# APPENDIX D

## CHAINAGE FIGURES

SECTOR 1

SECTOR 2B

SECTOR 2A

SECTOR 3A

SECTOR 3B

SECTOR 4A

SECTOR 4B

SECTOR 5A

SECTOR 5B

SECTOR 6A

SECTOR 6B

NORTH

**Legend**

- City of Rockingham Boundary
- Sector Boundary Line
- Chainage Line

Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



Date
18/12/2017

Size
A3

Scale
1:65,000

0 0.5 1 1.5 2 km

# CHAINAGE MAP OVERVIEW

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING

CITY OF ROCKINGHAM

59918065-GS-001-CHAINAGEMAPOVERVIEW 01

DATE PLOTTED:18/12/2017 11:43:02 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-ChainageMapOverview.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
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Web: www.cardno.com.au



city of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 1 CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR1_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 8:58:12 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector1_ChainageMap.mxd


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City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 2A CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR2A_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 8:58:19 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector2A_ChainageMap.mxd


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Web: www.cardno.com.au



City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 2B CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR2B_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 8:58:04 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector2B_ChainageMap.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
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Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 3A CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR3A_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 8:58:40 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector3A_ChainageMap.mxd


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Coordinate System: GDA 1994 MGA Zone 50

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Web: www.cardno.com.au



City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 3B CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR3B_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 8:58:31 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector3B_ChainageMap.mxd


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Coordinate System: GDA 1994 MGA Zone 50

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Web: www.cardno.com.au



City of Rockingham

Date
18/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 4A CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR4A_CHAINAGEMAP 01

DATE PLOTTED:18/12/2017 10:56:57 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector4A_ChainageMap.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 4B CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR4B_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 9:12:40 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector4B_ChainageMap.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
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City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

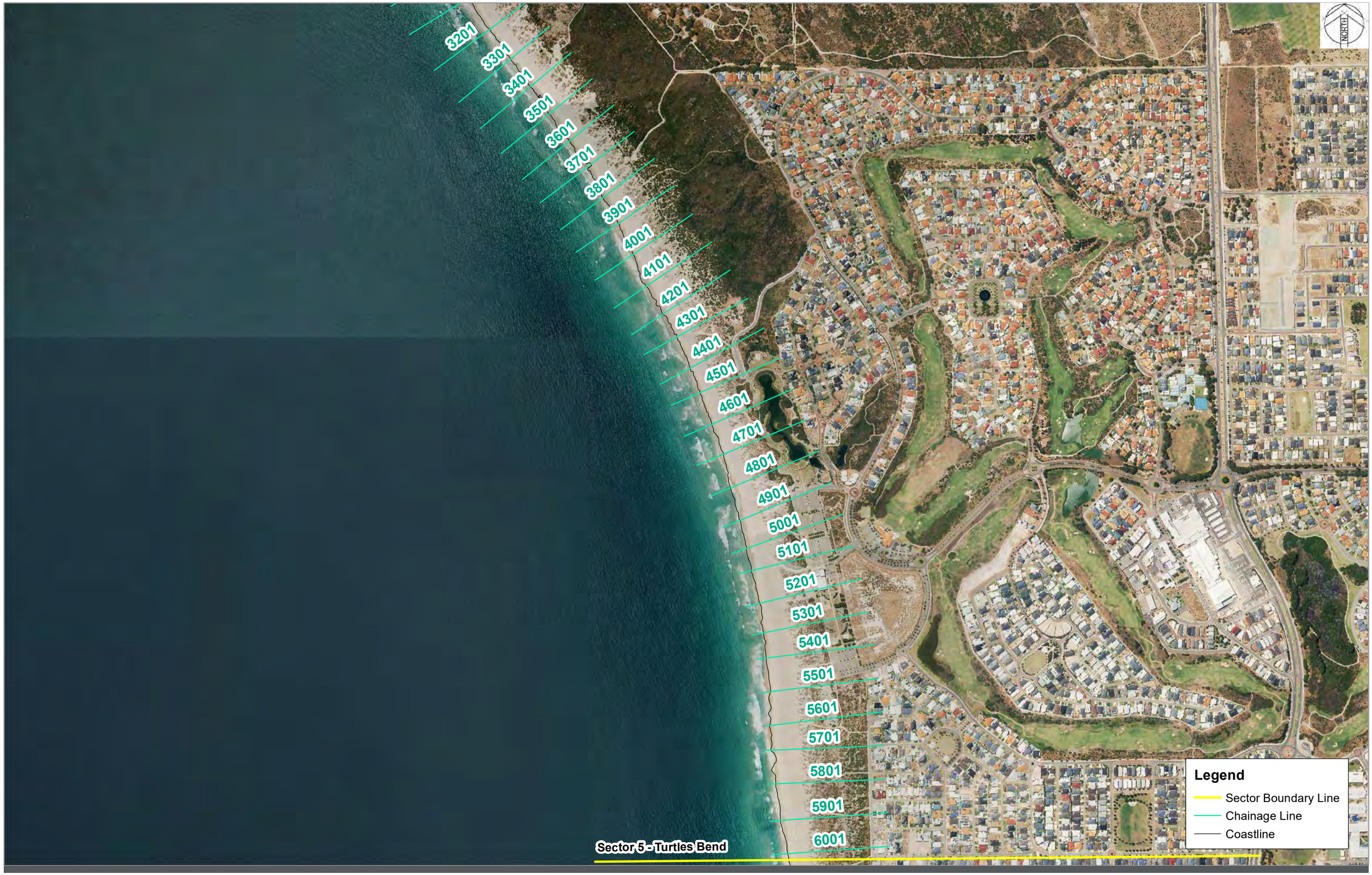
0 75 150 225 300
Meters

# SECTOR 5A CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR5A_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 9:13:05 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector5A_ChainageMap.mxd




Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

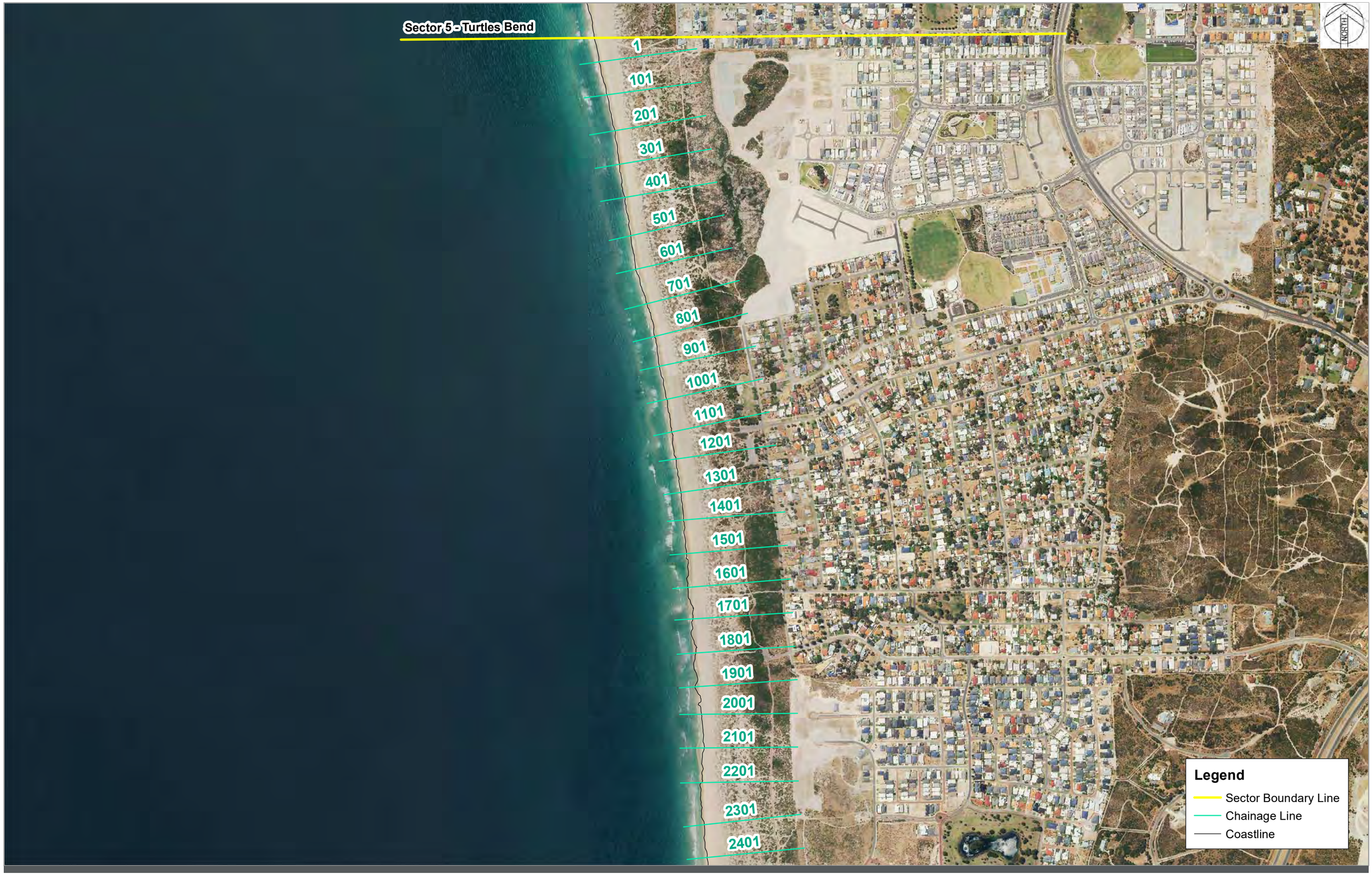
0 75 150 225 300
Meters

# SECTOR 5B CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR5B_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 9:12:49 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector5B_ChainageMap.mxd




Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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Web: www.cardno.com.au



City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 6A CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR6A_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 9:12:31 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector6A_ChainageMap.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
20/12/2017

Size
A3

Scale
1:10,000

0 75 150 225 300
Meters

# SECTOR 6B CHAINAGE MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR6B_CHAINAGEMAP 01

DATE PLOTTED:20/12/2017 9:12:56 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ChainageMaps\59918065-GS-001-Sector6B_ChainageMap.mxd

# APPENDIX E

## COASTAL EROSION ALLOWANCES

| Sector Number | Sector Chainage (m) | HSD Elev | Present Day (2017) Total (S1 only) | 2030 S1 | 2030 S2 | 2030 S3 | 2030 Uncertainty | 2030 Total (m) | 2070 S1 | 2070 S2 | 2070 S3 | 2070 Uncertainty | 2070 Total (m) | 2110 S1 | 2110 S2 | 2110 S3 | 2110 Uncertainty | 2110 Total (m) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | | **20** | 20 | 7 | 5 | 3 | **34** | 20 | 27 | 38 | 11 | **95** | 20 | 47 | 90 | 19 | **175** |
| 1 | 101 | 1.75 | **20** | 20 | 12 | 5 | 3 | **39** | 20 | 48 | 38 | 11 | **116** | 20 | 84 | 90 | 19 | **212** |
| 1 | 201 | | **20** | 20 | 7 | 5 | 3 | **34** | 20 | 27 | 38 | 11 | **95** | 20 | 47 | 90 | 19 | **175** |
| 1 | 301 | | **20** | 20 | 7 | 5 | 3 | **34** | 20 | 27 | 38 | 11 | **95** | 20 | 47 | 90 | 19 | **175** |
| 1 | 401 | | **17** | 17 | 7 | 5 | 3 | **32** | 17 | 28 | 38 | 11 | **94** | 17 | 50 | 90 | 19 | **175** |
| 1 | 501 | | **17** | 17 | 7 | 5 | 3 | **32** | 17 | 30 | 38 | 11 | **96** | 17 | 53 | 90 | 19 | **178** |
| 1 | 601 | 1.78 | **17** | 17 | 8 | 5 | 3 | **32** | 17 | 32 | 38 | 11 | **97** | 17 | 56 | 90 | 19 | **181** |
| 1 | 701 | | **17** | 17 | 0 | 5 | 3 | **25** | 17 | 0 | 38 | 11 | **66** | 17 | 0 | 90 | 19 | **126** |
| 1 | 801 | | **17** | 17 | 0 | 5 | 3 | **25** | 17 | 0 | 38 | 11 | **66** | 17 | 0 | 90 | 19 | **126** |
| 1 | 901 | | **8** | 8 | 0 | 5 | 3 | **16** | 8 | 0 | 38 | 11 | **57** | 8 | 0 | 90 | 19 | **117** |
| 1 | 1001 | | **8** | 8 | 0 | 5 | 3 | **16** | 8 | 0 | 38 | 11 | **57** | 8 | 0 | 90 | 19 | **117** |
| 1 | 1101 | | **8** | 8 | 0 | 5 | 3 | **16** | 8 | 0 | 38 | 11 | **57** | 8 | 0 | 90 | 19 | **117** |
| 1 | 1201 | 1.68 | **8** | 8 | 0 | 5 | 3 | **16** | 8 | 0 | 38 | 11 | **57** | 8 | 0 | 90 | 19 | **117** |
| 1 | 1301 | | **8** | 8 | 0 | 5 | 3 | **16** | 8 | 0 | 38 | 11 | **57** | 8 | 0 | 90 | 19 | **117** |
| 1 | 1401 | | **8** | 8 | 0 | 5 | 3 | **16** | 8 | 0 | 38 | 11 | **57** | 8 | 0 | 90 | 19 | **117** |
| 1 | 1501 | | **8** | 8 | 3 | 5 | 3 | **19** | 8 | 13 | 38 | 11 | **70** | 8 | 23 | 90 | 19 | **140** |
| 1 | 1601 | | **8** | 8 | 7 | 5 | 3 | **22** | 8 | 27 | 38 | 11 | **83** | 8 | 47 | 90 | 19 | **163** |
| 1 | 1701 | | **12** | 12 | 7 | 5 | 3 | **26** | 12 | 27 | 38 | 11 | **87** | 12 | 47 | 90 | 19 | **167** |
| 1 | 1801 | | **12** | 12 | 7 | 5 | 3 | **26** | 12 | 27 | 38 | 11 | **87** | 12 | 47 | 90 | 19 | **167** |
| 1 | 1901 | | **12** | 12 | 7 | 5 | 3 | **26** | 12 | 27 | 38 | 11 | **87** | 12 | 47 | 90 | 19 | **167** |
| 1 | 2001 | 1.73 | **12** | 12 | 7 | 5 | 3 | **26** | 12 | 27 | 38 | 11 | **87** | 12 | 47 | 90 | 19 | **167** |
| 1 | 2101 | | **12** | 12 | 7 | 5 | 3 | **26** | 12 | 27 | 38 | 11 | **87** | 12 | 47 | 90 | 19 | **167** |
| 1 | 2201 | | **12** | 12 | 7 | 5 | 3 | **26** | 12 | 27 | 38 | 11 | **87** | 12 | 47 | 90 | 19 | **167** |
| 1 | 2301 | | **12** | 12 | 7 | 5 | 3 | **26** | 12 | 27 | 38 | 11 | **87** | 12 | 47 | 90 | 19 | **167** |
| 1 | 2401 | | **16** | 16 | 6 | 5 | 3 | **29** | 16 | 24 | 38 | 11 | **88** | 16 | 42 | 90 | 19 | **166** |
| 1 | 2501 | | **16** | 16 | 5 | 5 | 3 | **29** | 16 | 21 | 38 | 11 | **86** | 16 | 37 | 90 | 19 | **162** |
| 1 | 2601 | | **16** | 16 | 5 | 5 | 3 | **28** | 16 | 20 | 38 | 11 | **84** | 16 | 35 | 90 | 19 | **159** |
| 1 | 2701 | 1.75 | **16** | 16 | 5 | 5 | 3 | **28** | 16 | 19 | 38 | 11 | **83** | 16 | 33 | 90 | 19 | **157** |
| 1 | 2801 | | **16** | 16 | 4 | 5 | 3 | **28** | 16 | 17 | 38 | 11 | **82** | 16 | 30 | 90 | 19 | **155** |
| 1 | 2901 | | **16** | 16 | 4 | 5 | 3 | **28** | 16 | 16 | 38 | 11 | **81** | 16 | 28 | 90 | 19 | **153** |
| 1 | 3001 | | **16** | 16 | 4 | 5 | 3 | **28** | 16 | 16 | 38 | 11 | **81** | 16 | 28 | 90 | 19 | **153** |
| 2.1 | 1 | | **12** | 12 | 0 | 5 | 3 | **20** | 12 | 0 | 38 | 11 | **61** | 12 | 0 | 90 | 19 | **121** |
| 2.1 | 101 | | **12** | 12 | 1 | 5 | 3 | **21** | 12 | 5 | 38 | 11 | **66** | 12 | 9 | 90 | 19 | **130** |
| 2.1 | 201 | | **12** | 12 | 3 | 5 | 3 | **22** | 12 | 11 | 38 | 11 | **71** | 12 | 19 | 90 | 19 | **139** |
| 2.1 | 301 | | **12** | 12 | 2 | 5 | 3 | **22** | 12 | 9 | 38 | 11 | **70** | 12 | 16 | 90 | 19 | **137** |
| 2.1 | 401 | | **12** | 12 | 2 | 5 | 3 | **22** | 12 | 8 | 38 | 11 | **69** | 12 | 14 | 90 | 19 | **135** |
| 2.1 | 501 | 1.72 | **12** | 12 | 2 | 5 | 3 | **21** | 12 | 7 | 38 | 11 | **67** | 12 | 12 | 90 | 19 | **132** |
| 2.1 | 601 | | **12** | 12 | 1 | 5 | 3 | **21** | 12 | 5 | 38 | 11 | **66** | 12 | 9 | 90 | 19 | **130** |
| 2.1 | 701 | | **12** | 12 | 4 | 5 | 3 | **24** | 12 | 16 | 38 | 11 | **77** | 12 | 28 | 90 | 19 | **149** |
| 2.1 | 801 | | **12** | 12 | 0 | 5 | 3 | **20** | 12 | 0 | 38 | 11 | **61** | 12 | 0 | 90 | 19 | **121** |
| 2.1 | 901 | | **12** | 12 | 0 | 5 | 3 | **20** | 12 | 0 | 38 | 11 | **61** | 12 | 0 | 90 | 19 | **121** |
| 2.1 | 1001 | | **12** | 12 | 0 | 5 | 3 | **20** | 12 | 0 | 38 | 11 | **61** | 12 | 0 | 90 | 19 | **121** |
| 2.1 | 1101 | | **12** | 12 | 0 | 5 | 3 | **20** | 12 | 0 | 38 | 11 | **61** | 12 | 0 | 90 | 19 | **121** |
| 2.1 | 1201 | | **9** | 9 | 0 | 5 | 3 | **17** | 9 | 0 | 38 | 11 | **58** | 9 | 0 | 90 | 19 | **118** |
| 2.1 | 1301 | | **9** | 9 | 0 | 5 | 3 | **17** | 9 | 0 | 38 | 11 | **58** | 9 | 0 | 90 | 19 | **118** |
| 2.1 | 1401 | | **9** | 9 | 0 | 5 | 3 | **17** | 9 | 0 | 38 | 11 | **58** | 9 | 0 | 90 | 19 | **118** |
| 2.1 | 1501 | 1.7 | **9** | 9 | 0 | 5 | 3 | **17** | 9 | 0 | 38 | 11 | **58** | 9 | 0 | 90 | 19 | **118** |
| 2.1 | 1601 | | **9** | 9 | 0 | 5 | 3 | **17** | 9 | 0 | 38 | 11 | **58** | 9 | 0 | 90 | 19 | **118** |
| 2.1 | 1701 | | **9** | 9 | 2 | 5 | 3 | **19** | 9 | 8 | 38 | 11 | **66** | 9 | 14 | 90 | 19 | **132** |
| 2.1 | 1801 | | **9** | 9 | 4 | 5 | 3 | **21** | 9 | 16 | 38 | 11 | **74** | 9 | 28 | 90 | 19 | **146** |
| 2.1 | 1901 | | **9** | 9 | 3 | 5 | 3 | **19** | 9 | 11 | 38 | 11 | **68** | 9 | 19 | 90 | 19 | **136** |
| 2.1 | 2001 | | **13** | 13 | 2 | 5 | 3 | **23** | 13 | 8 | 38 | 11 | **70** | 13 | 14 | 90 | 19 | **136** |
| 2.1 | 2101 | | **13** | 13 | 1 | 5 | 3 | **22** | 13 | 5 | 38 | 11 | **67** | 13 | 9 | 90 | 19 | **131** |
| 2.1 | 2201 | 1.69 | **13** | 13 | 1 | 5 | 3 | **21** | 13 | 3 | 38 | 11 | **64** | 13 | 5 | 90 | 19 | **126** |
| 2.1 | 2301 | | **13** | 13 | 0 | 5 | 3 | **21** | 13 | 0 | 38 | 11 | **62** | 13 | 0 | 90 | 19 | **122** |
| 2.1 | 2401 | | **13** | 13 | 0 | 5 | 3 | **21** | 13 | 0 | 38 | 11 | **62** | 13 | 0 | 90 | 19 | **122** |
| 2.1 | 2501 | | **4** | 4 | 1 | 5 | 3 | **13** | 4 | 5 | 38 | 11 | **58** | 4 | 9 | 90 | 19 | **122** |
| 2.1 | 2601 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.1 | 2701 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.1 | 2801 | 1.55 | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.1 | 2901 | | **4** | 4 | 1 | 5 | 3 | **13** | 4 | 5 | 38 | 11 | **58** | 4 | 9 | 90 | 19 | **122** |
| 2.1 | 3001 | | **4** | 4 | 1 | 5 | 3 | **13** | 4 | 5 | 38 | 11 | **58** | 4 | 9 | 90 | 19 | **122** |
| 2.1 | 3101 | | **4** | 4 | 5 | 5 | 3 | **17** | 4 | 21 | 38 | 11 | **74** | 4 | 37 | 90 | 19 | **150** |
| 2.1 | 3201 | | **5** | 5 | 7 | 5 | 3 | **19** | 5 | 27 | 38 | 11 | **80** | 5 | 47 | 90 | 19 | **160** |
| 2.1 | 3301 | | **5** | 5 | 4 | 5 | 3 | **17** | 5 | 16 | 38 | 11 | **70** | 5 | 28 | 90 | 19 | **142** |
| 2.1 | 3401 | 1.9 | **5** | 5 | 4 | 5 | 3 | **17** | 5 | 16 | 38 | 11 | **70** | 5 | 28 | 90 | 19 | **142** |
| 2.1 | 3501 | | **5** | 5 | 4 | 5 | 3 | **17** | 5 | 16 | 38 | 11 | **70** | 5 | 28 | 90 | 19 | **142** |
| 2.1 | 3601 | | **5** | 5 | 4 | 5 | 3 | **17** | 5 | 16 | 38 | 11 | **70** | 5 | 28 | 90 | 19 | **142** |
| 2.2 | 1 | | **13** | 13 | 10 | 5 | 3 | **31** | 13 | 42 | 38 | 11 | **104** | 13 | 74 | 90 | 19 | **196** |
| 2.2 | 101 | | **13** | 13 | 5 | 5 | 3 | **26** | 13 | 21 | 38 | 11 | **83** | 13 | 37 | 90 | 19 | **159** |
| 2.2 | 201 | | **13** | 13 | 17 | 5 | 3 | **38** | 13 | 69 | 38 | 11 | **131** | 13 | 121 | 90 | 19 | **243** |
| 2.2 | 301 | | **13** | 13 | 26 | 5 | 3 | **47** | 13 | 106 | 38 | 11 | **168** | 13 | 186 | 90 | 19 | **308** |
| 2.2 | 401 | 1.95 | **13** | 13 | 26 | 5 | 3 | **47** | 13 | 106 | 38 | 11 | **168** | 13 | 186 | 90 | 19 | **308** |
| 2.2 | 501 | | **13** | 13 | 26 | 5 | 3 | **47** | 13 | 106 | 38 | 11 | **168** | 13 | 186 | 90 | 19 | **308** |
| 2.2 | 601 | | **13** | 13 | 46 | 5 | 3 | **66** | 13 | 186 | 38 | 11 | **247** | 13 | 326 | 90 | 19 | **447** |
| 2.2 | 701 | | **13** | 13 | 37 | 5 | 3 | **57** | 13 | 150 | 38 | 11 | **212** | 13 | 263 | 90 | 19 | **385** |
| 2.2 | 801 | | **29** | 29 | 28 | 5 | 3 | **65** | 29 | 114 | 38 | 11 | **192** | 29 | 201 | 90 | 19 | **338** |
| 2.2 | 901 | 1.93 | **29** | 29 | 20 | 5 | 3 | **56** | 29 | 80 | 38 | 11 | **157** | 29 | 140 | 90 | 19 | **277** |
| 2.2 | 1001 | | **29** | 29 | 7 | 5 | 3 | **43** | 29 | 27 | 38 | 11 | **104** | 29 | 47 | 90 | 19 | **184** |
| 2.3 | 50 | | **29** | 29 | 1 | 5 | 3 | **38** | 29 | 5 | 38 | 11 | **83** | 29 | 9 | 90 | 19 | **147** |
| 2.4 | 1 | | **41** | 41 | 7 | 5 | 3 | **55** | 41 | 27 | 38 | 11 | **116** | 41 | 47 | 90 | 19 | **196** |

