOE ROAD, DRURY		Sheet 7 of 12				
Job Number:	J00784		Vane Head: 2153	Logged By: AB	Processor : AB	Date: 22.01.19	
Borehole Location:	mN	mE	Ground R.L.				
	Description: Refer to site plan						

SOIL DESCRIPTION	Legend	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL						
slightly clayey SILT, mottled grey and orange/ brown. Hard, dry, low to no plasticity [NATURAL]						
becoming clayey SILT, orange mottled grey, moist, low to medium plasticity		0.5		205+		Sample 1 Disturbed 0.5-1.0m
becoming very stiff, moderately sensitive		1.0		165/ 71	2.3	
becoming mottled orange/ brown and grey, with occasional limonite silt clast inclusions		1.5		165/ 66	2.5	
with occasional hardened clay clast inclusions becoming hard		2.0	▽	205+		
becoming saturated						
becoming very stiff		2.5		149/ 73	2.0	
		3.0		139/ 66	2.1	
becoming pink and orange streaked grey						
		3.5		128/ 60	2.1	
		4.0		124/ 53	2.3	
becoming green/ grey mottled orange and brown/ grey		4.5		149/ 71	2.1	
EOB at 5.0m. Target Depth.		5.0		165/ 73	2.3	
		5.5				
		6.0				

LANDER geotechnical

Comments:
Groundwater encountered 2.3m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm	Topsoil		Sand		Sandstone		Plutonic	
	Fill		Gravel		Siltstone		No Core	
Checked: KM	Clay		Organic		Limestone			
	Silt		Pumice		Volcanic			

Client : OYSTER CAPITAL

Project Location : 116 WAIHOEHOE ROAD, DRURY

Job Number: J00784

Auger Borehole No. HA107

Vane Head:	Logged By:	Processor :	Date:
1900	TK	AB	21.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
clayey SILT with some topsoil intermixed, brown/ orange streaked grey/ orange and dark grey. Stiff, wet, low plasticity, moderately sensitive, with trace organic staining [FILL]					
becoming orange mottled orange/ brown, grey and dark grey, with trace rootlets	0.5		92/ 33	2.8	
clayey SILT, grey/ brown. Very stiff, wet, low plasticity, moderately sensitive [NATURAL]					
at 0.9m, becoming light brown mottled grey/ brown	1.0		134/ 44	3.0	
with some organic inclusions to 1.4m					
with some green clay clasts		▽ (1.5m)			
becoming stiff, saturated, sensitive, without green clay clasts	1.5		95/ 21	4.5	
with trace fibrous wood inclusions to 2.2m					
becoming moderately sensitive	2.0		62/ 23	2.7	
SILT with trace fine sand, green. Very stiff, saturated, high plasticity, moderately sensitive	2.5		115/ 32	3.6	
	3.0		111/ 32	3.6	
becoming stiff, insensitive	3.5		60/ 32	1.9	
slightly sandy SILT, dark brownmottled green/ grey. Loose, wet, no plasticity, sensitive					
at 4.0m, becoming sandy SILT	4.0		164/ 37	4.4	
clayey fine SAND, green/ grey. Very stiff, saturated, low to medium plasticity, sensitive, with trace organic inclusions	4.5		151/ 37	4.1	
SAND, green/ grey. Loose, saturated, no plasticity, sensitive, with trace organic inclusions					
EOB at 5.0m. Target Depth.	5.0		149/ 32	4.7	
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater encountered 1.5m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: KM

Legend			
Topsoil	Sand	Sandstone	Plutonic
Fill	Gravel	Siltstone	No Core
Clay	Organic	Limestone	
Silt	Pumice	Volcanic	

Client :	OYSTER CAPITAL	**Auger Borehole No.**	HA108
Project Location :	116 WAIHOEHOE ROAD, DRURY	Sheet 9 of 12	
Job Number:	J00784		

Vane Head:	Logged By:	Processor :	Date:
2153	AB	AB	21.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Legend	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL						
slightly clayey SILT, mottled orange/ brown and grey. Hard, dry, low to no plasticity [NATURAL]		0.5		205+		
silty CLAY, grey streaked orange/ brown. Hard, moist, medium plasticity, moderately sensitive		1.0		201/ 71	2.8	
		1.5		201/ 71	2.8	
becoming orange speckled light grey						
becoming very stiff		2.0		114/ 46	2.5	
becoming stiff, moist to wet		2.5		93/ 43	2.2	
becoming light blue/ grey, saturated, high plasticity			▽			
becoming very stiff		3.0		108/ 46	2.3	
		3.5		124/ 51	2.4	
fine sandy CLAY, blue/ grey mottled dark grey. Very stiff, saturated, medium plasticity, moderately sensitive, with limited sample recovery due to groundwater suction						
becoming dark green/ grey		4.0		169/ 60	2.8	
becoming hard		4.5		201/ 65	3.1	
		5.0		205+		
EOB at 5.0m. Target Depth.						
		5.5				
		6.0				

LANDER geotechnical

Comments:
Groundwater encountered 2.8m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter:	Checked:
50mm	KLM

Topsoil		Sand		Sandstone		Plutonic	
Fill		Gravel		Siltstone		No Core	
Clay		Organic		Limestone			
Silt		Pumice		Volcanic			

Client : OYSTER CAPITAL

Project Location : 116 WAIHOEHOE ROAD, DRURY

Job Number: J00784

Auger Borehole No. HA109

Sheet 10 of 12

Vane Head:	Logged By:	Processor :	Date:
2153	AB	AB	21.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
clayey SILT, orange/ brown. Hard, dry to moist, low to medium plasticity [NATURAL]	0.5		205+		
becoming grey streaked orange/ brown, medium plasticity					
becoming very stiff, insensitive	1.0		146/ 76	1.9	
becoming moderately sensitive becoming orange/ brown mottled grey	1.5		149/ 66	2.3	
	2.0		165/ 66	2.5	
		▽			
becoming brown/ grey, saturated, with some fine to medium sand sized silt clast inclusions	2.5		169/ 71	2.4	
becoming orange speckled light blue/ grey becoming hard	3.0		205+		
clayey SILT, dark green/ grey. Hard, moist to wet, low plasticity	3.5		205+		
	4.0		UTP		
	4.5		UTP		
EOB at 5.0m. Target Depth.	5.0		UTP		
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater encountered 2.5m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: Km

Topsoil		Sand		Sandstone		Plutonic	
Fill		Gravel		Siltstone		No Core	
Clay		Organic		Limestone			
Silt		Pumice		Volcanic			

Client : OYSTER CAPITAL

Project Location : 116 WAIHOEHOE ROAD, DRURY

Job Number: J00784

Auger Borehole No. HA110

Sheet 11 of 12

Vane Head:	Logged By:	Processor :	Date:
1900	TK	AB	22.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
slightly clayey SILT, brown/ orange. Very stiff, moist, low plasticity, moderately sensitive [NATURAL]					
becoming orange mottled orange/ brown	0.5		151/ 76	2.0	
becoming stiff	1.0		92/ 46	2.0	
silty CLAY, orange/ brown mottled grey. Very stiff, moist, medium plasticity, with some organic inclusions					
SILT with trace fine sand, orange mottled light grey. Very stiff, moist to wet, low to no plasticity, with trace clay, with some organic staining	1.5		149/ 51	2.9	
with trace medium sand sized clast inclusions					
with some organic inclusions	2.0		175/ 76	2.3	
becoming wet to saturated					
silty CLAY, orange. Very stiff, moist, medium plasticity, moderately sensitive, with some limonite staining	2.5		127/ 54	2.4	
clayey SILT, dark grey. Very stiff, wet to saturated, medium plasticity, moderately sensitive at 3.0m, becoming saturated	3.0	▽	177/ 50	3.5	
becoming orange streaked blue/ grey					
becoming sensitive	3.5		140/ 32	4.4	
with some fibrous wood inclusions to 3.9m					
becoming green/ grey, moderately sensitive	4.0		175/ 64	2.7	
becoming hard	4.5		205+		
EOB at 5.0m. Target Depth.	5.0		UTP		
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater encountered 3.0m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter: 50mm

Checked: KM

Legend: Topsoil, Fill, Clay, Silt, Sand, Gravel, Organic, Pumice, Sandstone, Siltstone, Limestone, Volcanic, Plutonic, No Core

Client :	OYSTER CAPITAL	Auger Borehole No.	HA111
Project Location :	116 WAIHOEHOE ROAD, DRURY	Sheet	12 of 12
Job Number:	J00784		

Vane Head:	Logged By:	Processor :	Date:
1900	TK	AB	21.01.19

Borehole Location:	mN	mE	Ground R.L.
	Description:	Refer to site plan	

SOIL DESCRIPTION	Depth (m)	Standing Water Level	Vane Shear(kPa) peak / residual	Soil Sensitivity	Sample and Laboratory / Other Test Details
TOPSOIL					
clayey SILT with some topsoil intermixed, brown. Very stiff, moist, low plasticity, moderately sensitive [NATURAL]					
becoming orange streaked brown	0.5		168/ 64	2.6	
becoming slighlty clayey SILT, orange/ grey	1.0		127/ 62	2.0	
becoming orange mottled orange/ brown, hard					
becoming, wet, low to medium plasticity, with some fine sand, with some hardened clast inclusions	1.5		237+		
becoming very stiff, orange streaked orange/ brown, sensitive	2.0		175/ 34	5.1	
becoming wet to saturated					
becoming light brown					
silty CLAY, light brown mottled light brown/ grey. Hard, wet, medium plasticity, sensitive	2.5		237/ 40	5.9	
becoming saturated					
becoming dark grey	3.0	▽	UTP		
	3.5		UTP		
with trace fine sand to 4.0m					
becoming green mottled dark grey	4.0		UTP		
with some organic inclusions to 4.7m					
	4.5		237+		
becoming grey, with trace fine sand					
at 5.0m, becoming moderately sensitive					
EOB at 5.0m. Target Depth.	5.0		217/ 64	3.4	
	5.5				
	6.0				

LANDER geotechnical

Comments:
Groundwater encountered 2.9m.
UTP = unable to penetrate.
EOB = end of borehole.

Borehole Diameter:	Legend			
50mm	Topsoil	Sand	Sandstone	Plutonic
Checked:	Fill	Gravel	Siltstone	No Core
KM	Clay	Organic	Limestone	
	Silt	Pumice	Volcanic	

Lander Geotechnical Consultants Limited
Level 3, 3 Osterley Way
P O Box 97 385, Manukau, Auckland 2241
www.landergeotechnical.co.nz

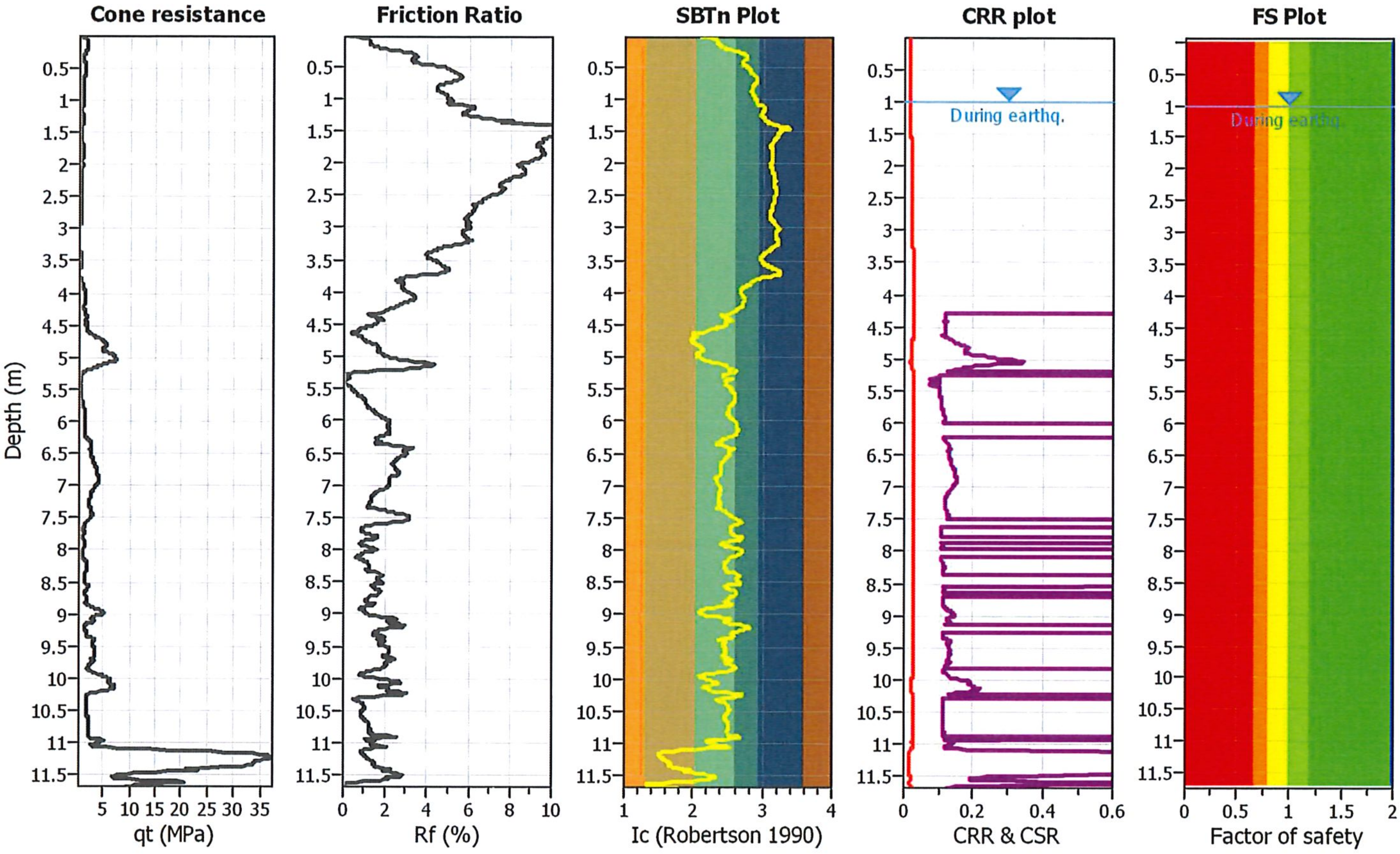
LIQUEFACTION ANALYSIS REPORT

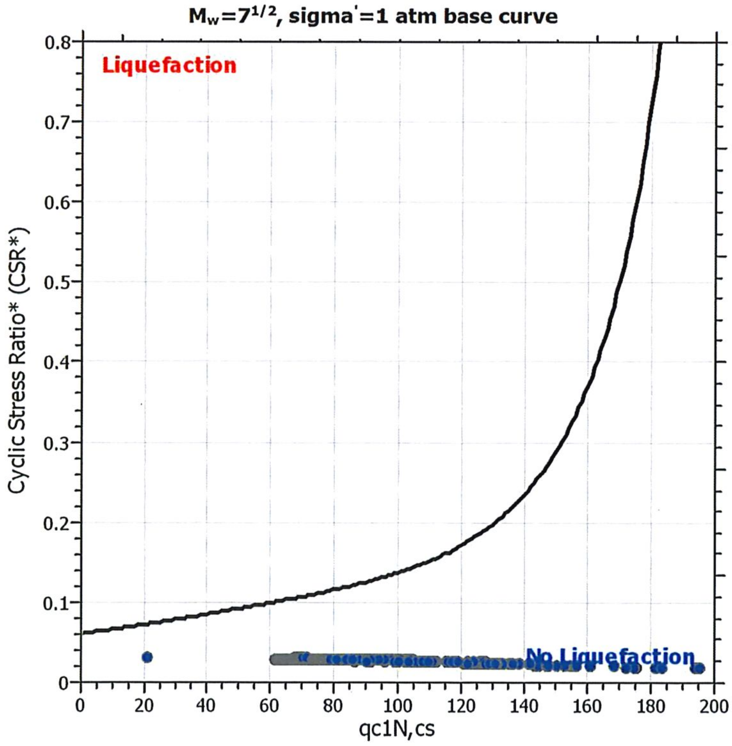
Project title : SLS(1/25) **Location : 116 Waihoehoe Road, Drury**

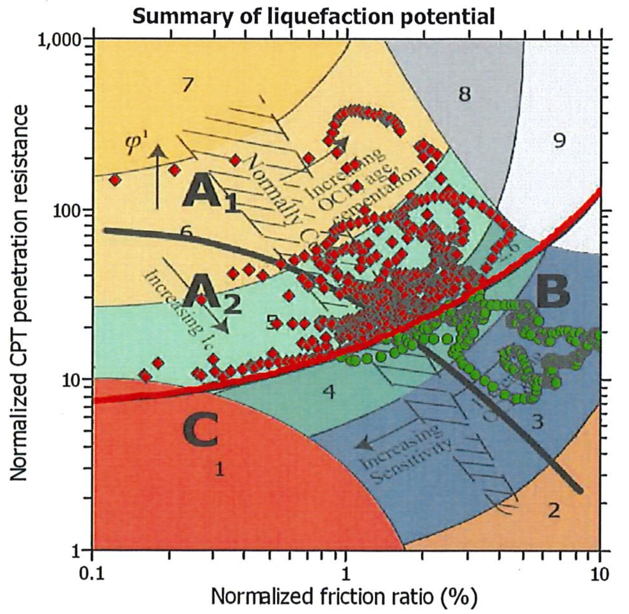
CPT file : Lander 116 Waihoehoe rd_CPT01

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.03	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

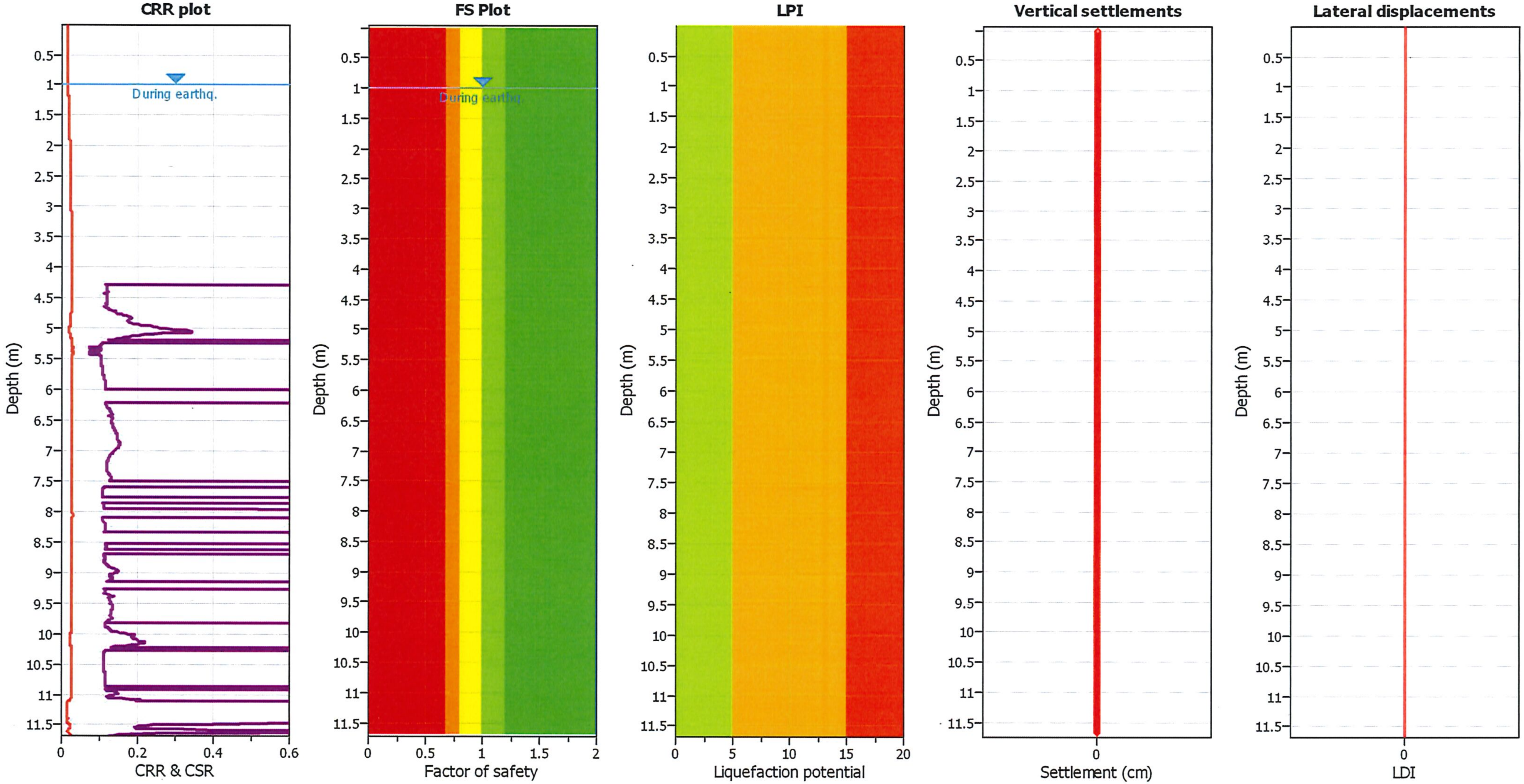






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.03	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

Lander Geotechnical Consultants Limited
Level 3, 3 Osterley Way
P O Box 97 385, Manukau, Auckland 2241
www.landergeotechnical.co.nz

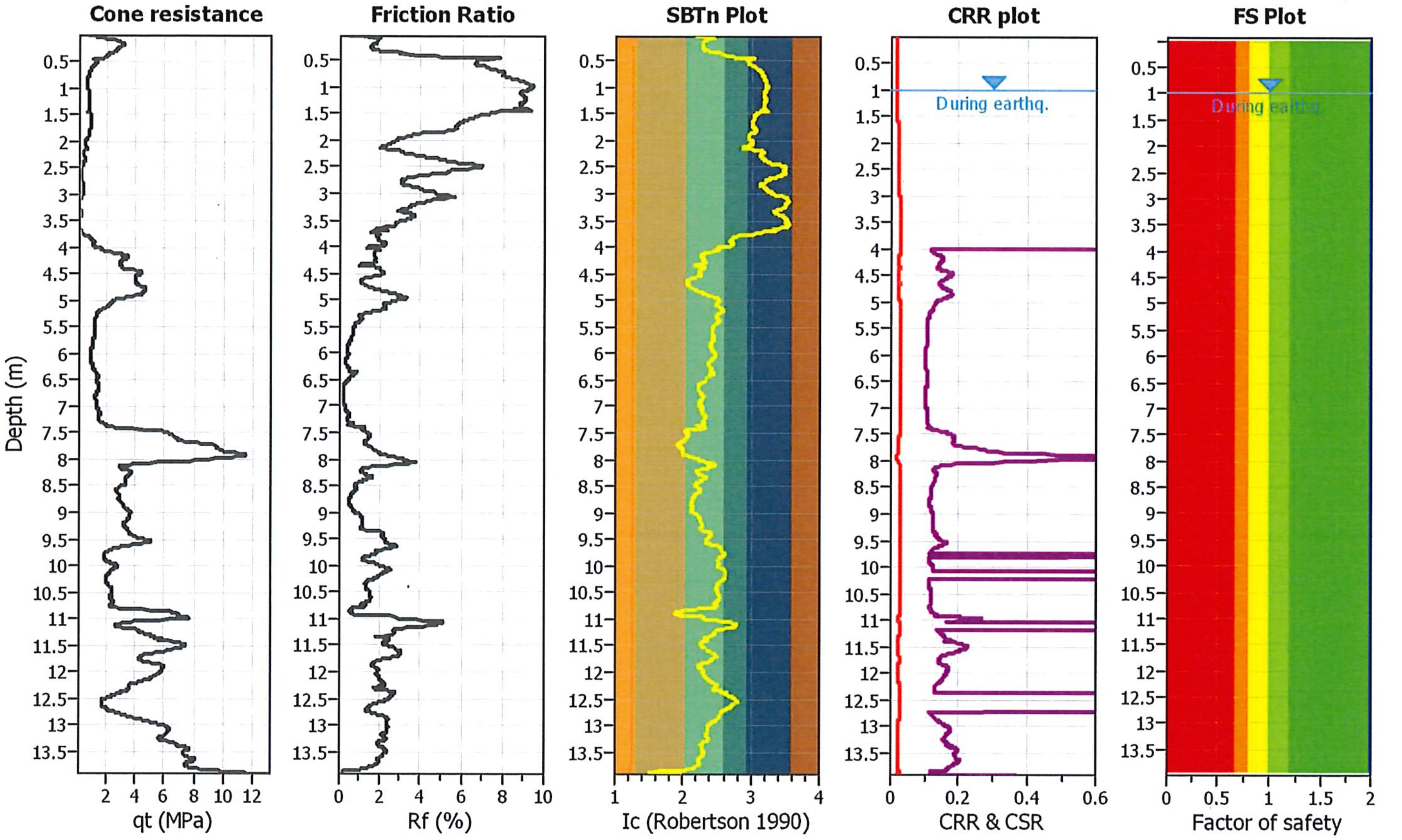
LIQUEFACTION ANALYSIS REPORT

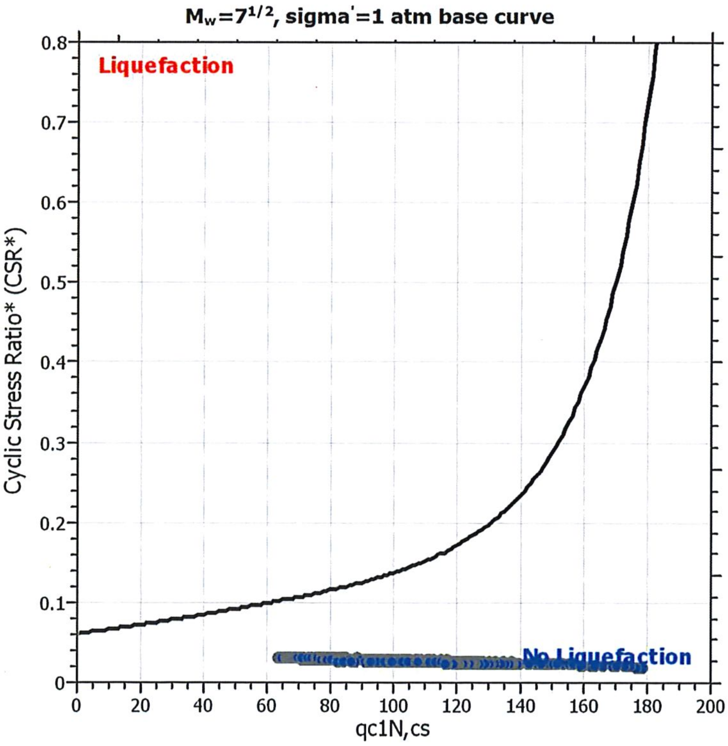
Project title : SLS(1/25) **Location : 116 Waihoehoe Road, Drury**

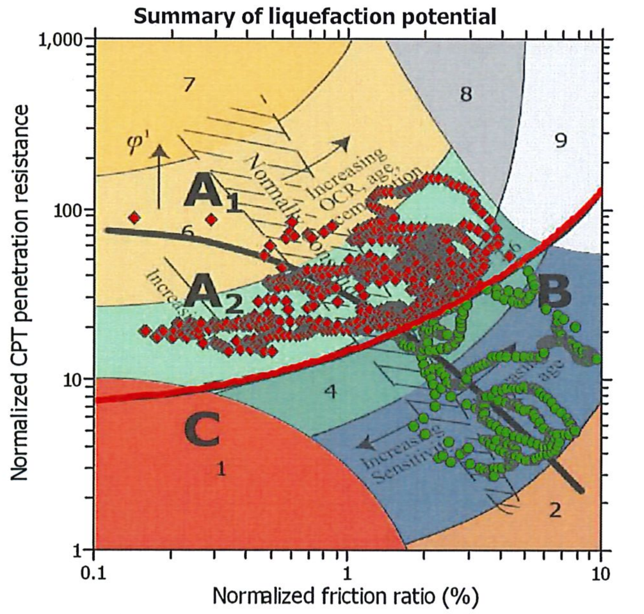
CPT file : Lander 116 Waihoehoe rd_CPT02

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.03	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

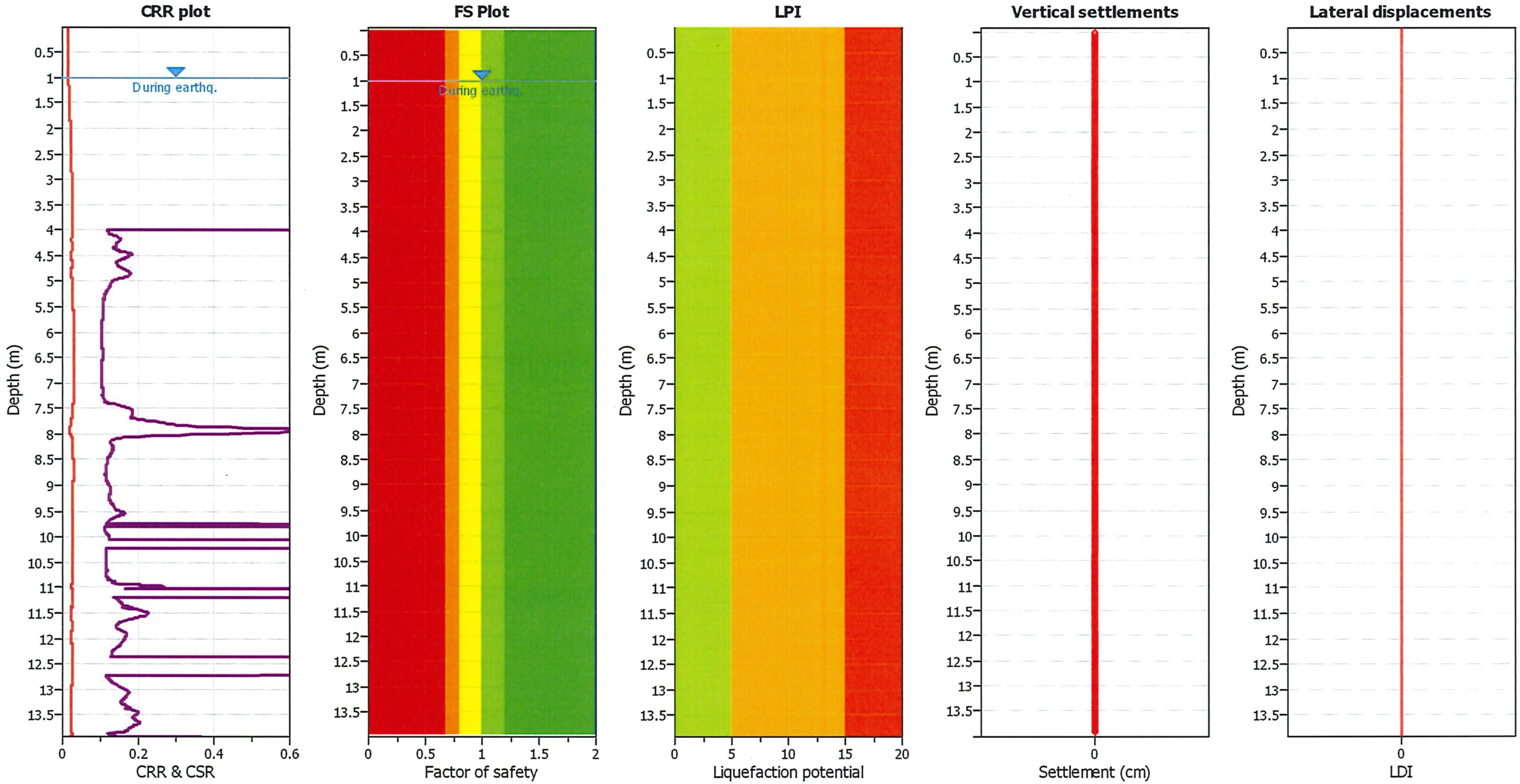






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.03	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

Lander Geotechnical Consultants Limited
Level 3, 3 Osterley Way
P O Box 97 385, Manukau, Auckland 2241
www.landergeotechnical.co.nz

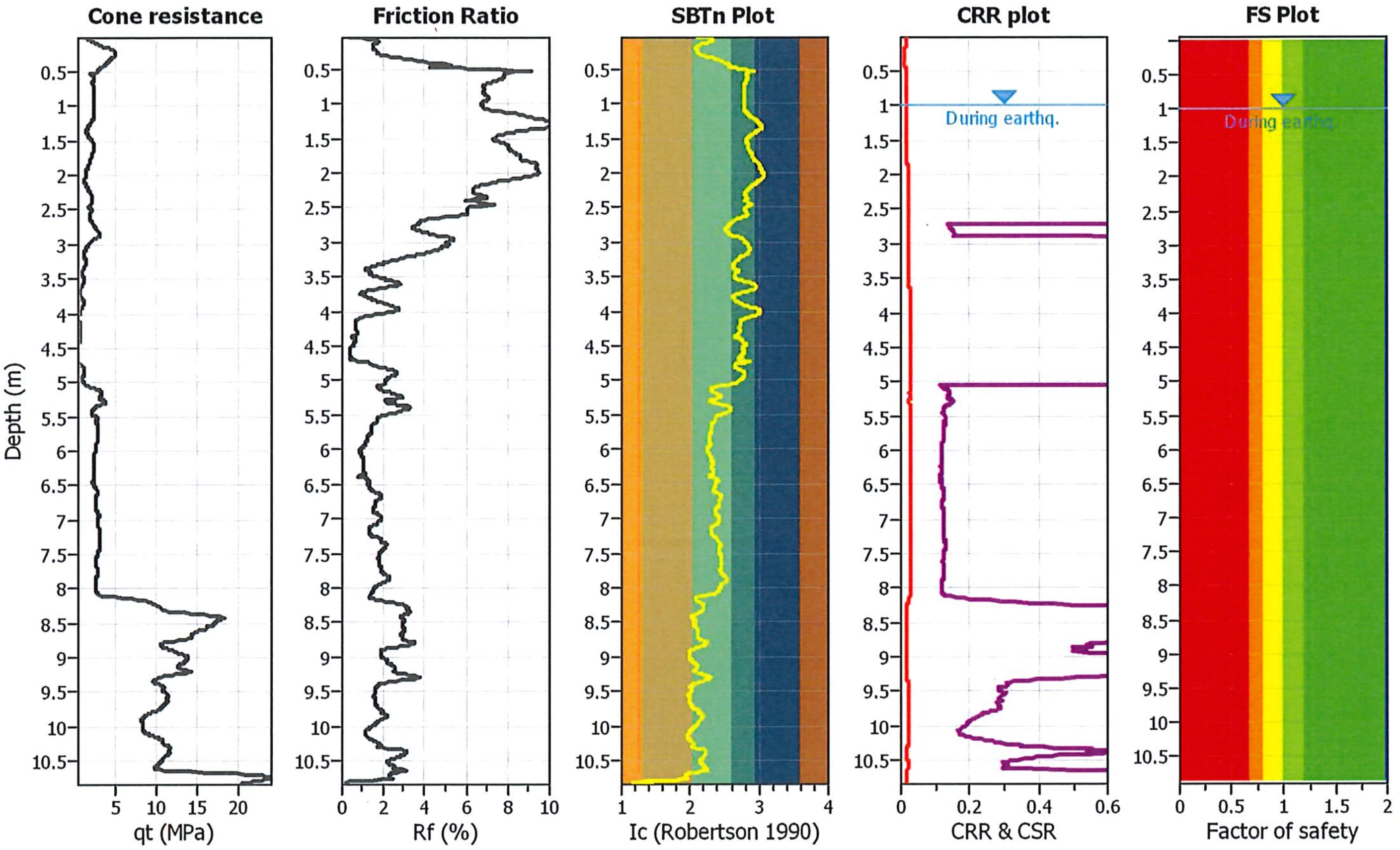
LIQUEFACTION ANALYSIS REPORT

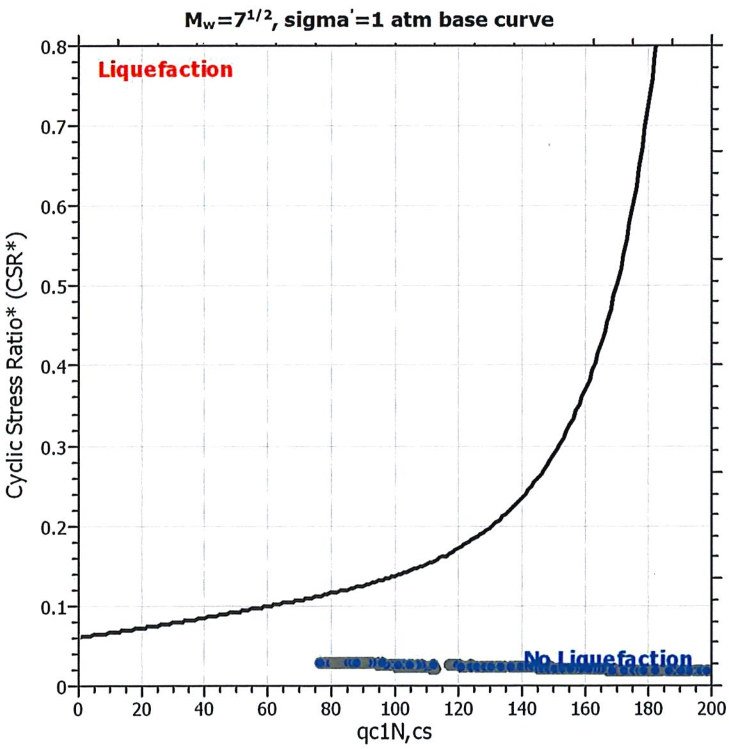
Project title : SLS(1/25) **Location : 116 Waihoehoe Road, Drury**

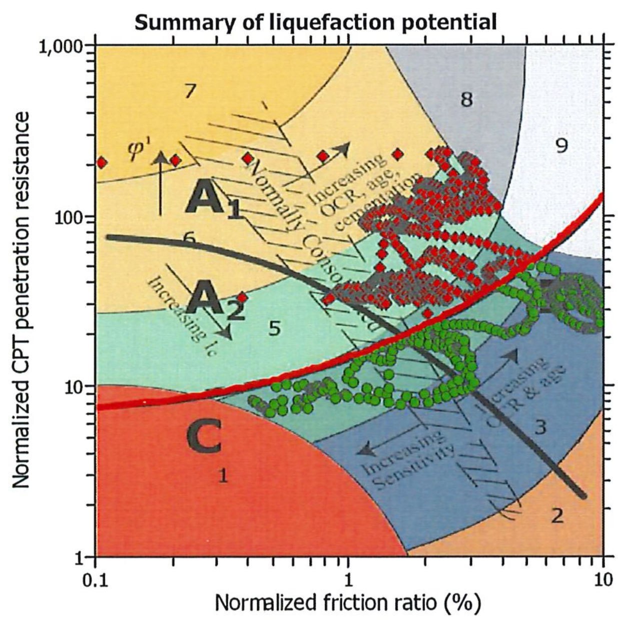
CPT file : Lander 116 Waihoehoe rd_CPT03

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.03	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

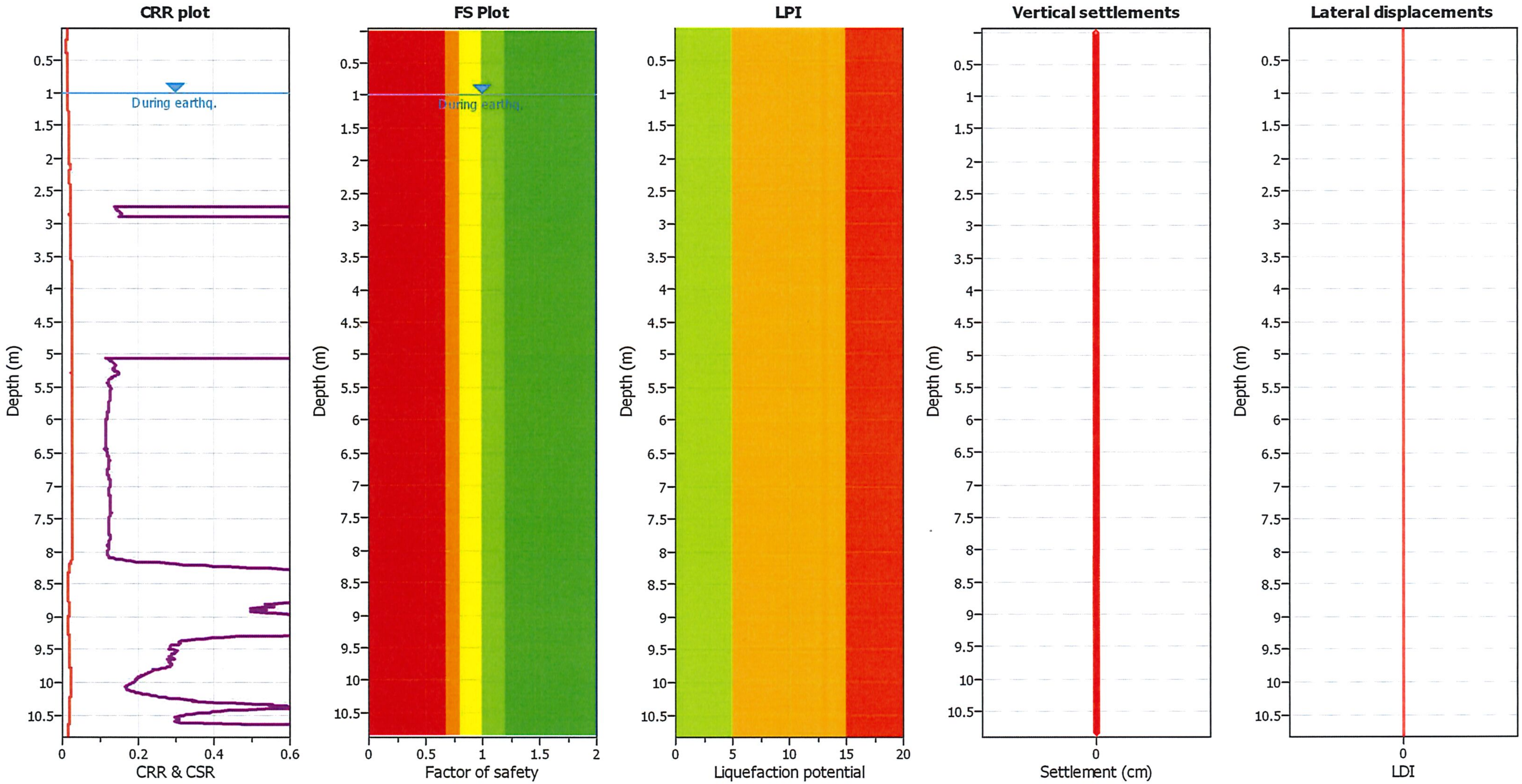






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.03	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

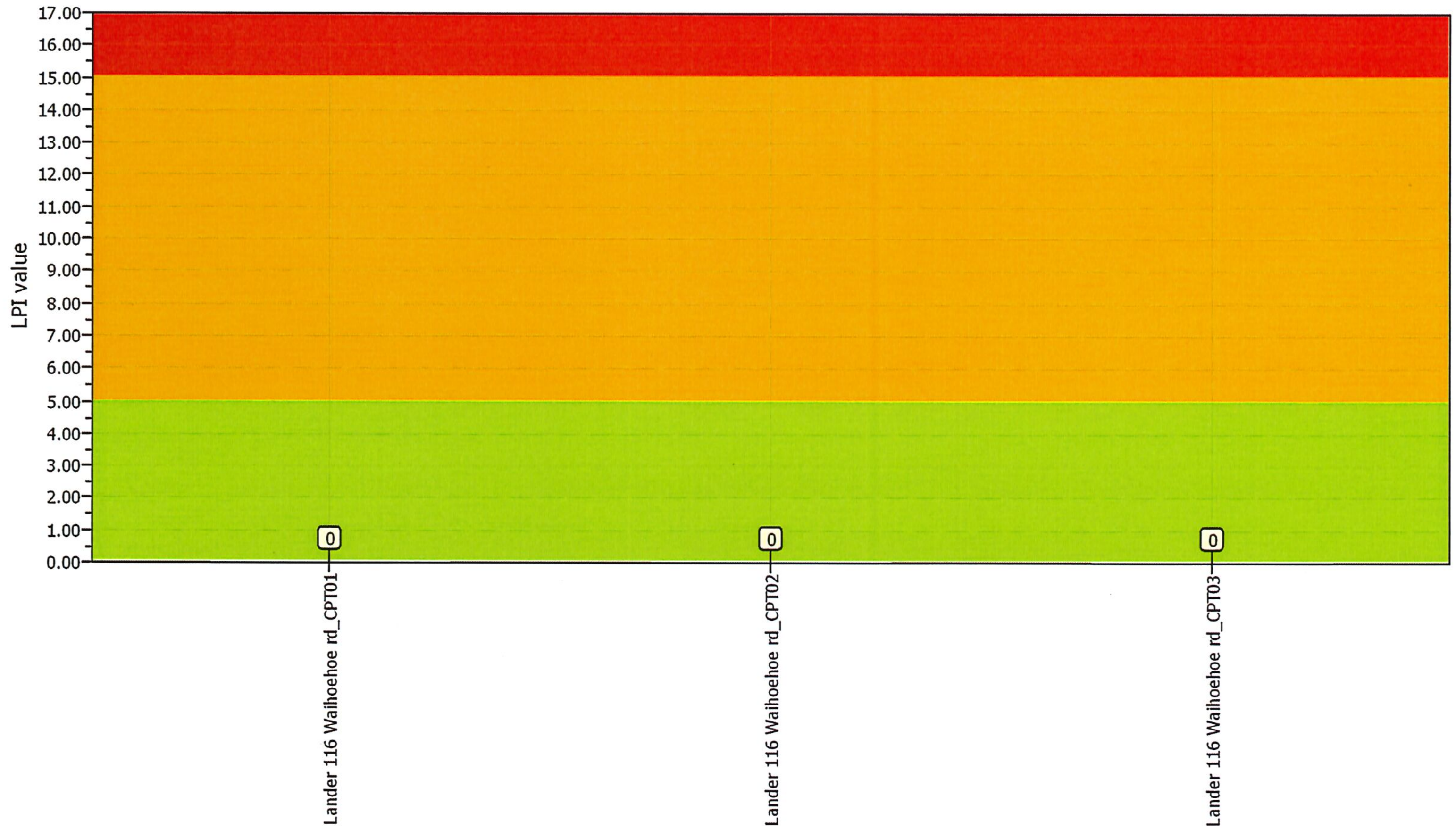
LPI color scheme

- Very high risk
- High risk
- Low risk

Project title : SLS(1/25)

Location : 116 Waihoehoe Road, Drury

Overall Liquefaction Potential Index report



LPI color scheme

- Very high risk
- High risk
- Low risk

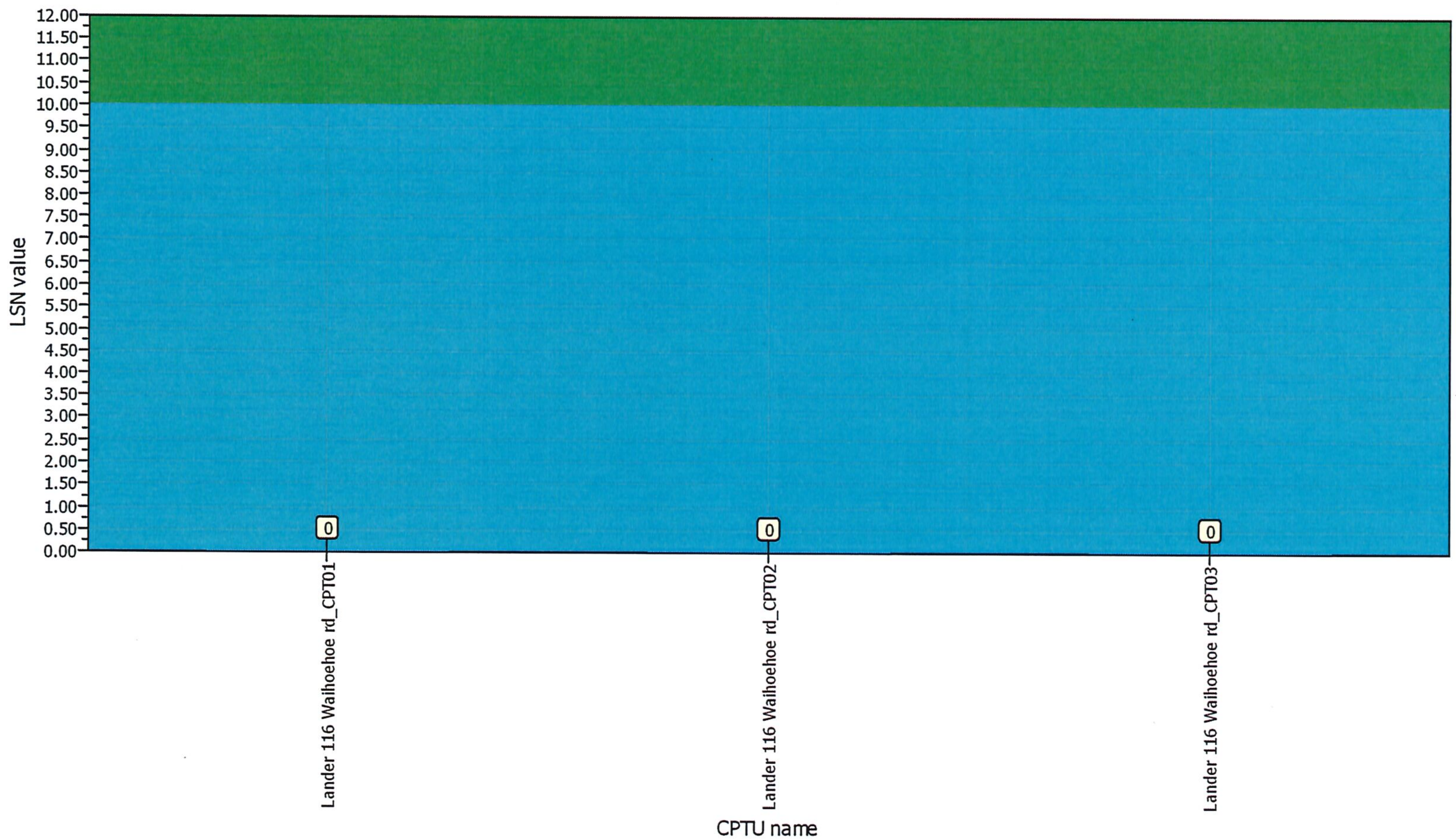
Basic statistics

Total CPT number: 3
100.00% low risk
0.00% high risk
0.00% very high risk

Project title : SLS(1/25)

Location : 116 Waihoehoe Road, Drury

Overall Liquefaction Severity Number report



LSN color scheme

- Severe damage
- Major expression of liquefaction
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction

Basic statistics

Total CPT number: 3

100.00% little liquefaction

0.00% minnor liquefaction

0.00% moderate liquefaction

0.00% moderate to major liquefaction

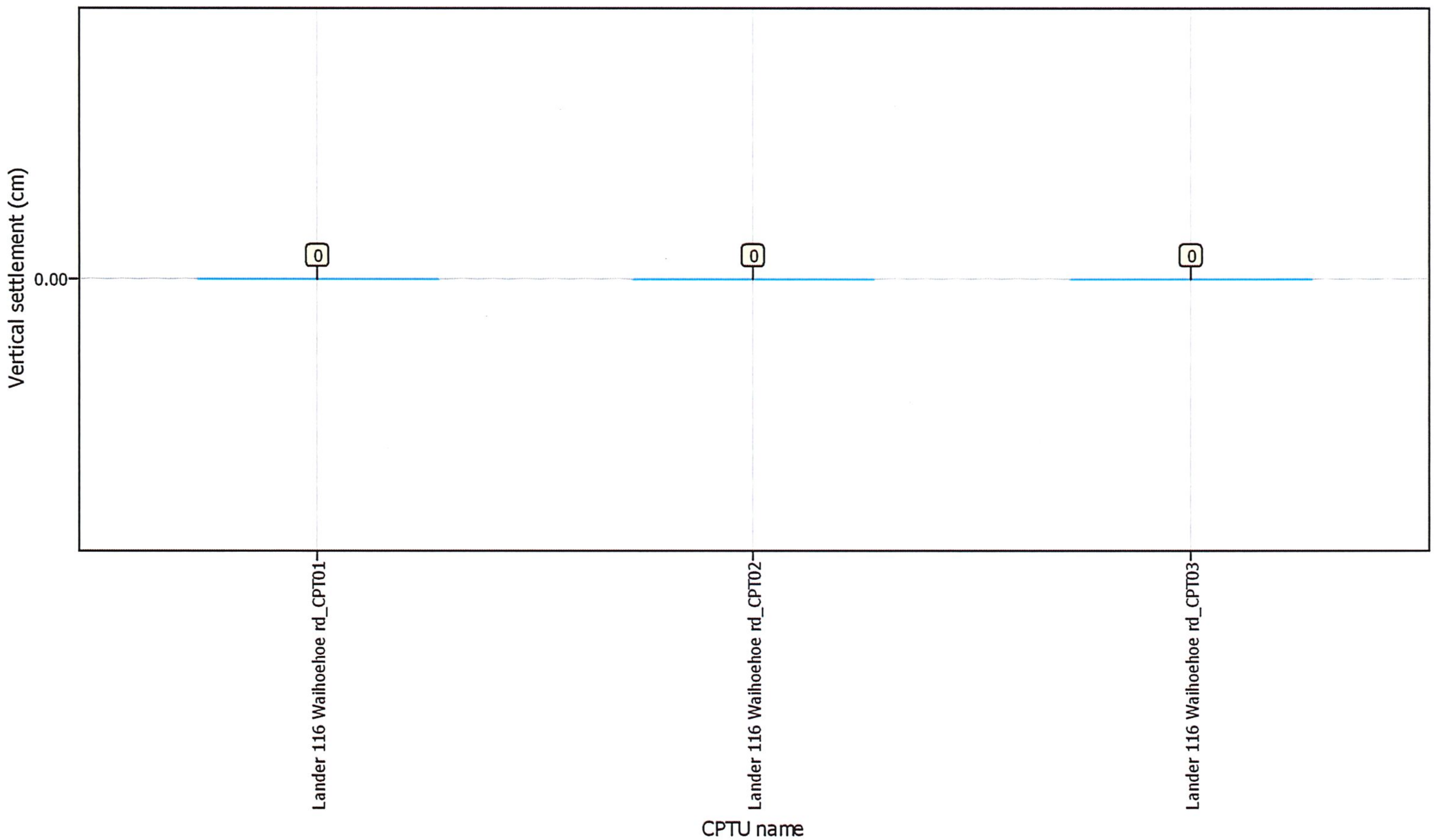
0.00% major liquefaction

0.00% severe liquefaction

Project title : SLS(1/25)

Location : 116 Waihoehoe Road, Drury

Overall vertical settlements report



Lander Geotechnical Consultants Limited
Level 3, 3 Osterley Way
P O Box 97 385, Manukau, Auckland 2241
www.landergeotechnical.co.nz

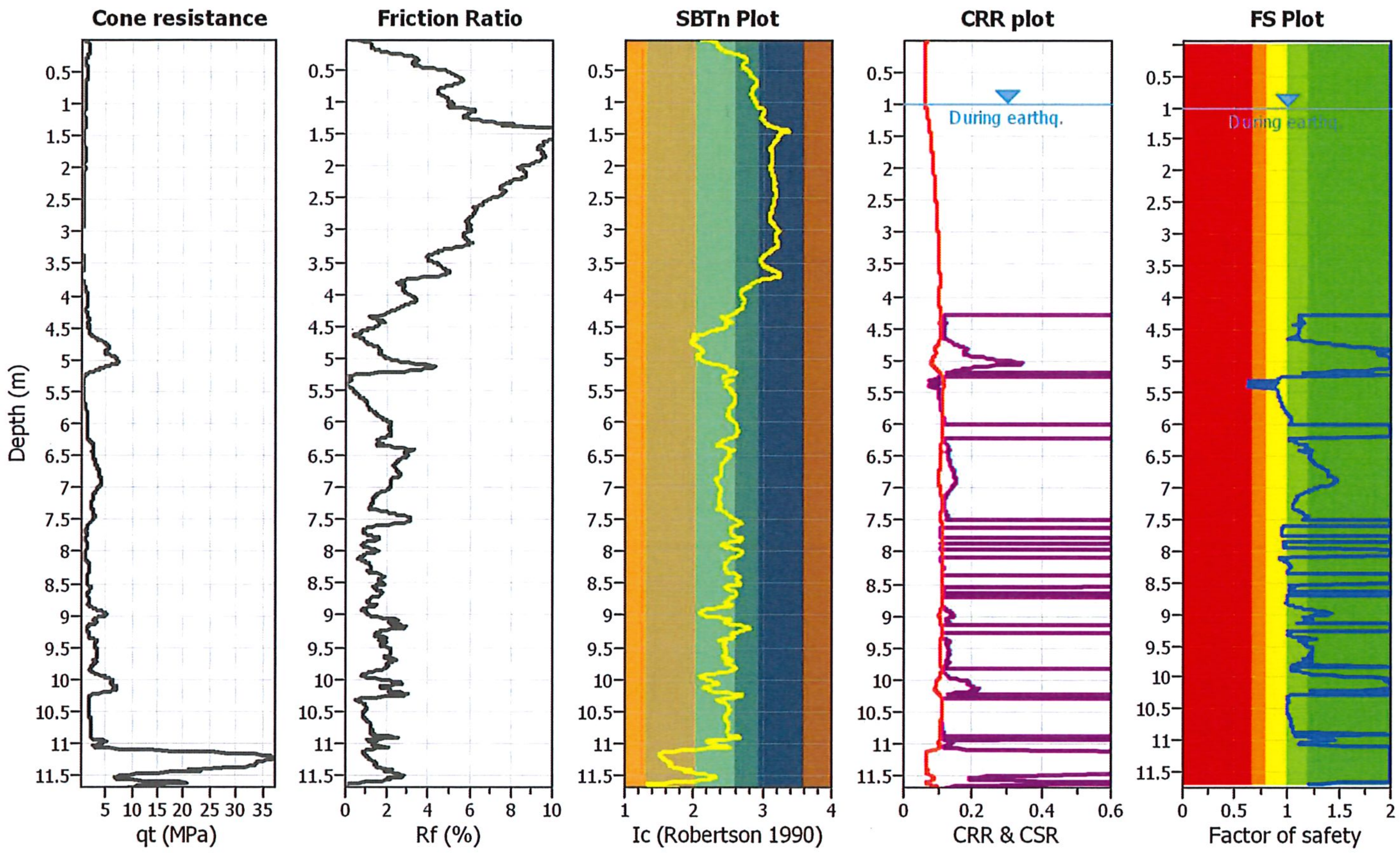
LIQUEFACTION ANALYSIS REPORT

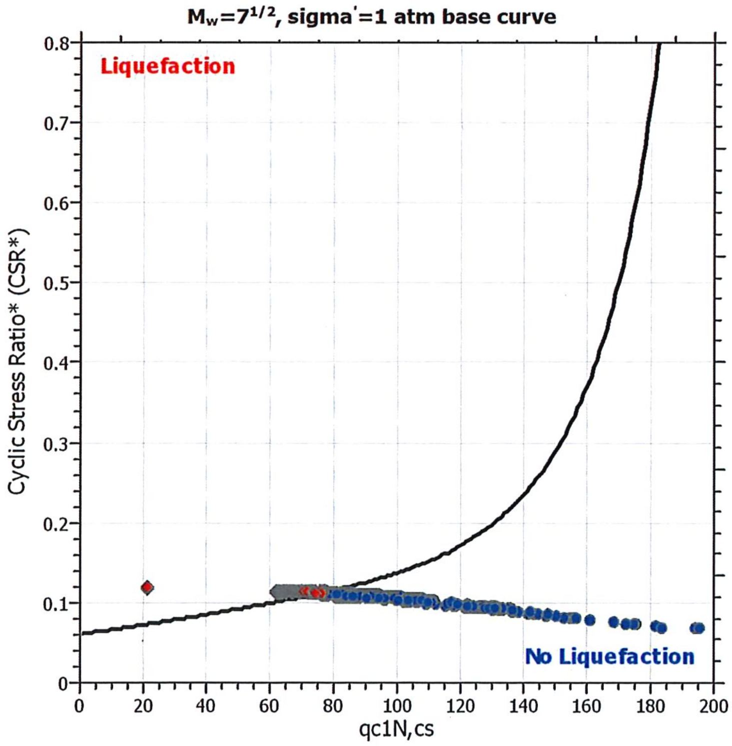
Project title : ULS(1/500) **Location : 116 Waihoehoe Road, Drury**

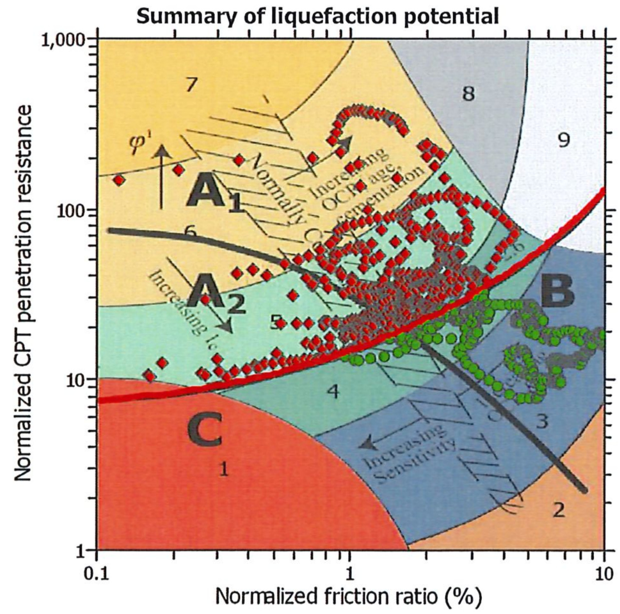
CPT file : Lander 116 Waihoehoe rd_CPT01

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.12	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

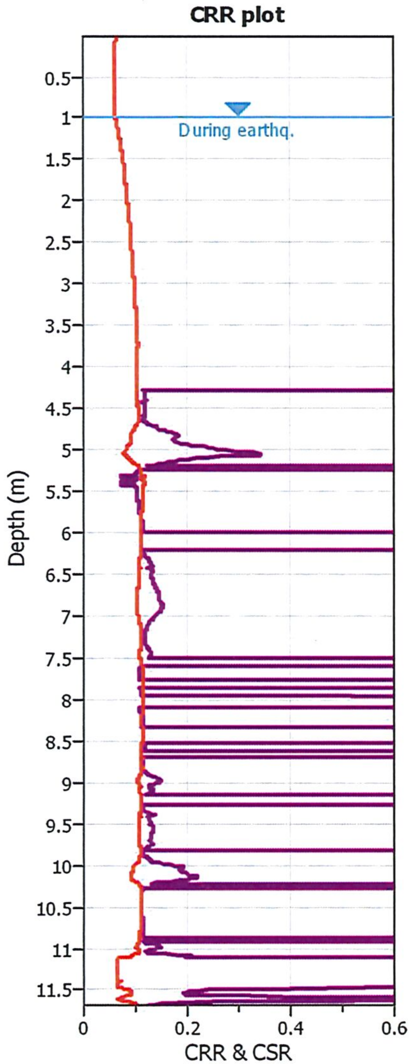


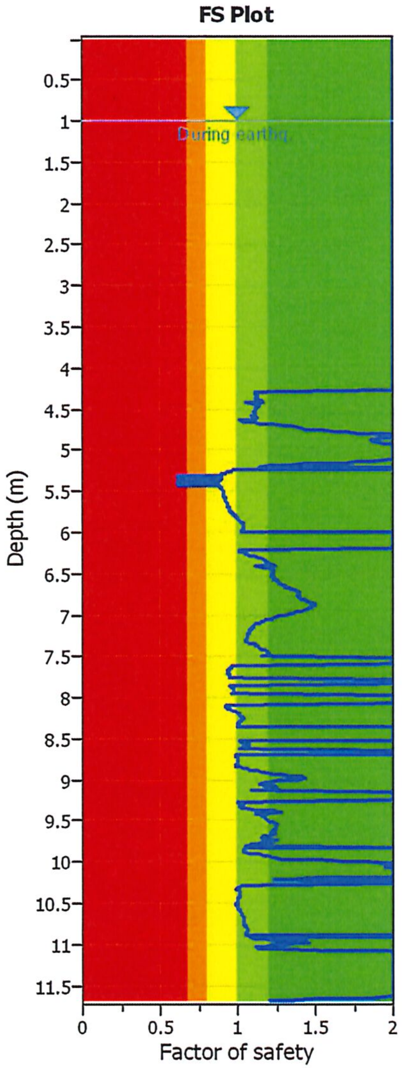


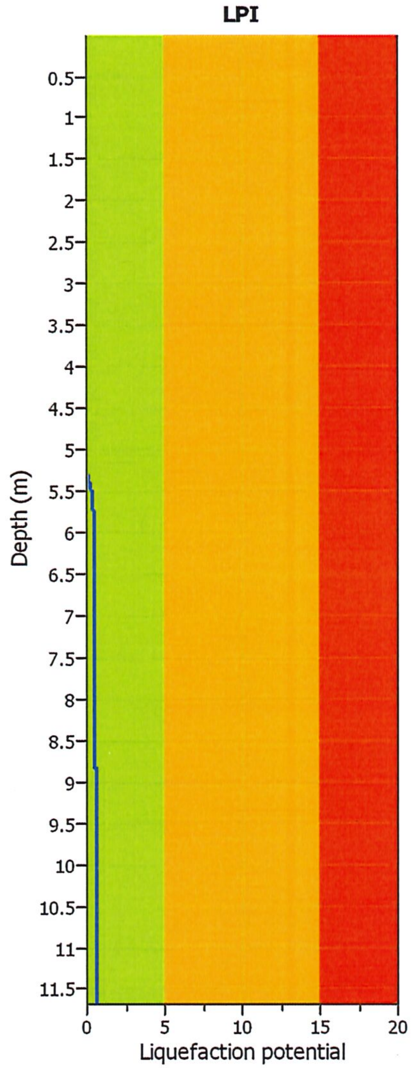


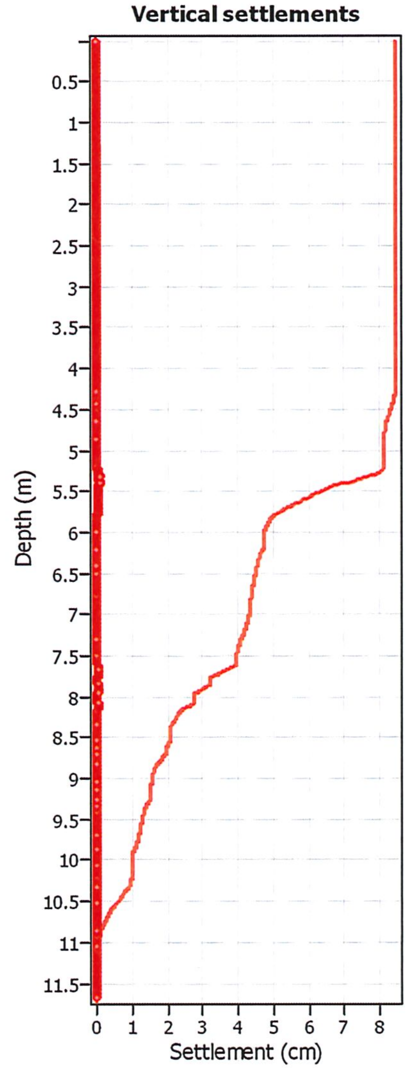
Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

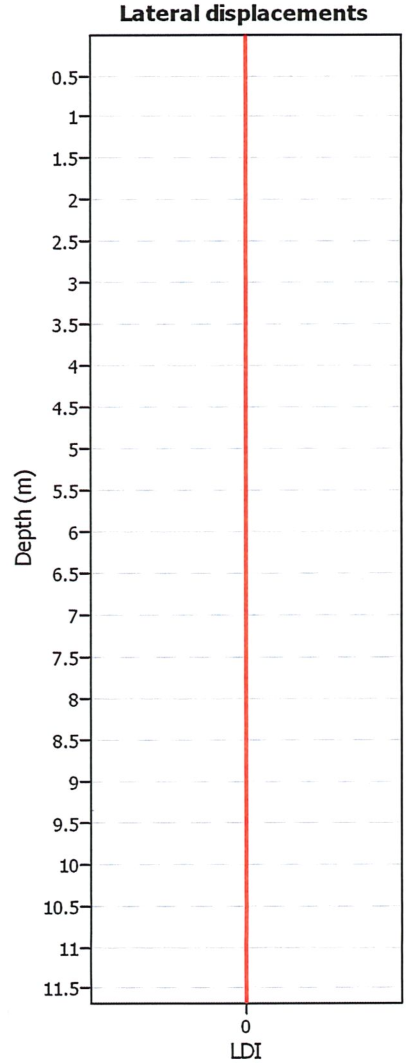
Liquefaction analysis overall plots











Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.12	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

Lander Geotechnical Consultants Limited
Level 3, 3 Osterley Way
P O Box 97 385, Manukau, Auckland 2241
www.landergeotechnical.co.nz

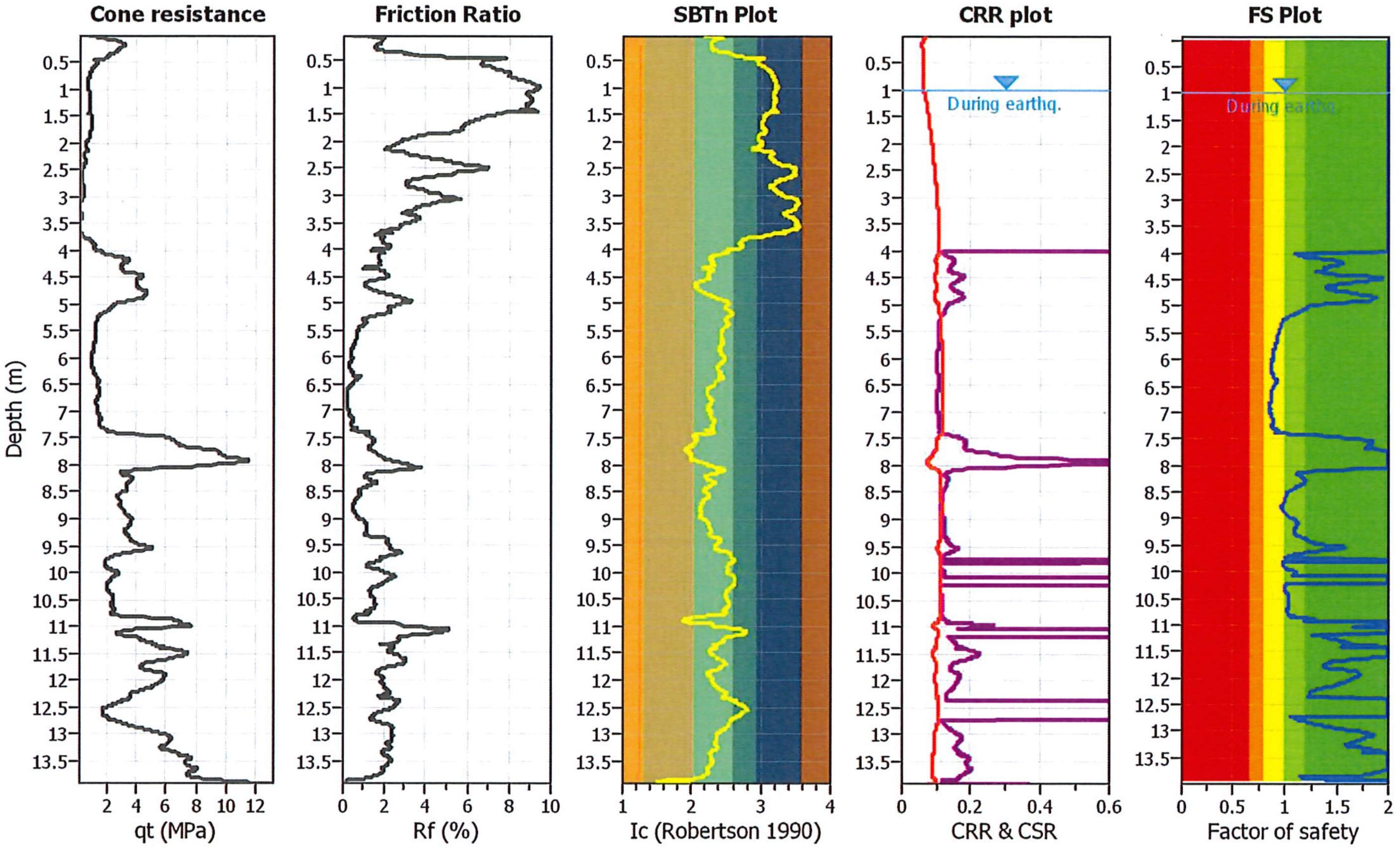
LIQUEFACTION ANALYSIS REPORT

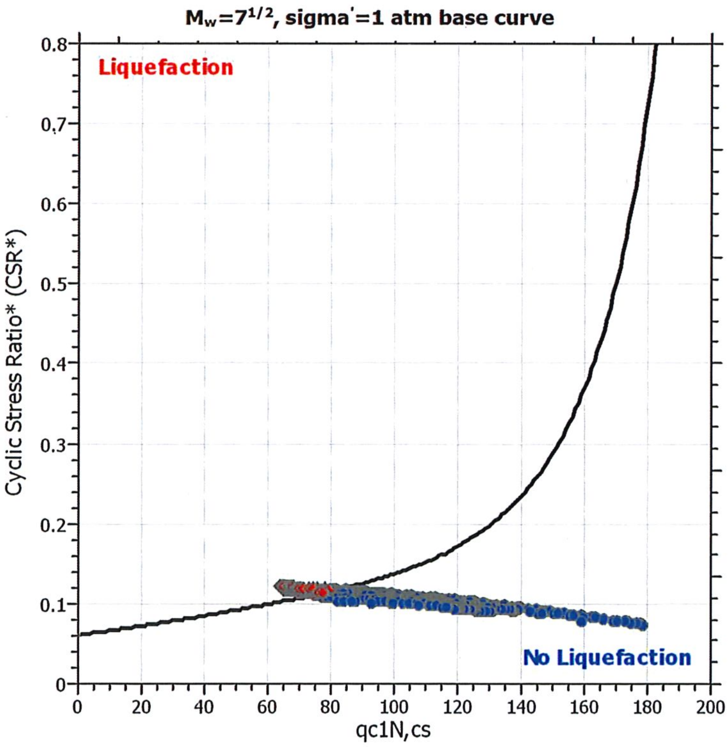
Project title : ULS(1/500) **Location : 116 Waihoehoe Road, Drury**

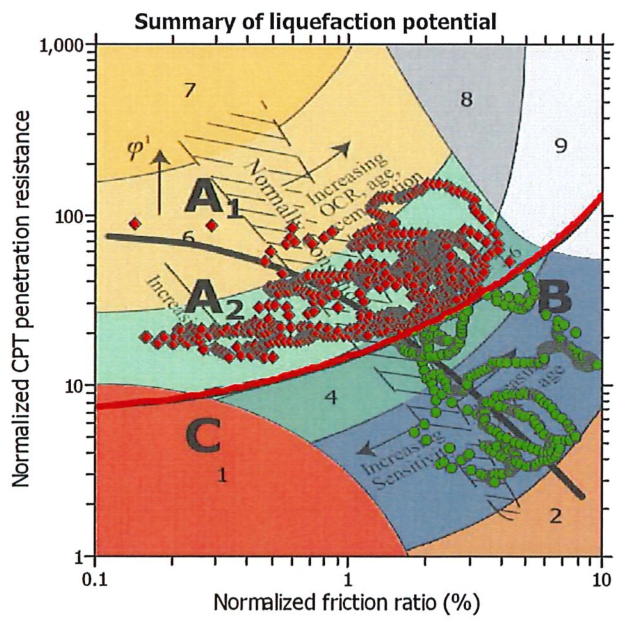
CPT file : Lander 116 Waihoehoe rd_CPT02

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.12	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

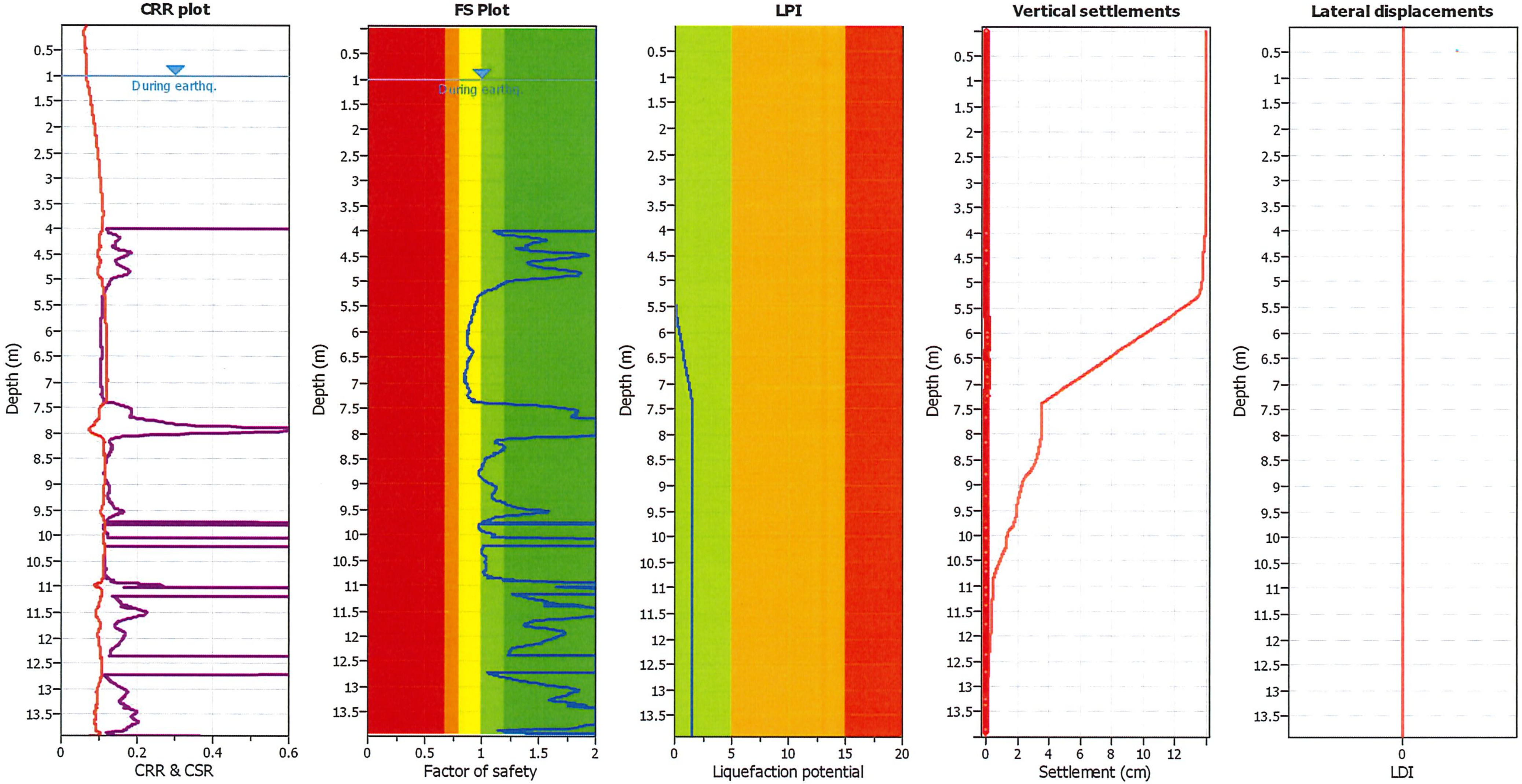






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.12	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

LPI color scheme

- Very high risk
- High risk
- Low risk

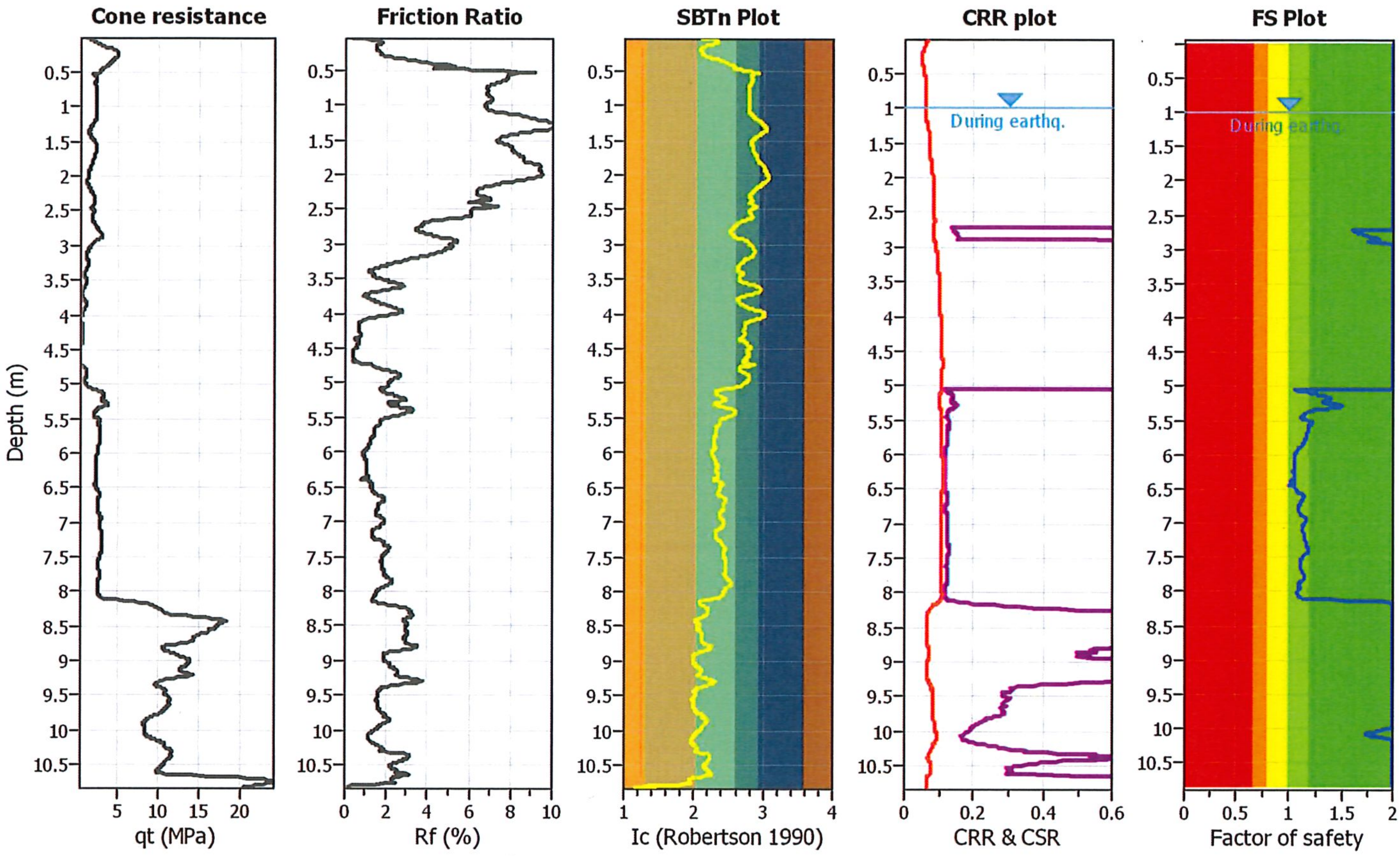
LIQUEFACTION ANALYSIS REPORT

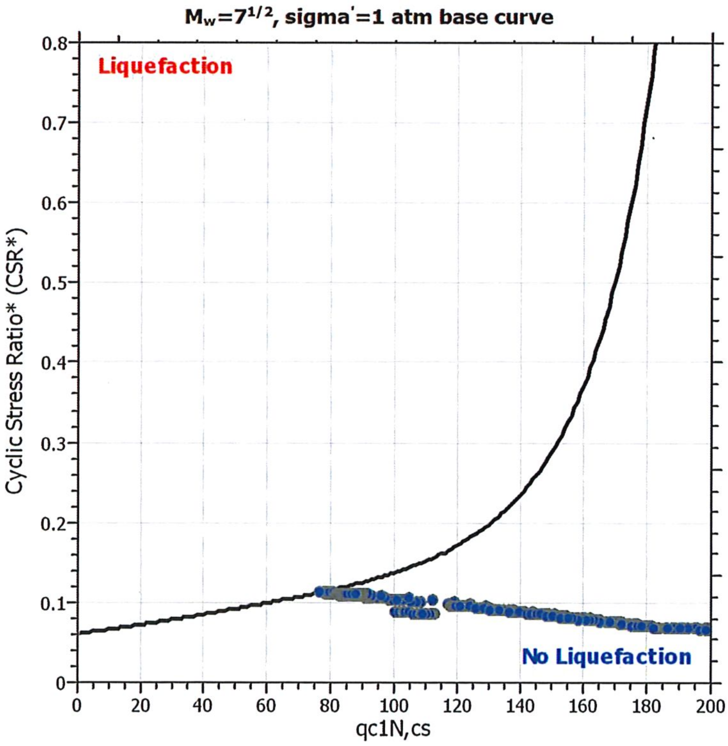
Project title : ULS(1/500) **Location : 116 Waihoehoe Road, Drury**

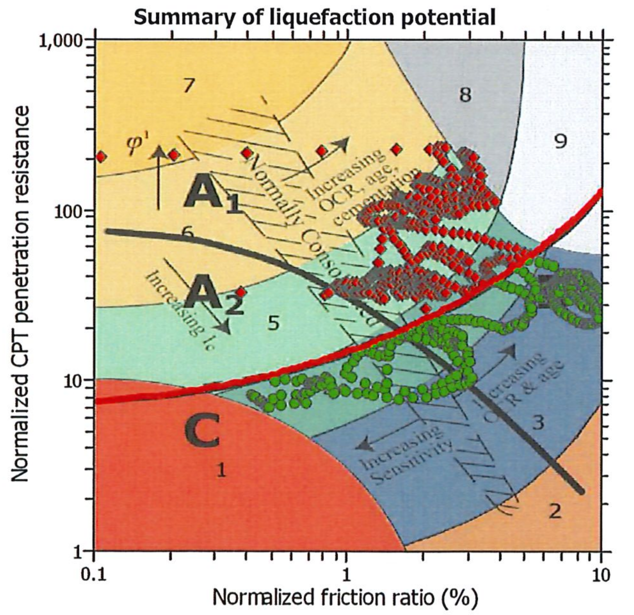
CPT file : Lander 116 Waihoehoe rd_CPT03

Input parameters and analysis data

Analysis method:	B&I (2014)	G.W.T. (in-situ):	1.00 m	Use fill:	No	Clay like behavior applied:	Sands only
Fines correction method:	B&I (2014)	G.W.T. (earthq.):	1.00 m	Fill height:	N/A	Limit depth applied:	No
Points to test:	Based on Ic value	Average results interval:	3	Fill weight:	N/A	Limit depth:	N/A
Earthquake magnitude M_w:	5.90	Ic cut-off value:	2.60	Trans. detect. applied:	No	MSF method:	Method based
Peak ground acceleration:	0.12	Unit weight calculation:	Based on SBT	K_σ applied:	Yes		

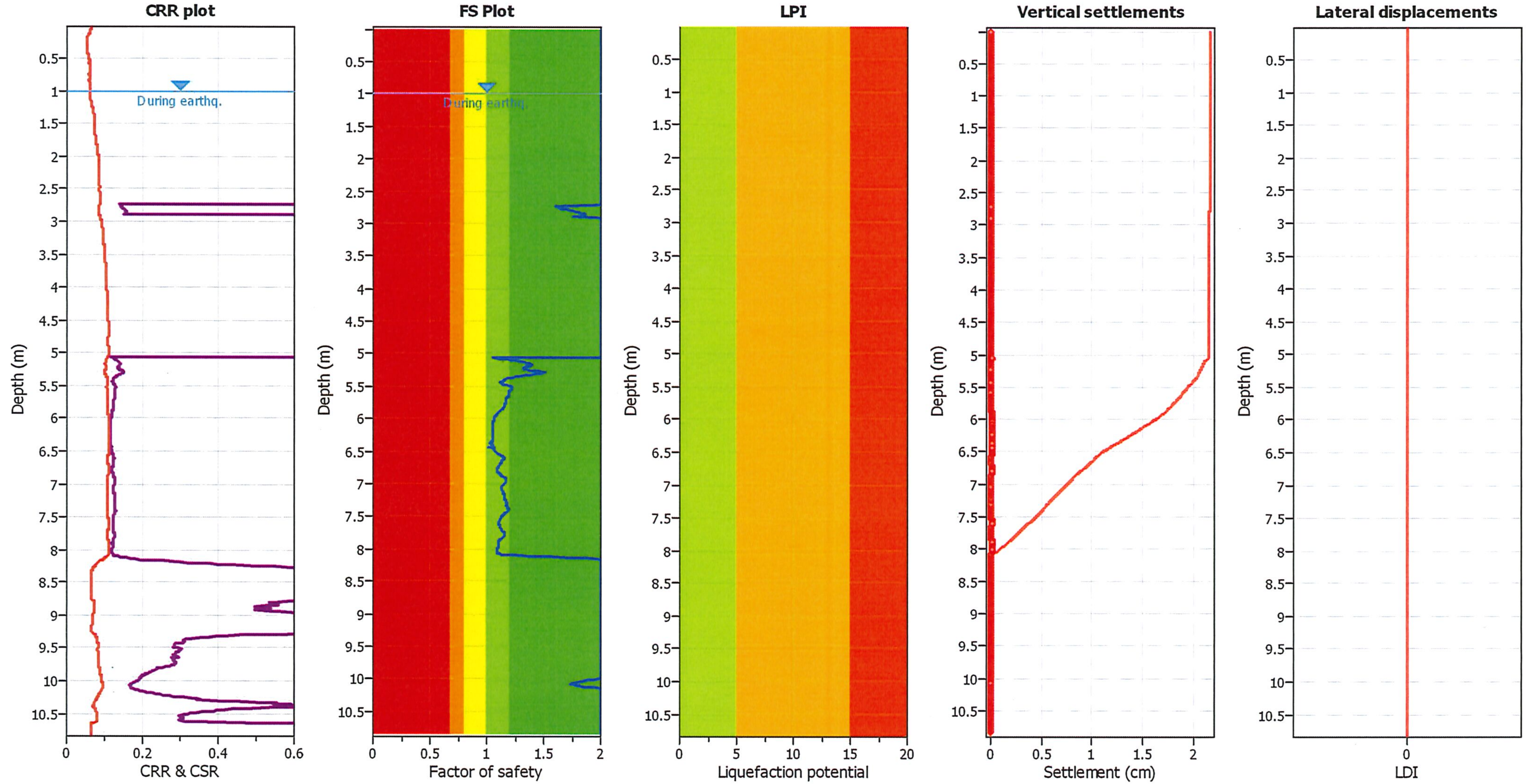






Zone A_1: Cyclic liquefaction likely depending on size and duration of cyclic loading
Zone A_2: Cyclic liquefaction and strength loss likely depending on loading and ground geometry
Zone B: Liquefaction and post-earthquake strength loss unlikely, check cyclic softening
Zone C: Cyclic liquefaction and strength loss possible depending on soil plasticity, brittleness/sensitivity, strain to peak undrained strength and ground geometry

Liquefaction analysis overall plots



Input parameters and analysis data

Analysis method:	B&I (2014)	Depth to GWT (erthq.):	1.00 m	Fill weight:	N/A
Fines correction method:	B&I (2014)	Average results interval:	3	Transition detect. applied:	No
Points to test:	Based on Ic value	Ic cut-off value:	2.60	K_σ applied:	Yes
Earthquake magnitude M_w:	5.90	Unit weight calculation:	Based on SBT	Clay like behavior applied:	Sands only
Peak ground acceleration:	0.12	Use fill:	No	Limit depth applied:	No
Depth to water table (insitu):	1.00 m	Fill height:	N/A	Limit depth:	N/A

F.S. color scheme

- Almost certain it will liquefy
- Very likely to liquefy
- Liquefaction and no liq. are equally likely
- Unlike to liquefy
- Almost certain it will not liquefy

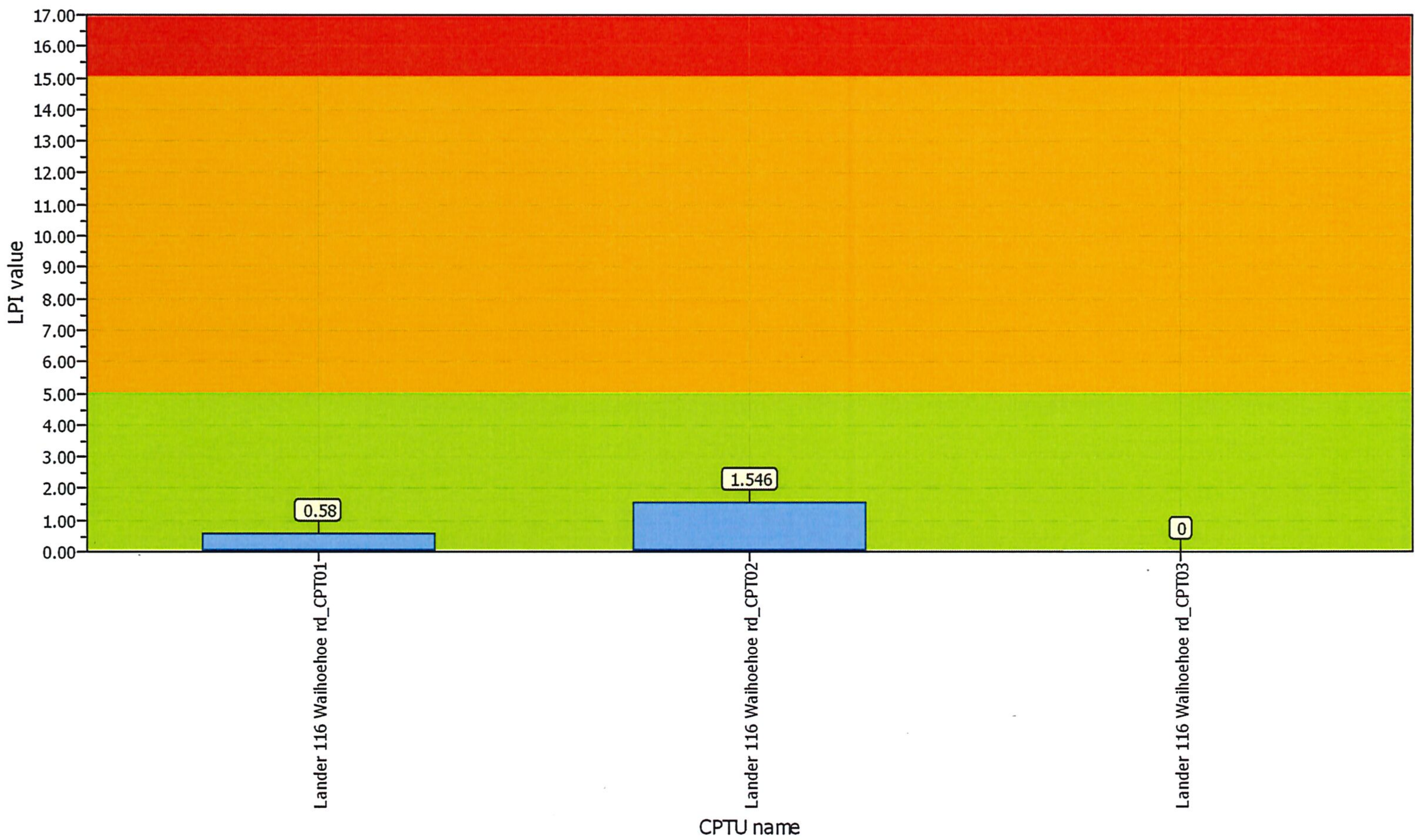
LPI color scheme

- Very high risk
- High risk
- Low risk

Project title : ULS(1/500)

Location : 116 Waihoehoe Road, Drury

Overall Liquefaction Potential Index report



LPI color scheme

- Very high risk
- High risk
- Low risk

Basic statistics

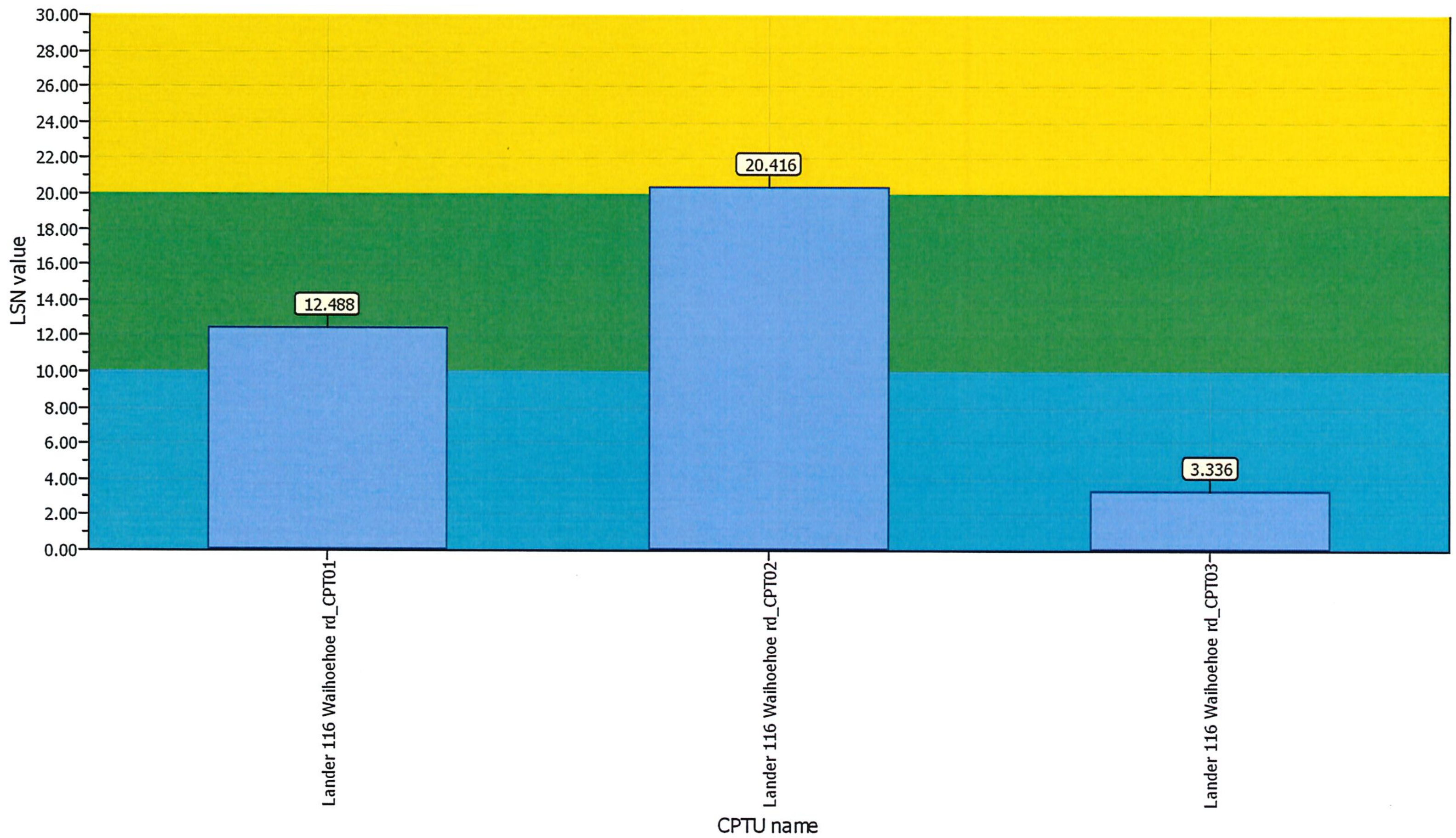
Total CPT number: 3
100.00% low risk
0.00% high risk
0.00% very high risk

Lander Geotechnical Consultants Limited
Level 3, 3 Osterley Way
P O Box 97 385, Manukau, Auckland 2241
www.landergeotechnical.co.nz

Project title : ULS(1/500)

Location : 116 Waihoehoe Road, Drury

Overall Liquefaction Severity Number report



LSN color scheme

- Severe damage
- Major expression of liquefaction
- Moderate to severe exp. of liquefaction
- Moderate expression of liquefaction
- Minor expression of liquefaction
- Little to no expression of liquefaction

Basic statistics

Total CPT number: 3

33.33% little liquefaction

33.33% minnor liquefaction

33.33% moderate liquefaction

0.00% moderate to major liquefaction

0.00% major liquefaction

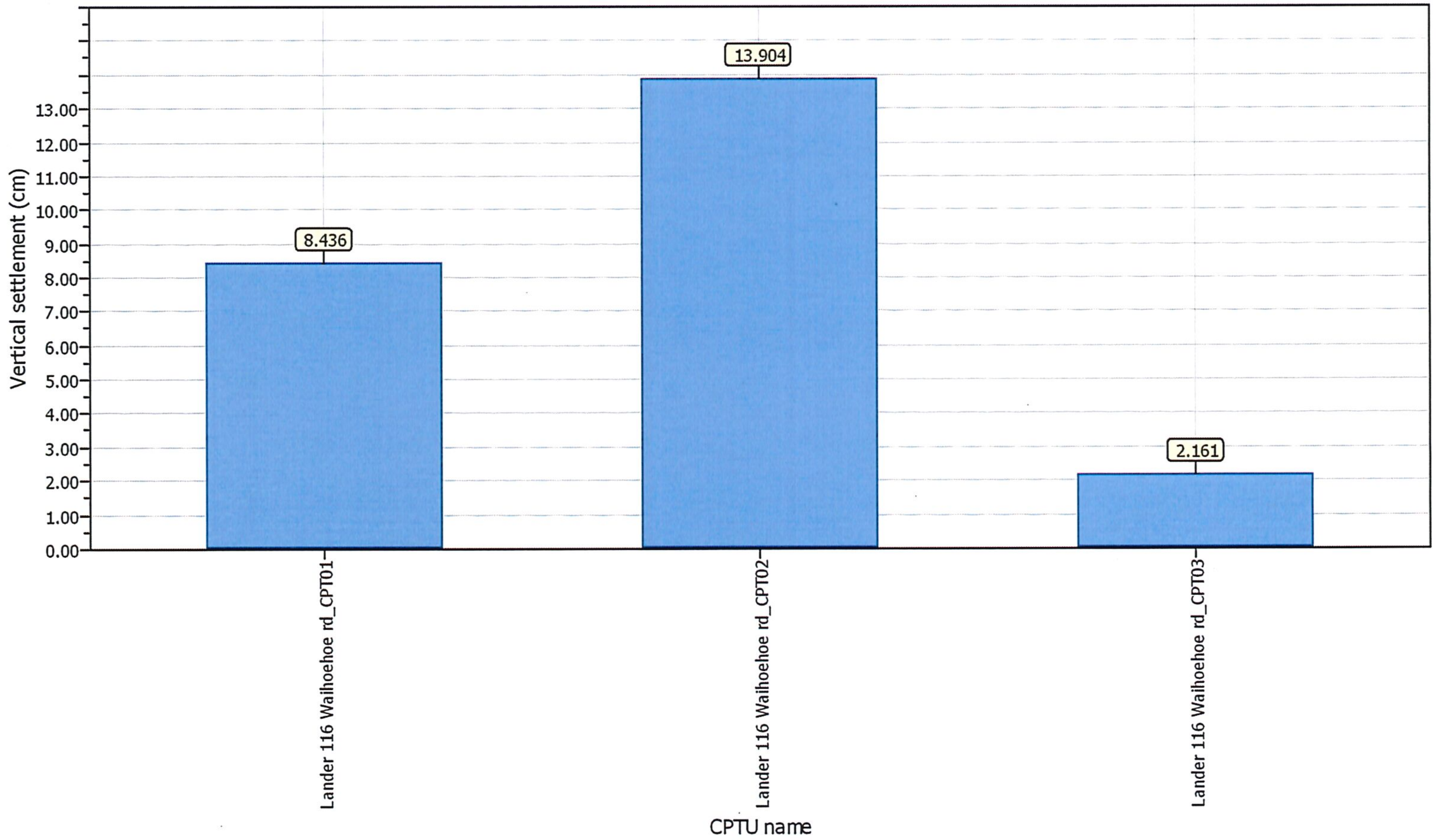
0.00% severe liquefaction

Lander Geotechnical Consultants Limited
Level 3, 3 Osterley Way
P O Box 97 385, Manukau, Auckland 2241
www.landergeotechnical.co.nz

Project title : ULS(1/500)

Location : 116 Waihoehoe Road, Drury

Overall vertical settlements report



GEOTECHNICS

Our Ref: 1009479.1000.0.0/REP01
Customer Ref: J00784
4 February 2019

Lander Geotechnical
Level 3, 3 Osterley Way
P O Box 97 385
Manukau, Auckland 2241

Attention: Shane Lander

Dear Shane

116 Waihoehoe Road, Drury

Laboratory Test Report

Samples from the above mentioned site have been tested as received according to your instructions. Test results are included in this report.

Samples not destroyed during testing will be retained for one month from the date of this report before being discarded.

Descriptions are enclosed for your information, but are not covered under the IANZ endorsement of this report.

Please reproduce this report in full when transmitting to others or including in internal reports.

If we can be of any further assistance, feel free to get in touch. Contact details are provided at the bottom of this page.

GEOTECHNICS LTD

Report prepared by:

....

Corey Papu-Gread
Christchurch Manager
Approved Signatory

Authorised for Geotechnics by:

Paul Burton
I have reviewed this document
2019.02.04 11:17:11 +13'00'

....

Paul Burton
Project Director

Report checked by:

....

Jack Singh
Laboratory Technician

IANZ ACCREDITED LABORATORY

All tests reported herein have been performed in accordance with the laboratory's scope of accreditation

4-Feb-19
\\ttgroup.local\corporate\geotechnicsgroup\projects\1009479\1009479.1000\workingmaterial\20190201.cxpg.jasi.1009479.1000.0.0.rep01.docx

GEOTECHNICS
45A Parkhouse Road
Wigram
Christchurch 8042
New Zealand
p. +64 3 361 0300

Geotechnics Project ID
1009479.1000.0.0
Customer Project ID
J00784

Determination of Water Content - NZS 4402:1986 Test 2.1

TEST DETAILS			
Location ID	116 Waihoehoe Road, Drury	116 Waihoehoe Road, Drury	
Location Description	116 Waihoehoe Road, Drury	116 Waihoehoe Road, Drury	
Location Data - Easting	N/A	N/A	
Location Data - Northing	N/A	N/A	
Location Data - Level	N/A	N/A	
Location Data - Chainage	N/A	N/A	
Location Data - Offset	N/A	N/A	
Geotechnics Sample ID	003/19-1	003/19-2	
Sample Reference	HA100 S1	HA110 S1	
Sample Depth	0.5-1.0	0.5-1.0	
Sample Description	Silty CLAY with trace sand and trace organics, orange brown mottled yellow brown and grey. Moist, extremely high plasticity.	Sandy silty CLAY, yellow brown mottled grey and orange brown. Moist, high plasticity.	
Specimen Reference	N/A	N/A	
Specimen Depth	N/A	N/A	
Specimen Description	N/A	N/A	
TEST RESULT			
Natural Water Content	**56.4%**	**30.9%**	
TEST REMARKS			
	• The material used for testing was natural. IANZ Accredited	• The material used for testing was natural. IANZ Accredited	
Approved By	CXPG	CXPG	
Date	1/02/2019	1/02/2019	

GEOTECHNICS
45A Parkhouse Road
Wigram
Christchurch 8042
New Zealand
p. p. +64 3 361 0300

Geotechnics Project ID	1009479.1000.0.0
Customer Project ID	J00784

Determination of Liquid & Plastic Limit, Plasticity Index - NZS 4402: 1986 Tests 2.2 (4 Point), 2.3 & 2.4

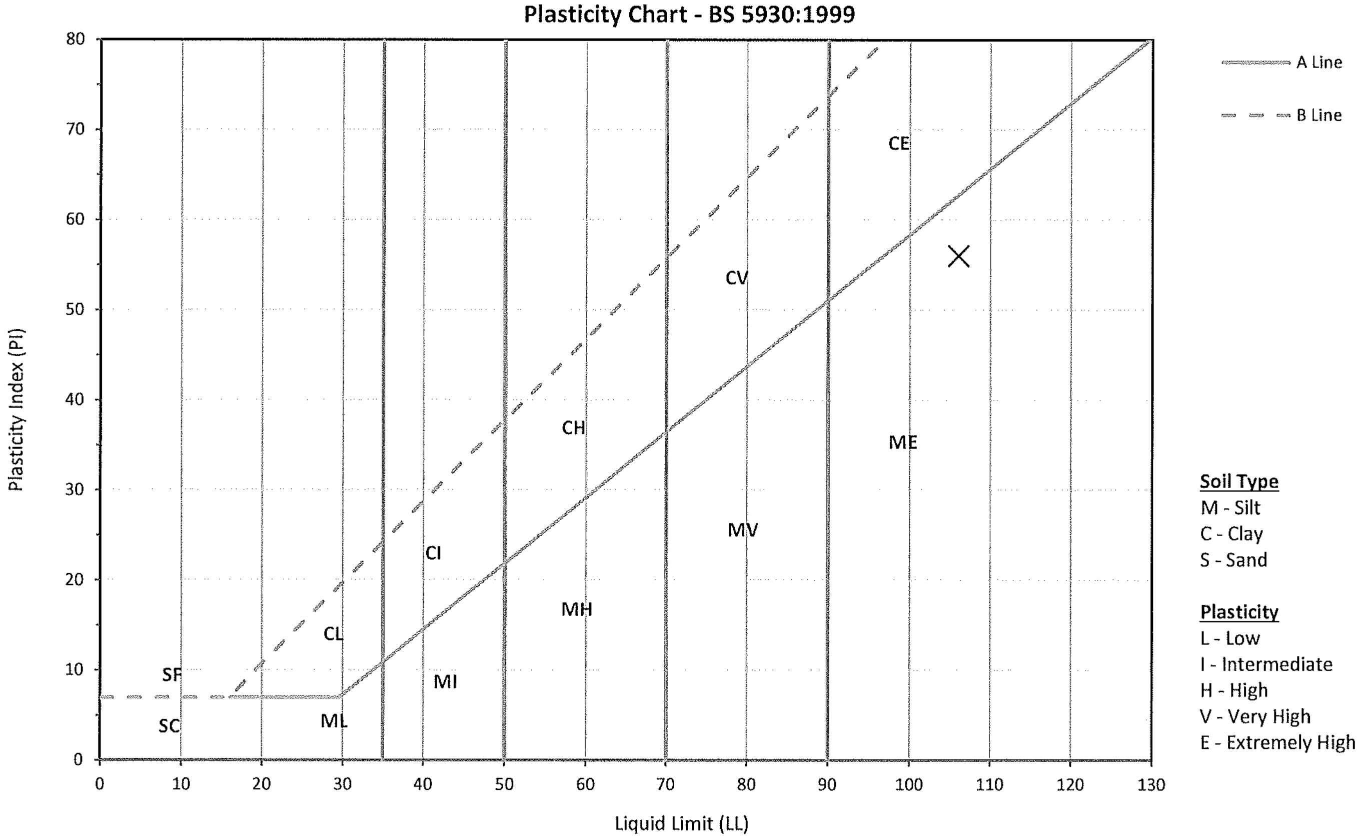
TEST DETAILS

LOCATION	**ID**	116 Waihoehoe Road, Drury		
	Description	116 Waihoehoe Road, Drury		
	Data	N/A		
SAMPLE	**Geotechnics ID**	003/19-1		
	Reference	HA100 S1	**Depth**	0.5-1.0
	Description	Silty CLAY with trace sand and trace organics, orange brown mottled yellow brown and grey. Moist, extremely high plasticity.		
SPECIMEN	**Reference**	N/A	**Depth**	N/A
	Description	N/A		

TEST RESULTS

Liquid Limit	**106**
Plastic Limit	**50**
Plasticity Index	**56**

Plasticity Chart - BS 5930:1999



The plasticity chart is provided for your inference only and is not covered under our scope of IANZ accreditation. Due to the nature of classifications it is possible to have discrepancies between observational behaviour descriptions and measured parameters

TEST REMARKS

- The material used for testing was natural, fraction passing a 425um sieve.

This test result is IANZ accredited.

Approved By	CXPG	**Date**	4/02/2019

GEOTECHNICS

45A Parkhouse Road
Wigram
Christchurch
New Zealand
p. +64 3 361 0300

Geotechnics Project ID	1009479.1000.0.0
Customer Project ID	J00784

Determination of Linear Shrinkage - Determination of the Linear Shrinkage - NZS 4402:1986 Test 2.6

TEST DETAILS

LOCATION	**ID**	116 Waihoehoe Road, Drury		
	Description	116 Waihoehoe Road, Drury		
	Data	N/A		
SAMPLE	**Geotechnics ID**	003/19-1		
	Reference	HA100 S1	**Depth**	0.5-1.0
	Description	Silty CLAY with trace sand and trace organics, orange brown mottled yellow brown and grey. Moist, extremely high plasticity.		
SPECIMEN	**Reference**	N/A	**Depth**	N/A
	Description	N/A		

TEST RESULT

Linear Shrinkage **25%**

TEST REMARKS

• The material used for testing was natural, fraction passing a 425um sieve.

This test result is IANZ accredited.

Approved By	CXPG	**Date**	31/01/2019

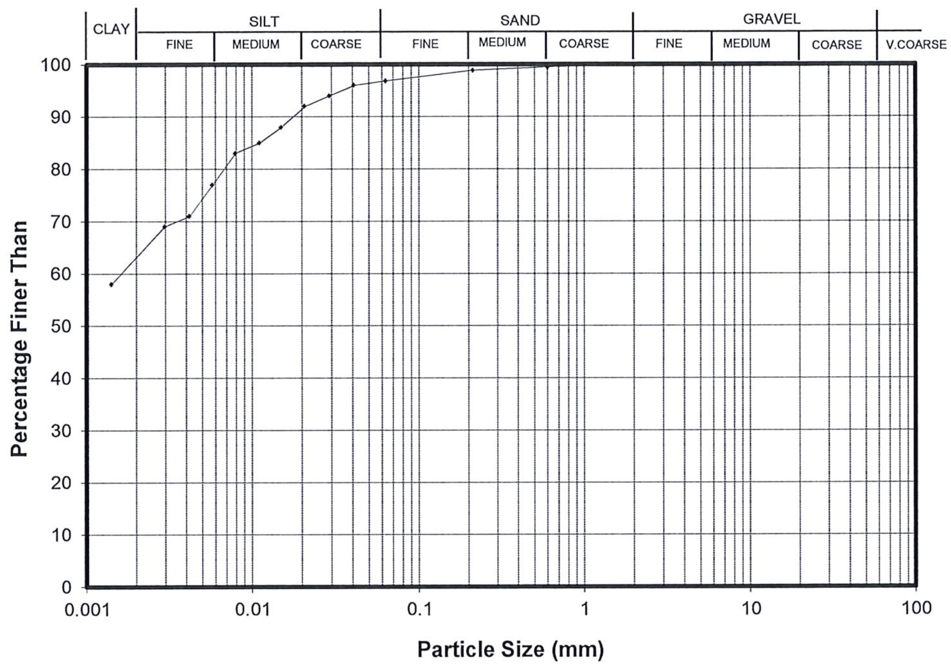
GEOTECHNICS

45a Parkhouse Road, Wigram, Christchurch 8142
P 64 03 361 0300
www.geotechnics.co.nz

Site: 116 Waihoehoe Road, Drury
BH No.: HA100S1 Sample ID.: 003/19-1
Test Method Used : NZS 4402:1986 Test 2.8.4 Hydrometer

Your Job No.: J00784
Our Job No.: 1009479.1000.0.0
Depth: 0.5-1.0m

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
4.75	-		
3.35	-		
2.00	100		
0.600	99		
0.212	99		
0.063	97		

Equivalent Particle Diameter D (mm)	% of Particles Finer than D
0.0406	96
0.0290	94
0.0207	92
0.0150	88
0.0110	85
0.0079	83
0.0057	77
0.0041	71
0.0030	69
0.0014	58

Sample history : Natural, whole soil
Description: Silty CLAY with trace sand and trace organics, orange brown mottled yellow brown and grey. Moist, extremely high plasticity.
Solid Density (Assumed) : 2.70t/m^3

Remarks : A sub sample was split from the original sample for hydrometer analysis. This sample was soaked with a dispersing agent (~2 hrs), then the mechanical shaker was used, until the material was brought into suspension, before proceeding with the test.
Suspension pH 8.0.
The classification of sand-silt-clay components were described on the basis of particle size analysis. Use of assumed values in calculations is at the customers discretion and risk.
Sample description is not IANZ accredited.

Entered by : CXPG Date : 31/01/2019 Checked by : CFK Date : 31/01/2019

GEOTECHNICS
45A Parkhouse Road
Wigram
Christchurch 8042
New Zealand
p. p. +64 3 361 0300

Geotechnics Project ID	1009479.1000.0.0
Customer Project ID	J00784

Determination of Liquid & Plastic Limit, Plasticity Index - NZS 4402: 1986 Tests 2.2 (4 Point), 2.3 & 2.4

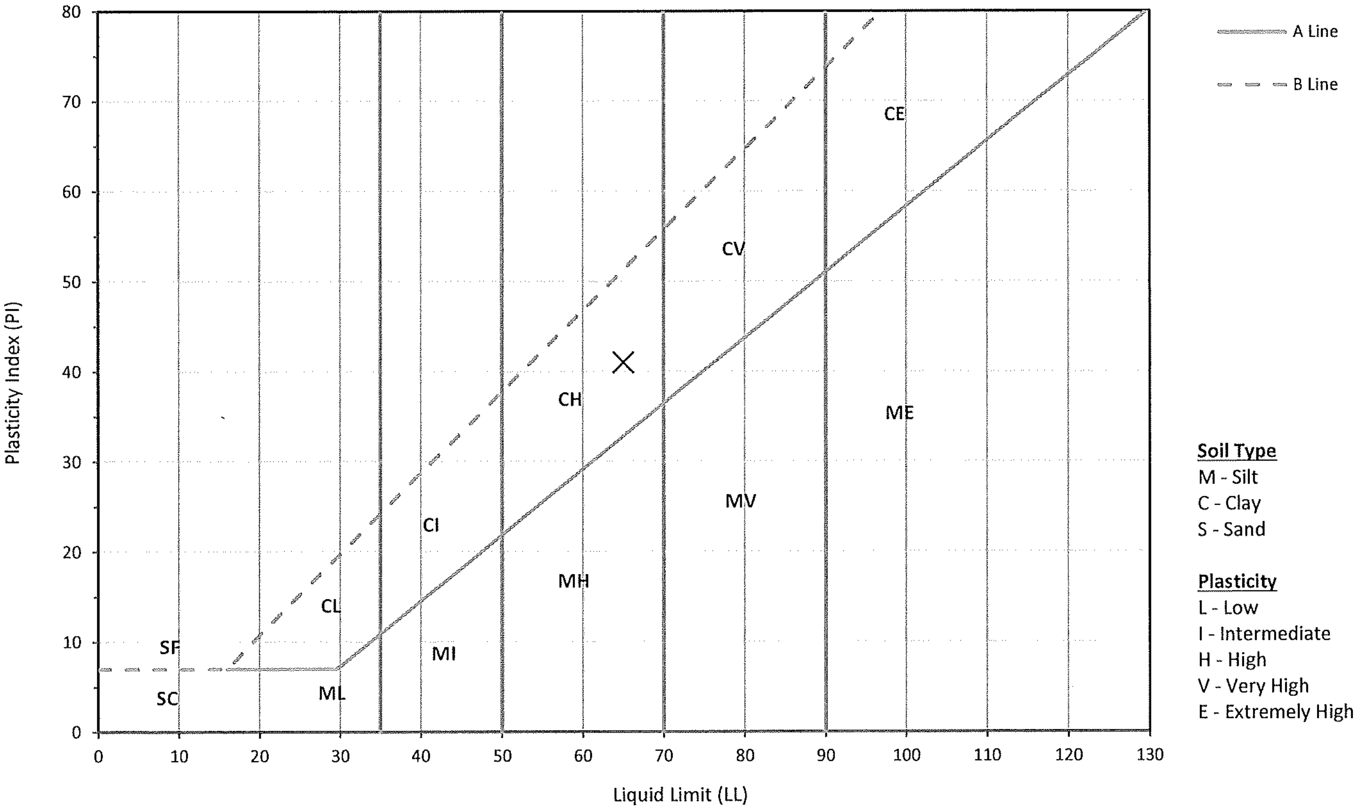
TEST DETAILS

LOCATION	ID	116 Waihoehoe Road, Drury		
	Description	116 Waihoehoe Road, Drury		
	Data	N/A		
SAMPLE	Geotechnics ID	003/19-2		
	Reference	HA110 S1	Depth	0.5-1.0
	Description	Sandy silty CLAY, yellow brown mottled grey and orange brown. Moist, high plasticity.		
SPECIMEN	Reference	N/A	Depth	N/A
	Description	N/A		

TEST RESULTS

Liquid Limit	**65**
Plastic Limit	**24**
Plasticity Index	**41**

Plasticity Chart - BS 5930:1999



The plasticity chart is provided for your inference only and is not covered under our scope of IANZ accreditation. Due to the nature of classifications it is possible to have discrepancies between observational behaviour descriptions and measured parameters

TEST REMARKS

- The material used for testing was natural, fraction passing a 425um sieve.

This test result is IANZ accredited.

Approved By	CXPG	**Date**	4/02/2019

45A Parkhouse Road
Wigram
Christchurch
New Zealand
GEOTECHNICS
p. +64 3 361 0300

Geotechnics Project ID	1009479.1000.0.0
Customer Project ID	J00784

Determination of Linear Shrinkage - Determination of the Linear Shrinkage - NZS 4402:1986 Test 2.6

TEST DETAILS

LOCATION	ID	116 Waihoehoe Road, Drury		
	Description	116 Waihoehoe Road, Drury		
	Data	N/A		
SAMPLE	Geotechnics ID	003/19-2		
	Reference	HA110 S1	Depth	0.5-1.0
	Description	Sandy silty CLAY, yellow brown mottled grey and orange brown. Moist, high plasticity.		
SPECIMEN	Reference	N/A	Depth	N/A
	Description	N/A		

TEST RESULT

Linear Shrinkage **17%**

TEST REMARKS

• The material used for testing was natural, fraction passing a 425um sieve.

This test result is IANZ accredited.

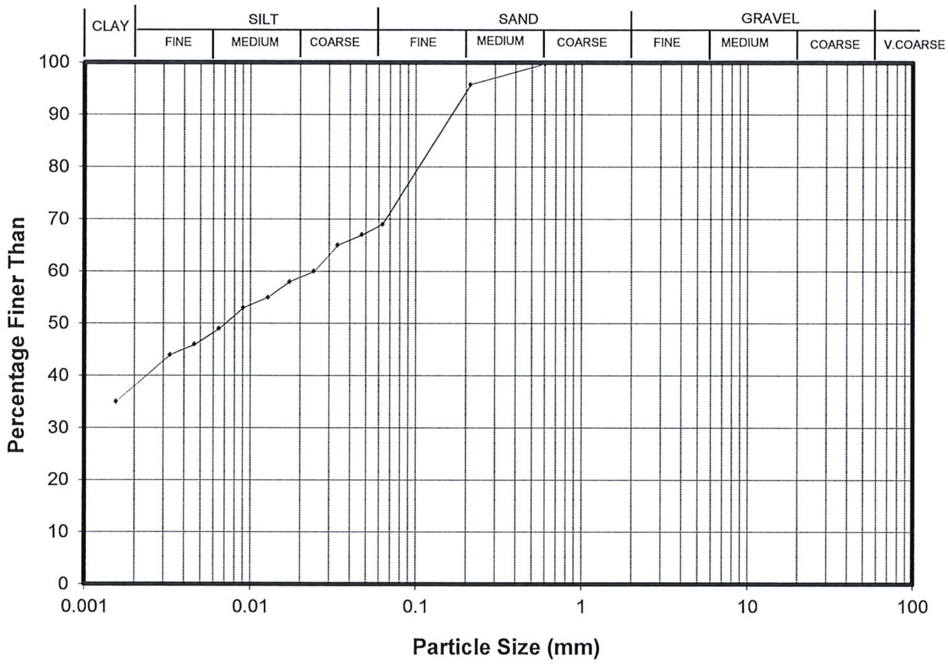
Approved By	CXPG	**Date**	31/01/2019

GEOTECHNICS
45a Parkhouse Road, Wigram, Christchurch 8142
P 64 03 361 0300
www.geotechnics.co.nz

Site: 116 Waihoehoe Road, Drury
BH No.: HA110S1 Sample ID.: 003/19-2
Test Method Used : NZS 4402:1986 Test 2.8.4 Hydrometer

Your Job No.: J00784
Our Job No.: 1009479.1000.0.0
Depth: 0.5-1.0m

PARTICLE SIZE ANALYSIS



Sieve (mm)	Total % Passing	Sieve (mm)	Total % Passing
4.75	-		
3.35	-		
2.00	100		
0.600	100		
0.212	96		
0.063	69		

Equivalent Particle Diameter D (mm)	% of Particles Finer than D
0.0473	67
0.0337	65
0.0242	60
0.0172	58
0.0127	55
0.0090	53
0.0065	49
0.0046	46
0.0033	44
0.0015	35

Sample history : Natural, whole soil
Description: Sandy silty CLAY, yellow brown mottled grey and orange brown. Moist, high plasticity.

Solid Density (Assumed) : 2.70t/m^3

Remarks : A sub sample was split from the original sample for hydrometer analysis. This sample was soaked with a dispersing agent (~2 hrs), then the mechanical shaker was used, until the material was brought into suspension, before proceeding with the test.
Suspension pH 8.0.
The classification of sand-silt-clay components were described on the basis of particle size analysis. Use of assumed values in calculations is at the customers discretion and risk.
Sample description is not IANZ accredited.

Entered by : CXPG Date : 31/01/2019 Checked by : CFK Date : 31/01/2019

Appendix G

Preliminary Site Investigation

PRELIMINARY SITE INVESTIGATION
WAIHOEHOE ROAD PLAN CHANGE AREA
DRURY
AUCKLAND

For the Attention of:

Oyster Capital Limited

Reference: FES 1198.001 March 2019

Company Information

Focus Environmental Services Limited

PO Box 11455

Ellerslie

Auckland 1542

Telephone: +64 9 579 4155

Email: mail@focusenvironmental.co.nz

Quality Information

Project Name	Preliminary Site Investigation Waihoehoe Road, Drury
Project Number	1198.001
File Reference	M:\2019 Jobs\Waihoehoe Road Plan Change, Waihoehoe Road, Drury\01 Report\1198.001_PSI_SD.docx
Date	March 2019

Author

Shane Dolan
Environmental Scientist

Reviewed

Samuel Woolley
Senior Environmental Scientist

Authorised

David O'Reilly
Principal Environmental Consultant

Distribution List

Parties	Copies
Oyster Capital Limited	1
Focus Environmental Services Limited	1

Contents

Figures

Appendices

Executive Summary

Focus Environmental Services Limited was contracted by Oyster Capital Limited to carry out a preliminary site investigation for the Waihoehoe Road Plan Change Area, Drury, Auckland.

This Preliminary Site Investigation has been prepared in general accordance with the requirements of the Contaminated Land Management Guidelines No. 1 (Ministry for the Environment, 2011).

The history of the site was researched by Focus Environmental Services personnel, which involved a review of the available historical aerial photographs of the site, a review of the Auckland Council property file, a contaminated sites enquiry to Auckland Council, a review of the historical certificates of title and an onsite interview. During the review of the available information any potentially contaminating activities or land uses were identified.

In summary, during the review of the available information the potential for ground contamination associated with the use of lead-based paint and potential asbestos ground contamination associated with former demolition activities at the site was noted.

Following the desk top assessment, the sites at 116, 136 and 140 Waihoehoe Road were visited and a site inspection and walk over was carried out. The sites were inspected by Focus Environmental Services Limited personnel on 8th of February 2019. During the site inspection any potentially contaminating activities or land uses were identified.

In summary, during the site inspection, potential ground contamination associated with underground fuel storage tanks, storage of waste oil and fuel/oil leaks, potential ground contamination associated with the Engineering Workshop and Foundry activities, evidence of waste/refuse burial, evidence of burning, and evidence of potential spray race operations were noted at 116 Waihoehoe Road; evidence of burning was noted at 136 Waihoehoe Road. There were no potentially contaminating land uses and/or activities were identified at the site at 140 Waihoehoe Road, Drury.

With the exception to 116, 136 and 140 Waihoehoe Road, access to the properties within the Waihoehoe Road Plan Change Area was restricted, therefore, the site investigation was limited to a historical review. During the historical review of these sites, potential for ground contamination associated with the use of lead-based paint were noted at 18 Waihoehoe Road, 28 Waihoehoe Road, 44 Waihoehoe Road, 76A Waihoehoe Road, 76 Waihoehoe Road, 112 Waihoehoe Road, 15 Kath Henry Lane, and 50 Kath Henry Lane.

In addition, potential asbestos ground contamination associated with former demolition activities were noted at 18 Waihoehoe Road, 44 Waihoehoe Road, 76A Waihoehoe Road, 76 Waihoehoe Road 112 Waihoehoe Road. Furthermore, historic and current horticultural activities were noted at 15 Kath Henry Lane.

The information obtained of the sites history and from the site inspection and walk over was assessed to determine if any potentially hazardous activities listed on the Hazardous Activities and Industries List (HAIL) had occurred on site as a result of past or current land use.

Due to the potential sources of contamination identified it is considered that there is evidence to suggest that an activity outlined in the Hazardous Activities Industries List (HAIL) has been, or is or is currently being, carried out on the following sites; 18 Waihoehoe Road, 28 Waihoehoe Road, 44 Waihoehoe Road, 76A Waihoehoe Road, 76 Waihoehoe Road, 112 Waihoehoe Road, 116 Waihoehoe Road, 136 Waihoehoe Road, 15 Kath Henry Lane, and 50 Kath Henry Lane.

Prior to the development of the site where potentially contaminating land uses and/or activities have taken place, a detailed site investigation is recommended. However, prior to the completion of the DSI, a thorough site walkover and inspection should be carried out to identify any further potentially contaminating land uses or activities across the site.

The detailed site investigation would confirm if the identified land uses and/or activities have affected the site soils and will confirm the consenting requirements for the site.

Submitted By,

David O'Reilly
Principal Environmental Consultant
Focus Environmental Services Limited

1.0 Scope

1.1 This report has been prepared at the request of Oyster Capital Limited ("the Client") in terms of the Focus Environmental Services Limited Agreement ("Agreement").

1.2 The following report is based on:

- *Information provided by the client;*
- *A review of historical aerial photographs available for the site;*
- *A search of the Auckland Council Property File;*
- *A search of the Auckland Council Contaminated Sites Database;*
- *A review of the Historical Certificate of Title;*
- *An onsite interview; and*
- *A site walkover and inspection.*

1.3 We have not independently verified the information provided to us by the Client or its completeness. We do not express an opinion on the accuracy or the reliability of such information.

1.4 No warranties are given, intended or implied.

1.5 Opinion, inferences, assumptions and interpretations made in this report should not be construed as legal opinion.

1.6 Where an assessment is given in this report, the Client must also rely upon their own judgement, knowledge and assessment of the subject of this report before undertaking any action.

1.7 This report must not be used in any other context or for any other purpose other than that for which it has been prepared without the prior written consent of Focus Environmental Services Limited.

1.8 This report is strictly confidential and intended for the sole use of the Client and shall not be disclosed without the prior written consent of Focus Environmental Services Limited.

2.0 Site Identification

The Waihoehoe Road Plan Change site consists of seventeen separate properties located at Waihoehoe Road and Kath Henry Lane, Drury, Auckland as shown in Figure 1 attached. The sites are a mix of rectangular and irregular in shape and are zoned 'Future Urban Zone' under the Auckland Unitary Plan: Operative in Part.

The site identification details are provided in Table 1 below.

Table 1: Site Identification Details: Waihoehoe Road Plan Change Area, Drury

Physical Address	Legal Description	Area (ha)	Grid Reference
18 Waihoehoe Road, Drury	Lot 10 DP 135804	0.3760	1773587mE 5891903mN
28 Waihoehoe Road, Drury	Lot 3 DP 60259	0.8468	1773663mE 5891890mN
44 Waihoehoe Road, Drury	Lot 1 DP 135804	1.0000	1773775mE 5891906mN
76A Waihoehoe Road, Drury	Lot 3 DP 115881	11.9877	1773934mE 5892461mN
76 Waihoehoe Road, Drury	Lot 2 DP 115881	4.1991	1773891mE 5892077mN
112 Waihoehoe Road, Drury	PT ALLOT 1 DP 60259	4.0231	1773989mE 5891934mN
116 Waihoehoe Road, Drury	Pt Lot 1 DP 146189, Pt Lot 2 DP 146189, Lot 2 DP 173904, Lot 3 DP 173904	15.1465	1774176mE 5892098mN
136 Waihoehoe Road, Drury	Lot 1 DP 371528	1.7945	1774086mE 5891881mN
140 Waihoehoe Road, Drury	Lot 2 DP 371528	1.5220	1774186mE 5891860mN
15 Kath Henry Lane, Drury	Lot 9 DP 135804	1.0000	1773661mE 5891985mN
18 Kath Henry Lane, Drury	Lot 2 DP 135804	1.0000	1773776mE 5892001mN
27 Kath Henry Lane, Drury	Lot 8 DP 135804, 1/6 SH Lot 12 DP 135804	1.0000	1746678mE 5926906mN
34 Kath Henry Lane, Drury	Lot 3 DP 135804, 1/6 SH Lot 12 DP 135804	1.0000	1773784mE 5892130mN
44 Kath Henry Lane, Drury	Lot 4 DP 135804, 1/6 SH Lot 12 DP 135804	1.0000	1773799mE 5892247mN
45 Kath Henry Lane, Drury	Lot 7 DP 135804, 1/6 SH Lot 12 DP 135804	1.0000	1773712mE 5892224mN

Physical Address	Legal Description	Area (ha)	Grid Reference
49 Kath Henry Lane, Drury	Lot 6 DP 135804, 1/6 SH Lot 12 DP 135804, 1/2 SH Lot 13 DP 135804	1.0000	1773723mE 5892361mN
50 Kath Henry Lane, Drury	Lot 5 DP 135804, 1/6 SH Lot 12 DP 135804, 1/2 SH Lot 13 DP 135804	1.0000	1773811mE 5892364mN

3.0 Site Topography

The properties within the Waihoehoe Road Plan Change Area contain undulating landscapes with a number of gullies and surface water bodies. Descriptions of the topographies of the individual sites are provided below.

The site contour plan is presented in Appendix A.

3.1 18 Waihoehoe Road, Drury

The property at 18 Waihoehoe Road is predominantly flat with a gradual slope towards the western boundary of the site.

The Hingaia Stream is located approximately 270m to the west of the site.

3.2 28 Waihoehoe Road, Drury

The property at 28 Waihoehoe Road is predominantly flat with a gradual slope towards the north-western portion of the site.

The Hingaia Stream is located approximately 310m to the west of the site.

3.3 44 Waihoehoe Road, Drury

The property at 44 Waihoehoe Road has a gradual slope towards the north-western portion of the site, with the highest point of the site located in the south-eastern portion of the site.

The Hingaia Stream is located approximately 470m to the west of the site.

3.4 76A Waihoehoe Road, Drury

The property at 76A Waihoehoe Road has an undulating landscape with the highest point located in the south-eastern portion of the site which flows towards a gully located in the north-western portion of the site.

The Waihoehoe Stream is located approximately 120m north-east of the site.

3.5 76 Waihoehoe Road, Drury

The property at 76 Waihoehoe Road is predominantly flat with a gentle slope towards a gully which is located in the central portion of the site.

The Waihoehoe Stream is located approximately 490m north-east of the site.

3.6 112 Waihoehoe Road, Drury

The property at 112 Waihoehoe Road is predominantly flat with a gentle slope towards a gully which is located in the central portion of the site.

The Waihoehoe Stream is located approximately 390m north-east of the site.

3.7 116 Waihoehoe Road, Drury

The property at 116 Waihoehoe Road is predominantly flat with a gentle slope towards the Waihoehoe Steam which is located along northern boundary of the site.

The Waihoehoe Stream is located adjacent to the northern boundary of the site.

3.8 136 Waihoehoe Road, Drury

The property at 136 Waihoehoe Road is predominantly flat with a gradual slope towards the pond which is located in the northern portion of the site.

An unnamed tributary to the Hingaia Steam is located approximately 390m to the south of the site.

3.9 140 Waihoehoe Road, Drury

The property at 140 Waihoehoe Road is predominantly flat with a gentle slope towards the north-western portion pf the site.

The Waihoehoe Stream is located approximately 355m to the north-east of the site.

3.10 15 Kath Henry Lane

The property at 15 Kath Henry Lane is predominantly flat with a gradual slope towards a gully in the central portion of the site.

The Hingaia Stream is located approximately 325m to the west of the site.

3.11 18 Kath Henry Lane

The property at 18 Kath Henry Lane is predominantly flat, with a general slope towards a gully located in the northern portion of the site.

The Hingaia Stream is located approximately 450m to the south-west of the site.

3.12 27 Kath Henry Lane

The property at 27 Kath Henry Lane has an undulating landscape with the residential dwelling located in the highest portion of the site which flows towards a gully located in the south-western portion of the site.

The Hingaia Stream is located approximately 370m to the south-west of the site.

3.13 34 Kath Henry Lane

The property at 34 Kath Henry Lane is predominantly flat.

The Hingaia Stream is located approximately 410m to the west of the site.

3.14 44 Kath Henry Lane

The property at 44 Kath Henry Lane is predominantly flat.

The Hingaia Stream is located approximately 440m to the south-west of the site.

3.15 45 Kath Henry Lane

The property at 45 Kath Henry Lane is predominantly flat.

The Hingaia Stream is located approximately 350m to the south-west of the site.

3.16 49 Kath Henry Lane

The property at 49 Kath Henry Lane is predominantly flat.

The Hingaia Stream is located approximately 410m to the south-west of the site.

3.17 50 Kath Henry Lane

The property at 50 Kath Henry Lane is predominantly flat with a gentle slope towards a low-lying are in the north-eastern portion of the site.

The Waihoehoe Stream is located approximately 390m to the north-east of the site

4.0 Geology and Hydrology

Published geological maps[1] indicate the subject sites are typically underlain by alluvial deposits of the East Coast Bays Formation. A description of the underlying geologies is presented in Table 2 below.

Table 2: Geology: Waihoehoe Road Plan Change Area, Drury

Key name	Late Pliocene to Middle Pleistocene pumiceous river deposits
Simple name	Neogene sedimentary rocks
Main rock name	Sand
Description	Pumiceous mud, sand and gravel with muddy peat and lignite: rhyolite pumice, including non-welded ignimbrite, tephra and alluvia
Subsidiary rocks	Mud gravel peat lignite tephra pumice
Key group	Late Pliocene to Middle Pleistocene sediments
Stratigraphic lexicon name	Puketoka Formation
Absolute age (min)	0.071 million years
Absolute age (max)	3.6 million years
Rock group	Sandstone
Rock class	Clastic sediment

No groundwater investigation was carried out as part of this investigation.

The nearest surface water body is Waihoehoe Stream which runs along the north-eastern boundary of 116 Waihoehoe Road, Drury.

[1] Geology of the Auckland Area (Institute of Geological &Nuclear Sciences 1:25,000 geological map 3, 2011)

5.0 Regulatory Framework

5.1 The National Environmental Standard

The Resource Management (National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health) Regulations 2011 (NES) came into effect on the 1st of January 2012 and supersedes any District Plan rules that related to contaminated land. Any Regional Plan rules relating to contaminated land are still applicable.

In brief, the objective of the NES is to ensure that land affected by contaminants is identified and assessed and, if necessary, remediated or managed to protect human health. The NES only applies to the activities: removing or replacing all, or part of, a fuel storage system; sampling the soil; disturbing the soil; subdividing the land; and changing the land use, and where an activity or industry described in the Hazardous Activities and Industries List (HAIL) is being, has been, or is more likely than not to have been undertaken on the piece of land.

The NES also contains reference to the soil contaminant standards for human health ($SCSs_{(health)}$), for a variety of land use scenarios along with reference to best practice reporting documents.

The Ministry for the Environment HAIL is presented as Appendix B.

5.2 Auckland Unitary Plan: Operative in Part

The contaminated land rules of the Auckland Unitary Plan: Operative in Part (AUP: OP) have immediate legal effect following its notification. As the AUP: OP was notified on the 15th of November 2016 the contaminated land rules of the AUP: OP must be considered.

In brief, the objective of the AUP: OP is to manage land containing elevated levels of contaminants to protect human health and the environment and to enable the effective use of the land.

The contaminated land rules of the AUP: OP apply when the land contains contaminants above those levels specified in Table E30.6.1.4.1 of Chapter E30 of the AUP: OP.

6.0 Site History

The history of the site was researched by Focus Environmental Services personnel, which involved a review of the available historical aerial photographs of the site, a search of the Auckland Council property file, an Auckland Council contaminated sites enquiry, a review of the historical certificate of titles and an onsite interview.

6.1 Historical Aerial Photographs

Descriptions of the historical aerial photographs for the subject sites are presented in Table 3 - 19 below. The historical aerial photographs for the sites are presented in Appendix C.

Table 3: Historical Photographs: 18 Waihoehoe Road, Drury

Date	Description
1942 - 1969	The 1942 - 1969 historical photographs show the subject site located to the north of the junction between Waihoehoe Road and Flanagan Road. The Southern Line train network can be seen adjacent to the western boundary of the site. The site appears to be occupied by four separate lots, potentially in use for residential purpose. The surrounding properties are predominantly rural in use.
1974 – 1996	The 1974 – 1996 historical photographs show the removal/demolition of the three dwellings (HB01 – HB03) which were located in the central and northern portion of the site. The remaining lot which is located in the southern portion of the site is occupied by a dwelling with a garage (1) to the north and what appears to be a shed to the west. The surrounding properties in use for rural and rural residential purposes.
2003/04 - 2011	The 2003/04 - 2011 historical photograph show the subject site relatively unchanged from the 1996 historical photograph with the southern portion of the site still developed for residential purposes. An additional structure, most likely the garage (2) can be seen to the north of the residential dwelling. The northern portion of the site is managed grass. The 2010 historical photograph also shows the addition of a further shed, which is located adjacent to the most recent shed added to the site (2008). With the exception of the properties to the east which are in use for commercial/industrial purpose and the properties to the south, which appear to be utilised for glasshouses, the surrounding properties appear to be predominantly rural residential in use.
2015 - 2017	The 2015 - 2017 historical photographs show the subject site generally as it appeared in the 2011 historical photograph. Further structures have been added to the north of the existing structure (Relocated storage shed) and along the eastern boundary (Vehicle maintenance shed) of the site. With the exception of the properties to the east which are in use for commercial/industrial purpose and the properties to the south which appear to be utilised for glasshouses, the surrounding properties appear to be predominantly rural residential in use.

Due to the age of the existing dwelling and garage (1) identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

In addition, due to the age of the historic site buildings (HB01 – HB03) identified (pre-1996) there is the potential for lead based paint to have been used on the external building materials and therefore there is the potential for lead to be present in the soils surrounding the site buildings. Furthermore, there is also potential for asbestos fibres to be present in the soils as a result of demolition/removal works.

It should be noted that no areas of potential filling were identified during the review of the available historical photographs.

Table 4: Historical Photographs: 28 Waihoehoe Road, Drury

Date	Description
1942, 1960, 1969, 1974, 1981	The 1942 - 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural residential purposes. What appears to be the existing residential dwelling, garage and shed can be seen in the central east portion of the site. The western portion of the site which boarders the eastern boundary of 18 Waihoehoe Road appears to be utilised as a grazing paddock. Waihoehoe Road can be seen adjacent to the southern boundary of the site. The surrounding properties appear to be predominantly rural in use.
1996, 2003/2004 - 2017	The 1996 historical photograph is of poor resolution, however, it appears to show no significant alterations to the site from the 1981 historical photograph. The addition of Kath Henry Lane can be seen adjacent to the eastern boundary of the site which provides access to the residential properties located to the north of the subject site. With the exception of the properties to the east which are in use for commercial/industrial purpose and the properties to the south which appear to be utilised for glasshouse, the surrounding properties appear to be predominantly rural residential in use.