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2.4 | 101 | 2.75 | **41** | 41 | 7 | 5 | 3 | **55** | 41 | 27 | 38 | 11 | **116** | 41 | 47 | 90 | 19 | **196** |
| 2.4 | 201 | | **41** | 41 | 0 | 5 | 3 | **49** | 41 | 0 | 38 | 11 | **90** | 41 | 0 | 90 | 19 | **150** |
| 2.4 | 301 | | **41** | 41 | 0 | 5 | 3 | **49** | 41 | 0 | 38 | 11 | **90** | 41 | 0 | 90 | 19 | **150** |
| 2.4 | 401 | | **41** | 41 | 0 | 5 | 3 | **49** | 41 | 0 | 38 | 11 | **90** | 41 | 0 | 90 | 19 | **150** |
| 2.5 | 1 | 2.31 | **27** | 27 | 7 | 5 | 3 | **41** | 27 | 27 | 38 | 11 | **102** | 27 | 47 | 90 | 19 | **182** |
| 2.5 | 101 | | **27** | 27 | 7 | 5 | 3 | **41** | 27 | 27 | 38 | 11 | **102** | 27 | 47 | 90 | 19 | **182** |
| 2.6 | 1 | | **27** | 27 | 1 | 5 | 3 | **36** | 27 | 5 | 38 | 11 | **81** | 27 | 9 | 90 | 19 | **145** |
| 2.6 | 101 | | **27** | 27 | 1 | 5 | 3 | **36** | 27 | 5 | 38 | 11 | **81** | 27 | 9 | 90 | 19 | **145** |
| 2.7 | 1 | 1.98 | **8** | 8 | 7 | 5 | 3 | **22** | 8 | 27 | 38 | 11 | **83** | 8 | 47 | 90 | 19 | **163** |
| 2.7 | 101 | | **8** | 8 | 3 | 5 | 3 | **18** | 8 | 11 | 38 | 11 | **67** | 8 | 19 | 90 | 19 | **135** |
| 2.7 | 201 | | **8** | 8 | 1 | 5 | 3 | **17** | 8 | 5 | 38 | 11 | **62** | 8 | 9 | 90 | 19 | **126** |
| 2.7 | 301 | | **8** | 8 | 11 | 5 | 3 | **27** | 8 | 45 | 38 | 11 | **102** | 8 | 79 | 90 | 19 | **196** |
| 2.7 | 401 | | **8** | 8 | 21 | 5 | 3 | **36** | 8 | 85 | 38 | 11 | **141** | 8 | 149 | 90 | 19 | **265** |
| 2.7 | 501 | | **8** | 8 | 17 | 5 | 3 | **33** | 8 | 69 | 38 | 11 | **126** | 8 | 121 | 90 | 19 | **238** |
| 2.7 | 601 | | **8** | 8 | 13 | 5 | 3 | **29** | 8 | 53 | 38 | 11 | **110** | 8 | 93 | 90 | 19 | **210** |
| 2.7 | 701 | | **8** | 8 | 44 | 5 | 3 | **60** | 8 | 104 | 38 | 11 | **161** | 8 | 164 | 90 | 19 | **281** |
| 2.7 | 801 | | **8** | 8 | 65 | 5 | 3 | **81** | 8 | 125 | 38 | 11 | **182** | 8 | 185 | 90 | 19 | **302** |
| 2.7 | 901 | | **8** | 8 | 33 | 5 | 3 | **48** | 8 | 93 | 38 | 11 | **149** | 8 | 153 | 90 | 19 | **269** |
| 2.7 | 1001 | 2.2 | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1101 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1201 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1301 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1401 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1501 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1601 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1701 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1801 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 1901 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 2.7 | 2001 | 2.21 | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 2.7 | 2101 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 2.7 | 2201 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 2.7 | 2301 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 1 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 101 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 201 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 301 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 401 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 501 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 601 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 701 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 801 | 1.86 | **39** | 39 | 13 | 5 | 3 | **60** | 39 | 53 | 38 | 11 | **141** | 39 | 93 | 90 | 19 | **241** |
| 3 | 901 | | **39** | 39 | 17 | 5 | 3 | **64** | 39 | 69 | 38 | 11 | **157** | 39 | 121 | 90 | 19 | **269** |
| 3 | 1001 | | **39** | 39 | 20 | 5 | 3 | **66** | 39 | 80 | 38 | 11 | **167** | 39 | 140 | 90 | 19 | **287** |
| 3 | 1101 | | **39** | 39 | 14 | 5 | 3 | **61** | 39 | 58 | 38 | 11 | **146** | 39 | 102 | 90 | 19 | **250** |
| 3 | 1201 | | **39** | 39 | 7 | 5 | 3 | **53** | 39 | 27 | 38 | 11 | **114** | 39 | 47 | 90 | 19 | **194** |
| 3 | 1301 | | **39** | 39 | 0 | 5 | 3 | **47** | 39 | 0 | 38 | 11 | **88** | 39 | 0 | 90 | 19 | **148** |
| 3 | 1401 | | **39** | 39 | 0 | 5 | 3 | **47** | 39 | 0 | 38 | 11 | **88** | 39 | 0 | 90 | 19 | **148** |
| 3 | 1501 | | **39** | 39 | 0 | 5 | 3 | **47** | 39 | 0 | 38 | 11 | **88** | 39 | 0 | 90 | 19 | **148** |
| 3 | 1601 | | **39** | 39 | 0 | 5 | 3 | **47** | 39 | 0 | 38 | 11 | **88** | 39 | 0 | 90 | 19 | **148** |
| 3 | 1701 | | **39** | 39 | 0 | 5 | 3 | **47** | 39 | 0 | 38 | 11 | **88** | 39 | 0 | 90 | 19 | **148** |
| 3 | 1801 | 1.93 | **8** | 8 | 0 | 5 | 3 | **16** | 8 | 0 | 38 | 11 | **57** | 8 | 0 | 90 | 19 | **117** |
| 3 | 1901 | | **8** | 8 | 1 | 5 | 3 | **17** | 8 | 5 | 38 | 11 | **62** | 8 | 9 | 90 | 19 | **126** |
| 3 | 2001 | | **8** | 8 | 4 | 5 | 3 | **20** | 8 | 16 | 38 | 11 | **73** | 8 | 28 | 90 | 19 | **145** |
| 3 | 2101 | | **8** | 8 | 5 | 5 | 3 | **20** | 8 | 19 | 38 | 11 | **75** | 8 | 33 | 90 | 19 | **149** |
| 3 | 2201 | 1.9 | **18** | 18 | 5 | 5 | 3 | **31** | 18 | 21 | 38 | 11 | **88** | 18 | 37 | 90 | 19 | **164** |
| 3 | 2301 | | **18** | 18 | 0 | 5 | 3 | **26** | 18 | 0 | 38 | 11 | **67** | 18 | 0 | 90 | 19 | **127** |
| 3 | 2401 | | **18** | 18 | 0 | 5 | 3 | **26** | 18 | 0 | 38 | 11 | **67** | 18 | 0 | 90 | 19 | **127** |
| 3 | 2501 | | **18** | 18 | 0 | 5 | 3 | **26** | 18 | 0 | 38 | 11 | **67** | 18 | 0 | 90 | 19 | **127** |
| 3 | 2601 | | **18** | 18 | 0 | 5 | 3 | **26** | 18 | 0 | 38 | 11 | **67** | 18 | 0 | 90 | 19 | **127** |
| 3 | 2701 | 1.76 | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 3 | 2801 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 3 | 2901 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 3 | 3001 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 3 | 3101 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 3 | 3201 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 3 | 3301 | | **4** | 4 | 0 | 5 | 3 | **12** | 4 | 0 | 38 | 11 | **53** | 4 | 0 | 90 | 19 | **113** |
| 3 | 3401 | | **4** | 4 | 4 | 5 | 3 | **16** | 4 | 16 | 38 | 11 | **69** | 4 | 28 | 90 | 19 | **141** |
| 3 | 3501 | | **4** | 4 | 7 | 5 | 3 | **18** | 4 | 27 | 38 | 11 | **79** | 4 | 47 | 90 | 19 | **159** |
| 3 | 3601 | | **4** | 4 | 8 | 5 | 3 | **19** | 4 | 32 | 38 | 11 | **84** | 4 | 56 | 90 | 19 | **168** |
| 3 | 3701 | | **4** | 4 | 7 | 5 | 3 | **19** | 4 | 28 | 38 | 11 | **81** | 4 | 50 | 90 | 19 | **162** |
| 3 | 3801 | | **4** | 4 | 6 | 5 | 3 | **18** | 4 | 25 | 38 | 11 | **77** | 4 | 43 | 90 | 19 | **156** |
| 3 | 3901 | | **4** | 4 | 5 | 5 | 3 | **17** | 4 | 21 | 38 | 11 | **74** | 4 | 37 | 90 | 19 | **150** |
| 3 | 4001 | | **4** | 4 | 5 | 5 | 3 | **17** | 4 | 21 | 38 | 11 | **74** | 4 | 37 | 90 | 19 | **150** |
| 3 | 4101 | 1.86 | **7** | 7 | 5 | 5 | 3 | **20** | 7 | 21 | 38 | 11 | **77** | 7 | 37 | 90 | 19 | **153** |
| 3 | 4201 | | **7** | 7 | 5 | 5 | 3 | **20** | 7 | 21 | 38 | 11 | **77** | 7 | 37 | 90 | 19 | **153** |
| 3 | 4301 | | **7** | 7 | 5 | 5 | 3 | **20** | 7 | 21 | 38 | 11 | **77** | 7 | 37 | 90 | 19 | **153** |
| 3 | 4401 | | **7** | 7 | 4 | 5 | 3 | **19** | 7 | 16 | 38 | 11 | **72** | 7 | 28 | 90 | 19 | **144** |
| 3 | 4501 | | **7** | 7 | 3 | 5 | 3 | **17** | 7 | 11 | 38 | 11 | **66** | 7 | 19 | 90 | 19 | **134** |
| 3 | 4601 | | **7** | 7 | 1 | 5 | 3 | **16** | 7 | 5 | 38 | 11 | **61** | 7 | 9 | 90 | 19 | **125** |
| 3 | 4701 | | **7** | 7 | 0 | 5 | 3 | **15** | 7 | 0 | 38 | 11 | **56** | 7 | 0 | 90 | 19 | **116** |
| 3 | 4801 | | **7** | 7 | 0 | 5 | 3 | **15** | 7 | 0 | 38 | 11 | **56** | 7 | 0 | 90 | 19 | **116** |
| 3 | 4901 | | **7** | 7 | 0 | 5 | 3 | **15** | 7 | 0 | 38 | 11 | **56** | 7 | 0 | 90 | 19 | **116** |
| 3 | 5001 | | **7** | 7 | 0 | 5 | 3 | **15** | 7 | 0 | 38 | 11 | **56** | 7 | 0 | 90 | 19 | **116** |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 5101 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 5201 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 5301 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 5401 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 5501 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 5601 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 5701 | | **15** | 15 | 0 | 5 | 3 | **23** | 15 | 0 | 38 | 11 | **64** | 15 | 0 | 90 | 19 | **124** |
| 3 | 5801 | | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 3 | 5901 | | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 3 | 6001 | | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 3 | 6101 | 2.12 | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 3 | 6201 | | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 3 | 6301 | | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 3 | 6401 | | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 3 | 6501 | | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 3 | 6601 | | **15** | 15 | 3 | 5 | 3 | **25** | 15 | 11 | 38 | 11 | **74** | 15 | 19 | 90 | 19 | **142** |
| 3 | 6701 | | **15** | 15 | 3 | 5 | 3 | **25** | 15 | 11 | 38 | 11 | **74** | 15 | 19 | 90 | 19 | **142** |
| 3 | 6801 | | **15** | 15 | 3 | 5 | 3 | **25** | 15 | 11 | 38 | 11 | **74** | 15 | 19 | 90 | 19 | **142** |
| 3 | 6901 | | **15** | 15 | 3 | 5 | 3 | **25** | 15 | 11 | 38 | 11 | **74** | 15 | 19 | 90 | 19 | **142** |
| 3 | 7001 | | **15** | 15 | 3 | 5 | 3 | **25** | 15 | 11 | 38 | 11 | **74** | 15 | 19 | 90 | 19 | **142** |
| 3 | 7101 | | **15** | 15 | 1 | 5 | 3 | **24** | 15 | 5 | 38 | 11 | **69** | 15 | 9 | 90 | 19 | **133** |
| 4 | 1 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 101 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 201 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 301 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 401 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 501 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 601 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 701 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 801 | | **23** | 23 | 3 | 5 | 3 | **33** | 23 | 11 | 38 | 11 | **82** | 23 | 19 | 90 | 19 | **150** |
| 4 | 901 | | **23** | 23 | 2 | 5 | 3 | **33** | 23 | 9 | 38 | 11 | **80** | 23 | 16 | 90 | 19 | **147** |
| 4 | 1001 | | **23** | 23 | 2 | 5 | 3 | **32** | 23 | 7 | 38 | 11 | **79** | 23 | 12 | 90 | 19 | **144** |
| 4 | 1101 | | **23** | 23 | 1 | 5 | 3 | **32** | 23 | 5 | 38 | 11 | **77** | 23 | 9 | 90 | 19 | **141** |
| 4 | 1201 | | **23** | 23 | 1 | 5 | 3 | **32** | 23 | 5 | 38 | 11 | **77** | 23 | 9 | 90 | 19 | **141** |
| 4 | 1301 | | **23** | 23 | 1 | 5 | 3 | **32** | 23 | 5 | 38 | 11 | **77** | 23 | 9 | 90 | 19 | **141** |
| 4 | 1401 | | **23** | 23 | 1 | 5 | 3 | **32** | 23 | 5 | 38 | 11 | **77** | 23 | 9 | 90 | 19 | **141** |
| 4 | 1501 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 1601 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 1701 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 1801 | 2.3 | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 1901 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2001 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2101 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2201 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2301 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2401 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2501 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2601 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2701 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2801 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 2901 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 3001 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 3101 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 3201 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 3301 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 3401 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 3501 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 3601 | | **23** | 23 | 0 | 5 | 3 | **31** | 23 | 0 | 38 | 11 | **72** | 23 | 0 | 90 | 19 | **132** |
| 4 | 3701 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 3801 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 3901 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4001 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4101 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4201 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4301 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4401 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4501 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4601 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4701 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4801 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 4901 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 5001 | 1.78 | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 5101 | | **61** | 61 | 0 | 5 | 3 | **69** | 61 | 0 | 38 | 11 | **110** | 61 | 0 | 90 | 19 | **170** |
| 4 | 5201 | | **61** | 61 | 8 | 5 | 3 | **76** | 61 | 32 | 38 | 11 | **141** | 61 | 56 | 90 | 19 | **225** |
| 4 | 5301 | | **61** | 61 | 17 | 5 | 3 | **86** | 61 | 69 | 38 | 11 | **179** | 61 | 121 | 90 | 19 | **291** |
| 4 | 5401 | | **61** | 61 | 22 | 5 | 3 | **91** | 61 | 90 | 38 | 11 | **200** | 61 | 158 | 90 | 19 | **328** |
| 4 | 5501 | | **61** | 61 | 23 | 5 | 3 | **92** | 61 | 95 | 38 | 11 | **205** | 61 | 167 | 90 | 19 | **337** |
| 4 | 5601 | | **61** | 61 | 24 | 5 | 3 | **93** | 61 | 98 | 38 | 11 | **208** | 61 | 172 | 90 | 19 | **342** |
| 4 | 5701 | | **61** | 61 | 25 | 5 | 3 | **93** | 61 | 101 | 38 | 11 | **210** | 61 | 177 | 90 | 19 | **346** |
| 4 | 5801 | | **61** | 61 | 33 | 5 | 3 | **101** | 61 | 133 | 38 | 11 | **242** | 61 | 233 | 90 | 19 | **402** |
| 4 | 5901 | | **61** | 61 | 40 | 5 | 3 | **109** | 61 | 164 | 38 | 11 | **274** | 61 | 288 | 90 | 19 | **458** |
| 4 | 6001 | | **61** | 61 | 39 | 5 | 3 | **108** | 61 | 159 | 38 | 11 | **269** | 61 | 279 | 90 | 19 | **449** |
| 4 | 6101 | | **61** | 61 | 39 | 5 | 3 | **108** | 61 | 159 | 38 | 11 | **269** | 61 | 279 | 90 | 19 | **449** |

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| 4 | 6201 | | **61** | 61 | 39 | 5 | 3 | **108** | 61 | 159 | 38 | 11 | **269** | 61 | 279 | 90 | 19 | **449** |
| 4 | 6301 | | **61** | 61 | 65 | 5 | 3 | **134** | 61 | 265 | 38 | 11 | **375** | 61 | 465 | 90 | 19 | **635** |
| 5 | 1 | | **20** | 20 | 17 | 5 | 3 | **45** | 20 | 69 | 38 | 11 | **138** | 20 | 121 | 90 | 19 | **250** |
| 5 | 101 | | **20** | 20 | 23 | 5 | 3 | **51** | 20 | 95 | 38 | 11 | **164** | 20 | 167 | 90 | 19 | **296** |
| 5 | 201 | | **20** | 20 | 21 | 5 | 3 | **48** | 20 | 85 | 38 | 11 | **153** | 20 | 149 | 90 | 19 | **277** |
| 5 | 301 | | **20** | 20 | 18 | 5 | 3 | **46** | 20 | 74 | 38 | 11 | **143** | 20 | 130 | 90 | 19 | **259** |
| 5 | 401 | | **20** | 20 | 20 | 5 | 3 | **47** | 20 | 80 | 38 | 11 | **148** | 20 | 140 | 90 | 19 | **268** |
| 5 | 501 | | **20** | 20 | 21 | 5 | 3 | **48** | 20 | 85 | 38 | 11 | **153** | 20 | 149 | 90 | 19 | **277** |
| 5 | 601 | | **20** | 20 | 21 | 5 | 3 | **49** | 20 | 87 | 38 | 11 | **156** | 20 | 153 | 90 | 19 | **282** |
| 5 | 701 | | **20** | 20 | 22 | 5 | 3 | **50** | 20 | 90 | 38 | 11 | **159** | 20 | 158 | 90 | 19 | **287** |
| 5 | 801 | | **20** | 20 | 25 | 5 | 3 | **52** | 20 | 101 | 38 | 11 | **169** | 20 | 177 | 90 | 19 | **305** |
| 5 | 901 | | **20** | 20 | 27 | 5 | 3 | **55** | 20 | 111 | 38 | 11 | **180** | 20 | 195 | 90 | 19 | **324** |
| 5 | 1001 | | **20** | 20 | 29 | 5 | 3 | **56** | 20 | 117 | 38 | 11 | **185** | 20 | 205 | 90 | 19 | **333** |
| 5 | 1101 | | **20** | 20 | 30 | 5 | 3 | **58** | 20 | 122 | 38 | 11 | **191** | 20 | 214 | 90 | 19 | **343** |
| 5 | 1201 | | **20** | 20 | 29 | 5 | 3 | **56** | 20 | 117 | 38 | 11 | **185** | 20 | 205 | 90 | 19 | **333** |
| 5 | 1301 | | **20** | 20 | 27 | 5 | 3 | **55** | 20 | 111 | 38 | 11 | **180** | 20 | 195 | 90 | 19 | **324** |
| 5 | 1401 | | **20** | 20 | 25 | 5 | 3 | **53** | 20 | 103 | 38 | 11 | **172** | 20 | 181 | 90 | 19 | **310** |
| 5 | 1501 | | **20** | 20 | 23 | 5 | 3 | **51** | 20 | 95 | 38 | 11 | **164** | 20 | 167 | 90 | 19 | **296** |
| 5 | 1601 | | **20** | 20 | 25 | 5 | 3 | **53** | 20 | 104 | 38 | 11 | **172** | 20 | 182 | 90 | 19 | **311** |
| 5 | 1701 | | **20** | 20 | 28 | 5 | 3 | **55** | 20 | 112 | 38 | 11 | **181** | 20 | 197 | 90 | 19 | **326** |
| 5 | 1801 | 1.8 | **20** | 20 | 30 | 5 | 3 | **57** | 20 | 121 | 38 | 11 | **189** | 20 | 212 | 90 | 19 | **341** |
| 5 | 1901 | | **20** | 20 | 32 | 5 | 3 | **59** | 20 | 129 | 38 | 11 | **198** | 20 | 227 | 90 | 19 | **356** |
| 5 | 2001 | | **20** | 20 | 34 | 5 | 3 | **61** | 20 | 138 | 38 | 11 | **206** | 20 | 242 | 90 | 19 | **370** |
| 5 | 2101 | | **20** | 20 | 33 | 5 | 3 | **61** | 20 | 136 | 38 | 11 | **205** | 20 | 239 | 90 | 19 | **367** |
| 5 | 2201 | | **20** | 20 | 33 | 5 | 3 | **61** | 20 | 134 | 38 | 11 | **203** | 20 | 236 | 90 | 19 | **364** |
| 5 | 2301 | | **20** | 20 | 33 | 5 | 3 | **60** | 20 | 133 | 38 | 11 | **201** | 20 | 233 | 90 | 19 | **361** |
| 5 | 2401 | | **20** | 20 | 30 | 5 | 3 | **58** | 20 | 123 | 38 | 11 | **192** | 20 | 216 | 90 | 19 | **344** |
| 5 | 2501 | | **20** | 20 | 28 | 5 | 3 | **55** | 20 | 113 | 38 | 11 | **182** | 20 | 199 | 90 | 19 | **328** |
| 5 | 2601 | | **20** | 20 | 25 | 5 | 3 | **53** | 20 | 104 | 38 | 11 | **172** | 20 | 182 | 90 | 19 | **311** |
| 5 | 2701 | | **20** | 20 | 23 | 5 | 3 | **51** | 20 | 94 | 38 | 11 | **163** | 20 | 166 | 90 | 19 | **294** |
| 5 | 2801 | | **20** | 20 | 21 | 5 | 3 | **48** | 20 | 85 | 38 | 11 | **153** | 20 | 149 | 90 | 19 | **277** |
| 5 | 2901 | | **20** | 20 | 16 | 5 | 3 | **43** | 20 | 64 | 38 | 11 | **132** | 20 | 112 | 90 | 19 | **240** |
| 5 | 3001 | | **20** | 20 | 16 | 5 | 3 | **43** | 20 | 64 | 38 | 11 | **132** | 20 | 112 | 90 | 19 | **240** |
| 5 | 3101 | | **20** | 20 | 13 | 5 | 3 | **41** | 20 | 53 | 38 | 11 | **122** | 20 | 93 | 90 | 19 | **222** |
| 5 | 3201 | | **20** | 20 | 10 | 5 | 3 | **38** | 20 | 42 | 38 | 11 | **111** | 20 | 74 | 90 | 19 | **203** |
| 5 | 3301 | | **20** | 20 | 8 | 5 | 3 | **35** | 20 | 32 | 38 | 11 | **100** | 20 | 56 | 90 | 19 | **184** |
| 5 | 3401 | | **20** | 20 | 5 | 5 | 3 | **33** | 20 | 21 | 38 | 11 | **90** | 20 | 37 | 90 | 19 | **166** |
| 5 | 3501 | | **20** | 20 | 3 | 5 | 3 | **30** | 20 | 11 | 38 | 11 | **79** | 20 | 19 | 90 | 19 | **147** |
| 5 | 3601 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 3701 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 3801 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 3901 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4001 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4101 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4201 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4301 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4401 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4501 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4601 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4701 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4801 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 4901 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5001 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5101 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5201 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5301 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5401 | 2.01 | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5501 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5601 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5701 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5801 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 5901 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 5 | 6001 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 1 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 101 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 201 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 301 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 401 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 501 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 601 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 701 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 801 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 901 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 1001 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 1101 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 1201 | | **24** | 24 | 0 | 5 | 3 | **32** | 24 | 0 | 38 | 11 | **73** | 24 | 0 | 90 | 19 | **133** |
| 6 | 1301 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 1401 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 1501 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 1601 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 1701 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 1801 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 1901 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |

| | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 2001 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2101 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2201 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2301 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2401 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2501 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2601 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2701 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2801 | 2.28 | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 2901 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3001 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3101 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3201 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3301 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3401 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3501 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3601 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3701 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3801 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 3901 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 4001 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 4101 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 4201 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |
| 6 | 4301 | | **16** | 16 | 0 | 5 | 3 | **24** | 16 | 0 | 38 | 11 | **65** | 16 | 0 | 90 | 19 | **125** |

# APPENDIX

# F

## EROSION HAZARD MAPS


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
19/12/2017

Size
A3

Scale
1:15,000

0 0.1 0.2 0.3 0.4km

# SECTOR 1 COASTAL EROSION HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR1_EROSIONHAZARDMAP 01

DATE PLOTTED:19/12/2017 11:57:58 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ErosionHazardMaps\59918065-GS-001-Sector1_ErosionHazardMap.mxd

Sector 1 - Wanliss Street

Sector 2 - Boundary Road

NORTH

**Legend**

- Sector Boundary Line
- Rocky Shoreline
- 2017 Hazard Line
- 2030 Hazard Line
- 2070 Hazard Line
- 2110 Hazard Line
- Coastline

Note: Erosion lines based on 100 yr ARI as per SPP2.6.

Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno

Map produced by Cardno WA Pty Ltd
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Web: www.cardno.com.au



City of Rockingham

Date
18/12/2017

Size
A3

Scale
1:15,000

0 0.1 0.2 0.3 0.4km

# SECTOR 2 COASTAL EROSION HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR2_EROSIONHAZARDMAP 01

DATE PLOTTED:18/12/2017 2:58:54 PM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ErosionHazardMaps\59918065-GS-001-Sector2_ErosionHazardMap.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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city of Rockingham

Date
18/12/2017

Size
A3

Scale
1:25,000

0 0.2 0.4 0.6 0.8km

# SECTOR 3 COASTAL EROSION HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR3_EROSIONHAZARDMAP 01

DATE PLOTTED:18/12/2017 2:58:21 PM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ErosionHazardMaps\t59918065-GS-001-Sector3_ErosionHazardMap.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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Web: www.cardno.com.au



City of Rockingham

Date
19/12/2017

Size
A3

Scale
1:25,000

0 0.2 0.4 0.6 0.8km

# SECTOR 4 COASTAL EROSION HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR4_EROSIONHAZARDMAP 01

DATE PLOTTED:19/12/2017 9:18:51 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ErosionHazardMaps\59918065-GS-001-Sector4_ErosionHazardMap.mxd


Note: Erosion lines based on 100 yr ARI as per SPP2.6.

Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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City of Rockingham

Date
18/12/2017

Size
A3

Scale
1:25,000

0 0.2 0.4 0.6 0.8km

# SECTOR 5 COASTAL EROSION HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR5_EROSIONHAZARDMAP 01

DATE PLOTTED:18/12/2017 2:58:49 PM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ErosionHazardMaps\59918065-GS-001-Sector5_ErosionHazardMap.mxd

Sector 5 - Turtles Bend

Sector 6 - Municipal Boundary

Note: Erosion lines based on 100 yr ARI as per SPP2.6.

**Legend**

- City of Rockingham Boundary (CoR)
- Sector Boundary Line
- 2017 Hazard Line
- 2030 Hazard Line
- 2070 Hazard Line
- 2110 Hazard Line
- Coastline

Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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Date
19/12/2017

Size
A3

Scale
1:20,000

0 0.15 0.3 0.45 0.6km

# SECTOR 6 COASTAL EROSION HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR6_EROSIONHAZARDMAP 01

DATE PLOTTED:19/12/2017 9:42:24 AM BY: ANIN.DHARMA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\ErosionHazardMaps\59918065-GS-001-Sector6_ErosionHazardMap.mxd

# APPENDIX

# G

## GROUNDWATER RISE AND DRAINAGE INFRASTRUCTURE HAZARD MAP


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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Web: www.cardno.au



Date
10/01/2018

Size
A3

Scale
1:15,000

# SECTOR 1 GROUNDWATER RISE AND DRAINAGE INFRASTRUCTURE HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 0.1 0.2 0.3 0.4km

59918065-GS-001-SECTOR1_GROUNDWATERRISEMAP 01

DATE PLOTTED:10/01/2018 9:27:11 AM BY: RICCARDO.DIVITA
FILE: V:\Jobs\59918065_Rockingham_CHRMAPID\Drawings\GIS\Workspaces\GroundwaterRiseMaps\t59918065-GS-001-Sector1_GroundwaterRiseMap.mxd

Sector 1 - Wanliss Street

Sector 2 - Boundary Road

NORTH

## Legend

- Sector Boundary Line
- Coastline
- Drainage Infrastructure Impacted 2017
- Drainage Infrastructure Impacted 2030
- Drainage Infrastructure Impacted 2070
- Drainage Infrastructure Impacted 2110
- Stormtech Impacted by Groundwater Rise 2110
- Drainage Infrastructure Impacted by Groundwater Rise 2110
- Groundwater Bores at Risk of Saline Intrusion 2110
- Groundwater Bores Impacted by Inundation 2110
- Groundwater Rise Inundation

Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



Date
10/01/2018

Size
A3

Scale
1:15,000

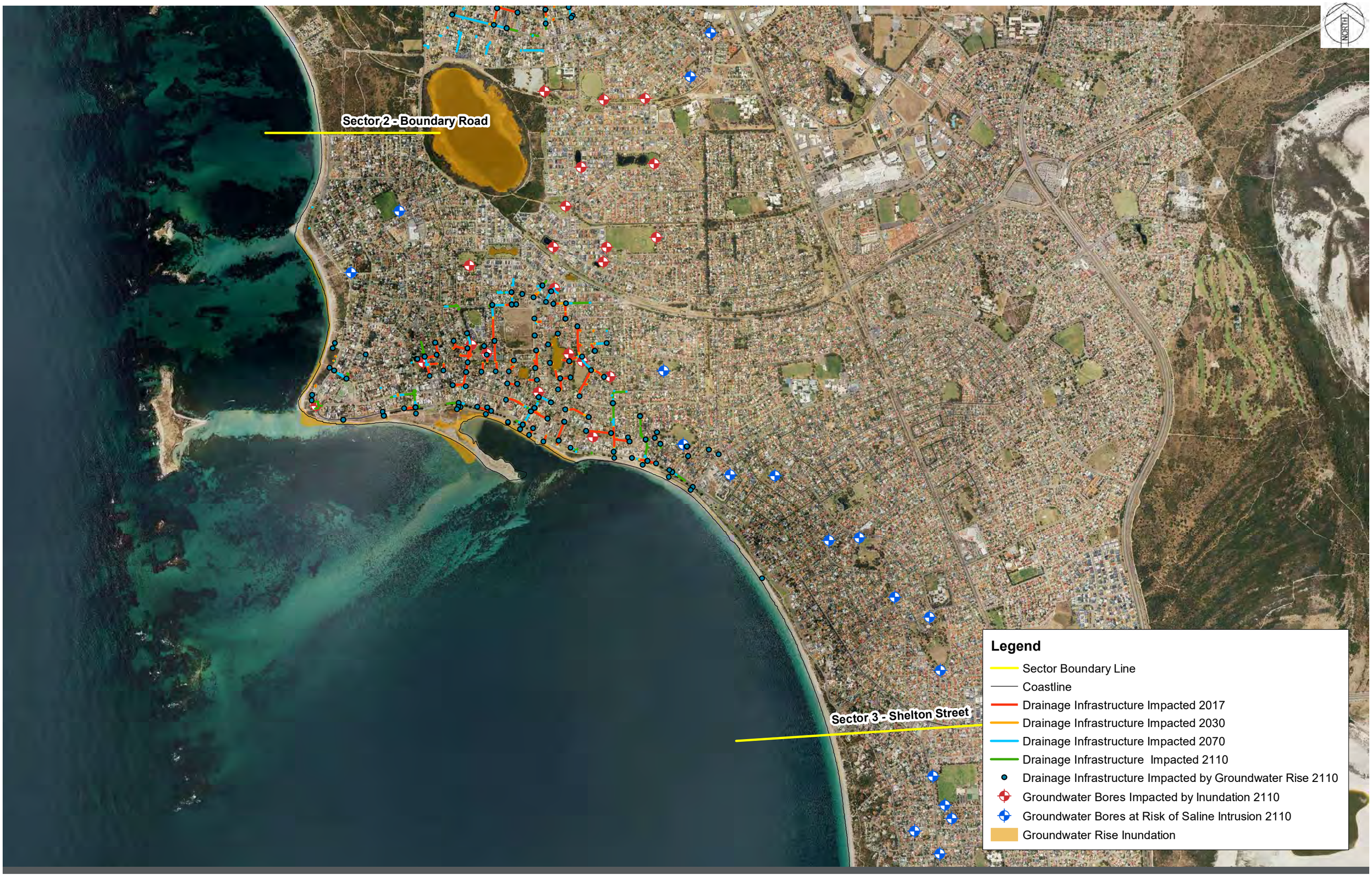
# SECTOR 2 GROUNDWATER RISE AND DRAINAGE INFRASTRUCTURE HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 0.1 0.2 0.3 0.4km