Due to the age of the existing dwelling, garage & shed identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 5: Historical Photographs: 44 Waihoehoe Road, Drury

Date	Description
1942	The 1942 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site is undeveloped with no structures present. Waihoehoe Road can be seen along the southern boundary of the site. The surrounding properties are predominantly rural in use.
1960, 1969, 1974, 1981,	The 1960 - 1981 historical photographs show the addition of a structure, potentially a farm shed (HB01) and what appears to be a stockholding yard located adjacent to the eastern boundary of the site. The remaining areas of the site are in use for rural purposes. The surrounding properties appear to be predominantly in use for rural purposes.
1996 – 2003/04	The 1996 – 2003/04 historical photographs are of poor resolution, however it appears to show the removal/demolition of the farm shed (HB01) and livestock holding pen. What appears to be a dwelling and shed (Packing shed) can be seen in the central and south eastern portion of the site respectively. The remaining areas of the site to the west are in use as grazing paddocks. A site access lane can be seen adjacent to the eastern boundary of the site. With the exception of the properties to the east which are in use for commercial/industrial purpose and the properties to the south which appear to be utilised for glasshouse, the surrounding properties appear to be predominantly rural residential in use.
2006 - 2017	The 2006 - 2017 historical photographs shows the subject site relatively unchanged from the 2003-04 historical photograph and in use for rural-residential purposes. The residential area of the site which consists of a dwelling, garage and associated curtilage can be seen in the north-eastern portion of the property. The elongated shed which is most likely the packing shed is located in the south-eastern corner of the site remains and the surrounding courtyard has now been extended. With the exception of the properties to the east which are in use for commercial/industrial purpose and the properties to the south which appear to be utilised for glasshouse, the surrounding properties appear to be predominantly rural residential in use.

Due to the age of the existing dwelling, garage, and packing shed identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

In addition, due to the age of the former farm shed (HB01) identified (pre-1996) located along the eastern boundary of the site, it is considered that asbestos containing materials and lead based paint may have been used on the external building materials. Therefore, there is the potential for lead and asbestos fibres to be present in the soils surrounding these structures following the maintenance and/or removal/demolition process.

It should be noted that no areas of potential filling were identified during the review of the available historical photographs.

Table 6: Historical Photographs: 76A Waihoehoe Road, Drury

Date	Description
1942	The 1942 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The only structure present is located on the existing laneway and is most likely a farm shed (HB01). A large gully can be seen running through the northern portion of the site in a south-easterly direction. The surrounding properties between are predominantly rural in use.
1960, 1969, 1974, 1981	The 1960 - 1981 historical photograph shows the subject site relatively unchanged from the 1942 historical photograph and still in use for rural purposes. The farm shed located on the existing access lane has been removed leaving the site undeveloped. The surrounding properties are unchanged from being predominantly rural-residential in use.
1996 & 2003/04	The 1996 & 2003/04 historical photographs are of poor resolution however, it appears to show the addition of an unidentified structure, most likely the existing dwelling located in the central portion of the site. A new access land has been constructed for the property which runs adjacent to the western boundary of 76 Waihoehoe Road. What appears to be a wetland pond can be seen to the south of the building in the 2003/04 historical photograph. With the exception to the properties located to the south western of the property which are utilised for rural residential purposes, the surrounding properties are predominantly rural in use.
2006 - 2017	The 2006 - 2017 historical photographs show the site in greater detail. The structure identified in the 1996 historical photograph now appears to be a dwelling. A small shed and concrete paving can be seen adjacent to the northern banks of the pond. A laneway which extends north towards an additional structure (shearers quarters &implement shed) can be seen to the north of the residential area. Despite being shaded by tree cover, what appears to be a stockholding pen can be seen to the south of the shed. An area of potential burning can also be seen to north of the shed. The surrounding land use appears to predominantly rural in use with the exception to the rural residential properties located to the south-west of the subject site.

Due to the age of the implement shed identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

In addition, due to the age of the former farm shed (HB01) identified (pre-1996) located in the along the existing laneway of the site, it is considered that asbestos containing materials and lead based paint may have been used on the external building materials. Therefore, there is the potential for lead and asbestos fibres to be present in the soils surrounding these structures following the maintenance and/or removal/demolition process.

It should be noted that no areas of potential filling were identified during the review of the available historical photographs.

Table 7: Historical Photographs: 76 Waihoehoe Road, Drury

Date	Description
1942	The 1942 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. An unidentified structure (HB01) can be seen on the boundary between the subject site and the property to the east (112 Waihoehoe Road). This structure is most likely a farm shed. Waihoehoe Road can be seen adjacent to the southern boundary of the property. The surrounding properties are predominantly rural in use.
1960 - 1996	The 1960 - 1996 historical photographs shows the subject site relatively unchanged from the 1942 and still in use for rural purposes. The unidentified structure (HB01) located on the boundary with the property to the east has been removed leaving the site undeveloped. With the exception to the properties located to the west of the property which are utilised for rural residential purposes, the surrounding properties are predominantly rural in use.
2006 - 2017	The 2006 - 2017 historical photographs shows the subject site relatively unchanged from the 1996 historical photograph and still in use for rural purposes. A small shed can be seen in the north-western corner of the site. The surrounding land use appears to predominantly rural in use with the exception to the rural residential properties located to the west of the subject site.

Due to the age of the historical building (HB01) identified (pre-1996) located adjacent to the eastern boundary of the site, it is considered that asbestos containing materials and lead based paint may have been used on the external building materials. Therefore, there is the potential for lead and asbestos fibres to be present in the soils surrounding these structures following the maintenance and/or removal/demolition process.

It should be noted that no areas of potential filling were identified during the review of the available historical photographs.

Table 8: Historical Photographs: 112 Waihoehoe Road, Drury

Date	Description
1942	The 1942 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. An unidentified structure (HB01) can be seen on the boundary between the subject site and the property to the west (76 Waihoehoe Road). This structure is most likely a farm shed. Waihoehoe Road can be seen adjacent to the southern boundary of the property. The surrounding properties are predominantly rural in use.
1960-1969	The 1960 - 1969 historical photographs shows the subject site relatively unchanged from the 1942 and still in use for rural purposes. The unidentified structure (HB01) located on the boundary with the property to the west has been removed leaving the site undeveloped. The surrounding properties are unchanged from rural in use.
1974 & 1981	The 1974 & 1981 historical photograph shows the subject site relatively unchanged from the 1969 historical photograph. A small shed can be seen in the south-eastern corner of the site. Adjacent to the shed appears to be a stockholding pen. Further north in the central portion of the site is a large shed. The surrounding properties appear to be a mix of rural and rural residential in use with the exception to the commercial/industrial activities being carried out on the neighbouring site (116 Waihoehoe Road).
1996 – 2017	The 1996-2017 historical photographs show the addition of what appears to be a dwelling and garage in the south-central portion of the site. A driveway can be seen along the eastern boundary to the site which leads to the residential area of the site. The surrounding properties appear to be a mix of rural and rural residential in use with the exception to the commercial/industrial activities being carried out on the neighbouring site (116 Waihoehoe Road).

Due to the age of the dwelling, garage and small shed identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

Due to the age of the historical building (HB01) identified (pre-1996) located adjacent to the western boundary of the site, it is considered that asbestos containing materials and lead based paint may have been used on the external building materials. Therefore, there is the potential for lead and asbestos fibres to be present in the soils surrounding these structures following the maintenance and/or removal/demolition process.

It should be noted that no areas of potential filling were identified during the review of the available historical photographs.

Table 9: Historical Photographs: 116 Waihoehoe Road, Drury

Date	Description
1940 – 1960, 1969	The 1940 - 1969 historical photographs show the subject site forming part of a larger plot of land and predominantly in use for rural purposes. What appears to be the existing dwelling (2) and farm shed can be seen in the south-western portion of the site. In addition, there appears to be three unidentified structures (HB01 – HB03) which surround the existing dwelling (2). These are most likely associated with surrounding rural activities. The existing garage (2) can be seen in the 1960 historical photograph as well as the removal/demolition of the unidentified structure (HB03) which was located to the south west of the existing dwelling (2). The surrounding properties appear to be predominantly rural in use.
1974	The 1974 historical photograph shows additions to the southern portion of the site, most noticeably the construction of the existing Engineering Workshop and office (1). A livestock holding pen can be seen to the north-west of the existing dwelling (2) and garage (2). The remaining area of the site, remain in use for rural purposes. The surrounding properties are predominantly rural in use.
1981	The 1981 historical photograph shows further additions to the southern portion of the site. The existing half round barn (2) can be seen to the west of the Engineering Workshop. The remaining area of the site, remain in use for rural purposes. The surrounding properties are predominantly rural in use.
1996	The 1996 historical photograph shows the addition of the Foundry and half round barn (1) which is located to the east and north of the Engineering Workshop respectively. What appears to be the existing firewood shed (1) can be seen to the east of the residential area while the existing site office appears to have been constructed adjacent to the Workshop. The existing lane way which runs along the western boundary of the property has been extended into the northern portion of the site. The last of the unidentified structure which were located in the areas surrounding the dwelling (2) have now been removed from site. With the exception to the horticultural activities located to the south-east of the site, the surrounding properties appear to be a mix of rural and rural residential in use.
2003/04	The 2003/04 historical photograph is of poor resolution however, it appears to show the addition of the existing open faced shed and dwelling (1) in the southern portion of the site. In addition, what appears to be the existing dwelling (3) can be seen in the central portion of the site. Again, with the exception to the horticultural activities located to the south-east of the site, the surrounding properties appear to be a mix of rural and rural residential in use.
2006 - 2017	The 2006 - 2017 historical photographs show the subject site generally as it appeared during the site walk over and inspection. An additional dwelling and attached garage and associated sheds (1 & 2) can be seen along the western boundary in the central portion of the site. Two rows of solar panels have been added to the northern boundary of the Engineering Workshop which is still in operation in the south-eastern portion of the site. The south western portion of the site is occupied by two dwelling (1 & 2) along with associated garages. With the exception to the horticultural activities located to the south-east of the site, the surrounding properties appear to be a mix of rural and rural residential in use.

Due to the age of the site buildings (site office, office 2, dwellings 1, 2 & 3, garage 2, farm shed and sheds 1 & 2) identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

In addition, due to the age of the historic buildings (HB01 – HB03) identified (pre-1996) there is the potential for lead based paint to have been used on the external building materials and therefore there is the potential for lead to be present in the soils surrounding the site buildings. Furthermore, there is also potential for asbestos fibres to be present in the soils as a result of demolition/removal works.

It should be noted that no areas of potential filling were identified during the review of the available historical photographs.

Table 10: Historical Photographs: 136 Waihoehoe Road, Drury

Date	Description
1942 - 1981	The 1942 - 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site is undeveloped with no buildings or structures present. Waihoehoe Road can be seen along the southern boundary of the site. The surrounding properties are predominantly rural in use.
1996	The 1996 historical photographs are of relatively poor resolution, however it appears to show the addition of a residential dwelling (HB01) in the central portion of the site. With the exception to the horticultural activities located to the east of the site, the surrounding properties appear to be a mix of rural and rural residential in use.
2003/04 -2006	The 2003/04 - 2006 historical photographs shows the addition of a pond which can be seen in the northern portion of the site. In addition, the dwelling which was located in the central portion of the site and been removed. This structure appears to have been relocated to the neighbouring site (116 Waihoehoe Road) which is located to the northern portion of the site. The 2006 historical photograph appears to show the footprint of a potentially new structure to be added to the site as well as a new swimming pool. With the exception to the horticultural activities located to the east of the site, the surrounding properties appear to be a mix of rural and rural residential in use.
2008 - 2017	The 2008 - 2017 historical photographs shows the subject site generally as it appeared during the site inspection and walkover. The new dwelling and attached garage have been constructed in the central portion of the site. A large structure, most likely the additional living quarters can be seen through the breaks in tree cover to the south of the dwelling. With the exception to the horticultural activities located to the east of the site, the surrounding properties appear to be a mix of rural and rural residential in use.

In addition, due to the age of the former dwelling (HB01) identified (pre-1996) there is the potential for lead based paint to have been used on the external building materials and therefore there is the potential for lead to be present in the soils surrounding the site buildings. Furthermore, there is also potential for asbestos fibres to be present in the soils as a result of demolition/removal works.

It should be noted that no areas of potential filling were identified during the review of the available historical photographs.

Table 11: Historical Photographs: 140 Waihoehoe Road, Drury

Date	Description
1942 - 2017	The 1940 - 2017 historical photographs show the subject site which once formed part of a larger plot of land in use for rural purposes. The site has never been developed as remains in use as a grazing paddock. With the exception to the horticultural activities located to the east of the site, the surrounding properties appear to be a mix of rural and rural residential in use.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 12: Historical Photographs: 15 Kathy Henry Lane, Drury

Date	Description
1942 - 1981	The 1942 – 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site appears undeveloped with no structures present. The Southern Line train network can be seen along the western boundary of the site. The surrounding properties are a mix of rural/rural residential in use.
1996 – 2003/04	The 1996 – 2003/04 historical photograph is of relatively poor resolution, however, it appears to show the construction a large structure, most likely a greenhouse in the north-eastern corner of the site. In addition, was appears to be the existing dwelling can be seen along the southern boundary of the site. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.
2006 - 2017	The 2006 - 2017 historical photograph shows the subject site relatively unchanged from the 2003/04 historical photograph. The northern eastern portion of the site appears to be utilised for market garden and contains a large greenhouse. This area of the site has separate access from the residential area which is located in the southern portion of the site. The residential area consists of a dwelling and small garage. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.

Due to the age of the dwelling and garage identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 13: Historical Photographs: 18 Kathy Henry Lane, Drury

Date	Description
1942 - 1981	The 1942 – 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site in undeveloped with no structures present. The Southern Line train network can be seen to the west of the site. The surrounding properties are a mix of rural/rural residential in use.
1996 – 2003/04	The 1996 – 2003/04 historical photographs are of relatively poor resolution, however it appears to show the construction of what appears to residential dwelling and garage in the south-eastern portion of the site. The remaining area of the site are in use as grazing paddocks. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.
2006 - 2015	The 2006 - 2015 historical photographs shows the south-western portion of the site developed into a courtyard with what appears to be a gravel base. An unidentified structure has been constructed along the western boundary. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.
2017	The 2017 historical photograph shows the site relatively unchanged from the 2015 historical photograph. Two additional structures have been constructed in the western courtyard while the northern portion of the site is in use for grazing purposes. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 14: Historical Photographs: 27 Kathy Henry Lane, Drury

Date	Description
1942 - 1981	The 1942 – 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site in undeveloped with no structures present. The Southern Line train network can be seen along the western boundary of the site. The surrounding properties are a mix of rural/rural residential in use.
1996 - 2017	The 1996 - 2017 historical photographs show the site has been developed for rural residential purposes with a dwelling and garage located in the central and northern portion of the site respectively. A gully cuts through the southern portion of the site which is in use for grazing purposes. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.

Due to the age of the dwelling identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 15: Historical Photographs: 34 Kathy Henry Lane, Drury

Date	Description
1942 - 1981	The 1942 – 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site in undeveloped with no structures present. The Southern Line train network can be seen to the west of the site. The surrounding properties are a mix of rural/rural residential in use.
1996 - 2017	The 1996 - 2017 historical photographs shows the site has been developed for rural residential purposes with a dwelling and elongated shed located in the south-eastern portion of the site. The remaining areas of the site are in use for grazing purposes. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.

Due to the age of the dwelling and storage shed identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 16: Historical Photographs: 44 Kathy Henry Lane, Drury

Date	Description
1942 - 1981	The 1942 – 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site in undeveloped with no structures present. The Southern Line train network can be seen to the west of the site. The surrounding properties are a mix of rural/rural residential in use.
1996 - 2017	The 1996 - 2017 historical photographs show the subject site developed for rural residential purposes. A dwelling and garage can be seen in the south-western portion of the site while the remaining areas are in use for grazing purposes. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.

Due to the age of the dwelling and garage identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 17: Historical Photographs: 45 Kathy Henry Lane, Drury

Date	Description
1942 - 2008	The 1942 - 2008 historical photographs show the subject site which once formed part of a larger plot of land in use for rural purposes. The site is undeveloped with no structure of buildings present. The Southern Line train network can be seen running along the western boundary of the site. The surrounding properties have changed from being predominantly rural in use to a mix of rural/ rural residential in use.
2011 - 2017	The 2011 - 2017 historical photographs show the site developed for residential purposes with a dwelling and two additional structures, most like the shed and garage located in the central portion of the site. The surrounding properties are a mix of rural and rural residential in use. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 18: Historical Photographs: 49 Kathy Henry Lane, Drury

Date	Description
1942 - 1981	The 1942 – 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site in undeveloped with no structures present. The Southern Line train network can be seen along the western boundary of the site. The surrounding properties are a mix of rural/rural residential in use.
1996 - 2017	The 1996 - 2017 historical photographs shows the subject site developed for rural residential purposes. What appears to be a dwelling and garage can be seen along the southern boundary of the site. The south-eastern potion of the site was been developed into a courtyard with what appears to be shipping contains located along the northern boundary. The northern portion of the site in use for grazing purposes. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.

Due to the age of the dwelling and garage identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

Table 19: Historical Photographs: 50 Kathy Henry Lane, Drury

Date	Description
1942 - 1981	The 1942 – 1981 historical photographs show the subject site forming part of a larger plot of land and in use for rural purposes. The site in undeveloped with no structures present. The Southern Line train network can be seen to the west of the site. The surrounding properties are a mix of rural/rural residential in use.
1996 - 2017	The 1996 - 2017 historical photographs shows the subject site developed for rural residential purposes. What appears to be a dwelling and attached garage as well as a shed can be seen in the southern portion of the site. A gully can be seen in the north-eastern portion of the site. The surrounding properties to the east and south are a mix of commercial and residential while the properties to the north and east are predominantly rural and rural residential.

Due to the age of the dwelling identified (pre-1996), it is considered there is the potential for lead based paint to have been used on the external building materials and therefore, there is the potential for lead contamination to be present in the soils surrounding these site buildings.

It should be noted that no historical buildings or areas of potential filling were identified during the review of the available historical photographs.

6.2 Previous Investigation

There were no previous environmental investigations relating to soil or groundwater contamination associated with the sites within Waihoehoe Road Plan Change Area on file with Auckland Council.

In addition, at the time of writing the results of a geotechnical investigation covering the entire Plan Change Area was not available.

6.3 Auckland Council Property File

The results of the council search showed a number of consents relating to the properties within the Waihoehoe Road Plan Change Area. The relevant details of the Property File search are presented in Table 20 - 36 below:

Table 20: Relevant Property File Information: 18 Waihoehoe Road, Drury

Proposed Activity	Applicant	Reference	Date
Construct Garage	R. Eagle	A55927	17/03/1983
Additions to Garage (Sleepout)	D & T Webber	*	15/06/1998
Construct Skyline Garage	A1 Building Certifiers Ltd	15197	30/06/1998
Construct Shed	Robert Stewart	*	25/11/2009
Construct Vehicle Maintenance Shed	Robert Stewart	9798	22/04/2010
Relocate Storage Building to Site.	BA. Stewart & A. Giles Trustee Ltd	B/2014/13180	21/10/2014

*indicates poor eligibility.

Due to the age of the skyline garage, shed and vehicle maintenance shed it is considered unlikely that lead based paint would have been used on the external building products.

Table 21: Relevant Property File Information: 28 Waihoehoe Road, Drury

Proposed Activity	Applicant	Reference	Date
Construct Hay/Implement shed	K.A. Henry	366	29/09/1953
Construct Dwelling	K.A. Henry	940	15/02/1955
Construct Garage	K.A. Henry	2170	05/12/1957
Additions to Dwelling	K.A. Henry	041413	17/03/1961
Construct 2-Bay Hay Barn	Nausori Development Ltd	D015674	15/10/1971

Table 22: Relevant Property File Information: 44 Waihoehoe Road, Drury

Proposed Activity	Applicant	Reference	Date
Construct Dwelling	Gary Thompson	63354	25/08/1988
Construct Packing/Storage shed	Gary Thompson	5325	01/11/1991
Construct Garage	William Screen	10638	07/01/1994
Additions to Dwelling	Gregory John Clarke	13635	29/07/1997
Relocate Garage	Gregory John Clarke	13721	18/08/1997

It was noted that the illegal operations a harnesses manufacturing workshop out of the packing/storage shed (consent no. 5325) were noted during the review of the property file.

Due to the age of the packing/storage and garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 23: Relevant Property File Information: 76A Waihoehoe Road, Drury

Proposed Activity	Applicant	Reference	Date
Construct implement shed	Mr & Mrs S.B. Ross	F64138	15/5/1989
Shearers quarters & implement shed	Mr & Mrs S.B. Ross	13985	14/11/1997
Construct Dwelling & attached garage	Stewart & Susan Ross	14540	14/01/2002
Additions to dwelling	Susan Ross	15587	14/01/2002

Due to the age of the shearer's quarters & implement shed and dwelling & attached garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 24: Relevant Property File Information: 76 Waihoehoe Road, Drury

Proposed Activity	Applicant	Reference	Date
Construct Dwelling & Attached Garage	Stuart & Susan Ross	14540	14/01/2002
Additions to Dwelling	Stuart & Susan Ross	15587	14/01/2002
Construct Implement Shed	Susan Ross	18393	27/08/2007

Table 25: Relevant Property Information: 112 Waihoehoe Road, Drury

Proposed Activity	Applicant	Reference	Date
Construct Dwelling	Mr & Mrs Kleinsman	E430	20/08/1986
Construct Garage & Implement Shed	Mr & Mrs Kleinsman	F30023	08/04/1988

Table 26: Relevant Property File Information: 116 Waihoehoe Road, Drury

Proposed Activity	Applicant	Reference	Date
Establish Forging & Manufacturing Industry	Fred Robinson	F27160	08/08/1973
Construct Office	*	F91923	26/02/1974
Erect a carport	South Auckland Forging Ltd	G60329	18/07/1975
Construct a dwelling	G.R.V. Land Company	H27633	16/06/1976
Construct 5-Bay Hay Barn	F. Robinson	K000658	13/04/1981
Construct 4-Bay Hay Barn	South Auckland Forging Ltd	B74405	15/02/1984
Construct Laboratory Building	South Auckland Forging Ltd	9375-76	13/03/1984
Construct 5-Bay hay barn	South Auckland Forging Ltd	8428	19/09/1986
2-Bay Extension to Hay Barn	South Auckland Forging Ltd	8471	30/09/1986
Boundary Adjustment	*	935577	11/11/1993
Subdivision	Brian Foote	16/94/76	23/03/1995
Relocate Dwelling on Site	South Auckland Forging Ltd	LUC6508	7/10/2002
Boundary Adjustment Subdivision	Dodd Civil Consultants	7831	09/06/2004
Dwelling & Attached Garage	Rob & Katherine Robinson	21040	24/11/2004

*indicates poor eligibility.

A reference to a Dangerous good licence (0095179) for the installation of two underground tanks 1,364 & 13,000 including one dispensing pump were noted during the review of the property file. It was not disclosed as to the location of these tank.

Due to the age of the dwelling and attached garage (Ref. 21040) and dwelling & attached garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 27: Relevant Property File Information: 136 Waihoehoe Road, Drury

Proposed Activity	Applicant	Reference	Date
Construct Dwelling	Barry Robinson	5149	02/09/1991
Construct residential Garage	F. Robinson	5850	19/10/1992
Construct a Pond Wetland	Edith Robinson	7831	11/06/2004
Construct Dwelling & Attached Garage	Barry Robinson	21155	20/01/2005
Boundary Adjustment	Barry Robinson	R/SUB/2012/3472	26/10/2012

Due to the age of the former dwelling (HB01), residential garage and dwelling & attached garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 28: Relevant Property File Information: 140 Waihoehoe Road, Drury.

Proposed Activity	Applicant	Reference	Date
Subdivision adjustment subdivision	Barry Robinson	8024	29/01/2013

Table 29: Relevant Property File Information: 15 Kath Henry Lane, Drury.

Proposed Activity	Applicant	Reference	Date
Subdivision	Screen & Thompson	6/15/699	23/03/89
Construct Dwelling & Garage	Multi Homes	003978	08/01/90
Construct Green House	Kevin Girling	10413	18/08/93

Due to the age of the dwelling and garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 30: Relevant Property File Information: 18 Kath Henry Lane, Drury.

Proposed Activity	Applicant	Reference	Date
Construct a Shed	G Cameron	905512	06/03/1992
Construct Dwelling & Garage	Grant Cameron & Melanie Webster	90/5568	08/04/1992

Due to the age of the shed and dwelling & garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 31: Relevant Property File Information: 27 Kath Henry Lane, Drury.

Proposed Activity	Applicant	Reference	Date
Construct New Dwelling	CL & AJ Bell	4669	20/11/1990
Construct Garage,	Keith Beckham	13802 & 14324	15/09/1997

Due to the age of the dwelling and garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 32: Relevant Property File Information: 34 Kath Henry Lane, Drury.

Proposed Activity	Applicant	Reference	Date
Construct Dwelling	Gary Thompson	4662	25/07/1990
Construct Storage Shed	Gary Thompson	10503	12/10/1993

During the review of the property file, the illegal addition of a lean-to stables was noted. This was observed during an inspection of the property in 1999 and can be seen adjacent to the northern aspect of the existing storage shed. This building is still visible in the most recent aerial photograph of the site (2017).

Due to the age of the dwelling and storage shed, it is considered unlikely that lead based paint would have been used on the external building products.

Table 33: Relevant Property File Information: 44 Kath Henry Lane, Drury.

Proposed Activity	Applicant	Reference	Date
Construct Dwelling	Mr & Mrs C Gillson	H4382	01/08/1990
Construct Garage	Mr & Mrs C Gillson	4499	25/09/1990

Due to the age of the dwelling and garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 34: Relevant Property File Information: 45 Kath Henry Lane, Drury.

Proposed Activity	Applicant	Reference	Date
Construct Dwelling & Shed	Kevin Speight	23828	13/02/2008
Erect Carport	Murray Gray	25139	19/04/2010
Construct Implement shed	Murray Gray	25140	20/10/2010

Resource consent (LU 9280) was granted in June 2008 for the earthworks associated with the construction of dwelling and shed. Proposed cut to fill volume of 100m^3 and will not exceed 0.5m across the site.

Table 35: Relevant Property File Information: 49 Kath Henry Lane, Drury.

Proposed Activity	Applicant	Reference	Date
Construct Dwelling	K. Stevens	H4324	12/07/1990
Construct Garage	M. Godfrey	10813	15/03/1994

Due to the age of the dwelling and garage, it is considered unlikely that lead based paint would have been used on the external building products.

Table 36: Relevant Property File Information: 50 Kath Henry Lane, Drury.

Proposed Activity	Applicant	Reference	Date
Relocate Dwelling to Site	Kenneth Pearce	9368	05/03/1991
Construct Garage	Steve & Diane Dawson	11849	26/03/1996

Due to the age of the garage, it is considered unlikely that lead based paint would have been used on the external building products. It should be noted, that as the existing dwelling was relocated to site, the age of the building could not be determined. Therefore, there is the potential for lead based paint to have been used on the external building materials.

6.4 Auckland Council Site Contamination Enquiry

The Auckland Council site contamination enquiry did not contain any records for the properties relating to the Waihoehoe Road Plan Change Area.

The site contamination enquiry did however contain a number of consents relating to the construction of boreholes within the area of the proposed Plan Change Area.

The Auckland Council Site Contamination Enquiry is presented in Appendix D.

6.5 Historical Certificate of Title Review

The historical certificate of title review was completed for the properties relating to the Waihoehoe Road Plan Change Area.

Following the review of the historical certificate of title no companies/entities were listed that would suggest that the subject sites have been utilised for an activity described in the HAIL.

The historical certificate of title is presented in full as Appendix E.

6.6 Onsite Interview

It should be noted that the only sites within the Waihoehoe Road Plan Change Area where site access was granted was 116, 136 and 140 Waihoehoe Road. In addition, these three sites were occupied by the same land owner who was part of a family who occupied the property since 1974.

During the site inspection and walkover an interview with the current occupier of 116, 136 and 140 Waihoehoe Road was conducted by Focus Environmental Services personnel.

During the interview with the current occupier of 116, 136 and 140 Waihoehoe Road the following items were noted:

- The landowner advised that the land surrounding the Engineering Workshop had been previously used for farming sheep and more recently beef cattle.
- The landowner also stated, that to his knowledge, no sheep dips or spray race operation were carried out at the property.
- Two soil stockpile/mounds, located to the west and south of the Engineering Workshop were generated during the construction of the Workshop and surrounding courtyard.
- Two machines in the Forge Shop have leaked lubricating oil into the ground over a period of approximately 40 years.
- A diesel spill (approximately 200 litres) occurred in 1975 in the engineering yard to the north of the Foundry (See Site Feature 11 on Figure 2-8 - A).
- There are two 10,000 litre underground diesel tanks located to the north of the Forge Shop which have been unused since the 1980’s, however, these may still contain residual diesel (See Site Feature 9 & 10 on Figure 2-8 - A).
- There was a 2,000 litre underground petrol tank located to the north of entrance driveway of the Engineering Workshop (See Site Feature 26 on Figure 2-8 - A).

- There is a refuse pit (1) located underneath the gravel yard in the south eastern corner of the engineering yard. This pit may contain material such general workshop waste, white asbestos gloves and white asbestos blocks (See Site Feature 15 on Figure 2-8 - A).
- The earth mound located to the south of the Machine Shop is being utilised as an effluent disposal field. This mound also contains several square metres of fire brick for drainage purposes (See Site Feature 18 on Figure 2-8 – A).
- There was an offal pit (1) located in the north eastern corner of the Engineering Workshop yard (See Site Feature 13 on Figure 2-8 – A).
- An additional refuse pit (2) was located in the south-western paddock of the Engineering Workshop (See Site Feature 21 on Figure 2-8 – A).
- There was an offal and household refuse pit located in the south-western portion of 116 Waihoehoe Road (See Site Feature 9 on Figure 2-8 – B).
- There was an additional offal pit (2) located along the south-western boundary of 116 Waihoehoe Road (See Site Feature 2 on Figure 2-8 – C).
- A further refuse pit (3) was located on the southern banks of the Waihoehoe Stream which contains material including general workshop waste (such as iron oxide scale, oily rags, white asbestos gloves, white asbestos blocks & steel shavings), drums of fire brick, car body, fridge and other general domestic and household rubbish (See Site Feature 6 on Figure 2-8 – D).
- General oil leaks on the property from the operation of engineering workshop machinery and farm equipment were also pointed out.

7.0 Site Walkover and Inspection

The site inspection and walk over was carried out by Focus Environmental Services Limited personnel on the 8th of February 2019. The site inspection was carried out during a period of fine weather.

7.1 18 Waihoehoe Road, Drury

A site inspection and walkover could not be completed for 18 Waihoehoe Road as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-1.

7.2 28 Waihoehoe Road, Drury

A site inspection and walkover could not be completed for 28 Waihoehoe Road as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-2.

7.3 44 Waihoehoe Road, Drury

A site inspection and walkover could not be completed for 44 Waihoehoe Road as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-3.

7.4 76A Waihoehoe Road, Drury

A site inspection and walkover could not be completed for 76A Waihoehoe Road as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-4 – A.

7.5 76 Waihoehoe Road, Drury

A site inspection and walkover could not be completed for 76 Waihoehoe Road as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-5.

7.6 112 Waihoehoe Road, Drury

A site inspection and walkover could not be completed for 112 Waihoehoe Road as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-6

7.7 116 Waihoehoe Road, Drury

The site was accessed from Waihoehoe Road via a tarmac driveway which extended past the western boundary of 136 Waihoehoe Road. A gravel track diverted east towards the S.A.F.E Engineering Workshop which was operating in the south-eastern portion of Lot 3 DP 173904.

The Engineering Workshop was constructed on a concrete base and clad with galvanised corrugated iron. During the inspection of the Workshop, hydrocarbon staining and iron oxide scale were observed in the areas surrounding the manufacturing equipment. The iron oxide scale and general engineering waste was collected regularly and placed in waste bins for appropriate disposal.

Two site offices were located to the south of the Workshop. Both of these structures were constructed on a raised platform and had a timber cladding which was painted. The soffits and baseboards were also identified as being constructed from potential asbestos containing materials.

To the east of the three-bay Engineering Workshop was an open sided storage shed which was constructed on hardstand and had a galvanised corrugated iron cladding. The shed contained a number of waste barrels which were generated from the Workshop activities, a chemical storage shed and oil/fuel storage shed. Residual hydrocarbon staining was observed on the soils surrounding the oil/fuel storage shed.

To the west of the open sided shed was a mound of topsoil. This material was generated following the constructed of the Workshop and yard.

To the north of the Engineering Workshop was a Half Round Barn (1) which was constructed on a hardstand base and had an external galvanised corrugated iron cladding. The Half Round Barn (1) was used for the storage of disused manufacturing equipment and machinery. It should be noted that hydrocarbon staining was observed on the base of the barn during the site walkover and inspection. A number of empty oil barrels were stacked adjacent to the southern aspect of the barn. A visual inspection of the surrounding soils could not be completed in the vicinity of the oil barrels as this area was overgrown with vegetation.

Directly east of the Half Round Barn was two rows of solar panels which are used to power the Engineering Workshop.

Two underground fuel storage tanks were observed to the north of the Engineering Workshop. These tanks were no longer in use, however, it was unknown if any diesel remained in these tanks.

To the east of the three-bay engineering Workshop was the Foundry. The Foundry was constructed on a concrete base and had a galvanised corrugated iron cladding which was not painted. The majority of the Engineering activities were located to the main Workshop and the Foundry appeared to only be in use for maintenance activities. During the inspection of the Foundry, no visual/olfactory evidence or sources of hydrocarbon contamination were observed within or surrounding the structure.

In the north-eastern portion of the engineering yard was an Offal Pit which was covered with metal sheeting.

Along the northern and eastern boundary engineering yard was the storage of raw materials and disused manufacturing equipment.

In the south-eastern comer of the engineering yard was an area identified to contain buried refuse which included asbestos.

A gas meter associated with the engineering works on site was located adjacent to the refuse pit. This are also contained an area of asbestos storage which included disused asbestos fire bricks.

On the eastern aspect of the Workshop was the Pressure Testing Shed. To the south of this was a large mound of clay and topsoil which also contained a large quantity of fire brick. This mound was utilised as an effluent disposal for the on-site wastewater which was pumped from the septic tank located on the southern aspect of the machine shop.

An additional refuse pit was identified to the south-west of the Engineering Workshop. As this was carried out historically, there was no visual evidence on the surface.

Continuing west along the driveway was a Half Round Barn (2) which was constructed on a hardstand base and had corrugated iron cladding which was not painted. This barn was being utilised for disused engineering equipment and machinery. There was no visual or olfactory evidence of contamination observed within or surrounding the barn.

To the west of the barn (2) was a small dwelling (1) and adjoining garage. The dwelling was constructed on a raised platform. The soffits and cladding were identified as being constructed from potential asbestos containing materials. The garage was constructed on a concrete base and had metal tin cladding. The garage was being utilised as a domestic gym at the time of the site walkover and inspection.

To the west of the dwelling and garage was an old farm shed which was constructed on a concrete base. The walls of the shed were also constructed of concrete and appeared to have been painted.

At the end of the driveway was a disused underground petrol tank. It was not determined if residual petrol still remains in the tanks during the site walkover and inspection.

In the paddock located to the north of the driveway was an area of burning (1). The area contained manufactured timber, furniture and general household waste.

To the south of the driveway was Lot 2 DP 193904 which consisted of a residential area. The residential area contained a dwelling (2), carport (1 & 2), garage (2) and swimming pool. The dwelling was constructed on a raised platform and had timber cladding which was painted.

The garage was constructed on a concrete base and had a render finish on the exterior wall which was painted. The shed was being utilised for general storage.

To the east of the residential area was a large shed (1) which was constructed on a hardstand base and had a corrugated iron cladding which was not painted. The shed (1) was being utilised for the storage of firewood, however, it was primarily empty. There was no visual or olfactory evidence of contamination identified within the shed (1).

To the south of the shed was a former offal pit which potentially contained household waste. Again, there was no visual evidence of ground disturbance in the area.

In the south-western corner of Lot 1 DP146189 was a livestock holding pen. Based on the age and orientation of the holding pen it is considered likely that this would have been utilised for spray race operations in the past. Directly east of the holding pen was a further offal pit (2).

A laneway extended along the southern boundary of the site before diverting to the left. This led to an additional residential area of the site. The residential area consisted of a large dwelling and attached garage, sheds (1 & 2) and a domestic vegetable garden which appeared to be no longer in use.

The dwelling and garage were constructed on a concrete and had a timber cladding. The sheds (1 & 2) were constructed on a hardstand base with a painted corrugated iron cladding. The sheds appeared to be in use for small scale workshop activities, however, no visual or olfactory evidence of contamination was observed in these areas.

An area of burning (2) was observed to the south-west of the dwelling, the area of burning contained carpet, timber and other miscellaneous items.

To the north-west of the residential area, along the western boundary of the site was a chicken coop most likely used for domestic purposes, however, this was overgrown and no longer in use.

The remaining areas of the site were in use as grazing paddocks.

The residential area located on Lot 2 DP 146189 was accessed via the laneway which ran along the south a boundary of Lot 1 DP 146189. The residential area consisted of a small dwelling, garage and temporary living accommodation.

The dwelling was constructed on a raise platform and had timber cladding which was painted. The soffits of the dwelling were identified as being constructed of potential asbestos containing materials.

The garage was constructed on a concrete base and had a metal tin and PACM cladding which was painted. The soffits of the garage were also identified as being constructed from potential asbestos containing materials. The garage was being utilised for the storage of general household items.

A shipping container, which had been converted into temporary living accommodation, was located to the south of the garage.

In the paddock to the north of the residential dwelling was an area of burning (3). The area of burning contained timber, newspapers and other miscellaneous items.

In the northern portion of the site, adjacent to the Waihoehoe Stream was an area which was identified as a refuse pit (3). This pit is thought to contain general workshop waste, included asbestos and other potentially contaminating objects. There were no obvious signs of dumping/burial in this area.

The fencing along all boundaries of the site were constructed from timber and wire.

The site inspection photographs are presented in Appendix F and the Site Features Plan is presented as Figure 2-8 (A-D).

7.8 136 Waihoehoe Road, Drury

The site was accessed from Waihoehoe Road via a tarmac sealed driveway which extended along the western boundary of the site. A small gravel carpark was located adjacent to the western portion of the residential area of the site.

The residential area consisted of a single storey dwelling and attached garage which was constructed on a concrete base. The dwelling had an exterior render finish which was painted. Due to the age of the dwelling it is considered unlikely that lead based paint has been utilised on the exterior of the dwelling. The garage appeared to be utilised for the storage of general household items including some scale workshop activities. No visual or olfactory evidence of hydrocarbon contamination was observed on the garage floor

A pool house and swimming pool were observed to the north-west of the dwelling. As there was water aerobics class in progress at the time of the site walkover, this area of the residential area was restricted.

A man-made pond was identified in the northern portion of the site. The material generated from the creation of the pond was deposited beneath the footprint and northern curtilage of the existing dwelling.

A converted shed, which was now utilised as additional living quarters, was located to the south of the dwelling. The living quarters was constructed on a concrete base and had metal cladding which was painted. The upper level had been converted for living accommodation while the ground floor was utilised as a garage.

To the west of the living accommodation was a domestic vegetable garden and shed. The shed was locked at the time of the site walkover and investigation, however, no visual or olfactory evidence of contamination was observed in the vicinity.

An area of burning was located in the central portion of the paddock which was located to the south of the residential area. The area of burning contained tree branches and some evidence of refuse.

Along the eastern boundary of the site was a car and trailer body. The car appeared to be in good condition and no visual or olfactory evidence of hydrocarbon contamination was identified during an inspection of the car and underlying soils.

The fencing along all boundaries of the site were constructed from timber and wire.

The site inspection photographs are presented in Appendix F and the Site Features Plan is presented as Figure 2-7.

7.9 140 Waihoehoe Road, Drury

The site was accessed from the northern boundary of the site via 116 Waihoehoe Road. The site was undeveloped and in use for grazing purposes. A section of dead vegetation was observed along the eastern boundary of the site.

The fences surrounding north and western portion of the site were constructed from timber and wire while the east and southern boundaries were hedgerows.

The fencing along all boundaries of the site were constructed from timber and wire.

The site inspection photographs are presented in Appendix F and the Site Features Plan is presented as Figure 2-7.

7.10 15 Kath Henry Lane, Drury

A site inspection and walkover could not be completed for 15 Kath Henry Lane as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-9.

7.11 18 Kath Henry Lane, Drury

A site inspection and walkover could not be completed for 18 Kath Henry Lane as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-10.

7.12 27 Kath Henry Lane, Drury

A site inspection and walkover could not be completed for 27 Kath Henry Lane as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-11.

7.13 34 Kath Henry Lane, Drury

A site inspection and walkover could not be completed for 34 Kath Henry Lane as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-12.

7.14 44 Kath Henry Lane, Drury

A site inspection and walkover could not be completed for 44 Kath Henry Lane as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-13.

7.15 45 Kath Henry Lane, Drury

A site inspection and walkover could not be completed for 45 Kath Henry Lane as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-14.

7.16 49 Kath Henry Lane, Drury

A site inspection and walkover could not be completed for 49 Kath Henry Lane as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-15.

7.17 50 Kath Henry Lane, Drury

A site inspection and walkover could not be completed for 50 Kath Henry Lane as access to the property was not permitted, therefore, the identification of any potential HAIL activities carried out across the site was limited to a desktop assessment.

A site feature plan based on a desktop assessment is presented as Figure 2-16.

8.0 Asbestos Management

Due to the age of some of the site buildings (pre-2000) and the visual inspection undertaken during the site walkover and inspection external ACM products are likely restricted to the soffit and baseboards of the site offices, soffits and cladding of dwelling (1), soffits of dwelling (3) and soffits and cladding of garage (3) at 116 Waihoehoe Road, Drury. These materials appeared painted and in relatively good condition, and are considered unlikely to present ground contamination in their current state.

It should be noted that due to access restrictions at the remaining sites within the Waihoehoe Road Plan Change Area, a visual inspection of the external building materials could not be conducted. However, due to the age (pre-2000) of the current site building located at 18 Waihoehoe Road, 28 Waihoehoe Road, 44 Waihoehoe Road, 76A Waihoehoe Road, 112 Waihoehoe Road, 15 Kath Henry Lane, 18 Kath Henry Lane, 27 Kath Henry Lane, 34 Kath Henry Lane, 44 Kath Henry Lane, 49 Kath Henry Lane and 50 Kath Henry Lane, there is the potential for ACM products to have been used during the construction of these buildings.

Following a search of the underground services database on Auckland Councils GeoMaps, no asbestos cement pipes were identified across the site within the Waihoehoe Road Plan Change Area.

Any removal of asbestos materials from the site will need to be conducted in accordance with the Health and Safety at Work (Asbestos) Regulations (MBIE, 2016) and the Approved Code of Practice for the Management and Removal of Asbestos (WorkSafe New Zealand, 2016) by a licensed asbestos removals specialist under an approved asbestos removal control plan.

It should be noted that ACM, other than that described, may also be present at the site and a thorough inspection should be carried out by a suitably qualified and competent asbestos surveyor prior to any demolition activities at the site.

9.0 Potentially Contaminating Activities or Land Uses

9.1 18 Waihoehoe Road, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint; and
- Potential ground contamination associated with asbestos fibres from former demolition activities.

It should be noted that the potential sources of contamination (as identified above) are limited to a historical review, and therefore, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.2 28 Waihoehoe Road, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint.

It should be noted that the potential sources of contamination (as identified above) are limited to a historical review, and therefore, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.3 44 Waihoehoe Road, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint; and
- Potential ground contamination associated with asbestos fibres from former demolition activities.

It should be noted that the potential sources of contamination (as identified above) are limited to a historical review, and therefore, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.4 76A Waihoehoe Road, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint; and
- Potential ground contamination associated with asbestos fibres from former demolition activities.

It should be noted that the potential sources of contamination (as identified above) are limited to a historical review, and therefore, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.5 76 Waihoehoe Road, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint; and
- Potential ground contamination associated with asbestos fibres from former demolition activities.

It should be noted that the potential sources of contamination (as identified above) are limited to a historical review, and therefore, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.6 112 Waihoehoe Road, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint; and
- Potential ground contamination associated with asbestos fibres from former demolition activities.

It should be noted that the potential sources of contamination (as identified above) are limited to a historical review, and therefore, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.7 116 Waihoehoe Road, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint;
- Potential ground contamination associated with asbestos fibres from former demolition activities and burial of asbestos waste;
- Potential hydrocarbon ground contamination associated with underground fuel storage tanks, storage of waste oil and fuel/oil leaks;
- Potential ground contamination associated with the Engineering Workshop activities;
- Potential ground contamination associated with the Foundry activities;
- Potential ground contamination associated with the burial of waste/refuse;
- Potential ground contamination associated with burning of refuse; and
- Potential ground contamination associated with spray race operations.

9.8 136 Waihoehoe Road, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint;
- Potential ground contamination associated with asbestos fibres from former demolition activities; and
- Potential ground contamination associated with burning of refuse.

9.9 140 Waihoehoe Road, Drury

Following the review of the history and the available information relating to the subject site, no potentially contaminating land uses and/or activities were identified at the site at 140 Waihoehoe Road, Drury.

9.10 15 Kath Henry Lane, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Historical horticultural activities.

It should be noted that the potential sources of contamination (as identified above) are limited to a historical review, and therefore, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.11 18 Kath Henry Lane, Drury

Following the review of the available information relating to the subject site, no potentially contaminating land uses and/or activities were identified at the site at 18 Kath Henry Lane, Drury.

However, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.12 27 Kath Henry Lane, Drury

Following the review of the available information relating to the subject site, no potentially contaminating land uses and/or activities were identified at the site at 27 Kath Henry Lane, Drury.

However, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.13 34 Kath Henry Lane, Drury

Following the review of the available information relating to the subject site, no potentially contaminating land uses and/or activities were identified at the site at 34 Kath Henry Lane, Drury.

However, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.14 44 Kath Henry Lane, Drury

Following the review of the available information relating to the subject site, no potentially contaminating land uses and/or activities were identified at the site at 44 Kath Henry Lane, Drury.

However, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.15 45 Kath Henry Lane, Drury

Following the review of the available information relating to the subject site, no potentially contaminating land uses and/or activities were identified at the site at 45 Kath Henry Lane, Drury.

However, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.16 49 Kath Henry Lane, Drury

Following the review of the available information relating to the subject site, no potentially contaminating land uses and/or activities were identified at the site at 49 Kath Henry Lane, Drury.

However, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

9.17 50 Kath Henry Lane, Drury

Following a review of the history and the available information relating to the subject site the following potential contaminating land uses and/or activities have been identified:

- Potential ground contamination associated with the use of lead-based paint.

It should be noted that the potential sources of contamination (as identified above) are limited to a historical review, and therefore, prior to the commencement of any development at the property, it is recommended that a site walkover and inspection be completed in order to confirm the potentially contaminating land uses and/or activities carried out at the site.

10.0 Conceptual Model of Exposure Pathways

The preliminary conceptual site model provided in Table 37 below expands on the potential sources of contamination (as identified above) and exposure pathways and was based on the potential effects of the proposed change of land use on human health and the environment.

Table 37: Preliminary Conceptual Site Model: Waihoehoe Road Plan Change Area.

Potential Source	Potential Pathways	Potential Receptors	Assessment
Contaminated Soil	Dermal Contact with Contaminated Soils	Human Health – Residential Land Use	Potentially Complete: Sampling and analysis is recommended to confirm the concentrations of contaminants in soil.
		Human Health – Commercial/Industrial Outdoor Worker	Potentially Complete: Sampling and analysis is recommended to confirm the concentrations of contaminants in soil.
	Ingestion of Contaminated Soils	Human Health – Residential Land Use	Potentially Complete: Sampling and analysis is recommended to confirm the concentrations of contaminants in soil.
		Human Health – Commercial/Industrial Outdoor Worker	Potentially Complete: Sampling and analysis is recommended to confirm the concentrations of contaminants in soil.
	Inhalation of Vapours/Fibres	Human Health – Residential Land Use	Potentially Complete: Sampling and analysis is recommended to confirm the concentrations of contaminants in soil.
		Human Health – Commercial/Industrial Outdoor Worker	Potentially Complete: Sampling and analysis is recommended to confirm the concentrations of contaminants in soil.
	Surface Water Run-off	Ecological Receptors - Waiarohia Inlet	Potentially Complete: Sampling and analysis is recommended to confirm the concentrations of contaminants in soil.
	Migration of Groundwater	Ecological Receptors - Waiarohia Inlet	Potentially Complete: Sampling and analysis is recommended to confirm the concentrations of contaminants in soil.

11.0 Conclusions and Recommendations

The history of the site was researched by Focus Environmental Services personnel, which involved a review of the available historical aerial photographs of the site, a review of the Auckland Council property file, a contaminated sites enquiry to Auckland Council, a review of the historical certificates of title and an onsite interview. During the review of the available information any potentially contaminating activities or land uses were identified.

In summary, during the review of the available information the potential for ground contamination associated with the use of lead-based paint and potential asbestos ground contamination associated with former demolition activities at the site was noted.

Following the desk top assessment, the sites at 116, 136 and 140 Waihoehoe Road were visited and a site inspection and walk over was carried out. The sites were inspected by Focus Environmental Services Limited personnel on 8th of February 2019. During the site inspection any potentially contaminating activities or land uses were identified.

In summary, during the site inspection, potential ground contamination associated with underground fuel storage tanks, storage of waste oil and fuel/oil leaks, potential ground contamination associated with the Engineering Workshop and Foundry activities, evidence of waste/refuse burial, evidence of burning, and evidence of potential spray race operations were noted at 116 Waihoehoe Road; evidence of burning was noted at 136 Waihoehoe Road. There were no potentially contaminating land uses and/or activities were identified at the site at 140 Waihoehoe Road, Drury.

With the exception to 116, 136 and 140 Waihoehoe Road, access to the properties within the Waihoehoe Road Plan Change Area were restricted, therefore, the site investigation was limited to a historical review. During the historical review of these sites, potential for ground contamination associated with the use of lead-based paint were noted at 18 Waihoehoe Road, 28 Waihoehoe Road, 44 Waihoehoe Road, 76A Waihoehoe Road, 76 Waihoehoe Road, 112 Waihoehoe Road, 15 Kath Henry Lane, and 50 Kath Henry Lane.

In addition, potential asbestos ground contamination associated with former demolition activities were noted at 18 Waihoehoe Road, 44 Waihoehoe Road, 76A Waihoehoe Road, 76 Waihoehoe Road 112 Waihoehoe Road. Furthermore, historic and current horticultural activities were noted at 15 Kath Henry Lane.

The information obtained of the sites history and from the site inspection and walk over was assessed to determine if any potentially hazardous activities listed on the Hazardous Activities and Industries List (HAIL) had occurred on site as a result of past or current land use.

Due to the potential sources of contamination identified it is considered that there is evidence to suggest that an activity outlined in the Hazardous Activities Industries List (HAIL) has been, or is or is currently being, carried out on the following sites; 18 Waihoehoe Road, 28 Waihoehoe Road, 44 Waihoehoe Road, 76A Waihoehoe Road, 76 Waihoehoe Road, 112 Waihoehoe Road, 116 Waihoehoe Road, 136 Waihoehoe Road, 15 Kath Henry Lane, and 50 Kath Henry Lane.

Prior to the development of the site where potentially contaminating land uses and/or activities have taken place, a detailed site investigation is recommended. However, prior to the completion of the DSI, a thorough site walkover and inspection should be carried out to identify any further potentially contaminating land uses or activities across the site.

The detailed site investigation would confirm if the identified land uses and/or activities have affected the site soils and will confirm the consenting requirements for the site.

Figures

Figure 1 – Site Location Plan

Figure 2 – Site Features Plan

Appendices

Appendix A – Site Contour Plan

Appendix B – Environmental HAIL

Appendix C – Historical Aerial Photographs

Appendix D – Site Contamination Enquiry

Appendix E – Historical Certificate of Title

Appendix F - Site Inspection Photographs

Appendix H

Ecological Assessment

report

March 2019

Waihoehoe Road Ecology Plan Change

Submitted to:
Oyster Capital Ltd
PO Box 1986
Auckland 1140

freshwater solutions
environmental consultants

Quality Assurance

This report has been prepared and reviewed by the following:

Prepared by:	Rebecca Bodley Ecologist		R.Bodley
Reviewed by:	Richard Montgomerie		R. Montgomerie
Status:	Draft v1	**Issued:**	4 March 2019

freshwater solutions

tauranga office
117 willow st tauranga 3141.
po box 13507
p: 07 5771700 f: 07 5771702

auckland office
building 8/level 1 ,666 great south road, ellerslie
po box 109640, Newmarket, Auckland 1149
p: 09 5224492

www.freshwatersolutions.co.nz

Table of Contents

Index to Figures

Index to Tables

Appendices

1.0 Introduction

This report describes the freshwater and terrestrial ecological characteristics and values at 18, 28, 44, 76a, 112, 116, 136 and 140 Waihoehoe Road and all properties located down Kath Henry Lane (collectively referred to as the site), Drury, as part of structure planning for the Drury Opaheke Future Urban Zone (Figure 1). The site is approximately 49.5 ha and bound by Waihoehoe Road to the south, the KiwiRail rail corridor to the west and farmland to the north and east (Figure 1). This report describes freshwater and terrestrial ecological values within the site. Desktop and field data were used to characterise the environment and determine overall ecological values which was used to outline potential ecological constraints and opportunities for ensuring beneficial ecological outcomes for the site.

2.0 Study Methods

2.1 Introduction

A site survey was completed at 116 Waihoehoe Road, which equates to approximately one third of the site (eastern bounds). No survey access was available for the other properties.

2.2 Terrestrial Environment

A terrestrial survey was completed within 116 Waihoehoe Road on 7 February 2019. Plant and fauna species encountered were recorded and existing terrestrial habitats described. Birds identified visually and audibly were recorded across the site, including native and introduced species.

Field data collected from 116 Waihoehoe Road was used to characterise the remaining site, and was supplemented with herpetofauna records (Department of Conservation Bioweb database), bat records (Naturespace NZ), and bird records (New Zealand eBird) and a desktop review of existing literature for the site and wider Drury area.

2.3 Freshwater Environment

Stream classifications within the 116 Waihoehoe Road site were assessed via a site walkover on 30 November 2018. The classification status of watercourses was assessed in accordance with criteria outlined in the Auckland Unitary Plan Operative in Part (AUPOP). Stream classifications in the remainder of the site were completed with reference to field information gathered from the survey of 116 Waihoehoe Road, Auckland Council GIS viewer and historical aerial imagery (Retrolens).

A more detailed survey of watercourses within the 116 Waihoehoe Road site was carried out on 7 February 2019 within the Waihoihoi Stream, as this stream held enough water to complete a stream ecological valuation (SEV), sample biological communities (invertebrates) and measure water physicochemistry (temperature, dissolved oxygen, conductivity and pH). A single macroinvertebrate sample was collected using a kick-net (mesh 0.5 mm) and following the semi-quantitative Protocol C2 (Stark et al. 2001).

The likely presence of fish within the site was discussed based on field collected habitat data supplemented with records held in the New Zealand Freshwater Fisheries Database (NZFFD). Water physicochemistry was measured using calibrated YSI meters.

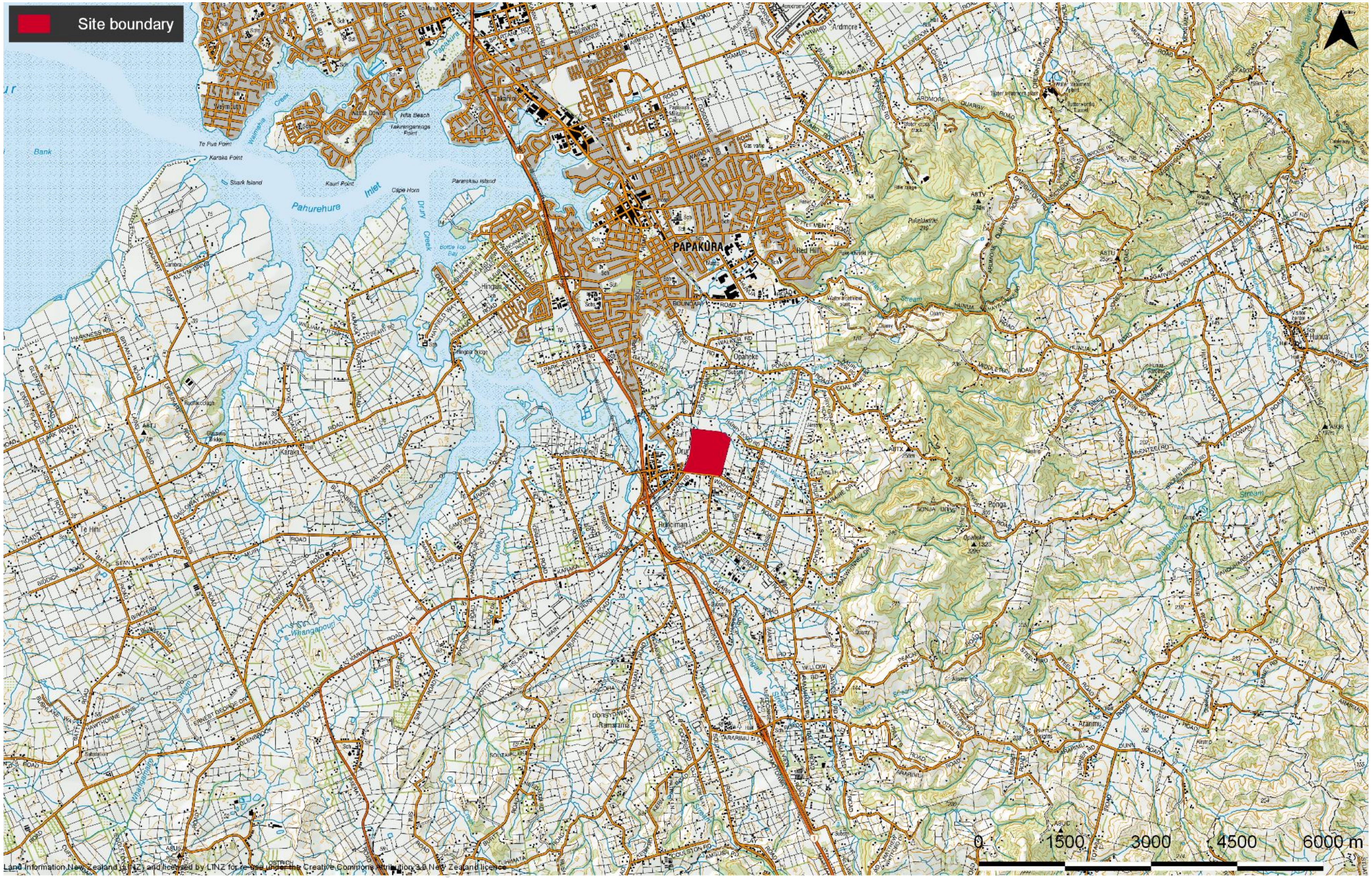


Figure 1: Location of proposed Waihoehoe Road Drury.

3.0 Ecological Setting

The site is located within the Manukau Ecological District which forms the southernmost portion of the Auckland Ecological Region (McEwen 1987). The Manukau Ecological District was characterised on the basis of geology and topography and encompasses low altitude flat to rolling land between the southern shores of the Manukau Harbour and the north bank of the Waikato River (McEwen 1987). The district experiences warm humid summers and mild winters with an annual rainfall of approximately 1100–1300 mm (McEwen 1987). Soils are generally well drained loam from old, strongly weathered volcanic ashes and vegetation has been highly modified by human activity particularly for farming and urbanisation (McEwen 1987).

The district comprises around 62,500 ha, but only c. 947 ha (1.5%) retains any indigenous vegetation cover. The remaining indigenous vegetation is sparse and highly fragmented: there are 296 fragments of forest, scrub or wetland, with the majority (85%) of sites less than 5 ha in size (Emmett et al. 2000). The present isolation and scarcity of remnant vegetation patches within the district means that all areas of indigenous vegetation, no matter how small or modified, are considered important for contributing to the maintenance of biodiversity (Auckland Regional Council 2004).

Manukau Harbour together with the Firth of Thames form the most important wintering grounds for wading birds in the Southwest Pacific (McEwen 1987). The Manukau Harbour is considered to be of international significance and has been identified as a Site of Special Wildlife Interest of 'Outstanding' significance. Important wader roosting areas on the south Manukau harbour include the shell banks and adjoining pasture at Karaka, Seagrove, Waipipi, Puhinui and Pollok Spit (Emmett et al. 2000).

Historically, lowland conifer-broadleaved forest was the most common vegetation type in the ecological district, followed by mixed kauri *(Agathis australis)* forest and kauri-hard beech *(Fuscospora truncata)* forest (Emmett et al. 2000). Auckland Council Geomaps[1] biodiversity layer historically characterises vegetation within the site as a mixture of WF8 – Kahikatea, pukatea forest and WF9 – Tararie, tawa podocarp forest.

Indigenous vegetation as per the Landcover Database (version 4.1) and Significant Ecological Areas (SEAs) in the Auckland Unitary Plan Operative in Part (AUPOP) within the local vicinity of the site are presented on Figure 2. Most fragments of indigenous vegetation remaining within the Manukau Ecological District are located south of Paerata and only 9% of the remaining indigenous vegetation lies within protected natural areas. More than half of the protected vegetation comprises conservation covenants on private land (Auckland Regional Council 2004). No areas of indigenous vegetation occur within the site, nor do any SEA areas.

Restoration and protection of indigenous vegetation using a variety of mechanisms was seen as a priority for both the Manukau Ecological District and the neighbouring Awhitu District by former Auckland Regional Council natural heritage staff in 2004 (Auckland Regional Council 2004).

[1] https://geomapspublic.aucklandcouncil.govt.nz/viewer/index.html

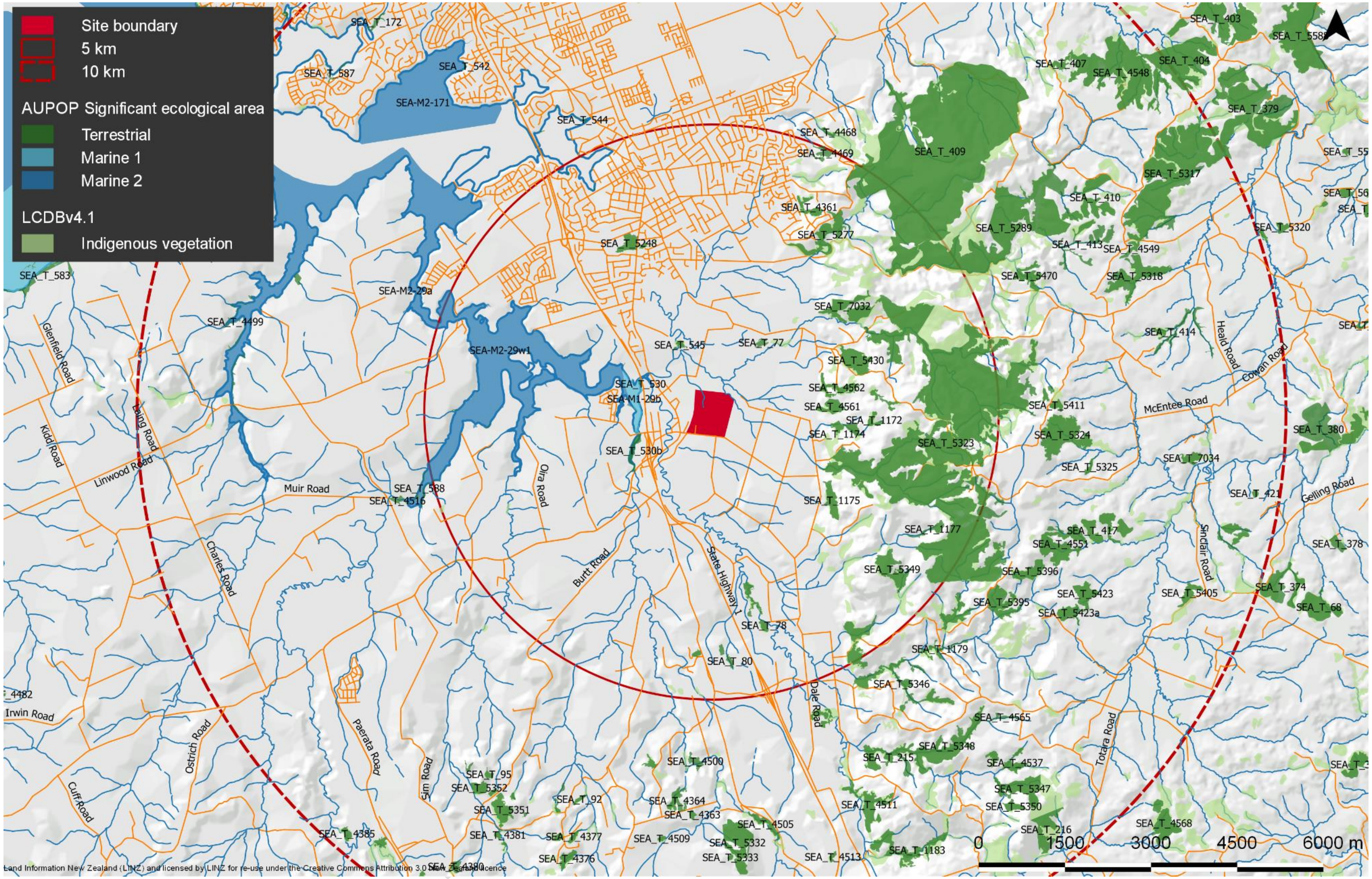


Figure 2: Significant Ecological areas (AUPOP) in the local vicinity of the site.

4.0 Terrestrial Habitats

4.1 Introduction

Terrestrial vegetation within the site at the time of the survey was characterised by pasture used to graze sheep and cattle with shelterbelts and amenity gardens (Figure 3). Very little indigenous vegetation was retained within 116 Waihoehoe Road (the wider site, likely to be similar) aside from occasional natives around dwellings and a small area of native planting along fence lines north and east of Pond P1.

Common species observed within 116 Waihoehoe Road included exotic shelterbelts of pine (*Pinus* sp.) and bald cypress *(Taxodium distichum),* and occasionally hedges of gorse *(Ulex europaeus),* tarata *(Pittosporum eugenioides)* and barberry *(Berberis glaucocarpa)* (Figure 4). Singular specimen trees and ornamental plants included common oak *(Quercus robusta)*, Norfolk pine *(Araucaria heterophylla),* macrocarpa (*Cupressus macrocarpa),* bead tree *(Melia azedarach),* Alder (*Alnus* sp.), *Magnolia* spp., fig *(Ficus carcia),* maple (*Acer* sp.), willow (*Salix* spp.), *Yucca* and fruit trees (i.e., *Malus*, *Citrus*, *Prunus* etc.) (Figure 5) Shrubs such as *Hydrangea*, *Alstroemeria*, flax (*Phormium* spp.), rose (*Rosa* spp.) and *Agapanthus* were common around dwellings and driveways. A similar collection of species are expected to be observed across the wider site.

Native planting along fence lines adjacent to Pond P1 included kāpuka *(Griselinia littoralis),* kōhūhū *(Pittosporum tenuifolium),* koromiko (*Veronica stricta* var. *stricta*), manuka *(Leptospermum scoparium),* kanuka *(Kunzea robusta),* cabbage tree *(Cordyline australis),* tarata, karo *(Pittosporum crassifolium),* flax and kowhai *(Sophora microphylla)* (Figure 6).

Figure 3: typical vegetation across the site.

Figure 4: Typical vegetation within the site, showing hedge of barberry and tarata.

Figure 5: Selection of fruit trees around a dwelling.

Riparian vegetation along watercourses throughout 116 Waihoehoe Road (with the exclusion of the Waihoihoi Stream) typically comprised pasture grasses and herbs such as mercer grass, paspalum *(Paspalum dilatatum),* narrow leaved plantain *(Plantago lanceolata)* and creeping buttercup *(Ranunculus repens)* with occasional gorse *(Ulex europaeus)* water pepper *(Persicaria hydropiper)* and *Juncus* rushes (Figure 7). Occasionally watercourses flowed adjacent to hedge rows of exotic tress such as pine providing some shading. A review of aerial imagery shows watercourses in the wider site are likely to have similar riparian vegetation.

The Waihoihoi Stream was overgrown with blackberry (*Rubus fruticosus* .agg) and great bind weed (*Calystegia silvatica* subsp. *disjuncta*) with occasional willow and arum lily *(Zantedeschia aethiopica)* (Figure 8). A hedgerow of pine was set back approximately 10 m on the true right bank.

Wetland areas were heavily degraded, open to stock grazing and contained minimal native values (Figure 9). Typical vegetation included exotic rushes such as sharp fruited rush *(Juncus acuminatus),* soft rush *(J. effusus var. effusus)*, toad rush *(Juncus bufonius)* and numerous other flat leaved and leafless rushes. Other species included marsh bedstraw *(Galium palustre* subsp. *palustre),* mercer grass, creeping bent *(Agrostis stolonifera)*, spearwort *(Ranunculus flammula), Isolepis* spp. water pepper *(Persicaria hydropiper* and starwort *(Callitriche stagnalis).*

Figure 6: Native vegetation nearing pond P1.

Figure 7: Typical riparian vegetation (February 2019).

Figure 8: Riparian vegetation along the Waihoihoi Stream (February 2019).

Figure 9: Typical wetland vegetation (February 2019).

5.0 Terrestrial Fauna

5.1 Avifauna

The bird life observed on the site (Table 1) reflects the modified state of this rural environment. Three of the five species recorded were native, and all species are considered common species, typical of urban and rural environments.

Nesting habitat for birds on the site comprises predominantly large, mature shelterbelt and amenity trees which are considered to be of reasonably low ecological value for birds.

Table 1: Bird species identified within the site.

Common name	Scientific name	NZ Status	Conservation status
Australian magpie	*Gymnorhina tibicen*	Introduced	-
Common myna	*Acridotheres tristis*	Introduced	-
Spur-wing plover	*Vanellus miles*	Native	Not Threatened
Welcome swallow	*Hirundo neoxena*	Native	Not Threatened
White faced heron	*Egretta novaehollandiae*	Native	Not Threatened

A total of 204 records of birds are listed on the eBird database[2] within 5 km of the site over

[2] eBird Basic Dataset. Version: EBD_relNov-2017. Cornell Lab of Ornithology, Ithaca, New York. Nov 2017.

the period between 1991 to 2018. Forty-seven species have been recorded, the most common include the native welcome swallow and pūkeko and the introduced common myna, Eurasian blackbird, European starling and house sparrow. A number of species of conservation interest have been identified. However, with the exception of a few, they are coastal species and are unlikely to be found as far inland as the site (particularly in the absence of a large river mouth or expanse of aquatic habitat).

Non-coastal birds within 10 km of the site include the freshwater loving New Zealand dabchick, which has been identified by a passenger on the Pukekohe-Papakura train in one of the NZ Hothouse ponds. The New Zealand dabchick is usually found in small lakes or sheltered inlets on larger lakes. Most birds inhabit freshwater lakes and ponds on the volcanic plateau, Rotorua Lakes area, Northland, Hawke's Bay and Wairarapa. The New Zealand dabchick could possibly visit the larger ponds within the site, however this would be unlikely due to their low population number and the likely presence of introduced predators within the site.

Land birds of conservation interest identified within 10 km of the site include the New Zealand falcon, which has a conservation status of 'At Risk' (Recovering) (Robertson et al. 2017). The New Zealand falcon are absent as breeders in most urban or intensive agricultural landscapes so would be unlikely to be found breeding within the site. However, juveniles are commonly observed across many landscapes in winter as they disperse from their natal territories, so there is the potential for them to be infrequent visitors to the site.

5.2 Herpetofauna

One skink was observed during the site visit upon brief observation of logs within the 116 Waihoehoe Road site. The lizard was only observed (not captured). Due to the habitat the lizard was identified in, there is the possibility is may have been a native *Oligosoma* species. The introduced rainbow skink *(Lampropholis delicata)* was also commonly observed. All lizards, except for the introduced rainbow skink are legally protected under an amendment to the Wildlife Act 1953, and their habitats by the Resource Management Act 1991 (Anderson et al. 2012). A significant component of our lizard fauna (~85%) are recognised as 'Threatened' or 'At Risk' in the latest Threat Ranking Lists (Hitchmough et al. 2015).

Herpetofauna recorded on the DOC Bioweb Herpetofauna Database in the vicinity of the site is presented on Figure 11 and include the native lizards; copper skink *(Oligosoma aeneum)*, an unidentified *Oligosoma* species, the introduced lizard rainbow skink, an introduced frog and a marine turtle. Other lizard species known to the Auckland Region include ornate skink *(Oligosoma ornatum)* gecko such as pacific gecko *(Dactylocnemis pacificus),* forest geko *(Hoplodactylus granulatus)* and the elegant geko *(Naultinus elegans)* and coastal skinks such as shore skink *(Oligosoma smithii).*

Both the native copper skink and ornate skink are adaptable ground dwelling skinks that prefer habitat such as wood and debris piles (common around dwellings), vegetated bush/shrub areas, gardens with vegetative cover and adjacent rank grass. There is a considerable amount of habitat within the site suitable for both the native copper skink and ornate skink, especially within the 116 Waihoehoe Road site, under large piles of woody debris (Figure 10). Copper skink and ornate skink can occupy areas of rank pasture when adjacent to other more suitable habitats but are unlikely to be disbursed throughout grazed pasture areas or mown lawn areas. Ornate skink are regarded as 'At Risk' (Declining) by Hitchmough et al. (2015).

Although lizards are mobile and capable of colonising sites from nearby undisturbed sites, the high level of modification and lack of remnant vegetation in the site surrounds make it less likely that native lizards will be present within the site in high numbers.

Figure 10: Large piles of woody debris suitable as lizard habitat within 116 Waihoehoe Road.

Arboreal (forest dwelling) gecko species (i.e., pacific gecko, forest gecko, elegant gecko) are unlikely to occur within the site due to an absence of suitable vegetated habitat. Shore skink is a coastal species that would be unlikely to be found as far inland as the site.

The southern bell frog *(Litoria raniformis)* has been recorded in the vicinity of the site. These species are both terrestrial and aquatic and common in farmland near water. The ponds within the site may provide habitat for these species. The southern bell frog is not protected under the New Zealand Wildlife act 1953 (noted in Schedule 5[3]). While in New Zealand these species are not protected, they are becoming less common in their country of origin Australia. The southern bell frog is considered “Endangered’ according to the 2004 International Union for Conservation of Nature and Natural Resources (IUCN) Red List of Threatened Species[4]. New Zealand is known as a stronghold for the southern bell frog.

[3] http://legislation.govt.nz/act/public/1953/0031/latest/DLM278571.html?search=sw_096be8ed815a96ef_litoria_25_se&p=1&sr=0
[4] http://www.iucnredlist.org/details/12143/0

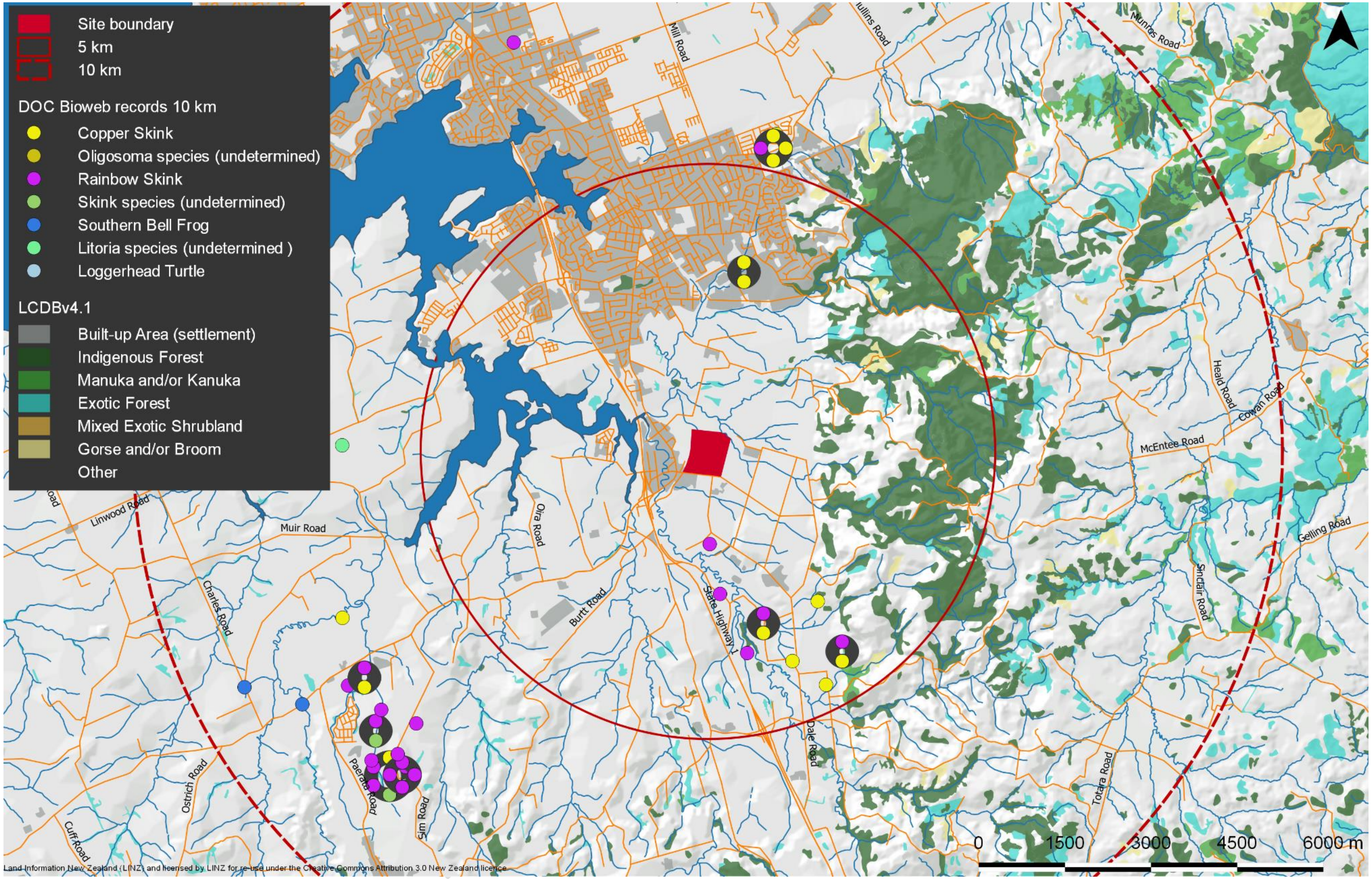


Figure 11: DOC Bioweb Herpetofauna Records in the vicinity of the site.

5.3 Bats

The site is within the ranging distance of known populations of long-tailed bat *(Chalinolobus tuberculatus)* at Point View Reserve Clevedon and the Hunua Ranges. Auckland Council complete bat monitoring regularly across the Auckland Region. Monitoring completed in nearby Redhill to the northeast of the site along Hayes Stream in 2013 has not detected bats, however bats have been detected south east of the site at Ponga Road in 2014. Auckland Council has detected low-high numbers of bats in generally forested habitat further east of the site in the Hunua Ranges, Waharau and Tapapakanga Regional Parks and Mangatangi.

Small numbers of bats have also been detected at nearby Makau, Puni, Patumahoe (Sinclair 2017, Nathan 2017). These locations are similar in character to the site (i.e., rural, lacking large tracts of native bush so are comparable to the site.

Long-tailed bats forage over farmland and urban areas favouring forest edge and riparian habitats where they feed on aquatic insects. Long-tailed bats can cover 50 km in a single night and have ranges extending up to 100 km^2. A study of long-tailed bats within the highly fragmented landscape of South Canterbury found they preferred roosting habitat that included indigenous forest, shrubland remnants and riparian zones (Sedgeley and O'Donnell 2004). Long-tailed bats usually find roosts in large old native canopy trees either beneath the bark or in cavities where they rest during the day and breed. However, they also find suitable roosts in mature exotic trees such as pine and macrocarpa.

It is possible bats are present within the site in low numbers, suitable roosts include any large mature native and exotic trees containing cavities.

Long-tailed bats in the North Island are regarded as 'Threatened' (nationally vulnerable) by O'Donnell et al. (2013). Short tailed bats are only known to be found on Little Barrier Island making their presence at the site unlikely.

6.0 Freshwater Habitats

6.1 Stream and Wetland Habitat

Watercourses and wetlands within the site are shown on Figure 12 along with their stream classifications in accordance with AUPOP criteria (refer to Appendix A for criteria). Historical aerial imagery of the site from 1942 is shown on Figure 13. Floodplains (100-year event) and flood prone areas (1% annual exceedance probability [AEP] extreme rainfall event) are shown on Figure 14. The 1% AEP floodplain extent is derived from Rapid Flood Hazard Mapping and simulates the 1% AEP rainfall event without climate change.

A walkover survey was carried out within 116 Waihoehoe Road on 30 November 2018. The survey was outside the recommended Auckland Council window for classifying intermittent and ephemeral watercourses (i.e., July–October). The walkover survey was carried out after 3.2 mm of rainfall within 48 hrs of the survey and 41.6 mm of rainfall over the previous 7 days at the Auckland Aero monitoring station (National Climate Database). Although the survey was not within the July-October window it was carried out during wet conditions.

All watercourses (A-J) originate within the site and are highly modified and have minimal natural character and low ecological value in their current state. Most of the watercourses within the site are located on the Drury Sand Aquifer, which is classified as a high use Aquifer Management Area and a Quality Sensitive Aquifer in the AUPOP.

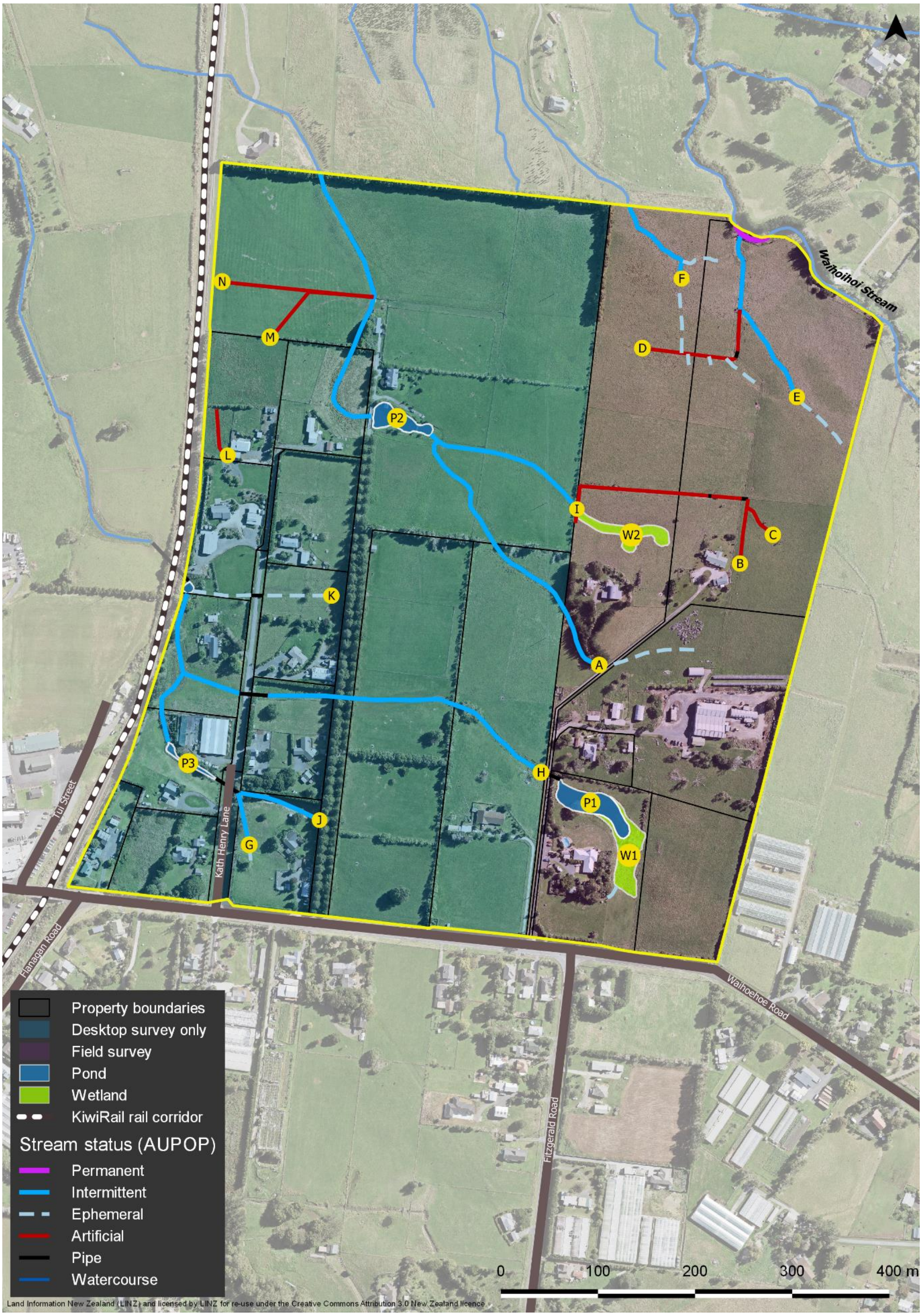


Figure 12: Stream status (AUPOP) and wetlands within the site.

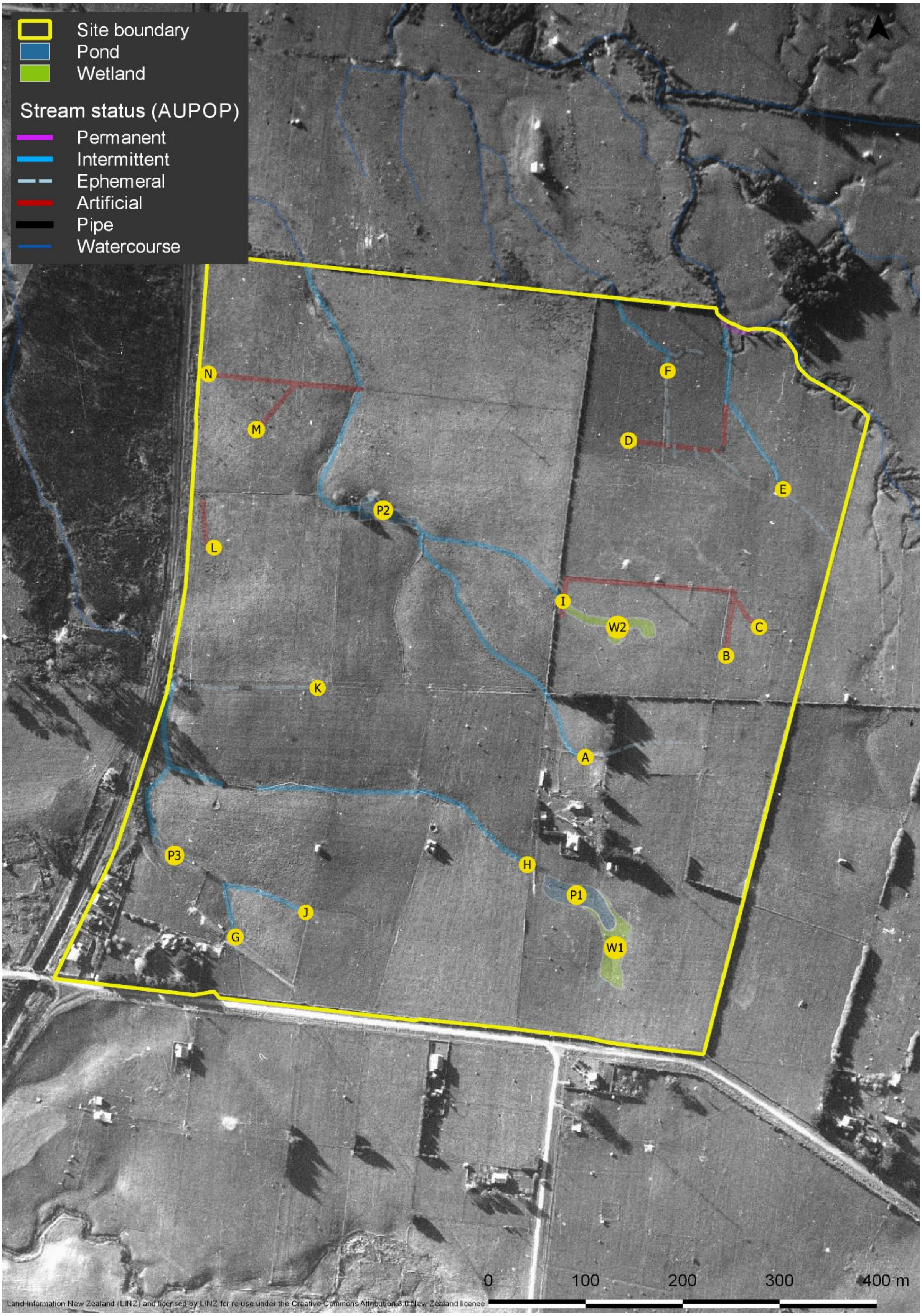


Figure 13: Historical aerial (1942) and showing watercourses.

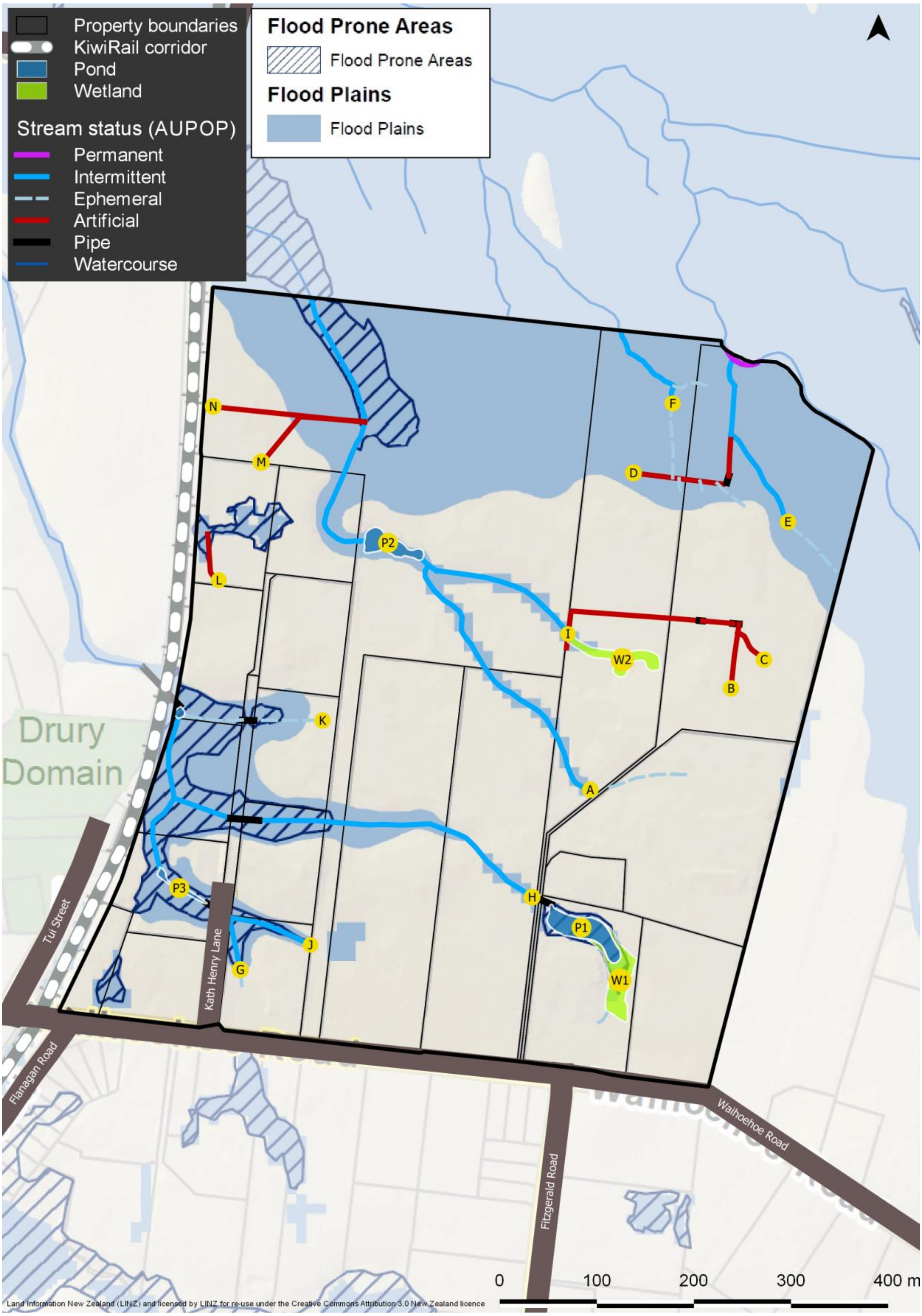


Figure 14: Floodplains and flood prone areas (Auckland Council Geomaps).

Waihoihoi Stream

There is a short section of the mainstem of the Waihoihoi Stream that drains along the north-eastern boundary of the site (Figure 15). The Waihoihoi Stream is one of four main watercourses within the Slippery Creek catchment. Slippery Creek joins Hingaia Stream to form the tidal Drury Creek at the northern end of Drury Township. The Waihoihoi Stream has a naturally meandering channel with a wetted width of 1–3 m and an average depth of 0.26 m at the time of the survey (Figure 15). The channel was incised with some connection with the floodplain during baseflow conditions. The streambed substrate was dominated by silt/sand and small gravels. Woody debris was common within the channel and increased stable aquatic habitat for invertebrates and shelter for fish. Aquatic habitat comprised mainly slow flowing run and pool habitat with occasional riffles. Riparian vegetation was dominated by exotic trees and shrubs and provided some channel shade.

Figure 15: The Waihoihoi Stream within the site.

Watercourse A (Ephemeral and Intermittent)

Watercourse A originates as an ephemeral flow path on 116 Waihoehoe Road and becomes an open intermittent channel surrounded by pine trees below a pipe outlet at the driveway (Figure 16 and Figure 17). The intermittent channel has been artificially widened (2–4 m) near its origin and is choked with emergent aquatic macrophytes (e.g., water pepper, starwort). The upper intermittent section held surface water (but not flowing) at the time of the 30 November 2018 survey and was dry during the 7 February 2019 survey. Watercourse A flows in a north-westerly direction onto 112 Waihoehoe Road over open grazed pasture and feeds into Watercourse I at Pond P2. Below pond P2, Watercourse A exits the site in its north western corner where it continues downstream until it drains into the mainstem of Waihoehoe Stream near Drury (~150 m upstream of Slipper Creek confluence). Watercourse A within the site provides marginal aquatic habitat of poor quality for invertebrates and fish.

Figure 16: Watercourse A within the site (November 2018).

Figure 17: Watercourse A within the site (February 2019).

Watercourses B, C, D, L, M and N (Artificial Watercourses)

Watercourses B, C, L, M and N were classified as artificial as they did not appear to be replacing natural drainage systems or appear as channels on the 1942 aerial photographs. Watercourse L in particular appears to have been dug recently (between 2015/16 and 2017 based on aerial imagery; Auckland Council Geomaps). Watercourse D was a straight aligned artificial channel and held water in November but was dry in February (Figure 18).

Figure 18: Watercourse D in November 2018 (top) and February 2019 (below).

All artificial watercourses surveyed had straight alignments with uniform and generally lacking riparian vegetation. Artificial watercourses within property 116 Waihoehoe Road held surface water during the November 2018 survey but were dry during the February 2019 survey. All artificial watercourses within the site represent highly modified aquatic habitats and provide very-poor quality aquatic habitat.

Watercourse E (Ephemeral and Intermittent)

Watercourse E originates in a shallow but natural depression in a grazed paddock as an ephemeral flow path. The ephemeral section transitions into an intermittent section that held a small amount of surface water in November 2018 but was dry in February 2019. The upper intermittent section has a wide and poorly defined channel affected by grazing pressure. The channel was choked with grasses (including mercer grass and creeping bent) and supported emergent macrophytes including water pepper and starwort in November 2018. This natural upper section discharges to a highly channelised mid-lower section that flows along a fence-line and a narrow strip of gorse before discharging into the mainstem of the Waihoihoi Stream (Figure 19). Watercourse E represents a highly modified environment and provides marginal aquatic habitat of poor quality.

Figure 19: Intermittent sections of Watercourse E (upper and lower sections).

Watercourse F (Ephemeral and Intermittent)

Watercourse F (Figure 20) is an intermittent stream that drains a natural shallow depression in a flat grazed paddock. The upper reach is fed by ephemeral flow paths including one that appeared t be joined with Watercourse D. The channel is grazing damaged, poorly defined, choked with pasture grasses and lacks riparian vegetation. The channel held a small amount of surface water during the November 2018 survey but was dry in February 2019. Aquatic macrophytes recorded during the November 2018 survey included water pepper and starwort. Watercourse F is highly modified intermittent stream that provides poor quality aquatic habitat in its current state.

Figure 20: Lower Watercourse F within the site (February 2019).

Watercourses G, H, I, J and K (Ephemeral and Intermittent)

It was not possible to walk over Watercourses G, H, I or J, however based on aerial imagery, these watercourses are likely to have similar characteristics to those observed in 116 Waihoehoe Road (i.e., unshaded, poorly defined, grazing damaged channels, lined with exotic grasses and herbs). A number of culverts (driveway crossings) and ponds have the potential to be acting as barriers to fish migration in Watercourses G, H, I and J.

Wetlands W1 and W2

The site contains two wetlands (W1 and W2). Wetland W1 is associated with the online Pond P1 (Figure 21). The boundary of wetland W2 was difficult to determine and was based on the presence of facultative and obligate wetland plant species (Figure 22). Rainfall in the week prior to the November 2018 survey may have resulted in wetland W2 holding more water than what would be expected. Wetland W2 did not hold surface water during the February 2019 survey and indicates it dries out after prolonged dry periods.

Wetland W1 and W2 are severely damaged through unrestricted grazing pressure and are typically lined with exotic grasses (mercer grass, *Paspalum distichum*), rushes and sedges (i.e., *Juncus* and *Isolepis*) and macrophytes such as water pepper and starwort in wetter seasons. These wetland habitats are wide, waterlogged (in winter) and lack natural defined stream channels. These wetland habitats are unlikely to support native fish due to inadequate surface water depths but may support invertebrates tolerant of degraded conditions during periods when they hold surface water.

Figure 21: Wetland W1 during November 2018 survey.

Figure 22: Wetland W2 during November 2018 survey.

Online Ponds P1, P2 and P3

Three artificial ponds were identified through a combination of reviewing aerial photography and site surveys. All ponds were online ponds and most were in the mid-upper reaches of intermittent tributaries. The largest pond occurs in the upper section of Watercourse H (Figure 23). Ponds are likely to be drained via perched culverts or structures that may be barriers to upstream fish passage. Artificial ponds within the site provided poor quality still water habitat and are likely to be adversely affecting downstream water physicochemistry.

Figure 23: Online Pond P1.

7.0 Water Quality and Aquatic Biota

7.1 Introduction

Water physiochemistry and invertebrate data were collected from the Waihoihoi Stream within 116 Waihoehoe Road. This reach was the only section of permanent stream (with surface water) within the 116 Waihoehoe Road site at the time of the February survey. Raw invertebrate data is presented in full in Appendix B.

7.2 Water Physiochemistry

Water temperature measured in the Waihoihoi Stream was moderate (20.0°C at 12:20 p.m.) and reflected the time of the year the survey was carried out. Dissolved oxygen was moderate (85%, 7.83 g/m^3), conductivity within the low range (91.9 µS/cm) and pH circum-neutral (7.15). Water physiochemistry would not have been limiting aquatic biota in the Waihoihoi Stream at the time of the survey.

7.3 Benthic Invertebrates

The Waihoihoi Stream within and immediately to the north of the site supported an invertebrate community with moderate taxa richness (25 taxa) and high abundance (2,900 individuals/m²) caused by high numbers of the snail *Potamopyrgus*. The most common taxonomic groups recorded were Mollusca (Snails), Diptera (true flies) and Platyhelminthes (Flatworms) which are typically associated with soft-bottomed streams and degraded habitat and water quality. Six water and habitat sensitive EPT taxa were recorded, including four different mayflies (*Austroclima, Deleatidium, Nesameletus* and *Zephlebia*) and two species of caddisfly (*Hydrobiosis* and *Pycnocentrodes*). No stoneflies were recorded. The MCI-sb score for the community recorded from the Waihoihoi Stream was 78.1 and indicative of ‘poor’ stream health (i.e., <80).

Other watercourses within the site are either intermittent, artificial or ephemeral and drain areas of grazed pasture without vegetated riparian margins. Watercourses are unfenced and grazing animals have direct access to streambanks and channels causing disturbance to benthic habitat and resulting in poor instream conditions for invertebrates. Although not sampled, in winter when flows allow, other watercourses within the site are likely to support invertebrate communities dominated by taxa that are tolerant of degraded instream conditions (e.g., ostracods, worms, dipterans, damselflies).

7.4 Freshwater Fish

Fish Fauna

Two shortfin eel measuring 500 mm and 420 mm were observed in the Waihoihoi Stream during the survey. No other fish species were observed.

The New Zealand Freshwater Fish Database (NZFFD) does not contain any records of freshwater fish within the site. There are 25 records of fish and kōura between 1980 and 2005 within the Waihoihoi catchment. Seven native fish species and kōura have been recorded from the catchment including three species of conservation interest: longfin eel, īnanga and torrentfish, which are ‘At Risk’ (Declining) (Dunn et al. 2017). The most commonly recorded species are kōura and banded kōkopu.

Overall, there is limited habitat for freshwater fish within the site with the exception of the Waihoihoi Stream and online ponds. All other watercourses within the site have been modified, have intermittent or ephemeral habitat characteristics, lack defined channels due to grazing damage, hold shallow surface water in winter, choked with grass and lack overhead cover and instream refugia. There are numerous barriers to fish passage within the site including culverts (pipes), bunded crossings and online ponds.

8.0 Summary of Ecological Values

8.1 Terrestrial Environment

The site is characterised by pasture, exotic shelterbelts, weeds and amenity gardens with a mixture of native and exotic species. Although vegetation within the site is of low value, given the absence of forested areas in the local landscape, shelterbelts and exotic trees and shrubs do provide a function as refuges for native fauna, while providing basic ecosystem services. No areas within the site were recognised under the AUPOP as having SEA status and our assessment of the site agrees with this conclusion.

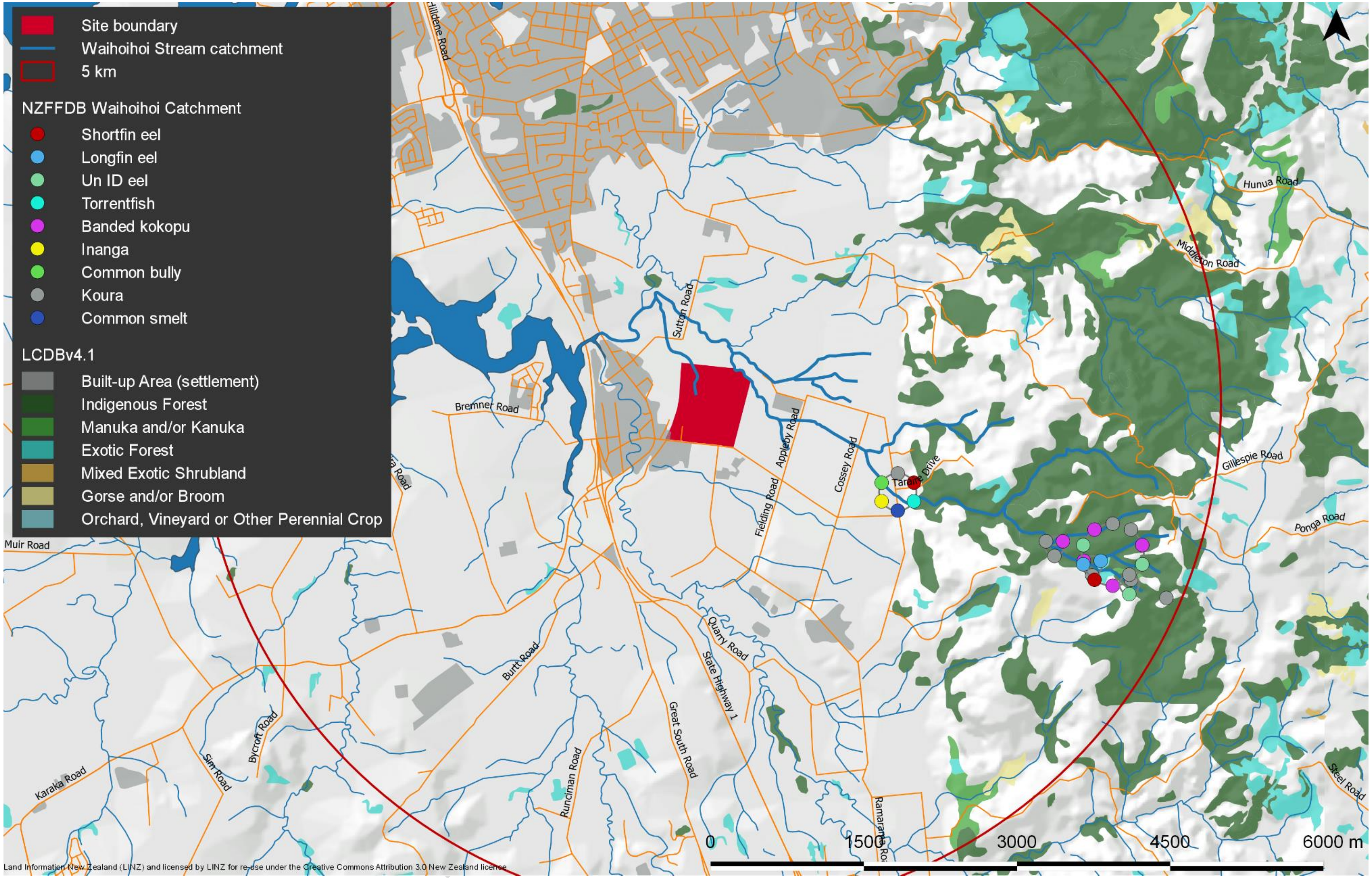


Figure 24: NZFFD fish records in the Waihoihoi Catchment

Bird species identified within the site and most historic records within the local area comprise common species typical of rural and urban areas. The only species of conservation interest from within the local area are unlikely to be more than infrequent visitors to the site due to the scarcity of suitable habitat.

Native tree dwelling gecko species known to the Auckland Region are unlikely to be present within the site, due to the absences of suitable habitat. Adaptable ground dwelling species such as the native copper skink and ornate skink may be present within the site (particularly in 116 Waihoehoe Road in wood piles). All native lizard species are legally protected under an amendment to the Wildlife Act 1953 and their habitats by the Resource Management Act 1991 (Anderson et al. 2012).

A search for bat roosts was not conducted within the site. It is possible very low numbers of bats may frequent mature exotic trees (including shelterbelts) within the site that contain suitable cavities. Particularly trees lining moderately large watercourses.

8.2 Freshwater Environment

Watercourses within the site have been influenced and shaped by a long history of rural landuse practices associated with stock grazing that has resulted in clearance of riparian vegetation, disturbance of channels and damage to streambanks and streambeds.

All watercourses within the site have been modified to varying degrees and have limited natural character. The watercourses generally provide aquatic habitat of moderate to poor quality due to vegetation clearance and grazing damage. All watercourses within the site, with the exception of the Waihoihoi Stream, have low ecological value.

The Waihoihoi Stream has good baseflow and shortfin eel was observed during the survey, and it also has the potential to support other species (e.g., īnanga or banded kōkopu) in future if enhanced through riparian planting and if there are no barriers to upstream fish passage in the lower catchment.

The online ponds P1, P2 and P3 are highly modified aquatic environment that provide still water habitat of low quality and ecological value. The online ponds have the potential to adversely affect downstream water quality through the discharge of water with elevated temperatures and depressed dissolved oxygen.

Freshwater wetlands within the site are highly modified and degraded, dominated by exotic species, artificially drained in places, are open to stock trampling and have minimal indigenous values and character in their current state. Nationally wetlands have been severely reduced in extent, the figure of 10% is often quoted for the area that now remains (Johnson and Gerbeaux 2004) and freshwater wetlands are a priority for protection in the Manukau Ecological District where only 0.4% of original wetlands remain. Therefore, while the wetlands within the site are highly degraded and somewhat water short, they are still regarded as valuable for their potential to be restored and function within the catchment.

The ecological and functional values of Waihoihoi Stream within and adjacent to the site was assessed using the Stream Ecological Valuation (SEV) method. SEV results are summarised in Table 1 (presented in full in Appendix D). The SEV score for the Waihoihoi Stream within and adjacent to the site was 0.531 (out of a maximum of 1.0) (Table 1). The SEV score for The Waihoihoi Stream in measured within and adjacent to the site is lower than the mean score of 0.610 (n = 19; range 0.25–0.96) for sites in Auckland Council’s monitoring network across rural, native forest, exotic forest and urban land uses (Storey et al. 2011).

Table 2: SEV scores for The Waihoihoi Stream within and adjacent to the site.

Function	Function	Waihoihoi Stream
Hydraulic	Natural flow regime	0.93
	Floodplain effectiveness	0.32
	Connectivity for species migrations	1.00
	Natural connectivity to groundwater	0.96
	Hydraulic function mean score	***0.80***
Biogeochemical	Water temperature control	0.16
	Dissolved oxygen levels maintained	0.50
	Organic matter input	0.07
	In-stream particle retention	0.85
	Decontamination of pollutants	0.50
	Biogeochemical function mean score	***0.42***
Habitat Provision	Fish spawning habitat	0.55
	Habitat for aquatic fauna	0.56
	Habitat provision function mean score	***0.56***
Biodiversity	Fish fauna intact	0.23
	Invertebrate fauna intact	0.59
	Riparian vegetation intact	0.21
	Biodiversity function mean score	***0.34***
	SEV score	**0.531**

9.0 Opportunities and Constraints

9.1 Terrestrial Habitat Protection and Enhancement

There is no existing terrestrial vegetation within the site that warrants specific protection nor enhancement. The AUPOP provides a comprehensive set of rules relating to vegetation in chapter E15 and these are considered to be appropriate to address the potential for adverse effects in the same way they already apply under the current zoning of the site.

9.2 Avifauna

Bird species identified within the site are common species typical of rural and urban areas, all of which readily habituate to disturbance so are unlikely to be especially affected by development of the site. The recommended riparian planting noted in Section 9.5 will benefit current and future bird species within the site by increasing habitat availability, diversity and food sources.

While the majority of birds within the site are expected to be common species of no conservation interest, vegetation clearance (particularly of mature trees) can adversely affect native species when completed over the breeding season (September – February inclusive). Ideally vegetation clearance should occur within autumn – winter as to not impact the breeding season. If vegetation clearance occurs during the breeding season, other mitigation techniques such as avoiding trees containing nests until chicks have fledged can be employed.

9.3 Herpetofauna

Areas most likely to support lizards within the site include rank grass, shrubs, amenity vegetation around buildings, and debris (e.g., wood and rubbish piles) which is especially common in 116 Waihoehoe Road. Copper skink and ornate skink can occupy areas of rank pasture when adjacent to other more suitable habitats but are unlikely to be disbursed throughout the entire grazed pasture or mown lawn areas.

It is recommended that the presence of lizards be confirmed by way of survey within the site and to thus inform the requirement for a lizard management plan.

Aside from riparian planting and enhancement that will create additional vegetated habitat for lizards (Section 9.5), other opportunities for enhancement include creating habitat (i.e., installing log stacks), ensuring long rank grass areas (or dense low growing native species) are retained along the margins of bush and scrub areas and implementing a long-term animal pest control plan to reduce predators.

The southern bell frog has been recorded in the vicinity of the site and has the potential to be present in ponds P1, P2 and P3 within the site. No mitigation is required for any loss of habitat for southern bell frog as they are an exotic species. There are no native amphibians near the location so disease risk and competition with native frogs are negligible.

9.4 Bats

There is the potential for bat roosts to occur within mature trees within the site that have hollows and cavities. This will need to be assessed and if confirmed mitigations may need to be implemented. All mature trees, regardless if they are native or exotic, are valuable in the long-term as they age to ensure sufficient bat roosting habitat is maintained across the landscape. There is potential to consider retaining mature existing (non-invasive) trees in riparian areas (preferential roosting locations for bats) where they can be incorporated into the development design as they have more immediate future potential to provide bat roosts given their current age.

9.5 Aquatic and Riparian Habitat Enhancement

There is significant potential to enhance streams and wetlands within the site through weed control, riparian planting, fencing from stock (where applicable), suitable legal protection (i.e., covenant) and through increasing habitat connectivity and restoration of ecological corridors within the site.

All streams within the site are currently unfenced and with no riparian vegetation. The removal of grazing stock and a programme of riparian planting will result in an increase in channel shade, woody debris inputs (e.g., potential instream habitat), improve streambank stability and improve overall ecological values. It is recommended that the planting of second generation diversity forest trees of the former forest type (i.e., kahikatea, pukatea, tawa, taraire, tītoki, etc.) is included amongst pioneer species (i.e., mānuka and kānuka) to help to kick-start natural forest regeneration. This will also have the added benefit of diversifying the food available for current and future lizard and bird species within the site, and in the very long-term provide potential suitable bat roosts.

Likewise, the restoration of wetland areas with suitable native plants and native terrestrial buffer vegetation will help to increase ecosystem diversity within the site and restore some of the valuable ecosystem functions that wetlands provide such as flood water attenuation, sustaining and balancing base flow rates, and filtration and removal of sediment, nutrients and other pollutants reaching watercourses through overland flow.

All riparian and wetland areas should be fenced to prevent stock access where this is applicable in any future development.

9.6 Modification or Reclamation of Natural Watercourses and Wetlands

Any reclamation or modification of intermittent or permanent natural streams or wetlands within the site will require offsetting through the enhancement of another section of stream or wetland within the site or offsite to ensure 'no-net-loss' of overall ecological function and values. Works in watercourses during reclamation should adhere to strict sediment control and hygiene protocols to avoid the discharge of sediment to the downstream environment and spreading aquatic weed species.

9.7 Modification of Ephemeral Flow Paths and Artificial Channels

Overland flow paths occur within the site in areas of grazed pasture. Modification of overland flow paths does not require offsetting under AUPOP rules. Overland flow paths can provide functional roles in catchments so their retention and enhancement would have some benefit to the catchment.

The AUPOP defines artificial watercourses as *'constructed watercourses that contain no natural portions from their confluence with a river or stream to their headwaters'*. Artificial watercourses are not included in the definition of a river under the Resource Management Act and can be modified or removed as a permitted activity under AUPOP rules.

9.8 Removal of Artificial Ponds

The removal of artificial ponds has the potential to improve downstream water quality and fish passage and result in an overall enhancement of aquatic ecological values and natural character within the site. Any works within ponds should adhere to sediment control and hygiene protocols to avoid the discharge of sediment to downstream aquatic environments and the spreading of aquatic weed species.

9.1 Removal or Retrofitting Potential Fish Barriers

There is an opportunity to improve fish passage for native diadromous fish and increase natural stream character within the site through the removal of perched culverts and blocked culverts.

9.2 Development Within Floodplains

The site is partially located on the Drury Sand Aquifer which is classified as a high use Aquifer Management Area and a Quality Sensitive Aquifer in the AUPOP. Watercourses within the site are likely to be aquifer fed to some extent and could be affected by a reduction in aquifer recharge if development in the catchment is not managed appropriately. Retaining natural landform and avoiding development within the floodplain will help to protect groundwater levels and remaining watercourses in the site and wider stream catchments.

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APPENDIX A

Stream Classification Criteria (AUPOP)

Auckland Unitary Plan Operative in Part

River or stream

A continually or intermittently flowing body of fresh water, excluding ephemeral streams, and includes a stream or modified watercourse; but does not include any artificial watercourse (including an irrigation canal, water supply race, canal for the supply of water for electricity power generation, and farm drainage canal except where it is a modified element of a natural drainage system).

Permanent river or stream

The continually flowing reaches of any river or stream.

Intermittent stream

Stream reaches that cease to flow for periods of the year because the bed is periodically above the water table. This category is defined by those stream reaches that do not meet the definition of permanent river or stream and meet at least three of the following criteria:

a) it has natural pools
b) it has a well-defined channel, such that the bed and banks can be distinguished;
c) it contains surface water more than 48 hours after a rain event which results in stream flow;
d) rooted terrestrial vegetation is not established across the entire cross-sectional width of the channel;
e) organic debris resulting from flood can be seen on the floodplain; or
f) there is evidence of substrate sorting process, including scour and deposition.

Ephemeral stream

Stream reaches with a bed above the water table at all times, with water only flowing during and shortly after rain events. This category is defined as those stream reaches that do not meet the definition of permanent river or stream or intermittent stream.

Artificial watercourse

Constructed watercourses that contain no natural portions from their confluence with a river or stream to their headwaters.

Includes:

- canals that supply water to electricity power generation plants;
- farm drainage canals;
- irrigation canals; and
- water supply races.

Excludes: naturally occurring watercourses

APPENDIX B

Raw Invertebrate Data

	MCI-sb	Waihoehoe Road
Ephemeroptera		
Austroclima	6.5	2
Deleatidium	5.6	13
Nesameletus	8.6	1
Zephlebia	8.8	24
Trichoptera		
Hydrobiosis	6.7	2
Oxyethira	1.2	14
Pycnocentrodes	3.8	1
Hemiptera		
Microvelia	4.6	1
Coleoptera		
Elmidae	7.2	48
Diptera		
Austrosimulium	3.9	320
Corynoneura	1.7	1
Orthocladiinae	3.2	18
Polypedilum	8.0	7
COLLEMBOLA	5.3	2
Crustacea		
Amphipoda	5.5	1
Copepoda	2.4	2
Ostracoda	1.9	2
MOLLUSCA		
Lymnaeidae	1.2	1
Physella (Physa)	0.1	2
Potamopyrgus	2.1	2288
OLIGOCHAETA	3.8	48
HIRUDINEA	1.2	1
PLATYHELMINTHES	0.9	96
NEMERTEA	1.8	2
Hydra	1.6	3

Appendix I

Hydraulic Structures Assessment

MOTT MACDONALD

Drury Opaheke Future Urban Zone Major Structures Flooding Assessment

14 December 2018

Mott MacDonald
Mason Bros. Building
Level 2, 139 Pakenham
Street West
Wynyard Quarter
Auckland 1010
PO Box 37525, Parnell,
1151
New Zealand

T +64 (0)9 375 2400
mottmac.com

Drury Opaheke Future Urban Zone Major Structures Flooding Assessment

14 December 2018

Mott MacDonald New Zealand Limited
Registered in New Zealand no. 3338812

Issue and Revision Record

Revision	Date	Originator	Checker	Approver	Description
A	14 Dec 2018	Carmel O'Sullivan			Work in Progress

Document reference: 391951 | 1 | A

Information class: Standard

Contents

Executive summary

Auckland Council have carried out a hydraulic assessment of the major structures (bridges and major culverts) within and downstream of the Drury Opaheke Future Urban Zone (FUZ).

The modelling indicates that ten bridges and or their approach roads will be overtopped during a 100 year ARI Maximum Probable Development (MPD) with Climate Change (CC) storm event. These bridges are located within and downstream of the FUZ.

The railway line at the northern end of the FUZ is also predicted to be overtopped during a 100 year ARI MPD CC storm event as is the motorway south of the motorway bridge.

The two Great South Road bridges (and associated approach roads) along the Hingaia Stream (within Drury East) and Slippery Creek (within Opaheke) respectively are predicted to be overtopped during a 100 year ARI MPD CC scenario. Both bridges are downstream of the Future Urban Zone. The maximum depth of flow over Great South Road (within Drury West) is predicted to be 1.356m during a 100 year ARI MPD CC event and 0.8m during a 100 year ARI MPD event without climate change. Raising Great South Road is a potential option to address this.

Sutton Road bridge and the approach road to Opaheke Road bridge are predicted to be overtopped during a 100 year ARI MPD CC scenario. Sutton Road bridge is also predicted to be overtopped during a 10 year storm event (without climate change).

The modelling indicates that Flanagan Road bridge and Norrie Road bridge (within Drury East) will be overtopped during a 100 year ARI MPD CC event. Flanagan Road bridge is within the FUZ while Norrie Road bridge is within Drury township. The road level above two culverts within Drury East is also predicted to be inundated during this storm event. One of these culverts is beneath Great South Road. The second culvert spans Flanagan Road and the railway. Modelling indicates that the railway will not be inundated as it is higher than Flanagan Road.

Three bridges along the Ngakoroa Stream (within Drury West) are predicated to be overtopped in a 100 year storm event both with and without climate change. These bridges are the Runciman Road bridge, Pitt Road bridge and Bremner Road bridge which is located downstream of the FUZ. Runciman Road bridge is also predicted to overtop during a 10 year storm event. All three bridges are currently classed as minor urban but it is understood that Bremner Road bridge is a future arterial. Potentially the level of service for local roads could be lower (such as being required not to overtop during a 10 year storm event) than for arterial roads. This needs to be discussed with AT.

This is a live document which will be updated as more information becomes available.

1 Introduction

Auckland Council have carried out a hydraulic assessment of the major structures (bridges and major culverts) within and downstream of the Drury Opaheke Future Urban Zone (FUZ). One of the objectives of the assessment was to determine how the structures would 'cope' in a 100 year ARI storm event - did they have capacity to convey the 100 year ARI storm event (for example) would they be overtopped, do they meet AT / NZTA freeboard requirements?

All the structures were assessed for the following scenarios

1. 100 year ARI Maximum Probable Development (MPD) with Climate Change (CC) with FUZ
2. 100 year ARI MPD with CC without FUZ
3. 100 year ARI MPD without CC without FUZ

The modelling indicates that there is minimal difference (if any) in flows and associated water levels between scenarios 1 and 2. Therefore, it appears that development of the FUZ will have minimal impact (if any) on 100 year flows (and associated water levels).

Some structures have been assessed for the 10 year ARI storm event without CC. Modelling is currently being undertaken to assess the remainder of the structures for this event. Auckland Council modelling spec requires that local roads not overtop during a 10 year storm event. Input will be sought from AT to confirm this meets their standards.

Table 1 identifies the major structures that were assessed within the Slippery Creek (Opaheke) catchment. It includes the modelled scenarios (such as 100 year ARI MPD CC), water levels associated with those scenarios, bridge deck level, road overtopping level (where applicable), whether the structure meets the AT / NZTA freeboard requirements and Level of Service Requirements. The assessed structures can be seen in Figure 1.

Table 2 identifies the major structures that were assessed in the Hingaia Stream (Drury East) catchment.

Table 3 identifies the major structures that were assessed in the Ngakoroa and Oira (Drury West) catchments. The assessed structures can be seen in Figure 2.

Individual project sheets for each structure that is predicted to be overtopped in a 100 year ARI MPD CC event or that has minimal freeboard have been prepared. These sheets include information such as flows and water levels at the structure for the various modelled scenarios, whether the structure is overtopped, potential options, modelled options and additional comments. The purpose of the project sheets is to set out as many facts as possible to facilitate decision making on whether the structure is acceptable, needs to be replaced, upsized, etc.

The project sheets are located in Section 2 of this report. Structures for which Project Sheets have been prepared can be seen in Figure 3.

It's important to note that this is a 'living' document which will be updated as more information becomes available.

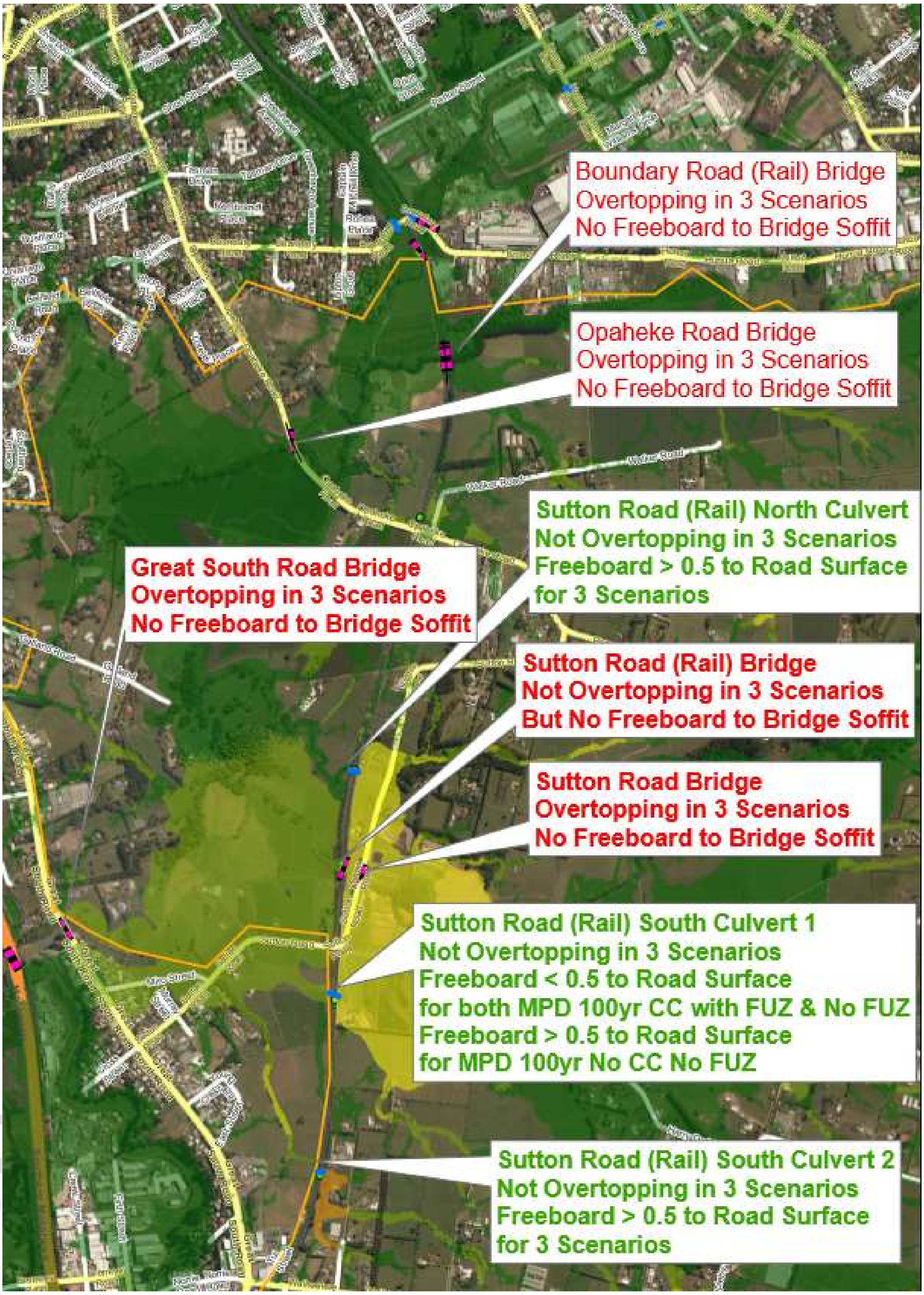


Figure 1 Structures Assessed within Slippery Creek (Opaheke)

Table 1: Slippery Creek Catchment Structures Assessment

Structures	Scenarios	Full Flow Capacity (m3/s)	Peak Flow (m3/S)	Maximum U/S WL (m RL)	Maximum D/S WL (m RL)	Bridge Soffit Level (m RL)	Bridge Deck Level (m RL)	Road Overtopping Level (m RL)	Freeboard Based on NZTA Bridge Manual (m)	Satisfy 100-year ARI LOS (NZTA)	Notes
Boundary Road (Rail) Bridge	MPD 100yr CC with FUZ	120.0	204.3	14.83	14.11	14.4	15.0	14.3	0.0	No	Lowest overtopping level is not at the bridge location.
	ED 10yr without CC with FUZ		56.2	13.13	12.95				1.3	-	
	MPD 100yr CC without FUZ		203.8	14.82	14.11				0.0	No	
	MPD 100yr without CC without FUZ		163.0	14.47	13.89				0.0	No	
Opaheke Road Bridge	MPD 100yr CC with FUZ	87.0	260.0	11.77	11.68	11.6	11.8	11.3	0.0	No	Lowest overtopping level is not at the bridge location.
	ED 10yr without CC with FUZ		59.6	11.06	11.01				0.5	-	
	MPD 100yr CC without FUZ		259.0	11.77	11.68				0.0	No	
	MPD 100yr without CC without FUZ		202.0	11.60	11.53				0.0	No	
Sutton Road (Rail) North Culvert	MPD 100yr CC with FUZ	7.0	8.6	8.22	7.56	-	-	10.6	2.4	Yes	-
	ED 10yr without CC with FUZ		3.7	6.78	6.64				3.8	-	
	MPD 100yr CC without FUZ		8.5	8.18	7.55				2.4	Yes	
	MPD 100yr without CC without FUZ		6.4	7.75	7.38				2.9	Yes	
Sutton Road Bridge	MPD 100yr CC with FUZ	32.0	130.9	8.94	8.85	7.1	7.4	7.2	0.0	No	Lowest overtopping level is not at
	ED 10yr without CC with FUZ		45.3	7.58	7.37				0.0	-	

	MPD 100yr CC without FUZ		130.0	8.89	8.81				0.0	No	the bridge location.
	MPD 100yr without CC without FUZ		113.0	8.52	8.40				0.0	No	
Sutton Road (Rail) Bridge	MPD 100yr CC with FUZ	67.0	123.9	8.77	8.10	7.5	9.2	9.2	0.0	No	-
	ED 10yr without CC with FUZ		44.6	7.16	7.01				0.3	-	
	MPD 100yr CC without FUZ		121.8	8.72	8.08				0.0	No	
	MPD 100yr without CC without FUZ		102.0	8.29	7.87				0.0	No	
Great South Road Bridge	MPD 100yr CC with FUZ	320.0	362.0	6.10	5.68	5.7	5.9	5.8	0.0	No	Lowest overtopping level is not at the bridge location.
	ED 10yr without CC with FUZ		115.2	4.01	3.99				1.7	-	
	MPD 100yr CC without FUZ		358.0	6.10	5.67				0.0	No	
	MPD 100yr without CC without FUZ		285.0	5.78	5.42				0.0	No	
Sutton Road (Rail) South Culvert 1	MPD 100yr CC with FUZ	1.2	2.8	9.08	6.97	-	-	9.3	0.2	No	-
	ED 10yr without CC with FUZ		1.3	7.52	6.68				1.8	-	
	MPD 100yr CC without FUZ		2.8	9.02	6.97				0.3	No	
	MPD 100yr without CC without FUZ		2.5	8.67	6.89				0.6	Yes	
Sutton Road (Rail) South Culvert 2	MPD 100yr CC with FUZ	1.0	1.8	12.08	10.90	-	-	13.1	1.0	Yes	-
	ED 10yr without CC with FUZ		0.8	11.24	10.68				1.9		
	MPD 100yr CC without FUZ		1.8	11.99	10.89				1.1	Yes	

MPD 100yr without CC without FUZ	1.5	11.77	10.85				1.3	Yes

Table 2: Hingaia Stream Structures Assessment

Structures	Scenarios	Full Flow Capacity (m3/s)	Peak Flow (m3/S)	Maximum U/S WL (m RL)	Maximum D/S WL (m RL)	Bridge Soffit Level (m RL)	Bridge Deck Level (m RL)	Road Overtopping Level (m RL)	Freeboard Based on NZTA Bridge Manual (m)	Satisfy 100-year ARI LOS (NZTA)	Notes
Great South Road Culvert	MPD 100yr CC with FUZ	12.0	16.5	8.263	8.035	4.37		7.116			Currently being re-modelled.
	ED 10yr without CC with FUZ										
	MPD 100yr CC without FUZ		16.5	8.263	8.035						
	MPD 100yr without CC without FUZ		16.0	7.729	7.526						
Flanagan Road Culvert	MPD 100yr CC with FUZ	12	18	8.71	8.263	4.303		6.987	0.0	No	Flanagan Road is overtopped but the adjacent railway is not.
	ED 10yr without CC with FUZ									-	
	MPD 100yr CC without FUZ		18	8.71	8.263				0.0	No	
	MPD 100yr without CC without FUZ		16.2	8.021	7.729					No	
Flanagan Road Bridge	MPD 100yr CC with FUZ	350	313	9.658	9.235	8.9	9.4		0.0	No	-
	ED 10yr without CC with FUZ									-	
	MPD 100yr CC without FUZ		313	9.658	9.234				0.0	No	

Structures	Scenarios	Full Flow Capacity (m3/s)	Peak Flow (m3/S)	Maximum U/S WL (m RL)	Maximum D/S WL (m RL)	Bridge Soffit Level (m RL)	Bridge Deck Level (m RL)	Road Overtopping Level (m RL)	Freeboard Based on NZTA Bridge Manual (m)	Satisfy 100-year ARI LOS (NZTA)	Notes
	MPD 100yr without CC without FUZ		224	9.037	8.694				0.0		
Great South Road Bridge	MPD 100yr CC with FUZ	165	277	8.456	8.241	5.9	7.1		0.0	No	.
	ED 10yr without CC with FUZ									-	
	MPD 100yr CC without FUZ		277	8.456	8.241				0.0	No	
	MPD 100yr without CC without FUZ		204	7.911	7.746				0.0	No	
Norrie Road Bridge	MPD 100yr CC with FUZ	210	373	7.947	7.524	5.5	6.18		0.0	No	-
	ED 10yr without CC with FUZ										
	MPD 100yr CC without FUZ		373	7.947	7.524				0.0		
	MPD 100yr without CC without FUZ		217	7.357	7.054				0.0		
Southern Motorway Bridge	MPD 100yr CC with FUZ	>100yr	527	5.86	5.587	5.5					Lowest overtopping level is not at the bridge location. Spills south of bridge
	ED 10yr without CC with FUZ										
	MPD 100yr CC without FUZ		527	5.86	5.587						

Structures	Scenarios	Full Flow Capacity (m3/s)	Peak Flow (m3/S)	Maximum U/S WL (m RL)	Maximum D/S WL (m RL)	Bridge Soffit Level (m RL)	Bridge Deck Level (m RL)	Road Overtopping Level (m RL)	Freeboard Based on NZTA Bridge Manual (m)	Satisfy 100-year ARI LOS (NZTA)	Notes
	MPD 100yr without CC without FUZ		467	5.528	5.182				0.0		
Motorway south of bridge	MPD 100yr CC with FUZ		91	5.86						No	Modelling indicates approx 900m length of SH1 will flood in 100yr ARI MPD CC event. Refer project sheet for more discussion -
	ED 10yr without CC with FUZ									-	
	MPD 100yr CC without FUZ		91	5.86						No	
	MPD 100yr without CC without FUZ		15.5								

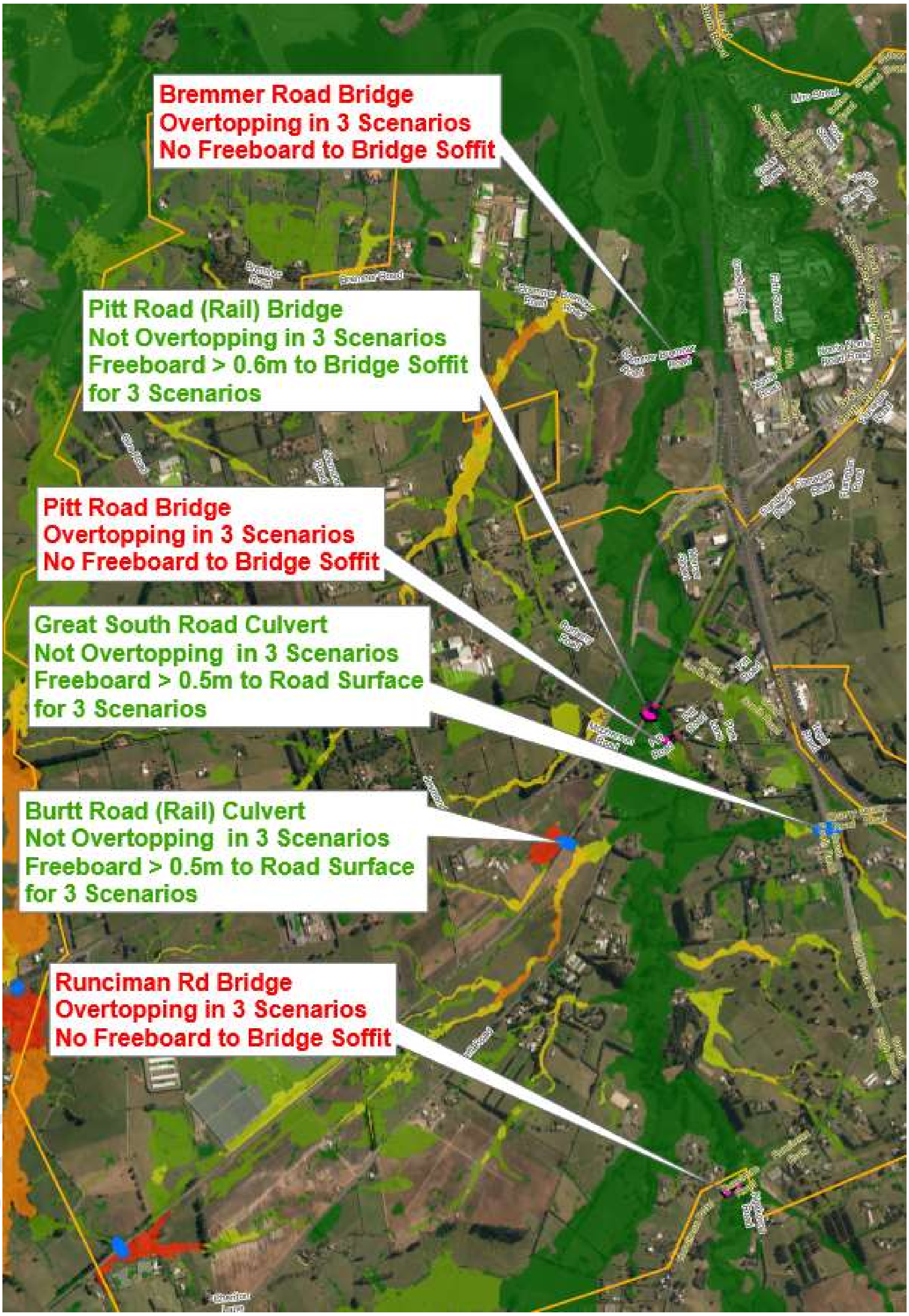


Figure 2 Structures Assessed within Ngakoroa and Oira (Drury West)

Table 3: Ngakoroa-Oira Structures Assessment

Structures	Scenarios	Full Flow Capacity (m3/s)	Peak Flow (m3/S)	Maximum U/S WL (m RL)	Maximum D/S WL (m RL)	Bridge Soffit Level (m RL)	Bridge Deck Level (m RL)	Road Overtopping Level (m RL)	Freeboard Based on NZTA Brdige Manual (m)	Satisfy 100-year ARI LOS (NZTA)	Notes
Runciman Road Bridge	MPD 100yr CC with FUZ	57.0	126.0	11.11	11.07	10.5	10.7	9.8	0.0	No	Lowest overtopping level is not at the bridge location.
	ED 10yr without CC with FUZ		33.7	10.10	10.05				0.4	-	
	MPD 100yr CC without FUZ		126.0	11.11	11.07				0.0	No	
	MPD 100yr without CC without FUZ		95.0	10.86	10.82				0.0	No	
Great South Road Culvert	MPD 100yr CC with FUZ	11.0	6.2	11.18	9.16	-	-	14.9	3.7	Yes	-
	ED 10yr without CC with FUZ		1.7	9.86	8.78				5.0	-	
	MPD 100yr CC without FUZ		5.2	11.00	9.10				3.9	Yes	
	MPD 100yr without CC without FUZ		4.0	10.79	9.01				4.1	Yes	
Burtt Road (Rail) Culvert	MPD 100yr CC with FUZ	1.0	1.5	10.86	8.40	-	-	11.9	1.0	Yes	-
	ED 10yr without CC with FUZ		1.1	9.48	8.28				2.4	-	
	MPD 100yr CC without FUZ		1.5	10.64	8.37				1.3	Yes	

Structures	Scenarios	Full Flow Capacity (m3/s)	Peak Flow (m3/S)	Maximum U/S WL (m RL)	Maximum D/S WL (m RL)	Bridge Soffit Level (m RL)	Bridge Deck Level (m RL)	Road Overtopping Level (m RL)	Freeboard Based on NZTA Brdige Manual (m)	Satisfy 100-year ARI LOS (NZTA)	Notes
	MPD 100yr without CC without FUZ		1.4	10.39	8.35				1.5	Yes	
Pitt Road Bridge	MPD 100yr CC with FUZ	28.0	141.0	7.33	7.31	5.5	6.4	6.0	0.0	No	Lowest overtopping level is not at the bridge location.
	ED 10yr without CC with FUZ		29.7	5.5	5.5				0.0	-	
	MPD 100yr CC without FUZ		140.0	7.31	7.30				0.0	No	
	MPD 100yr without CC without FUZ		107.0	6.79	6.78				0.0	No	
Pitt Road (Rail) Bridge	MPD 100yr CC with FUZ	190.0	102.0	7.05	7.04	7.9	8.3	8.3	0.85	Yes	-
	ED 10yr without CC with FUZ		30.4	4.81	4.81				3.1	-	
	MPD 100yr CC without FUZ		102.0	7.05	7.04				0.85	Yes	
	MPD 100yr without CC without FUZ		80.0	6.50	6.49				1.4	Yes	
Bremner Road Bridge	MPD 100yr CC with FUZ	24.0	138.6	6.22	6.17	3.9	4.2	4.2	0.0	No	-
	ED 10yr without CC with FUZ		37.5	3.33	3.28				0.6	-	
	MPD 100yr CC without FUZ		138.5	6.22	6.17				0.0	No	

Structures	Scenarios	Full Flow Capacity (m3/s)	Peak Flow (m3/S)	Maximum U/S WL (m RL)	Maximum D/S WL (m RL)	Bridge Soffit Level (m RL)	Bridge Deck Level (m RL)	Road Overtopping Level (m RL)	Freeboard Based on NZTA Brdige Manual (m)	Satisfy 100-year ARI LOS (NZTA)	Notes
	MPD 100yr without CC without FUZ		107.0	5.28	5.26				0.0	No	

2 Project Sheets

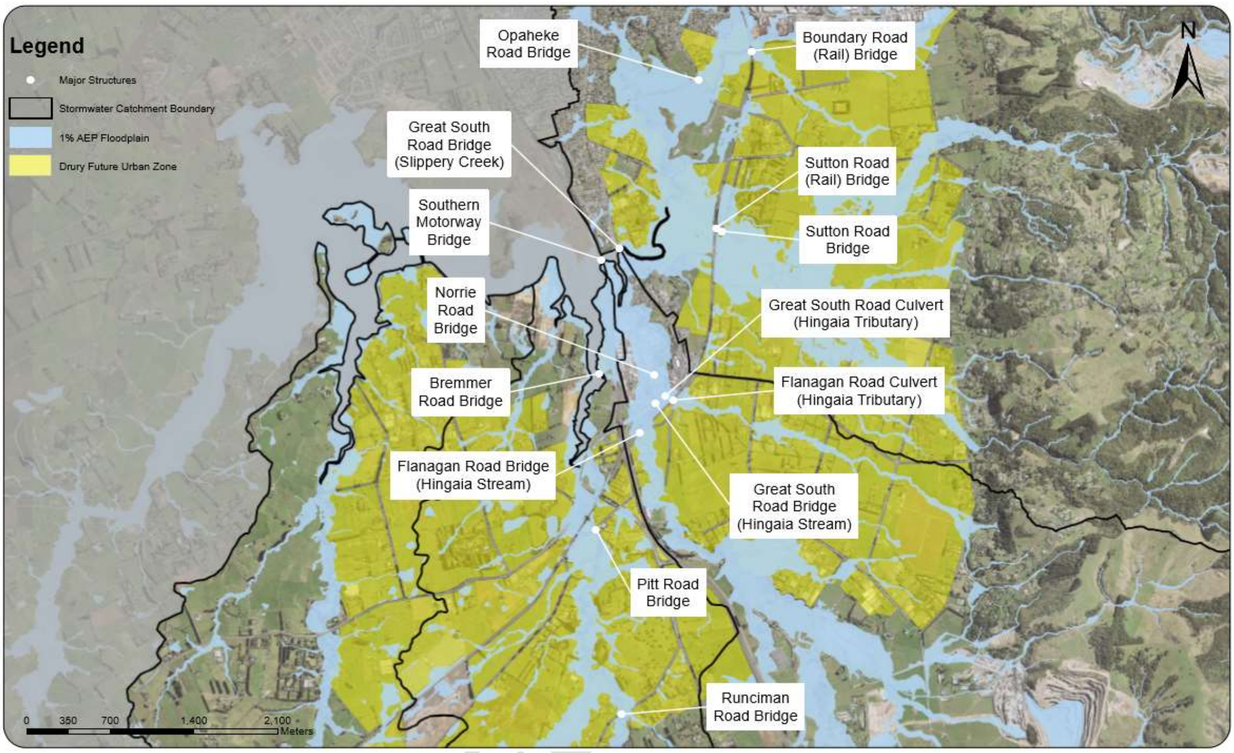
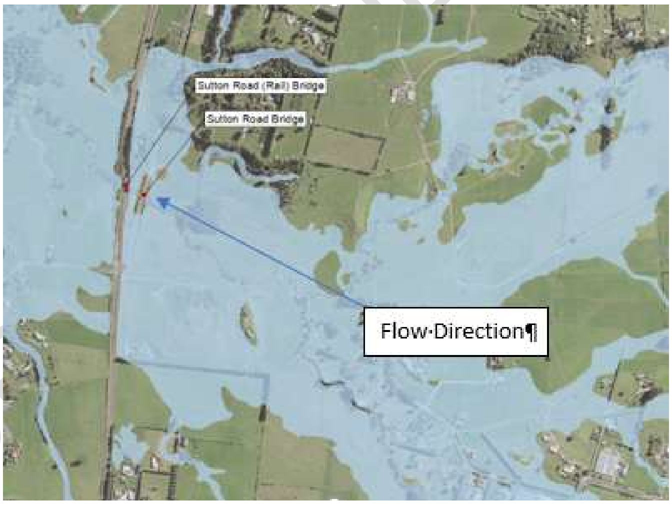
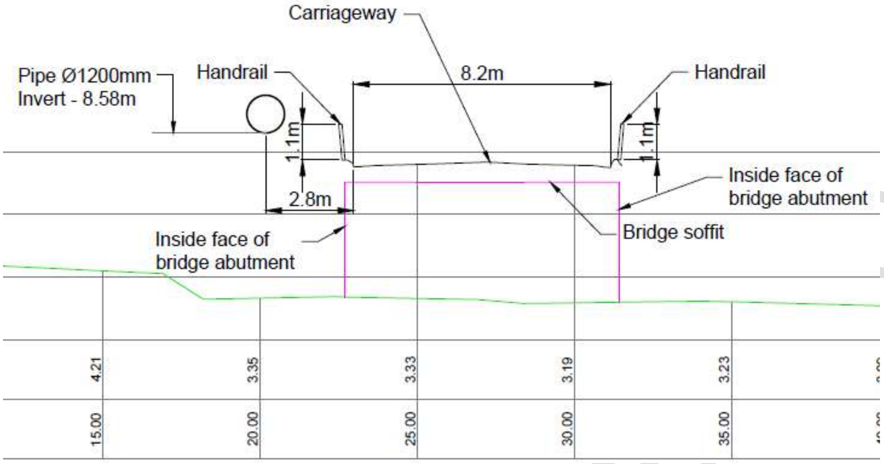


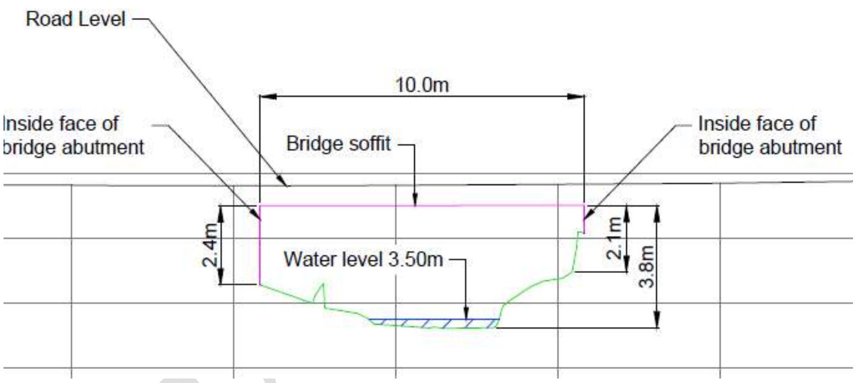
Figure 3 Structures for which Project Sheets have been Prepared

2.1 Sutton Road Bridge



Drawing of bridge





Issue	• The lack of flow capacity through the undersized bridge waterway contributes to overtopping of the bridge and road plus potentially limiting development yield due to flooding. This is also exacerbated by the NIMT Sutton Road rail bridge immediately downstream of Sutton Road which also has limited capacity and creates backwater effects to Sutton Road. • Bridge deck level is 7.4mRL. Adjacent road level is 7.2mRL • 100 year ARI MPD CC level is 8.94mRL. • 100 year ARI MPD level is 8.52mRL • 10 year ARI MPD level is 7.58mRL
Overtopping	• The bridge deck is predicted to overtop by 1.54m in the future 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • The approach road is 0.2m lower than the bridge deck, thus the depth of flow over the road is predicted to be 1.74m for the same rainfall event. • Depth of flow over the bridge deck in the 100 year ARI MPD event without climate change and sea level rise is predicted to be 1.12m. • The bridge deck is predicted to overtop by 0.18m in the 10 year ED event. • The approach road is predicted to overtop by 0.38m in the same event.
Flood Hazard Assessment	Significant (as defined in AC Flood Modelling Spec) with flood depth over deck > 0.3m
100 year ARI MPD CC flow to bridge (with FUZ)	130.9m³/s flow based on 60% imperviousness of Future Urban Zone (FUZ), climate change and 10% imperviousness of upstream rural catchment draining to bridge

100 year ARI MPD CC flow to bridge (without FUZ)	130m³/s flow based on 10% imperviousness of the catchment draining to the bridge and climate change. The 'with' and 'without' FUZ flows are similar because of timing effects.
100 year ARI MPD flow to bridge (without FUZ)	113m³/s flow based on 10% imperviousness of the catchment draining to the structure and no climate change.
10 year ED flow to bridge	45.3m³/s
Conveyance capacity of bridge	32m³/s (is the free full capacity if there was no downstream constriction. However, the downstream railway bridge acts as a flow constraint.)
Conveyance capacity of channel	To be determined
Headloss across Sutton Rd and NIMT railway bridges	0.800 (in a 100 year ARI MPD CC event)
Criticality	Currently a local road. Future designation unknown
Meeting NZTA / AT Level of Service	No • NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • The 2015 Slippery Creek Watercourse Assessment Report noted that the lower reaches of Waihoihoi Stream and Symonds Stream (which drain to this bridge) had mature willows on the immediate margins and that shelter belts of poplar or other exotic trees were also common on stream margins. Thus a freeboard of 1.2m is appropriate. • The SMP will likely recommend replacing willows with natives. However, there is a large upstream rural catchment which can produce debris. • Installation of bridge protection structures could be considered. This would lower the freeboard requirement to 0.6m.
On-site Assessment of Structure	
Potential Options	• Do Nothing • Increase conveyance capacity of bridge, raise it and raise adjacent road. The conveyance capacity of the rail bridge would also need to be increased to provide benefit as it is a downstream constraint.
Options modelled, results and comment	• Increasing the flow area through the bridge from 38m² to 200m² by increasing the bridge length to 50m (from 10m) and increasing the bridge height by 0.2m reduced the water depth over the bridge by 30mm (in a 100 year ARI MPD CC event). The downstream Sutton Road rail bridge is a flow constraint and must be addressed at the same time to get benefits at both sites. • Removing the bridges (Sutton Road bridge and Sutton Road rail bridge) and providing a larger embankment opening reduces the water level over the road to 0.65m in a 100 year ARI MPD event with climate change. The water level drops by 1.09m between this option and the 'Do Nothing' option. The unrestricted flow increases to 163m³/s from 130.9m³/s. The purpose of this option was to determine the impact on flood levels XXX
Constraints	• The downstream railway bridge is a constraint to flow and creates upstream flooding issues as well. • Above ground 1200 dia CLS transmission water pipe adjacent to the bridge. • Above ground power lines crossing the bridge. • Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction within a watercourse and floodplain
Comments	• Discuss option of "Do Nothing" with AT. • Provide signage at Sutton Road indicating that road is flood prone and potentially a warning light when flood waters exceed a certain water level or some other warning method. • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures • The downstream Bellfield SHA is sensitive to an increase in flood levels and flows. Any works to address flooding at Sutton Road Bridge must consider Bellfield.