59918065-GS-001-SECTOR2_GROUNDWATERRISEMAP 01

DATE PLOTTED:10/01/2018 9:27:00 AM BY: RICCARDO.DIVITA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\GroundwaterRiseMaps\59918065-GS-001-Sector2_GroundwaterRiseMap.mxd




Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
Map produced by Cardno WA Pty Ltd
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Date
10/01/2018

Size
A3

Scale
1:25,000

# SECTOR 3 GROUNDWATER RISE AND DRAINAGE INFRASTRUCTURE HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 0.2 0.4 0.6 0.8km

59918065-GS-001-SECTOR3_GROUNDWATERRISEMAP 01

DATE PLOTTED:10/01/2018 9:27:25 AM BY: RJCCARDO.DIVITA
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Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



Date
10/01/2018

Size
A3

Scale
1:25,000

# SECTOR 4 GROUNDWATER RISE AND DRAINAGE INFRASTRUCTURE HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 0.2 0.4 0.6 0.8km

59918065-GS-001-SECTOR4_GROUNDWATERRISEMAP 01

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Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

# SECTOR 5 GROUNDWATER RISE AND DRAINAGE INFRASTRUCTURE HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

Date
10/01/2018

Size
A3

Scale
1:25,000

0 0.2 0.4 0.6 0.8km

59918065-GS-001-SECTOR5_GROUNDWATERRISEMAP 01

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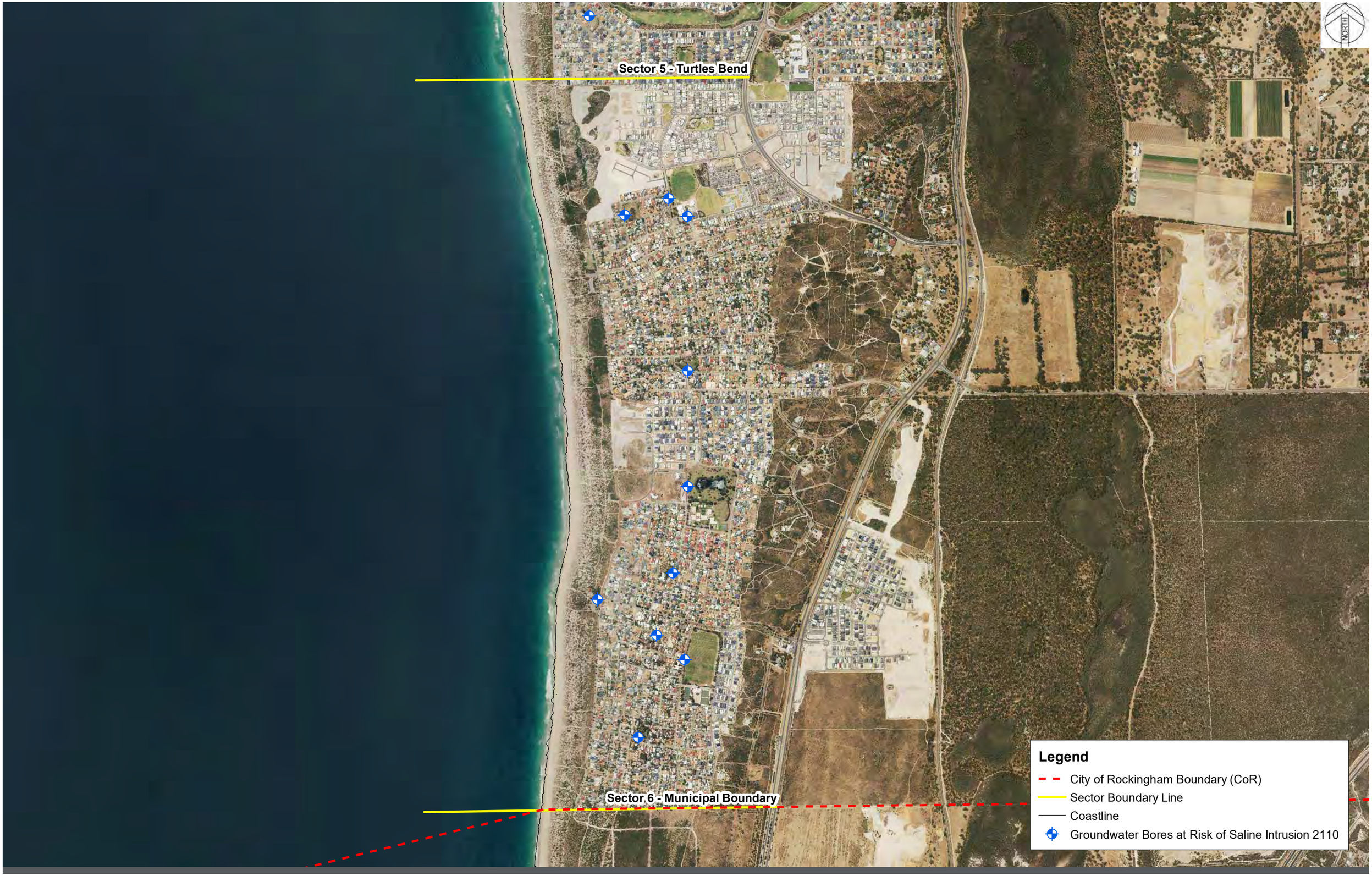


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Date
10/01/2018

Size
A3

Scale
1:20,000

# SECTOR 6 GROUNDWATER RISE AND DRAINAGE INFRASTRUCTURE HAZARD MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 0.15 0.3 0.45 0.6km

59918065-GS-001-SECTOR6_GROUNDWATERRISEMAP 01

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# APPENDIX

# H

## COASTAL HAZARD RISK ASSESSMENT

# Coastal Hazard Risk Assessment

## City of Rockingham Coastal Hazard Risk Management and Adaptation Plan

59918065

Prepared for
City of Rockingham

19 February 2018

Cardno
Shaping the Future

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# Figures

# 1 INTRODUCTION

## 1.1 Background

Globally, mean sea level (MSL) has risen since the nineteenth century and is predicted to continue to rise, at an increasing rate, through the twenty first century (Intergovernmental Panel on Climate Change [IPCC], 2014), bringing changes to the Western Australian (WA) coastline over the coming decades. To prepare for sea level rise (SLR) induced coastal hazards, such as coastal erosion and inundation, all levels of government are putting processes in place to ensure that communities understand the risks to values and assets on the coast, and to plan to adapt over time.

Changes to MSL over the past century have been observed for the coastline adjacent to the Perth Metropolitan Area. *Sea Level Change in Western Australia – Application to Coastal Planning* (Department of Transport [DoT], 2010) reviewed information relating to SLR at a local scale and recommended an allowance for SLR be adopted for planning purposes. The WA State Government revised the State Coastal Planning Policy in 2013 to incorporate a projected SLR for WA of 0.9 m between 2010 and 2110 (**Figure 1-1**).


**Figure 1-1 Recommended allowance for sea level rise in coastal planning in Western Australia (DoT 2010)**

The Rockingham Local Government Area (LGA) coastline is low lying and sandy, featuring coastal dunes, nearshore reefs, islands and seagrass meadows. For sandy coastlines, increases in local MSL generally result in shoreline recession, with a “rule of thumb” often used, that a 1 cm rise will result in 1 m of landward recession of the shoreline (**Figure 1-2**; CoastAdapt, 2017).

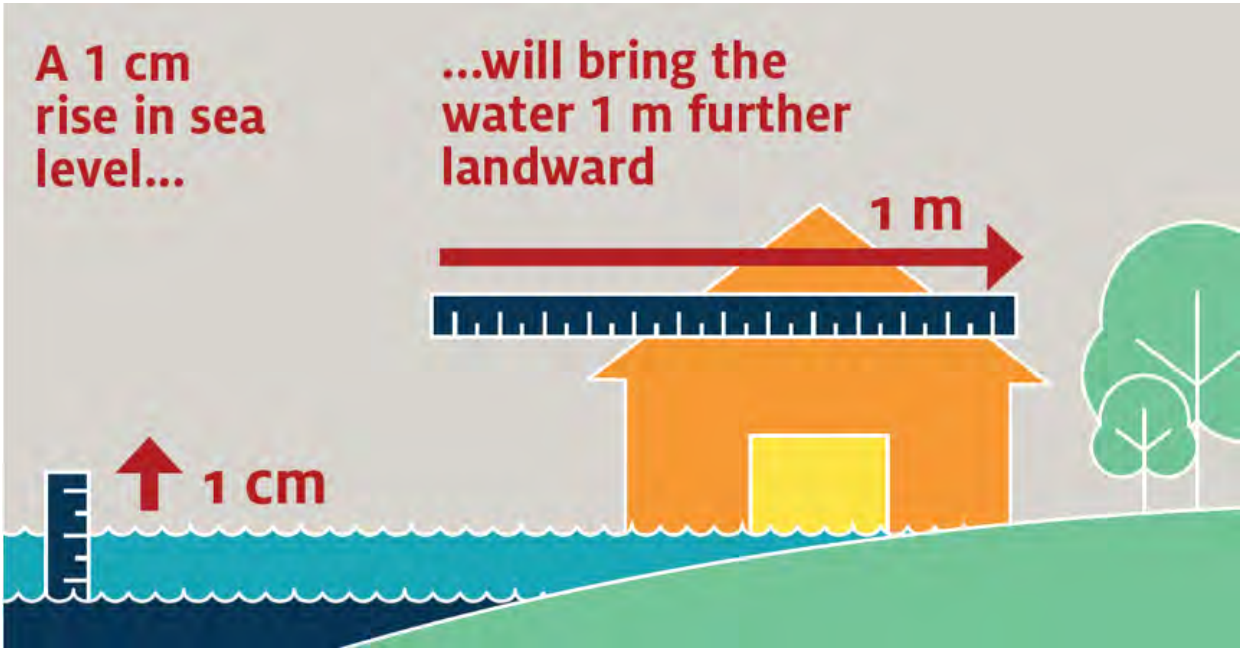


**Figure 1-2 Simplified schematic of how sea level rise will impact shorelines (CoastAdapt, 2017)**

The City of Rockingham (the City) is developing a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP), with technical input from Cardno, to identify risks and plan to adapt to the potential impacts associated with predicted SLR along their coastline.

The purpose of the CHRMAP process is to:

> Ensure that development and the location of coastal facilities takes into account coastal processes, landform stability, coastal hazards, climate change and biophysical criteria;

> Guide the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities;

> Provide for public coastal foreshore reserves on the coast and ensure access to them; and

> Protect, conserve and enhance coastal zone values, particularly in areas of landscape, biodiversity and ecosystem integrity, indigenous and cultural significance.

## 1.2 Overview of the CHRMAP Process

The key policy governing coastal planning in WA is the *State Planning Policy No. 2.6: State Coastal Planning Policy* (Western Australian Planning Commission [WAPC], 2013a) (SPP2.6). SPP2.6 recommends that management authorities develop a CHRMAP, using a risk mitigation approach to planning, that identifies the hazards associated with existing and future development in the coastal zone. SPP2.6 and the *State Coastal Planning Policy Guidelines* (WAPC, 2013b) contain prescriptive details, for example in relation to scales of assessment, storm event types and SLR allowances.

The WAPC (2014a) has also developed the *Coastal hazard risk management and adaptation planning guidelines* (the CHRMAP Guidelines) which are less prescriptive, but are aimed to ensure that planning is carried out using a risk based approach with due regard given to stakeholder engagement, community consultation and education, and that a full range of adaptation options is considered. An overview of the typical CHRMAP process is shown in **Figure 1-3**.

Coastal planning in accordance with SPP2.6 also needs to take into consideration the requirements of other planning policies, including *Statement of Planning Policy No. 2: Environment and Natural Resources Policy* (WAPC, 2003) and *Statement of Planning Policy No. 3: Urban Growth and Settlement* (WAPC, 2006).

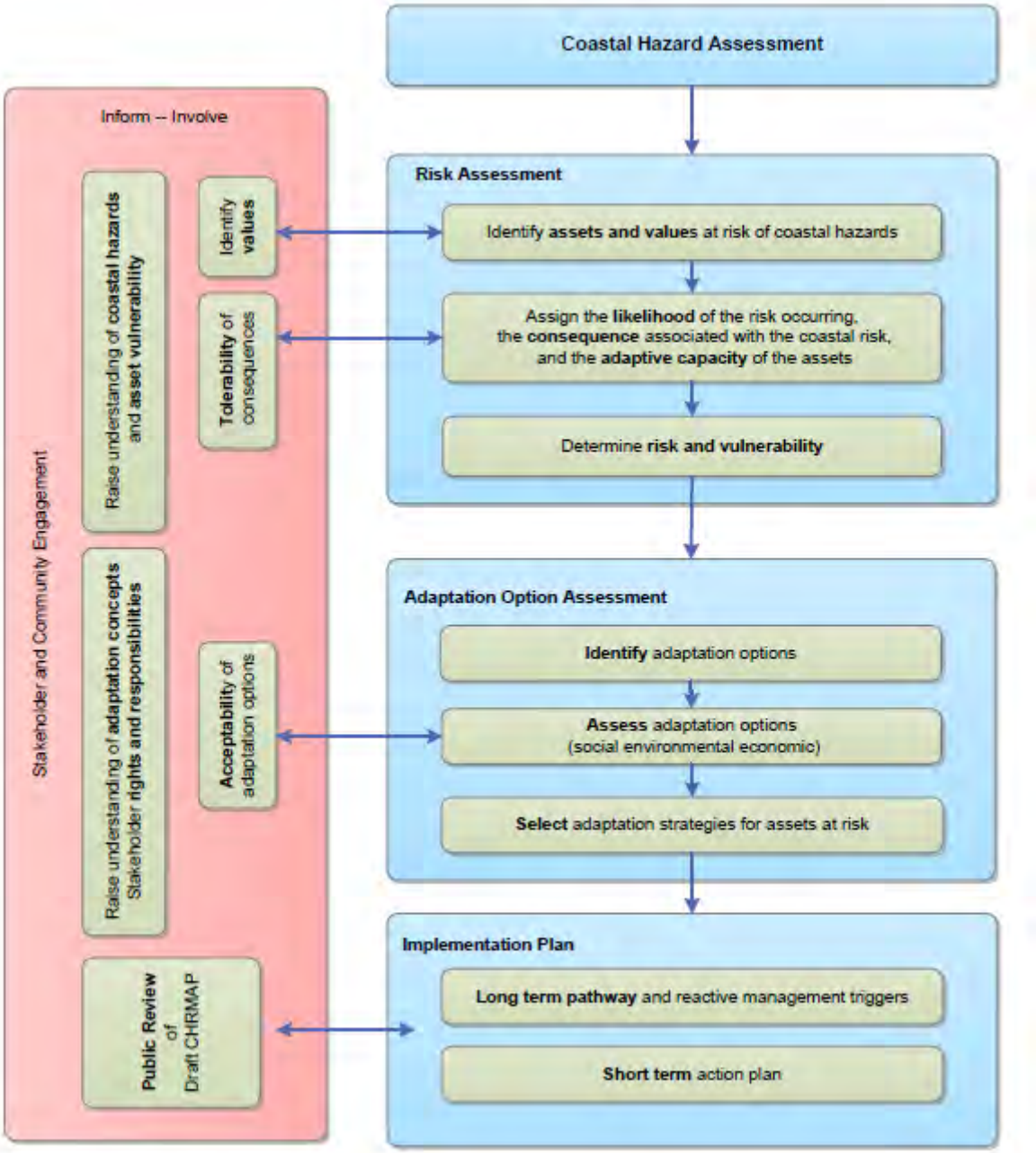


**Figure 1-3 CHRMAP methodology flow chart (adapted from the CHRMAP Guidelines (WAPC, 2014a))**

## 1.3 Purpose and Structure of this Report

**Appendix A** outlines the interpretation of coastal hazard risk modelling, to assess the risk and vulnerability of assets along the City's coastline. It has been written to satisfy Clause 3.2(c) of the City's Scope.

The Chapter Report aims to identify priority areas of risk and vulnerability for the City, allowing adaptation options to be considered for these areas. This document has been designed to inform the community and provide direction to the City in planning for climate change risks facing its coastal areas.

The risk assessment process has been guided by the Project's success criteria (see **Section 2.2.3**), defined through the City's community engagement process. These success criteria have been used to determine community values and refine consequence ratings for the potential impacts of coastal hazards.

The chapter report is structured as follows:

> **Section 1** provides an introduction to the stand-alone chapter report;

> **Section 2** establishes the context of this CHRMAP;

> **Section 3** defines the risk assessment methodology;

> **Section 4** discusses the outcomes of the risk assessment for each Sector; and

> **Section 5** summarises the key findings of the report and outlines the next steps in the process.

The structure of the document also allows for the information base and context of individual assets or groups of assets to be separated from the main document.

# 2 ESTABLISHING THE CONTEXT

## 2.1 City of Rockingham

The study area for the City's CHRMAP spans the length of its Local Governments Area (LGA) coastline. The Rockingham LGA is located approximately 38 km south-southwest of the Perth Central Business District (CBD) (**Figure 2-1**).


**Figure 2-1 CHRMAP location map**

The Rockingham LGA is one of the fastest growing areas in Western Australia and it is anticipated that the City's population will grow from 134,538 to approximately 171,763 by 2026, increasing to 192,805 by 2036 (City of Rockingham, 2017). The City of Rockingham (2017) Community Profile lists the dominant demographic as parents and homebuilders aged between 35 and 49 (around 20% of the population).

Retail trade is the City's primary economic contributor. In addition to retail the City's economy is also based around tourism, with coastal areas experiencing a large influx of people during the summer holiday season.

This CHRMAP will focus on existing areas (including future development areas), where the services from human-made and natural assets provide key social, economic and environmental values to the community. The hazard assessment extends for 36 km along the coast, and has been delineated into six sectors.

The LGA is relatively low lying, sitting as low as approximately 1.5 m above MSL in Safety Bay (DoT, 2009). Historically, management of erosion has included sand nourishment and protection works, such as the Waikiki Seawall, to maintain the beach and prevent loss of public foreshore areas.

The LGA lies between tertiary sediment cells R06C10b to R06E17a (Stul et al., 2015). The coast in this region is generally sheltered by limestone ridges and inshore basins. There are two main islands close to the shore, the smaller Penguin Island and the larger Garden Island. Inshore basins were formed adjacent to large sand banks in Warnbro Sound and Cockburn Sound (Stu et al., 2015).

The main coastal erosion and inundation risk areas are in Cockburn Sound and Warnbro Sound, with multiple private residences located only approximately 60 m from the coast.

## 2.2 Stakeholder and Community Engagement

### 2.2.1 Objectives

Community and stakeholder engagement is an important element of the CHRMAP process, as depicted in **Figure 1-3**. It is necessary to identify the social values provided by the study area, to determine the tolerability of risks and to assess the acceptability of adaptation options designed to preserve the area's value.

The objectives of the community and stakeholder engagement process are:

> To inform the community about the extent of potential coastal hazards, adaptation strategies available to respond to those hazards and the need for flexibility in response to future environmental, social and economic changes;

> To explain the State and Local Governments' responsibilities and capacity to respond to potential coastal hazards;

> To explain the benefits and challenges of each adaptation strategy, in terms of residents and landowners, as well as the broader community;

> To provide community members with multiple opportunities to provide input into proposed adaptation strategies, and to offer alternative strategies or to voice questions and concerns;

> To receive and document feedback and concerns regarding each adaptation strategy from community members and affected residents and landowners; and

> To report on the feedback, including analysis that highlights the level of community understanding, the principal concerns and preferences concerning the proposed adaptation strategies and funding mechanisms, and preferred methods of continued community engagement.

### 2.2.2 Community Coastal Values Survey

In October 2017, the City undertook a survey focused on capturing the coastal values of the community. Additional information was collected to assess the demographic of respondents; including the proximity to the coast of where they live, how frequently they use the coast and for what purpose(s). The surveys were mailed to households and also made available online.

There was a generally good response to the survey with 1,040 surveys completed and a good distribution of respondents in terms of their perceived attachment to the coast (i.e. not all lived near the beach or necessarily were regular beach users).

### 2.2.3 Success Criteria

Based on the results of the Coastal Values Survey, the following success criteria have been developed to guide the CHRMAP process:

> SC1: Conserve natural attributes (e.g. clear water, vegetated dunes and sandy beaches);

> SC2: Ensure public safety and access;

> SC3. Minimise impacts on existing residential areas;

> SC4. Provision and maintenance of public amenities;

> SC5. Conserve areas for recreational and passive use;

> SC6. Provision of foreshore areas for local economic benefit;

> SC7. Provision of access infrastructure (e.g. roads, carparks, paths); and

> SC8. Maintenance and preservation of indigenous and cultural heritage sites.

Success criteria do not necessarily imply assets should be preserved in their current setting. For example, *SC1: Conserve natural attributes* does not require dunes to be maintained in their current position and state, but rather their function and natural attributes will be conserved into the future.

It is noted that legally there is no obligation of the State or Local Governments to either protect public and private assets within the coastal hazard zone, nor to compensate for any losses incurred due to coastal hazards. While SC3 is considered a community aspiration it must be recognised that assets currently located in present and future potential impact zones are subject to a rigorous procedure for determining their suitability to attract state or local government funding for mitigation works.

The success criteria are used in the risk assessment process to inform the consequence ratings, by adding value to assets whose economic value is difficult to define without detailed analysis. For example, the economic value of a beach is more difficult to define than that of a house or road. The consequence rating for the loss or degradation of the beach should, therefore, be guided by the value attributed to beaches by the community. This value is reflected in the success criteria and has been incorporated into the consequence ratings (see **Table 3-2**).

## 2.3 Risk Assessment Inputs

To effectively assess the risks and plan for the future management of the coastal zone, as illustrated in **Figure 2-2**, information is needed on:

> Present and future erosion and inundation hazards;

> Existing assets, their values and lifecycles; and

> Community and stakeholder values.

The changing interrelationship between these components over time is the key to defining the priorities for future adaptation planning.

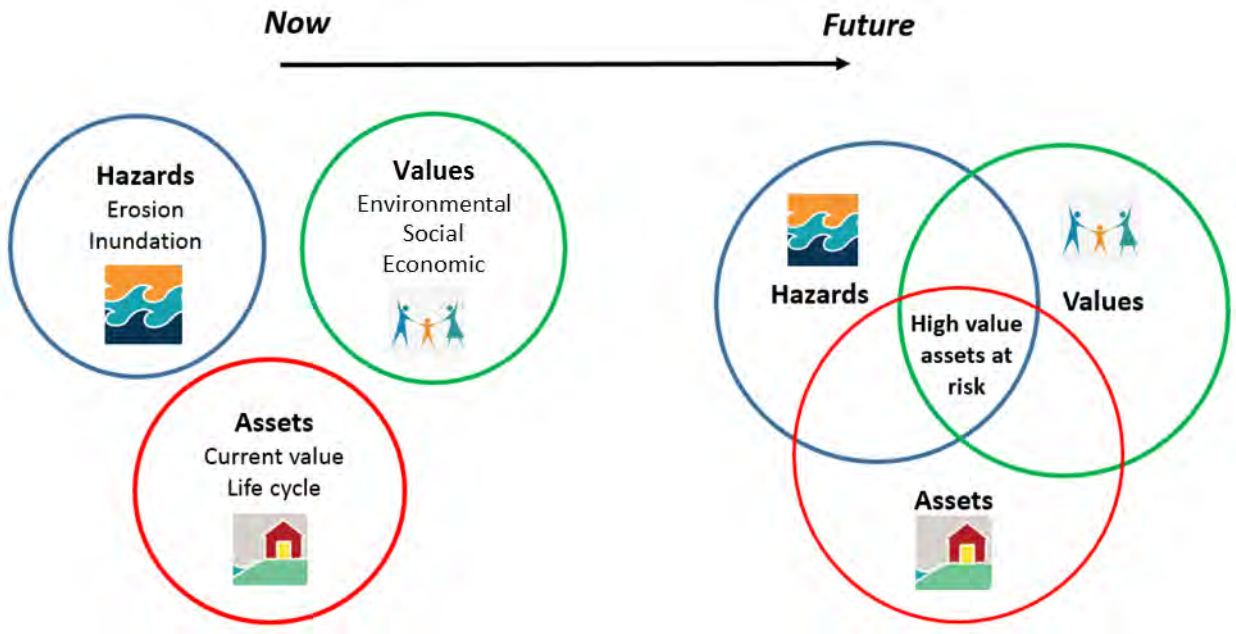


**Figure 2-2 Conceptual relationship between key inputs to the coastal risk assessment process**

### 2.3.2 Hazards

Schedule One of SPP 2.6 provides guidance for calculating the coastal foreshore reserve to allow for coastal processes including present day erosion, historical shoreline movement, SLR and storm tide inundation.

The allowance for erosion on a sandy coast is calculated as the sum of the S1, S2 and S3 Erosion components, plus a 0.2 m per year allowance for uncertainty, and should be measured from the horizontal shoreline datum (HSD):

> (S1 Erosion) Allowance for the current risk of storm erosion

> (S2 Erosion) Allowance for historic shoreline movement trends

> (S3 Erosion) Allowance for erosion caused by future sea-level rise

The allowance for current risk of inundation, according to SPP2.6, is calculated as the maximum extent of storm inundation, defined as the peak steady water-level plus wave run-up. Consideration must be given to the likelihood of breaching any manmade structure, e.g. seawall, or natural barriers, for example a dune system.

Schedule One of SPP2.6 describes different areas for the definition of the storm event for use as the design storm in assessing inundation and erosion. The Rockingham LGA lies within Area 3 as defined in SPP2.6. Policy guidance for coastal erosion is that a mid-latitude depression or extra-tropical low storm event corresponding to the 100-year ARI ocean forces and coastal processes should be selected, tracking to maximise its erosion potential.

### 2.3.3 Assets

Assets include both natural and built features of coastal areas. Assets at risk of coastal erosion and inundation were identified by overlaying the hazard lines and inundation extents over recent aerial photography of the City's LGA. Classifications of commercial and residential property boundaries were drawn from the City's GIS cadastral layers. Carpark areas and footpaths were also drawn from the City's GIS layers, while all other assets were based on interpretation of aerial images. Information on the assets at risk and existing coastal erosion controls are provided for each sector in **Appendix J**.

### 2.3.4 Values

It is clear that the community places a high value on the natural coastal assets and foreshore amenities, expressed through the Coastal Values Survey. In establishing the values of assets and coastal areas for risk assessment, this social and environmental value has been fully considered alongside economic value.

A preliminary summary of the values associated with assets at risk is provided for each Sector in **Appendix J**.

# 3 RISK ASSESSMENT METHODOLOGY

## 3.1 Risk Assessment Framework

To provide a transparent and logical basis for determining adaptation planning priorities, a risk assessment was undertaken based on the Australian Standard Guideline *Climate change adaptation for settlements and infrastructure – A risk based approach* (AS5334-2013), and the CHRMAP guidelines (WAPC, 2014a). As illustrated in **Figure 3-1**, risk was assessed in relation to likelihood, consequence and adaptive capacity. Likelihood was assigned using the results of the coastal hazard assessment. Consequence ratings were informed by estimated economic values and additional values determined through community consultation. Risk is considered to be the combination of likelihood and consequence, with consideration of adaptive capacity determining an asset's (or group of assets') overall vulnerability to climate change.

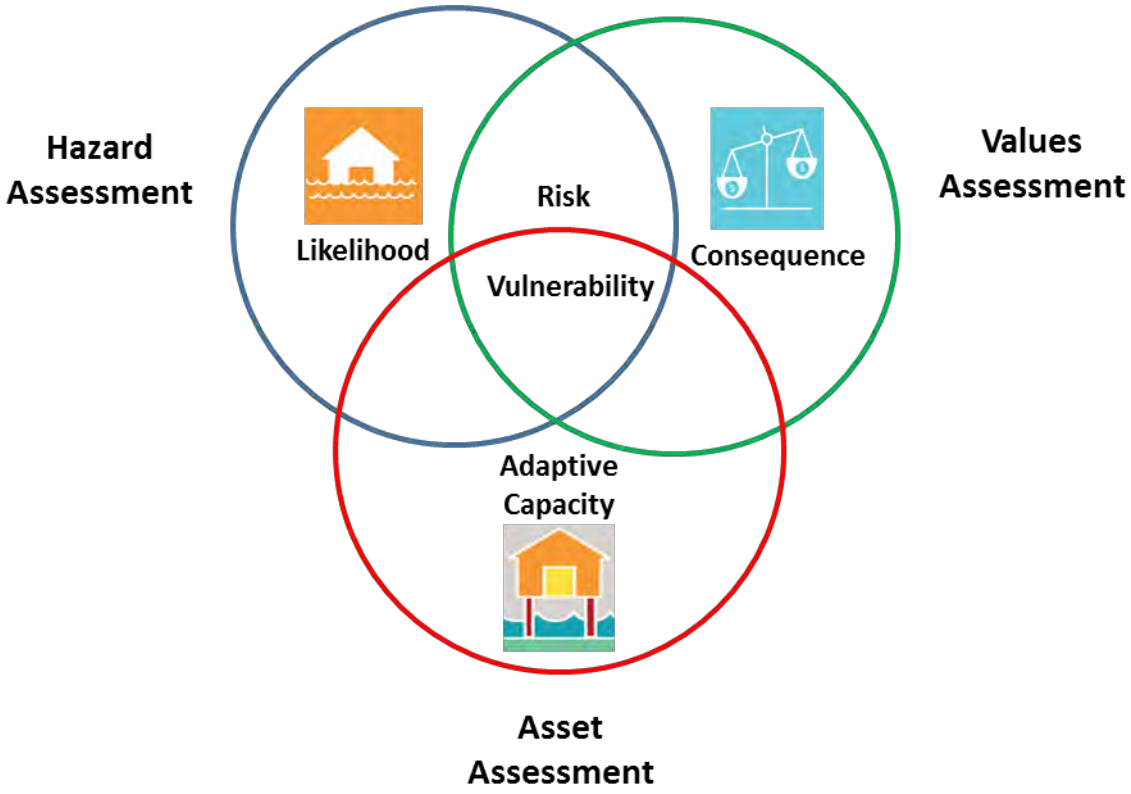


**Figure 3-1 Conceptual relationship between risk assessment elements**

All steps in the risk assessment process call for interpretation, and allocation of consequence in particular may be based on subjective judgement. However, the adopted framework means that specific outcomes can be clearly traced to inputs. The inputs can be updated in response to new information or stakeholder input, and the risk assessment outcomes can be revised accordingly. Additional details on how the input parameters were derived, and the ratings were developed is provided below.

A full description of the risk assessment process, with accompanying examples, is provided in **Appendix I**. Summary tables of the assigned likelihood, consequence and adaptive capacity ratings, as well as the resultant risk and vulnerability profiles over time are provided in **Appendix J**, for assets within each Sector.

## 3.2 Likelihood

According to WAPC (2014a) and for the purposes of this study, likelihood is defined as the chance of erosion or storm surge inundation impacting on existing assets and their values. A description of the likelihood scale is presented in **Table 3-1**.

The erosion and inundation hazard extents are made up of a number of components. Each of these is based on a suite of assumptions and each has a degree of uncertainty which may influence the likelihood of the predicted level of erosion or inundation occurring at each planning horizon. For example, the extent of the coastal erosion hazard lines assume a 100 year ARI storm event occurs exactly at the planning timeframe (2030, 2070 etc.), which in reality is highly unlikely. There is also the assumption that the probability of the design coastal hazard event occurring is the same each year, which is not necessarily the case when considering the effects of climate change and the rise in sea level on the severity of storm events.

There is considerable scope for confusion in defining and allocating likelihood in terms of recurrence frequency/probability (as per AS 5334) for the purposes of risk assessment, particularly given this terminology has specific meaning in the coastal context. Cardno has adopted the approaches presented in **Figure 3-2**, which are generally consistent with guidance in WAPC (2014a).

**Table 3-1 CHRMAP Likelihood descriptions**

| Rating | Description |
|---|---|
| **Almost Certain** | High possibility of impact to asset shoreline for a given planning timeframe |
| **Likely** | Impact to asset shoreline for a given planning timeframe is likely |
| **Possible** | Impact to asset shoreline for a given planning timeframe is possible |
| **Unlikely** | Impact to asset shoreline for a given planning timeframe is unlikely |
| **Rare** | May occur in exceptional circumstances |

## 3.3 Consequence

Consequence is the result of a hazard impacting an area, asset or group of assets. For this analysis, consequence has been divided into five ratings ranging from catastrophic to insignificant (**Table 3-2**). The consequence ratings for this risk assessment have been adapted from those presented in AS 5334-2013, and WAPC (2014a), which focus on the social, economic and environmental consequences.

A heritage component has been incorporated alongside environmental impacts to ensure impacts to heritage sites are accounted for in the risk assessment process. The consequence descriptions have also been scaled to be applicable to the local context in which this study is being undertaken, where as previously their higher ratings were associated with consequences on a global scale. Generally, the consequence categories incorporate all of the values outlined by the Success Criteria and align comparatively between categories with the level of response to these Success Criteria. Assessment of the economic component was based on estimating the total cost for replacement of impacted assets with costs taken from the *Australian Construction Handbook* (Rawlinsons, 2016).

Generally coastal inundation and coastal erosion will occur at the same time during a storm event. In the majority of circumstances and locations for the City's coastline, the impacts of coastal erosion on infrastructure will be more severe and long-lasting than the impacts of coastal inundation. For maritime infrastructure located in close proximity to coastal hazards, such as jetties and boat ramps, the nature of these assets was considered in defining the consequence (and likelihood) of impact. Such infrastructure is generally designed to withstand the ongoing impacts of the coastal environment (though not necessarily changes associated with SLR) and cannot be treated in the same way as other built assets. The vulnerability of such assets is, therefore, relatively low, despite their close proximity to the ocean.

## 3.4 Adaptive Capacity

The adaptive capacity (**Table 3-3**) is based upon the potential for the system to be modified or acclimatise to cope with the impacts of identified hazards. The system of existing controls, such as a coastal protection structure, dune system or reef, all have an influence on the ability of hazards to affect a study site. The aim of the CHRMAP is to develop options that realise the potential adaptive capacity through techniques such as managed retreat, accommodation, and protection. An asset or group of assets with a high adaptive capacity is one that can easily (i.e. at low cost) be adapted or one that has some capacity to self-adapt with changing

conditions (e.g. beaches and dune systems can migrate across shore as the MSL changes). Assets with a high risk level and low adaptive capacity are deemed vulnerable and management options should be investigated.

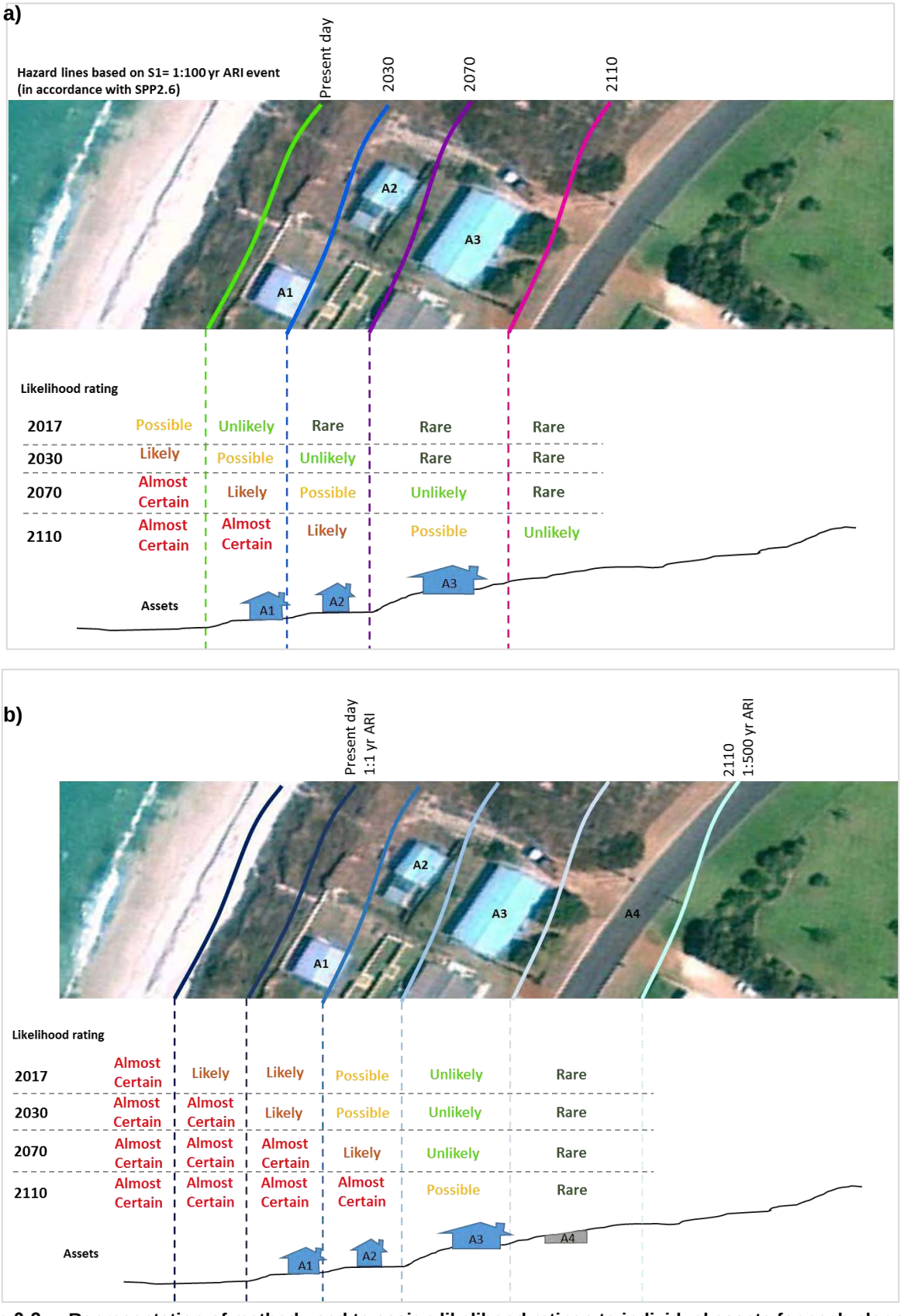


**Figure 3-2 Representation of method used to assign likelihood ratings to individual assets for each planning timeframe for a) erosion and b) inundation**

**Table 3-2 Consequence criteria used in the risk assessment**

| Consequence (based on AS 5334-2013) | | | |
|---|---|---|---|
| Scale | Social | Economic | Environment |
| Catastrophic | Loss of life and serious injury. Large long-term or permanent (~1 yr) loss of essential services, public access/amenity, employment, wellbeing or culture. No suitable alternative sites exist within the LGA. | Permanent and/or entire loss or damage to property, plant and equipment, finances >$10 million. Regional economic decline, widespread business failure and impacts on state economy. | Permanent and entire loss of flora, fauna conservation or heritage area (no chance of recovery) . |
| Major | Serious injury. Medium term (~6 months) disruption to essential services, public access/amenity, employment, wellbeing or culture. Very limited suitable alternative sites exist within the LGA. | Permanent and/or large scale loss or damage to property, plant and equipment, finances > $2 - $10 million. Lasting downturn of local economy with isolated business failures and major impacts in regional economy. | Long-term and/or large scale loss of flora, fauna or heritage area (limited chance of recovery) with local impact. |
| Moderate | Minor injury. Major short term or minor long-term (~1 month) disruption to services, public access/amenity, employment, wellbeing, or culture. Limited suitable alternative sites exist within the LGA. | Permanent and/or medium scale loss or damage to property, plant and equipment, finances > $100,000 - $2 million. Significant impacts on local economy and minor impacts on regional economy. | Medium-term and/or medium scale loss of flora, fauna or heritage area (recovery likely) with local impact. |
| Minor | Small to medium short-term (~1 day) disruption to services, public access/amenity, employment, wellbeing, or culture. Many suitable alternative sites exist within the LGA. | Permanent and/or small scale loss or damage to property, plant and equipment, finances > $10,000 - $100,000. Individually significant but isolates impacts on local economy. | Short-term and/or small scale loss of flora, fauna or heritage area (strong recovery) with local impact. |
| Insignificant | Minimal short-term (~1 hr) inconveniences to services, public access/amenity, employment, wellbeing, or culture. Many suitable alternative sites exist within the LGA. | Permanent loss or damage to property, plant and equipment, finances < $10,000. Minor short-term impacts on local economy. | Negligible to no loss of flora, fauna or heritage area (strong recovery) with local impact. |

**Table 3-3 Adaptive Capacity criteria used in the risk assessment**

| Adaptive Capacity | | | |
|---|---|---|---|
| Scale | Engineering Feasibility | Economic | Social and Environmental Values |
| Very High | Good adaptive capacity. Functionality restored easily by repair, redesign or relocation. | Cost to relocate or modify design of property, plant and equipment > $10,000 - $100,000 | Adaptation has little or no impact on current environmental and or social values |
| High | Decent adaptive capacity. Functionality can be restored, although additional adaptive measures should still be considered. Natural adaptive capacity restored slowly over time under average conditions. | Cost to relocate or modify design of property, plant and equipment > $100,000 - $2 million | Current environmental / social values may be affected. Natural adaptive capacity restored over time under average conditions. |
| Moderate | Small amount of adaptive capacity. Difficult but possible to restore functionality through repair, redesign or relocation. | Cost to relocate or modify design of property, plant and equipment > $2 - $10 million | Limited natural adaptive capacity. Current environmental / social values would be negatively impacted. |
| Low | Little or no adaptive capacity. Potential impact would destroy all functionality. Not possible to relocate asset. | Cost to relocate or modify design of property, plant and equipment >$10 million | Adaptation would significantly damage or negate current environmental and or social values |

# 4 RISK ASSESSMENT OUTCOMES

The outcomes of the risk assessment for each Sector are discussed in the sub-sections below. A full description of the risk assessment process, with accompanying examples, is provided in **Appendix A**. Summary tables of the assigned likelihood, consequence and adaptive capacity ratings, as well as the resultant risk and vulnerability profiles over time are provided in **Appendix J**, for assets within each Sector.

### 4.1.1 Sector 1

Sector 1 covers approximately 3,060 m of coastline extending from the Northern Boundary of the LGA to Wanliss Street, Rockingham. The section of coastline lies within Tertiary Sediment Cell 17a (Stul et al., 2015).

The beach and coastal dunes/vegetation are bounded to various extents on the landward side by public infrastructure, including a number of parks and recreation areas and carparks. Rockingham Beach Road lies behind these assets. Residential properties are located relatively inland from the coast, but are still predicted to be impacted by coastal hazards. Commercial assets include the CBH Kwinana Grain Terminal located near the northern Sector boundary (**Figure 4-1**). Additional information and the values of the assets are provided in **Appendix J**.

**Figure 4-1 Sector 1 Coastline (source: Real Commercial, 2017. Available: www.realcommercial.com.au)**

#### *4.1.1.2 Coastal Erosion*

Existing physical controls associated with this Sector, which have been considered in the risk assessment process, include extensive offshore reefs and two offshore breakwaters located near the northern Sector boundary. The Sector 1 coastline was classified as sandy for coastal vulnerability assessment and the calculation of the hazard lines. The estimated hazard lines advance steadily landward (see **Appendices A, E and F**) to the 2110 width, ranging from 117 to 212 m.

A total of 102 residential properties lie seaward of the 2110 erosion hazard line. These assets are predicted to be highly vulnerable by 2070 and very highly vulnerable by 2110. The beach and coastal dunes/vegetation have increasing vulnerability across the planning timeframes as their ability to adapt is restricted by development on their landward side. The beach is predicted to have high vulnerability by 2070 and the dune system to be very highly vulnerable by 2070. Due to the value of the Rockingham Beach Road, it being a main road, its vulnerability is medium at 2030, increasing to very high by 2110. The CBH Kwinana Grain Terminal is predicted to have low vulnerability across the planning timeframes. The Terminal Jetty is a popular location for diving with visitors frequently using the Rockingham Road Conservation Reserve Carpark. Its vulnerability

is predicted to increase to medium by 2070 and high by 2110. The Naval Memorial Park, its adjacent carpark and the Phoebe Hymus Carpark all have low vulnerability at present, increasing to medium or high later in the century. The Rockingham Foreshore Park, Governor Reserve Carpark and dual use paths are predicted to have medium vulnerability by 2070 increasing to high by 2110.

Approximately 510 m of drainage pipes may be at risk of erosion with vulnerability reaching medium by 2070, increasing to high by 2110. 25 drainage pits generally have low vulnerability increasing to medium by 2110. See **Appendix J** for the complete risk assessment inputs and results.

#### *4.1.1.3 Coastal Inundation*

The shoreline in this sector has a relatively high dune system at approximately +5 mAHD. The estimated inundation levels in this Sector reach approximately 3.0 mAHD in 2110 for the 500-year ARI storm event (see **Appendices A and B**). Areas near the southern Sector boundary, however, may be impacted by coastal inundation.

The beach will almost certainly be inundated during storm events, but due to its high adaptive capacity, the risk profile and vulnerability of this asset is low to medium across the planning timeframes. Coastal dune/vegetation is predicted to have medium vulnerability by 2070. Built assets, including the Rockingham Foreshore Park and Rockingham Beach Road have low vulnerability across the planning timeframes.

Approximately 2 m of drainage pipes may be at risk of inundation, having low vulnerability across the planning timeframes. See **Appendix J** for the complete risk assessment inputs and results.

### 4.1.2 Sector 2

Sector 2 covers approximately 8,695 m of coastline extending from Wanliss Street, Rockingham to Boundary Road, Shoalwater. The section of coastline lies within Tertiary Sediment Cells 14b, 14c, 15a, 16a and 17a (Stul et al., 2015).

The section of coastline to the east of Cape Peron is heavily developed (**Figure 3-3**). Rockingham Beach, one of the most popular beaches in the LGA, lies within this Sector. The beach and coastal dunes/vegetation are bounded extensively on the landward side by public infrastructure and residential development. A number of carparks and park and recreation areas have been identified to be at risk of coastal hazards including the environmentally sensitive Lake Richmond. Commercial assets include the blocks along Rockingham Beach Road and Railway Terrace. Public facilities include the Point Peron Boating Facility. Community facilities include the Alfred Hines Seaside Home and Point Peron Camp School. Social clubs in this Sector include the Cruising Yacht Club, Mangles Bay Fishing Club and Rockingham Naval Club. There are two primary schools in this Sector, which may be impacted by coastal hazards; Rockingham Beach Primary and Star of the Sea Catholic Primary School. Other assets include jetties, boat ramps, roads and dual use paths. The Department of Defence Land adjacent to the Causeway may be at risk of coastal hazards. The Point Peron Wastewater Treatment Plant, originally planned to be decommissioned by the end of 2015, will be open until at least 2025. For this reason, the Plant has been included in this risk assessment. Vegetation at Point Peron is managed by the Department of Biodiversity, Conservation and Attractions (DoBCA). South of Point Peron, there are three holiday parks along Memorial Drive which may be at risk of coastal hazards. Additional information and the values of the assets are provided in **Appendix J**.

**Figure 4-2 Sector 2 Coastline (source: World Health Organisation, 2017. Available: https://extranet.who.int/)**

#### *4.1.2.2 Lake Richmond*

Forming part of Rockingham Lakes Regional Park, Lake Richmond has a number of characteristics that are of significant value to the community. The Lake includes two Threatened Ecological Communities (TEC) receiving recognition under the EPBC Act (1999) and requiring protection (DEC, 2010).

Lake Richmond and associated open drain infrastructure may be impacted by SLR and inundation during the planning period. As shown in **Appendix J,** a long-section of the Lake and its associated drains may be exposed to coastal hazards by 2110. The vulnerability of Lake Richmond has been approximated with respect to coastal inundation as part of this CHRMAP. A detailed assessment of how the lake and its TECs will respond to climate change should be undertaken. This should include an assessment of responses to the combined effects of changes in rainfall patterns and changes to average temperatures and associated evaporation, as well as changes to the underlying water table a potential future influxes of coastal inundation. Changes to human-induced pressure on the lake must also be considered.

#### *4.1.2.3 Coastal Erosion*

Existing physical controls associated with this Sector, which have been considered in the risk assessment process, include extensive offshore reefs and islands. Built structures include the Hymus St timber groyne, Rockingham Foreshore GSC Seawall, Garden Island Causeway, groynes west of the Causeway, informal rock seawall and GSC Groyne at the Point Peron Camp School. The section of shoreline at Point Peron is rocky throughout with intermittent sections of beach. The remaining coastline is classified as sandy for coastal vulnerability assessment and for the calculation of hazard lines. The estimated hazard lines advance steadily landward (see **Appendices A, E and F**) to the 2110 width, ranging from 113 to 447 m.

A total of 157 residential properties located along the Esplanade lie seaward of the 2110 erosion hazard line. Due to the values of these assets, they have high vulnerability by 2030 increasing to very high vulnerability by 2070. Roads in this Sector have high vulnerability by 2030, increasing to very high by 2070. The commercial area on Railway Terrace and the Mangles Bay Fishing Club have very high vulnerability by 2030 due to their proximity to the coast and high social value. The three blocks of commercial area along Rockingham Beach Road presently have low vulnerability and don't increase to very high until 2110. The Alfred Hines Seaside Home is predicted to have very high vulnerability by 2030. Club facilities in this Sector have varying vulnerability depending on their likelihood. The Cruising Yacht Club has high vulnerability at present, increasing to very high by 2030, whilst the Rockingham Naval Club does not reach very high until 2110. The Point Peron Wastewater Treatment Facility is predicted to have very high vulnerability by 2070. Due to the popularity of boating facilities in this Sector, including boat ramps and jetties, these assets are considered to be socially valuable resulting in high and very high vulnerabilities by 2070. Carparks along the coast and east of the Causeway, vary in vulnerability, with the car parking areas adjacent to Catalpa Park being most vulnerable

reaching very high by 2070. Carparks at Point Peron also vary in vulnerability due to their proximity to erosion hazards. The northeast and southwest carpark are most vulnerable, respectively reaching high and very high by 2070. The three holiday parks along Memorial Drive have increasing vulnerability, generally reaching high ratings by the end of the century. Dual use paths, which are frequently used in this Sector, presently have medium vulnerability, increasing to high by 2070.

Bell Park and Churchill Park have increasing vulnerability over time increasing to medium by 2030 and very high by 2070. Catalpa Park has a low vulnerability rating at present, increasing to high by 2070 and very high by 2110. Rotary Park, which sits behind the Esplanade, is at lower risk of erosion, having medium vulnerability by 2110.

Due to existing development landward of natural assets, the consequence of predicted erosion has been deemed moderate and their adaptive capacity decreases from high to low over time. Erosion is predicted to degrade the dunes and foreshore vegetation, including the DoBCA managed land, over the planning timeframes, affecting the amenity of the beach and ecological functions of the dunes adjacent to developed areas. These natural assets are predicted to be very highly vulnerable by 2070.

Approximately 3800 m of drainage pipes and 192 drainage pits may be at risk of erosion. Both of these drainage assets have increasing vulnerability across the planning timeframes, reaching very high vulnerability by 2070. One bore is predicted to have medium vulnerability by 2110. Underground storage along the Esplanade may be at risk being very highly vulnerable by 2070. See **Appendix J** for the complete risk assessment inputs and results.

#### *4.1.2.4 Coastal Inundation*

The estimated inundation levels in this Sector reach approximately 3.0 mAHD east and 3.43 mAHD south of Cape Peron in 2110 for the 500 year ARI storm event (see **Appendices A and B**). The dune elevation varies greatly within this Sector between +2 and +16 mAHD, with all the significantly higher elevations being around Cape Peron and the lower elevations being in the remainder of this sector.
A total of 985 properties may be at risk by 2110, however the consequences of coastal inundation are seen to be significantly lower than those for coastal erosion. The vulnerability of residential properties is high by 2030 and very high by 2070. Due to the number of parks and recreation areas impacted by inundation, collectively these assets have high vulnerability by 2070, predicted to increase to very high by 2110. Roads in this Sector presently have medium vulnerability, increasing to high by 2070 and very high by 2110. Dual use paths, which are frequently used by residents, have medium vulnerability increasing to very high by 2110. The most vulnerable carpark is the parking area adjacent to Catalpa Park due to its proximity to the coast. This asset has medium vulnerability, increasing to high by 2110. The Alfred Hines Seaside Home and Point Peron Camp School are valuable assets with diminishing adaptive capacity. As a result, these assets have low to medium vulnerability at present and are very highly vulnerable by 2070. The two primary schools, Rockingham Beach Primary and Star of the Sea Catholic Primary School, presently have low vulnerability, increasing to high by 2070. The Department of Defence Land and Point Peron Wastewater Facility have medium vulnerability at present, increasing to very high by the end of the century. Club facilities currently have low vulnerability, increasing across the planning timeframes to very high by 2110. The DoBCA managed land at Point Peron is predicted to have low vulnerability across the planning timeframes. Coastal dune/vegetation is predicted to have medium vulnerability by 2070. The beach will almost certainly be inundated during storm events, but due to its high adaptive capacity, the risk profile and vulnerability of this asset is low to medium across the planning timeframes.

Approximately 3,930 m of drainage pipes and 202 drainage pits may be at risk of inundation. Drainage pipes and pits presently have low vulnerability, increasing to medium by 2030 and high by 2070. Five bores have low vulnerability increasing to medium by 2030. Underground storage along the Esplanade may be at risk being very highly vulnerable by 2070. See **Appendix J** for the complete risk assessment inputs and results.

### 4.1.3 Sector 3

Sector 3 covers approximately 7,340 m of coastline extending from Boundary Road, Shoalwater to Shelton Street, Warnbro. The section of coastline lies within Tertiary Sediment Cells 12a, 13a, 14a and 14b (Stul et al, 2015).

The beach and coastal dunes/vegetation are bounded extensively on the landward side by public infrastructure and residential development. A number of foreshore reserves and carparks were identified along the length of the coastline, such as at Safety Bay and Waikiki. Roads and dual use paths are at risk of coastal hazards in this Sector. Commercial assets include Rockingham Wild Encounters, the Safety Bay Tennis Club, a BP Petrol Station and various restaurants along Bent Street. The Safety Bay Yacht Club and Safety Bay Primary School lie within the central portion of the Sector (**Figure 4-4**). Additional information and the values of the assets are provided in **Appendix J**.

**Figure 4-3 Sector 3 Coastline (source: DoT, 2015)**

#### *4.1.3.2 Coastal Erosion*

Existing physical controls associated with this Sector, which have been considered in the risk assessment process, include extensive offshore reefs and islands, the South Mersey Point Rock Seawall and the Waikiki Rock Seawall. The Sector 3 coastline was classified as sandy for coastal vulnerability assessment and the calculation of the hazard lines. The estimated hazard lines advance steadily landward (see **Appendices A, C and F**) to the 2110 width, ranging from 113 to 287 m.

A total of 520 residential properties lie seaward of the 2110 erosion hazard line. Due to the value of residential properties and roads in this Sector and the increasing risk of coastal erosion impacts, these assets are predicted to be highly vulnerable by 2030 and very highly vulnerable by 2070. The proximity of the Safety Bay Yacht Club to coastal hazards has deemed it to have medium vulnerability at present and very high vulnerability by 2070. Carparks along the coast vary in vulnerability due to their proximity to coastal hazards. Collectively, the seven Safety Bay Foreshore carparks reach a high rating by 2070 and very high by 2110. Safety Bay Foreshore Park is the most vulnerable to erosion due to the popularity of the beach, predicted to have a very high vulnerability by 2070. The Shoalwater Foreshore Park and Waikiki Foreshore Park have medium vulnerability by 2030 increasing to high by 2070. Lions Park to the north of Mersey Point is predicted to have high vulnerability by 2070. The Noel France Reserve is located relatively inland, potentially impacted by erosion towards the end of the century, which results in low vulnerability across the planning timeframes. The

commercial area along Bent Street and the BP Petrol Station are highly and very highly vulnerable by 2070, respectively. Rockingham Wild Encounters is predicted to be very highly vulnerable by 2070 due to its significant tourism value. Dual use paths are frequently used by the community in this Sector. Combined with an increasing risk of erosion, their vulnerability is presently medium, increasing to high by 2030.

Due to existing development landward of natural assets, the consequence of predicted erosion has been deemed moderate and the adaptive capacity decreases from high to low over time. Erosion is predicted to degrade the dunes and foreshore vegetation over the planning timeframes, affecting the amenity of the beach and ecological functions of the dunes adjacent to developed areas. These natural assets are predicted to be very highly vulnerable by 2070.