	It's worth noting that Section 2.3.2 of the NZTA Bridge Manual, (Third Edition, Amendment 3, Effective from October 2018) has the following comment with respect to designing for climate change Where it is practical and economic for a bridge or culvert structure to be retrofitted at a later date to accommodate increased flood flows arising from the effects of climate change, the structure need not initially be designed to accommodate increased flood flows arising from the effects of climate change. Where future retrofitting is not practical or does not reflect value for money, future climate change impacts shall be taken into account in the design Potentially bridge could be designed for 1/25 event. Discuss AT
Adopted option	•

Table 2.1: Importance level and annual probabilities of exceedance for wind, snow, floodwater and earthquake actions for bridges

Bridge categorisation	Importance level (as per AS/NZS 1170.0[4])	Bridge permanence*	Annual probability of exceedance for the ultimate limit state		Annual probability of exceedance for the serviceability limit state	
			ULS for wind, snow and floodwater actions	DCLS† for earthquake actions	SLS 1 for wind, snow and floodwater actions	SLS 2 for floodwater actions
Bridges of high importance to post-disaster recovery (eg bridges in major urban areas providing direct access to hospitals and emergency services or to a major port or airport from within a 10km radius). Bridges with a construction cost (including associated ground improvements) exceeding $16 million (as at June 2018)‡.	4	Permanent	1/2500	1/2500	1/25	1/100
		Temporary	1/1000	1/1000	1/25	1/100
Bridges on highways classified as National (High Volume) in the One Network Road Classification§ (ONRC).	3+	Permanent	1/1500	1/1500	1/25	1/100
		Temporary	1/700	1/700	1/25	-
Bridges on highways classified as National, Regional, Arterial, Primary Collector or Secondary Collector in the ONRC.	3	Permanent	1/1000	1/1000	1/25	1/100
		Temporary	1/500	1/500	1/25	-
Bridges on highways classified as Access or Access (Low Volume) in the ONRC. Bridges, not falling into other levels. Footbridges.	2	Permanent	1/500	1/500	1/25	1/50
		Temporary	1/250	1/250	1/25	-
Bridges where failure would not be likely to endanger human life and the loss of which would not be detrimental to post-disaster recovery activities for an extended period.	1	Permanent	1/250	1/250	1/25	1/25
		Temporary	1/50	1/50	-	-

Notes:

* Permanent bridge: design working life = 100 years assumed (see 2.1.3, 2.1.5). Temporary bridge: design working life ≤ 5 years.

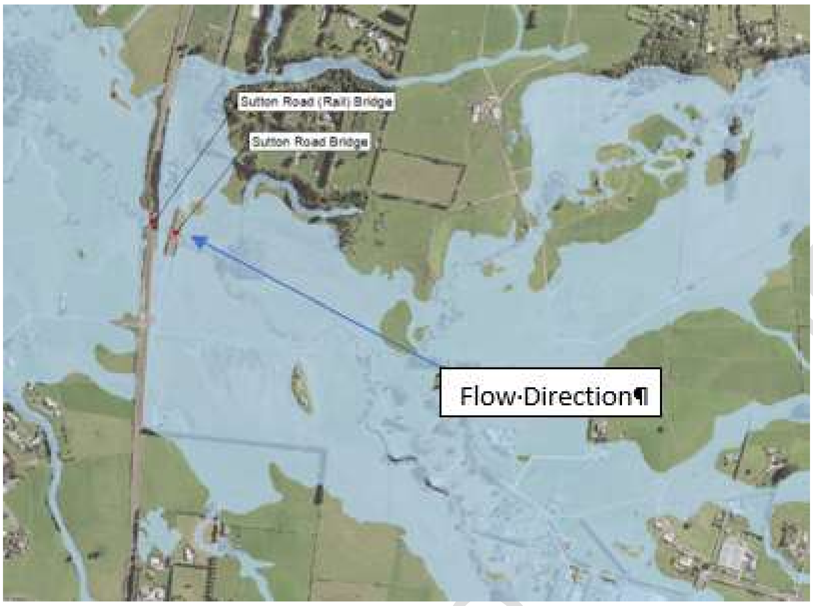
† DCLS – damage control limit state. See 5.1.2 (a) for definition.

‡ Values shall be adjusted to current value. For the relevant cost adjustment factor refer to the NZ Transport Agency's (NZTA) *Procurement manual*, Procurement manual tools, Latest values for 1991 infrastructure cost indexes, NZ Transport Agency Bridge index[5].

§ The One Network Road Classification (ONRC) is a classification system, which divides New Zealand's roads into six categories based on how busy they are, whether they connect to important destinations, or are the only route available (see *One network road classification*[6]). See figures figure 2.1(a), 2.1(b) and 2.1(c) herein for the classification of state highways or *Tables of state highways in each ONRC classification category*[7].

2.2 Sutton Road Rail Bridge

Plan



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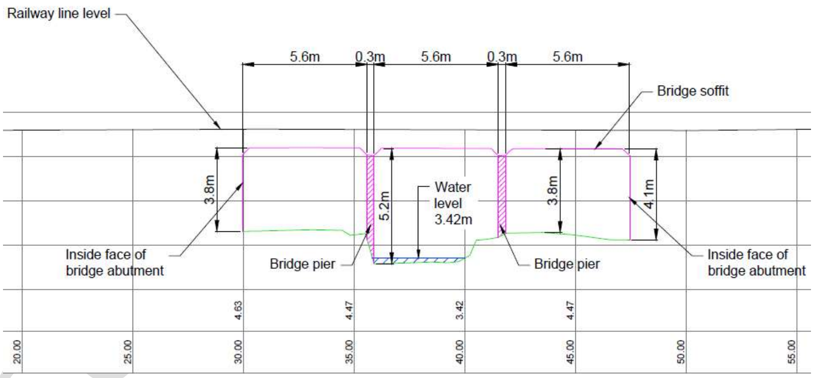
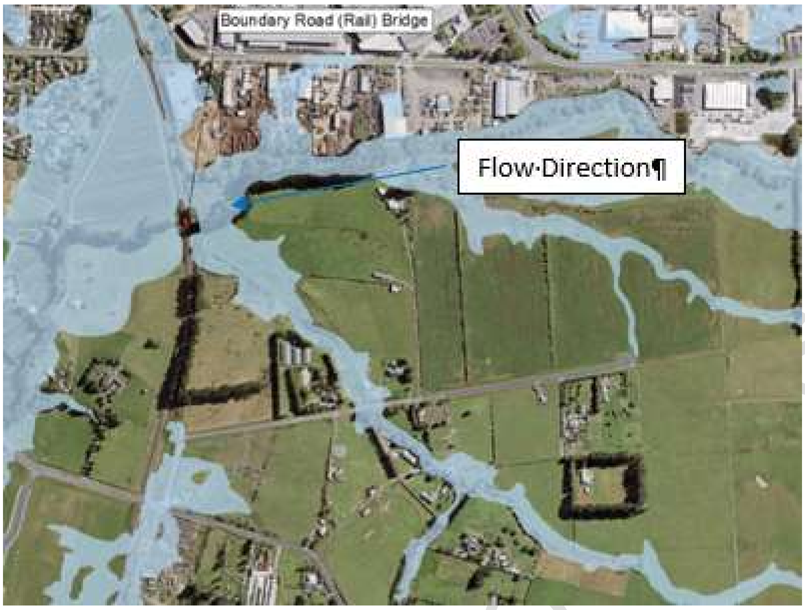
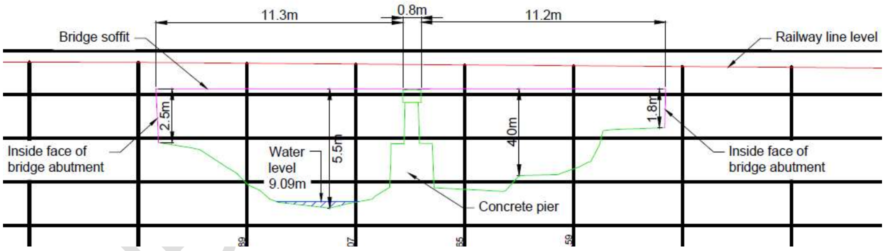
Drawing of bridge



Issue	• The lack of flow capacity through the undersized bridge waterway causes a backwater effect to the upstream Sutton Road bridge. This contributes to Sutton Road bridge being overtopped, contributes to upstream floodplain extents, potentially limiting development yield. • Possibility that the railway embankment will act as a stopbank during significant storm event. • Bridge deck level is 9.2mRL. Bridge soffit level is 8.43mRL • 100 year ARI MPD CC level is 8.77mRL. • 100 year ARI MPD level is 8.29mRL • 10 year ARI MPD level is 7.16mRL
Overtopping	No • 0.43m clearance between 100 year ARI MPD CC flood level and bridge deck. • 0.91m clearance between 100 year ARI MPD flood level and bridge deck
Flood Hazard Assessment	
100 year ARI MPD CC flow to bridge (with FUZ)	• 123.9m³/s - flow based on 60% imperviousness of Future Urban Zone (FUZ) and 10% imperviousness of upstream rural catchment draining to bridge. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m.

100 year ARI MPD CC flow to bridge (without FUZ)	121.8m³/s - flow based on 10% imperviousness of the catchment draining to the bridge and climate change.
100 year ARI MPD flow to bridge (without FUZ)	102m³/s - flow based on 10% imperviousness of the catchment draining to the structure and no climate change.
10 year ED flow to bridge	44.6m³/s
Conveyance capacity of bridge	67m³/s – we believe the 'bridge' is actually 3 No culverts laid side by side. The survey indicates the possibility that there is sediment in the outer culverts. Removing this sediment would increase the conveyance capacity of the 'bridge'.
Conveyance capacity of channel	
Headloss across Sutton Rd and NIMT railway bridges	0.8m (in a 100 year ARI MPD CC event)
Criticality	High Any damage to the bridge or adjoining embankments will impact on rail services
Meeting NZTA Level of Service – Kiwirail use the NZTA Bridge manual	No • NZTA Bridge Manual specifies 0.6m clearance between underside of structure and predicted flood level. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • The 2015 Slippery Creek Watercourse Assessment Report noted that the lower reaches of Waihoihoi Stream and Symonds Stream (which drain to this bridge) had mature willows on the immediate margins and that shelter belts of poplar or other exotic trees were also common on stream margins. • The SMP will likely recommend replacing willows with natives. However, there is a large upstream rural catchment which can produce debris. • Bridge soffit is 8.43mRL. • 100 year ARI MPD CC level is 8.77mRL (so higher than the bridge soffit). • 100 year ARI MPD level is 8.29mRL
Freeboard	Less than required
On-site assessment of structure	
Potential Options	• Do Nothing • Make Kiwirail aware of the modelling outputs • Increase conveyance capacity of Sutton Road rail bridge in conjunction with increasing conveyance capacity of Sutton Road bridge. Both would need to be carried out in order to obtain benefit. • Clean out the two barrels either side of the central barrel if sedimentation confirmed.
Options modelled, results and comment	• Removing the bridge and providing a larger embankment opening reduces the upstream water level by 1.05m (from 8.77mRL to 7.72mRL) in a 100 year ARI MPD CC event. The unrestricted flow increases to 163m³/s from 126m³/s. The purpose of modelling this option was to determine the impact on flood levels of removing the structure from the model and providing a widened embankment. It is not a feasible option.
Constraints	• Raising the bridge may not be feasible as this would require vertical realignment of a significant length of rail line and changing the box culverts. Adding another culvert alongside is an option if capacity is a constraint. • Working on a railway line • Consents associated with working on Kiwirail infrastructure
Comments	• This bridge is located approximately 42m downstream of the Sutton Road Bridge.
Adopted Option	•

2.3 Boundary Road (Hays Stream) Rail bridge

Plan	
Drawing of bridge	
Issue	• The lack for flow capacity through the undersized bridge waterway contributes to overtopping of the railway line north of the bridge during a 100 year ARI MPD event. • Bridge deck level is 15mRL. Rail overtopping level is 14.3mRL • 100 year ARI MPD CC level is 14.83mRL. • 100 year ARI MPD level is 14.47mRL • 10 year ARI MPD level is 13.13mRL
Overtopping	• Modelling indicates that the railway line north of the bridge will be overtopped by 0.53m during a 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • Depth of flow over the railway north of the bridge in the 100 year ARI MPD event without climate change and sea level rise is predicted to be 0.17m. • The low point of the railway line is 14.3mRL. The 100 year ARI MPD CC flood level is predicted to be 14.83mRL. • The 100 year ARI MPD flood level is predicted to be 14.47mRL.
Flood Hazard Assessment	Significant as modelling indicates that overtopping of the railway will occur in a 100 year ARI MPD storm event.
100 year ARI MPD CC flow to bridge (with FUZ)	204.3m³/s - flow based on 60% imperviousness of Future Urban Zone (FUZ), climate change, maximum allowable imperviousness of existing urban area allowed under the Unitary Plan and 10% imperviousness of upstream rural catchment draining to structure.

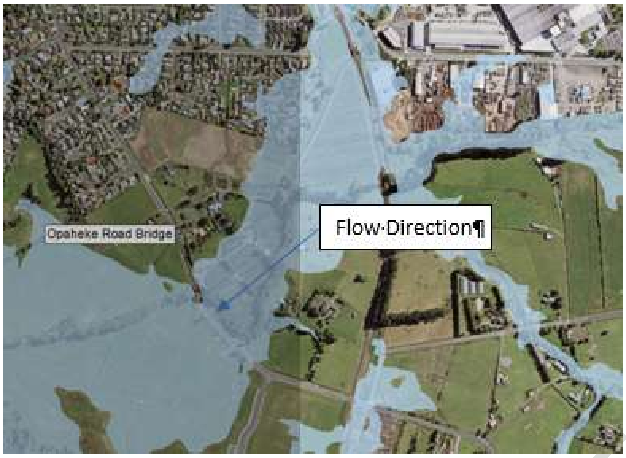
100 year ARI MPD CC flow to bridge (without FUZ)	203.8m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, 10% imperviousness for the remaining catchment (including the FUZ) draining to the structure and climate change. The purpose of this model run was to determine if development of the FUZ impacted on flows.
100 year ARI MPD flow to bridge (without FUZ)	163m³/s flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, 10% imperviousness for the remaining catchment (including the FUZ) draining to the structure and no climate change.
10 year ED flow to bridge	56.2m³/s
Conveyance capacity of bridge	120m³/s (is the free full capacity if there was no downstream constriction)
Conveyance capacity of channel	
Headloss across structure	0.72 (in a 100 year ARI MPD CC event) 0.58 (in a 100 year ARI MPD event)
Criticality	High Any damage to the bridge or inundation of the railway will impact on rail services
Meeting NZTA Level of Service – Kiwirail use the NZTA Bridge manual	No • NZTA Bridge Manual specifies 0.6m clearance between underside of structure and predicted flood level. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • The Watercourse Assessment report identified that the main reaches of Hays Stream along the border of the industrial zone (so upstream of this bridge) were dominated by mature willows. Thus a freeboard of 1.2m may be appropriate. • The SMP will likely recommend replacing willows with natives. However, there is a large upstream rural catchment which can produce debris. • Installation of bridge protection structures could be considered. This would lower the freeboard requirement to 0.6m. • Bridge soffit is 14.4mRL. • Bridge deck is 15mRL. • 100 year ARI MPD CC level is 14.83mRL. • 100 year ARI MPD level is 14.47mRL
Freeboard	• Freeboard indicates a maximum flood level of 13.2m (1.2m below soffit of 14.4m) therefore in the 100yr MPD CC event the flood level exceeds this by 1.63m and in the 100yr MPD without CC event it exceeds it by 1.27m.
On-site assessment of structure	
Potential Options	• Do Nothing • Increase flow capacity of bridge • Raise railway line where it overtops which will also require regrading of the track either side of the bridge
Options modelled, results and comment	• Increasing the conveyance capacity of the bridge from 107m² to 180m² reduces the upstream water level by 0.75m (from 14.83mRL to 14.08mRL) for a 100 year ARI MPD CC event. The freeboard between the top water level and the underside of the bridge would be 0.32m so would not meet the 0.6m freeboard requirement. However, it would likely meet the level of service for a 100 year ARI MPD event. • Removing the bridge structure and widening the embankment reduces the upstream water level by 0.97m and the downstream water level by 0.37m. The freeboard between the top water level and the underside of the bridge would be 0.54m so would not meet the 0.6m freeboard requirement. However, it would likely meet the level of service for a 100 year ARI MPD event. The purpose of modelling this option was to determine the impact on flood levels of removing the bridge and widening the embankment.
Constraints	• Increasing the conveyance capacity of the bridge and raising adjacent railway line would have significant cost implications. In addition, the works would impact on rail users as the line would have to be closed while the works were being carried out. • Potential impacts on downstream flood levels and flows

Comments	Discuss modelling outputs with Kiwirail
Adopted Option	

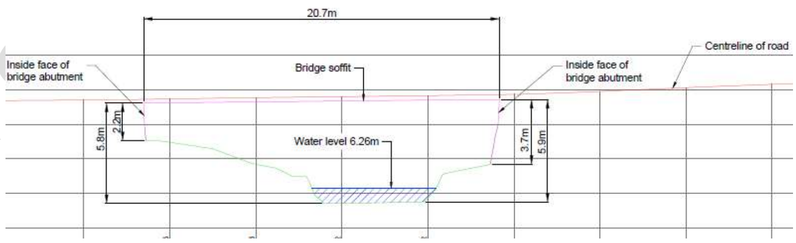
Source: <Insert Notes or Source>

2.4 Opaheke Road Bridge

Plan



Drawing of bridge



Issue

- The lack for flow capacity through the undersized bridge waterway contributes to overtopping of Opaheke Road south of the bridge, contributes to upstream floodplain extents potentially limiting development yield.
- Bridge deck level is 11.8mRL. Adjacent road overtopping level is 11.3mRL
- 100 year ARI MPD CC level is 11.77mRL.
- 100 year ARI MPD level is 11.6mRL
- 10 year ARI MPD level is 11.06mRL

Overtopping

- Modelling indicates that the approach road to the bridge will overtop by 0.43m during a 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m.
- Depth of flow over the approach road in the 100 year ARI MPD event without climate change and sea level rise is predicted to be 0.3m during a 100 year ARI MPD event. The adjacent road is approximately 0.5m lower than the bridge deck.

	• The approach road is 0.5m lower than the bridge deck.
Flood Hazard Assessment	Significant (as defined in AC Flood Modelling Spec) with flood depth over road > 0.3m
100 year ARI MPD CC flow to bridge (with FUZ)	260m³/s - flow based on 60% imperviousness of Future Urban Zone (FUZ), climate change, maximum allowable imperviousness of existing urban area allowed under the Unitary Plan and 10% imperviousness of upstream rural catchment draining to structure
100 year ARI MPD CC flow to bridge (without FUZ)	259m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, 10% imperviousness for the remaining catchment (including the FUZ) draining to the structure and climate change.
100 year ARI MPD flow to bridge (without FUZ)	202m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, 10% imperviousness for the remaining catchment (including the FUZ) draining to the structure and no climate change.
10 year ED flow to bridge	59.6m³/s
Conveyance capacity of bridge	87m³/s (is the free full capacity if there is no downstream constriction)
Headloss across structure	0.09m (in a 100 year ARI MPD CC event) 0.07m (in a 100 year ARI MPD CC event)
Conveyance capacity of channel	
Criticality	Currently classed as a medium rural road. Future designation arterial?? Discuss AT
Meeting NZTA / AT Level of Service	No • NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • Willows are present in the upstream catchment so a freeboard of 1.2m may be appropriate. • The SMP will likely recommend replacing willows with natives. However, there is a large upstream rural catchment which can produce debris. • Installation of bridge protection structures upstream of the bridge could be considered. This would lower the freeboard requirement to 0.6m. • Modelling indicates 0.03m clearance between 100 year ARI MPD CC water level (11.77mRL) and bridge deck (11.8mRL) and 0.2m clearance between 100 year ARI MPD water level (11.6mRL) and bridge deck – hence not meeting level of service.
Freeboard	• Freeboard indicates a maximum flood level of 10.4mRL (1.2m below soffit of 11.6mRL) therefore in the 100 year ARI MPD CC event the flood level (11.77mRL) exceeds this by 1.37m and in the 100 year ARI MPD without CC event it exceeds it by 1.2m.
On-site Assessment of Structure	
Potential Options	• Do Nothing • Increase conveyance capacity of bridge, raise it and raise adjacent road. This has the potential to worsen upstream flooding as raising the road will act as a dam. The impact on downstream flows and water levels also needs to be considered.
Options modelled, results and comment	• Increasing the flow area through the bridge from 120m² to 255m² by increasing the bridge length to 44m (from 20.7m) reduced the upstream water level by 0.31m and the downstream water level by 0.39m for a 100 year ARI MPD CC event. The freeboard between the top water level and the underside of the bridge would be 0.14m so would not meet the freeboard requirements. It would not meet the level of service for a 100 year ARI MPD event either. • Removing the bridge and providing a larger embankment opening reduces the upstream water level by 0.58m in a 100 year ARI MPD CC event. The freeboard between the top water level and the underside of the bridge would be 0.41m so would not meet freeboard requirements. It would not meet the level of service for a 100 year ARI MPD event either.
Constraints	• The downstream Bellfield SHA is sensitive to an increase in flows and associated increases in water levels. The habitable floor levels have been set with respect to modelled flows which did not consider increased flows as a result of opening up structures. • Above ground power lines crossing the bridge.

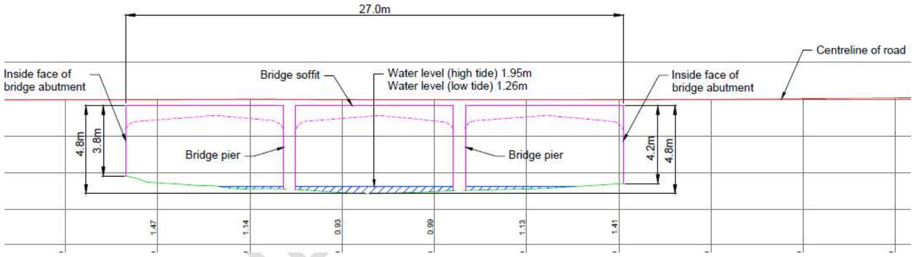
	• Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction within a watercourse and floodplain
Comments	• Provide signage at Opaheke Road indicating that road is flood prone during extreme storm events and potentially a warning light when flood waters exceed a certain water level or some other warning method.. • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures • The downstream Bellfield SHA is sensitive to an increase in flood levels and flows. Any works to address flooding at Opaheke Road bridge must consider Bellfield SHA.
Adopted option	•

Source: <Insert Notes or Source>

2.5 Great South Road Bridge (Slippery Creek)

Plan

Drawing of bridge



Issue

- The lack for flow capacity through the undersized bridge waterway contributes to overtopping of the bridge and approach road.
- During extreme storm events water leaves the Slippery Creek channel upstream of the bridge in the vicinity of Miro Street as there is a low point there. A significant storm event in 1989 resulted in flow leaving the Slippery Creek channel in the vicinity of Miro Street, overtopping Great South Road and going through two commercial properties on the other side of Great South Road. This is borne out in the modelling results.
- Bridge deck level is 5.9mRL. Adjacent road overtopping level is 5.8mRL
- 100 year ARI MPD CC level is 6.10mRL.
- 100 year ARI MPD level is 5.78mRL
- 10 year ARI MPD level is 4.016mRL

Overtopping

- The bridge deck is predicted to overtop by 0.2m in the future 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m.
- The approach road is 0.1m lower than the bridge deck, thus the depth of flow over the road is predicted to be 0.3m for the same rainfall event.

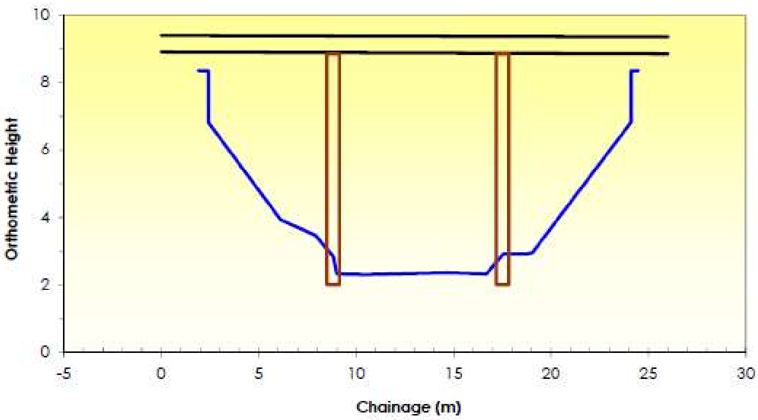
Flood Hazard Assessment	Significant (as defined in AC Flood Modelling Spec) with flood depth over road equal to 0.3m
100 year ARI MPD CC flow to bridge (with FUZ)	362m³/s - flow based on 60% imperviousness of Future Urban Zone (FUZ), climate change, maximum allowable imperviousness of existing urban area allowed under the Unitary Plan and 10% imperviousness of upstream rural catchment draining to bridge
100 year ARI MPD CC flow to bridge (without FUZ)	358m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, 10% imperviousness for the remaining catchment (including the FUZ) draining to the structure and climate change.

100 year ARI MPD flow to bridge (without FUZ)	285m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, 10% imperviousness for the remaining catchment (including the FUZ) draining to the structure and no climate change.
10 year ED flow to bridge	115.2m³/s
Conveyance capacity of bridge	320m³/s (is the free full capacity if there was no downstream constriction. However, high tail water levels in Drury Creek are a downstream constraint.)
Conveyance capacity of channel	
Headloss across bridge	0.42 (in a 100 year ARI MPD CC event)
Criticality	Arterial Road
Meeting AT / NZTA Level of Service	No • NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • Blockage of structures in the Slippery Creek catchment is possible because of the large areas of debris producing bush in the upper catchment. • Installation of bridge protection structures upstream of the bridge could be considered. A freeboard of 0.6m might then be acceptable.
Freeboard	• To achieve a freeboard of 0.6m the top water level in a 100 year ARI MPD CC event would need to be 5.1mRL (0.6m below bridge soffit of 5.7mRL). The modelled water level for this event is 6.1mRL. • To achieve a freeboard of 0.6m the top water level in a 100 year ARI MPD event would need to be 5.1mRL. The modelled water level for this event is 5.78mRL.
On-site Assessment of Structure	We understand this bridge was constructed in 1930's with a 100 year design life. Potentially it may be due for an upgrade.
Potential Options	• Do Nothing • Increase conveyance through bridge • Upsize bridge • New bridge • Raise road
Options modelled, results and comment	• Increasing the flow area through the bridge from 129.6m² to 366m² by increasing the bridge length to 70m (from 27m) reduced the upstream water level by 0.32m for a 100 year ARI MPD CC event. The water level would be 0.08m higher than the underside of the bridge and 0.12m below the bridge deck. It would not meet the level of service for a 100 year ARI MPD event either. • Removing the bridge and providing a larger embankment opening reduces the upstream water level by 0.56m in a 100 year ARI MPD CC event. The 'freeboard' between the top water level and the underside of the bridge would be 0.16m so would not meet freeboard requirements. It would not meet the level of service for a 100 year ARI MPD event either. • The purpose of modelling the second option was to determine if removing the bridge and providing a larger embankment would have much of an impact on flood levels
Constraints	• Above ground power lines crossing upstream of bridge. • Water and wastewater lines strapped to bridge. • Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction within a watercourse and floodplain
Comments	• Provide signage indicating that road is flood prone during extreme storm events and potentially a warning light when flood waters exceed a certain water level or some other warning method. • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures • Watercare pump station located in floodplain downstream of bridge
Adopted option	•

2.6 Flanagan Road Bridge (Hingaia Stream Catchment)

Plan

Drawing of bridge



Taken from Hingaia Stream Model Build Report, 2017

Issue

- The lack of flow capacity through the bridge waterway contributes to overtopping of the bridge and road plus potentially limiting development yield due to flooding. This is possibly exacerbated by the NIMT railway

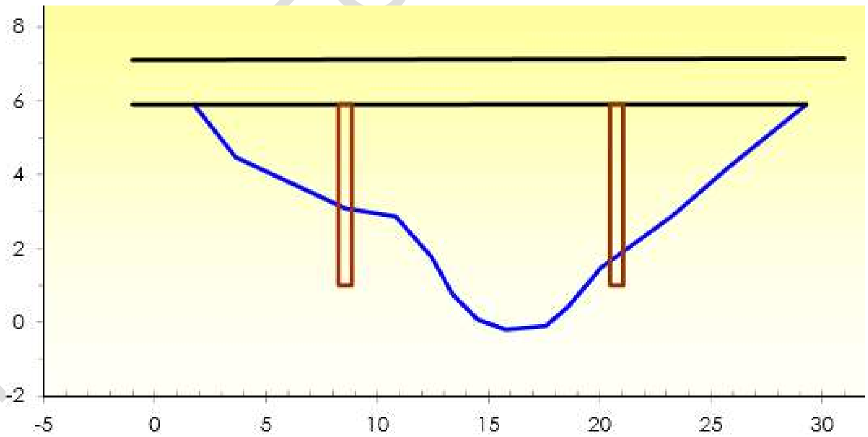
	bridge located immediately downstream of the Flanagan Road bridge which creates backwater effects to Flanagan Road. • Bridge deck level is 9.4mRL. • 100 year ARI MPD CC level is 9.658mRL. • 100 year ARI MPD level is 9.037mRL • 10 year ARI MPD level – currently being modelled
Overtopping	• The bridge is predicted to overtop by 0.25m depth of water in a 100-year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • There will be 0.363 'freeboard' between the top water level and the bridge deck in a 100-year ARI MPD event without Climate Change.
Flood Hazard Assessment	•
100 year ARI MPD CC flow to bridge (with FUZ)	313m³/s (flow based on 70% imperviousness of FUZ, climate change, development of Drury South Precinct (with associated proposed mitigation measures and Mill Road) and 10% imperviousness of upstream rural catchment.)
100 year ARI MPD CC flow to bridge (without FUZ)	313m³/s flow based on full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change and 10% imperviousness of the remaining catchment draining to the bridge.
100 year ARI MPD flow to bridge (without FUZ)	224m³/s flow based on full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), no climate change and 10% imperviousness of FUZ and upstream rural catchment.
Conveyance capacity of bridge	350m³/s (is the free full capacity if there was no downstream constriction)
Conveyance capacity of channel	
Headloss through structure	0.423m (in 100 year ARI MPD CC event) 0.343m (in 100 year ARI MPD event)
Criticality	Currently classed as minor urban but zoned ?????
Meeting AT / NZTA Level of Service	No – bridge is overtopped in a 100 year ARI MPD CC event. In addition it does not meet freeboard requirements (discussed below).
Freeboard	• NZTA Bridge manual specifies a freeboard of 0.6m between the 100-year ARI without Climate Change event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • Blockage of structures in the Hingaia Stream catchment is possible due to the large upstream rural catchment and its potential to generate debris. • To achieve a freeboard of 0.6m the top water level in a 100 year ARI MPD CC event would need to be 8.3mRL (0.6m below the bridge soffit of 8.9mRL). The modelled water level for this event is 9.658mRL. The modelled water level for a 100 year ARI MPD event (ie without climate change) is 9.037mRL (0.6m above the bridge soffit).
On-site Assessment of Structure	Railway bridge needs to be checked on site
Potential Options	• Do Nothing
Options modelled, results and comment	• Flanagan Road bridge was removed from the model. The upstream water level dropped by 0.24m in a 100 year ARI MPD CC event. Downstream water levels increased by 0.02m. The downstream railway bridge is a flow constraint. The depth of water behind Flanagan Road bridge is 8m. If this bridge were to be widened there would be an increased impact on the railway embankment.

	• Both Flanagan Road bridge and Great South Road bridge were removed from the model. The modelled water level upstream of Flanagan Road bridge dropped by 0.23m. The downstream water level increased by 0.04m. • Flanagan Road bridge, Great South Road bridge and Norrie Road bridge were removed from the model. The modelled water level upstream of Flanagan Road bridge dropped by 0.25m. The downstream water level increased by 0.01m.
Constraints	• 1200 CLS water main located adjacent to bridge • Adjacent railway line • Transpower transmission lines passing over bridge • Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction within a watercourse and floodplain
Comments	• Adjacent railway line bridge is not in the model • Provide signage indicating that road is flood prone during extreme storm events. Potentially a warning light when flood waters exceed a certain water level or some other warning method could also be utilised. • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures
Adopted option	•

2.7 Great South Road Bridge (Hingaia Stream Catchment)

Plan

Drawing of bridge



Issue

- The lack of flow capacity through the undersized bridge waterway contributes to overtopping of the bridge and adjacent road.
- Flood waters will extend east and west along Great South Road.
- Drury Creek (along with a huge contributing area of approximately 150sq km) is a flow constraint resulting in high downstream water levels which contribute to floodplain extents potentially limiting development yield
- Bridge Deck level is 7.1mRL
- 100 year ARI MPD CC level is 8.456mRL
- 100 year ARI MPD level is 7.911mRL
- 10 year ARI MPD level – currently being determined

Overtopping

- The bridge deck is predicted to overtop by 1.356m depth of water in a 100-year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m.

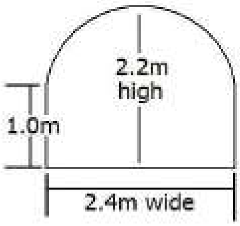
	• Depth of flow over the bridge deck in the 100-year ARI MPD without climate change and sea level rise is predicted to be 0.811m
Flood Hazard Assessment	• Significant (as defined in AC Flood Modelling Spec) with flood depth over deck > 0.3m
100 year ARI MPD CC flow to bridge (with FUZ)	277m³/s - flow based on 70% imperviousness of FUZ, climate change, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road) and 10% imperviousness of upstream rural catchment.
100 year ARI MPD CC flow to bridge (without FUZ)	277m³/s - flow based on full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change and 10% imperviousness of the remaining catchment draining to the bridge.
100 year ARI MPD flow to bridge (without FUZ)	204m³/s - flow based on full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), no climate change and 10% imperviousness of FUZ and upstream rural catchment.
Conveyance capacity of bridge	165m³/s (is the free full capacity if there was no downstream constriction. However, the downstream Drury Estuary is a flow constraint)
Conveyance capacity of channel	
Headloss through structure	0.215m (in 100-year ARI MPD CC) 0.165m (in 100-year ARI MPD without CC)
Criticality	Arterial
Meeting AT / NZTA Level of Service	No – bridge is predicted to overtop in a 100 year ARI MPD event
Freeboard	• NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • Blockage of structures in the Hingaia Stream catchment is possible due to the large upstream rural catchment and its potential to generate debris. • To achieve a freeboard of 0.6m the top water level in a 100 year ARI MPD CC event would need to be 5.3mRL (0.6m below the bridge soffit of 5.9mRL). The modelled water level for this event is 8.456mRL. The modelled water level for a 100 year ARI MPD event (ie without climate change) is 7.911mRL (2.0m above the bridge soffit).
On-site Assessment of Structure	
Potential Options	• Do Nothing • Increase conveyance capacity of bridge, raise Great South Road and bridge
Options modelled, results and comment	• Flanagan Road bridge was removed from the model. The water levels upstream and downstream of Great South Rd bridge (for a 100-year ARI MPD CC event) increased by 0.01m. The downstream water levels are a flow constraint. • Both Flanagan Road bridge and Great South Road bridge were removed/widened in the model. The modelled water levels upstream and downstream of Great South Road bridge increased by 0.01m and 0.02m respectively. • Flanagan Road bridge, Great South Road bridge and Norrie Road bridge were removed from the model. The modelled water levels upstream and downstream of Great South Road bridge dropped by 0.08m and 0.07m respectively
Constraints	• Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction within a watercourse and floodplain and along an arterial • 65mm dia wastewater rising main crossing the bridge. • 100mm dia water line crossing the bridge
Comments	• Provide signage indicating that road is flood prone during extreme storm events. Potentially a warning light when flood waters exceed a certain water level or some other warning method could also be utilised • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures

	• We understand that Kiwi Property are considering raising Great South Road to facilitate access to their property. Engage with developers to determine extent of Great South road raising in their plans.
Adopted option	•

Source: <Insert Notes or Source>

2.8 2100mm Arch culvert spanning Flanagan Road and the downstream railway line (52.2m long culvert)

Plan

Drawing of culvert	
Issue	• The lack of flow capacity through the undersized culvert contributes to overtopping of Flanagan Road plus potentially limiting development yield due to flooding. • Drury Creek (with a huge contributing catchment area of over 200sq km) is a flow constraint which contributes to floodplain extents (upstream of Flanagan Rd) potentially limiting development yield • Flanagan Road level is 7mRL • 100 year ARI MPD CC level is 8.71mRL • 100 year ARI MPD level is 8.021mRL
Overtopping	• Flanagan Road is predicted to overtop by 1.7m in the future 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • Depth of flow over Flanagan Road in a 100-year ARI MPD event without climate change and sea level rise is predicted to be 1m. • Flanagan Road is overtopped but the railway is not overtopped as it is at a higher elevation (9.876mRL versus 7mRL).
Flood Hazard Assessment	• Significant (as defined in AC Flood Modelling Spec) with flood depth over road > 0.3m • Maximum Flow velocity (in the stream) in 100-year ARI MPD CC event is 3.6 m/s • Maximum Flow velocity (in the stream) in 100-year ARI MPD event is 3.5 m/s
100 year ARI MPD CC flow to culvert (with FUZ)	18m³/s (flow based on 70% imperviousness of FUZ, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road) and 10% imperviousness of upstream rural catchment.
100 year ARI MPD CC flow to culvert (without FUZ)	18m³/s flow based on full development Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change and 10% imperviousness for the catchment draining to the culvert.

100 year ARI MPD flow to culvert (without FUZ)	16.2m³/s (flow based on full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), no climate change and 10% imperviousness for the catchment draining to the culvert.
Conveyance capacity of culvert	12m³/s (is the free full capacity if there was no downstream constriction)
Conveyance capacity of channel	To be determined
Headloss through structure	0.675m (MPD with CC) 0.495m (MPD without CC)
Criticality	High as it passes beneath the railway Flanagan Road is currently classed as minor urban but future zoning is unknown ?????
Meeting AT / NZTA Level of Service	No – Flanagan Road overtops •
Freeboard	• NZTA Bridge manual specifies a freeboard of 0.5m between the road level and the top water level in a 1% event. • Auckland Council Stormwater Code of Practice requires that the headwater depth of water (in a 1% event) not exceed 3m above the invert of the pipe. The headwater depth of water is approximately 6.5m deep (above culvert invert at upstream end).
On-site Assessment of Structure	
Potential Options	• Do Nothing • Provide additional culvert • Fill in upstream depressions (ie floodplain) upstream of Flanagan Road culvert to enable flows to pass forward and upsize culvert along with all upstream culverts (Cossey Road, Fielding Road, Fitzgerald Road,. The downstream Great South Road culvert would also need to be enlarged to provide benefit as it is a downstream constraint.
Options modelled, results and comment	• A number of options were modelled. These are discussed in a technical memo titled 'High level options assessment for Great South road tributary of Hingaia Stream upstream of Drury township' dated 9th March 2018. The most relevant option is discussed here • All the culverts (Cossey Road, Fielding Road, Fitzgerald Road, Flanagan Road and Great South Road) along this tributary were removed from the hydraulic model. Removing the culverts has a similar effect (in the model) to upsizing them to convey the 100 year ARI MPD CC flows. The purpose of this model run was to determine if there were any increases in water levels in Drury township or around critical locations such as Great South Road or Norrie Road. There was no increase in water levels. This indicates that passing flows forward from this sub-catchment is feasible.
Constraints	• Working on a railway line • Consents associated with working on Kiwirail infrastructure • Above ground power lines passing over culvert on Flanagan Road • A 100mm dia water pipeline in the road • Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction on a railway line, within a watercourse and floodplain
Comments	• Provide signage indicating that road is flood prone during extreme storm events. Potentially a warning light when flood waters exceed a certain water level or some other warning method could also be utilised • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures. • CCTV of the culvert carried out in January / February 2018 identified that the culvert had a Level of Failure of 3 which means that collapse is unlikely in the near future and that the remaining life is 5-10 years. A

	functionally sound pipe but with heavy wear and tear and deterioration is beginning to affect structural integrity and performance. • Adopting a Pass Flows Forward approach for the upstream sub-catchment requires that this culvert and the downstream 2100mm dia culvert (beneath Great South Road) be upsized. It is assumed that the upstream culverts will be upsized by developers. • Improving the inletting arrangement of the culvert will increase its flow conveyance capacity
Adopted option	•

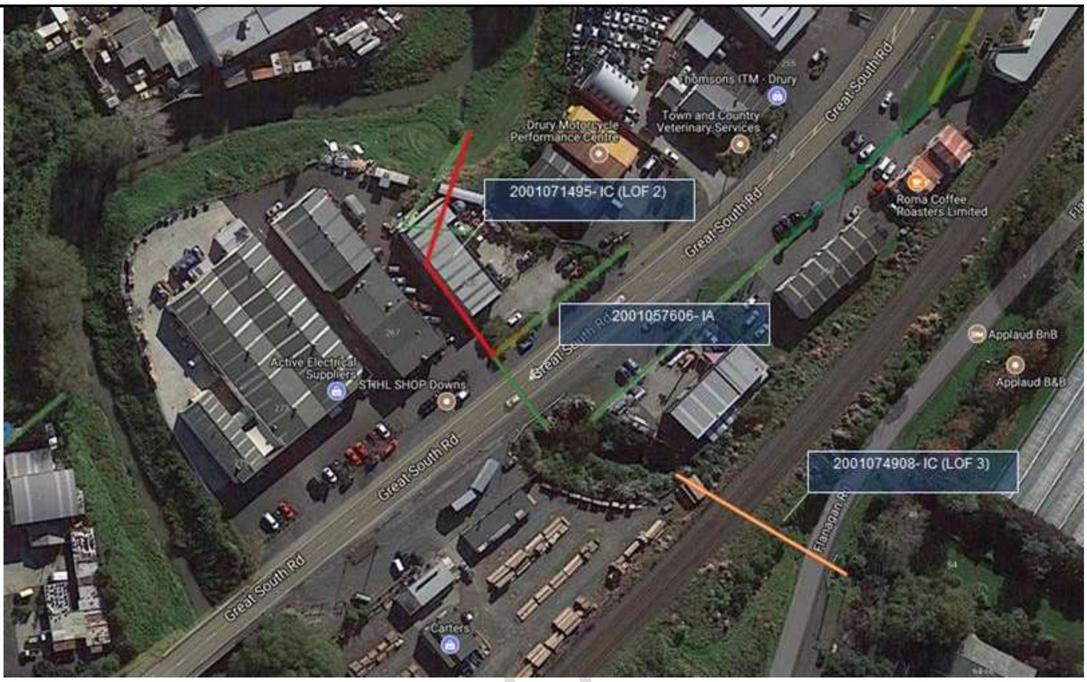
2.9 Great South Road 2100mm dia Culvert

Plan

Drawing of culvert	
Issue	• The lack of flow capacity through the undersized culvert contributes to overtopping of Great South Road during a 100-year ARI MPD CC event. • Drury Creek (with a huge contributing catchment area of over 200sq km) is a flow constraint which contributes to floodplain extents (upstream of Flanagan Rd) potentially limiting development yield • Level of Great South Road – 7mRL (approx.) • 100 year ARI MPD CC level is 8.263mRL • 100 year ARI MPD level is 7.729mRL
Overtopping	• Great South Road is predicted to overtop by 1.2m in the future 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • Depth of flow over Great South Road in the 100 year ARI MPD event without climate change and sea level rise is predicted to be 0.7m • Yes – levels currently being re-assessed
Flood Hazard Assessment	• Significant (as defined in AC Flood Modelling Spec) with flood depth over road > 0.3m
100 year ARI MPD CC flow to culvert (with FUZ)	16.5m³/s (flow based on 70% imperviousness of FUZ, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road) and 10% imperviousness of upstream rural zoned land.
100 year ARI MPD CC flow to culvert (without FUZ)	16.5m³/s flow based on full development Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change and 10% imperviousness for the catchment draining to the culvert.
100 year ARI MPD flow to culvert (without FUZ)	16m³/s (flow based on full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), no climate change and 10% imperviousness for the catchment draining to the culvert.
Conveyance capacity of culvert	12m³/s (is the free full capacity if there was no downstream constriction)
Conveyance capacity of channel	

Headloss across structure	
Criticality	Great South Road is an arterial
Meeting AT / NZTA Level of Service	• No – modelling indicates that Great South Road will be inundated during a 100 year ARI MPD event
Freeboard	None • NZTA Bridge manual specifies a freeboard of 0.5m between the road level and the top water level in a 1% event. • Auckland Council Stormwater Code of Practice requires that the headwater depth of water (in a 1% event) not exceed 3m above the invert of the pipe. The headwater depth of water is approximately 6.0m deep (above culvert invert at upstream end).
On-site Assessment of Structure	
Potential Options	• Do Nothing • Provide additional culvert • Fill in upstream depressions (ie floodplain) upstream of Flanagan Road culvert to enable flows to pass forward and upsize culvert along with all upstream culverts (Cossey Road, Fielding Road, Fitzgerald Road, and Flanagan Road culvert).
Options modelled, results and comment	• A number of options were modelled. These are discussed in a technical memo titled 'High level options assessment for Great South Road tributary of Hingaia Stream upstream of Drury township' dated 9th March 2018. The most relevant option is discussed here • All the culverts (Cossey Road, Fielding Road, Fitzgerald Road, Flanagan Road and Great South Road) along this tributary were removed from the hydraulic model. Removing the culverts has a similar effect (in the model) to upsizing them to convey the 100 year ARI MPD CC flows. The purpose of this model run was to determine if there were any increases in water levels in Drury township or around critical locations such as Great South Road or Norrie Road. There was no increase in water levels. This indicates that passing flows forward from this sub-catchment is feasible
Constraints	• Carrying out work on an arterial road • The culvert beneath Great South Road is an arch culvert which transforms into a 2100mm dia circular culvert soon after entering the property at 263 Great South Road. The circular culvert extends down to Hingaia Stream. Refer Figure below. As can be seen on the figure part of the pipe is located beneath the building at 263 Great South Road.

Comments	• Provide signage indicating that road is flood prone during extreme storm events. Potentially a warning light when flood waters exceed a certain water level or some other warning method could also be utilised • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures. • Adopting a Pass Flows Forward approach for the upstream sub-catchment requires that this culvert and all upstream culverts be upsized to convey the 100 year ARI MPD CC event • The culvert underneath Great South Road has a different asset ID to the downstream 2100 dia circular culvert. Refer screen shot below. CCTV of the downstream culvert was carried out in Januaty / February 2018. This culvert was identified to have a Level of Failure of 2 which means minimal risk of collapse and useful remaining life is 10-20 years. It was noted that the actual alignment of this culvert is different to that shown in GIS. The CCTV log sheet notes the following 'the downstream manhole (of the Great South Road culvert) has no access for a man or a camera. It is a small cut out on top of the pipeline'. • Total length of culvert is approximately 94m

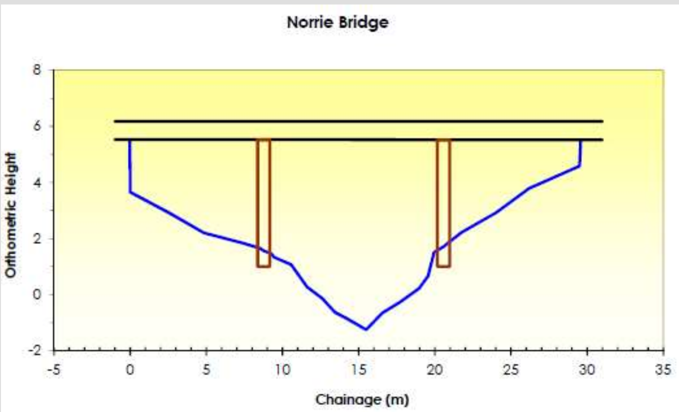


Adopted option	•

2.10 Norrie Road Bridge

Plan

Taken from Hingaia Stream Model Build Report (2017)

Drawing of bridge	 Taken from Hingaia Stream Model Build Report (2017)
Issue	• The lack of flow capacity through the undersized bridge waterway contributes to overtopping of the bridge and road plus potentially limiting development yield due to flooding. This is exacerbated by Drury Creek (with its huge contributing catchment area of over 200sq km) which has high downstream water levels which create a backwater effect to Norrie Road Bridge. • Bridge deck level is 6.18mRL. • 100 year ARI MPD CC level is 7.947mRL.

	• 100 year ARI MPD level is 7.357mRL • 10 year ARI MPD level to be determined •
Overtopping	• The bridge deck is predicted to overtop by 1.767m in the future 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • The approach road is 0.2m lower than the bridge deck, thus the depth of flow over the road is predicted to be 1.74m for the same rainfall event. • Depth of flow over the bridge deck in the 100 year ARI MPD event without climate change and sea level rise is predicted to be 1.177m.
Flood Hazard Assessment	Significant (as defined in AC Flood Modelling Spec) with flood depth over deck > 0.3m
100 year ARI MPD CC flow to bridge (with FUZ)	373m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, 70% imperviousness of FUZ, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change and 10% imperviousness of rural zoned land.
100 year ARI MPD CC flow to bridge (without FUZ)	373m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, full development Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change, 10% imperviousness of the FUZ and 10% imperviousness of the rural zoned land
100 year ARI MPD flow to bridge (without FUZ)	217m³/s flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, full development Drury South Precinct (with associated proposed mitigation measures and Mill Road), no climate change, 10% imperviousness of the FUZ and 10% imperviousness of the rural zoned land.
Conveyance capacity of bridge	210m³/s - is the free full capacity if there was no downstream constriction. However, high tail water levels in Drury Creek are a downstream constraint.
Conveyance capacity of channel	
Headloss across bridge	0.423m (in 100 year ARI MPD CC event) 0.303m (in 100 year ARI MPD event)
Criticality	Zoned Minor Urban
Meeting AT/ NZTA Level of Service	No Bridge soffit is 5.5mRL. Bridge deck is 6.18mRL. Modelled 100 year ARI MPD CC water level is 7.947mRL. 100 year ARI MPD water level is 7.357mRL i.e. both modelled water levels are above the bridge soffit. NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m.
Freeboard	• NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • Blockage of structures in the Hingaia Stream catchment is possible due to the large upstream rural catchment and its potential to generate debris. • To achieve a freeboard of 0.6m the top water level in a 100 year ARI MPD CC event would need to be 4.9mRL (0.6m below the bridge soffit of 5.5mRL). The modelled water level for this event is 7.947mRL. The modelled water level for a 100 year ARI MPD event (ie without climate change) is 7.357mRL (2.457m above the bridge soffit).
On-site Assessment of Structure	
Potential Options	• Do Nothing • Increase conveyance capacity of bridge, raise it and raise adjacent road itself.
Options modelled, results and comment	• Flanagan Road bridge was widened/removed from the model. The water levels upstream of Norrie Road bridge increased by 0.03m and decreased by 0.01m downstream of the bridge (for a 100-year ARI MPD CC event). The downstream water levels from Drury Creek are a flow constraint.

	• Both Flanagan Road bridge and Great South Road bridge were widened/removed from the model. The modelled water levels upstream and downstream of Norrie Road bridge increased by 0.04m and 0.03m respectively for a 100-year ARI MPD CC event. • Flanagan Road bridge, Great South Road bridge and Norrie Road bridge were widened/removed from the model. The modelled water levels upstream of Norrie Road dropped by 0.16m for a 100 year ARI MPD CC event. The downstream water levels increased by 0.01m.
Constraints	Works required in a watercourse adding diversion, erosion and consenting complexity. Safety in Design issues – construction within a watercourse and floodplain
Comments	• Provide signage indicating that road is flood prone during extreme storm events. Potentially a warning light when flood waters exceed a certain water level or some other warning method could also be utilised • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures
Adopted option	•

2.11 Motorway South of Motorway Bridge

Plan

Issue	• Modelling indicates that the motorway south of the motorway bridge will be overtopped (by water from Ngakoroa and Hingaia Streams) during a 100-year ARI MPD with CC event. The flooding will extend for approximately 900m in length between the Motorway bridge and Great South Road intersection and last for approximately 100min. The maximum depth of water will be approximately 1.2m. • The flooding is caused because of Drury Creek (with its huge contributing catchment area of over 200sq km) which is a flow constraint resulting in high downstream water levels and increased rainfall with Climate Change during a 100-year ARI event.
Overtopping	Yes – discussed above
Flood Hazard Assessment	Significant (as defined in AC Flood Modelling Spec) with flood depth of 1.2m and 1.0m on the motorway for 100-year ARI MPD with and without CC events respectively. Flow velocity in 100-year ARI MPD CC event is 1.8 m/s Flow velocity in 100-year ARI MPD event is 2.1 m/s
100-year ARI MPD CC overtopping flow (with FUZ)	91m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, 70% imperviousness of FUZ, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change and 10% imperviousness of rural zoned land
100-year ARI MPD overtopping flow (without FUZ)	15.5m³/s - flow based on maximum allowable imperviousness of existing urban area allowed under the Unitary Plan, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), no climate change, 10% imperviousness of the FUZ and 10% imperviousness of rural zoned land.
Criticality	High
Meeting NZTA Level of Service	No
Potential Options	• Do Nothing • Raise motorway • Bund motorway
Options modelled, results and comment	• Provision of a 900m long (approx.) bund between Southern Motorway bridge and intersection with Great South Road interchange was modelled. Initial results indicate that this would result in an increase in water levels of approximately 0.2m between Norrie Road bridge (in Drury township) and SH1 bridge in a 100 year ARI MPD CC event. Water levels between Norrie Road bridge and Flanagan Road bridge would rise by approximately 0.1m for the same event. Modelling ongoing.

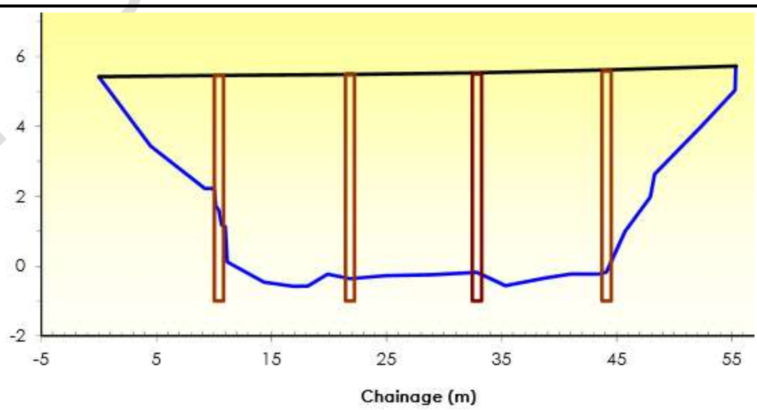
Issue	• Modelling indicates that the motorway south of the motorway bridge will be overtopped (by water from Ngakoroa and Hingaia Streams) during a 100-year ARI MPD with CC event. The flooding will extend for approximately 900m in length between the Motorway bridge and Great South Road intersection and last for approximately 100min. The maximum depth of water will be approximately 1.2m. • The flooding is caused because of Drury Creek (with its huge contributing catchment area of over 200sq km) which is a flow constraint resulting in high downstream water levels and increased rainfall with Climate Change during a 100-year ARI event.
Constraints	• Carrying out works on a motorway
Comments	Flooding of the Motorway is observed between the Motorway bridge and intersection with Great South Road from Ngakaroa Stream on the left of the motorway around 1:50pm (2hours after peak of rainfall) of the 100-year ARI event and subsequently from Hingaia Stream around 2:15pm.
Adopted option	

2.12 Southern Motorway Bridge

Plan

Taken from Hingaia Stream Model Build Report (2017)

Drawing of bridge



Taken from Hingaia Stream Model Build Report (2017)

Issue

- Modelling indicates that the motorway alignment south of the bridge will be overtopped by water from Ngakaroa and Hingaia Streams during a 100-year ARI MPD CC event. This water will then flow down to the motorway bridge.
- Bridge soffit – varies from 5.42mRL to 5.72mRL

	• 100 year ARI MPD CC level is 5.86mRL • 100 year ARI MPD level is 5.5mRL
Overtopping	• Currently being assessed.
Flood Hazard Assessment	
100-year ARI MPD CC flow to bridge (with FUZ)	527m³/s - flow based on 70% imperviousness of the FUZ, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change, full development allowed under the Unitary Plan and 10% imperviousness of rural zoned land.
100-year ARI MPD CC flow to bridge (without FUZ)	527m³/s - flow based on 10% imperviousness of the FUZ, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), climate change, full development allowed under the Unitary Plan and 10% imperviousness of rural zoned land.
100-year ARI MPD flow to bridge (without FUZ)	467m³/s flow based on 10% imperviousness of the FUZ, full development of Drury South Precinct (with associated proposed mitigation measures and Mill Road), no climate change, full development as allowed under the Unitary Plan and 10% imperviousness for rural zoned land.
Conveyance capacity of bridge	650m³/s (is the free full capacity if there was no downstream constriction. However, the high water levels in the downstream Drury Creek are a significant flow constraint))
Conveyance capacity of channel	
Headloss across structure	
Criticality	Critical
Meeting Level of Service	
Freeboard	• NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • Blockage of this bridge is possible due to the large upstream rural catchment and its potential to generate debris. • To achieve a freeboard of 0.6m the top water level in a 100 year ARI MPD CC event would need to be 4.82mRL (0.6m below the bridge soffit of 5.42mRL). The modelled water level for this event is 5.86mRL. The modelled water level for a 100 year ARI MPD event (ie without climate change) is 5.5mRL (0.68m above the bridge soffit).
On-site Assessment of Structure	
Potential Options	• Do Nothing • Increase conveyance capacity of bridge, raise it and raise adjacent road itself. • Bund motorway to prevent flow from Hingaia and Ngakoroa overtopping the alignment
Options modelled, results and comment	• Flanagan Road bridge was widened/removed from the model. This had minimal effect on water levels in the vicinity of the SH1 bridge • Both Flanagan Road bridge and Great South Road bridge were widened/removed from the model. This had minimal effect on water levels in the vicinity of the SH1 bridge. • Flanagan Road bridge, Great South Road bridge and Norrie Road bridge were widened/removed from the model. This had minimal effect on water levels in the vicinity of the SH1 bridge.
Constraints	Works on a motorway have significant health and safety and cost implications. Works required in a watercourse adding diversion, erosion and consenting complexity. Safety in Design issues – construction within a watercourse and floodplain
Comments	Provide signage indicating that road is flood prone during extreme storm events. SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures
Adopted option	

2.13 Bremner Road Bridge (also referred to as Jesmond Bridge)

Plan

Drawing of bridge	
Issue	• The lack of flow capacity through the undersized bridge waterway contributes to overtopping of the bridge and road plus potentially limiting development yield due to flooding. In addition, the water levels in the downstream Drury Creek are a flow constraint. • Bridge deck level is 4.2mRL. • 100 year ARI MPD CC level is 6.22mRL. • 100 year ARI MPD level is 5.28mRL • 10 year ARI MPD level is 3.33mRL
Overtopping	• The bridge deck is predicted to overtop by 2m depth of water in a 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • Depth of flow over the bridge deck in the 100 year ARI MPD event without climate change and sea level rise is predicted to be 1.08m.
Flood Hazard Assessment	Significant (as defined in AC Flood Modelling Spec) with flood depth over deck > 0.3m
100 year ARI MPD CC flow to bridge (with FUZ)	138.6m³/s - flow based on 70% imperviousness of Future Urban Zone (FUZ), climate change and 10% imperviousness of upstream rural catchment draining to bridge
100 year ARI MPD CC flow to bridge (without FUZ)	138.5m³/s - flow based on 10% imperviousness of the catchment (including the FUZ) draining to the bridge and climate change.
100 year ARI MPD flow to bridge (without FUZ)	107m³/s - flow based on 10% imperviousness of the catchment (including the FUZ) draining to the structure and no climate change.
10 year ED flows	37.5m³/s

Conveyance capacity of bridge	$24m^3/s$ - is the free full capacity if there was no downstream constriction. However, high tail water levels in Drury Creek are a significant downstream constraint.
Conveyance capacity of channel	
Headloss across bridge	0.05m
Criticality	Currently classed as minor urban but zoned Future Arterial Road Confirm
Meeting AT / NZTA Level of Service	No • NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • Blockage of structures in the Ngakoroa catchment is possible because of the large upstream rural catchment. • Installation of bridge protection structures upstream of the bridge could be considered. A freeboard of 0.6m might then be acceptable.
On-site Assessment of Structure	
Potential Options	• Do Nothing • Increase conveyance through bridge, raise it and raise adjacent road level
Options modelled, results and comment	• Increasing the flow area through the bridge from $138.5m^2$ to $163.2m^2$ by increasing the bridge length to 34m (from 28.9m) reduced the upstream water level by 0.06m for a 100 year ARI MPD CC event. The downstream water level is a significant flow constraint. • Removing the bridge and providing a larger embankment opening reduces the upstream water level by 0.06m in a 100 year ARI MPD CC event. The purpose of modelling this option was to determine if removing the bridge and providing a larger embankment would have much of an impact on flood levels. It didn't
Constraints	• Options are limited as the downstream water levels in Drury Creek are a significant constraint • Above ground power lines crossing parallel to bridge. • Transpower transmission lines in close proximity to bridge • Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction within a watercourse and floodplain
Comments	• Provide signage indicating that road is flood prone during extreme storm events and potentially a warning light when flood waters exceed a certain water level or some other warning method. • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures
Adopted option	•

2.14 Pitt Road Bridge

Plan

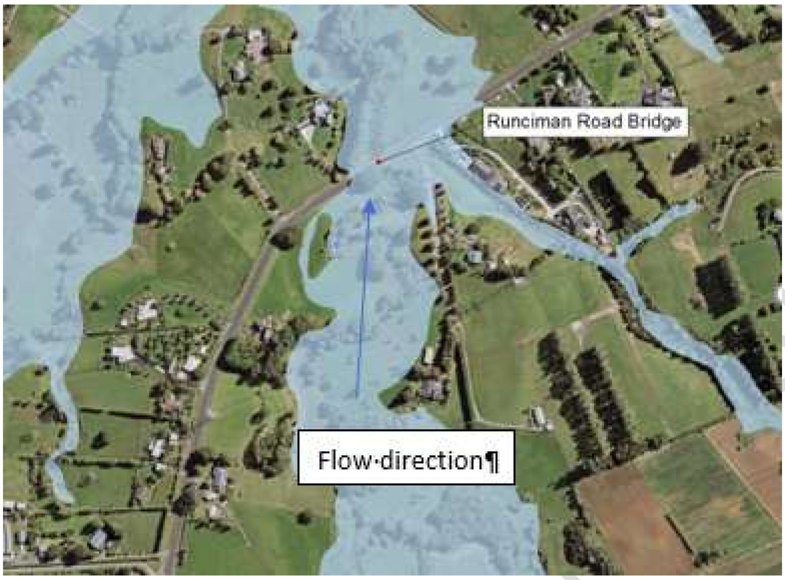
Drawing of bridge	
Issue	• The lack of flow capacity through the undersized bridge waterway contributes to overtopping of the bridge and approach road plus potentially limiting development yield due to flooding. • Bridge deck level is 6.4mRL. Adjacent road level is 6.0mRL • 100 year ARI MPD CC level is 7.33mRL. • 100 year ARI MPD level is 6.79mRL • 10 year ARI MPD level is 5.5mRL

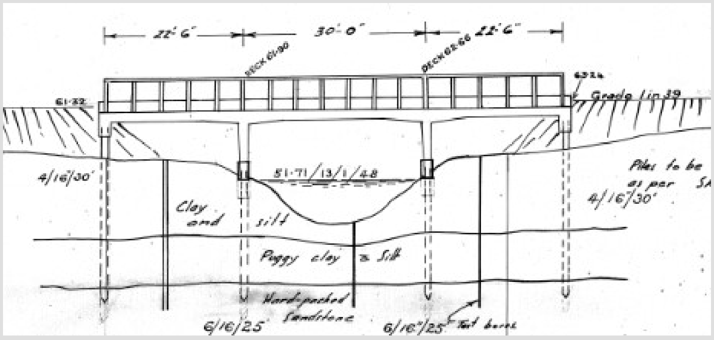
Overtopping	• The bridge deck is predicted to overtop by 0.93m depth of water in a 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • The approach road is 0.4m lower than the bridge deck, thus the depth of flow over the road is predicted to be 1.33m during the same rainfall event. • Depth of flow over the bridge deck in the 100 year ARI MPD event without climate change and sea level rise is predicted to be 0.39m. • Depth of flow over the approach road is predicted to be 0.79m for the same rainfall event.
Flood Hazard Assessment	Significant (as defined in AC Flood Modelling Spec) with flood depth over deck > 0.3m
100 year ARI MPD CC flow to bridge (with FUZ)	141m³/s - flow based on 70% imperviousness of Future Urban Zone (FUZ), climate change and 10% imperviousness of upstream rural catchment draining to bridge
100 year ARI MPD CC flow to bridge (without FUZ)	140m³/s - flow based on 10% imperviousness of the catchment (including the FUZ) draining to the bridge and climate change.
100 year ARI MPD flow to bridge (without FUZ)	107m³/s - flow based on 10% imperviousness of the catchment (including the FUZ) draining to the structure and no climate change.
10 year ED flows	29.7m³/s
Conveyance capacity of bridge	28m³/s - is the free full capacity if there was no downstream constriction.
Conveyance capacity of channel	
Headloss across road bridge and railway bridge	0.29m (in a 100 year ARI MPD CC event)
Criticality	Currently classed as minor urban
Meeting AT / NZTA Level of Service	
Freeboard	• NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. • Blockage of structures in the Ngakoroa catchment is possible because of the large upstream rural catchment. • Installation of bridge protection structures upstream of the bridge could be considered. A freeboard of 0.6m might then be acceptable.
On-site Assessment of Structure	
Potential Options	• Do Nothing • Increase conveyance through bridge, raise it and raise adjacent road level
Options modelled, results and comment	• Increasing the flow area through the bridge from 60m² to 140m² by increasing the bridge length to 28m (from 12m) reduced the upstream water level by 0.07m for a 100 year ARI MPD CC event. The downstream railway bridge is a flow constraint. • Removing the bridge and providing a larger embankment opening reduces the upstream water level by 0.03m in a 100 year ARI MPD CC event. The purpose of modelling this option was to determine if removing the bridge and providing a larger embankment would have much of an impact on flood levels. It didn't.
Constraints	• Above ground power lines crossing parallel to bridge. • Pipes strapped to bridge. • Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction within a watercourse and floodplain
Comments	• Provide signage indicating that road is flood prone during extreme storm events and potentially a warning light when flood waters exceed a certain water level or some other warning method.

	• SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures
Adopted option	•

2.15 Runciman Road Bridge (also called Glasgow Bridge)

Plan



Drawing of bridge	
Issue	• The lack of flow capacity through the undersized bridge waterway contributes to overtopping of the bridge and road plus potentially limiting development yield due to flooding. • Bridge deck level is 10.7mRL. Adjacent road level is 9.8mRL • 100 year ARI MPD CC level is 11.11mRL. • 100 year ARI MPD level is 10.86mRL • 10 year ARI MPD level is 10.1mRL •

Overtopping	• The bridge deck is predicted to overtop by 0.41m depth of water in a 100 year ARI MPD CC event. This event includes the effects of climate change and a Mean High Water Springs (MHWS) tidal boundary with sea level rise of 1m. • The low point of the approach road is 0.9m lower than the bridge deck, thus the depth of flow over the road is predicted to be 1.31m during the same rainfall event. • Depth of flow over the bridge deck in the 100 year ARI MPD event without climate change and sea level rise is predicted to be 0.16m. • Depth of flow over the approach road is predicted to be 1.06m for the same rainfall event. •
Flood Hazard Assessment	Significant (as defined in AC Flood Modelling Spec) with flood depth over deck > 0.3m
100 year ARI MPD CC flow to bridge (with FUZ)	126m³/s - flow based on 70% imperviousness of Future Urban Zone (FUZ), climate change and 10% imperviousness of upstream rural catchment draining to bridge
100 year ARI MPD CC flow to bridge (without FUZ)	126m³/s - flow based on 10% imperviousness of the catchment (including the FUZ) draining to the bridge and climate change.
100 year ARI MPD flow to bridge (without FUZ)	95m³/s - flow based on 10% imperviousness of the catchment (including the FUZ) draining to the structure and no climate change.
10 year ED flows	33.7m³/s
Conveyance capacity of bridge	57m³/s - is the free full capacity if there was no downstream constriction.
Conveyance capacity of channel	
Headloss across bridge	0.04m (in a 100 year ARI MPD CC event)
Criticality	Currently classed as minor urban
Meeting AT / NZTA Level of Service	
Freeboard	• NZTA Bridge manual specifies a freeboard of 0.6m between the 100 year ARI event and the underside of the superstructure. Where the possibility exists that large trees may be carried down the waterway then the freeboard requirement increases to 1.2m. This is a possibility given the large upstream rural catchment. • Blockage of structures in the Ngakoroa catchment is possible because of the large upstream rural catchment. • Installation of bridge protection structures upstream of the bridge could be considered. A freeboard of 0.6m might then be acceptable
On-site Assessment of Structure	
Potential Options	• Do Nothing • Increase conveyance through bridge, raise it and raise adjacent road level
Options modelled, results and comment	• Not carried out to date as this bridge is located at the top of the FUZ. Widening the waterway will lower upstream water levels but will result in more flows going downstream
Constraints	• Above ground power lines crossing parallel to bridge. • Above ground 1200 dia CLS transmission water pipe adjacent to the bridge. • Works required in a watercourse adding diversion, erosion and consenting complexity. • Safety in Design issues – construction within a watercourse and floodplain
Comments	• Provide signage indicating that road is flood prone during extreme storm events and potentially a warning light when flood waters exceed a certain water level or some other warning method. • SMP to recommend that Emergency Management Plan be prepared for Structure Plan Area. The purpose of the Plan is to identify flood prone structures
Adopted option	•

Appendix J

Healthy Waters Review of Adequacy of Information

Healthy Waters Review of Adequacy of Information for a Private Plan Change (PPC) Request

Drury East – Fulton Hogan and Kiwi Property

02 February 2020

The table below includes the requests for additional and further information from Healthy Waters in relation to the three Drury East Plan changes. Reference to the full responses to these requests as developed by T+T and Woods is indicated in the "Response" column of the table.

Assessment category		**Comments /requests**	**Reason for comments/requests**	**Responses**
No	**Category**			
01	Stormwater Planning	Please provide an assessment of how the proposed plan changes meet the outcomes of the NPS-FM and the related matters in the AUP Regional Policy Statement. How does the s32 report acknowledge and address methods to meet regional policy statement objectives that are relevant to the plan change areas, including B7.3 E1.3.8 and E1.310? Please update if necessary.	The policy framework acknowledged in the s32 reports primarily addresses matters relating to urban development and the provision of land for urban growth. While there is some acknowledgement of the NPS-FM, this appears to be limited to how streams and other natural hydrological features are recognized in the proposed plan changes. NPS-FM Objectives and Policies relating to water quality, and Regional Policy Statement objectives and policies for water quality and integrated stormwater management, do not appear to be addressed. The process and outcome of urbanising land has significant environmental effects both immediately and into the future. There appears to be little acknowledgement of these effects on the receiving environment (which the NPS and RPS objectives and policies refer to) or adequate demonstration of how these effects will be mitigated through the proposed precinct plan provisions and proposed stormwater management plan.	Refer to Planning Response and the Response to Auckland Council Further Information Request for Drury East – Drury East Plan Changes - Ecology Response in Appendix N.
02	Stormwater quality	Please clarify how objectives in the AUP for water quality will be met. The Planning report (pg46) emphasises that high contaminant generating roads and carparks will be treated (treatment of these roads is covered by region wide rules in Chapter E9 AUP). However, it is unclear how many roads are anticipated to meet the thresholds to trigger E9 rules and if	AUP E1.3.8 directs to avoid as far as practicable the adverse effects of development on water quality. AUP Objective E1.2.3 and Policies 1.3.2 and 1.3.3 directly implements the NPS-FM 2017. Avoiding adverse effects on water quality should be demonstrated in the planning report	Refer to Table 6.1 in the SMP or Section 1: Stormwater management in the Response to Auckland Council Further Information Request on Stormwater Matters for Drury East memo in Appendix L.

		additional roads should be treated to meet the proposed objective. There is also reference in the Drury East – Fulton Hogan request (page 46) to a treatment train approach and secondary treatment but it is unclear if this is part of the approach to treat high contaminant generating roads or is an additional response applied to all roads to meet objectives E1.3.8 and E1.3.8 and meet Schedule 4 NDC requirements greenfield developments. A matrix showing what tools will be used in what proposed land use zone to avoid any adverse effects on water quality should be included in the SMPs as part of identifying how adverse effects will be mitigated and how these achieve AUP policies for water quality.	and SMP. The creation of adverse effects on water quality due to contaminants in runoff from impervious surfaces is an effect of urban land use. Therefore, this should be part of the S32 report and AEE. Reliance on region wide rules in the AUP may not be sufficient to meet AUP policies for this plan change area and for the associated receiving environment which is a Significant Ecological Area; some of which (such as Drury Creek Islands) have further restoration and enhancement underway. Additional detail on the methods for treating stormwater to avoid adverse effects may also be sought prior to notification of this plan change as part of the SMP in support of stormwater discharge authorisation.	
03	Water quality	Please more fully describe how the water quality policies in E1 will be achieved, and what options have been considered to meet the policies.	The current descriptions in the SMPs are confusing and appear to rely solely on the region-wide rules. Given the AUP policy directives for greenfield development and the sensitivity of the receiving environment, additional treatment (such as a treatment train approach) may be justified.	Refer to Planning Response and the Response to Auckland Council Further Information Request for Drury East – Drury East Plan Changes - Ecology Response in Appendix N.
04	Hydrology Mitigation	Please provide an assessment of the degree to which SMAF1 avoids or remedies changes in hydrology which will result from the urban land uses proposed in the plan changes. A Regional Erosion Threshold Metric risk assessment identifies areas at risk of erosion and provides some quantification of the amount of erosion caused, however it does not address how effects will be avoided, remedied or mitigated. Identification of measures to avoid effects and mitigate should also be made and the BSTEM model is appropriate for this	The AUP states that for greenfield areas adverse effects of development shall be avoided as far as practicable or otherwise remedied or mitigated and this includes changes in hydrology (Policy E1.3.8). No SMAF controls were applied to greenfield areas in the AUP as it was expected that an assessment on what hydrological mitigation is required would be undertaken as part of plan change process. The Drury-Opaheke Structure Plan SMP also identified that hydrological mitigation and erosion assessments should be completed at the scale of the plan changes so that the particular effects of proposed land uses would be identified, and mitigation measures would be determined, at scale proportionate to the proposed activities and effects.	We recommend that Oyster refers to the Drury East (Oyster Capital) flood modelling - Response to Auckland Council Further Information Request on Stormwater Matters (Version 2) Stream Erosion Assessment for the Hingaia catchment attached in Appendix M and waits for feedback on that before progressing with this assessment.

		task. More detail on this tool is being supplied to the applicants.		
05	Flooding	Please address the matters identified and discussed in the memo to Healthy Waters from Tonkin + Taylor dated 19 February 2020. We note that all applicants need to explain what the effect cumulatively across developments will be on the Drury township flooding and parts of the catchment that interact with the Slippery Creek floodplain.	Flooding in the Hingaia catchment is complex and needs to be considered in conjunction with other plan changes proposed for the area; acknowledge any interactions with other catchments and the cumulative impact of potential development in the surrounding areas and the point of discharge downstream. Understanding the impact of development on the flood plain within the plan change sites and impacts downstream is necessary to evaluate the plan change proposal and ensure any potential flood effects are avoided or mitigated. Several discussions between Healthy Waters and the applicant's planners have occurred on the best way to approach flood modelling and the memo from T+T dated 19 February 2020 reflects our agreement with regard to flooding matters.	Refer to Section 2 of the flood modelling Response to Auckland Council Further Information Request on Stormwater Matters (Version 2) memo in Appendix O.
06	Riparian Margins	Please explain why a 10m wide riparian margin is proposed when the Drury-Opaheke Structure Plan Stormwater Management Plan identified a 20m riparian margin as being appropriate. No evaluation of these two options is provided including their consistency with the objectives and policies of the AUP.	A 20m wide riparian margin was consulted on as part of the Drury-Opaheke Structure Plan 'Blue Green Network' and associated the Stormwater Management Plan. The purpose of the wide margin is to provide an ecological corridor and provide a buffer for the stream noting that stream meander may occur due to erosion. These benefits support achievement of AUP objectives and policies. A rationale for a lesser width margin is not provided in the s32 report.	Refer to Planning Response and the Response to Auckland Council Further Information Request for Drury East – Drury East Plan Changes - Ecology Response in Appendix N.
07	Ecological corridors and Blue Green network.	Please clarify what the ecological corridors are and how they contribute to meeting objectives and policies of the AUP. They are mentioned briefly but there is no description on how these align to the Blue Green network identified in the Drury-Opaheke Structure Plan, nor are the streams or corridors noted specifically in the precinct plan or stormwater management plan.	A blue green network utilising the natural hydrological features of existing streams was identified as part of Auckland Council's Drury-Opaheke Structure Plan. If and how streams are used in this way has implications in relation to: Identifying the impact of urban development on streams (if they are intended to be retained or not). Keeping flood conveyance channels available as part of the 'pass-it-forward' approach outlined in the Drury-Opaheke Structure Plan.	Refer to Planning Response and the Response to Auckland Council Further Information Request for Drury East – Drury East Plan Changes - Ecology Response in Appendix N.

		Planning provisions to enable the ecological corridor are not provided in the precinct plan nor is an assessment given in s32 assessment reports.	Mitigation of effects anticipated by urban development, including hydrology mitigation. The precinct plan and stormwater management plan lack information on the ecological corridors making their purpose for achieving AUP objectives and policies or as part of effects mitigation unclear. We note public access such as walkways/cycle network need to be located outside riparian setbacks and the minimum width required to accommodate water sensitive devices.	
08	Development staging	Please explain if and how the precinct plan is to manage flood risks (such as staging of development in conjunction with flood mitigation measures). Flood attenuation is proposed in the SMP but there are no precinct plan provisions to ensure that flood attenuation is provided or when it would be appropriate to not have flood attenuation.	The plan change areas are areas of significant flood hazard and developing the plan change areas could increase the flooding downstream in the existing Drury township. Fulton Hogan, in their SMP page 6 propose as part of their flood management approach for Zone A to provide: *Temporary flood attenuation to pre-develop flow – to enable development in advance of culvert upgrades* There is no indication in their SMP or precinct plan of when this would be provided or when it will not be provided. The attenuation relates to current culvert capacity at Great South Rd and Flannagan Rd. These culverts will likely need upgrading in the future when road upgrades are done but this requirement is not linked to transport infrastructure upgrades or backed up by analysis of culvert capacity.	Not applicable to this development

Appendix K

Response to Further Information Request on Stormwater Matters for Drury East

To

Auckland Council
Carmel O'Sullivan; Mark Iszard

From

Woods
Pranil Wadan - Principal Engineer

Tonkin + Taylor
Tim Fisher - Engineering Executive Leader

W-REF: P16-335
25 March 2020

Response to Auckland Council Further Information Request on Stormwater Matters for Drury East

This memo has been written to summarise the additional stormwater assessments undertaken in response to the Further Information Request (FIR) from Auckland Council for the Drury East Plan Change requests.

The structure of the memo is as follows:

- Stormwater management
- Hydrological mitigation
- Flood management

How the response relates to the Auckland Council FIR table is summarised in Appendix A.

1. Stormwater management

A matrix of stormwater management outcomes and tools for different land use zones is presented in Table 1 to demonstrate that an integrated stormwater management approach will be implemented across all three Plan Change Areas (Kiwi Property, Fulton Hogan and Oyster Property). The matrix is compiled from the current Stormwater Management Plans (SMP) for each Plan Change and will form part of the updated SMP. It shows alignment of stormwater quality, hydrological mitigation and flood attenuation approaches across the three Plan Change Areas. An ecological assessment will be provided to address potential impacts on the Significant Ecological Area.

In addition, a broad range of Best Practicable Options (BPOs) for mitigating effects and/or achieving these outcomes are listed for the corresponding land-use. This toolbox will be used to develop each development's stormwater management approach, though different devices and/or combinations may be adopted across the three Plan Change Areas to achieve the outcomes.

Feedback from Auckland Council at our update meeting of 19 February 2020 was that the performance standards should be as consistent as possible across the three Plan Change Areas, and the stormwater management toolbox as broad as possible to have flexibility of implementation.

Table 1: Stormwater Management Toolbox

Zone	Land Use	Performance Outcomes				Best Practicable Options	Notes
		Water Quality	**Hydrological Mitigation**	**Flood Attenuation**	**Water Sensitivity Design** [1]		[1] The proposed stormwater management options adopt a Blue Green Corridor approach that includes other devices or measures which are not listed in this table i.e. filter strips, green outfalls (where practicable), streams protected and enhanced with riparian buffer and re-vegetation planting. The need for bank stabilisation/instream works to be determined by stream erosion assessments. [2] Stormwater Management Devices in the Auckland Region –Guideline Document 20017/001 (GD01). (December 2017). Auckland Council [3] Auckland Unitary Plan –Operative in Part (AUP:OP). Auckland Council The Plan Change Area does not fall within a Stormwater Management Area - Flow 1 (SMAF 1) overlay but this will be adopted as the minimum requirement across all three sites. This stormwater management approach is consistent with Policy E1.3.10. The minimum hydrological mitigation requirements proposed are as follows: • Retention (volume reduction) of at least 5mm of runoff depth from impervious surfaces • Detention of the 95th percentile event for the difference between the pre-development and post-development runoff volumes from a 95th percentile, 24 hour rainfall event minus the achieved retention volume. Exceptions for providing retention can be made in cases where soil infiltration rates preclude disposal to ground and rainwater reuse is not possible. It is noted that if retention cannot be met, devices are to be lined with the retention volume being treated as a detention through bioretention devices. An erosion assessment is to be carried out to determine if additional measures (such as additional detention requirements) are required to mitigate the hydrological impacts of development. [4] Post-development peak flows to match pre-development peak flows for the 1 % Annual Exceedance Event (AEP). [5] Devices will be provided and sized for WQ treatment for carparks (greater than 30 vehicles) only for the Residential Zones. [6] Includes the option for large communal devices to provide treatment and hydrology mitigation to public roads and impervious areas. Gross Pollutant Traps (GPT) or alternative proprietary devices will be installed upstream of communal devices. The communal devices may be dual-purpose as they could also provide flood attenuation, if required. [7] Flood attenuation for Oyster Southern Zone. [8] Hydrology mitigation will be provided for these impervious areas; the use of devices such as bio-retention for mitigation will also provide WQ treatment.
Performance standard		GD01[2]	AUP:OP SMAF 1[3]	1% AEP: $Q_{pre} = Q_{post}$[4]			
Mixed use Metropolitan Centre	Roads	✓	✓	X	✓	**Bio-retention devices including:** • Raingardens • Tree pits • Vegetated swales	
	Non Roads	✓	✓	X	✓	Inert Building materials Rainwater tanks for re-use of roof runoff Permeable pavements for public realm areas Communal detention devices **Bio-retention devices including:** • Raingardens • Tree pits • Vegetated swales	
Mixed Housing – Urban Mixed Housing – Suburban Terraced Housing Apartment Buildings	Roads	✓	✓	X✓[6,7]	✓	Communal devices[5] Offline Wetlands/Dry Basins[5] **Bio-retention devices including:** • Raingardens[4] • Tree pits • Vegetated swales	
	Carparks > 30 Vehicles	✓[5]	✓	X✓[6,7]	✓	Inert Building materials Rainwater tanks for re-use of roof runoff Permeable pavements for driveways or laneways Communal devices[5] **Bio-retention devices including:** • Communal detention devices • Living Roofs • Raingardens • Vegetated swales	
	Roofs, JOALS, driveways, gardens/landscaping	X✓[8]	✓	✓	✓		

2. Hydrological Mitigation

2.1 Stormwater management

Hydrological mitigation controls should be applied within the Plan Change Area as it is located upstream of a Stormwater Management Area control - Flow 1 (SMAF 1) and is a greenfield development where Policy E1.3.8 requires "…*minimising or mitigating changes in hydrology*…" and effects on rivers and streams.

The proposed Drury East (three Plan Change Areas) approach to hydrological mitigation and addressing stream erosion risk is to provide a minimum of SMAF 1 hydrological mitigation (detention and retention) for all impervious surfaces . The minimum hydrological mitigation requirements proposed are as follows:

- Retention (volume reduction) of at least 5mm of runoff depth from impervious surfaces where possible (refer Table E10.6.3.1.1)
- Detention of the 95th percentile event for the difference between the pre-development and post-development runoff volumes from a 95th percentile, 24 hour rainfall event minus the achieved retention volume.

A stream erosion assessment (refer Section 2.2) is to be carried out to identify high risk areas and determine if additional measures (such as additional detention requirements) are required to mitigate the hydrological impacts of development.

Exceptions for providing retention can be made in cases where soil infiltration rates preclude disposal to ground and rainwater reuse is not possible. It is noted that if retention cannot be met, devices are to be lined with the retention volume being treated as a detention through bioretention devices.

For roads and car-parks within the Plan Change Area, hydrological mitigation can be achieved through vegetated bio-retention devices such as raingardens, tree pits and swales. These devices generally provide multiple functions: retention/detention, visual amenity and water quality treatment close to the source.

For residential lots within the Plan Change Area, hydrological mitigation of roof runoff may be achieved through rainwater tanks. Rainwater tanks promote the recycling and re-use of rainwater, while mitigating stormwater runoff at source. Stormwater runoff from other impervious surfaces within residential lots could be managed within permeable pavements on private or shared driveways. If this is not practicable, communal underground detention tanks could be utilised to minimise the land take required whilst achieving the required detention volume.

Within the Metropolitan Centre, rainwater tanks, communal detention devices and/or permeable pavements could be used to achieve hydrological mitigation. Rainwater tanks will only be utilised where there is sufficient demand for water reuse. Where practicable, raingardens can also be used to achieve hydrological mitigation alongside water quality mitigation e.g. for roads and carparks and surrounding public spaces where practicable.

2.2 Stream erosion

The extend and effects of stream erosion on the streams and Drury Creek are described in the Drury East Plan Change – Ecology Response (19 March).

All stream tributaries within the Plan Change Area are highly eroded and degraded. This is attributed to a combination of poor bank stability, unrestricted stock access leading to ongoing agricultural related nutrient inputs, instream channel disturbance, minimal stream channel shading and bare or sparsely vegetated riparian vegetation within the catchment.

Drury East Plan Change – Ecology Response (19 March) has identified the follow mitigation measures as being those which will aid in the management of erosion and sedimentation in the Plan Change aArea:

- Removal of stock from the site and therefore avoiding active bank de-stabilisation through stock access and pugging.

- Incorporation of green spaces adjacent to stream networks to provide for planting of riparian margins to improve bank stability and reduce erosion potential.
- Modification of hydrograph mitigated through stormwater retention/detention (SMAF 1 hydrological mitigation) measures which will slow flows.
- Remediation or removal of existing in-stream structures (culverts, inlets/outlets) which are currently identified as having erosion issues.
- Realignment of streams which have been channelised to a more natural alignment.
- Incorporation of erosion and scour protection measures at all outfalls to minimise erosion at new structures.
- Targeted in-stream erosion protection measures may be required within the Hingaia Stream and other larger streams.

While the effectiveness of these measures cannot be quantified at this stage, these are still considered to provide some benefit to erosion and sediment generation from stream channels affected by the change in hydrology within the Plan Change Area.

This proposed approach to addressing stream erosion risk recognises that there are several mitigating factors including the fact that Plan Change Area is proportionally a very small part of the overall Hingaia Catchment and is towards the bottom of the catchment so instream works are likely to be the best way to address locally derived erosion risk. Also, that the proposed urban land use has typically a lower sediment load than for rural land.

2.3 Stream erosion risk assessment

The Auckland Council Stream Erosion Risk Tool was investigated as a mechanism to analyse stream erosion resulting from the development. We have encountered issues with the simplistic tool, that means this assessment cannot be completed within the timeframes of the FIR response.

The issues and our next steps are summarised below:

#	Issue	Next step
1	TP108 hydrology is too coarse for a large catchment such as the Hingaia where a refined hydraulic model is available	Use hydrographs from the flood model. Rebuild Stream Erosion Risk Tool to allow this.
2	Hydraulic shear stress is very sensitive to Slope (S) and thalweg/bed levels are too variable and result in non-sensible results	Use bed shear stress calculated by the hydraulic model at all locations and at all time steps. Rebuild the Stream Erosion Risk Tool to allow for these inputs.
3	Simplification of channel cross-sections to a trapezoid is too coarse	
4	Critical shear stress cannot be determined from the geotechnical testing already done for the site.	Estimate this from Auckland Council databases in the Stream Erosion Risk Tool.
5	Quantification of change in exceedance of critical shear stress will only indicate a change in erosion potential. It will not quantify how much extra erosion and what the change in sediment load will be to the receiving environment, so it cannot be used to assess effects.	Auckland Council to advise how they see this working. The tool will identify areas with increased erosion risk and where extra mitigation measures should be applied.

The technology and understanding in this area are evolving but is not ready yet. We will work with Council to complete this assessment for the hearing stage of the Plan Change.

3. Flood Management

Additional flood modelling was undertaken to assess the potential flooding mechanisms and effects caused by a "development only flood' scenario. This scenario assumes extreme rainfall (2, 10, 100 year ARI rainfall) in the lower catchment only (over existing Drury and Plan Change Areas). A proposed flood modelling methodology was outlined in the memo *Drury East (Kiwi and Fulton Hogan) flood modelling – response to Auckland Council Modelling requests* prepared by Tonkin + Taylor to Auckland Council on 10 and 19 February 2020, and accepted as a part of the lodgement of Plan Changes for Drury East by Fulton Hogan and Kiwi Property in the FIR from Auckland Council.

The proposed steps outlined in the memo were:

1. *For 10-year and 100-year ARI model runs (pre-development and post development) map the buildings with floors at risk from flooding. This is the "full catchment flood scenario". Shape file with building extents and floor levels to be supplied by Auckland Council. Use T+T/Woods current models as they are (model version, Drury South included and impervious assumptions).*
2. *Simulate the potential flooding caused by development of the lower catchment. This is the "development only flood scenario". Reconfigure the post development models to:*
    - *apply 10-year and 100-year ARI rainfall to the lower catchment including existing Drury Township and the developed Future Urban areas inclusive of developments (e.g. MPD in the FU areas)*
    - *Allow for nominal "fresh" flow of 50 m3/s from the upper catchment*
    - *Map the buildings that flood*
3. *Compare the flood extents and buildings that flood for full catchment flood scenario (pre and post) to development only flood scenario*
4. *Assess the impacts on existing Drury due to the developments from both the flood for full catchment flood scenario and development only flood scenario*

3.1 Model build and updates

These model scenarios were based on the Drury South Precinct Plan Change model that has been reviewed and signed off by Auckland Council as a part of the Drury South Precinct Plan Change application. Previous changes to the model have been documented in the *Drury Town Centre - Kiwi Property - Model Build* Memo prepared by Tonkin +Taylor to Auckland Council on 17 June 2019, and includes changes to the Hingaia Stream catchment model representing the pre- and post-development catchment scenarios supplied by Fulton Hogan and Kiwi Property for the Drury East Plan Change applications.

Any additional changes to the models are captured in Tables 2 and 3 below, which outline the catchment and development only model matrices agreed with Auckland Council as a part of this request. Associated supporting information will be supplied to Auckland Council for review of the flood model build/changes.

3.1.1 Post Development Model Structures

A plan showing the structures that have been "opened" or modified is available in Appendix B; a summary of this is as follows:

- Great South Road Culvert, Railway Culvert, Flanagan Road Culvert –Supplemented with 2mx2.5m box culvert
- Off Flanagan Rd (Private Bridge) - Opened
- Fitzgerald Culvert - Opened
- Field Road Culvert - Opened
- Cossey Road Culvert - Opened
- Fitzgerald Road Culvert (off – Fielding Road) - Opened
- Fitzgerald Road Culvert (off – Cossey Road) - Opene

Table 2: Model matrix – Catchment Models

Scenario	Baseline Model (and key assumptions)	Great South Road tributary culvert status	Land use outside Fulton Hogan and Kiwi Property Plan Change Area	Land use within Fulton Hogan and Kiwi Property Plan Change Area	Model ID	Event	Climate Change	Model Changes
Pre-Development Model	Drury South Precinct Plan Change model *(post development impervious and landforms)*	Existing Culverts	10% Imperviousness within FUZ; Drury South - Post Development; Upstream rural zonings at 10% imperviousness	10% Imperviousness within FUZ (including PCA)	01	2yr	Yes	- Hydrology updated to use 2yr Future Rainfall using Model 02 - No other changes
					02	10yr		- Model developed as a part of preparing Stormwater Management Plan for Drury East Plan Change Area for Fulton Hogan and Kiwi Properties
					03	100yr		- Model developed as a part of preparing Stormwater Management Plan for Drury East Plan Change Area for Fulton Hogan and Kiwi Properties
Post-Development Model	Drury South Precinct Plan Change model *(post development impervious and landforms)*	Culverts open with post development landforms within Plan Change areas (these culverts will be designed for 100yr conveyance capacity based on pass flows forward approach)	10% Imperviousness within FUZ; Drury South - Post Development; Upstream rural zonings at 10% imperviousness	Imperviousness for Metropolitan Centre = 100% Imperviousness for Kiwi Property land = 70% Imperviousness for Fulton Hogan land = 65% Future Urban Zone outside of Plan Change Area = 60%	04	2yr	yes	- Hydrology updated to use 2yr Future Rainfall using Model 05 - No other changes
					05	10yr		- Model developed as a part of preparing Stormwater Management Plan for Drury East Plan Change Area for Fulton Hogan and Kiwi Properties
					06	100yr		- Model developed as a part of preparing Stormwater Management Plan for Drury East Plan Change Area for Fulton Hogan and Kiwi Properties
					07	2yr	No	- Hydrology updated to use 2yr Existing Rainfall using Model 01 - No other changes

Table 3: Model matrix – Development Only Models

<table>
<tr><th>Scenario</th><th>Model ID</th><th>Event</th><th>Climate Change</th><th>Model Changes</th></tr>
<tr><td rowspan="2">Pre-Development Model</td><td>08</td><td>10yr</td><td rowspan="2">Yes</td><td rowspan="2">- Mike 11 network model updated using Model 02
- Hingaia Stream river branch was disconnected at chainage 14723 to a dummy outlet
o Dummy outlet was modelled with dummy river branch and wide cross sections
o Channel bed of dummy branch was set equal to the channel bed on Hingaia Stream branch at chainage 14723
o Q-h relationship was set as a boundary condition to discharge unrestricted flows out of the system
- Hingaia Stream river branch was modelled with inflows of 30m³/s and 50m³/s are applied for 10yr and 100yr scenarios respectively along Hingaia Stream at upstream chainage of 14724
- No other changes</td></tr>
<tr><td>09</td><td>100yr</td></tr>
<tr><td rowspan="2">Post-Development Model</td><td>10</td><td>10yr</td><td rowspan="2">Yes</td><td rowspan="2">- Mike 11 network model updated using Model 05
- Hingaia Stream river branch was disconnected at chainage 14723 to a dummy outlet
o Dummy outlet was modelled with dummy river branch and wide cross sections
o Channel bed of dummy branch was set equal to the channel bed on Hingaia Stream branch at chainage 14723
o Q-h relationship was set as a boundary condition to discharge unrestricted flows out of the system
- Hingaia Stream river branch was modelled with inflows of 30m³/s and 50m³/s are applied for 10yr and 100yr scenarios respectively along Hingaia Stream at upstream chainage of 14724
- No other changes</td></tr>
<tr><td>11</td><td>100yr</td></tr>
</table>

3.2 Results analysis

Model results were analysed for flood extents, peak water levels and flood depths for all building footprints for each scenario to understand the flood risk for the pre and post development scenarios. Analysis was limited to the building footprints within Drury Township (excludes existing building footprints within the Plan Change Areas) and covers the area encompassed by –

- Southern Motorway bridge to the north
- Southern Motorway to the west
- Great South Road to the east
- Flanagan Road to the south.

This is shown as 'Area of interest' on the flood maps provided in Appendix B.

The intention of this assessment was to understand if there is any increase in flood risk to properties downstream of the Plan Change Areas with the increases in flows associated with higher imperviousness within these developments. This area of analysis is shown in figures (provided in Appendix B) and all flood results outside this extent as less reliable with the model setup.

3.3 Building Flood Risk

The approach identified for understanding Flood Risk for buildings was as below –

- Peak modelled Flood levels were extracted for buildings footprints where floor levels were available
- Peak Flood Depths were extracted for buildings footprints where floor levels were not available and habitable floor level was assumed to be 150mm above the respective ground levels
- Flood maps were generated for all scenarios (provided in Appendix B) to understand the differences.

A total of 81 buildings footprints within the 'Area of interest' were analysed based on the above approach and tabulated in Table 4 below.

The 'Development only' models were run for the 10yr and 100yr scenarios and Catchment models were run for the 2yr scenario with and without climate change.

The 2yr model Catchment model results were analysed in addition to agreed scenarios to understand if there are any adverse flood risks with the proposed development for smaller rainfall events.

The analysis shows that the total number of properties flooded are unchanged, for the 'Development only' as well as Catchment models for the scenarios analysed. This confirms there is no additional flood risk to habitable floor or properties with the proposed development in place.

Table 4: Building footprints at Flood Risk

Scenario	Flood Risk	Development only Model		Catchment Model	
	Building Flooding	Pre - Development Model	Post - Development Model	Pre - Development Model	Post - Development Model
2yr without Climate Change	Above Floor Level	n/a	n/a	-	-
	Below Floor Level	n/a	n/a	1	1
	Flood Depth > 0.15m	n/a	n/a	-	-
	Flood Depth < 0.15m	n/a	n/a	1	1
	Total Flooded properties	**n/a**	**n/a**	2	**2**
2yr with Climate Change	Above Floor Level	n/a	n/a	-	-
	Below Floor Level	n/a	n/a	1	1
	Flood Depth > 0.15m	n/a	n/a	-	-
	Flood Depth < 0.15m	n/a	n/a	1	1
	Total Flooded properties	**n/a**	**n/a**	**2**	**2**
10yr with Climate Change	Above Floor Level	-	-	n/a	n/a
	Below Floor Level	4	4	n/a	n/a
	Flood Depth > 0.15m	1	1	n/a	n/a
	Flood Depth < 0.15m	1	1	n/a	n/a
	Total Flooded properties	**6**	**6**	**n/a**	**n/a**
100yr with Climate Change	Above Floor Level[1]	2	1	n/a	n/a
	Below Floor Level[1]	10	12	n/a	n/a
	Flood Depth > 0.15m[2]	5	4	n/a	n/a
	Flood Depth < 0.15m[2]	1	1	n/a	n/a
	Total Flooded properties	**18**	**18**	**n/a**	**n/a**

1 Above Floor level: Model water level > Building Floor Levels (provided by Auckland Council
Below Floor level: Model water level < Building Floor Levels (provided by Auckland Council)
2 Flood Depth > 0.15m: Model flood depth > 0.15m at building where floor level is not available
Flood Depth < 0.15m: Model flood depth < 0.15m at building where floor level is not available.

The number of buildings attributed for 100yr with Climate Change scenario for 'Development only' is denoted in grey to indicate differences in the results as the total number of flooded properties are overall unchanged but there is an improvement with one property which flooded above floor level, floods below floor level for the post development scenario.

3.4 Flow and peak time comparisons

Flows were extracted for the 10yr and 100yr scenarios to understand the differences between the pre and post development scenarios for the 'Development only'. The post development flows are peakier when compared to the pre-development scenario but have shorter time to peak with no lag as seen in Figure 1 and 2 below.

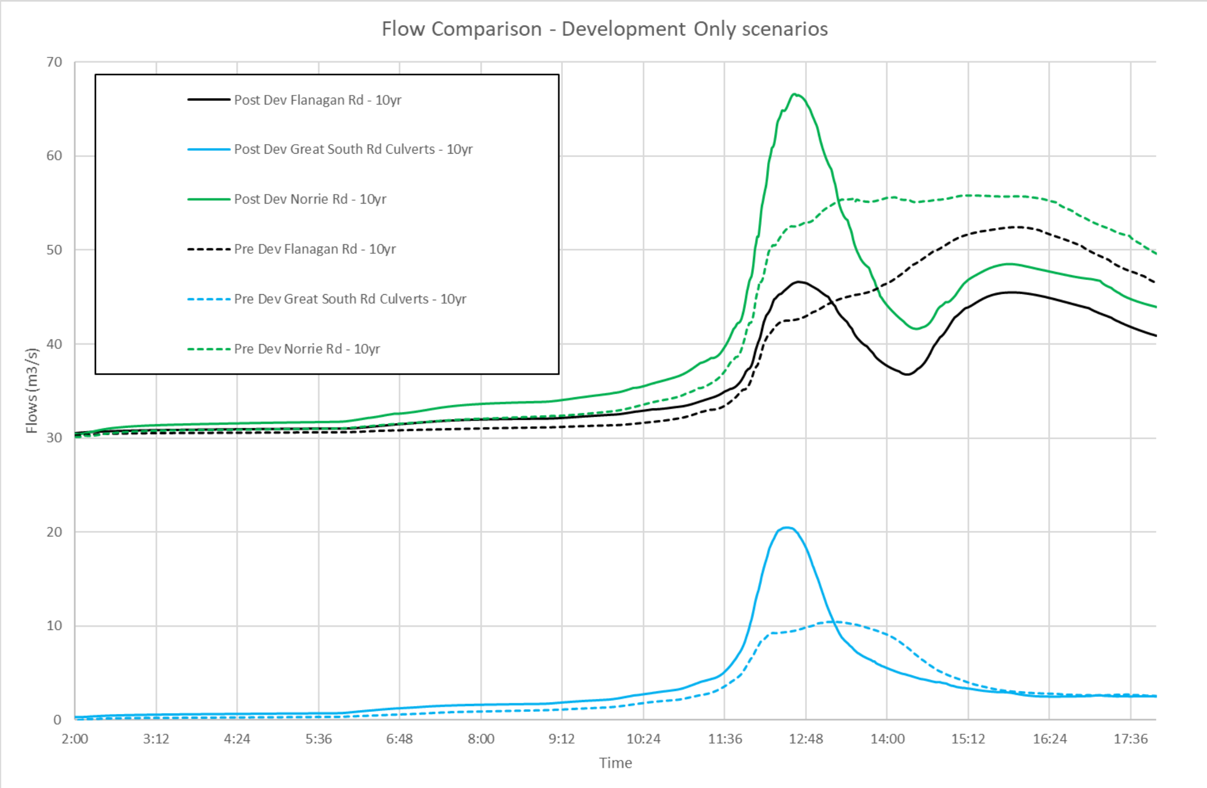


Figure 1: Flow comparison – 10yr

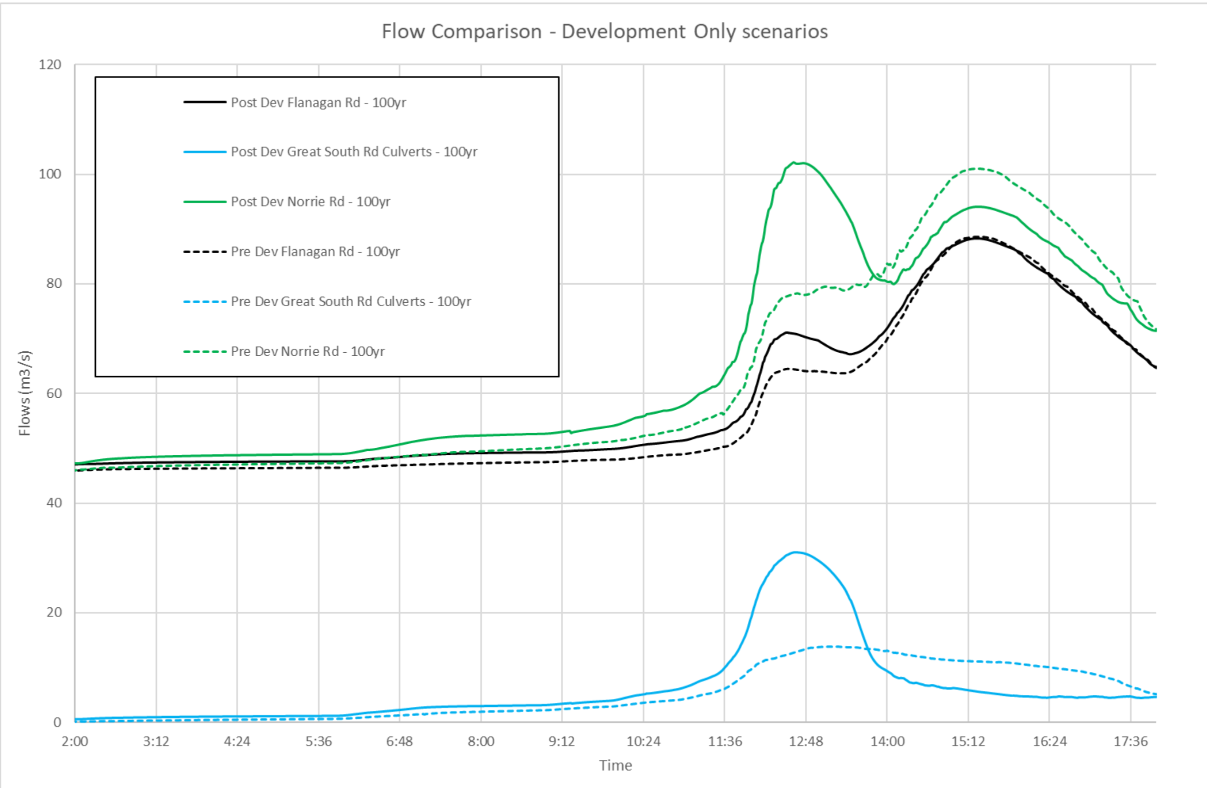


Figure 2: Flow comparison – 100yr

The 10yr flows at Norrie Road bridge were compared for the catchment and 'Development only' models flows which confirm that a 'pass flows' forward approach works better for the proposed development to discharge majority of the flows before the peak of the upstream flows reach Drury township.

This is supported by the building floor risk analysis which shows no increased flood risk to buildings/habitable floors with the 'pass flows forward' approach.

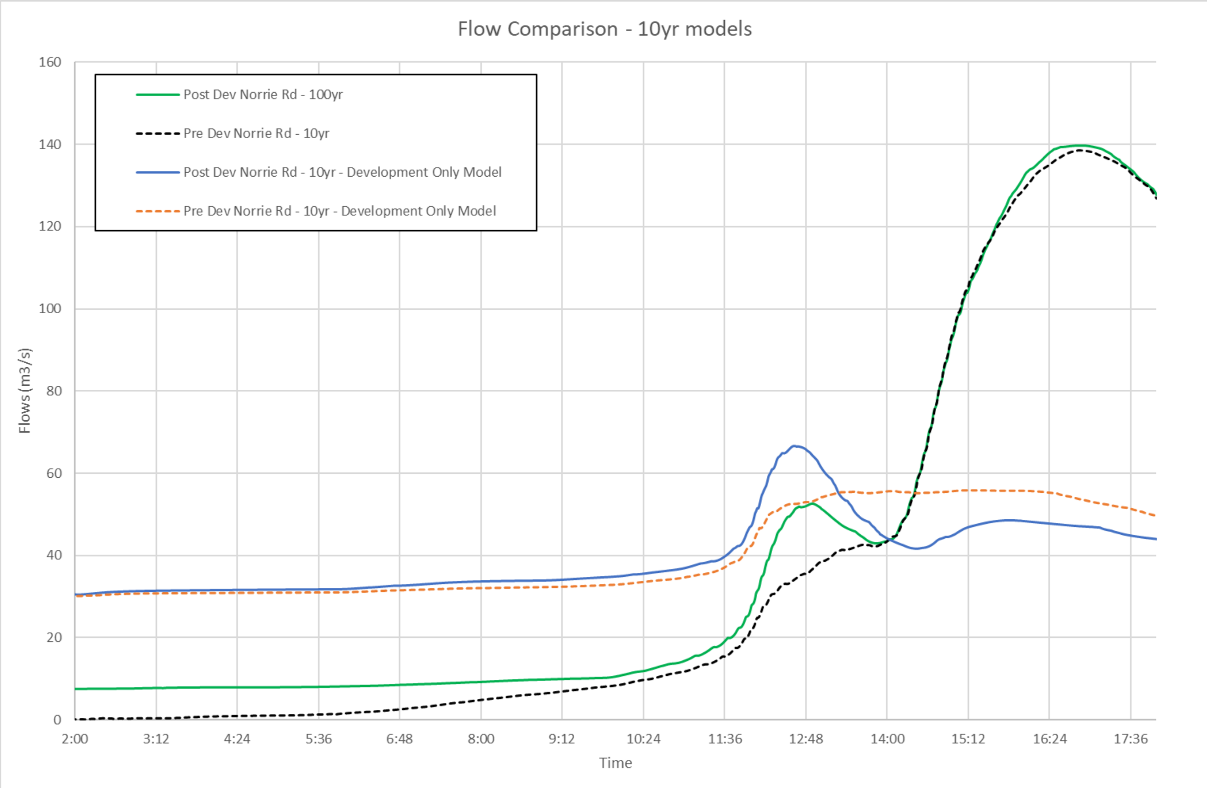


Figure 3: 10yr Flow comparison

APPENDIX A: Technical Memos

<table>
<tr><th colspan="2">Assessment category</th><th rowspan="2">Comments /requests</th><th rowspan="2">Reason for comments/requests</th><th rowspan="2">Responses</th></tr>
<tr><th>No</th><th>Category</th></tr>
<tr><td>01</td><td>Stormwater Planning</td><td>Please provide an assessment of how the proposed plan changes meet the outcomes of the NPS-FM and the related matters in the AUP Regional Policy Statement.

How does the s32 report acknowledge and address methods to meet regional policy statement objectives that are relevant to the plan change areas, including B7.3
E1.3.8 and E1.310? Please update if necessary.</td><td>The policy framework acknowledged in the s32 reports primarily addresses matters relating to urban development and the provision of land for urban growth. While there is some acknowledgement of the NPS-FM, this appears to be limited to how streams and other natural hydrological features are recognized in the proposed plan changes. NPS-FM Objectives and Policies relating to water quality; and Regional Policy Statement objectives and policies for water quality and integrated stormwater management do not appear to be addressed.

The process and outcome of urbanising land has significant environmental effects both immediately and into the future. There appears to be little acknowledgement of these effects on the receiving environment (which the NPS and RPS objectives and policies refer to) or adequate demonstration of how these effects will be mitigated through the proposed precinct plan provisions and proposed stormwater management plan.</td><td>Refer to Planning and Ecology Response</td></tr>
<tr><td>02</td><td>Stormwater quality</td><td>Please clarify how objectives in the AUP for water quality will be met. The Planning report (pg46) emphasises that high contaminant generating roads and carparks will be treated (treatment of these roads is covered by region wide rules in Chapter E9 AUP). However, it is unclear how many roads are anticipated to meet the thresholds to trigger E9 rules and if additional roads should be treated to meet the proposed objective.

There is also reference in the Drury East – Fulton Hogan request (page 46) to a treatment train approach and secondary treatment but it is unclear if this is part of the approach to treat high contaminant generating roads or is an additional response applied to all roads to meet objectives E1.3.8 and E1.3.8 and meet Schedule 4 NDC requirements greenfield developments.</td><td>AUP E1.3.8 directs to avoid as far as practicable the adverse effects of development on water quality.

AUP Objective E1.2.3 and Policies 1.3.2 and 1.3.3 directly implements the NPS-FM 2017. Avoiding adverse effects on water quality should be demonstrated in the planning report and SMP. The creation of adverse effects on water quality due to contaminants in runoff from impervious surfaces is an effect of urban land use. Therefore, this should be part of the S32 report and AEE.

Reliance on region wide rules in the AUP may not sufficient to meet AUP policies for this plan change area and for the associated receiving environment which is a Significant Ecological Area; some of which (such as Drury Creek Islands) have further restoration and enhancement underway.

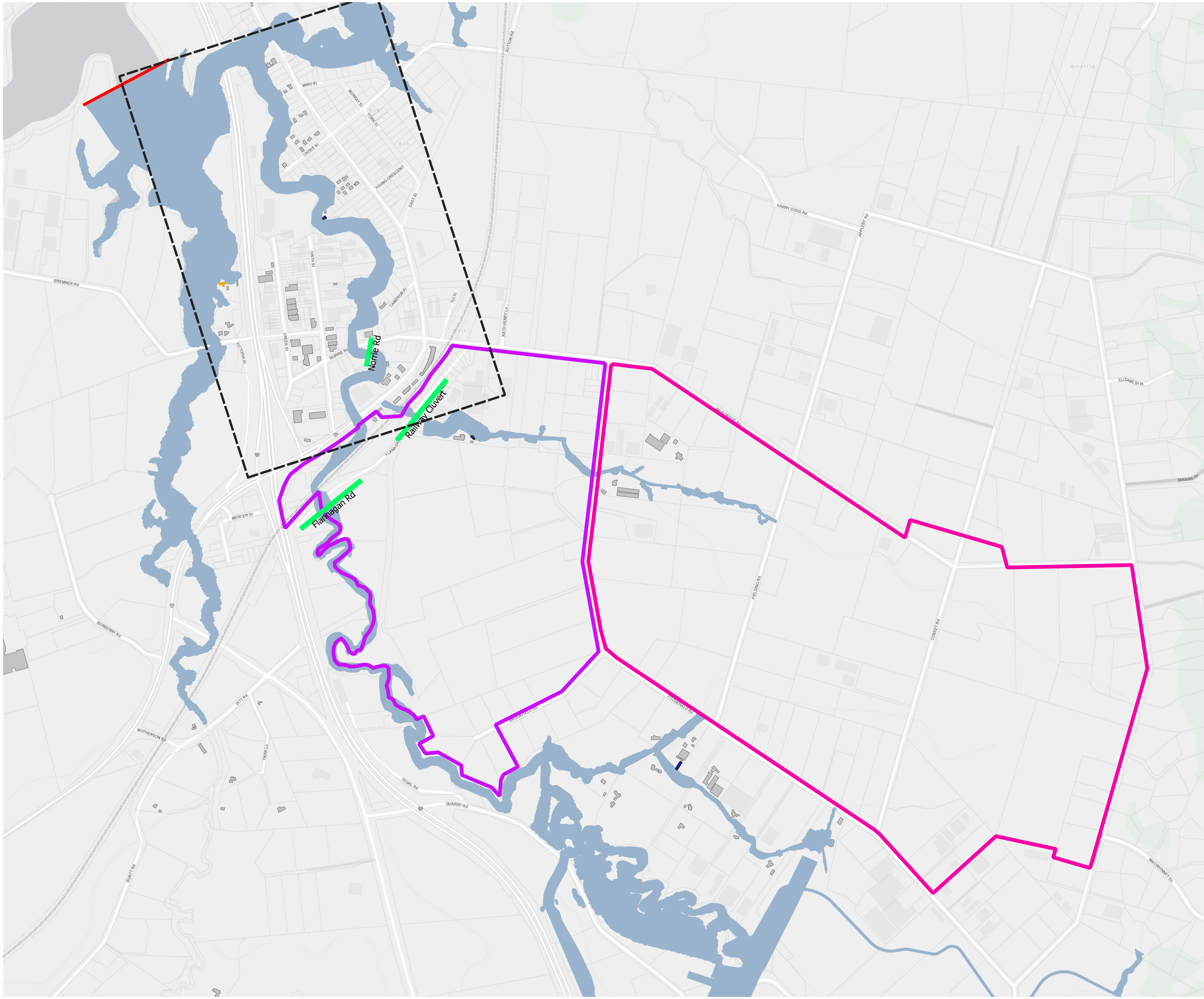
Additional detail on the methods for treating stormwater to avoid adverse effects may also be sought prior to notification of this plan change as part of the SMP in support of stormwater discharge authorisation.</td><td>Refer to Section 1: Stormwater management of Memo P16-335.</td></tr>
</table>

		A matrix showing what tools will be used in what proposed land use zone to avoid any adverse effects on water quality should be included in the SMPs as part of identifying how adverse effects will be mitigated and how these achieve AUP policies for water quality.		
03	Water quality	Please more fully describe how the water quality policies in E1 will be achieved, and what options have been considered to meet the policies.	The current descriptions in the SMPs are confusing and appear to rely solely on the region wide rules. Given the AUP policy directives for greenfield development and the sensitivity of the receiving environment, additional treatment (such as a treatment train approach) may be justified.	Refer to Planning and Ecology Response
04	Hydrology Mitigation	Please provide an assessment of the degree to which SMAF1 avoids or remedies changes in hydrology which will result from the urban land uses proposed in the plan changes. A Regional Erosion Threshold Metric risk assessment identifies areas at risk of erosion and provides some quantification of the amount of erosion caused, however it does not address how effects will be avoided, remedied or mitigated. Identification of measures to avoid effects and mitigate should also be made and the BSTEM model is appropriate for this task. More detail on this tool is being supplied to the applicants.	The AUP states that for greenfield areas adverse effects of development shall be avoided as far as practicable or otherwise remedied or mitigated and this includes changes in hydrology (Policy E1.3.8). No SMAF controls were applied to greenfield areas in the AUP as it was expected that an assessment on what hydrological mitigation is required, would be undertaken as part of plan change process. The Drury-Opaheke Structure Plan SMP also identified that hydrological mitigation and erosion assessments should be completed at the scale of the plan changes so that the particular effects of proposed land uses would be identified, and mitigation measures would be determined, at scale proportionate to the proposed activities and effects.	Refer to Section 2: Hydrological Mitigation of Memo P16-335.
05	Flooding	Please address the matters identified and discussed in the memo to Healthy Waters from Tonkin and Taylor dated 19 Feb 2020. We note that all applicants need to explain what the effect cumulatively across developments will be on the Drury township flooding and parts of the catchment that interact with the Slippery Creek floodplain.	Flooding in the Hingaia catchment is complex and needs to be considered in conjunction with other plan changes proposed for the area; acknowledge any interactions with other catchments and the cumulative impact of potential development in the surrounding areas and the point of discharge downstream. Understanding the impact of development on the flood plain within the plan change sites and impacts downstream is necessary to evaluate the plan change proposal and ensure any potential flood effects are avoided or mitigated. Several discussions between Healthy Waters and the applicant's planners have occurred on the best way to approach flood	Refer to Section 3: Flooding of Memo P16-335.

			modelling and the memo from T&T dated 19 Feb 2020 reflects our agreement with regards to flooding matters.	
06	Riparian Margins	Please explain why a 10m wide riparian margin is proposed when the Drury-Opaheke Structure Plan Stormwater Management Plan identified a 20m riparian margin as being appropriate. No evaluation of these two options is provided including their consistency with the objectives and policies of the AUP.	A 20m wide riparian margin was consulted on as part of the Drury-Opaheke Structure Plan 'Blue Green Network' and associated the Stormwater Management Plan. The purpose of the wide margin is to provide an ecological corridor and provide a buffer for the stream noting that stream meander may occur due to erosion. These benefits support achievement of AUP objectives and policies. A rationale for a lesser width margin is not provided in the s32 report.	Refer to Planning and Ecology Response
07	Ecological corridors and blue green network.	Please clarify what the ecological corridors are and how they contribute to meeting objectives and policies of the AUP. They are mentioned briefly but there is no description on how these align to the Blue-Green network identified in the Drury-Opaheke Structure Plan, nor are the streams or corridors noted specifically in the precinct plan or stormwater management plan. Planning provisions to enable the ecological corridor are not provided in the precinct plan nor is an assessment given in s32 assessment reports.	A blue green network utilising the natural hydrological features of existing streams was identified as part of Auckland Council's Drury-Opaheke Structure Plan. If and how streams are used in this way has implications in relation to: • Identifying the impact of urban development on streams (if they are intended to be retained or not); • Keeping flood conveyance channels available as part of the 'pass-it-forward' approach outlined in the Drury-Opaheke Structure Plan • Mitigation of effects anticipated by urban development, including hydrology mitigation. The precinct plan and stormwater management plan lack information on the ecological corridors making their purpose for achieving AUP objectives and policies or as part of effects mitigation unclear. We note public access such as walkways/cycle network need to be located outside riparian setbacks and the minimum width required to accommodate water sensitive devices.	Refer to Planning and Ecology Response
08	Development staging	Please explain if and how the precinct plan is to manage flood risks (such as staging of development in conjunction with flood mitigation measures). Flood attenuation is proposed in the SMP but there are no precinct plan provisions to ensure that flood attenuation is provided or when it	The plan change areas are areas of significant flood hazard and developing the plan change areas could increase the flooding downstream in the existing Drury township. Fulton Hogan, in their SMP page 6 propose as part of their flood management approach for Zone A to provide: *Temporary flood attenuation to pre-develop flow – to enable development in advance of culvert upgrades*	With respect to Fulton Hogan and their proposed attenuation, this will be provided once more clarity around development and staging is available. The SMP was alluding to the potential for development to occur prior to upgrade of

		would be appropriate to not have flood attenuation.	There is no indication in their SMP or precinct plan of when this would be provided or when it will not be provided. The attenuation relates to current culvert capacity at Great South Rd and Flannagan Rd. These culverts will likely need upgrading in the future when road upgrades are done but this requirement is not linked to transport infrastructure upgrades or backed up by analysis of culvert capacity.	downstream assets i.e. railway culverts. A staging plan will be provided upon finalization of approach which won't be available until resource consent stage.

APPENDIX B: Flood Maps



Tonkin+Taylor

WOODS EST.1970

LEGEND

Flood Extent

Buildings

- Flood depth <0.15m
- No flooding
- Flood level < Building level
- Flood level > Building level
- Flood level > 0.15m

Flood Model Boundary

Fulton Hogan Development

Kiwi Property Plan Change (Feb 2019)

Flow Cross Sections

Area of Interest

REVISION DETAILS		BY	DATE
1.0	Issued for Information	PW	17/03/2020

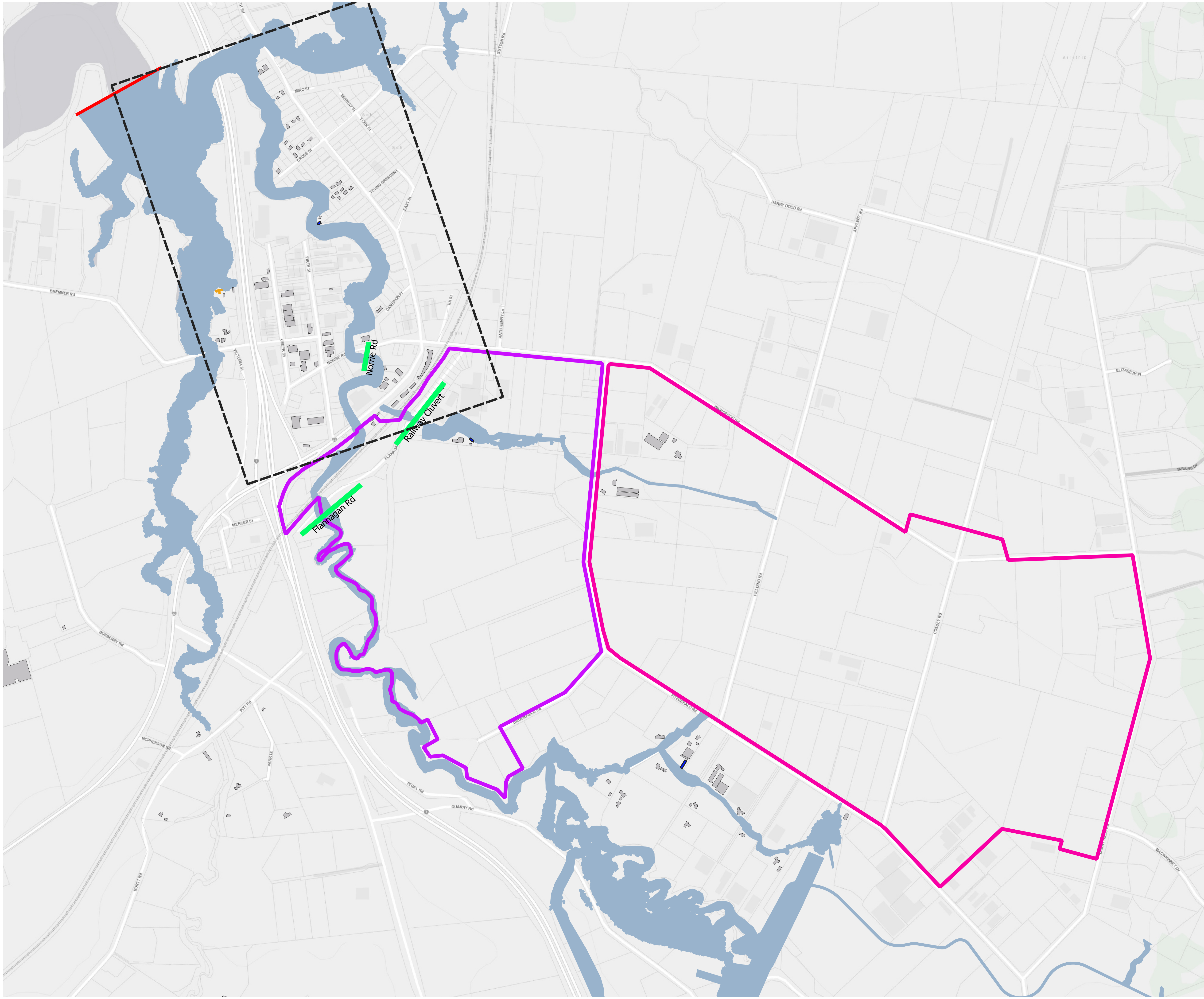
SURVEYED	AC	
DESIGNED	PW/AD	
DRAWN	SH	
CHECKED	PW	
APPROVED	PW	WOODS.CO.NZ

N

Pre Development 2 Year MPD Flood Assessment
Catchment Model
Climate Change - YES

STATUS	ISSUED FOR INFORMATION	REV	
SCALE	1:12000 @ A3	1.0	
COUNCIL	AUCKLAND COUNCIL		
DWG NO	P16-335-SKT-0003		

This drawing was generated from QGIS



Tonkin+Taylor

WOODS
EST.1970

LEGEND

Flood Extent

Buildings

- Flood depth <0.15m
- No flooding
- Flood level < Building level
- Flood level > Building level
- Flood level > 0.15m
- Flood Model Boundary
- Fulton Hogan Development
- Kiwi Property Plan Change (Feb 2019)
- Flow Cross Sections
- Area of Interest

	REVISION DETAILS	BY	DATE
1.0	Issued for Information	PW	17/03/2020

SURVEYED	AC	
DESIGNED	PW/AD	
DRAWN	SH	
CHECKED	PW	
APPROVED	PW	WOODS.CO.NZ

N

Post Development 2 Year MPD Flood Assessment
Catchment Model
Climate Change - YES

STATUS	ISSUED FOR INFORMATION	REV
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COUNCIL	AUCKLAND COUNCIL	
DWG NO	P16-335-SKT-0004	

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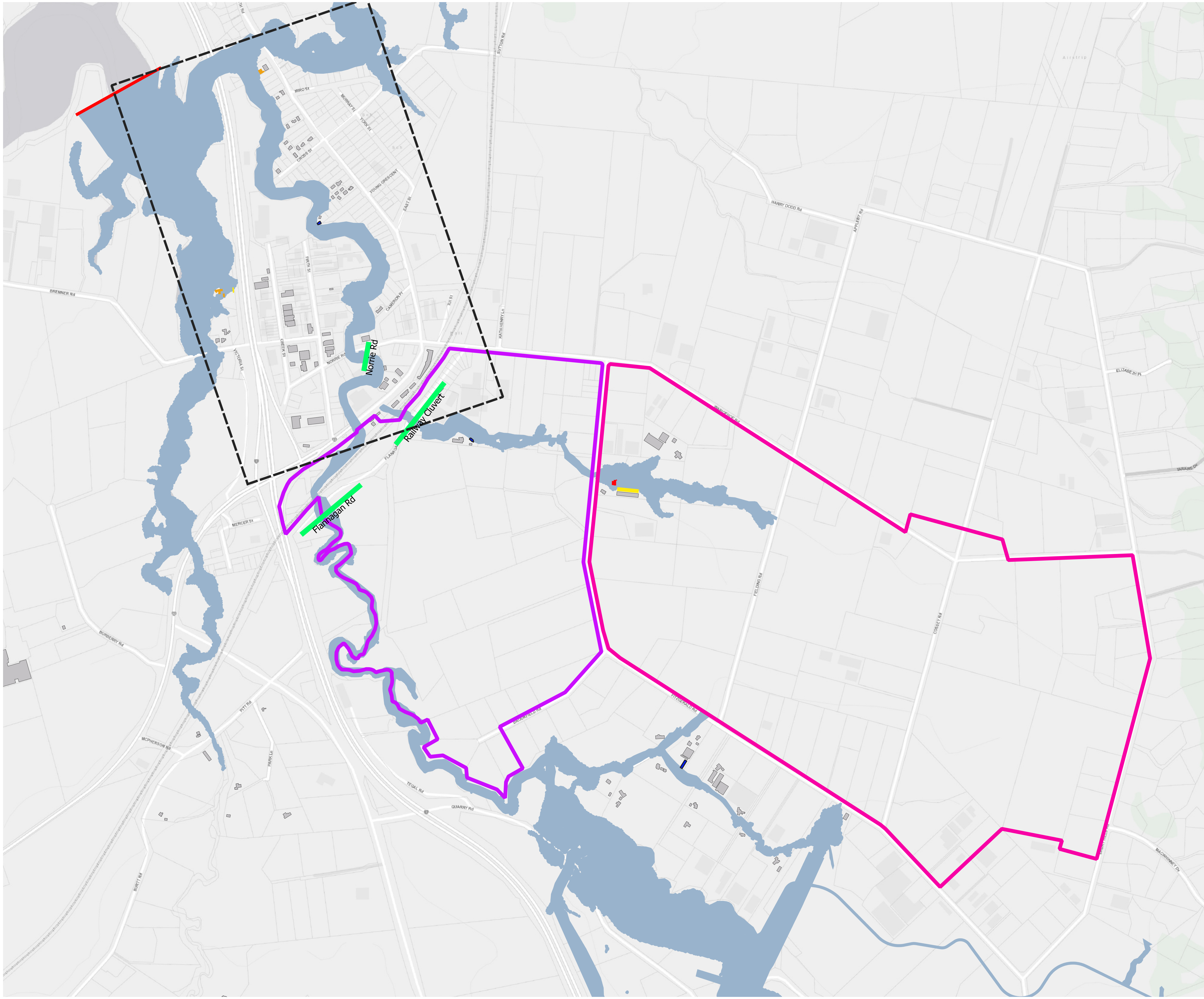

Tonkin+Taylor

WOODS EST.1970

LEGEND

Flood Extent

Buildings

- Flood depth <0.15m
- No flooding
- Flood level < Building level
- Flood level > Building level
- Flood level > 0.15m
- Flood Model Boundary
- Fulton Hogan Development
- Kiwi Property Plan Change (Feb 2019)
- Flow Cross Sections
- Area of Interest

	REVISION DETAILS	BY	DATE
1.0	Issued for Information	PW	17/03/2020

SURVEYED	AC	
DESIGNED	PW/AD	
DRAWN	SH	
CHECKED	PW	
APPROVED	PW	WOODS.CO.NZ

N

Pre Development 10 Year MPD Flood Assessment
Development Model
Climate Change - YES

STATUS	ISSUED FOR INFORMATION	REV
SCALE	1:12000 @ A3	1.0
COUNCIL	AUCKLAND COUNCIL	
DWG NO	P16-335-SKT-0007	

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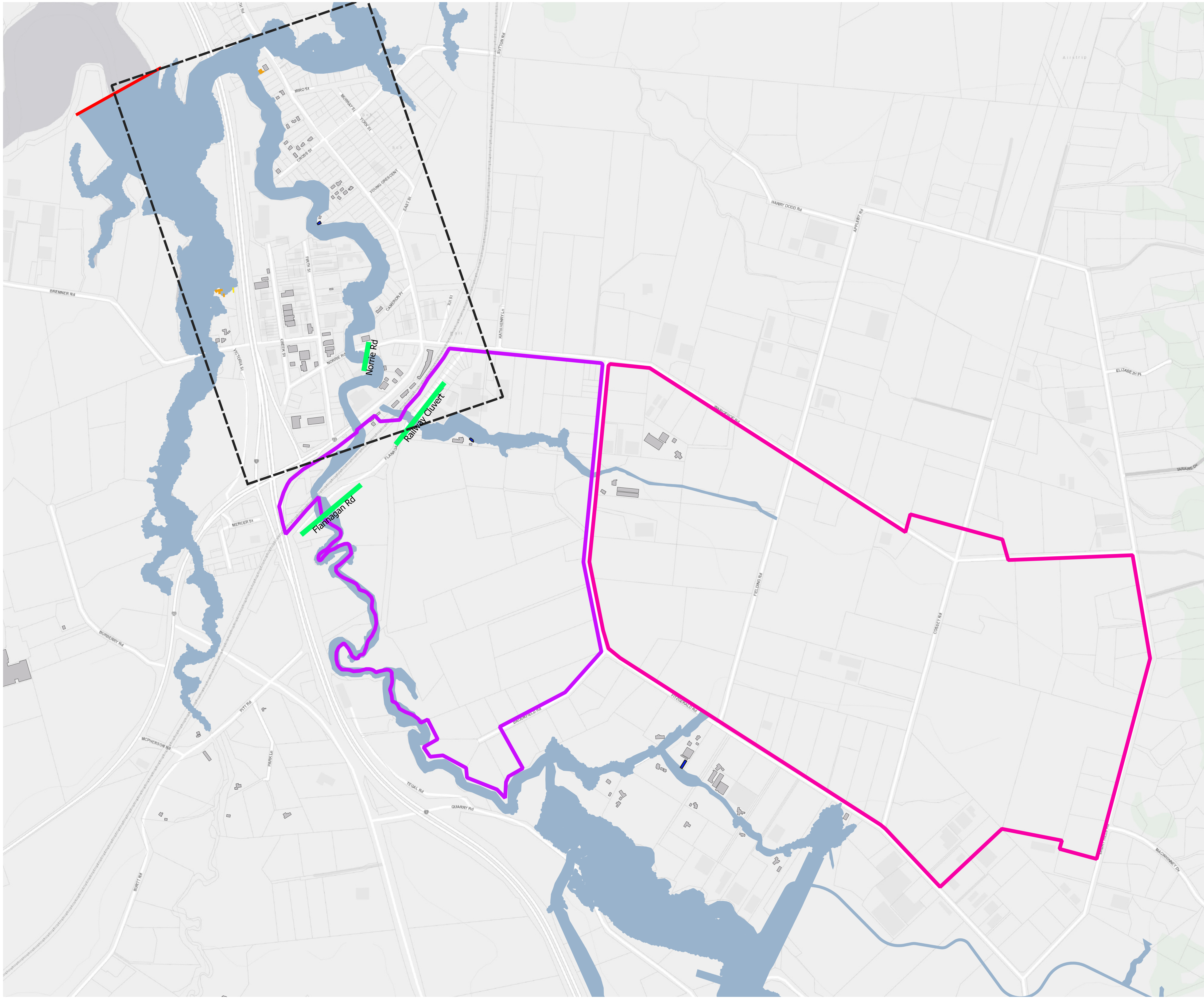

Tonkin+Taylor

WOODS
EST.1970

LEGEND

- Flood Extent

Buildings

- Flood depth <0.15m
- No flooding
- Flood level < Building level
- Flood level > Building level
- Flood level > 0.15m
- Flood Model Boundary
- Fulton Hogan Development
- Kiwi Property Plan Change (Feb 2019)
- Flow Cross Sections
- Area of Interest

	REVISION DETAILS	BY	DATE
1.0	Issued for Information	PW	17/03/2020

SURVEYED	AC	
DESIGNED	PW/AD	
DRAWN	SH	
CHECKED	PW	
APPROVED	PW	WOODS.CO.NZ

N

Post Development 10 Year MPD Flood Assessment
Development Model
Climate Change - YES

STATUS	ISSUED FOR INFORMATION	REV
SCALE	1:12000 @ A3	1.0
COUNCIL	AUCKLAND COUNCIL	
DWG NO	P16-335-SKT-0008	

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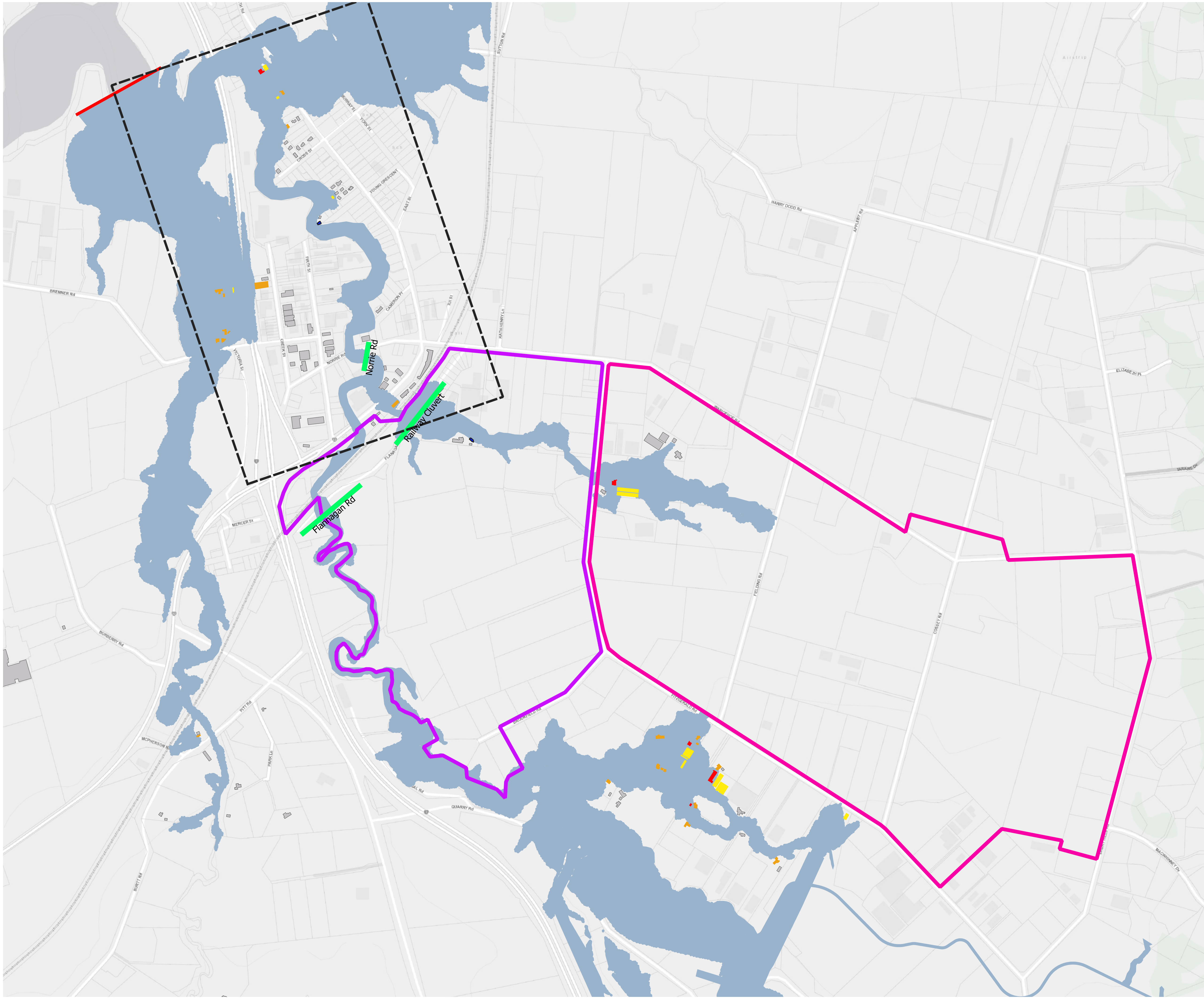


This drawing was generated from QGIS

Tonkin+Taylor

WOODS EST.1970

LEGEND

- Flood Extent

Buildings

- Flood depth <0.15m
- No flooding
- Flood level < Building level
- Flood level > Building level
- Flood level > 0.15m
- Flood Model Boundary
- Fulton Hogan Development
- Kiwi Property Plan Change (Feb 2019)
- Flow Cross Sections
- Area of Interest

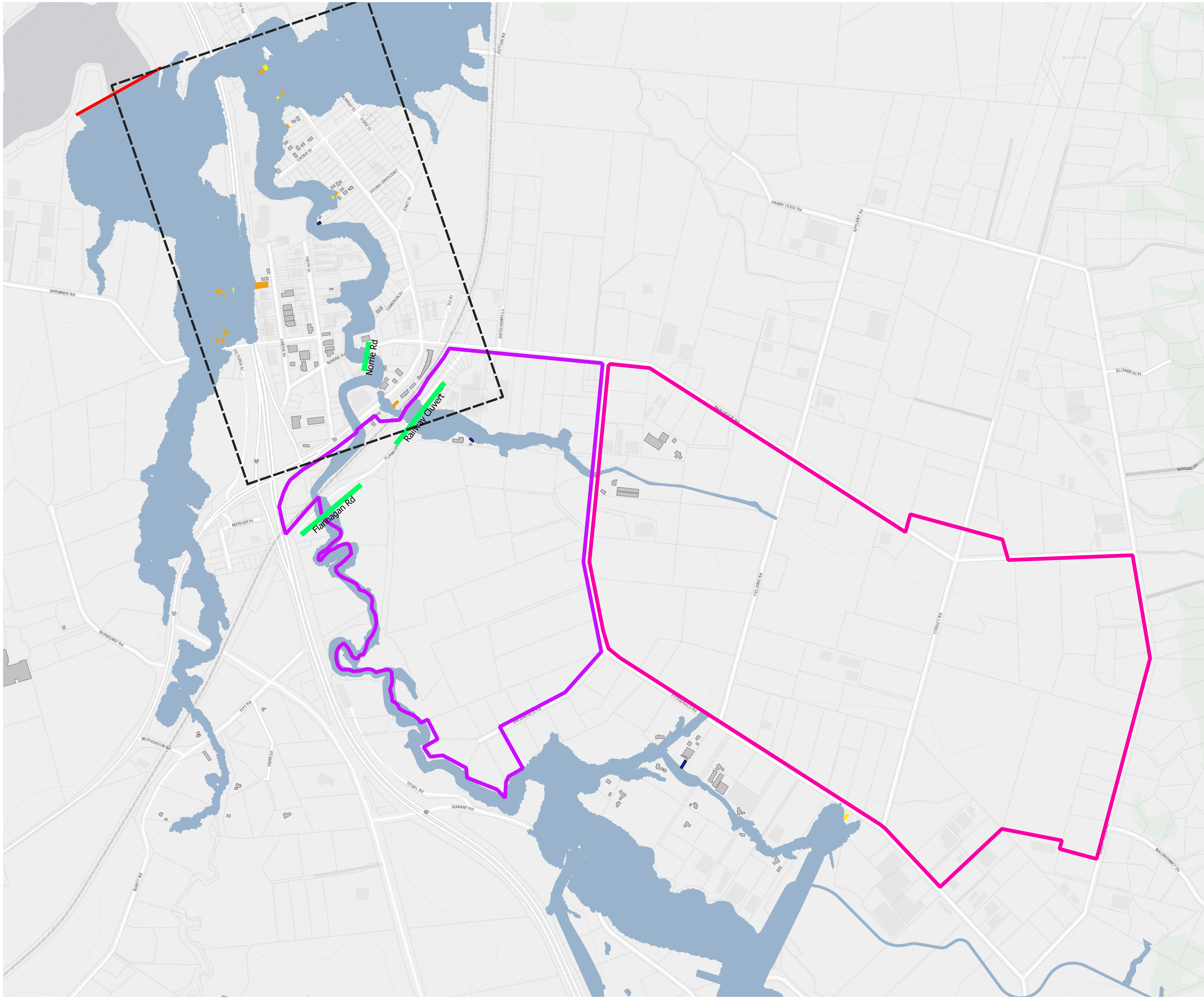
	REVISION DETAILS	BY	DATE
1.0	Issued for Information	PW	17/03/2020

SURVEYED	AC	
DESIGNED	PW/AD	
DRAWN	SH	
CHECKED	PW	
APPROVED	PW	WOODS.CO.NZ

N

Pre Development 100 Year MPD Flood Assessment
Development Model
Climate Change - YES

STATUS	ISSUED FOR INFORMATION	REV
SCALE	1:12000 @ A3	1.0
COUNCIL	AUCKLAND COUNCIL	
DWG NO	P16-335-SKT-0011	



Tonkin+Taylor

WOODS
EST.1970

LEGEND

- Flood Extent

Buildings

- Flood depth <0.15m
- No flooding
- Flood level < Building level
- Flood level > Building level
- Flood level > 0.15m
- Flood Model Boundary
- Fulton Hogan Development
- Kiwi Property Plan Change (Feb 2019)
- Flow Cross Sections
- Area of Interest

	REVISION DETAILS	BY	DATE
1.0	Issued for Information	PW	17/03/2020

SURVEYED	AC	
DESIGNED	PW/AD	
DRAWN	SH	
CHECKED	PW	
APPROVED	PW	WOODS.CO.NZ

N

Post Development 100 Year MPD
Flood Assessment
Development Model
Climate Change - YES

STATUS	ISSUED FOR INFORMATION	REV
SCALE	1:12000 @ A3	1.0
COUNCIL	AUCKLAND COUNCIL	
DWG NO	P16-335-SKT-0012	

This drawing was generated from QGIS

Appendix L

Response to Further Information Request on Stormwater Matters for Drury East – Stream Erosion Risk Assessment

Memo

To:	Mark Iszard and Carmel O'Sullivan (Auckland Council)	Job No:	1003297
From:	Charlotte Peyroux and Tim Fisher (T+T) and Pranil Wadan (Woods)	Date:	6 April 2020
cc:	David Schwartfeger (Kiwi Property), Greg Dewe (Fulton Hogan), Andrew McCarthy (Oyster), Nick Roberts (Barkers),		
Subject:	Response to Auckland Council Further Information Request on Stormwater Matters for Drury East - Stream Erosion Risk Assessment for Hingaia Catchment		

1 Introduction

This memo summarises the findings of a stream erosion assessment undertaken to verify the proposed hydrological mitigation approach, identify high risk areas and determine if additional mitigation measures are required for two developments (Kiwi Property and Fulton Hogan) at Drury East in the Hingaia catchment.