Approximately 4,645 m of drainage pipes and 216 drainage pits may be at risk of erosion. Both of these drainage assets have increasing vulnerability across the planning timeframes, reaching very high vulnerability by 2070. Two bores are predicted to have medium vulnerability by 2110. See **Appendix J** for the complete risk assessment inputs and results.

#### *4.1.3.3 Coastal Inundation*

The estimated inundation levels in this Sector reach approximately +3.43 mAHD in 2110 for the 500 year ARI storm event (see **Appendices A and B**). The Safety Bay Foreshore area is low lying (dune elevation varies between +3 and +7 mAHD across this sector) resulting in many areas inland being prone to coastal
inundation.

A total of 3,578 residential properties may be at risk, being highly to very highly vulnerable across the planning timeframes, due to their value and low adaptive capacity. The Safety Bay Primary School and Safety Bay Tennis Club have very high vulnerability ratings by 2110. The Safety Bay Yacht Club is predicted to have medium vulnerability increasing to high by 2070 and very high by 2110. Roads have increasing vulnerability reaching very high by 2110. Due to the number of parks and recreation areas impacted by inundation, these assets have medium vulnerability at present, predicted to increase to very high by 2070. Carparks in the sector have medium vulnerability, with the Safety Bay Foreshore Carparks increasing to high by 2070 and the Mersey Point Carpark by 2110. Dual use paths, which are frequently used by residents, have medium vulnerability increasing to high by 2070. Due to the relatively high foreshore area fronting Rockingham Wild Encounters, its likelihood rating is initially rare resulting in low vulnerability, increasing to high by 2070. Coastal dunes/vegetation are predicted to have medium vulnerability by 2070. The beach will almost certainly be inundated during storm events, but due to its high adaptive capacity, the risk profile and vulnerability of this asset is low to medium across the planning timeframes.

Approximately 10,440 m of drainage pipes and 455 drainage pits may be at risk of inundation. Drainage pipes and pits will have medium vulnerability by 2030, increasing to high by 2070. 19 bores have low vulnerability increasing to medium by 2070. See **Appendix J** for the complete risk assessment inputs and results.

### 4.1.4 Sector 4

Sector 4 covers approximately 6,430 m of coastline extending from Shelton Street, Warnbro to Becher Point, Port Kennedy. The section of coastline lies within Tertiary Sediment Cells 12a and 11a (Stu et al., 2015).

The beach and coastal dunes/vegetation are bounded to various extents on the landward side by public infrastructure and residential development. The section of coastline at the southern boundary fronts the Port Kennedy Scientific Park. A portion of coastal land at Port Kennedy is allocated for recreation use, including a boat ramp, park and recreation area, beach access paths and car parking. A number of car parking areas are located along the northern half of the Sector to provide access to Warnbro Beach (**Figure 4-4**). Additional information and the values of the assets are provided in **Appendix J**.

**Figure 4-4 Sector 4 Coastline (source: DoT, 2015)**

#### *4.1.4.2 Coastal Erosion*

The Sector 4 coastline was classified as sandy for coastal vulnerability assessment and the calculation of the hazard lines. The estimated hazard lines advance steadily landward (see **Appendices A, E and F**) to the 2110 width, ranging from 635 m in the southern half to 150 m in the northern half.

A total of 98 residential properties lie seaward of the 2110 erosion hazard line. At the northern end of the study area they are predicted to have a high vulnerability by 2070 and very high vulnerability by 2110. The foreshore recreation area at Port Kennedy has an increasing vulnerability reaching very high by 2110. The Port Kennedy boat ramp is a highly valued and used asset, therefore having a very high vulnerability by 2070. The carpark adjacent to the boat ramp presently has a medium vulnerability, increasing to high by 2030 and very high by 2070. Other carparks in the northern half of the coastline generally have low vulnerability, increasing to medium by 2110. The Port Kennedy Scientific Park has increasing vulnerability ratings across the planning timeframes, becoming highly vulnerability by 2110 due to its high environmental value. Dual use paths presently have medium vulnerability increasing to high by 2110. The vulnerability of the beach and coastal dunes/vegetation are predicted to increase as coastal erosion risk increases and their ability to adapt diminishes, due mainly to development restricting inland migration. The beach is predicted to be highly vulnerable by 2070 and the dune system to be very highly vulnerable by 2070.

Approximately 510 m of drainage pipes and 66 drainage pits may be at risk of erosion. Both of these drainage assets have increasing vulnerability, having a medium vulnerability by 2030. Pipes are predicted to increase to high by 2070 and pits by 2110. See **Appendix J** for the complete risk assessment inputs and results.

#### *4.1.4.3 Coastal Inundation*

The estimated inundation levels in this Sector reach approximately +3.43 mAHD in 2110 for the 500-year ARI storm event (see **Appendices A and B**). Due to the low lying nature of the dunes at Port Kennedy, only in this portion of this sector are built assets predicted to be at risk of coastal inundation. The dune elevation varies across this sector between +3 and +9m AHD, with the higher elevations in the northern part of this area and the lower elevations in the southern part.

A total of 28 residential properties may be impacted, being very highly vulnerable by 2110, due to their value and proximity to potential coastal inundation hazards. Roads and the park and recreation area are predicted to have medium vulnerability by 2070. The Port Kennedy Foreshore Carpark presently has low vulnerability, increasing to high by 2070 due to its likelihood of inundation. Dual use paths, which are frequently used by residents, have low to medium vulnerability across the planning timeframes. Natural assets, including the Port

Kennedy Scientific Park and the coastal dunes/vegetation are predicted to have medium vulnerability by 2070. The beach will almost certainly be inundated during storm events, but due to its high adaptive capacity, the risk profile and vulnerability of this asset is low medium across the planning timeframes.

Approximately 620 m of drainage pipes and 55 drainage pits may be at risk of inundation. Drainage pipes and pits presently have a low vulnerability rating, increasing to high by 2110. See **Appendix J** for the complete risk assessment inputs and results.

### 4.1.5 Sector 5

Sector 5 covers approximately 6,140 m of coastline extending from Becher Point, Port Kennedy to Turtles Bend, Secret Harbour. The section of coastline lies within Tertiary Sediment Cell 11a (Stu et al., 2015).

The northern half of the coastline fronts the Port Kennedy Scientific Park. The southern half contains assets including the beach and dune vegetation, Secret Harbour Beach Carparks, Lagoon Park, roads and pedestrian pathways (**Figure 4-6**). Additional information and the values of the assets are provided in **Appendix J**.

**Figure 4-5 Southern Section of Sector 5 Coastline (source: DoT, 2015)**

#### *4.1.5.2 Coastal Erosion*

The Sector 5 coastline was classified as sandy for coastal vulnerability assessment and the calculation of the hazard lines. The estimated hazard lines advance steadily landward (see **Appendices A, E and F**) to the 2110 width, ranging from 130 m in the southern half to 370 m in the northern half.

Having an increasing consequence of erosion due to its environmental value, the Port Kennedy Scientific Park has a low vulnerability increasing to medium by 2110. The beach and coastal dunes/vegetation have increasing vulnerability across the planning timeframes as their ability to adapt is restricted by some development on their landward side. The beach is predicted to have medium vulnerability from 2030 and the dune system to be highly vulnerable by 2070. Lagoon Park, being a socially valuable asset, is predicted to have medium vulnerability by 2110. The Secret Harbour Beach Carpark off Siracusa Street reaches a medium vulnerability by 2070. The other carparks do not reach medium vulnerability until 2110 due to their lower risk of erosion. Due to its low adaptive capacity, the Secret Harbour Surf Lifesaving Club reaches a high vulnerability by 2070, increasing to very high by 2110. Pedestrian pathways are predicted to have medium vulnerability by 2070 due to their increasing risk of erosion.

Approximately 370 m of drainage pipes and 19 drainage pits may be at risk of erosion. Both of these drainage assets have low vulnerability across the planning timeframes, with pipes increasing to medium by 2110. See **Appendix J** for the complete risk assessment inputs and results.

#### *4.1.5.3 Coastal Inundation*

Due to a relatively high dune system in the southern section of coastline at approximately +5 mAHD, only natural assets are predicted to be impacted by coastal inundation. The estimated inundation levels in this Sector reach approximately +3.43 mAHD in 2110 for the 500-year ARI storm event (see **Appendices A and B**), which is below the dune level.

The beach will almost certainly be inundated during storm events, but due to its high adaptive capacity, the risk profile and vulnerability of this asset is low to medium across the planning timeframes. Coastal dunes/vegetation fronting the Port Kennedy Scientific Park in the north are predicted to have a medium vulnerability by 2110. Similarly, the Port Kennedy Scientific Park itself has medium vulnerability by 2110. See **Appendix J** for the complete risk assessment inputs and results.

### 4.1.6 Sector 6

Sector 6 covers approximately 4,365 m of coastline extending from Turtles Bend, Secret Harbour to the Southern Boundary of the LGA. This section of coastline lies within Tertiary Sediment Cell 10b (Stu et al., 2015).

Sector 6 contains predominantly natural assets, such as the beach and dune vegetation with built assets located significantly inland from the coast (**Figure 4-6**). Additional information and the values of assets are provided in **Appendix J**.

**Figure 4-6 Sector 6 Coastline (source: DoT, 2015)**

#### *4.1.6.2 Coastal Erosion*

The Sector 6 coastline was classified as sandy for coastal vulnerability assessment and the calculation of the hazard lines. The estimated hazard lines advance steadily landward (see **Appendices A, E and F**) to the 2110 width of approximately 130 m.

Although the current beach and vegetated dune system is likely to be eroded over time, this dunal ecosystem extends over broad areas of the coast and hence the consequence of future erosion within this management unit is considered insignificant to moderate. The adaptive capacity of these natural assets is also considered high through their ability to migrate inland. The risk profile and vulnerability of the beach in this area are therefore low to medium across the planning timeframes. The medium to high rating for coastal dunes/vegetation towards the end of the century is based on the assumption that inland migration of the dune habitat is likely, and it is uncertain that all ecological functions will be retained. The vulnerability of the Singleton Foreshore Reserve is low across the planning timeframes increasing to medium by 2110, due primarily to its ability to be relocated.

Approximately 2 m of drainage pipe and one drainage pit may be at risk of erosion. Both of these drainage assets have low vulnerability across the planning timeframes. See **Appendix J** for the complete risk assessment inputs and results.

#### *4.1.6.3 Coastal Inundation*

This section of shoreline has a relatively high dune system at approximately +5 mAHD. The estimated inundation levels in this Sector reach approximately +3.43 mAHD in 2110 for the 500-year ARI storm event (see **Appendices A and B**), which is below the dune level.

The beach will almost certainly be inundated during storm events, but due to its high adaptive capacity, the risk profile and vulnerability of this asset is low to medium across the planning timeframes. Due to the rare likelihood of it being inundated, the coastal dune/vegetation has a low vulnerability rating across the planning timeframes. See **Appendix J** for the complete risk assessment inputs and results.

# 5 Conclusion

The risk and vulnerability assessment has identified assets, groups of assets and areas potentially vulnerable to coastal erosion and inundation hazards at present and up to the 2110 planning timeframe. In general, coastal erosion hazards lead to the highest vulnerability in the short-term, due to their greater capacity to damage assets. The risk of coastal inundation, however, increases substantially over future planning timeframes and extends across large areas of low-lying land along the City's coastline. Although options for short-term implementation will be generally focused on mitigating the threat of coastal erosion, they must also consider and account for future hazards associated with coastal inundation.

## 5.1 Preliminary Prioritisation

Through the vulnerability assessment process, several assets or groups of assets were identified as being highly or very highly vulnerable by the 2030 planning timeframe. Sectors containing these assets have been prioritised for further assessment and discussion in **Appendix I**. The options for treatment in these Sectors will be considered in greater detail, to better inform decision making and assist in presenting the options to the community for their consideration. Sectors 2, 3 and 4 were identified as having assets highly vulnerable to coastal erosion within the 2030 planning timeframe. Key assets vulnerable to coastal erosion and their vulnerability timeframes are presented for each of these Sectors in **Tables 5-1** to **5-3**, respectively, below.

**Table 5-1 Key assets vulnerable to coastal erosion in Sector 2 and their vulnerability timeframes.**

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Vulnerability | | | |
| Alfred Hines Seaside Home | High | Very High | Very High | Very High |
| Coastal/dune vegetation | Medium | High | Very High | Very High |
| Commercial area (Railway Tce) | Low | Very High | Very High | Very High |
| Drainage Pipes | Medium | High | Very High | Very High |
| Mangles Bay Fishing Club | High | Very High | Very High | Very High |
| Point Peron Wastewater Treatment Plant | Medium | High | Very High | Very High |
| Residential | Low | High | Very High | Very High |
| Roads | Low | High | Very High | Very High |
| Rockingham Naval Club | High | High | High | Very High |
| The Cruising Yacht Club | High | Very High | Very High | Very High |
| Underground Storage | Medium | High | Very High | Very High |

**Table 5-2 Key assets vulnerable to coastal erosion in Sector 3 and their vulnerability timeframes.**

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Vulnerability | | | |
| Drainage Pipes | Medium | High | Very High | Very High |
| Dual use paths | Medium | High | High | Very High |
| Residential | Low | High | Very High | Very High |
| Roads | Medium | High | Very High | Very High |

**Table 5-3 Key asset vulnerable to coastal erosion in Sector 4 and their vulnerability timeframes.**

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Vulnerability | | | |
| Port Kennedy Foreshore Carpark | Medium | High | Very High | Very High |

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# APPENDIX

# I

## RISK ASSESSMENT METHODOLOGY

# APPENDIX I RISK ASSESSMENT METHODOLOGY

## 1.1 Overview

The risk assessment process uses the outcomes of the coastal hazard modelling to characterise the risk and vulnerability of assets over the planning timeframe. An overview of the framework adopted in this assessment is presented in **Figure 1-1**.

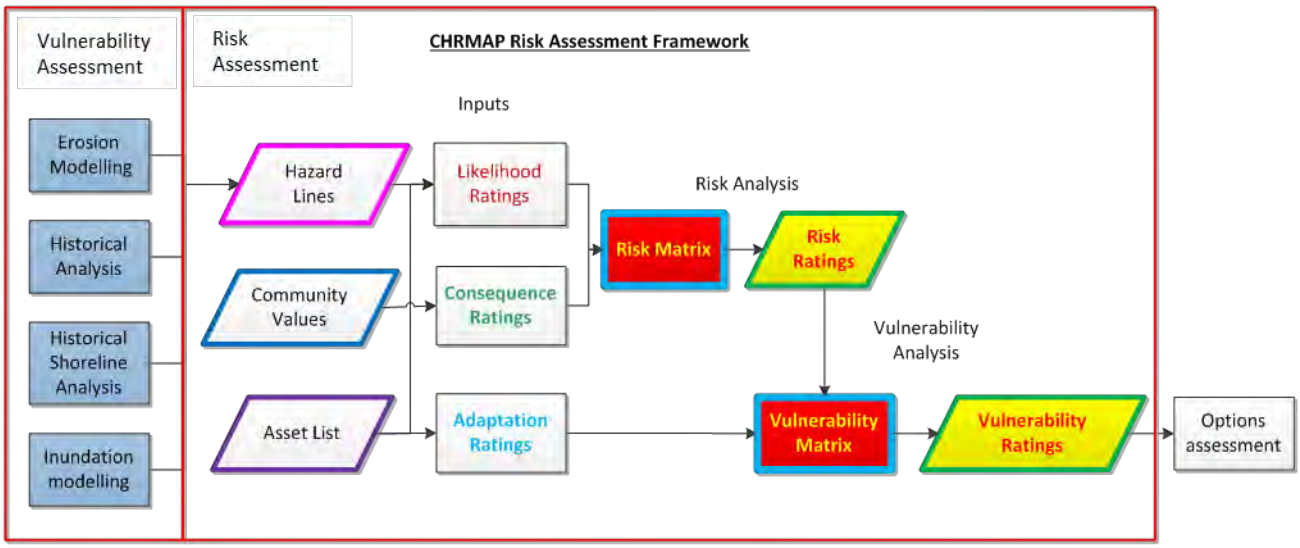


**Figure 1-1 Schematic representation of the risk assessment process**

There are a number of steps involved in the risk assessment process:

1. Define likelihood categories (ratings);
2. Allocate the likelihood of the risk occurring to specific assets for a particular planning timeframe based on the results of the hazard assessment;
3. Define consequence categories (ratings);
4. Allocate the consequence of the risk occurring to specific assets for a particular planning timeframe based on CHRMAP guidance, AS 5334-2013 and the project specific Success Criteria;
5. Define risk categories (ratings) based on the acceptability (or tolerability); and
6. Allocate the risk ratings for combinations of likelihood and consequence.

The process aims to be objective, logical and transparent. All steps call for interpretation, and allocation of consequence in particular may be based on subjective judgement. However, once the framework has been adopted, specific outcomes can be clearly traced to inputs. The inputs can be updated in response to new information or stakeholder input, and the risk assessment outcomes will be revised accordingly. Additional details on how the input parameters were derived, and the ratings were developed is provided below.

## 1.2 Risk Analysis

To assess the level of risk, or potential impact, posed to the assets by the identified coastal hazards, this CHRMAP has employed risk analysis techniques outlined in AS 5334-2013. The risk assessment entails the combination of likelihood and consequence of exposure to coastal hazard to produce the risk level, or potential impact, for each asset, as presented in **Figure 1-2** below.

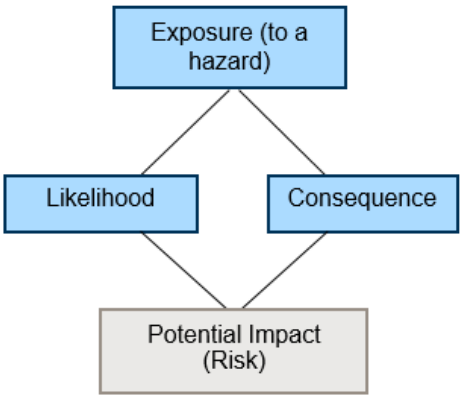


**Figure 1-2 Risk analysis structure**

The potential impact (risk) has been assessed for each asset or group of assets, at each of the planning timeframes:

> Present Day (2017)
> 2030
> 2070
> 2110

This allows risk prioritisation and assessment of each asset's risk level over the 100 year planning horizon as required by SPP2.6.

For the purposes of this study 'short-term' refers to the period between 2017 and 2030, 'medium-term' refers to the period between 2030 and 2070, and long-term refers to the period beyond 2070. The 'immediate-term' or 'immediately' may also be used, generally referring to within the next 5 years.

### 1.2.2 Likelihood

According to WAPC (2014a) and for the purposes of this study, likelihood is defined as the chance of erosion and storm surge inundation impacting on existing assets and their values. A description of the likelihood scale is presented in **Table 1-1**.

Table 1-1 **CHRMAP likelihood ratings**

| Rating | Description |
|---|---|
| **Almost Certain** | High possibility of impact to asset shoreline for a given planning timeframe |
| **Likely** | Impact to asset shoreline for a given planning timeframe is likely |
| **Possible** | Impact to asset shoreline for a given planning timeframe is possible |
| **Unlikely** | Impact to asset shoreline for a given planning timeframe is unlikely |
| **Rare** | May occur in exceptional circumstances |

The erosion and inundation hazard extents are made up of a number of components. Each of these is based on a suite of assumptions and each has a degree of uncertainty which may influence the likelihood of the predicted level of erosion or inundation occurring at each planning horizon. For example, the extent of the coastal erosion hazard lines assume a 100 year ARI storm event occurs exactly at the planning timeframe (2030, 2070 etc.), which in reality is highly unlikely. There is also the assumption that the probability of the design coastal hazard event occurring is the same each year, which is not necessarily the case when considering the effects of climate change and the rise in sea level on the severity of storm events.

There is considerable scope for confusion in defining and allocating likelihood in terms of recurrence frequency/probability (as per AS 5334) for the purposes of risk assessment, particularly given this terminology has specific meaning in the coastal context. Cardno has therefore adopted the approaches presented in **Figure 1-3**, which are generally consistent with guidance in WAPC (2014a). An example of the likelihood rating input format for assets in a particular study site is provided in **Table 1-2**.

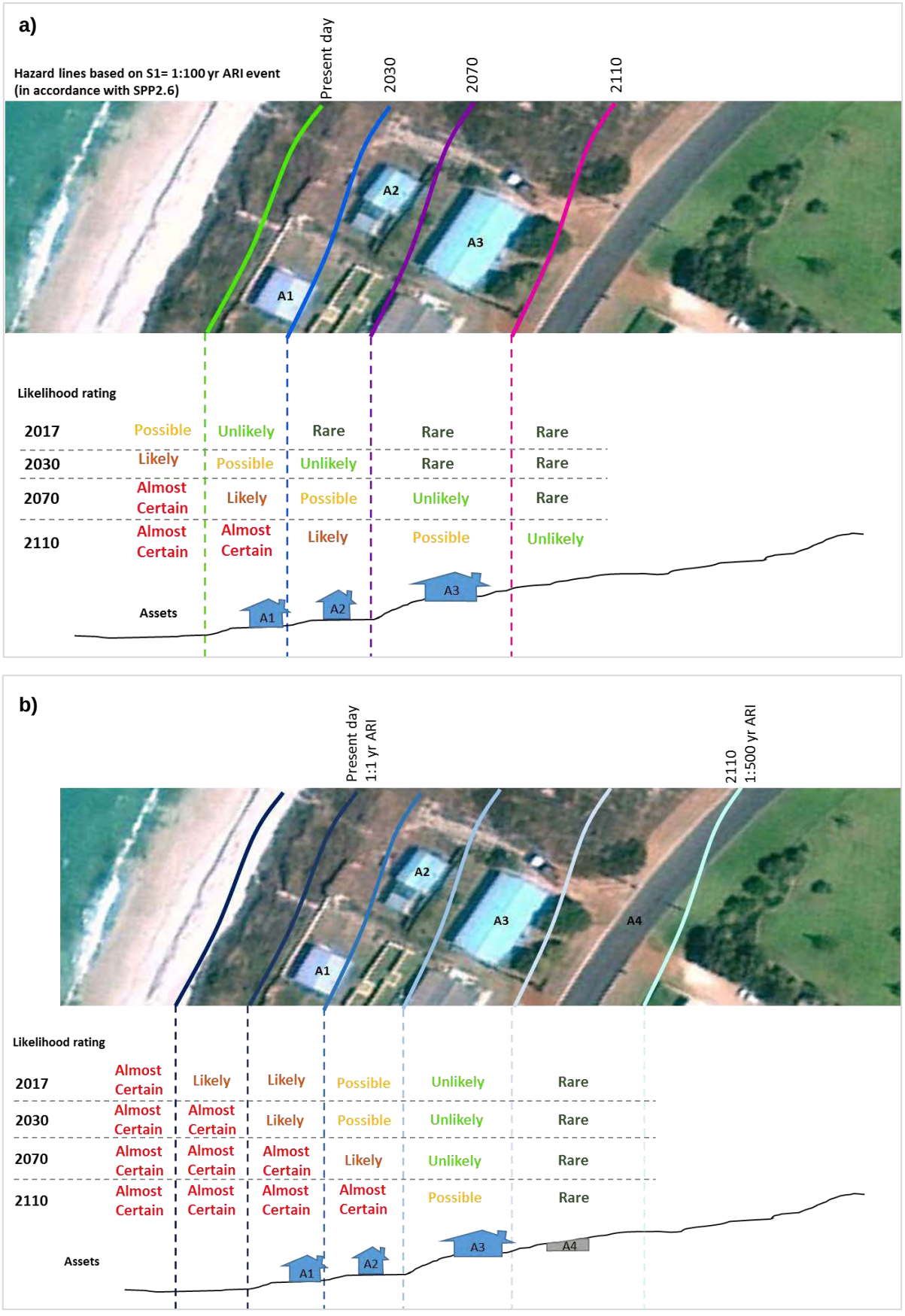


**Figure 1-3 Representation of method used to assign likelihood ratings to individual assets for each planning timeframe for a) erosion and b) inundation**

Table 1-2 **Example likelihood rating inputs table**

| | Planning timeframe | | | |
|---|---|---|---|---|
| | Present Day | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Unlikely | Possible | Almost Certain | Almost Certain |
| Car Park | Rare | Rare | Possible | Almost Certain |
| Road | Rare | Rare | Possible | Almost Certain |
| Residential Lots | Rare | Rare | Unlikely | Likely |

### 1.2.3 Consequence

Consequence is the result of a hazard impacting an area, asset or group of assets. For this analysis, consequence has been divided into five ratings ranging from catastrophic to insignificant (**Table 1-3**). The consequence ratings for this risk assessment have been adapted from those presented in AS 5334-2013, and WAPC (2014a), which focus on the social, economic and environmental consequences.

A heritage component has been incorporated alongside environmental impacts to ensure impacts to heritage sites are accounted for in the risk assessment process. The consequence descriptions have also been scaled to be applicable to the local context in which this study is being undertaken, where as previously their higher ratings were associated with consequences on a global scale. Generally, the consequence categories incorporate all of the values outlined by the Success Criteria and align comparatively between categories with the level of response to these Success Criteria. Assessment of the economic component was based on estimating the total cost for replacement of impacted assets with costs taken from the *Australian Construction Handbook* (Rawlinsons, 2016).

Generally coastal inundation and coastal erosion will occur at the same time during a storm event. In the majority of circumstances and locations for the City's coastline, the impacts of coastal erosion on infrastructure will be more severe and long-lasting than the impacts of coastal inundation. There are circumstances where coastal erosion will not occur (e.g. where the shoreline is rock) and in these instances only the consequences of coastal inundation require consideration.

Table 1-3 **Consequence ratings (adapted from AS 5334-2013)**

| Rating | Social | Economic | Environment |
|---|---|---|---|
| **Catastrophic** | Loss of life and serious injury. Large long-term or permanent (~1 yr) loss of services, public access/amenity, employment, wellbeing or culture. No suitable alternative sites exist within the LGA. | Permanent and/or entire loss or damage to property, plant and equipment, finances >$10 million. Regional economic decline, widespread business failure and impacts on state economy. | Permanent and entire loss of flora, fauna conservation or heritage area (no chance of recovery) . |
| **Major** | Serious injury. Medium term (~1 month) disruption to services, public access/amenity, employment, wellbeing or culture. Very limited suitable alternative sites exist within the LGA. | Permanent and/or large scale loss or damage to property, plant and equipment, finances > $2 - $10 million. Lasting downturn of local economy with isolated business failures and major impacts in regional economy. | Long-term and/or large scale loss of flora, fauna or heritage area (limited chance of recovery) with local impact. |
| **Moderate** | Minor injury. Major short term or minor long-term (~1 week) disruption to services, public access/amenity, employment, wellbeing, or culture. Limited suitable alternative sites exist within the LGA. | Permanent and/or medium scale loss or damage to property, plant and equipment, finances > $100,000 - $2 million. Significant impacts on local economy and minor impacts on regional economy. | Medium-term and/or medium scale loss of flora, fauna or heritage area (recovery likely) with local impact. |
| **Minor** | Small to medium short-term (~1 day) disruption to services, public access/amenity, employment, wellbeing, or culture. Many suitable alternative sites exist within the LGA. | Permanent and/or small scale loss or damage to property, plant and equipment, finances > $10,000 - $100,000. Individually significant but isolates impacts on local economy. | Short-term and/or small scale loss of flora, fauna or heritage area (strong recovery) with local impact. |
| **Insignificant** | Minimal short-term (~1 hr) inconveniences to services, public access/amenity, employment, wellbeing, or culture. Many suitable alternative sites exist within the LGA. | Permanent loss or damage to property, plant and equipment, finances < $10,000. Minor short-term impacts on local economy. | Negligible to no loss of flora, fauna or heritage area (strong recovery) with local impact. |

Consequence was allocated for each asset within a vulnerable area, and for each of the planning timeframes. It was possible for the severity of consequence to increase over time, assuming that impacts could be greater as well as more likely to occur. An example of the format of consequence rating inputs is provided in **Table 1-4**.

Table 1-4 **Example consequence ratings applied to a vulnerable area**

| | Planning timeframe | | | |
|---|---|---|---|---|
| | Present day | 2030 | 2070 | 2110 |
| **Asset** | **Consequence** | | | |
| Impact on Beach | **Major** | **Major** | **Catastrophic** | **Catastrophic** |
| Impact on Car Park | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| Impact on Road | **Moderate** | **Moderate** | **Major** | **Major** |
| Impact on Residential Lots | **Minor** | **Minor** | **Minor** | **Major** |

## 1.3 Risk Evaluation

### 1.3.1 Potential Impact (Risk Rating)

The CHRMAP uses a risk assessment matrix which is based on that provided in AS5334-2013 (**Table 1-5**). Risk ratings are defined by risk acceptability / tolerance and the urgency of required action (**Table 1-6**). This will help to prioritise multiple identified risks within the study area. It can also provide a mechanism to compare the level of risk after a preferred adaptation option is determined, for example, at present a risk may be "extreme" in the short term, after the implementation of adaption option 'X' the risk level is re-evaluated and reduces to "medium".