The third Drury East development by Oyster Capital is in the adjacent Slippery Creek catchment, which will be addressed separately. However, the context and the learnings from this assessment are relevant to the Oyster Capital plan change.

This memo builds on the *Response to Auckland Council Further Information Request on Stormwater Matters for Drury East* prepared by Woods and Tonkin + Taylor on 25 March 2020 in response to Item 4 of the *Further Information Request (FIR) - Drury East Plan Changes* included in the *Healthy Waters Review of Adequacy of Information for a Private Plan Change (PPC) Request – Drury East - Fulton Hogan and Kiwi Property* memo from Auckland Council on 2 February 2020.

2 Background

2.1 Proposed approach to hydrological mitigation

The three Plan Change Areas at Drury East are greenfield developments and the proposed approach for the developments is to provide a minimum of Stormwater Management Area control - Flow 1 (SMAF 1) hydrological mitigation (detention and retention) for all impervious surfaces.

This responds to Auckland Unitary Plan Operative in part (AUP OP) Policy E1.3.8 that requires *minimising or mitigating changes in hydrology including loss of infiltration, to: minimise erosion and* *associated effects on stream health and values; maintain stream baseflows; and support groundwater recharge.* This approach aligns with the Auckland Councils Region-wide Network Discharge Consent and Guidance Document 01 (GD01).

The minimum hydrological mitigation requirements follow SMAF 1 in AUP OP Table E10.6.3.1.1 as follows:

- Retention (volume reduction) of at least 5mm of runoff depth from impervious surfaces where possible with limitations set out in Table E10.6.3.1.1.
- Detention of the 95th percentile event for the difference between the pre-development and post-development runoff volumes from a 95th percentile, 24-hour rainfall event minus the achieved retention volume.

2.2 Proposed approach to stream erosion

Drury East Plan Change – Ecology Response (19 March 2020) and *Response to Auckland Council Further Information Request on Stormwater Matters for Drury East* by Woods and Tonkin + Taylor (25 March 2020) have identified the follow mitigation measures as being those, which will aid in the management of stream erosion and sedimentation in the Plan Change Area:

- Removal of stock from the site and therefore avoiding active bank de-stabilisation through stock access and pugging.
- Incorporation of green spaces adjacent to stream networks to provide for planting of riparian margins to improve bank stability and reduce erosion potential.
- Modification of hydrograph mitigated through stormwater retention/detention (SMAF 1 hydrological mitigation) measures which will slow flows.
- Remediation or removal of existing in-stream structures (culverts, inlets/outlets) which are currently identified as having erosion issues.
- Realignment of streams which have been channelised to a more natural alignment.
- Incorporation of erosion and scour protection measures at all outfalls to minimise erosion at new structures.
- Targeted in-stream erosion protection measures may be required within the Hingaia Stream and other larger streams.

3 Stream Erosion Risk Assessment

3.1 Auckland Council Stream Erosion Risk Tool

Auckland Council have assisted in this matter by supplying the Auckland Council Stream Erosion Risk Tool and by providing a technical briefing on 14 February 2020.

The Auckland Council Stream Erosion Risk Tool was initially investigated as a mechanism to analyse stream erosion. The tool was considered too simplistic for the Drury East area because better quality inputs were available, as summarised below:

Table 1 - Identified issues of use for Auckland Council Stream Erosion Tool

#	Issue	Next step
1	TP108 hydrology is too coarse for a large catchment such as the Hingaia where a refined hydraulic model is available	Use hydrographs from the flood model. Rebuild Stream Erosion Risk Tool to allow this. Note, input hydrology is not required if hydraulic shear stress is available from hydraulic models, refer issues #2 and #3
2	Hydraulic shear stress is very sensitive to Slope (S) and thalweg/bed levels are too variable and result in non-sensible results	Use bed shear stress calculated by the hydraulic model at all locations and at all time steps as this uses the actual channel cross-section and simulated flow, water surface slope, velocity and depth. Rebuild the Stream Erosion Risk Tool to allow for these inputs.
3	Simplification of channel cross-sections to a trapezoid is too coarse	
4	Critical shear stress cannot be determined from the geotechnical testing already done for the site.	Estimate this from Auckland Council databases and references.
5	Quantification of change in exceedance of critical shear stress will only indicate a change in erosion potential. It will not quantify how much extra erosion and what the change in sediment load will be to the receiving environment, so it cannot be used to assess effects.	Auckland Council to advise how they see this working. T+T/Woods consider that the tool will identify areas with increased erosion risk and where extra mitigation measures might be considered.

3.2 Modified Stream Erosion Risk Tool

In response to the issues identified with the Auckland Council Stream Erosion Risk Tool a Modified Stream Erosion Risk Tool was developed. The overarching principal remains the same, which is to compare the hydraulic shear stress[1] exerted by the driving force of water to the critical shear stress of the material lining the stream channel. The modified methodology is as follows:

- Select locations for the Stream Erosion Risk assessment – Refer to Section 2.1.
- Extract the 2, 10, and 100 year Annual Recurrence Internal (ARI) hydraulic shear stress at the analysis locations from the flood model for pre- and post-development scenarios – Refer to Section 2.2.
- Assess for potential erosion and identify high risk areas:
  - Use 2, 10, and 100 year ARI hydraulic shear stress as described above and compare against an expected critical shear stress – Refer to Section 2.3.
  - Use the Auckland Council defined erosion thresholds to determine the stream erosion potential at each location during each design storm - Refer Section 2.4.

The tool will indicate a change in **erosion potential** by quantifying the duration of exceedance of critical shear stress.

It will not quantify how much extra erosion will occur, nor will it quantify the change in sediment load to the receiving environment, so it cannot be used to directly assess effects. Therefore, to support the Plan Change, the tool will be used to identify areas with erosion risk, and where these change as a result of the development, and where extra mitigation measures may be required.

The results of this assessment are included in Section 3 of this memo.

3.3 Assessment locations

A stream erosion risk assessment was carried out at 10 locations relevant to the Kiwi Property and Fulton Hogan Plan Change Areas. These locations are along the Hingaia stream and tributaries including Fitzgerald Stream. The locations were selected to assess for potential erosion due to hydrology changes attributed to the land use change associated with the Plan Change.

The details of these locations are included in Table 2 and a locality plan included in Appendix A.

[1] Hydraulic shear stress is the MIKE output date type "bed shear stress" as given by Manning's equation $=pgV^2n^2/y^{1/3}$

Table 2 - Assessment locations for Modified Stream Erosion Risk Tool

ID	Description	Model Location	Chainage
Location 1	Hingaia Stream, mid-point of Kiwi Plan Change Area	HINGAIA STREAM	16585.5
Location 2	Hingaia Stream, upstream of Flanagan Bridge	HINGAIA STREAM	17105.5
Location 3	Hingaia Stream, upstream of Norrie Road	HINGAIA STREAM	17848.6
Location 4	Hingaia Stream, lower	HINGAIA STREAM	18918
Location 5	Fitzgerald Stream, upstream of Flanagan Road	HINGAIA TRIBUTARY 7	2086.75
Location 6	Fitzgerald Stream, downstream of Fitzgerald Road	HINGAIA TRIBUTARY 7	1323
Location 7	Fitzgerald Stream, mid-point of Kiwi Plan Change Area	HINGAIA TRIBUTARY 7	1768
Location 8	Hingaia Tributary, downstream of Fulton Hogan Plan Change Areas	HINGAIA SUB TRIBUTARY 2	851.5
Location 9	Hingaia Tributary, downstream of Fulton Hogan Plan Change Areas	HINGAIA TRIBUTARY 6	1241
Location 10	Fitzgerald Stream, within Fulton Hogan Plan Change Areas	HINGAIA TRIBUTARY 7	325

3.4 Flood models

The 2, 10 and 100 year ARI storm events (inclusive of climate change) were run in the Hingaia hydraulic model for both the pre- and post-development scenarios and a corresponding time series of the estimated hydraulic shear stresses occurring within the channel extracted at each location.

The 2 year ARI storm event is considered to be the most relevant frequency as the 2 year ARI flood event strongly influences the geomorphology of the stream, especially the size of the main channel.

The flood models included an allowance for climate change and used our baseline model for the pre-development scenarios which includes Drury South. Suitability of this baseline (pre-development) model is discussed in the *Drury East (Kiwi and Fulton Hogan) flood modelling – response to Auckland Council modelling requests* memo prepared by Tonkin + Taylor on 10 February 2020 for Auckland Council. For pre-development scenario the flood model assumed 10% imperviousness for undeveloped catchments within Future Urban Zone (FUZ) (including the Plan Change Area) and upstream rural zonings. The post-development scenario includes the development of the Plan Change Areas flood model in accordance with Table 2 of *Response to Auckland Council Further Information Request on Stormwater Matters for Drury East* prepared by Woods and Tonkin + Taylor on 25 March 2020, but does not include allowances for SMAF-1 hydrological mitigation as these target the smaller more frequent 95th percentile rainfall event.

3.5 Critical shear stress of the stream

The critical shear stress of a stream refers to when the hydraulic shear stress exerted by the driving force of water in the stream channel exceeds the critical shear stress of the material lining of the stream channel, at which point erosion is initiated. The critical shear stress is a parameter associated with the bed media. It is smallest (more erodible) for silts and sand but increases (less erodible) with grain size e.g. gravel and cobbles, and also increases (less erodible) for percentage of clays as these soils become cohesive. If the bed and bank materials and riparian planting vary along a stream, then it is challenging to find a representative critical shear stress.

According to geological maps, the 10 stream erosion assessment locations are located in three different geological units: Puketoka formation; Holocene river deposits and Kerikeri Volcanic group. The site geotechnical testing is not at these locations, nor does it cover all of these geological units so we do not have soils descriptions for all of these units, nor does the geotechnical testing include critical shear stress which is a very specialised test.

The geological maps aren't spatially accurate or reliable enough to describe the geology at specific locations along the streams. Even if they were, there isn't enough information in the following references and studies to support a specific critical shear stress based on a geological base unit, nor prove this correlation between Auckland streams and Auckland geological layers.

- *Erosion Parameters for Cohesive Sediment in Auckland Streams*, Auckland Council Technical Report 038 (2009)
- *Auckland Urban stream erodibility investigations,* Prepared by Elliot et al. for NIWA Client Report HAM2005-031 (2005)
- *Resistance and Critical Height of Streambanks in Selected Catchments of the Auckland Region*. Prepared by Cardno for Auckland Council (Draft version, March 2020)
- B-STEM (Bank-Stability and Toe Erosion Model) slides provided by Auckland Council

Furthermore, in light of the lockdown to slow the spread of Covid-19, site-specific investigation is not possible at this time.

In the absence of site-specific geotechnical parameters, the 50th percentile median critical shear stress (32.6 Pa) was adopted from Auckland-specific data compiled by Cardno for Auckland Council (refer Table 3) and included in the Stream Erosion Tool. This is supported by recommendations in Auckland Council Technical Report 038 / 2009 *Erosion Parameters for Cohesive Sediment in Auckland Streams* which suggests "using the median critical shear stress (approximately 33 Pa)" if specific parameters are not developed for a stream. A sensitivity assessment is included in Section 4.

Table 3 – Critical shear stress in the bank materials at various locations around the Auckland region.

All Cardno Data		Hoteo	Awaruku	Omaru	Oakley	Misc. Urban	Elliott et al. (2005)		
Percentile	τ_c	τ_c	τ_c	τ_c	τ_c	τ_c	τ_c	Avg	Median
99.99	403	404	164	218	64.2	336	72.3	237.4	218.4
99.9	395	398	163	218	63.9	334	72.1	234.9	218.4
99	324	335	158	218	61.4	312	70.1	211.2	217.8
95	208	158	134	215	50.5	262	62.1	155.6	157.8
90	138	121	117	168	39.7	237	57.6	125.7	121.2
85	113	109	109	147	34.8	194	57.1	109.0	109.1
80	85.3	72.0	95.4	128	30.9	155	55.9	89.0	85.3
75	**71.6**	**62.1**	**78.4**	**102**	**27.6**	**78.3**	**54.5**	**67.8**	**71.6**
70	61.3	54.5	76.6	97.6	22.9	76.9	53.3	63.3	61.3
65	52.4	45.2	72.3	90.2	19.8	65.3	47.5	56.1	52.4
60	41.4	29.7	63.3	64.6	19.4	51.7	36.9	43.9	41.4
55	32.0	24.7	54.4	57.2	19.3	40.5	36.1	37.8	36.1
50	**25.0**	**15.9**	**42.8**	**49.1**	**19.2**	**35.1**	**32.6**	**31.4**	**32.6**
45	19.4	13.5	33.8	36.1	16.9	30.7	26.4	25.3	26.4
40	13.8	10.2	30.1	25.0	15.2	21.9	24.5	20.1	21.9
35	10.4	8.6	21.2	21.7	14.2	8.3	22.1	15.2	14.2
30	7.8	6.6	15.3	19.9	10.9	4.4	22.0	12.4	10.9
25	**6.4**	**5.0**	**11.0**	**14.2**	**6.5**	**3.1**	**21.3**	**9.6**	**6.5**
20	4.4	3.1	8.4	10.3	6.4	3.1	19.7	7.9	6.4
15	2.8	1.5	6.3	7.0	5.7	2.8	16.8	6.1	5.7
10	1.0	0.61	4.2	4.2	3.5	1.5	13.7	4.1	3.5
5	0.34	0.17	2.4	2.6	2.1	0.46	9.1	2.5	2.1
1	0.06	0.05	0.78	0.67	1.2	0.22	5.3	1.2	0.7
0.1	0.04	0.04	0.42	0.22	1.0	0.18	4.4	0.9	0.2

3.6 Erosion Thresholds

Auckland Council use four bands to assess the magnitude of predicted erosion in the Auckland Council Stream Erosion Risk Tool. Each threshold is based on the excess shear - a ratio of the hydraulic shear stress exerted by the driving force of water in the stream channel to critical shear stress. Potential erosion occurs when the excess shear is greater than 1 and erosion is theoretically initiated in the channel. When excess shear is more than 2 there is potential for active erosion and the channel to be mobile. Anything greater than 10 indicates a very rapid rate of erosion. The basis of the thresholds for excess shear at 2 and 10 is not clear.

Table 4 - Auckland Council Erosion Risk Thresholds

Threshold	Excess Shear	Description
Green	<1.0	Indicates no erosion predicted to occur
Yellow	>1.0 <2.0	Indicates the potential for some erosion of the channel
Orange	>2.0 <10.0	Indicates the potential for channel to be mobile, (likely active erosion)
Red	>10.0	Indicates potential rapid rates of erosion and incision of channel

Many stream tributaries within the Drury East Plan Change Area have some erosion so excess shear greater than 1 is expected at peak flow. We are interested in the change from the pre and post development design storms and do this by comparing the duration that a threshold is exceeded.

4 Results

4.1 Erosion potential

Note: The 2 year ARI storm event was run for 24 hours while the 10 and 100 year ARI storm events were only run for 18 hours and this impacts the duration data, which invalidates comparison between the 2 year ARI storm and the 10 and 100 year ARI events. Also, there was a spike at the beginning of the design storm which is abnormal and attributed to initial conditions, so data is only presented from 1 hour into the storm event.

The excess shear for the 2 year ARI storm event is presented in normalised bar chart form in Figure 1. The 10 and 100 year ARI storm events are included in Appendix B. Time series of hydraulic shear stress at each location for all three storms are also included in Appendix B.

The results from the 2 year ARI storm suggest there is erosion potential (duration of excess shear >1) at Locations 1, 6, 7 and 10 during the pre- development scenario. For the post-development scenarios the erosion potential increases very slightly at these locations, with the excess shear exceeding 2 for a small amount of time at Location 6 and a small amount of new erosion potential at Location 9.

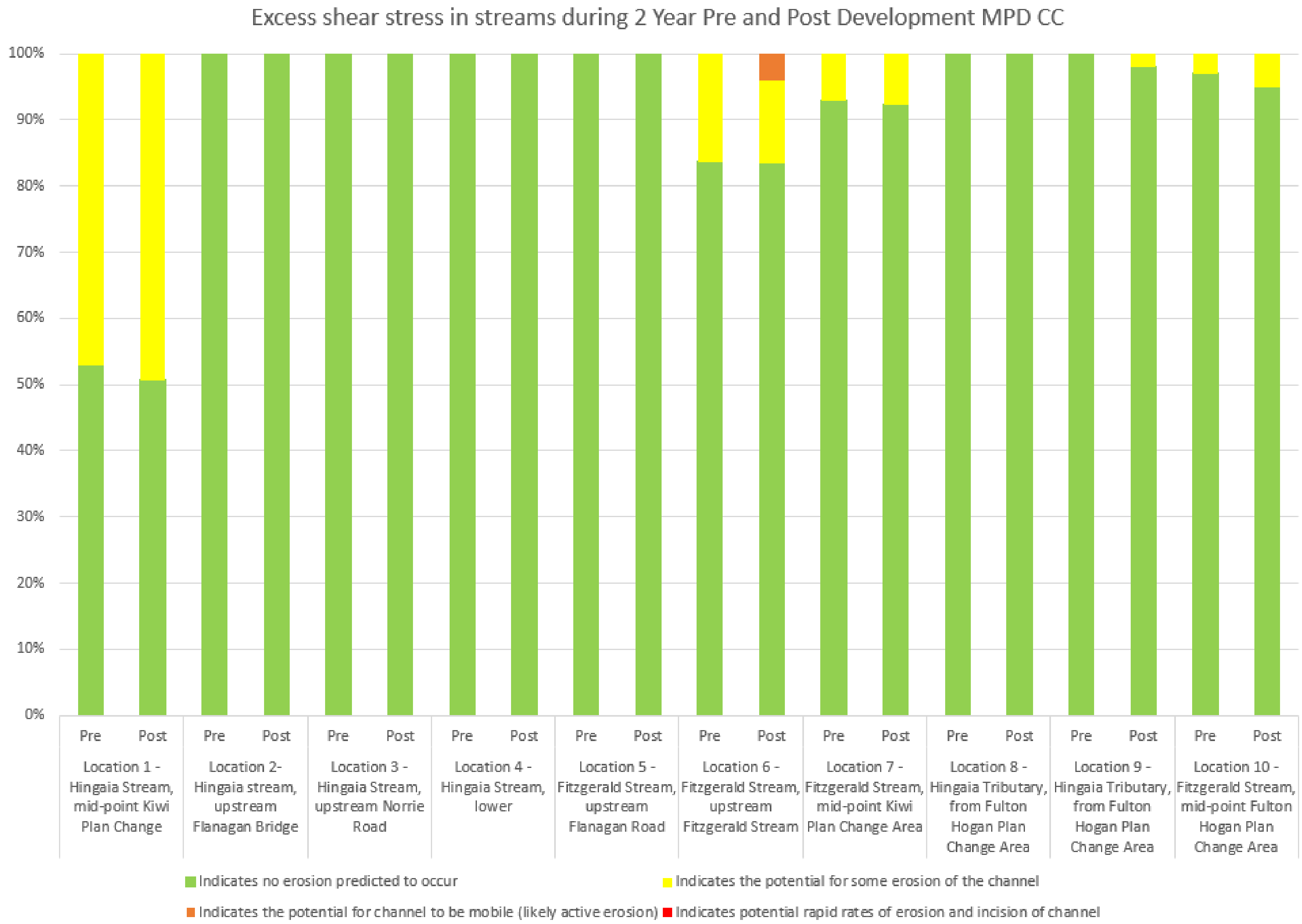
For Locations 1, 6, 7, 9 and 10, Table 5 quantifies the exceedance of critical shear stress by comparing maximum excess shear and durations for which the excess shear was greater than 1 (erosion potential).

Table 5 – Maximum excess shear between pre- and post-development 2 year storm events at five locations

	Location 1		Location 6		Location 7		Location 9		Location 10	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Max Excess shear	1.41	1.41	1.76	2.64	1.21	1.95	0.66	1.04	1.11	1.93
Difference		-		0.87		0.73		0.38		0.82
% of Duration >1 1< & >2	45%	47%	16%	12% 4%	7%	7%	0%	2%	3%	5%

The change in duration over which excess shear exceeds the threshold for the five locations (1, 6, 7, 9 and 10) was 2%, 4%, 1%, 2% and 2%, respectively. These are considered to be very small changes. The changes in maximum excess shear are higher for four locations (6, 7, 9 and 10) that are smaller streams with more land use changes in the catchments.

Figure 1- Normalised bar chart comparing excess shear stress during 2 year pre- and post-development events



4.2 Verification

These changes in erosion potential were compared against a survey of the erosion scars and bank stability within the Hingaia Stream Catchment Watercourse completed by Auckland Council in 2018. The results of both the watercourse survey and this erosion assessment are summarised in Table 6. The map from the Auckland Council survey showing the engineering asset locations, stream bank and outlet erosion has been marked up with the ten assessment locations and included in Appendix A. There is no clear correlation between the observed erosion and the predicted erosion.

Table 6 - Comparison of results from 2018 Hingaia watercourse survey and Modified Stream Erosion Risk Tool

	Auckland Council Watercourse survey		Modified Stream Erosion Risk Tool	
ID	**Erosion Scars**	**Bank Stability**	**Maximum Erosion Threshold**	
Location 1	0 – 20%	Poor	1.41	1.42
Location 2	0 – 20%	Poor	0.98	0.99
Location 3	0 – 20%	Fair	0.66	0.66
Location 4	0 – 20%, 21 – 40%	Fair	0.33	0.34
Location 5	0 – 20% - 21 - 40%	Fair	0.46	0.68
Location 6	21 – 40%	Good	1.76	2.64
Location 7	0 – 20%, 21 – 40%	Fair	1.21	1.95
Location 8	0 – 20%	Fair	0.48	0.75
Location 9	21 – 40%	Fair	0.66	1.04
Location 10	0 – 20% *	Fair	1.11	1.93

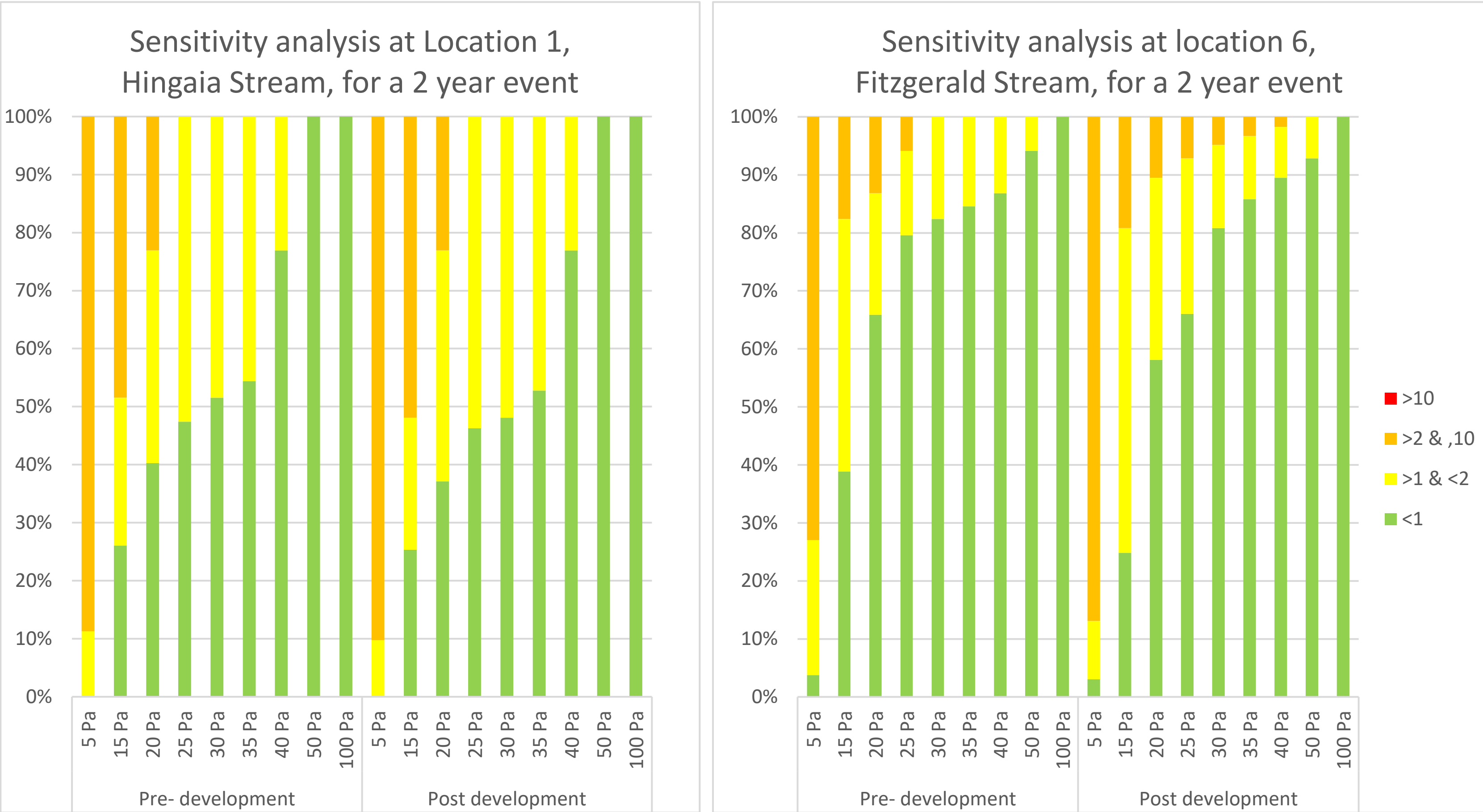
4.3 Discussion

The lack of correlation between observed and predicted, puts doubt in the predictive ability of the stream erosion risk erosion assessment to identify erosion risk locations. Although the Stream Erosion Risk Assessment has value in assessing the change in erosion risk due to development.

5 Sensitivity

The critical shear stress of the stream is very site specific and dependent on factors including underlying geological features, substrate types, channel conditions such as the degree of weathering and the channel shape, and the conditions along the stream banks, such as vegetation. All of these variables change spatially along and across the stream channel. A sensitivity analysis was done at two locations to assess the suitability of estimating the critical shear stress from region wide testing due to the lack of site-specific testing. Figure 2 analyses the estimated erodibility potential at two locations (Location 1 at the mid-point along the Hingaia Stream of the Kiwi Property Plan Change Area and Location 6 along Fitzgerald Stream) for the 2 year event for a range of critical shear stresses between 5 Pa and 100 Pa. These both show a significant change in erosion potential depending on the critical shear stress.

Figure 2a and b - Sensitivity analysis for excess shear stress at Location 1, Hingaia stream and Location 6, Fitzgerald Stream for a 2 year event



However, Table 7 summarises the percentage increase in duration with an excess shear of more than 1 (which indicates that no erosion is expected to occur during that timestep).

Table 7: Percentage duration change in excess shear exceeding varying critical shear stress

	Duration change in excess shear exceeding 1 for varying critical shear stress (%)								
	5 Pa	**15 Pa**	**20 Pa**	**25 Pa**	**30 Pa**	**35 Pa**	**40 Pa**	**50 Pa**	**100 Pa**
Location 1	0%	0.7%	3.0%	1.2%	3.5%	1.6%	0.1%	0%	0%
Location 6	0.7%	14.0%	7.8%	13.5%	1.6%	-1.2%	-2.7%	1.3%	0%

This suggests that whilst there is a significant change in the predicted erosion for different critical shear stresses (shown by Figure 2), there are small percentage changes in erodibility potential between the pre-development and post development scenarios for each critical shear stress (Table 7) with Location 1 being more consistently low than Location 6. Therefore, the change in erosion potential (duration of excess shear >1) is reasonably insensitive of the critical shear stress.

6 Conclusion

A Modified Stream Erosion Risk Assessment was developed to utilise high quality hydraulic modelling results that were available for the site, which we consider has enhanced the Auckland Council Stream Erosion Risk Assessment.

A Modified Stream Erosion Risk Assessment has shown that there is existing erosion potential at four out of 10 assessed locations along the Hingaia stream and its tributaries. However, there was poor correlation between predicted erosion locations and observed erosion, which puts doubt in the predictive ability of the Stream Erosion Risk Assessment to identify erosion risk areas.

Nonetheless, the stream erosion risk erosion assessment has value in assessing the change in erosion risk due to development. There was a very minor increase to erosion potential (duration of excess shear >1) at five locations due to hydrological changes as a result of the development. The changes in maximum excess shear are higher for four locations (6, 7, 9 and 10) that are smaller streams (including Fitzgerald Stream) with more land use changes in the catchments. The erosion potential in the main Hingaia Stream was not materially changed.

At this stage we have not run flood models or assessed the erosion potential that accounts for the proposed SMAF 1 hydrological mitigation for all impervious surfaces in the Plan Change Areas. The application of SMAF 1 hydrological mitigation will result in an even smaller increase to the erosion risk than the post-development scenario assessed in this memo. The benefit from SMAF 1 hydrological mitigation will increase for smaller events.

In conclusion, the Modified Stream Erosion Risk Assessment adds a more detailed assessment, but uncertainty remains as to the existing and future erosion risk.

7 Recommendations

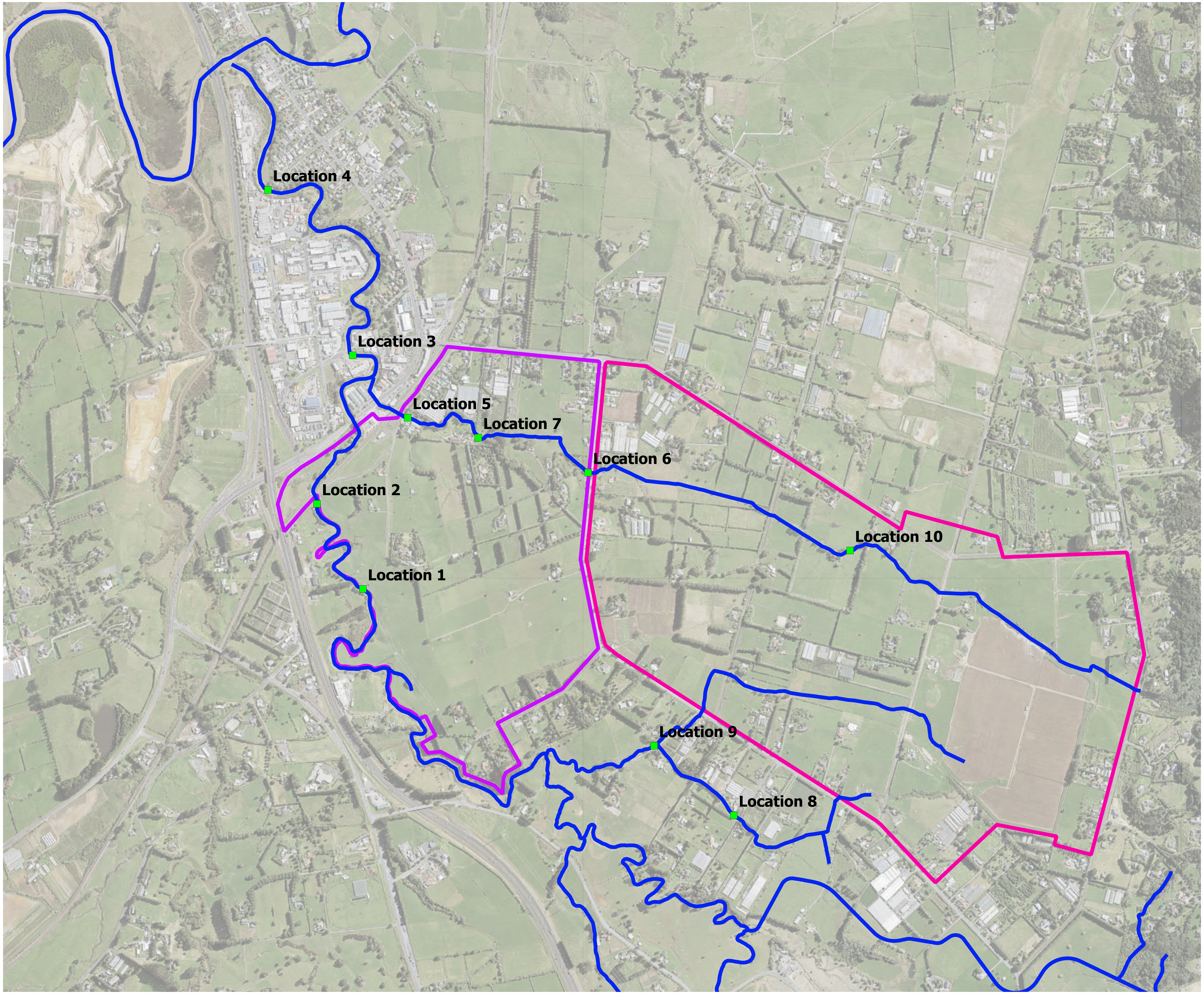
The ecology and stormwater experts for Kiwi Property and Fulton Hogan recommend stream erosion mitigation measures for the Plan Change Areas as follows:

- Removal of stock from the site and therefore avoiding active bank de-stabilisation through stock access and pugging.
- Incorporation of green spaces adjacent to stream networks to provide for planting of riparian margins to improve bank stability and reduce erosion potential.
- Modification of hydrograph mitigated through stormwater retention/detention (SMAF 1 hydrological mitigation) measures which will slow flows.

- Remediation or removal of existing in-stream structures (culverts, inlets/outlets) which are currently identified as having erosion issues.
- Realignment of streams which have been channelised to a more natural alignment.
- Incorporation of erosion and scour protection measures at all outfalls to minimise erosion at new structures.
- Targeted in-stream erosion protection measures may be required within the Hingaia Stream and other larger streams.

6-Apr-20
t:\tauranga\projects\1003297\1003297.6000\issueddocuments\rfi final response to barkers\drury east fir response - stream erosion risk assessment memo.docx

Appendix A:



Tonkin+Taylor

WOODS
EST.1970

LEGEND

- Locations
- Rivers
- Fulton Hogan Plan Change Area
- Kiwi Property Plan Change

	REVISION DETAILS	BY	DATE
1.0	Issued for Information	PW	31/3/2020

SURVEYED	AC	
DESIGNED	PW/AD	
DRAWN	SH	
CHECKED	PW	
APPROVED	PW	WOODS.CO.NZ

N

Modified Stream Erosion Risk Tool
Assessment Locations

STATUS	ISSUED FOR INFORMATION	REV
SCALE	1:12000 @ A3	1.0
COUNCIL	AUCKLAND COUNCIL	
DWG NO	P16-335-SKT-0014	

This drawing was generated from QGIS

Map 4: Engineering Asset Locations, Stream Bank & Outfall Erosion

Document Path: F:\FELIX_DATA\4SIGHT\AA3135_Hingaia_WAR\MAPS\MAP_04_Eng_Assets.mxd

Auckland Council

HINGAIA CATCHMENT STREAM SURVEY

Erosion Scars
- 0-20%
- 21-40%
- 41-60%
- >60%
- Erosion Hotspot

Bank Stability
- Excellent
- Good
- Fair
- Poor
- Wetland

Inlet/Outlet Erosion
- None
- Slight
- Moderate
- Severe
- Could not locate

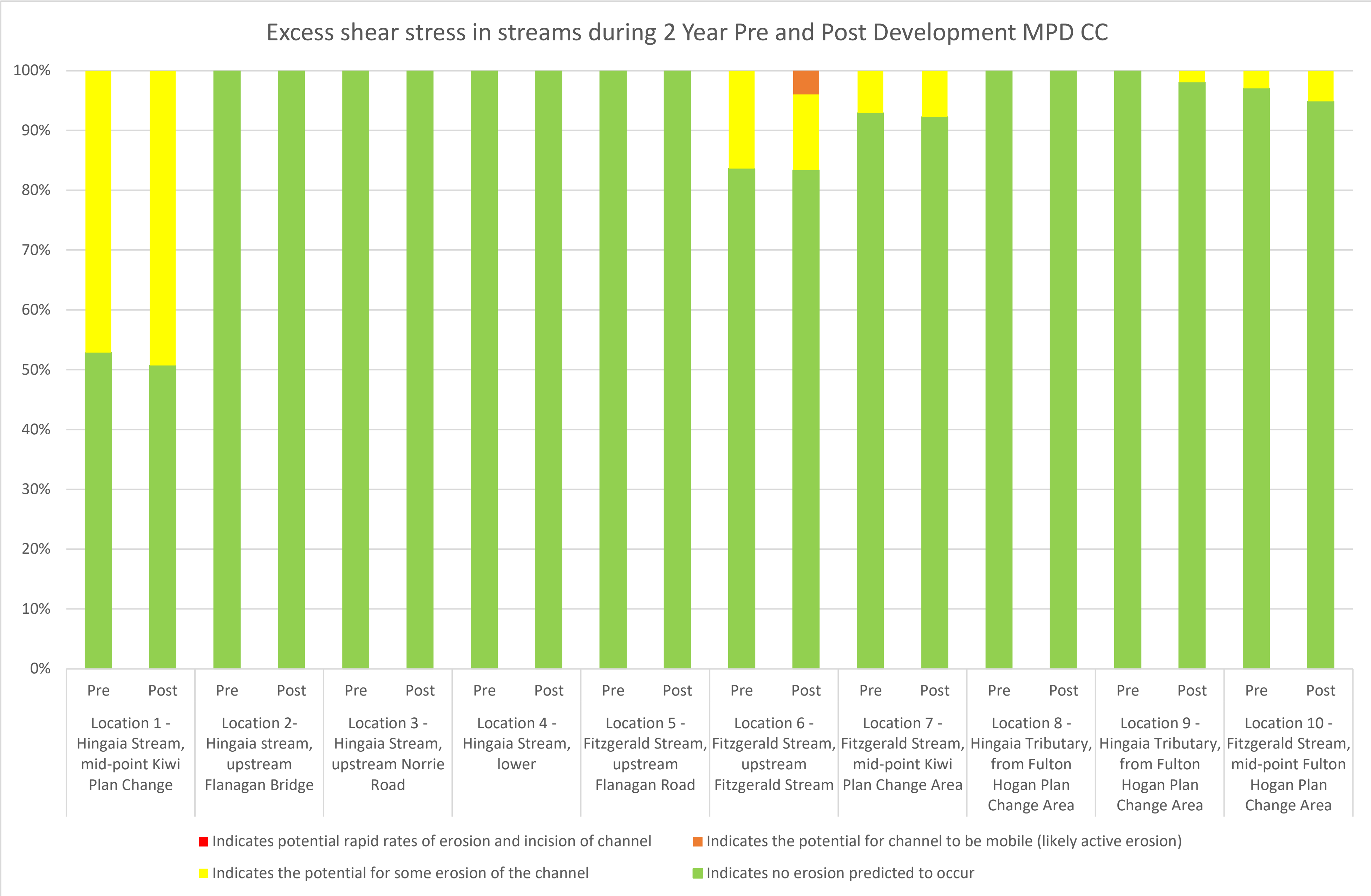
0 0.25 0.5 1 km

1	2	3	4
5	6	7	8
9	10	11	12	13
	14	15	16	17

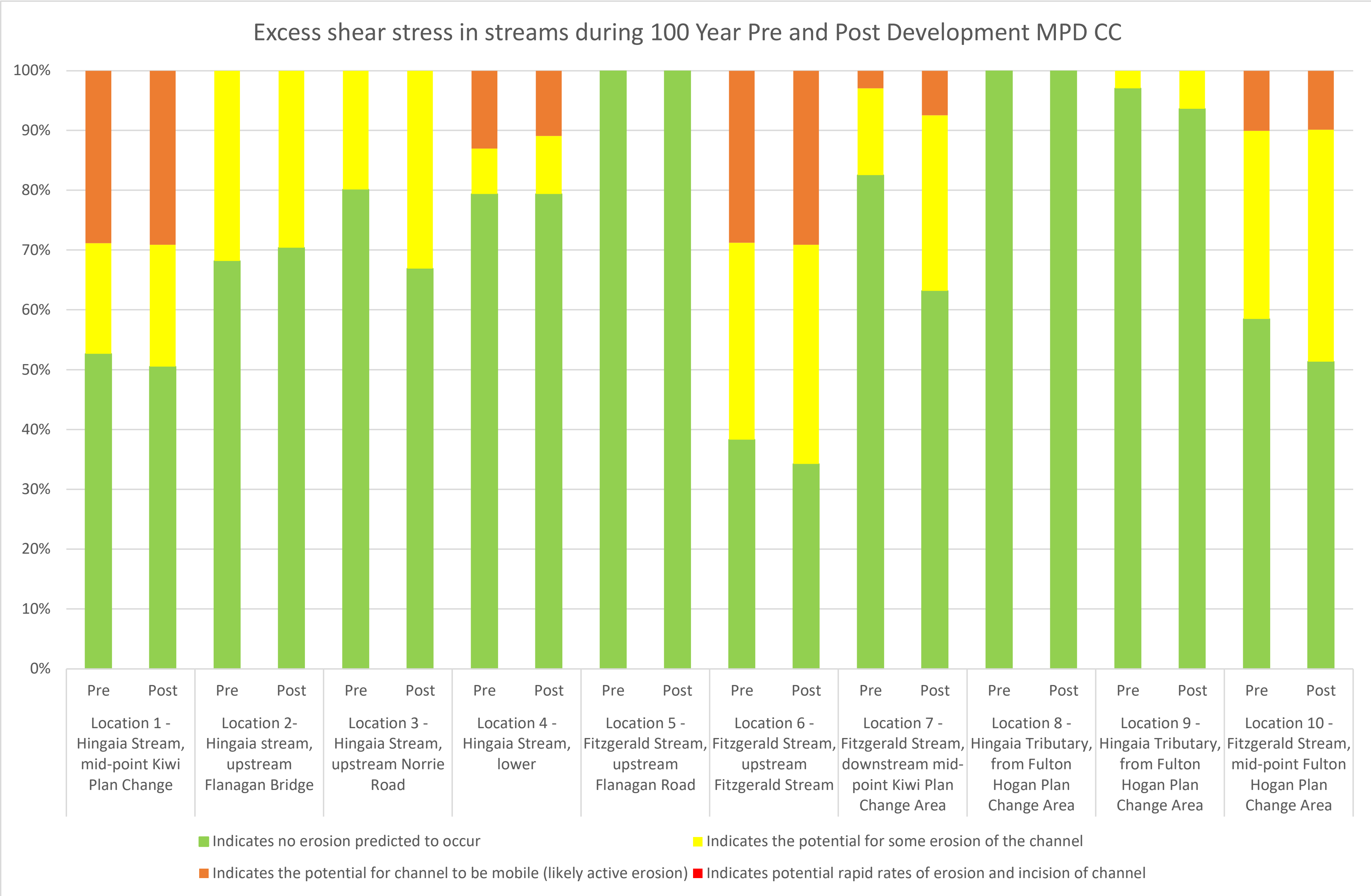
Page 2 out of 18

Date Created:	4/07/2018
Scale:	1:10,000
Page Size:	A3
Status:	Draft
Author:	FP
Checked:	AS
Approved:	KB

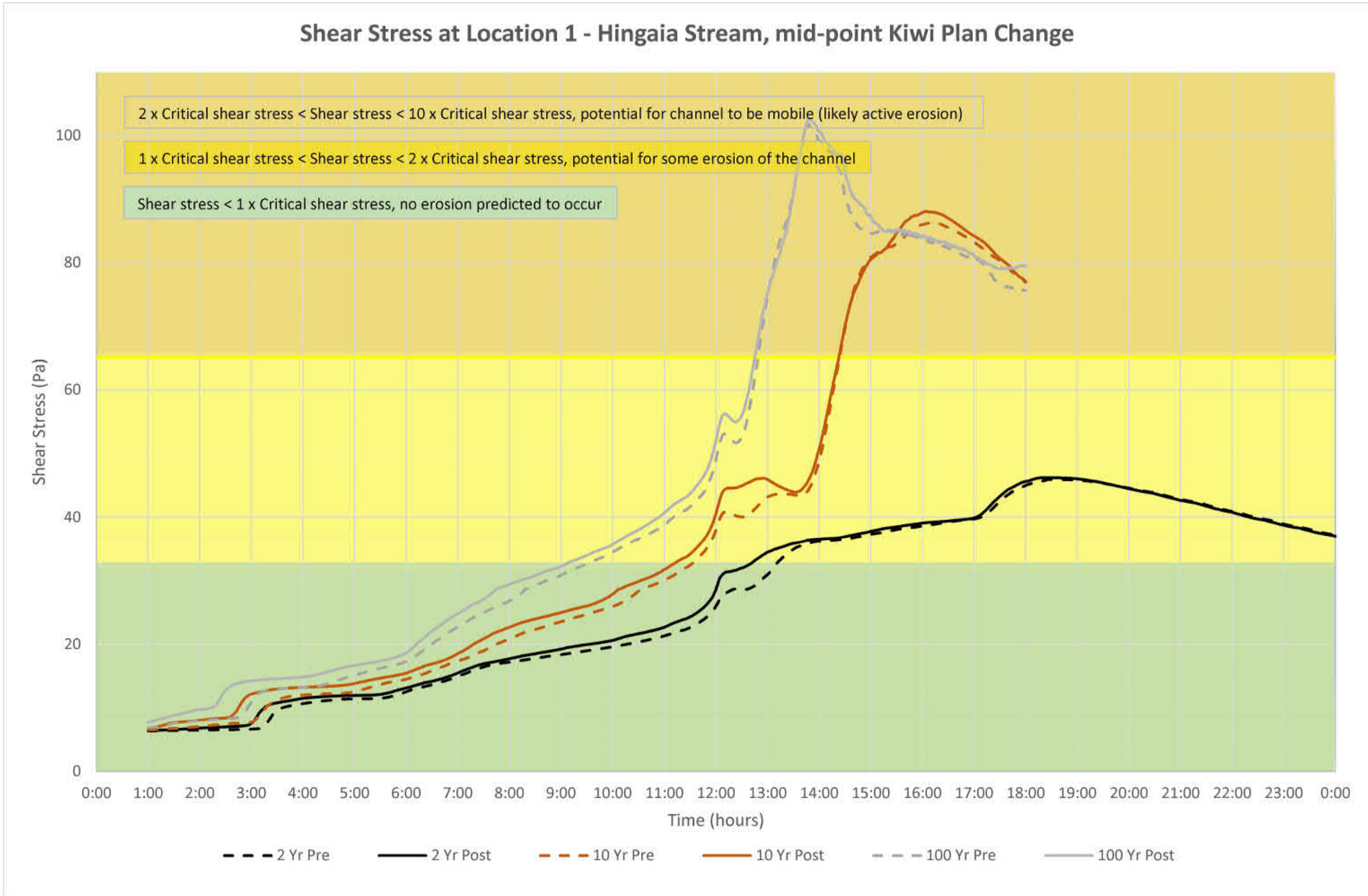
Appendix B:


Excess shear stress in streams during 2 Year Pre and Post Development MPD CC
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pre
Post
Location 1 - Hingaia Stream, mid-point Kiwi Plan Change
Location 2- Hingaia stream, upstream Flanagan Bridge
Location 3 - Hingaia Stream, upstream Norrie Road
Location 4 - Hingaia Stream, lower
Location 5 - Fitzgerald Stream, upstream Flanagan Road
Location 6 - Fitzgerald Stream, upstream Fitzgerald Stream
Location 7 - Fitzgerald Stream, mid-point Kiwi Plan Change Area
Location 8 - Hingaia Tributary, from Fulton Hogan Plan Change Area
Location 9 - Hingaia Tributary, from Fulton Hogan Plan Change Area
Location 10 - Fitzgerald Stream, mid-point Fulton Hogan Plan Change Area
Indicates potential rapid rates of erosion and incision of channel
Indicates the potential for channel to be mobile (likely active erosion)
Indicates the potential for some erosion of the channel
Indicates no erosion predicted to occur

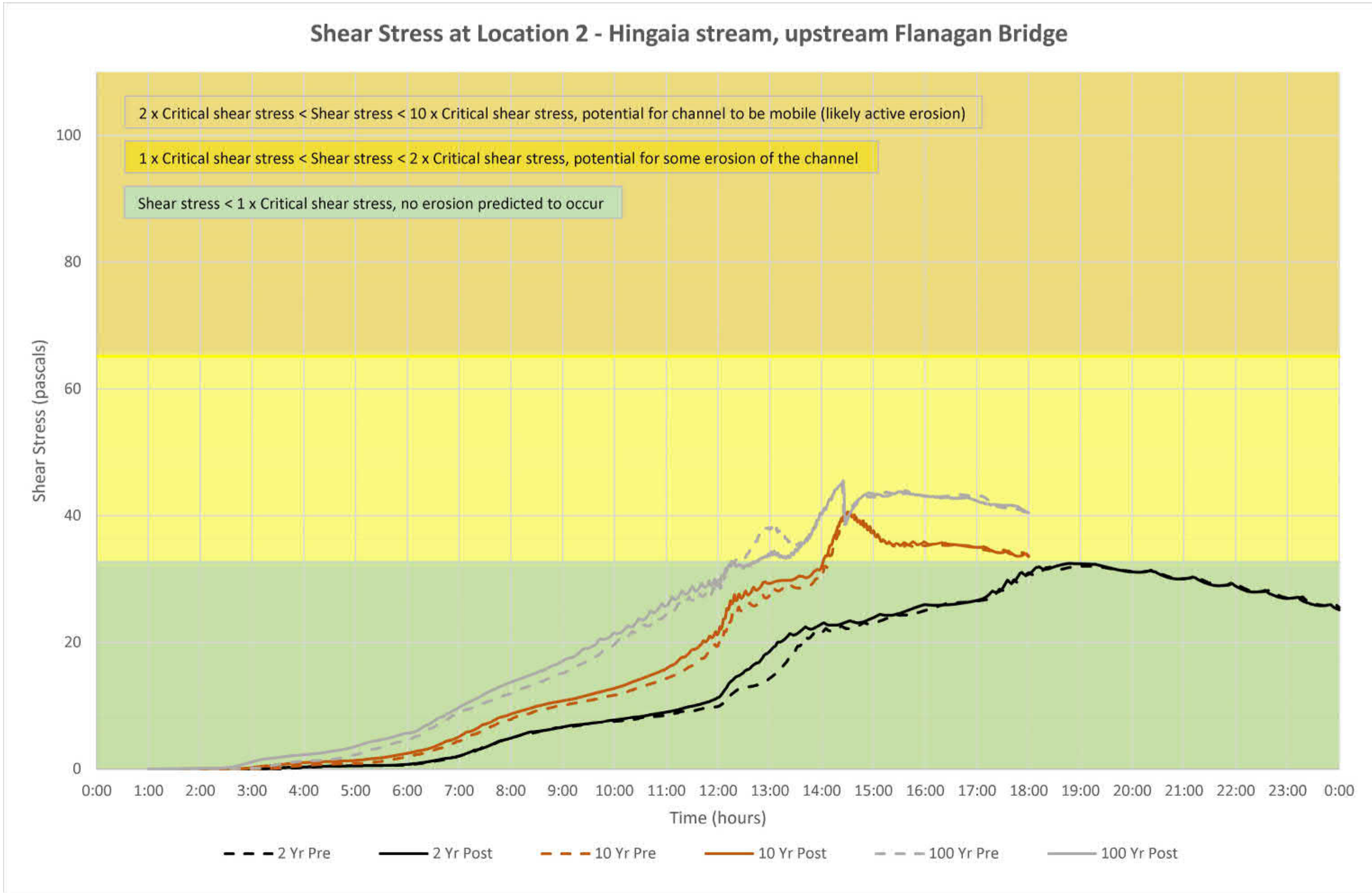

Excess shear stress in streams during 10 Year Pre and Post Development MPD CC
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pre
Post
Location 1 - Hingaia Stream, mid-point Kiwi Plan Change
Location 2- Hingaia stream, upstream Flanagan Bridge
Location 3 - Hingaia Stream, upstream Norrie Road
Location 4 - Hingaia Stream, lower
Location 5 - Fitzgerald Stream, upstream Flanagan Road
Location 6 - Fitzgerald Stream, upstream Fitzgerald Stream
Location 7 - Fitzgerald Stream, mid-point Kiwi Plan Change Area
Location 8 - Hingaia Tributary, from Fulton Hogan Plan Change Area
Location 9 - Hingaia Tributary, from Fulton Hogan Plan Change Area
Location 10 - Fitzgerald Stream, mid-point Fulton Hogan Plan Change Area
Indicates potential rapid rates of erosion and incision of channel
Indicates the potential for channel to be mobile (likely active erosion)
Indicates the potential for some erosion of the channel
Indicates no erosion predicted to occur



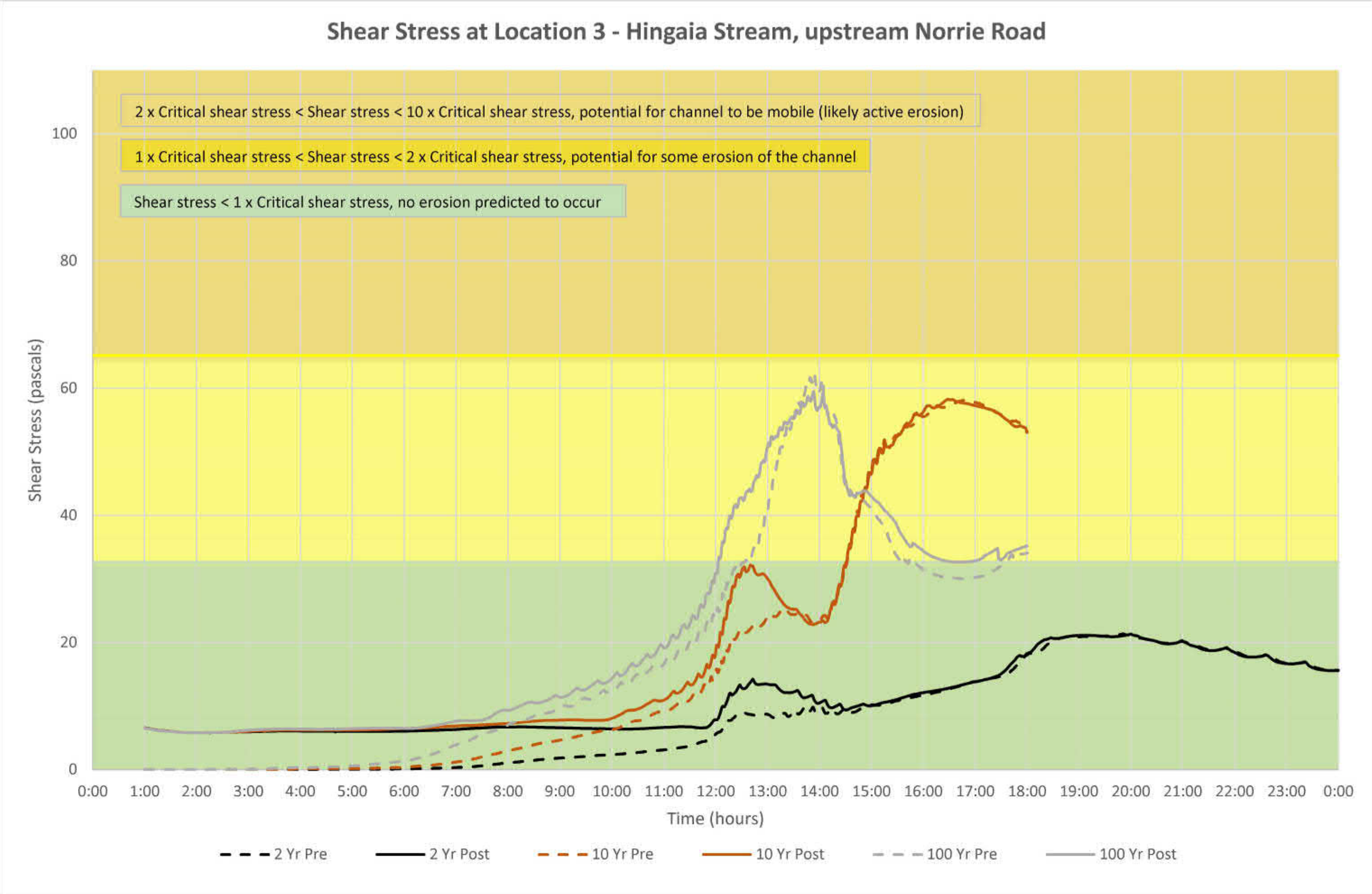
Excess shear stress in streams during 100 Year Pre and Post Development MPD CC
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Pre
Post
Location 1 - Hingaia Stream, mid-point Kiwi Plan Change
Location 2- Hingaia stream, upstream Flanagan Bridge
Location 3 - Hingaia Stream, upstream Norrie Road
Location 4 - Hingaia Stream, lower
Location 5 - Fitzgerald Stream, upstream Flanagan Road
Location 6 - Fitzgerald Stream, upstream Fitzgerald Stream
Location 7 - Fitzgerald Stream, downstream mid-point Kiwi Plan Change Area
Location 8 - Hingaia Tributary, from Fulton Hogan Plan Change Area
Location 9 - Hingaia Tributary, from Fulton Hogan Plan Change Area
Location 10 - Fitzgerald Stream, mid-point Fulton Hogan Plan Change Area
Indicates no erosion predicted to occur
Indicates the potential for some erosion of the channel
Indicates the potential for channel to be mobile (likely active erosion)
Indicates potential rapid rates of erosion and incision of channel



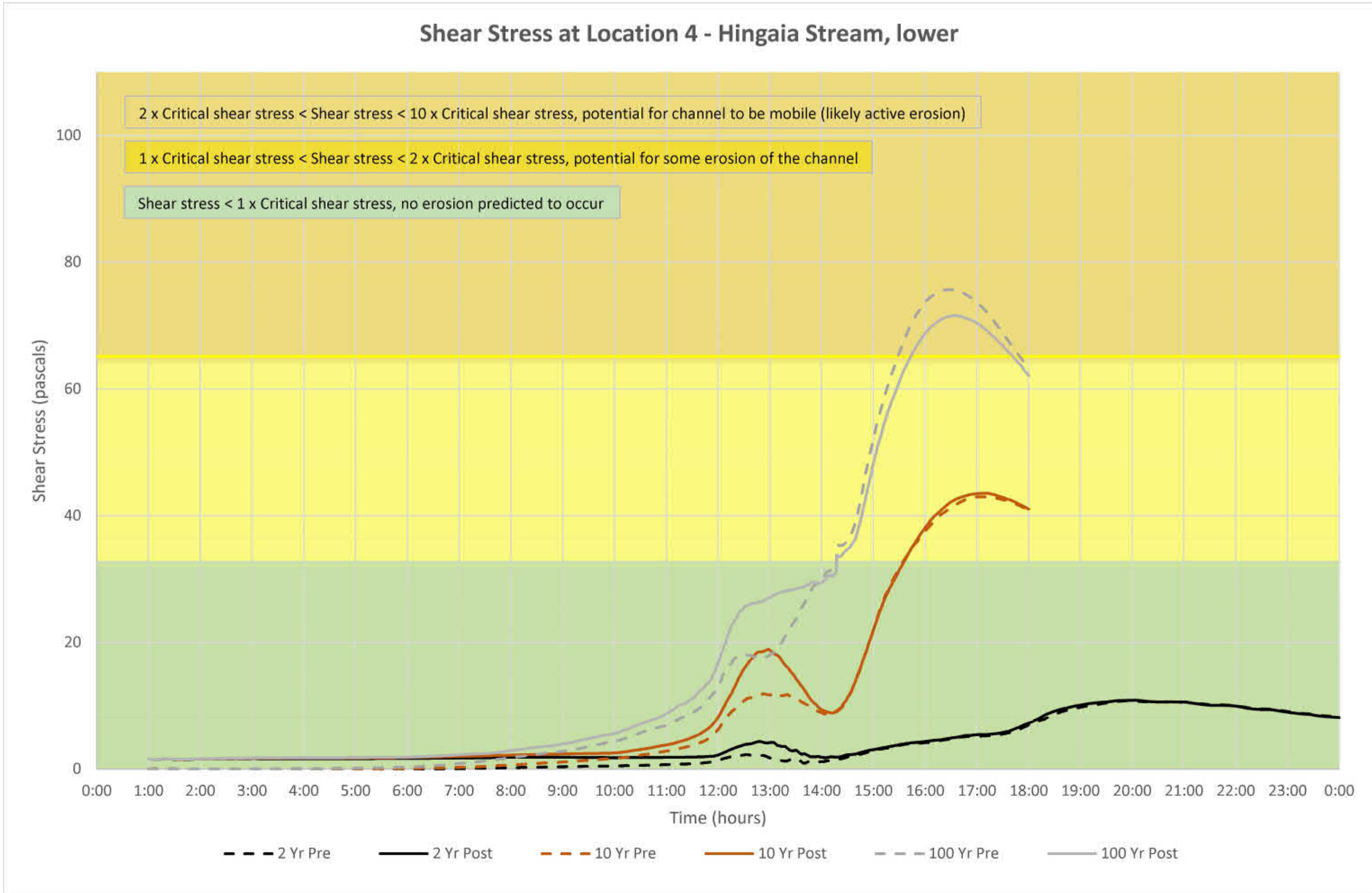
Shear Stress at Location 1 - Hingaia Stream, mid-point Kiwi Plan Change
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (Pa)
0
20
40
60
80
100
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
Time (hours)
2 Yr Pre
2 Yr Post
10 Yr Pre
10 Yr Post
100 Yr Pre
100 Yr Post



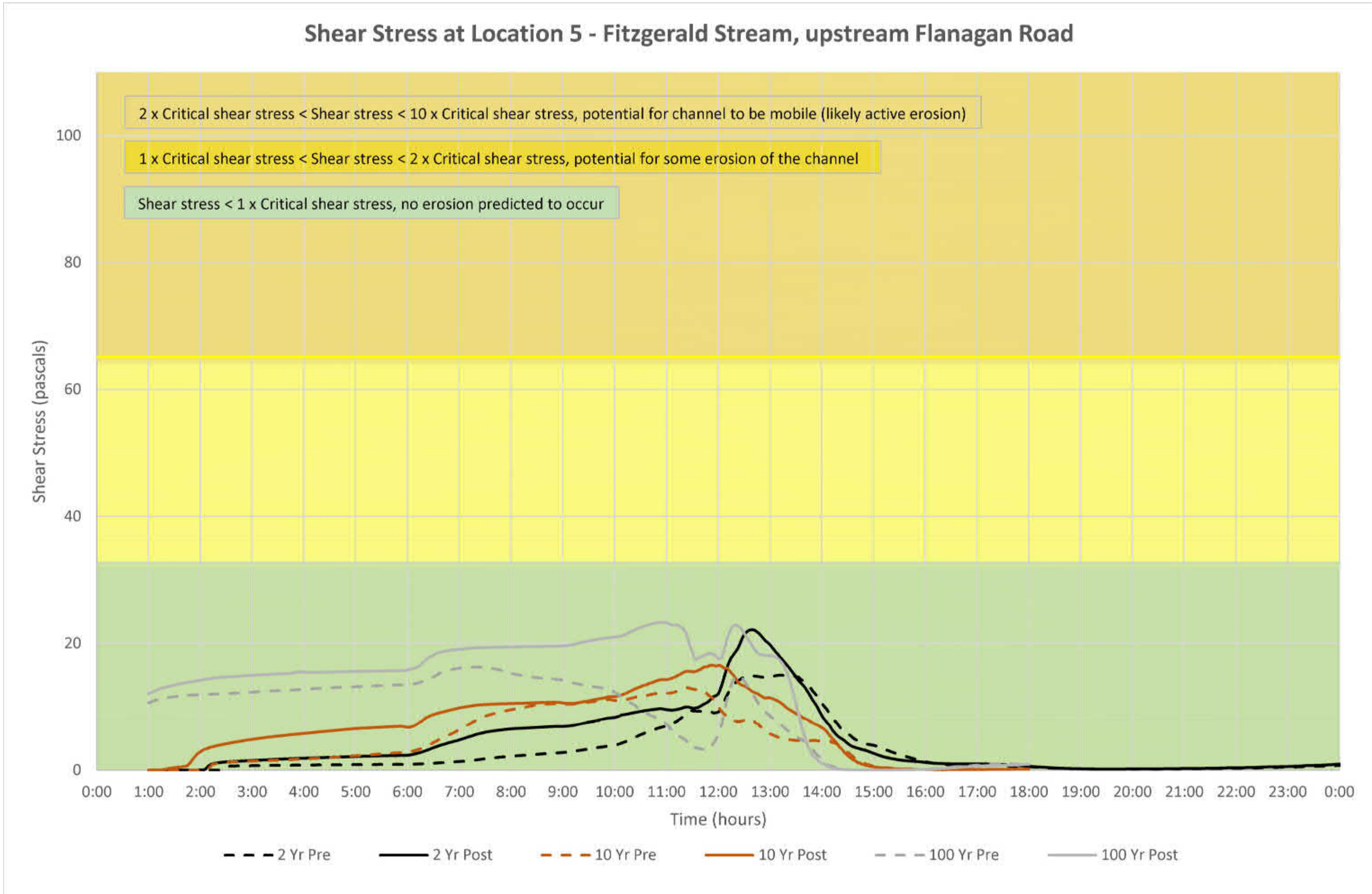
Shear Stress at Location 2 - Hingaia stream, upstream Flanagan Bridge
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
100
80
60
40
20
0
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
Time (hours)
2 Yr Pre
2 Yr Post
10 Yr Pre
10 Yr Post
100 Yr Pre
100 Yr Post