Table 1-5 **Risk matrix (Based on AS5334-2013)**

| Likelihood | Consequences | | | | |
|---|---|---|---|---|---|
| | Insignificant | Minor | Moderate | Major | Catastrophic |
| Almost Certain | L | M | H | E | E |
| Likely | L | M | M | H | E |
| Possible | L | L | M | H | E |
| Unlikely | L | L | M | M | H |
| Rare | L | L | L | M | M |

Table 1-6 **Risk levels and tolerances**

| Risk Level | Action Required | Acceptance / Tolerance |
|---|---|---|
| Extreme (E) | Immediate action required to eliminate or reduce risk to acceptable levels. | Unacceptable |
| High (H) | Immediate to short-term action required to eliminate or reduce risk to acceptable levels. | Tolerable / Unacceptable |
| Medium (M) | Short to medium term action to reduce risk to acceptable levels, or accept risk. | Tolerable |
| Low (L) | Accept risk. | Acceptable |

The risk evaluation process utilises the outcomes of the risk analysis as inputs. Likelihood and consequence allocated for assets, under each scenario, are combined to derive a risk rating for each asset within each of the vulnerable areas. Examples of the derived risk ratings for a particular study site are provided in **Table 1-7**.

Table 1-7 **Example of risk rating results by asset and planning timeframe**

| | Planning Timeframe | | | |
|---|---|---|---|---|
| | Present Day | 2030 | 2070 | 2110 |
| **Asset** | **Risk** | | | |
| Beach | Medium | Medium | Extreme | Extreme |
| Car Park | Low | Low | Medium | High |
| Road | Low | Low | High | Extreme |
| Residential Lots | Low | Low | Medium | High |

## 1.4 Vulnerability Analysis

As per AS 5334-2013, detailed risk analysis should include a vulnerability analysis to thoroughly examine how coastal hazards and climate change may affect the asset.

Vulnerability analysis involves assessing the asset's existing capacity to adapt to a potential impact; a flow chart for the process of establishing the vulnerability is presented in Figure 1-4. Adaptive capacity and vulnerability are detailed in the following sections

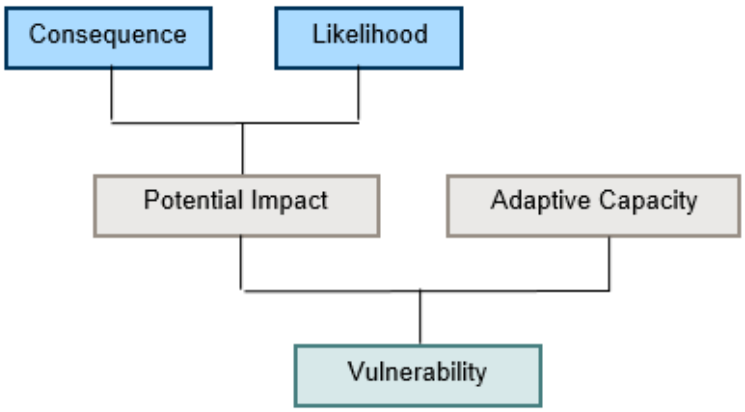


**Figure 1-4 Vulnerability assessment structure**

### 1.4.2 Adaptive Capacity

The adaptive capacity (**Table 1-8**) is based upon the potential for the system to be modified or acclimatise to cope with the impacts of identified hazards. The system of existing controls, such as a coastal protection structure, dune system or reef, all have an influence on the ability of hazards to affect a study site. The aim of the CHRMAP is to develop options that realise the potential adaptive capacity through techniques such as managed retreat, accommodation, and protection. An asset or group of assets with a high adaptive capacity is one that can easily (i.e. at low cost) be adapted or one that has some capacity to self-adapt with changing conditions (e.g. beaches and dune systems can migrate across shore as the mean sea level (MSL) changes). Assets with a high risk level and low adaptive capacity are deemed vulnerable and management options should be investigated. Examples of the adaptive capacity ratings allocated for a particular study site are provided in **Table 1-9**.

Table 1-8 **CHRMAP adaptive capacity ratings**

| Rating | Adaptive Capacity |
|---|---|
| **Low** | Little or no adaptive capacity. Potential impact would destroy all functionality. |
| **Moderate** | Small amount of adaptive capacity. Difficult but possible to restore functionality through repair and redesign. |
| **High** | Decent adaptive capacity. Functionality can be restored, although additional adaptive measures should still be considered. Natural adaptive capacity restored slowly over time under average conditions. |
| **Very High** | Good adaptive capacity. Functionality restored easily. Adaptive systems restored at a relatively low cost or naturally over time. |

Table 1-9 **Example of adaptive capacity ratings applied to assets and timeframes**

| | Planning Timeframe | | | |
|---|---|---|---|---|
| | Present Day | 2030 | 2070 | 2110 |
| **Asset** | **Adaptive Capacity** | | | |
| Beach | High | High | Moderate | Low |
| Car Park | Moderate | Moderate | Moderate | Moderate |
| Road | Moderate | Low | Low | Low |
| Residential Lots | Low | Low | Low | Low |

### 1.4.3 Vulnerability

Vulnerability is the potential for a system to suffer damage or ill effects as a result of coastal hazards or climate change. Vulnerability is a function of the likelihood of an event occurring, the consequences of the event and the capacity to adapt and change. In a similar fashion to the risk methodology, potential impact and adaptive capacity can be combined using a customised matrix (**Table 1-10**) with the significance of the vulnerability rating listed in relation to acceptability and tolerances provided in **Table 1-11**. An example outcome from the analysis is provided in **0**.

Table 1-10 **Vulnerability Analysis Matrix**

| **Risk Level (Potential Impact)** | **Adaptive Capacity** | | | |
|---|---|---|---|---|
| | **Very High** | **High** | **Moderate** | **Low** |
| **Extreme** | H | H | VH | VH |
| **High** | M | H | H | VH |
| **Medium** | M | M | M | H |
| **Low** | L | L | L | L |

Table 1-11 **Vulnerability levels and tolerances**

| Vulnerability Level | Action Required | Acceptance / Tolerance |
|---|---|---|
| **Very High (VH)** | Significant further adaption required to ensure asset is not lost. Reconsideration of design if vulnerability cannot be reduced. | Unacceptable |
| **High (H)** | Further adaption required. All stakeholders should be fully aware of risks if vulnerability cannot be reduced. | Tolerable / Unacceptable |
| **Medium (M)** | Further adaption should be investigated, acceptable in certain circumstances. Monitoring programs recommended. | Tolerable |
| **Low (L)** | Acceptable; adaption and monitoring may be required over the asset's lifetime. | Tolerable / Acceptable |

Table 1-12 **Example of outcome from vulnerability analysis**

| | Planning Timeframe | | | |
|---|---|---|---|---|
| | Present Day | 2030 | 2070 | 2110 |
| **Asset** | **Vulnerability** | | | |
| Beach | Low | Low | Medium | High |
| Car Park | Low | Low | Medium | High |
| Road | Low | Low | Low | Medium |
| Residential Lots | Low | Low | Low | High |

## 1.5 References

*Rawlinsons Publishing (2016). Australian Construction Handbook, Edition 35. Published by Rawlinsons Publishing, Perth, WA.*

*Standards Australia (2013) AS 5334-2013 Climate change adaptation for settlements and infrastructure— A risk based approach. Published by SAI Global Limited under licence from Standards Australia Limited, Sydney, New South Wales.*

*WAPC. (2014a) Coastal Hazard Risk Management and Adaptation Planning Guidelines. Published by the Western Australian Planning Commission, Perth, WA. Available at https://www.planning.wa.gov.au/dop_pub_pdf/CHRMAP_Guidelines.pdf*

# APPENDIX

# J

## VULNERABLE ASSET INFORMATION & RISK ASSESSMENT RESULTS

**Sector 1**

| Values | Inundation | | Erosion | |
|---|---|---|---|---|
| | Assets at Risk | Extent | Assets At Risk | Extent |
| **Environmental** | Beach | 3.1 km | Beach | 3.1 km |
| | Coastal / Dune Vegetation | | Coastal / Dune Vegetation | |
| **Social** | Rockingham Foreshore Park | 6,095 $m^2$ | Rockingham Foreshore Park | 27,125 $m^2$ |
| | | | Naval Memorial Park | 29,900 $m^2$ |
| **Economic - Private** | | | Residential Properties | 102 |
| | | | CBH Kwinana Grain Terminal | 5,325 $m^2$ |
| **Economic - Public** | Road - Rockingham Beach Rd | 0.17 km | Road - Rockingham Beach Rd | 4.1 km |
| | | | Dual Use Path | 2.6 km |
| | | | Naval Memorial Park Carpark | 1,620 $m^2$ |
| | | | Governor Reserve Carpark | 1,490 $m^2$ |
| | | | Rockingham Road Conservation Reserve Carpark | 2,960 $m^2$ |
| | | | Phoebe Hymus Carpark | 1,490 $m^2$ |
| | | | Emerald Park Carpark | 685 $m^2$ |
| **Existing Coastal Controls** | | | | |
| 2 Offshore Breakwaters | | | | |


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 1 ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR1_VULNERABLEASSETS_REV1 01

DATE PLOTTED:19/02/2018 3:16:21 PM BY: JAMES.DRACUP
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## Sector 1 - Erosion

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Possible | Likely | Almost Certain | Almost Certain |
| CBH Kwinana Grain Terminal | Rare | Rare | Unlikely | Possible |
| Coastal/dune vegetation | Possible | Likely | Almost Certain | Almost Certain |
| Drainage Pipes | Rare | Unlikely | Possible | Likely |
| Drainage Pits | Rare | Unlikely | Possible | Likely |
| Dual use paths | Rare | Unlikely | Possible | Likely |
| Emrald Park Carpark | Rare | Unlikely | Possible | Likely |
| Governor Reserve Carpark | Rare | Rare | Unlikely | Possible |
| Naval Memorial Park | Rare | Unlikely | Possible | Likely |
| Naval Memorial Park Carpark | Rare | Unlikely | Possible | Likely |
| Offshore Breakwaters | Rare | Possible | Likely | Almost Certain |
| Phoebe Hymus Carpark | Rare | Unlikely | Possible | Likely |
| Residential | Rare | Rare | Unlikely | Possible |
| Road (Rockingham Beach Rd) | Rare | Unlikely | Unlikely | Possible |
| Rockingham Foreshore Park | Rare | Unlikely | Possible | Likely |
| Rockingham Rd Conservation Reserve Carpark | Rare | Unlikely | Possible | Likely |

| Asset | Consequence of Erosion | | | |
|---|---|---|---|---|
| Beach | Insignificant | Minor | Moderate | Major |
| CBH Kwinana Grain Terminal | Insignificant | Insignificant | Insignificant | Minor |
| Coastal/dune vegetation | Insignificant | Minor | Major | Catastrophic |
| Drainage Pipes | Insignificant | Insignificant | Moderate | Major |
| Drainage Pits | Insignificant | Insignificant | Minor | Moderate |
| Dual use paths | Insignificant | Minor | Moderate | Major |
| Emrald Park Carpark | Insignificant | Insignificant | Moderate | Major |
| Governor Reserve Carpark | Insignificant | Insignificant | Major | Major |
| Naval Memorial Park | Insignificant | Minor | Major | Major |
| Naval Memorial Park Carpark | Insignificant | Minor | Major | Major |
| Offshore Breakwaters | Insignificant | Insignificant | Minor | Minor |
| Phoebe Hymus Carpark | Insignificant | Moderate | Moderate | Major |
| Residential | Moderate | Moderate | Major | Catastrophic |
| Road (Rockingham Beach Rd) | Moderate | Moderate | Major | Catastrophic |
| Rockingham Foreshore Park | Insignificant | Minor | Major | Major |
| Rockingham Rd Conservation Reserve Carpark | Insignificant | Insignificant | Moderate | Major |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Beach | High | High | Moderate | Low |
| CBH Kwinana Grain Terminal | Low | Low | Low | Low |
| Coastal/dune vegetation | High | Moderate | Moderate | Low |
| Drainage Pipes | Moderate | Moderate | Moderate | Moderate |
| Drainage Pits | Moderate | Moderate | Moderate | Moderate |
| Dual use paths | High | High | High | High |
| Emerald Park Carpark | High | High | Moderate | Low |
| Governor Reserve Carpark | High | High | Moderate | Low |
| Naval Memorial Park | High | High | Moderate | Low |
| Naval Memorial Park Carpark | High | High | Moderate | Low |
| Offshore Breakwaters | High | High | High | High |
| Phoebe Hymus Carpark | High | High | Moderate | Low |
| Residential | Low | Low | Low | Low |
| Road (Rockingham Beach Rd) | Moderate | Moderate | Moderate | Low |
| Rockingham Foreshore Park | High | High | Moderate | Low |
| Rockingham Rd Conservation Reserve Carpark | High | High | High | Moderate |

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | **Risk** | | | |
| **Beach** | Low | Medium | High | Extreme |
| **CBH Kwinana Grain Terminal** | Low | Low | Low | Low |
| **Coastal/dune vegetation** | Low | Medium | Extreme | Extreme |
| **Drainage Pipes** | Low | Low | Medium | High |
| **Drainage Pits** | Low | Low | Low | Medium |
| **Dual use paths** | Low | Low | Medium | High |
| **Emrald Park Carpark** | Low | Low | Medium | High |
| **Governor Reserve Carpark** | Low | Low | Medium | High |
| **Naval Memorial Park** | Low | Low | High | High |
| **Naval Memorial Park Carpark** | Low | Low | High | High |
| **Offshore Breakwaters** | Low | Low | Medium | Medium |
| **Phoebe Hymus Carpark** | Low | Medium | Medium | High |
| **Residential** | Low | Low | Medium | Extreme |
| **Road (Rockingham Beach Rd)** | Low | Medium | Medium | Extreme |
| **Rockingham Foreshore Park** | Low | Low | High | High |
| **Rockingham Rd Conservation Reserve Carpark** | Low | Low | Medium | High |

| | **Vulnerability** | | | |
|---|---|---|---|---|
| **Beach** | Low | Medium | High | Very High |
| **CBH Kwinana Grain Terminal** | Low | Low | Low | Low |
| **Coastal dune/vegetation** | Low | Medium | Very High | Very High |
| **Drainage Pipes** | Low | Low | Medium | High |
| **Drainage Pits** | Low | Low | Low | Medium |
| **Dual use paths** | Low | Low | Medium | High |
| **Emrald Park Carpark** | Low | Low | Medium | Very High |
| **Governor Reserve Carpark** | Low | Low | Medium | Very High |
| **Naval Memorial Park** | Low | Low | High | Very High |
| **Naval Memorial Park Carpark** | Low | Low | High | Very High |
| **Offshore Breakwaters** | Low | Low | Medium | Medium |
| **Phoebe Hymus Carpark** | Low | Medium | Medium | Very High |
| **Residential** | Low | Low | High | Very High |
| **Road (Rockingham Beach Rd)** | Low | Medium | Medium | Very High |
| **Rockingham Foreshore Park** | Low | Low | High | Very High |
| **Rockingham Rd Conservation Reserve Carpark** | Low | Low | Medium | High |

## Sector 1 - Inundation

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Almost Certain | Almost Certain | Almost Certain | Almost Certain |
| Coastal/dune vegetation | Possible | Possible | Likely | Almost Certain |
| Drainage Pipes | Rare | Rare | Rare | Rare |
| Offshore Breakwaters | Rare | Possible | Possible | Likely |
| Rockingham Beach Rd | Rare | Rare | Rare | Rare |
| Rockingham Foreshore Park | Rare | Rare | Rare | Rare |

| Asset | Consequence of Inundation | | | |
|---|---|---|---|---|
| Beach | Insignificant | Insignificant | Minor | Minor |
| Coastal/dune vegetation | Insignificant | Insignificant | Minor | Minor |
| Drainage Pipes | Insignificant | Insignificant | Insignificant | Insignificant |
| Offshore Breakwaters | Insignificant | Insignificant | Minor | Minor |
| Rockingham Beach Rd | Insignificant | Insignificant | Insignificant | Minor |
| Rockingham Foreshore Park | Insignificant | Insignificant | Insignificant | Minor |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Beach | High | High | High | High |
| Coastal/dune vegetation | High | High | High | High |
| Drainage Pipes | High | High | High | High |
| Offshore Breakwaters | Moderate | Moderate | Moderate | Moderate |
| Rockingham Beach Rd | High | Moderate | Moderate | Moderate |
| Rockingham Foreshore Park | High | High | High | High |

| Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | **Risk** | | | |
| Beach | Low | Low | Medium | Medium |
| Coastal dune/vegetation | Low | Low | Medium | Medium |
| Drainage Pipes | Low | Low | Low | Low |
| Offshore Breakwaters | Low | Low | Low | Medium |
| Rockingham Beach Rd | Low | Low | Low | Low |
| Rockingham Foreshore Park | Low | Low | Low | Low |

| | Vulnerability | | | |
|---|---|---|---|---|
| Beach | Low | Low | Medium | Medium |
| Coastal/dune vegetation | Low | Low | Medium | Medium |
| Drainage Pipes | Low | Low | Low | Low |
| Offshore Breakwaters | Low | Low | Low | Medium |
| Rockingham Beach Rd | Low | Low | Low | Low |
| Rockingham Foreshore Park | Low | Low | Low | Low |

**Sector 2**

| Values | Inundation | | Erosion | |
|---|---|---|---|---|
| | Assets at Risk | Extent | Assets At Risk | Extent |
| **Environmental** | Beach | 7.5 km | Beach | 7.5 km |
| | Coastal / Dune Vegetation | | Coastal / Dune Vegetation | |
| | DoBCA Managed Land (Point Peron) | 159,520 $m^2$ | DoBCA Managed Land (Point Peron) | 509,555 $m^2$ |
| **Social** | All Parks & Recreation Areas | 96,460 $m^2$ | The Cruising Yacht Club | 1,505 $m^2$ |
| | Boat Ramps (Catalpa Park) | | Boat Ramps (Catalpa Park) | 27,125 $m^2$ |
| | Mangles Bay Fishing Club | 46,680 $m^2$ | Mangles Bay Fishing Club | 67,295 $m^2$ |
| | Rockingham Naval Club | 1,025 $m^2$ | Rockingham Naval Club | 1,335 $m^2$ |
| | Rockingham Beach Primary | 4,2180 $m^2$ | Bell Park | 14,775 $m^2$ |
| | Star of the Sea Catholic Primary School | 36,035 $m^2$ | Churchill Park | 12,350 $m^2$ |
| | Bell Park | 16,245 $m^2$ | Catalpa Park | 19,995 $m^2$ |
| | Catalpa Park | 3,825 $m^2$ | Rotary Park | 11,680 $m^2$ |
| | Rotary Park | 27,440 $m^2$ | Point Peron Boating Facility | 340 m |
| **Economic - Private** | Point Peron Camp School | 23,015 $m^2$ | Point Peron Camp School | 102 |
| | Point Peron Wastewater Treatment Plant | | Point Peron Wastewater Treatment Plant | 5,325 $m^2$ |
| | Alfred Hines Seaside Homes | 12,105 $m^2$ | Alfred Hines Seaside Homes | 12,130 $m^2$ |
| | Residential Properties | 985 | Residential Properties | 157 |
| | | | The Cruising Yacht Club Carpark | 1,430 $m^2$ |
| | | | Commercial area (Railway Tce) | 2,4735 $m^2$ |
| | | | Commercial area (Rockingham Beach Rd) | 5,990 $m^2$ |
| | | | L&S Recreation Centre | 20,195 $m^2$ |
| | | | Maritime Union of Australia Holiday Camp | 8,255 $m^2$ |
| | | | Rockingham Recreation Centre (Memorial Dr) | 13,140 $m^2$ |

| Values | Inundation | | Erosion | |
|---|---|---|---|---|
| | Assets at Risk | Extent | Assets At Risk | Extent |
| Economic - Public | Roads | 23.4 km | Road - Rockingham Beach Rd; Esplanade | 11.3 km |
| | Jetty Abutments (Val St and Fisher St) | | Jetty abutments (Val St and Fisher St) | |
| | Bell Park Carpark | 2,140 $m^2$ | Bell Park Carpark | 2,140 $m^2$ |
| | Samuel Street Carpark | 440 $m^2$ | Samuel Street Carpark | 440 $m^2$ |
| | Catalpa Park Carpark | 5,965 $m^2$ | Catalpa Park Carpark | 6,570 $m^2$ |
| | | | Railway Terrace Carpark | 1,760 $m^2$ |
| | | | Rockingham Beach Road Parking | 2,900 $m^2$ |
| | | | Flinders Lane Carpark | 805 $m^2$ |
| | Point Peron Boating Facility Carpark | 13,905 $m^2$ | Point Peron Boating Facility Carpark | 9,275 $m^2$ |
| | | | Point Peron Foreshore Carpark (NE) | 1,550 $m^2$ |
| | | | Point Peron Foreshore Carpark (SW) | 1,385 $m^2$ |
| | | | Point Peron Foreshore Carpark (Central) | 480 $m^2$ |
| | | | Point Peron Dive Site Carpark | 500 $m^2$ |
| | Dual Use Path | 10.0 km | Dual Use Path | 8.0 km |
| | Department of Defence Land | 15,405 $m^2$ | Department of Defence Land | 18,463 $m^2$ |

| Existing Coastal Controls | |
|---|---|
| Hymus St Timber Groyne | Spur for sand trap |
| Hymus St informal seawall | Informal rock seawall west of Point Peron Camp School |
| Rockingham Foreshore - GSC Seawall | GSC Groyne at Point Peron Camp School |
| Garden Island Causeway | Offshore reefs |
| Groyne west of Causeway | |


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 2A ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR2A_VULNERABLEASSETS_REV1 01

DATE PLOTTED:19/02/2018 3:17:25 PM BY: JAMES.DRACUP
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\VulnerableAssets\59918065-GS-001-Sector2A_VulnerableAssets_Rev1.mxd

Offshore Reefs

Point Peron Foreshore Carpark (NE)

Informal Rock Seawall

Point Peron Camp School

Point Peron Camp School GSC Groyne

Garden Island Causeway

Spur for Sand Trap

Groyne West of Causeway

Point Peron Boating Facility

Point Peron Foreshore Carpark (Central)

Point Peron Foreshore Carpark (SW)

Point Peron Dive Site Carpark

Point Peron Wastewater Treatment Plan

Point Peron Boating Facility Carpark

Rockingham Naval Club

Point Peron Rd

Memorial Dr

L&S Recreation Centre

Maritime Union of Australia Holiday Camp

Rockingham Recreation Centre

Sector 2 - Boundary Road

NORTH

**Legend**

- Sector Boundary Line
- Horizontal Shoreline Datum
- Coastline
- 2110 100yr ARI Coastal Erosion Hazard Line
- 2110 500yr ARI Inundation

Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 2B ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR2B_VULNERABLEASSETS_REV1 01

DATE PLOTTED:19/02/2018 3:18:23 PM BY: JAMES.DRACUP
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## Sector 2 - Erosion

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| Asset | Likelihood | | | |
| Alfred Hines Seaside Home | Unlikely | Possible | Likely | Almost Certain |
| Beach | Possible | Likely | Almost Certain | Almost Certain |
| Bell Park | Rare | Unlikely | Possible | Likely |
| Bell Park Carpark | Rare | Unlikely | Possible | Likely |
| Boat Ramps (Catalpa Park) | Possible | Likely | Almost Certain | Almost Certain |
| Bores | Unlikely | Possible | Likely | Almost Certain |
| Catalpa Park | Unlikely | Possible | Likely | Almost Certain |
| Catalpa Park Carpark | Unlikely | Possible | Likely | Almost Certain |
| Churchill Park | Rare | Unlikely | Possible | Likely |
| Coastal/dune vegetation | Possible | Likely | Almost Certain | Almost Certain |
| Commercial area (Railway Tce) | Possible | Likely | Almost Certain | Almost Certain |
| Commercial area (Rockingham Beach Rd) | Rare | Rare | Unlikely | Possible |
| Department of Defence Land | Rare | Unlikely | Possible | Likely |
| DoBCA Managed Land | Possible | Likely | Almost Certain | Almost Certain |
| Drainage Pipes | Possible | Likely | Almost Certain | Almost Certain |
| Drainage Pits | Possible | Likely | Almost Certain | Almost Certain |
| Dual use paths | Unlikely | Possible | Likely | Almost Certain |
| Flinders Lane Carpark | Unlikely | Possible | Likely | Almost Certain |
| Garden Island Causeway | Rare | Unlikely | Likely | Almost Certain |
| Hymus St Informal Seawall | Rare | Unlikely | Possible | Likely |
| Hymus St Timber Groyne | Rare | Unlikely | Possible | Likely |
| Jetty abutments (Val St and Fisher St) | Possible | Likely | Almost Certain | Almost Certain |
| L&S Recreation Centre | Rare | Rare | Unlikely | Possible |
| Mangles Bay Fishing Club | Possible | Likely | Almost Certain | Almost Certain |
| Maritime Union of Australia Holiday Camp | Rare | Rare | Unlikely | Possible |
| Point Peron Boating Facility Carpark | Rare | Rare | Unlikely | Possible |
| Point Peron Boating Facility including Groynes and Sand Trap | Unlikely | Possible | Likely | Almost Certain |
| Point Peron Camp School | Unlikely | Likely | Likely | Almost Certain |
| Point Peron Camp School GSC Groyne | Rare | Possible | Likely | Almost Certain |
| Point Peron Camp School Informal Seawall | Rare | Possible | Likely | Almost Certain |
| Point Peron Dive Site Carpark | Rare | Unlikely | Possible | Likely |
| Point Peron Foreshore Carpark (Central) | Rare | Rare | Unlikely | Possible |
| Point Peron Foreshore Carpark (NE) | Unlikely | Possible | Likely | Almost Certain |
| Point Peron Foreshore Carpark (SW) | Possible | Likely | Almost Certain | Almost Certain |
| Point Peron Wastewater Treatment Plant | Rare | Unlikely | Possible | Likely |
| Railway Terrace Carpark | Rare | Unlikely | Possible | Likely |
| Residential | Unlikely | Unlikely | Possible | Likely |
| Roads | Unlikely | Possible | Likely | Almost Certain |
| Rockingham Beach Road Parking | Rare | Rare | Unlikely | Possible |
| Rockingham Foreshore GSC Seawall | Rare | Possible | Likely | Almost Certain |
| Rockingham Naval Club | Rare | Rare | Unlikely | Possible |
| Rockingham Recreation Centre (Memorial Dr) | Rare | Rare | Unlikely | Possible |
| Rotary Park | Rare | Unlikely | Possible | Likely |
| Samuel Street Carpark | Rare | Rare | Unlikely | Possible |
| The Cruising Yacht Club | Unlikely | Possible | Likely | Almost Certain |

| | | | | |
|---|---|---|---|---|
| **The Cruising Yacht Club Carpark** | **Rare** | **Rare** | **Unlikely** | **Possible** |
| **Underground Storage** | **Possible** | **Likely** | **Almost Certain** | **Almost Certain** |