Shear Stress at Location 3 - Hingaia Stream, upstream Norrie Road
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
0
20
40
60
80
100
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
Time (hours)
2 Yr Pre
2 Yr Post
10 Yr Pre
10 Yr Post
100 Yr Pre
100 Yr Post



Shear Stress at Location 4 - Hingaia Stream, lower
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
0
20
40
60
80
100
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
Time (hours)
2 Yr Pre
2 Yr Post
10 Yr Pre
10 Yr Post
100 Yr Pre
100 Yr Post


Shear Stress at Location 5 - Fitzgerald Stream, upstream Flanagan Road
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
0
20
40
60
80
100
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
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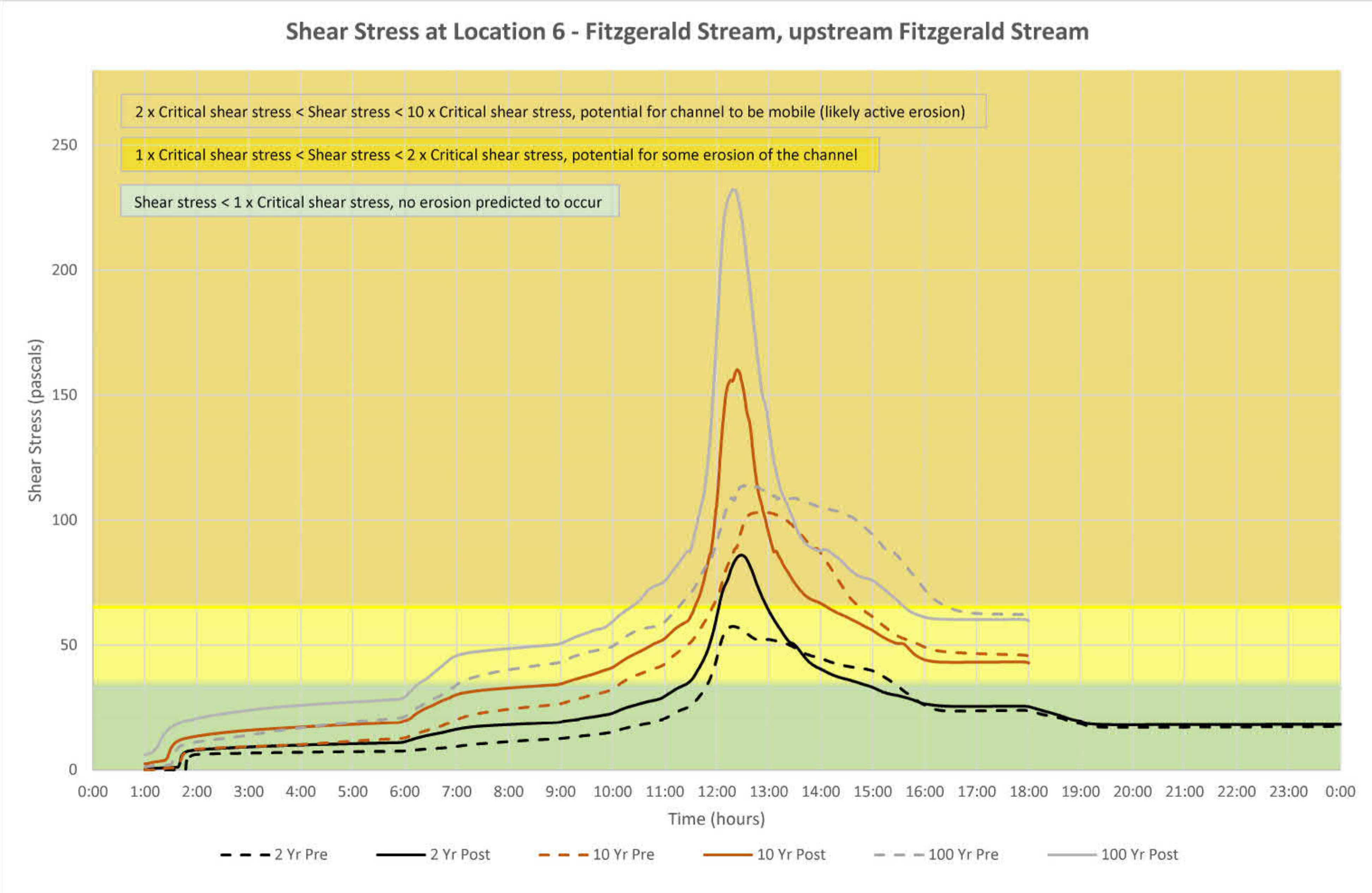
Time (hours)
2 Yr Pre
2 Yr Post
10 Yr Pre
10 Yr Post
100 Yr Pre
100 Yr Post


Shear Stress at Location 6 - Fitzgerald Stream, upstream Fitzgerald Stream
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
0
50
100
150
200
250
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
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23:00
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Time (hours)
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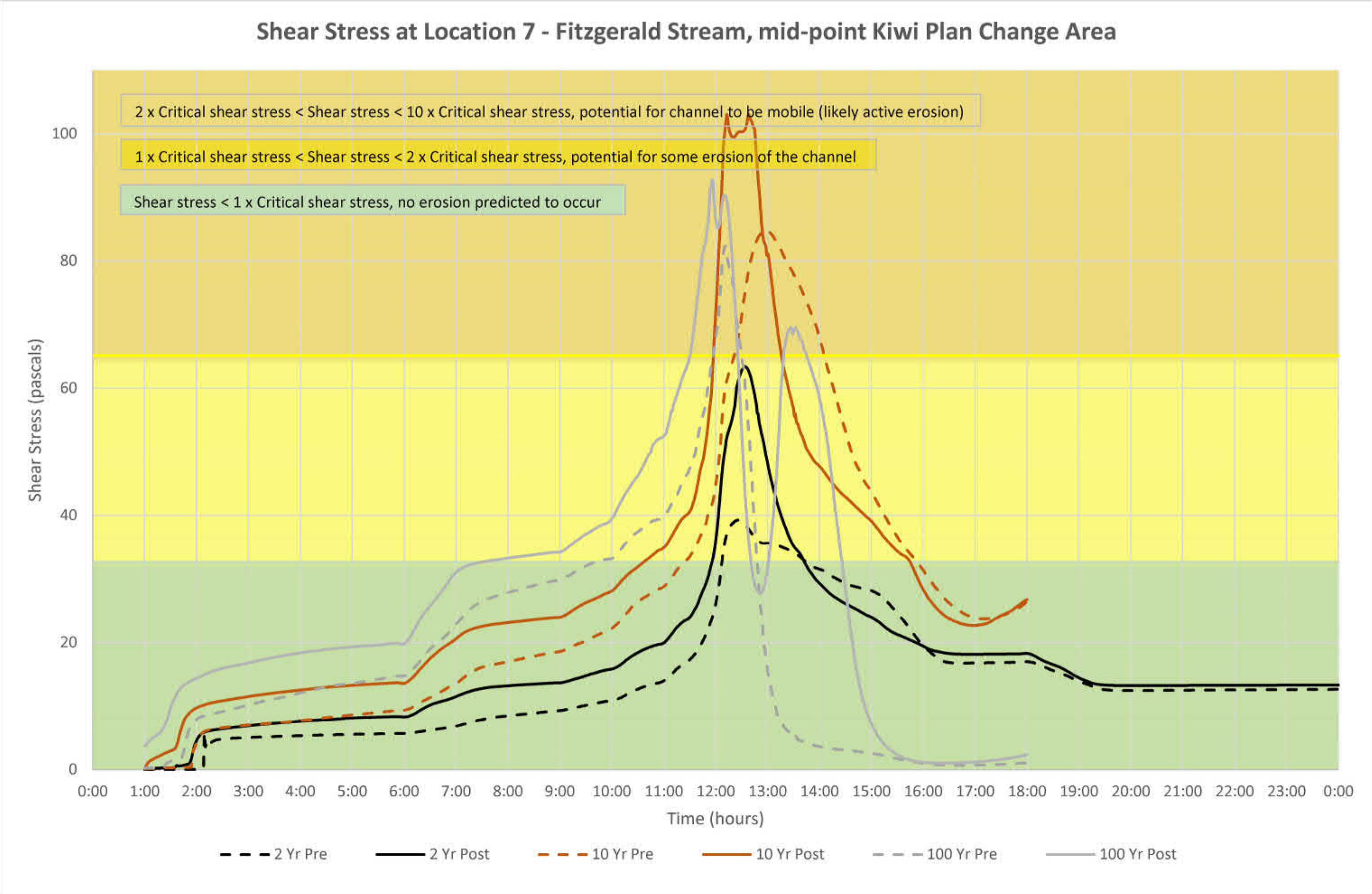
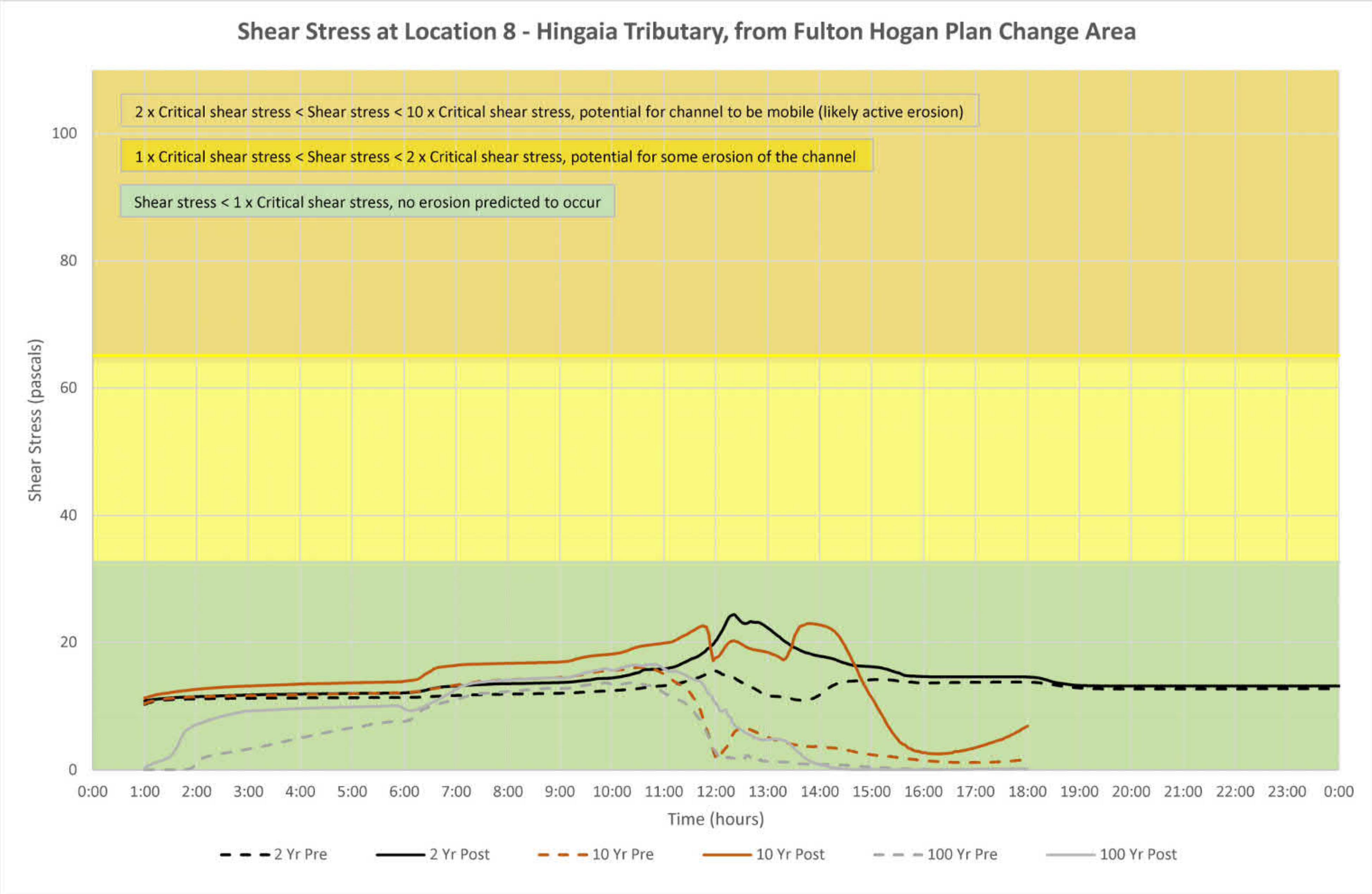
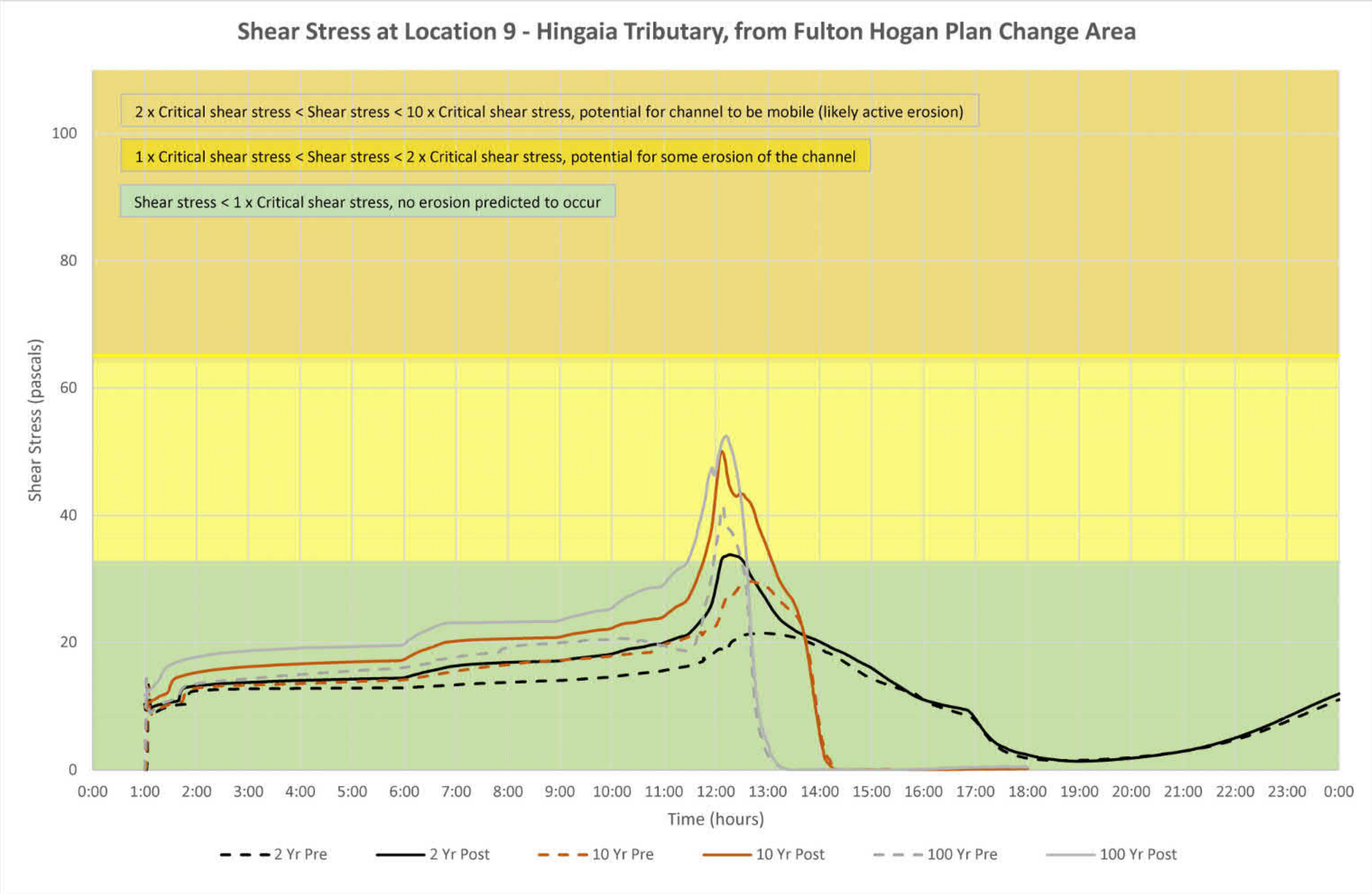
2 Yr Post
10 Yr Pre
10 Yr Post
100 Yr Pre
100 Yr Post


Shear Stress at Location 7 - Fitzgerald Stream, mid-point Kiwi Plan Change Area
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
0
20
40
60
80
100
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
Time (hours)
2 Yr Pre
2 Yr Post
10 Yr Pre
10 Yr Post
100 Yr Pre
100 Yr Post



Shear Stress at Location 8 - Hingaia Tributary, from Fulton Hogan Plan Change Area
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
0
20
40
60
80
100
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
0:00
Time (hours)
2 Yr Pre
2 Yr Post
10 Yr Pre
10 Yr Post
100 Yr Pre
100 Yr Post



Shear Stress at Location 9 - Hingaia Tributary, from Fulton Hogan Plan Change Area
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
0
20
40
60
80
100
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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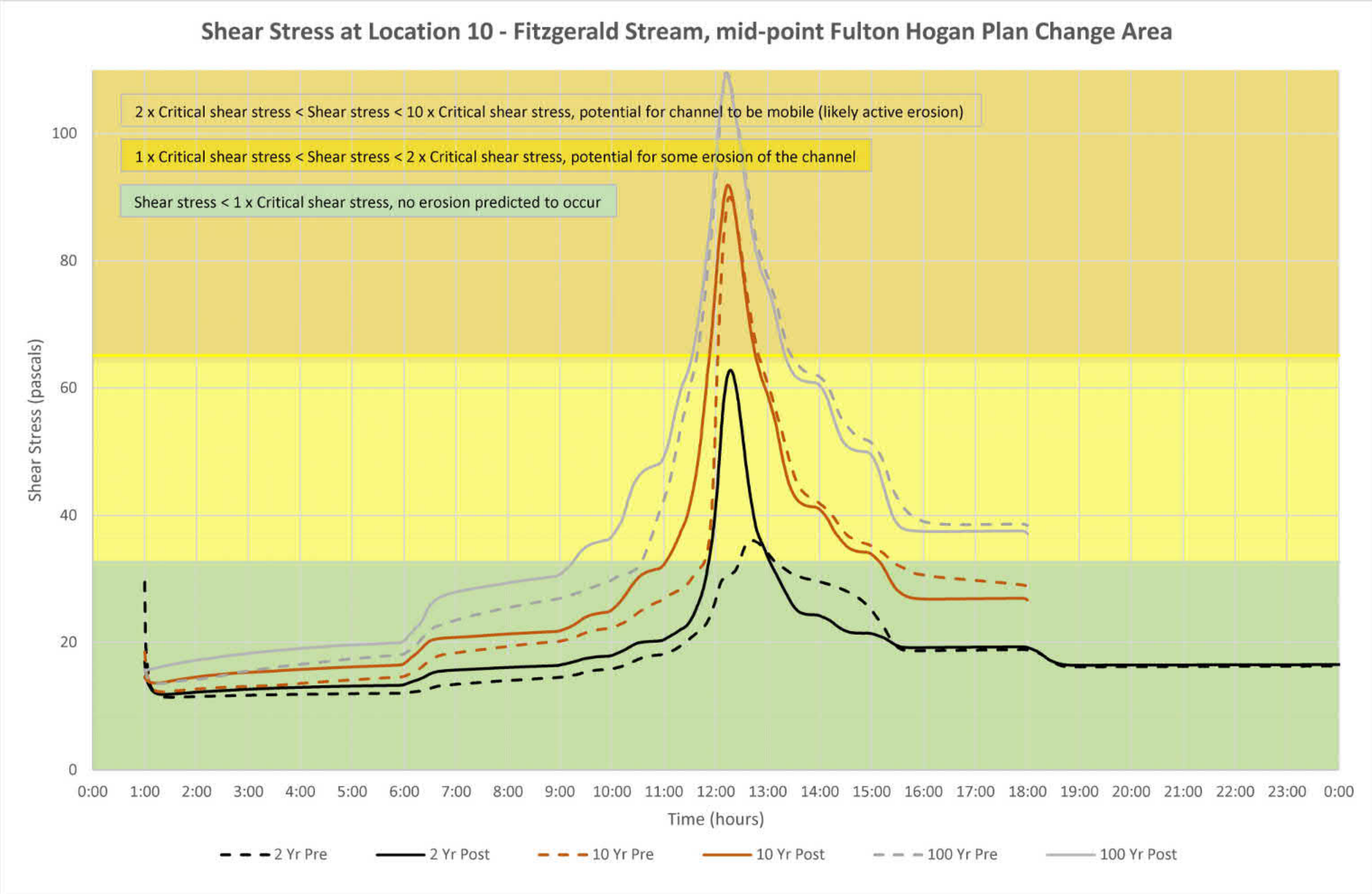
Shear Stress at Location 10 - Fitzgerald Stream, mid-point Fulton Hogan Plan Change Area
2 x Critical shear stress < Shear stress < 10 x Critical shear stress, potential for channel to be mobile (likely active erosion)
1 x Critical shear stress < Shear stress < 2 x Critical shear stress, potential for some erosion of the channel
Shear stress < 1 x Critical shear stress, no erosion predicted to occur
Shear Stress (pascals)
0
20
40
60
80
100
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
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15:00
16:00
17:00
18:00
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21:00
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Time (hours)
2 Yr Pre
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100 Yr Pre
100 Yr Post

Appendix M

Ecology Memo

Memo

To:	**Rachel Morgan**	**Job No:**	**1003297.6000**
From:	**Justine Quinn**	**Date:**	**24 March 2020**
cc:	**Nick Carter, Gary Bramley**		
Subject:	**Drury East Plan Changes - Ecology Response**		

This memo has been prepared to address selected ecological responses as required by the Request for Further Information (RFI) from Auckland Council for Drury East Plan Change requests by Fulton Hogan, Oyster Capital and Kiwi Property. It has been prepared by three ecologists, being Gary Bramley (for Fulton Hogan), Justine Quinn (for Kiwi Property) and Nick Carter (for Oyster Capital) and summarises the results of an ecology workshop, literature review and collaborative drafting of this response. This memo should be read in conjunction with the stormwater memo and only applies to those specific matters outlined below.

1 Erosion and sedimentation effects

The following response has been prepared in relation to RFI E10 (Kiwi), E11 + E12 (Fulton Hogan), E10 + E11 (Oyster) which collectively request that more information is provided to assess the effects of sediment and erosion on the life supporting capacity of the marine significant ecological area.

Existing environment – plan change area

The collective area that the three plan changes apply to (the plan change area) is currently in predominantly agricultural and horticultural land use, including cropping, dairy farming and grazing. Many of the streams within the plan change area are intermittently flowing headwater systems that have unrestricted stock access to enable grazing when the streams are dry in summer. The Hingaia Stream which flows along the western boundary of the wider plan change area is the largest stream affected by the plan change. Photograph 1.1 below provides a representative image of the smaller streams within the plan change area.

Riparian vegetation is effectively absent over much of the plan change area and most of the stream length is unfenced. Stream banks and channels have been impacted by stock access, with slumping and bank instability prevalent throughout the plan change area. Auckland Council's survey of streams in the Hingaia area[1] revealed that bank stability was generally poor to fair. While erosion scars were typically less than 20%, erosion at inlet/outlets was often moderate or severe. Banks were identified as being highly erodible due to the general lack of vegetation and the soft erosive soils within the catchment. Sediment deposition was overserved to be ~17% on average across the entire Hingaia catchment, and notably, areas of active sediment deposition of >30% were linked to areas where stream banks of >20% erosion scarring was present.

[1] Spyksma, A., Bennett, K., Kane-Sanderson, P., Lindgreen, M., Pertziger, F., Allen, J., Gasson, S and Canal, L. (2018) Hingaia Stream Catchment Watercourse Assessment Report. 4Sight Consulting and Urban Solutions for Auckland Council. Auckland Council [technical report, TR20xx/xxx]

Auckland Council also surveyed streams within the Slippery Creek area[2], however most of the stream length present within the plan change area was not mapped. Therefore, we rely on the observations made during field assessments and reported in Freshwater Solutions (2019) where intermittent watercourses were found to be unfenced with severely damaged streambanks and channels. The section of the Waihoihoi Stream flowing adjacent to the plan change area was fenced but lined with low stature weed species and occasional mature trees so the streambanks were susceptible to streambank undercutting, slumping (i.e., due to poor root stability) and sedimentation (Photograph 1.2).

Photograph 1.1: Evidence of unrestricted stock access, lack of riparian margins, upper bank instability.

Photograph 1.2: Lack of riparian margins and bank instability along Waihoihoi Stream.

[2] Ingley, R., Rieger, A., Magee, J., Reeves, E., Macintosh, K., Lowe, M., Young, D. (2016) Watercourse Assessment Report: Slippery Creek Catchment. Morphum Environmental for Auckland Council. Auckland Council [technical report, TR20xx/xxx]

Existing environment – marine receiving environment

The marine receiving environment is the Drury Creek and wider Pahurehure Inlet. The immediate marine environment is recognised as a Significant Ecological Area (SEA), which includes SEA-M1_29a, SEA-M2_29b and SEA-M2_29w1-2, shown on Figure 1.1.

Immediately adjacent to State Highway One, the intertidal area is classified as an 'SEA-M1' indicating that its physical form, scale or inherent values are considered to be the most vulnerable to any adverse effects of inappropriate subdivision, use and development. The AUP OP identifies that within these upper tidal reaches of Drury Creek there are a variety of marshes, grading from mangroves through to extensive areas of jointed rush-dominated saltmarsh, to freshwater vegetation in response to salinity changes. This same area is a migration pathway between the marine and freshwater environments for a number of native diadromous freshwater fish species.

Beyond this, the wider intertidal area is classified as an 'SEA-M2' being an area of regional, national or international significance which does not warrant a SEA-M1 identification as they are generally more robust. This has similar ecological values, but also provides roost areas of importance to wading birds including pied stilt.

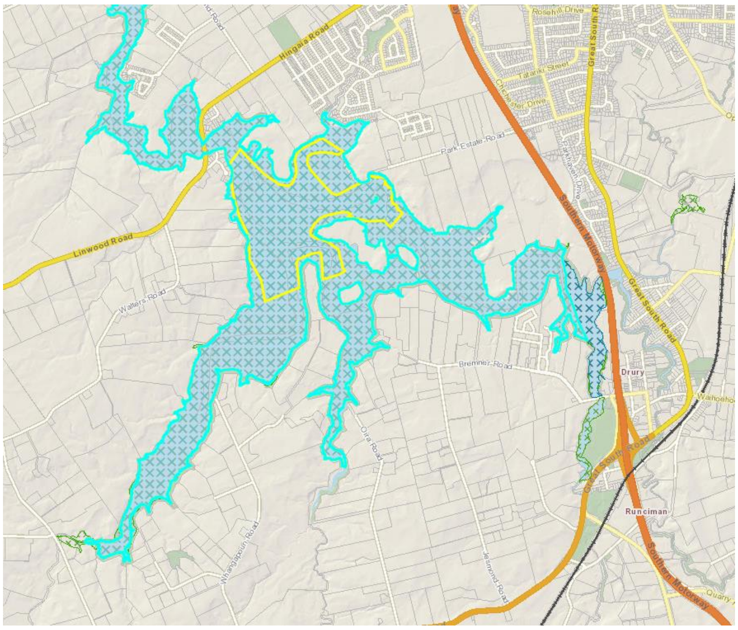

Figure 1.1: Marine SEA in the Pahurehure Inlet and wider Drury Creek estuarine area

Sediment in the marine environment

NIWA were engaged by the Ministry for the Environment to develop and apply a new empirical model that estimates mean annual river suspended sediment load and sediment deposition in coastal hydrosystems[3]. The model includes suspended sediment load and inherently includes sediment supply from eroding streambanks as well as upstream hill-slope erosion processes.

Shallow drowned valleys such as the Pahurehure Inlet have intermediate level deposition rates (median of 0.7 mm/year), where near-bed velocities are low, little resuspension by currents occurs, and a main channel morphology tends to be absent. The trapping efficiency of a shallow drowned valley is typically quite high, and the Pahurehure Inlet has a predicted trapping efficiency of 0.963. Trapping efficiency is the proportion of incoming sediment load that is retained and settles within the water body measured on a scale of 0 to 1, where 1 means that 'all river-sourced sediment is

[3] Hicks, M., Semadeni-Davies, A., Haddadchi, A., Shankar, U and Plew, D. (2019). Updated Sediment Load Estimator for New Zealand. Prepared by NIWA for the Ministry for the Environment. March 2019. NIWA client report 2018341CH.

retained in the coastal hydrosystem'. What this tells us, is that the marine receiving environment is a natural deposition zone and sediment deposition is expected and required for the environment to continue to function.

Zostera, the sea grass grows in soft-sediment environments and is present in the wider Pahurehure Inlet. One of the key functions of seagrass is to trap and stabilise bottom sediments, to protect against sediment erosion in the coastal environment[4]. Seagrasses also depend on sediments for nutrients and anchorage.

Potential sedimentation effects of the plan change

The plan change area is currently predominantly in rural land use which typically has a higher overall sediment load than urban land use[5]. The change in hydrological regime may result in streambank sediment entering the receiving environment at times (e.g. after heavy rain). This will be balanced in part by the effective removal of contributing sediment loads from agricultural land use and the future potential benefits associated with planting along the blue-green network throughout the plan change area (e.g., root establishment, increased streambank stability and filtering capacity).

The Hingaia Stream, which is known to have erosion issues, is most affected by the flows entering the stream from the wider catchment, which is currently undergoing significant development, thus the impact of the proposal on Hingaia Stream needs to be considered in the wider context of the whole catchment. The plan change area comprises only a very small portion of the 37,637 ha[5] Pahurehure Inlet catchment. Even at the more local scale of the upper Drury Creek, the plan change area comprises a small proportion of the overall contributing catchment. On that basis, any changes within the plan change area on sediment levels in Hingaia Stream would be very difficult to distinguish from changes elsewhere within the catchment.

Auckland Council Stream Erosion Risk Tool

As is explained in the stomwater memo (ref W-REF: P16-335), the Auckland Council Stream Erosion Risk Tool was investigated to provide further quantifiable information regarding the potential risks of erosion from within the plan change. Some issues with this tool were identified and next steps are proposed within the stormwater memo. The tool when working will quantify the change in exceedance of critical shear stress will only indicate a change in erosion potential i.e. how much the erosion risk changes. It will not quantify how much extra erosion will occur, nor the change in sediment load will be to the receiving environment, so it cannot be used to directly assess effects. The tool will identify areas with increased erosion risk and where extra mitigation measures should be applied.

Until further assessment is undertaken, a robust ecological assessment of the potential effects of sedimentation in the marine SEA cannot be completed. Further assessment of the change in sediment contribution to the wider environment will be undertaken prior to a plan change hearing, although this may be risk based. This will provide more assessment of the anticipated changes in sediment risk and will incorporate mitigation measures which will reduce the potential stream bank erosion and therefore sediment generation.

Until further assessment or quantification is undertaken, a robust ecological assessment of the potential effects of sedimentation in the marine SEA cannot be completed. Further assessment to quantify the change in sediment contribution to the wider environment will be undertaken prior to a plan change hearing. This will provide a more quantitative assessment of the anticipated changes in sediment generation and will incorporate mitigation measures which will reduce the potential

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[4] Turner, S. and Schwarz, A. (2006). Management and conservation of seagrass in New Zealand: an introduction. Science for Conservation 264. Prepared by the Department of Conservation.

[5] Parshotam, A. (2008). Southeastern Manukau Harbour / Pahurehure Inlet Contaminant Study. Sediment Load Model Results. Prepared by NIWA for Auckland Regional Council. Auckland Regional Council Technical Report 2008/052.

stream bank erosion and therefore sediment generation. We have identified a range of potential mitigation measures which may aid in the management of erosion and sedimentation in the plan change area:

- Removal of stock from the site and therefore avoiding active bank de-stabilisation through stock access and pugging.
- Incorporation of green spaces adjacent to stream networks to provide for planting of riparian margins to improve bank stability and reduce erosion potential.
- Modification of hydrograph mitigated through stormwater retention/detention (MSAF 1 hydrological mitigation) measures which will slow flows.
- Remediation or removal of existing in-stream structures (culverts, inlets/outlets) which are currently identified as having erosion issues.
- Realignment of streams which have been channelised to a more natural alignment.
- Incorporation of erosion and scour protection measures at all outfalls to minimise erosion at new structures.
- Potential targeted in-stream erosion protection measures within the Hingaia Stream and other larger streams.

While the effectiveness of these measures cannot be quantified at this stage, these are still considered to provide some benefit to erosion and sediment generation from stream channels affected by the change in hydrology within the plan change area.

2 Water quality

The following response has been prepared in relation to RFI Stormwater 01 and 03 to address questions pertaining to water quality and effects on ecology. This response should be read in conjunction with the planning response and stormwater memo.

Chapter E1 of the AUP OP identifies that where freshwater quality is degraded, that it be improved over time and that the macroinvertebrate community index (MCI) be used as a ‘guideline’ or indicator of freshwater ecosystem health. Aquatic macroinvertebrate community structure, abundance and diversity are standard indicators of the long-term health of streams. Different aquatic invertebrate taxa have varying tolerances of pollutants so their presence or absence can provide an indication of stream condition and overall health (i.e., water quality and habitat quality).

Policy E1.3.(2) identifies some ‘national bottom lines’ for stream health using the MCI and directs that where the current condition is lower than the bottom line that these systems be enhanced. If the bottom line is met, then the current condition should be maintained or enhanced. The bottom line MCIs of 94 and 68 for rural and urban environments respectively are relevant to this assessment. An MCI score of 94 is indicative of ‘fair’ stream health (i.e., MCI range 80-99) whilst anything lower than 80 is deemed ‘poor’ and representative of a degraded aquatic system.

In the 2018 Hingaia Watercourse Assessment Report[1] (WAR), a sample taken from the Fitzgerald Stream was indicative of poor water and habitat quality (MCIsb = 68). Just downstream of the plan change area near Wykita Lane, a similar MCI of 67 was recorded. A similar assessment was undertaken for the 2016 Slippery Creek WAR however the streams within the plan change were not assessed. Downstream and in the mainstem of the Waihoihoi Stream a sample was taken which indicates ‘fair’ water and habitat quality (MCIsb=99). Freshwater Solutions sampled a section of the Waihoihoi Stream within the plan change area and reported an MCI-sb indicative of poor stream health (MCIsb = 78). The current state of freshwater ecosystems within the plan change area is typically below the bottom line for rural landuse (i.e., MCI = <94). Under a future landuse of urban the national bottom line of 68 is met. The proposed stormwater management approach needs to at least maintain, but preferably improve, on the existing condition.

Many of the stream systems are expected to be nutrient enriched at present based on the observed prevalence of macrophytes, unrestricted access by livestock and the adjacent agricultural and horticultural land use. Further, with a near complete lack of shade along a high proportion of watercourses within the plan change area, it is expected that elevated water temperatures may be limiting the presence of some invertebrate taxa. It is considered that the main driver of poor macroinvertebrate communities is the lack of riparian vegetation which provides shade, adult aquatic insect habitat, bank stability and source of woody debris and leaf litter. Proposed riparian planting along stream corridors to develop the blue-green network will result in a demonstrable improvement in instream habitat (i.e., increased stability, woody debris) and water temperature control that will enhance conditions for aquatic fauna. Further, the connectivity of the riparian margins with existing vegetation east of Drury Hills Road, will provide a corridor from source populations of macroinvertebrates in the headwaters throughout the catchment. Restoration of streams including restoring sinuosity, removal of inline ponds, adding retreats and armouring where appropriate is also expected to improve stream habitat quality.

An integrated stormwater management approach has been proposed as a 'Stormwater Management Toolbox' which incorporates a range of measures to manage potential effects associated with the proposed change in land use and outlines the devices proposed within each of the proposed zones. The proposed stormwater management approach includes a range of different devices that will be consistent with GD01[6]. The devices proposed and the overall approach is consistent with the recommendations of TR2013/035. Specifically, these devices (if designed and constructed properly) will meet the historically proposed 'design effluent quality requirements' (DEQR). In relation to zinc and copper (as surrogates for other urban contaminants) these were defined as 30 ug/l for zinc and 10 ug/L for copper. These concentrations were at the point of discharge and do not take into consideration the assimilative capacity of the environment, reasonable mixing or the benefits of a treatment train approach. Further, these values were considered to be conservative, in that most devices perform substantially better than these DEQRs and were chosen for that reason after consultation with Mana Whenua.

It is considered that the implementation of the stormwater management toolbox in conjunction with the enhancement of riparian margins will be sufficient to manage the potential effects associated with changes in water quality and as measured by the macroinvertebrate community indices.

3 Blue-green network

The following response has been prepared in relation to Stormwater 07 in relation to the blue-green network. Refer to Appendix A which shows the Blue-Green Network envisaged under the Structure Plan, overlain with the riparian corridors as proposed in the Plan Change. There are some parts of the site where stream alignment does not correspond between the two datasets. We consider that for the most part this relates to a lack of spatial resolution. The plan is conceptual and provides sufficient information at this time to identify that the Blue-Green Network, including the important connectivity with SEA to the west of Drury Hills Road, is integral to the Plan Change.

4 Riparian margins

Please refer to the Planning response in relation to RFI E11 + E12 + E13 + E14 (Kiwi), E14 + E16 (Fulton Hogan), E12 + E13 + E14 (Oyster) and Stormwater 06 to address questions in regards to riparian margins around streams and wetlands.

[6] Stormwater Management Devices in the Auckland Region, December 2017, Guideline Document 2017/001 Version1.

Appendix A: Blue Green Network Map

KEY

- Council indicated new suburb park (Size 3-5ha) (Structure Plan)
- Council indicated new neighbourhood park (Size 0.3-0.5ha) (Structure Plan)
- Flood Plains
- Stream Connections
- Permanent and Intermitent Streams and 20m Riparian Margins (width may change) - from Structure Plan
- Rail line
- Rail station (indicative)
- State Highway 1
- Arterial roads (existing & upgrades)
- New arterial roads (indicative)
- Collector Road (existing & upgrades) with pedestrian and cycle connections
- New collector roads (indicative) with pedestrian and cycle connections
- Stream with pedestrian & cycle connections and a 10m riparian margin (Plan Change)
- Parks (indicative) (Plan Change)

Scale 1:11,000

Appendix N

Response to Further Information Request on Stormwater Matters (Version 2)

Tonkin+Taylor

Memo

To:	Mark Iszard and Carmel O'Sullivan (Healthy Waters)	Job No:	1008200.2000
From:	Tim Fisher and Charlotte Peyroux (Tonkin + Taylor)	Date:	6 April 2020
cc:	Andrew McCarthy (Oyster), Nick Roberts (Barkers)		
Subject:	Drury East (Oyster Capital) flood modelling - Response to Auckland Council Further Information Request on Stormwater Matters (Version 2)		

This memo responds to the Auckland Council Further Information Request (FIR) for the Oyster Capital Plan Change Area (also referred to as 116 Waihoehoe Road and surrounds). While the three Drury East Plan Change Areas (Kiwi Property, Fulton Hogan and Oyster Capital) work towards an integrated stormwater management approach, the Oyster Capital development is located within a different catchment to the other developments and therefore a different flood assessment approach is needed because of the different catchment issues, scale of development and availability of modelling tools.

The flood assessment approach adopted below supplements the *Drury East (Kiwi and Fulton Hogan) flood modelling – response to Auckland Council modelling requests* memo prepared by Tonkin + Taylor on 19 February 2020. That memo demonstrated that existing flooding in Drury was not worsened by those developments and that a pass-forward approach was suitable. The same principles apply for the Oyster Plan Change Area, which is similarly located at the bottom of the large adjacent Slippery Creek catchment.

This memo builds on the *Response to Auckland Council Further Information Request on Stormwater Matters for Drury East* memo prepared by Woods and Tonkin + Taylor on 25 March 2020.

The structure of the memo is as follows:

- Background
- Flooding effects
- Stream erosion
- Water quality

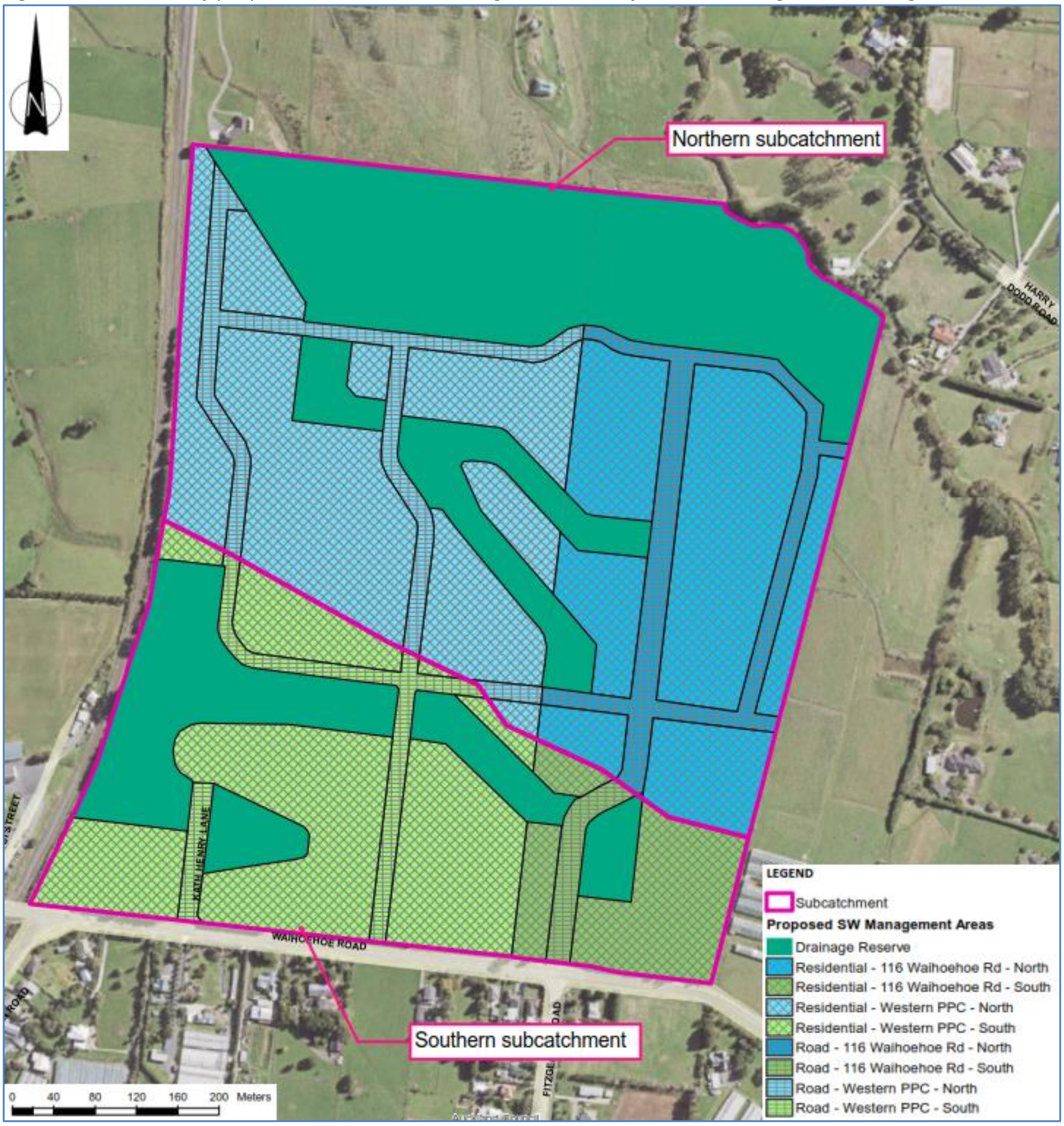
How the response relates to the Auckland Council FIR table is summarised in Appendix A.

1 Background

The Oyster Capital development comprises two sub-catchments (refer Figure 1.1), which lie at the downstream end of the Slippery Creek catchment and within the Slippery Creek flood plain. These two sub-catchments have different catchment opportunities and constraints and therefore require separate stormwater and flood management approaches. The proposed approaches outlined in the 116 Waihoehoe Road and surrounds Stormwater Management Plan (SMP) prepared by Tonkin + Taylor in August 2019 are:

- The northern sub-catchment will allow for quick conveyance of flows into Wahoihoi Stream to pass flows forward before flows of upper catchments reaches the area.
- The southern sub-catchment will detain flows of up to 100 year Annual Recurrence Interval (ARI) storms within the sub-catchment to mitigate flooding within the western part of the plan change area and further downstream.

Figure 1.1: Division of proposed stormwater management areas for the discharge to receiving environment



2 Flooding effects

We understand that Auckland Council want additional assessment for the potential flooding caused by a 'development only flood scenario' in accordance with Item 5 of the *Further Information Request (FIR) - Drury East Plan Changes* included in the *Healthy Waters Review of Adequacy of Information for a Private Plan Change (PPC) Request – Drury East - Fulton Hogan and Kiwi Property* memo from Auckland Council on 2 February 2020. The purpose of this assessment is to ascertain whether the development with its additional runoff causes a new flooding mechanism and effects and to confirm the suitability of the flood management approaches.

2.1 Northern sub-catchment - Proposed methodology

The *Response to Auckland Council Further Information Request on Stormwater Matters for Drury East* memo prepared by Woods and Tonkin + Taylor on 25 March 2020 demonstrates that the "pass flows forward" solution works for the Fulton Hogan and Kiwi Property developments. As the Oyster Capital development is smaller in size, albeit in the adjacent catchment, we anticipate that the peak flows generated on the northern sub-catchment as a result of the development will be negligible in comparison to the peak flows generated by the upstream catchment. Additionally, it is expected that the peak flows from the development will occur earlier than the peak of the upstream catchment, which is why it is preferable to discharge the stormwater in advance of the catchment flood peak.

This memo seeks to test this "pass flows forward" solution with the following simple approach:

- Build a HEC-HMS[1] model (hydrology model rather than full flood model) for the pre- and post-development 2, 10 and 100 year ARI rainfall events and generate development only flows.
  - Estimate 24 hour rainfall depths for 2, 10 and 100 years from the TP108 isopleths and use those totals to prepare hyetographs using TP108 temporal distribution.
- Compare post-development flows to:
  a Pre-development flows from the site.
  b Slippery Creek model flows at the Slippery and Waihoihoi culvert crossings under the railway to show the much smaller size of the development flows compared to the catchment flows.
  c Compare the increase in flood volume (and timing) to size/volume of the receiving flood plain to demonstrate that the development causes negligible differences in the flood levels.

2.2 Northern sub-catchment - Results

Figure 2.1 shows the northern sub-catchment development only hydrographs generated in HEC HMS and Table 1 shows the peak flow rates for the pre- and post-development 2, 10 and 100 year ARI rainfall events.

[1] Hydrologic Engineering Center – Hydrologic Modelling System software designed to simulate the complete hydrologic processes of dendritic watershed systems.

Figure 2.1 - Northern sub-catchment 'development only' hydrographs

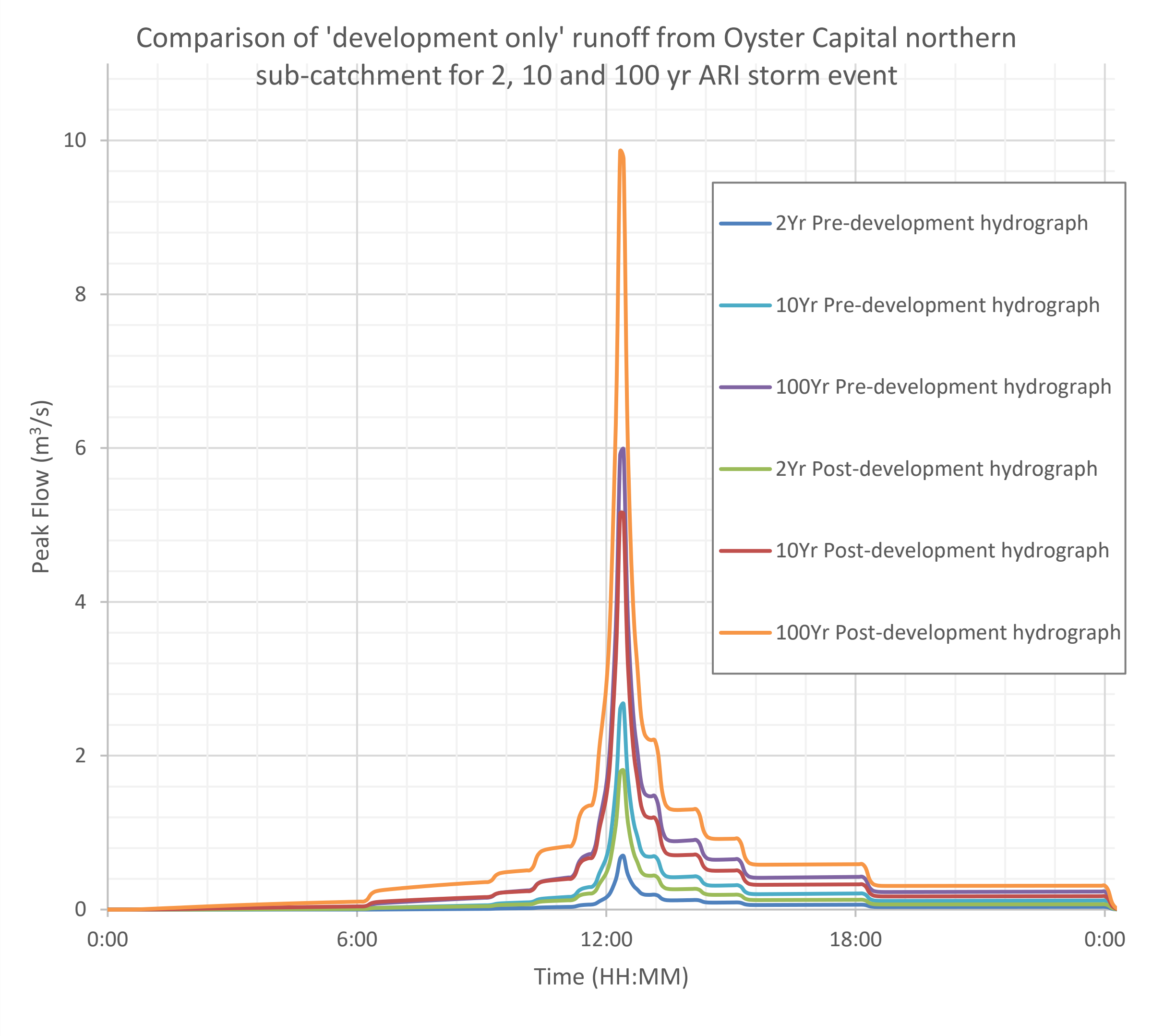


Table 1 – Peak development only flow rates from the Northern sub-catchment for the pre- and post-development 2, 10 and 100 year ARI rainfall events.

ARI rainfall event	2 Year	10 Year	100 Year
Pre-development *(m^3/s)*	0.73	2.83	6.36
Post-development *(m^3/s)*	1.92	5.50	10.46
Difference (m^3/s)	**1.19**	**2.67**	**4.10**

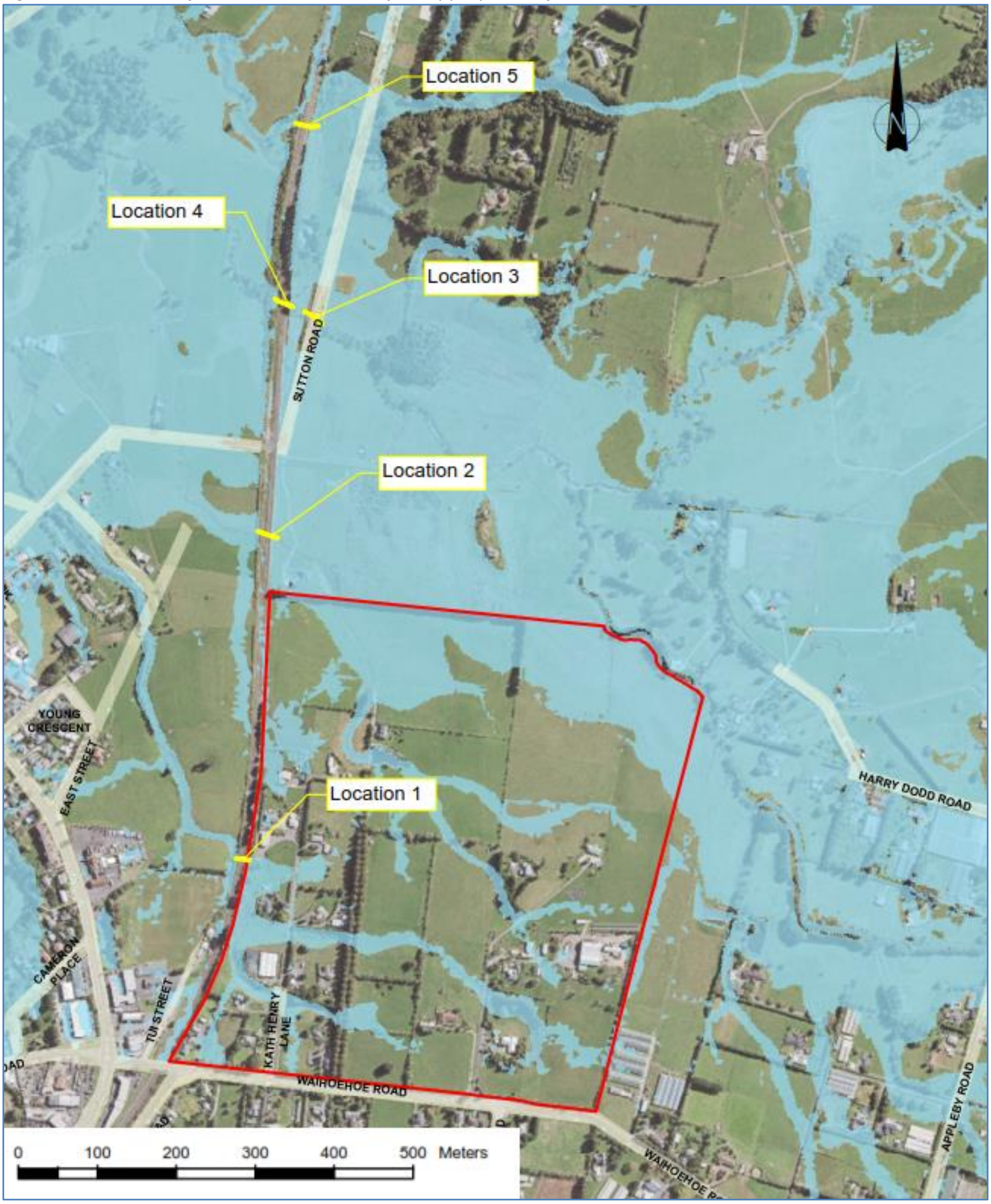
The results show that in all design rainfall events the post-development flows are almost twice that of pre-development flows.

Auckland Council has a Slippery Creek rapid flood hazard assessment model, which includes effective rainfall and major inflows from Slippery Creek, Hingaia Creek, Waihoihoi Stream, Symonds Creek, Whangapouri Creek, Ngakaroa Creek and Oira Creek, and associated tributaries complied in Infoworks ICM[2] .

[2] Infoworks Integrated all source Catchment Modelling software

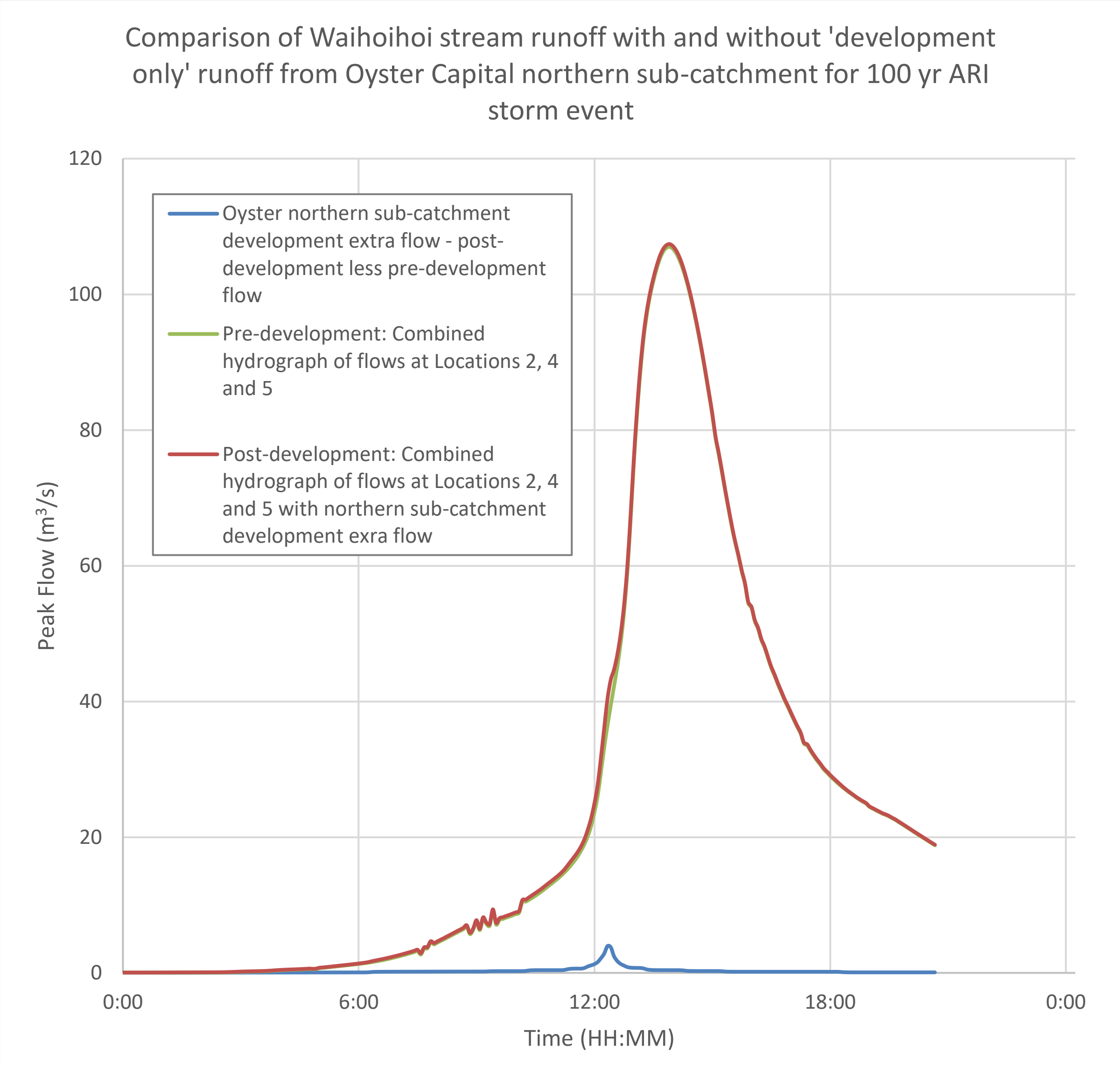
A number of design scenarios and locations were assessed using this model during the Slippery Creek flood hazard assessments to support the SMP (refer Section 5 of the SMP). The baseline scenario for this assessment is the 100 year ARI existing development condition (no future development modelled within the upstream Future Urban Zone, no climate change) as this is what is there now. Downstream of the site the Southern Railway Line crosses the floodplain and this a good location to compare flows. For the Oyster northern sub-catchment, the receiving flood plan is large and wide and in the 100 year event the wider catchment drains through three railway structures at Locations 2, 4 and 5 shown in Figure 2.2 below.

Figure 2.2: Location of model cross-sections for Slippery Creek flood hazard assessments included in the SMP



A combined hydrograph of flows at those three locations is shown at “Pre-development” in Figure 2.3. The “Post-development” flow is based on the “extra flow” from the Oyster northern sub-catchment development (represented by the post-development less the pre-development flows from the site) added “Pre-development” hydrograph. Only “extra flow” from the development is added because the “Pre-development” case already accounts for the greenfield runoff from the Oyster Plan Change Area.

Figure 3.3 – Waihoihoi stream hydrographs with and without ‘development only’ flows.



The “Pre-development” and “Post-development” hydrographs almost look identical, except for a very negligible change in flow at approximately 12:20pm, which corresponds with the developments peak flows. This change occurs prior to the catchment peak flow at 1:50pm.

The pass forward flows approach is best as otherwise the additional runoff adds to the flood peak. The volume of additional flow from the development is 21,100m^3 and surface area of the Waihoehoe 100 year flood plain between the development and the Slippery Creek confluence is approximately 984,000m^2. This suggests that the maximum change that the Oyster northern sub-catchment development extra flow could have on the 100 year flood level is 21 mm if the peaks coincided, which is best mitigated if the proposed pass forward flow approach is adopted.

The minimal change shown on the hydrographs in Figure 2.3 confirms that the northern sub-catchment development “extra flows” are negligible and occur earlier in comparison to the peak flows generated by the upstream catchment. This confirms that the development should adopt a “passing flows forward” approach. Flows from the site will be discharged directly into Waihoihoi Stream and Slippery Creek as quickly as possible in order to pass them through before the peak flows from the upper reaches of the catchment reach the area.

2.3 Southern sub-catchment

For the southern sub-catchment, multiple attenuation basins are proposed to achieve staged attenuation to ensure post-development flow match pre-development flows for the 1 in 100 year ARI storm event, as well as for more frequent events such as the 1 in 2 and 1 in 10 year ARI storms. The controlled release of stormwater discharge will match pre-development conditions, thereby minimising the impact of increased peak flow from the development on the downstream environments. The attenuation devices will be designed at Resource Consent.

3 Stream Erosion

Auckland Council has provided an Erosion Stream Risk Tool as a mechanism to analyse stream erosion risk resulting from the development. It requires an understanding of the stream cross section, bed slope and critical shear stress, inter alia, as inputs to the assessment. The Auckland Council Infoworks model uses a bathymetric surface (3D terrain model based on LiDAR) with structures. It does not include a channel survey and therefore we do not have stream cross sections from the model to use in the erosion assessment.

We are also working through a number of other challenges with the Erosion Stream Risk Tool (i.e. assumptions for the critical shear stress of the channel in the absence of site-specific testing) and concerns with the effectiveness of the model at predicting erosion potential. These are documented in the Response to Auckland Council Further Information *Request on Stormwater Matters for Drury East – Stream Erosion Risk Assessment for Hingaia Catchment* memo prepared by Tonkin + Taylor and Woods on 3 April 2020.

We recommend that Oyster refers to the Stream Erosion Assessment for the Hingaia catchment and waits for feedback on that before progressing with this assessment. We can say that SMAF 1 hydrological mitigation will be the minimum. Any additional mitigation for stream erosion can be developed as the SMP progresses based on site observations of erosion and/or improved erosion modelling when the data is available and the methodology is improved.

4 Water quality

Refer to response in *Auckland Council Further Information Request on Stormwater Matters for Drury East* memo prepared by Woods and Tonkin + Taylor on 25 March 2020.

Appendix A:

Assessment category		Comments /requests	Reason for comments/requests	Responses
No	**Category**			
01	Stormwater Planning	Please provide an assessment of how the proposed plan changes meet the outcomes of the NPS-FM and the related matters in the AUP Regional Policy Statement. How does the s32 report acknowledge and address methods to meet regional policy statement objectives that are relevant to the plan change areas, including B7.3 E1.3.8 and E1.310? Please update if necessary.	The policy framework acknowledged in the s32 reports primarily addresses matters relating to urban development and the provision of land for urban growth. While there is some acknowledgement of the NPS-FM, this appears to be limited to how streams and other natural hydrological features are recognized in the proposed plan changes. NPS-FM Objectives and Policies relating to water quality, and Regional Policy Statement objectives and policies for water quality and integrated stormwater management, do not appear to be addressed. The process and outcome of urbanising land has significant environmental effects both immediately and into the future. There appears to be little acknowledgement of these effects on the receiving environment (which the NPS and RPS objectives and policies refer to) or adequate demonstration of how these effects will be mitigated through the proposed precinct plan provisions and proposed stormwater management plan.	Refer to Planning and Ecology Response
02	Stormwater quality	Please clarify how objectives in the AUP for water quality will be met. The Planning report (pg46) emphasises that high contaminant generating roads and carparks will be treated (treatment of these roads is covered by region wide rules in Chapter E9 AUP). However, it is unclear how many roads are anticipated to meet the thresholds to trigger E9 rules and if additional roads should be treated to meet the proposed objective. There is also reference in the Drury East – Fulton Hogan request (page 46) to a treatment train approach and secondary treatment but it is unclear if this is part of the approach to treat high contaminant generating roads or is an additional response applied to all roads to meet objectives E1.3.8 and E1.3.8 and meet Schedule 4 NDC requirements greenfield developments. A matrix showing what tools will be used in what proposed land use zone to avoid any adverse effects on water quality should be included in the SMPs as part of identifying how adverse effects will be mitigated and how these achieve AUP policies for water quality.	AUP E1.3.8 directs to avoid as far as practicable the adverse effects of development on water quality. AUP Objective E1.2.3 and Policies 1.3.2 and 1.3.3 directly implements the NPS-FM 2017. Avoiding adverse effects on water quality should be demonstrated in the planning report and SMP. The creation of adverse effects on water quality due to contaminants in runoff from impervious surfaces is an effect of urban land use. Therefore, this should be part of the S32 report and AEE. Reliance on region wide rules in the AUP may not be sufficient to meet AUP policies for this plan change area and for the associated receiving environment which is a Significant Ecological Area; some of which (such as Drury Creek Islands) have further restoration and enhancement underway. Additional detail on the methods for treating stormwater to avoid adverse effects may also be sought prior to notification of this plan change as part of the SMP in support of stormwater discharge authorisation.	Refer to Section 1: Stormwater management of Auckland Council. Further Information Request on Stormwater Matters for Drury East memo prepared by Woods and Tonkin + Taylor on 25 March 2020.
03	Water quality	Please more fully describe how the water quality policies in E1 will be achieved, and what options have been considered to meet the policies.	The current descriptions in the SMPs are confusing and appear to rely solely on the region-wide rules. Given the AUP policy directives for greenfield development and the sensitivity of the receiving environment, additional treatment (such as a treatment train approach) may be justified.	Refer to Planning and Ecology Response
04	Hydrology Mitigation	Please provide an assessment of the degree to which SMAF1 avoids or remedies changes in hydrology which will result from the urban land uses proposed in the plan changes. A Regional Erosion Threshold Metric risk assessment identifies areas at risk of erosion and provides some quantification of the amount of erosion caused, however it does not address how effects will be avoided, remedied or mitigated. Identification of measures to avoid effects and mitigate should also be made and the BSTEM model is appropriate for this task. More detail on this tool is being supplied to the applicants.	The AUP states that for greenfield areas adverse effects of development shall be avoided as far as practicable or otherwise remedied or mitigated and this includes changes in hydrology (Policy E1.3.8). No SMAF controls were applied to greenfield areas in the AUP as it was expected that an assessment on what hydrological mitigation is required would be undertaken as part of plan change process. The Drury-Opaheke Structure Plan SMP also identified that hydrological mitigation and erosion assessments should be completed at the scale of the plan changes so that the particular effects of proposed land uses would be identified, and mitigation measures would be determined, at scale proportionate to the proposed activities and effects.	We recommend that Oyster refers to the Drury East (Oyster Capital) flood modelling - Response to Auckland Council Further Information Request on Stormwater Matters (Version 2) Stream Erosion Assessment for the Hingaia catchment and waits for feedback on that before progressing with this assessment
05	Flooding	Please address the matters identified and discussed in the memo to Healthy Waters from Tonkin + Taylor dated 19 February 2020. We note that all applicants need to explain what the effect cumulatively across developments will be on the Drury township flooding and parts of the catchment that interact with the Slippery Creek floodplain.	Flooding in the Hingaia catchment is complex and needs to be considered in conjunction with other plan changes proposed for the area; acknowledge any interactions with other catchments and the cumulative impact of potential development in the surrounding areas and the point of discharge downstream. Understanding the impact of development on the flood plain within the plan change sites and impacts downstream is necessary to evaluate the plan change proposal and ensure any potential flood effects are avoided or mitigated.	Refer to Section 2 of this memo

			Several discussions between Healthy Waters and the applicant's planners have occurred on the best way to approach flood modelling and the memo from T+T dated 19 February 2020 reflects our agreement with regard to flooding matters.	
06	Riparian Margins	Please explain why a 10m wide riparian margin is proposed when the Drury-Opaheke Structure Plan Stormwater Management Plan identified a 20m riparian margin as being appropriate. No evaluation of these two options is provided including their consistency with the objectives and policies of the AUP.	A 20m wide riparian margin was consulted on as part of the Drury-Opaheke Structure Plan 'Blue Green Network' and associated the Stormwater Management Plan. The purpose of the wide margin is to provide an ecological corridor and provide a buffer for the stream noting that stream meander may occur due to erosion. These benefits support achievement of AUP objectives and policies. A rationale for a lesser width margin is not provided in the s32 report.	Refer to Planning and Ecology Response
07	Ecological corridors and Blue Green network.	Please clarify what the ecological corridors are and how they contribute to meeting objectives and policies of the AUP. They are mentioned briefly but there is no description on how these align to the Blue Green network identified in the Drury-Opaheke Structure Plan, nor are the streams or corridors noted specifically in the precinct plan or stormwater management plan. Planning provisions to enable the ecological corridor are not provided in the precinct plan nor is an assessment given in s32 assessment reports.	A blue green network utilising the natural hydrological features of existing streams was identified as part of Auckland Council's Drury-Opaheke Structure Plan. If and how streams are used in this way has implications in relation to: Identifying the impact of urban development on streams (if they are intended to be retained or not). Keeping flood conveyance channels available as part of the 'pass-it-forward' approach outlined in the Drury-Opaheke Structure Plan. Mitigation of effects anticipated by urban development, including hydrology mitigation. The precinct plan and stormwater management plan lack information on the ecological corridors making their purpose for achieving AUP objectives and policies or as part of effects mitigation unclear. We note public access such as walkways/cycle network need to be located outside riparian setbacks and the minimum width required to accommodate water sensitive devices.	Refer to Planning and Ecology Response
08	Development staging	Please explain if and how the precinct plan is to manage flood risks (such as staging of development in conjunction with flood mitigation measures). Flood attenuation is proposed in the SMP but there are no precinct plan provisions to ensure that flood attenuation is provided or when it would be appropriate to not have flood attenuation.	The plan change areas are areas of significant flood hazard and developing the plan change areas could increase the flooding downstream in the existing Drury township. Fulton Hogan, in their SMP page 6 propose as part of their flood management approach for Zone A to provide: *Temporary flood attenuation to pre-develop flow – to enable development in advance of culvert upgrades* There is no indication in their SMP or precinct plan of when this would be provided or when it will not be provided. The attenuation relates to current culvert capacity at Great South Rd and Flannagan Rd. These culverts will likely need upgrading in the future when road upgrades are done but this requirement is not linked to transport infrastructure upgrades or backed up by analysis of culvert capacity.	Not applicable to this development