| Asset | Consequence of Erosion | | | |
|---|---|---|---|---|
| Alfred Hines Seaside Home | Major | Major | Major | Major |
| Beach | Minor | Moderate | Major | Major |
| Bell Park | Minor | Moderate | Major | Catastrophic |
| Bell Park Carpark | Insignificant | Minor | Moderate | Catastrophic |
| Boat Ramps (Catalpa Park) | Minor | Moderate | Major | Major |
| Bores | Insignificant | Insignificant | Insignificant | Minor |
| Catalpa Park | Minor | Minor | Major | Major |
| Catalpa Park Carpark | Insignificant | Minor | Major | Major |
| Churchill Park | Minor | Moderate | Major | Catastrophic |
| Coastal/dune vegetation | Moderate | Major | Catastrophic | Catastrophic |
| Commercial area (Railway Tce) | Minor | Major | Catastrophic | Catastrophic |
| Commercial area (Rockingham Beach Rd) | Insignificant | Insignificant | Minor | Catastrophic |
| Department of Defence Land | Insignificant | Insignificant | Moderate | Catastrophic |
| DoBCA Managed Land | Insignificant | Moderate | Major | Catastrophic |
| Drainage Pipes | Moderate | Major | Major | Major |
| Drainage Pits | Minor | Moderate | Major | Major |
| Dual use paths | Moderate | Moderate | Major | Catastrophic |
| Flinders Lane Carpark | Insignificant | Moderate | Major | Catastrophic |
| Garden Island Causeway | Moderate | Moderate | Major | Major |
| Hymus St Informal Seawall | Insignificant | Insignificant | Minor | Minor |
| Hymus St Timber Groyne | Insignificant | Insignificant | Minor | Minor |
| Jetty abutments (Val St and Fisher St) | Minor | Moderate | Catastrophic | Catastrophic |
| L&S Recreation Centre | Insignificant | Insignificant | Moderate | Major |
| Mangles Bay Fishing Club | Major | Major | Major | Major |
| Maritime Union of Australia Holiday Camp | Insignificant | Insignificant | Insignificant | Moderate |
| Point Peron Boating Facility Carpark | Insignificant | Insignificant | Minor | Catastrophic |
| Point Peron Boating Facility including Groynes and Sand Trap | Minor | Minor | Moderate | Moderate |
| Point Peron Camp School | Moderate | Moderate | Moderate | Moderate |
| Point Peron Camp School GSC Groyne | Insignificant | Minor | Minor | Minor |
| Point Peron Camp School Informal Seawall | Insignificant | Insignificant | Minor | Minor |
| Point Peron Dive Site Carpark | Insignificant | Insignificant | Minor | Major |
| Point Peron Foreshore Carpark (Central) | Insignificant | Insignificant | Insignificant | Moderate |
| Point Peron Foreshore Carpark (NE) | Minor | Moderate | Major | Major |
| Point Peron Foreshore Carpark (SW) | Minor | Moderate | Major | Major |
| Point Peron Wastewater Treatment Plant | Catastrophic | Catastrophic | Catastrophic | Catastrophic |
| Railway Terrace Carpark | Insignificant | Insignificant | Major | Catastrophic |
| Residential | Insignificant | Moderate | Catastrophic | Catastrophic |
| Roads | Insignificant | Moderate | Catastrophic | Catastrophic |
| Rockingham Beach Road Parking | Insignificant | Minor | Moderate | Catastrophic |
| Rockingham Foreshore GSC Seawall | Minor | Minor | Moderate | Moderate |
| Rockingham Naval Club | Major | Major | Major | Major |
| Rockingham Recreation Centre (Memorial Dr) | Insignificant | Insignificant | Insignificant | Major |
| Rotary Park | Insignificant | Insignificant | Minor | Moderate |
| Samuel Street Carpark | Insignificant | Insignificant | Insignificant | Moderate |
| The Cruising Yacht Club | Major | Major | Major | Major |
| The Cruising Yacht Club Carpark | Insignificant | Insignificant | Insignificant | Moderate |
| Underground Storage | Moderate | Major | Major | Major |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Alfred Hines Seaside Home | Low | Low | Low | Low |
| Beach | High | Moderate | Low | Low |
| Bell Park | High | Moderate | Low | Low |
| Bell Park Carpark | Moderate | Moderate | Moderate | Moderate |
| Boat Ramps (Catalpa Park) | Moderate | Moderate | Moderate | Moderate |
| Bores | High | High | High | High |
| Catalpa Park | Moderate | Moderate | Moderate | Moderate |
| Catalpa Park Carpark | Moderate | Moderate | Moderate | Moderate |
| Churchill Park | High | Moderate | Low | Low |
| Coastal/dune vegetation | Moderate | Moderate | Low | Low |
| Commercial area (Railway Tce) | Low | Low | Low | Low |
| Commercial area (Rockingham Beach Rd) | Low | Low | Low | Low |
| Department of Defence Land | Low | Low | Low | Low |
| DoBCA Managed Land | High | High | Low | Low |
| Drainage Pipes | Moderate | Moderate | Moderate | Moderate |
| Drainage Pits | Moderate | Moderate | Moderate | Moderate |
| Dual use paths | High | High | Moderate | Moderate |
| Flinders Lane Carpark | Moderate | Moderate | Moderate | Moderate |
| Garden Island Causeway | Moderate | Moderate | Low | Low |
| Hymus St Informal Seawall | Moderate | Moderate | Low | Low |
| Hymus St Timber Groyne | Moderate | Moderate | Moderate | Moderate |
| Jetty abutments (Val St and Fisher St) | Moderate | Moderate | Moderate | Moderate |
| L&S Recreation Centre | Moderate | Moderate | Moderate | Moderate |
| Mangles Bay Fishing Club | Moderate | Low | Low | Low |
| Maritime Union of Australia Holiday Camp | Moderate | Moderate | Moderate | Moderate |
| Point Peron Boating Facility Carpark | Moderate | Moderate | Moderate | Low |
| Point Peron Boating Facility including Groynes and Sand Trap | Moderate | Moderate | Moderate | Low |
| Point Peron Camp School | Moderate | Moderate | Low | Low |
| Point Peron Camp School GSC Groyne | Moderate | Moderate | Low | Low |
| Point Peron Camp School Informal Seawall | Moderate | Moderate | Low | Low |
| Point Peron Dive Site Carpark | Moderate | Moderate | Moderate | Moderate |
| Point Peron Foreshore Carpark (Central) | Moderate | Moderate | Moderate | Moderate |
| Point Peron Foreshore Carpark (NE) | Moderate | Moderate | Moderate | Moderate |
| Point Peron Foreshore Carpark (SW) | Moderate | Moderate | Moderate | Moderate |
| Point Peron Wastewater Treatment Plant | Moderate | Moderate | Low | Low |
| Railway Terrace Carpark | Moderate | Moderate | Moderate | Moderate |
| Residential | Low | Low | Low | Low |
| Roads | Low | Low | Low | Low |
| Rockingham Beach Road Parking | Moderate | Moderate | Moderate | Moderate |
| Rockingham Foreshore GSC Seawall | Moderate | Moderate | Low | Low |
| Rockingham Naval Club | Low | Low | Low | Low |
| Rockingham Recreation Centre (Memorial Dr) | Moderate | Moderate | Moderate | Moderate |
| Rotary Park | Moderate | Moderate | Moderate | Moderate |
| Samuel Street Carpark | Moderate | Moderate | Moderate | Moderate |
| The Cruising Yacht Club | Low | Low | Low | Low |
| The Cruising Yacht Club Carpark | Moderate | Moderate | Moderate | Moderate |
| Underground Storage | Moderate | Moderate | Moderate | Moderate |

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Risk | | | |
| Alfred Hines Seaside Home | Medium | High | High | Extreme |
| Beach | Low | Medium | Extreme | Extreme |
| Bell Park | Low | Medium | High | Extreme |
| Bell Park Carpark | Low | Low | Medium | Extreme |
| Boat Ramps (Catalpa Park) | Low | Medium | Extreme | Extreme |
| Bores | Low | Low | Low | Medium |
| Catalpa Park | Low | Low | High | Extreme |
| Catalpa Park Carpark | Low | Low | High | Extreme |
| Churchill Park | Low | Medium | High | Extreme |
| Coastal/dune vegetation | Medium | High | Extreme | Extreme |
| Commercial area (Railway Tce) | Low | High | Extreme | Extreme |
| Commercial area (Rockingham Beach Rd) | Low | Low | Low | Extreme |
| Department of Defence Land | Low | Low | Medium | Extreme |
| DoBCA Managed Land | Low | Medium | Extreme | Extreme |
| Drainage Pipes | Medium | High | Extreme | Extreme |
| Drainage Pits | Low | Medium | Extreme | Extreme |
| Dual use paths | Medium | Medium | High | Extreme |
| Flinders Lane Carpark | Low | Medium | High | Extreme |
| Garden Island Causeway | Low | Medium | High | Extreme |
| Hymus St Informal Seawall | Low | Low | Low | Medium |
| Hymus St Timber Groyne | Low | Low | Low | Medium |
| Jetty abutments (Val St and Fisher St) | Low | Medium | Extreme | Extreme |
| L&S Recreation Centre | Low | Low | Medium | High |
| Mangles Bay Fishing Club | High | High | Extreme | Extreme |
| Maritime Union of Australia Holiday Camp | Low | Low | Low | Medium |
| Point Peron Boating Facility Carpark | Low | Low | Low | Extreme |
| Point Peron Boating Facility including Groynes and Sand Trap | Low | Low | Medium | High |
| Point Peron Camp School | Medium | Medium | Medium | High |
| Point Peron Camp School GSC Groyne | Low | Low | Medium | Medium |
| Point Peron Camp School Informal Seawall | Low | Low | Medium | Medium |
| Point Peron Dive Site Carpark | Low | Low | Low | High |
| Point Peron Foreshore Carpark (Central) | Low | Low | Low | Medium |
| Point Peron Foreshore Carpark (NE) | Low | Medium | High | Extreme |
| Point Peron Foreshore Carpark (SW) | Low | Medium | Extreme | Extreme |
| Point Peron Wastewater Treatment Plant | Medium | High | Extreme | Extreme |
| Railway Terrace Carpark | Low | Low | High | Extreme |
| Residential | Low | Medium | Extreme | Extreme |
| Roads | Low | Medium | Extreme | Extreme |
| Rockingham Beach Road Parking | Low | Low | Medium | Extreme |
| Rockingham Foreshore GSC Seawall | Low | Low | Medium | High |
| Rockingham Naval Club | Medium | Medium | Medium | High |
| Rockingham Recreation Centre (Memorial Dr) | Low | Low | Low | High |
| Rotary Park | Low | Low | Low | Medium |
| Samuel Street Carpark | Low | Low | Low | Medium |
| The Cruising Yacht Club | Medium | High | High | Extreme |
| The Cruising Yacht Club Carpark | Low | Low | Low | Medium |
| Underground Storage | Medium | High | Extreme | Extreme |

| | Vulnerability | | | |
|---|---|---|---|---|
| **Alfred Hines Seaside Home** | High | Very High | Very High | Very High |
| **Beach** | Low | Medium | Very High | Very High |
| **Bell Park** | Low | Medium | Very High | Very High |
| **Bell Park Carpark** | Low | Low | Medium | Very High |
| **Boat Ramps (Catalpa Park)** | Low | Medium | Very High | Very High |
| **Bores** | Low | Low | Low | Medium |
| **Catalpa Park** | Low | Low | High | Very High |
| **Catalpa Park Carpark** | Low | Low | High | Very High |
| **Churchill Park** | Low | Medium | Very High | Very High |
| **Coastal/dune vegetation** | Medium | High | Very High | Very High |
| **Commercial area (Railway Tce)** | Low | Very High | Very High | Very High |
| **Commercial area (Rockingham Beach Rd)** | Low | Low | Low | Very High |
| **Department of Defence Land** | Low | Low | High | Very High |
| **DoBCA Managed Land** | Low | Medium | Very High | Very High |
| **Drainage Pipes** | Medium | High | Very High | Very High |
| **Drainage Pits** | Low | Medium | Very High | Very High |
| **Dual use paths** | Medium | Medium | High | Very High |
| **Flinders Lane Carpark** | Low | Medium | High | Very High |
| **Garden Island Causeway** | Low | Medium | Very High | Very High |
| **Hymus St Informal Seawall** | Low | Low | Low | High |
| **Hymus St Timber Groyne** | Low | Low | Low | Medium |
| **Jetty abutments (Val St and Fisher St)** | Low | Medium | Very High | Very High |
| **L&S Recreation Centre** | Low | Low | Medium | High |
| **Mangles Bay Fishing Club** | High | Very High | Very High | Very High |
| **Maritime Union of Australia Holiday Camp** | Low | Low | Low | Medium |
| **Point Peron Boating Facility Carpark** | Low | Low | Low | Very High |
| **Point Peron Boating Facility including Groynes and Sand Trap** | Low | Low | Medium | Very High |
| **Point Peron Camp School** | Medium | Medium | High | Very High |
| **Point Peron Camp School GSC Groyne** | Low | Low | High | High |
| **Point Peron Camp School Informal Seawall** | Low | Low | High | High |
| **Point Peron Dive Site Carpark** | Low | Low | Low | High |
| **Point Peron Foreshore Carpark (Central)** | Low | Low | Low | Medium |
| **Point Peron Foreshore Carpark (NE)** | Low | Medium | High | Very High |
| **Point Peron Foreshore Carpark (SW)** | Low | Medium | Very High | Very High |
| **Point Peron Wastewater Treatment Plant** | Medium | High | Very High | Very High |
| **Railway Terrace Carpark** | Low | Low | High | Very High |
| **Residential** | Low | High | Very High | Very High |
| **Roads** | Low | High | Very High | Very High |
| **Rockingham Beach Road Parking** | Low | Low | Medium | Very High |
| **Rockingham Foreshore GSC Seawall** | Low | Low | High | Very High |
| **Rockingham Naval Club** | High | High | High | Very High |
| **Rockingham Recreation Centre (Memorial Dr)** | Low | Low | Low | High |
| **Rotary Park** | Low | Low | Low | Medium |
| **Samuel Street Carpark** | Low | Low | Low | Medium |
| **The Cruising Yacht Club** | High | Very High | Very High | Very High |
| **The Cruising Yacht Club Carpark** | Low | Low | Low | Medium |
| **Underground Storage** | Medium | High | Very High | Very High |

## Sector 2 - Inundation

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Alfred Hines Seaside Home | Possible | Possible | Likely | Almost Certain |
| All Parks & Recreation areas | Possible | Possible | Likely | Almost Certain |
| Beach | Almost Certain | Almost Certain | Almost Certain | Almost Certain |
| Bell Park | Rare | Rare | Rare | Rare |
| Bell Park Carpark | Possible | Possible | Likely | Almost Certain |
| Boat Ramps (Catalpa Park) | Likely | Likely | Almost Certain | Almost Certain |
| Bores | Likely | Likely | Almost Certain | Almost Certain |
| Catalpa Park | Possible | Likely | Almost Certain | Almost Certain |
| Catalpa Park Carpark | Possible | Possible | Likely | Almost Certain |
| Coastal/dune vegetation | Possible | Possible | Likely | Almost Certain |
| Department of Defence Land | Likely | Likely | Almost Certain | Almost Certain |
| DoBCA Managed Land | Rare | Rare | Rare | Rare |
| Drainage Pipes | Likely | Almost Certain | Almost Certain | Almost Certain |
| Drainage Pits | Likely | Likely | Almost Certain | Almost Certain |
| Dual use path | Possible | Possible | Likely | Almost Certain |
| Hymus St Informal Seawall | Rare | Possible | Possible | Likely |
| Hymus St Timber Groyne | Rare | Possible | Possible | Likely |
| Jetty abutments (Val St and Fisher St) | Likely | Likely | Almost Certain | Almost Certain |
| Lake Richmond | Unlikely | Possible | Likely | Almost Certain |
| Mangles Bay Fishing Club | Possible | Possible | Likely | Almost Certain |
| Point Peron Boating Facility Carpark | Unlikely | Unlikely | Unlikely | Possible |
| Point Peron Camp School | Likely | Likely | Almost Certain | Almost Certain |
| Point Peron Camp School GSC Groyne | Rare | Possible | Possible | Likely |
| Point Peron Camp School Informal Seawall | Rare | Possible | Possible | Likely |
| Point Peron Wastewater Treatment Plant | Possible | Possible | Likely | Almost Certain |
| Residential | Likely | Likely | Almost Certain | Almost Certain |
| Roads | Likely | Likely | Almost Certain | Almost Certain |
| Rockingham Beach Primary | Unlikely | Unlikely | Unlikely | Possible |
| Rockingham Foreshore GSC Seawall | Rare | Possible | Possible | Likely |
| Rockingham Naval Club | Possible | Possible | Likely | Almost Certain |
| Rotary Park | Possible | Likely | Almost Certain | Almost Certain |
| Samuel St Carpark | Possible | Possible | Likely | Almost Certain |
| Star of the Sea Catholic Primary School | Unlikely | Unlikely | Unlikely | Possible |
| Underground Storage | Likely | Likely | Almost Certain | Almost Certain |

| **Asset** | **Consequence of Inundation** | | | |
|---|---|---|---|---|
| Alfred Hines Seaside Home | Minor | Moderate | Major | Major |
| All Parks & Recreation areas | Moderate | Moderate | Major | Major |
| Beach | Insignificant | Insignificant | Minor | Minor |
| Bell Park | Minor | Minor | Moderate | Moderate |
| Bell Park Carpark | Insignificant | Minor | Moderate | Moderate |
| Boat Ramps (Catalpa Park) | Insignificant | Insignificant | Minor | Minor |
| Bores | Insignificant | Minor | Minor | Minor |
| Catalpa Park | Minor | Minor | Moderate | Moderate |
| Catalpa Park Carpark | Moderate | Moderate | Moderate | Moderate |
| Coastal/dune vegetation | Insignificant | Insignificant | Minor | Minor |
| Department of Defence Land | Minor | Moderate | Moderate | Major |
| DoBCA Managed Land | Minor | Minor | Minor | Moderate |
| Drainage Pipes | Insignificant | Minor | Moderate | Moderate |
| Drainage Pits | Insignificant | Minor | Moderate | Moderate |
| Dual use path | Moderate | Moderate | Moderate | Major |
| Hymus St Informal Seawall | Insignificant | Insignificant | Minor | Minor |
| Hymus St Timber Groyne | Insignificant | Insignificant | Minor | Minor |
| Jetty abutments (Val St and Fisher St) | Minor | Minor | Minor | Minor |

| | | | | |
|---|---|---|---|---|
| Lake Richmond | Minor | Moderate | Major | Major |
| Mangles Bay Fishing Club | Minor | Moderate | Major | Major |
| Point Peron Boating Facility Carpark | Insignificant | Insignificant | Minor | Major |
| Point Peron Camp School | Moderate | Moderate | Catastrophic | Catastrophic |
| Point Peron Camp School GSC Groyne | Insignificant | Insignificant | Minor | Minor |
| Point Peron Camp School Informal Seawall | Insignificant | Insignificant | Minor | Minor |
| Point Peron Wastewater Treatment Plant | Moderate | Moderate | Catastrophic | Catastrophic |
| Residential | Moderate | Major | Catastrophic | Catastrophic |
| Roads | Minor | Minor | Moderate | Major |
| Rockingham Beach Primary | Insignificant | Insignificant | Major | Major |
| Rockingham Foreshore GSC Seawall | Insignificant | Insignificant | Minor | Minor |
| Rockingham Naval Club | Minor | Moderate | Moderate | Moderate |
| Rotary Park | Minor | Minor | Moderate | Moderate |
| Samuel St Carpark | Minor | Minor | Moderate | Moderate |
| Star of the Sea Catholic Primary School | Insignificant | Insignificant | Moderate | Major |
| Underground Storage | Moderate | Moderate | Major | Major |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Alfred Hines Seaside Home | Moderate | Moderate | Low | Low |
| All Parks & Recreation areas | High | High | Moderate | Low |
| Beach | Very High | Very High | High | Moderate |
| Bell Park | Moderate | Moderate | Low | Low |
| Bell Park Carpark | Moderate | Moderate | Moderate | Moderate |
| Boat Ramps (Catalpa Park) | Moderate | Moderate | Moderate | Moderate |
| Bores | High | High | High | High |
| Catalpa Park | Moderate | Moderate | Low | Low |
| Catalpa Park Carpark | Moderate | Moderate | Moderate | Moderate |
| Coastal/dune vegetation | High | Moderate | Moderate | Moderate |
| Department of Defence Land | High | Moderate | Moderate | Moderate |
| DoBCA Managed Land | Very High | Very High | High | Moderate |
| Drainage Pipes | Moderate | Moderate | Moderate | Moderate |
| Drainage Pits | Moderate | Moderate | Moderate | Moderate |
| Dual use path | High | High | High | Moderate |
| Hymus St Informal Seawall | Moderate | Moderate | Moderate | Moderate |
| Hymus St Timber Groyne | Moderate | Moderate | Moderate | Moderate |
| Jetty abutments (Val St and Fisher St) | Moderate | Moderate | Moderate | Moderate |
| Lake Richmond | High | High | Moderate | Low |
| Mangles Bay Fishing Club | Moderate | Moderate | Moderate | Moderate |
| Point Peron Boating Facility Carpark | Moderate | Moderate | Moderate | Moderate |
| Point Peron Camp School | Moderate | Moderate | Low | Low |
| Point Peron Camp School GSC Groyne | Moderate | Moderate | Moderate | Moderate |
| Point Peron Camp School Informal Seawall | Moderate | Moderate | Moderate | Moderate |
| Point Peron Wastewater Treatment Plant | Moderate | Moderate | Low | Low |
| Residential | Moderate | Moderate | Low | Low |
| Roads | Moderate | Moderate | Moderate | Moderate |
| Rockingham Beach Primary | Low | Low | Low | Low |
| Rockingham Foreshore GSC Seawall | Moderate | Moderate | Moderate | Moderate |
| Rockingham Naval Club | Moderate | Moderate | Low | Low |
| Rotary Park | Moderate | Moderate | Low | Low |
| Samuel St Carpark | Moderate | Moderate | Moderate | Moderate |
| Star of the Sea Catholic Primary School | Low | Low | Low | Low |
| Underground Storage | Moderate | Moderate | Moderate | Moderate |

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Risk | | | |
| Alfred Hines Seaside Home | Low | Medium | High | Extreme |
| All Parks & Recreation areas | Medium | Medium | High | Extreme |
| Beach | Low | Low | Medium | Medium |
| Bell Park | Low | Low | Low | Low |
| Bell Park Carpark | Low | Low | Medium | High |
| Boat Ramps (Catalpa Park) | Low | Low | Medium | Medium |
| Bores | Low | Medium | Medium | Medium |
| Catalpa Park | Low | Medium | High | High |
| Catalpa Park Carpark | Medium | Medium | Medium | High |
| Coastal/dune vegetation | Low | Low | Medium | Medium |
| Department of Defence Land | Medium | Medium | High | Extreme |
| DoBCA Managed Land | Low | Low | Low | Low |
| Drainage Pipes | Low | Medium | High | High |
| Drainage Pits | Low | Medium | High | High |
| Dual use path | Medium | Medium | Medium | Extreme |
| Hymus St Informal Seawall | Low | Low | Low | Medium |
| Hymus St Timber Groyne | Low | Low | Low | Medium |
| Jetty abutments (Val St and Fisher St) | Medium | Medium | Medium | Medium |
| Lake Richmond | Low | Medium | High | Extreme |
| Mangles Bay Fishing Club | Low | Medium | High | Extreme |
| Point Peron Boating Facility Carpark | Low | Low | Low | High |
| Point Peron Camp School | Medium | Medium | Extreme | Extreme |
| Point Peron Camp School GSC Groyne | Low | Low | Low | Medium |
| Point Peron Camp School Informal Seawall | Low | Low | Low | Medium |
| Point Peron Wastewater Treatment Plant | Medium | Medium | Extreme | Extreme |
| Residential | Medium | High | Extreme | Extreme |
| Roads | Medium | Medium | High | Extreme |
| Rockingham Beach Primary | Low | Low | Medium | High |
| Rockingham Foreshore GSC Seawall | Low | Low | Low | Medium |
| Rockingham Naval Club | Low | Medium | Medium | High |
| Rotary Park | Low | Medium | High | High |
| Samuel St Carpark | Low | Low | Medium | High |
| Star of the Sea Catholic Primary School | Low | Low | Medium | High |
| Underground Storage | Medium | Medium | Extreme | Extreme |

| | Vulnerability | | | |
|---|---|---|---|---|
| Alfred Hines Seaside Home | Low | Medium | Very High | Very High |
| All Parks & Recreation areas | Medium | Medium | High | Very High |
| Beach | Low | Low | Medium | Medium |
| Bell Park | Low | Low | Low | Low |
| Bell Park Carpark | Low | Low | Medium | High |
| Boat Ramps (Catalpa Park) | Low | Low | Medium | Medium |
| Bores | Low | Medium | Medium | Medium |
| Catalpa Park | Low | Medium | Very High | Very High |
| Catalpa Park Carpark | Medium | Medium | Medium | High |
| Coastal/dune vegetation | Low | Low | Medium | Medium |
| Department of Defence Land | Medium | Medium | High | Very High |
| DoBCA Managed Land | Low | Low | Low | Low |
| Drainage Pipes | Low | Medium | High | High |
| Drainage Pits | Low | Medium | High | High |
| Dual use path | Medium | Medium | Medium | Very High |
| Hymus St Informal Seawall | Low | Low | Low | Medium |
| Hymus St Timber Groyne | Low | Low | Low | Medium |
| Jetty abutments (Val St and Fisher St) | Medium | Medium | Medium | Medium |
| Lake Richmond | Low | Medium | High | Very High |
| Mangles Bay Fishing Club | Low | Medium | High | Very High |

| | | | | |
|---|---|---|---|---|
| **Point Peron Boating Facility Carpark** | Low | Low | Low | High |
| **Point Peron Camp School** | Medium | Medium | Very High | Very High |
| **Point Peron Camp School GSC Groyne** | Low | Low | Low | Medium |
| **Point Peron Camp School Informal Seawall** | Low | Low | Low | Medium |
| **Point Peron Wastewater Treatment Plant** | Medium | Medium | Very High | Very High |
| **Residential** | Medium | High | Very High | Very High |
| **Roads** | Medium | Medium | High | Very High |
| **Rockingham Beach Primary** | Low | Low | High | Very High |
| **Rockingham Foreshore GSC Seawall** | Low | Low | Low | Medium |
| **Rockingham Naval Club** | Low | Medium | High | Very High |
| **Rotary Park** | Low | Medium | Very High | Very High |
| **Samuel St Carpark** | Low | Low | Medium | High |
| **Star of the Sea Catholic Primary School** | Low | Low | High | Very High |
| **Underground Storage** | Medium | Medium | Very High | Very High |

**Sector 3**

| Values | Inundation | | Erosion | |
|---|---|---|---|---|
| | Assets at Risk | Extent | Assets At Risk | Extent |
| **Environmental** | Beach | 7.4 km | Beach | 7.4 km |
| | Coastal / Dune Vegetation | | Coastal / Dune Vegetation | |
| **Social** | Parks & Recreation areas | 404,800 $m^2$ | Shoalwater Foreshore Park | 5,805 $m^2$ |
| | Safety Bay Tennis Club | 13,920 $m^2$ | Lions Park | 5,895 $m^2$ |
| | Safety Bay Yacht Club | 520 $m^2$ | Safety Bay Yacht Club | 595 $m^2$ |
| | Safety Bay Primary School | 28,435 $m^2$ | Safety Bay Foreshore Park | 19,265 $m^2$ |
| | Safety Bay Foreshore Park | 66,730 $m^2$ | Waikiki Foreshore Park | 66,800 $m^2$ |
| | Noel France Reserve (Park) | 11,429 $m^2$ | Noel France Reserve (Park) | 1,075 $m^2$ |
| **Economic - Private** | Rockingham Wild Encounters (Mersey Point) | 2,020 $m^2$ | Rockingham Wild Encounters (Mersey Point) | 2,020 $m^2$ |
| | Residential Properties | 3,578 | Residential Properties | 1,830 $m^2$ |
| | | | Commercial area (Bent St) | 520 |
| | | | BP Petrol Station | 3,535 $m^2$ |
| **Economic - Public** | Dual Use Path | 27.5 km | Dual Use Path | 13.0 km |
| | Roads | 45.1 km | Road - Arcadia Dr; Safety Bay Rd; Warnbro Beach Rd | 7.4 km |
| | Mersey Point Carpark | 3,650 $m^2$ | Mersey Point Carpark | 4,070 $m^2$ |
| | Safety Bay Foreshore Carparks (6 total): Carlisle St; Watts Rd; Safety Bay Yacht Club; Waimea Rd; Bent St; Between June Rd and Donald Dr | 7,395 $m^2$ | Safety Bay Foreshore Carparks (7 total): Carlisle St; Watts Rd; Safety Bay Yacht Club; Waimea Rd; Bent St; Between June Rd and Donald Dr | 7,685 $m^2$ |

| Values | Inundation | | Erosion | | |
|---|---|---|---|---|---|
| | Assets at Risk | Extent | Assets At Risk | | Extent |
| | Waikiki Beach Access Ramp | | | Corner of Safety Bay Rd and Warnbro Beach Rd | |
| | Bent Street Boat Ramp | | Waikiki Foreshore Carparks (5 total) | View Rd | 5,200 $m^2$ |
| | | | | Viking Rd | |
| | | | | Between Julia St and Michael Rd | |
| | | | | Hilda Rd | |
| | | | | Warnbro Beach Rd adjacent to Shelton St | |
| | | | Shoalwater Foreshore Park Carpark | | 4,510 $m^2$ |
| | | | Lions Park Carpark | | 1,120 $m^2$ |
| | | | Bent Street Boat Ramp | | |
| | | | Waikiki Beach Access Ramp | | |
| **Existing Coastal Controls** | | | | | |
| South Mersey Point Rock Seawall | | | | | |
| Bent St Boat Ramp Rock Protection | | | | | |
| Waikiki Rock Seawall | | | | | |
| Offshore Reefs | | | | | |
| South Mersey Point Rock Seawall | | | | | |


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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Web: www.cardno.com.au



City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 3A ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR3A_VULNERABLEASSETS_REV1 01

DATE PLOTTED:19/02/2018 3:20:18 PM BY: JAMES.DRACUP
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\VulnerableAssets\tS9918065-GS-001-Sector3A_VulnerableAssets_Rev1.mxd


DATE PLOTTED:19/02/2018 3:21:22 PM BY: JAMES.DRACUP
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\VulnerableAssets\59918065-GS-001-Sector3B_VulnerableAssets_Rev1.mxd

Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

Cardno
Map produced by Cardno WA Pty Ltd
11 Harvest Terrace, West Perth WA 6005, Australia
Phone: +61 8 9273 3888
Web: www.cardno.com.au



City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 3B ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR3B_VULNERABLEASSETS_REV1 01

## Sector 3 - Erosion

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Possible | Likely | Almost Certain | Almost Certain |
| Bent St Boat Ramp | Rare | Unlikely | Likely | Likely |
| Bores | Rare | Unlikely | Possible | Likely |
| BP Petrol Station | Rare | Rare | Unlikely | Possible |
| Coastal/dune vegetation | Possible | Likely | Almost Certain | Almost Certain |
| Commercial area (Bent St) | Rare | Unlikely | Possible | Likely |
| Drainage Pipes | Possible | Likely | Almost Certain | Almost Certain |
| Drainage Pits | Possible | Likely | Almost Certain | Almost Certain |
| Dual use paths | Unlikely | Possible | Likely | Almost Certain |
| Lions Park | Rare | Unlikely | Possible | Likely |
| Lions Park Carpark | Rare | Unlikely | Possible | Likely |
| Mersey Point Carpark | Rare | Unlikely | Possible | Likely |
| Mersey Point Jetty | Rare | Unlikely | Likely | Likely |
| Noel France Reserve (park) | Rare | Rare | Unlikely | Possible |
| Residential | Rare | Unlikely | Possible | Likely |
| Road | Rare | Unlikely | Possible | Likely |
| Rockingham Wild Encounters | Rare | Unlikely | Possible | Likely |
| Safety Bay Foreshore Carparks (7 total) | Unlikely | Possible | Likely | Almost Certain |
| Safety Bay Foreshore Park | Possible | Likely | Almost Certain | Almost Certain |
| Safety Bay Yacht Club | Possible | Possible | Likely | Almost Certain |
| Shoalwater Foreshore Carpark | Rare | Unlikely | Possible | Likely |
| Shoalwater Foreshore Park | Possible | Likely | Almost Certain | Almost Certain |
| South Mersey Point Rock Seawall | Rare | Unlikely | Likely | Likely |
| Waikiki Beach Access Ramp | Rare | Unlikely | Likely | Likely |
| Waikiki Foreshore Carparks (5 total) | Unlikely | Possible | Likely | Almost Certain |
| Waikiki Foreshore Park | Rare | Unlikely | Possible | Likely |
| Waikiki Rock Seawall | Rare | Unlikely | Likely | Likely |

| Asset | Consequence of Erosion | | | |
|---|---|---|---|---|
| Beach | Insignificant | Minor | Major | Catastrophic |
| Bent St Boat Ramp | Minor | Minor | Moderate | Moderate |
| Bores | Insignificant | Insignificant | Insignificant | Minor |
| BP Petrol Station | Major | Major | Catastrophic | Catastrophic |
| Coastal/dune vegetation | Insignificant | Minor | Major | Catastrophic |
| Commercial area (Bent St) | Minor | Minor | Moderate | Major |
| Drainage Pipes | Moderate | Major | Major | Major |
| Drainage Pits | Minor | Moderate | Major | Major |
| Dual use paths | Moderate | Major | Major | Major |
| Lions Park | Insignificant | Insignificant | Moderate | Moderate |
| Lions Park Carpark | Insignificant | Insignificant | Moderate | Major |
| Mersey Point Carpark | Insignificant | Minor | Major | Major |
| Mersey Point Jetty | Insignificant | Insignificant | Minor | Minor |
| Noel France Reserve (park) | Insignificant | Insignificant | Insignificant | Minor |
| Residential | Moderate | Major | Catastrophic | Catastrophic |
| Road | Major | Major | Catastrophic | Catastrophic |
| Rockingham Wild Encounters | Insignificant | Minor | Major | Major |
| Safety Bay Foreshore Carparks (7 total) | Moderate | Moderate | Major | Major |
| Safety Bay Foreshore Park | Insignificant | Minor | Major | Major |
| Safety Bay Yacht Club | Moderate | Moderate | Major | Major |
| Shoalwater Foreshore Carpark | Insignificant | Minor | Moderate | Major |
| Shoalwater Foreshore Park | Insignificant | Minor | Moderate | Moderate |
| South Mersey Point Rock Seawall | Insignificant | Minor | Moderate | Moderate |
| Waikiki Beach Access Ramp | Insignificant | Minor | Minor | Minor |
| Waikiki Foreshore Carparks (5 total) | Moderate | Moderate | Major | Major |
| Waikiki Foreshore Park | Moderate | Moderate | Major | Catastrophic |
| Waikiki Rock Seawall | Insignificant | Minor | Moderate | Moderate |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Beach | High | High | Low | Low |
| Bent St Boat Ramp | Moderate | Moderate | Low | Low |
| Bores | High | High | High | High |
| BP Petrol Station | Moderate | Moderate | Low | Low |
| Coastal/dune vegetation | High | High | Low | Low |
| Commercial area (Bent St) | Low | Low | Low | Low |
| Drainage Pipes | Moderate | Moderate | Moderate | Moderate |
| Drainage Pits | Moderate | Moderate | Moderate | Moderate |
| Dual use paths | High | High | Moderate | Moderate |
| Lions Park | Moderate | Moderate | Low | Low |
| Lions Park Carpark | Moderate | Moderate | Moderate | Moderate |
| Mersey Point Carpark | Moderate | Moderate | Low | Low |
| Mersey Point Jetty | Moderate | Moderate | Low | Low |
| Noel France Reserve (park) | Moderate | Moderate | Moderate | Moderate |
| Residential | Low | Low | Low | Low |
| Roads | Moderate | Low | Low | Low |
| Rockingham Wild Encounters | Moderate | Moderate | Low | Low |
| Safety Bay Foreshore Carparks (7 total) | Moderate | Moderate | Moderate | Moderate |
| Safety Bay Foreshore Park | Moderate | Moderate | Low | Low |
| Safety Bay Yacht Club | Moderate | Moderate | Low | Low |
| Shoalwater Foreshore Carpark | Moderate | Moderate | Moderate | Moderate |
| Shoalwater Foreshore Park | Moderate | Moderate | Low | Low |
| South Mersey Point Rock Seawall | Moderate | Moderate | Moderate | Moderate |
| Waikiki Beach Access Ramp | Moderate | Moderate | Low | Low |
| Waikiki Foreshore Carparks (5 total) | Moderate | Moderate | Low | Low |
| Waikiki Foreshore Park | Moderate | Moderate | Low | Low |
| Waikiki Rock Seawall | Moderate | Moderate | Moderate | Moderate |

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Risk | | | |
| Beach | Low | Medium | Extreme | Extreme |
| Bent St Boat Ramp | Low | Low | Medium | Medium |
| Bores | Low | Low | Low | Medium |
| BP Petrol Station | Medium | Medium | High | Extreme |
| Coastal/dune vegetation | Low | Medium | Extreme | Extreme |
| Commercial area (Bent St) | Low | Low | Medium | High |
| Drainage Pipes | Medium | High | Extreme | Extreme |
| Drainage Pits | Low | Medium | Extreme | Extreme |
| Dual use paths | Medium | High | High | Extreme |
| Lions Park | Low | Low | Medium | Medium |
| Lions Park Carpark | Low | Low | Medium | High |
| Mersey Point Carpark | Low | Low | High | High |
| Mersey Point Jetty | Low | Low | Medium | Medium |
| Noel France Reserve (park) | Low | Low | Low | Low |
| Residential | Low | Medium | Extreme | Extreme |
| Roads | Medium | Medium | Extreme | Extreme |
| Rockingham Wild Encounters | Low | Low | High | High |
| Safety Bay Foreshore Carparks (7 total) | Medium | Medium | High | Extreme |
| Safety Bay Foreshore Park | Low | Medium | Extreme | Extreme |
| Safety Bay Yacht Club | Medium | Medium | High | Extreme |
| Shoalwater Foreshore Carpark | Low | Low | Medium | High |
| Shoalwater Foreshore Park | Low | Medium | High | High |
| South Mersey Point Rock Seawall | Low | Low | Medium | Medium |
| Waikiki Beach Access Ramp | Low | Low | Medium | Medium |
| Waikiki Foreshore Carparks (5 total) | Medium | Medium | High | Extreme |
| Waikiki Foreshore Park | Low | Medium | High | Extreme |
| Waikiki Rock Seawall | Low | Low | Medium | Medium |

| | Vulnerability | | | |
|---|---|---|---|---|
| **Beach** | Low | Medium | Very High | Very High |
| **Bent St Boat Ramp** | Low | Low | High | High |
| **Bores** | Low | Low | Low | Medium |
| **BP Petrol Station** | Medium | Medium | Very High | Very High |
| **Coastal/dune vegetation** | Low | Medium | Very High | Very High |
| **Commercial area (Bent St)** | Low | Low | High | Very High |
| **Drainage Pipes** | Medium | High | Very High | Very High |
| **Drainage Pits** | Low | Medium | Very High | Very High |
| **Dual use paths** | Medium | High | High | Very High |
| **Lions Park** | Low | Low | High | High |
| **Lions Park Carpark** | Low | Low | Medium | High |
| **Mersey Point Carpark** | Low | Low | Very High | Very High |
| **Mersey Point Jetty** | Low | Low | High | High |
| **Noel France Reserve (park)** | Low | Low | Low | Low |
| **Residential** | Low | High | Very High | Very High |
| **Roads** | Medium | High | Very High | Very High |
| **Rockingham Wild Encounters** | Low | Low | Very High | Very High |
| **Safety Bay Foreshore Carparks (7 total)** | Medium | Medium | High | Very High |
| **Safety Bay Foreshore Park** | Low | Medium | Very High | Very High |
| **Safety Bay Yacht Club** | Medium | Medium | Very High | Very High |
| **Shoalwater Foreshore Carpark** | Low | Low | Medium | High |
| **Shoalwater Foreshore Park** | Low | Medium | Very High | Very High |
| **South Mersey Point Rock Seawall** | Low | Low | Medium | Medium |
| **Waikiki Beach Access Ramp** | Low | Low | High | High |
| **Waikiki Foreshore Carparks (5 total)** | Medium | Medium | Very High | Very High |
| **Waikiki Foreshore Park** | Low | Medium | Very High | Very High |
| **Waikiki Rock Seawall** | Low | Low | Medium | Medium |

## Sector 3 - Inundation

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| All Parks & Recreation areas | Possible | Likely | Likely | Almost Certain |
| Beach | Almost Certain | Almost Certain | Almost Certain | Almost Certain |
| Bent St Boat Ramp | Likely | Likely | Almost Certain | Almost Certain |
| Bores | Possible | Possible | Likely | Almost Certain |
| Coastal/dune vegetation | Likely | Likely | Almost Certain | Almost Certain |
| Drainage Pipes | Likely | Almost Certain | Almost Certain | Almost Certain |
| Drainage Pits | Likely | Likely | Almost Certain | Almost Certain |
| Dual use paths | Likely | Likely | Almost Certain | Almost Certain |
| Mersey Point Carpark | Possible | Possible | Likely | Almost Certain |
| Mersey Point Jetty | Rare | Possible | Possible | Likely |
| Noel France Reserve (park) | Possible | Likely | Likely | Almost Certain |
| Residential | Possible | Possible | Likely | Almost Certain |
| Roads | Possible | Likely | Likely | Almost Certain |
| Rockingham Wild Encounters | Rare | Rare | Likely | Almost Certain |
| Safety Bay Foreshore Carparks (6 total) | Likely | Likely | Almost Certain | Almost Certain |
| Safety Bay Foreshore Park | Possible | Likely | Likely | Almost Certain |
| Safety Bay Primary School | Possible | Possible | Likely | Almost Certain |
| Safety Bay Tennis Club | Possible | Possible | Likely | Almost Certain |
| Safety Bay Yacht Club | Possible | Likely | Likely | Almost Certain |
| South Mersey Point Rock Seawall | Rare | Possible | Possible | Likely |
| Waikiki Beach Access Ramp | Likely | Likely | Almost Certain | Almost Certain |
| Waikiki Rock Seawall | Rare | Possible | Possible | Likely |

| **Asset** | **Consequence of Inundation** | | | |
|---|---|---|---|---|
| All Parks & Recreation areas | Moderate | Moderate | Major | Catastrophic |
| Beach | Insignificant | Insignificant | Minor | Minor |
| Bent St Boat Ramp | Insignificant | Insignificant | Minor | Minor |
| Bores | Minor | Minor | Minor | Minor |
| Coastal/dune vegetation | Insignificant | Insignificant | Minor | Minor |
| Drainage Pipes | Insignificant | Minor | Moderate | Moderate |
| Drainage Pits | Insignificant | Minor | Moderate | Moderate |
| Dual use paths | Moderate | Moderate | Major | Major |
| Mersey Point Carpark | Moderate | Moderate | Moderate | Moderate |
| Mersey Point Jetty | Insignificant | Insignificant | Minor | Minor |
| Noel France Reserve (park) | Insignificant | Minor | Moderate | Moderate |
| Residential | Moderate | Moderate | Major | Catastrophic |
| Roads | Minor | Moderate | Major | Catastrophic |
| Rockingham Wild Encounters | Insignificant | Insignificant | Moderate | Major |
| Safety Bay Foreshore Carparks (6 total) | Moderate | Moderate | Moderate | Moderate |
| Safety Bay Foreshore Park | Insignificant | Minor | Moderate | Moderate |
| Safety Bay Primary School | Minor | Minor | Moderate | Moderate |
| Safety Bay Tennis Club | Minor | Minor | Moderate | Moderate |
| Safety Bay Yacht Club | Moderate | Moderate | Moderate | Major |
| South Mersey Point Rock Seawall | Insignificant | Insignificant | Minor | Minor |
| Waikiki Beach Access Ramp | Insignificant | Insignificant | Minor | Minor |
| Waikiki Rock Seawall | Insignificant | Insignificant | Minor | Minor |

| **Asset** | **Adaptive capacity** | | | |
|---|---|---|---|---|
| All Parks & Recreation areas | High | High | Moderate | Low |

| | | | | |
|---|---|---|---|---|
| **Beach** | **Very High** | **Very High** | **High** | **Moderate** |
| **Bent St Boat Ramp** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Bores** | **High** | **High** | **High** | **High** |
| **Coastal/dune vegetation** | **High** | **Moderate** | **Moderate** | **Moderate** |
| **Drainage Pipes** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Drainage Pits** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Dual use paths** | **High** | **High** | **High** | **Moderate** |
| **Mersey Point Carpark** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Mersey Point Jetty** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Noel France Reserve (park)** | **Moderate** | **Moderate** | **Low** | **Low** |
| **Residential** | **Low** | **Low** | **Low** | **Low** |
| **Roads** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Rockingham Wild Encounters** | **Moderate** | **Moderate** | **Low** | **Low** |
| **Safety Bay Foreshore Carparks (6 total)** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Safety Bay Foreshore Park** | **Moderate** | **Moderate** | **Low** | **Low** |
| **Safety Bay Primary School** | **Moderate** | **Moderate** | **Low** | **Low** |
| **Safety Bay Tennis Club** | **Moderate** | **Moderate** | **Moderate** | **Low** |
| **Safety Bay Yacht Club** | **Moderate** | **Moderate** | **Low** | **Low** |
| **South Mersey Point Rock Seawall** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Waikiki Beach Access Ramp** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |
| **Waikiki Rock Seawall** | **Moderate** | **Moderate** | **Moderate** | **Moderate** |

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Risk | | | |
| All Parks & Recreation areas | Medium | Medium | High | Extreme |
| Beach | Low | Low | Medium | Medium |
| Bent St Boat Ramp | Low | Low | Medium | Medium |
| Bores | Low | Low | Medium | Medium |
| Coastal/dune vegetation | Low | Low | Medium | Medium |
| Drainage Pipes | Low | Medium | High | High |
| Drainage Pits | Low | Medium | High | High |
| Dual use paths | Medium | Medium | Extreme | Extreme |
| Mersey Point Carpark | Medium | Medium | Medium | High |
| Mersey Point Jetty | Low | Low | Low | Medium |
| Noel France Reserve (park) | Low | Medium | Medium | High |
| Residential | Medium | Medium | High | Extreme |
| Roads | Low | Medium | High | Extreme |
| Rockingham Wild Encounters | Low | Low | Medium | Extreme |
| Safety Bay Foreshore Carparks (6 total) | Medium | Medium | High | High |
| Safety Bay Foreshore Park | Low | Medium | Medium | High |
| Safety Bay Primary School | Low | Low | Medium | High |
| Safety Bay Tennis Club | Low | Low | Medium | High |
| Safety Bay Yacht Club | Medium | Medium | Medium | Extreme |
| South Mersey Point Rock Seawall | Low | Low | Low | Medium |
| Waikiki Beach Access Ramp | Low | Low | Medium | Medium |
| Waikiki Rock Seawall | Low | Low | Low | Medium |

| | Vulnerability | | | |
|---|---|---|---|---|
| All Parks & Recreation areas | Medium | Medium | High | Very High |
| Beach | Low | Low | Medium | Medium |
| Bent St Boat Ramp | Low | Low | Medium | Medium |
| Bores | Low | Low | Medium | Medium |
| Coastal/dune vegetation | Low | Low | Medium | Medium |
| Drainage Pipes | Low | Medium | High | High |
| Drainage Pits | Low | Medium | High | High |
| Dual use paths | Medium | Medium | High | Very High |
| Mersey Point Carpark | Medium | Medium | Medium | High |
| Mersey Point Jetty | Low | Low | Low | Medium |
| Noel France Reserve (park) | Low | Medium | High | Very High |
| Residential | High | High | Very High | Very High |
| Roads | Low | Medium | High | Very High |
| Rockingham Wild Encounters | Low | Low | High | Very High |
| Safety Bay Foreshore Carparks (6 total) | Medium | Medium | High | High |
| Safety Bay Foreshore Park | Low | Medium | High | Very High |
| Safety Bay Primary School | Low | Low | High | Very High |
| Safety Bay Tennis Club | Low | Low | Medium | Very High |
| Safety Bay Yacht Club | Medium | Medium | High | Very High |
| South Mersey Point Rock Seawall | Low | Low | Low | Medium |
| Waikiki Beach Access Ramp | Low | Low | Medium | Medium |
| Waikiki Rock Seawall | Low | Low | Low | Medium |

**Sector 4**

| Values | Inundation | | Erosion | |
|---|---|---|---|---|
| | Assets at Risk | Extent | Assets At Risk | Extent |
| **Environmental** | Beach | 6.4 km | Beach | 6.4 km |
| | Coastal / Dune Vegetation | | Coastal / Dune Vegetation | |
| | Port Kennedy Scientific Park | 663,590 $m^2$ | Port Kennedy Scientific Park | 173,935 $m^2$ |
| **Social** | Port Kennedy Boat Ramp | | Port Kennedy Boat Ramp | |
| | The Links Kennedy Bay Golf Course | 14,865 $m^2$ | Port Kennedy Foreshore Recreation Area (Park) | 4,092 $m^2$ |
| | Port Kennedy Foreshore Recreation Area (Park) | 5,895 $m^2$ | | |
| **Economic - Private** | Residential Properties | 28 | Residential Properties | 4,095 $m^2$ |
| **Economic - Public** | Roads | 1.7 km | Roads | 98 |
| | Dual Use Path | 2.1 km | Dual Use Path | 5.8 km |
| | Port Kennedy Foreshore Carpark | 10,595 $m^2$ | Port Kennedy Foreshore Carpark | 9,325 $m^2$ |
| | | | St Malo Cove Carpark | 520 $m^2$ |
| | | | La Seyne Crescent Carpark | 990 $m^2$ |
| | | | St Ives Cove Carpark | 600 $m^2$ |
| | | | Capella Pass Carpark | 640 $m^2$ |
| | | | Cote D'Azur Gardens Carpark | 2,195 $m^2$ |
| | | | Bayeux Avenue Carpark | 675 $m^2$ |
| **Existing Coastal Controls** | | | | |
| Offshore Reefs | | | | |

Sector 3 - Shelton Street

St Malo Cove Carpark

La Seyne Crescent Carpark

St Ives Cove Carpark

Capella Pass Carpark

Currie St

Warnbro Sound Ave

NORTH

**Legend**

- Sector Boundary Line
- Horizontal Shoreline Datum
- Coastline
- 2110 100yr ARI Coastal Erosion Hazard Line
- 2110 500yr ARI Inundation

Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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city of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 4A ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR4A_VULNERABLEASSETS_REV1 01

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Aerial imagery supplied by City of Rockingham (February 2017)
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City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 4B ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR4B_VULNERABLEASSETS_REV1 01

## Sector 4 - Erosion

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Bayeux Avenue Carpark | Rare | Rare | Unlikely | Possible |
| Beach | Possible | Likely | Almost Certain | Almost Certain |
| Capella Pass Carpark | Rare | Unlikely | Possible | Likely |
| Coastal/dune vegetation | Possible | Likely | Almost Certain | Almost Certain |
| Cote D'Azur Gardens Carpark | Rare | Rare | Unlikely | Possible |
| Drainage Pipes | Possible | Likely | Almost Certain | Almost Certain |
| Drainage Pits | Possible | Likely | Almost Certain | Almost Certain |
| Dual use paths | Unlikely | Possible | Likely | Almost Certain |
| La Seyne Crescent Carpark | Rare | Rare | Unlikely | Possible |
| Port Kennedy boat ramp | Possible | Likely | Almost Certain | Almost Certain |
| Port Kennedy Foreshore Carpark | Possible | Likely | Almost Certain | Almost Certain |
| Port Kennedy Foreshore Recreation Area (park) | Possible | Likely | Almost Certain | Almost Certain |
| Port Kennedy Scientific Park | Unlikely | Possible | Likely | Almost Certain |
| Residential - North | Rare | Rare | Unlikely | Possible |
| Residential - Port Kennedy | Rare | Unlikely | Possible | Likely |
| Roads | Rare | Rare | Unlikely | Possible |
| St Ives Cove Carpark | Rare | Unlikely | Possible | Likely |
| St Malo Cove Carpark | Rare | Unlikely | Possible | Likely |

| Asset | Consequence of Erosion | | | |
|---|---|---|---|---|
| Bayeux Avenue Carpark | Insignificant | Insignificant | Insignificant | Minor |
| Beach | Insignificant | Minor | Moderate | Moderate |
| Capella Pass Carpark | Insignificant | Insignificant | Minor | Minor |
| Coastal/dune vegetation | Minor | Minor | Moderate | Major |
| Cote D'Azur Gardens Carpark | Insignificant | Insignificant | Insignificant | Moderate |
| Drainage Pipes | Minor | Minor | Moderate | Moderate |
| Drainage Pits | Minor | Minor | Minor | Moderate |
| Dual use paths | Moderate | Moderate | Moderate | Major |
| La Seyne Crescent Carpark | Insignificant | Insignificant | Insignificant | Moderate |
| Port Kennedy boat ramp | Minor | Moderate | Major | Catastrophic |
| Port Kennedy Foreshore Carpark | Moderate | Major | Major | Catastrophic |
| Port Kennedy Foreshore Recreation Area (park) | Minor | Moderate | Moderate | Major |
| Port Kennedy Scientific Park | Insignificant | Insignificant | Minor | Moderate |
| Residential - North | Insignificant | Insignificant | Major | Catastrophic |
| Residential - Port Kennedy | Minor | Minor | Major | Catastrophic |
| Roads | Insignificant | Insignificant | Minor | Moderate |
| St Ives Cove Carpark | Insignificant | Insignificant | Minor | Minor |
| St Malo Cove Carpark | Insignificant | Insignificant | Minor | Minor |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Bayeux Avenue Carpark | Moderate | Moderate | Moderate | Moderate |
| Beach | High | High | Moderate | Low |
| Capella Pass Carpark | Moderate | Moderate | Moderate | Moderate |
| Coastal/dune vegetation | High | High | Low | Low |
| Cote D'Azur Gardens Carpark | Moderate | Moderate | Moderate | Moderate |
| Drainage Pipes | Moderate | Moderate | Moderate | Moderate |
| Drainage Pits | Moderate | Moderate | Moderate | Moderate |
| Dual use paths | High | High | High | High |
| La Seyne Crescent Carpark | Moderate | Moderate | Moderate | Moderate |
| Port Kennedy boat ramp | Moderate | Moderate | Moderate | Low |
| Port Kennedy Foreshore Carpark | Moderate | Moderate | Moderate | Moderate |
| Port Kennedy Foreshore Recreation Area (park) | High | High | Moderate | Low |
| Port Kennedy Scientific Park | High | High | High | High |
| Residential - North | Low | Low | Low | Low |
| Residential - Port Kennedy | Low | Low | Low | Low |
| Roads | Low | Low | Low | Low |
| St Ives Cove Carpark | Moderate | Moderate | Moderate | Moderate |
| St Malo Cove Carpark | Moderate | Moderate | Moderate | Moderate |

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Risk | | | |
| Bayeux Avenue Carpark | Low | Low | Low | Low |
| Beach | Low | Medium | High | High |
| Capella Pass Carpark | Low | Low | Low | Medium |
| Coastal/dune vegetation | Low | Medium | High | Extreme |
| Cote D'Azur Gardens Carpark | Low | Low | Low | Medium |
| Drainage Pipes | Low | Medium | High | High |
| Drainage Pits | Low | Medium | Medium | High |
| Dual use paths | Medium | Medium | Medium | Extreme |
| La Seyne Crescent Carpark | Low | Low | Low | Medium |
| Port Kennedy boat ramp | Low | Medium | Extreme | Extreme |
| Port Kennedy Foreshore Carpark | Medium | High | Extreme | Extreme |
| Port Kennedy Foreshore Recreation Area (park) | Low | Medium | High | Extreme |
| Port Kennedy Scientific Park | Low | Low | Medium | High |
| Residential - North | Low | Low | Medium | Extreme |
| Residential - Port Kennedy | Low | Low | High | Extreme |
| Roads | Low | Low | Low | Medium |
| St Ives Cove Carpark | Low | Low | Low | Medium |
| St Malo Cove Carpark | Low | Low | Low | Medium |

| | Vulnerability | | | |
|---|---|---|---|---|
| Bayeux Avenue Carpark | Low | Low | Low | Low |
| Beach | Low | Medium | High | Very High |
| Capella Pass Carpark | Low | Low | Low | Medium |
| Coastal/dune vegetation | Low | Medium | Very High | Very High |
| Cote D'Azur Gardens Carpark | Low | Low | Low | Medium |
| Drainage Pipes | Low | Medium | High | High |
| Drainage Pits | Low | Medium | Medium | High |
| Dual use paths | Medium | Medium | Medium | High |
| La Seyne Crescent Carpark | Low | Low | Low | Medium |
| Port Kennedy boat ramp | Low | Medium | Very High | Very High |
| Port Kennedy Foreshore Carpark | Medium | High | Very High | Very High |
| Port Kennedy Foreshore Recreation Area (park) | Low | Medium | High | Very High |
| Port Kennedy Scientific Park | Low | Low | Medium | High |
| Residential - North | Low | Low | High | Very High |
| Residential - Port Kennedy | Low | Low | Very High | Very High |
| Roads | Low | Low | Low | High |
| St Ives Cove Carpark | Low | Low | Low | Medium |
| St Malo Cove Carpark | Low | Low | Low | Medium |

## Sector 4 - Inundation

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Almost Certain | Almost Certain | Almost Certain | Almost Certain |
| Drainage Pipes | Possible | Possible | Likely | Almost Certain |
| Drainage Pits | Possible | Possible | Likely | Almost Certain |
| Dual use paths | Unlikely | Unlikely | Unlikely | Possible |
| Port Kennedy Foreshore Carpark | Likely | Likely | Almost Certain | Almost Certain |
| Port Kennedy Foreshore Recreation Area (park) | Possible | Possible | Likely | Likely |
| Port Kennedy Scientific Park | Likely | Likely | Almost Certain | Almost Certain |
| Residential | Possible | Possible | Likely | Almost Certain |
| Roads | Possible | Possible | Likely | Likely |
| The Links Kennedy Bay Golf Course | Rare | Rare | Rare | Rare |

| Asset | Consequence of Inundation | | | |
|---|---|---|---|---|
| Beach | Insignificant | Insignificant | Minor | Minor |
| Drainage Pipes | Insignificant | Minor | Minor | Moderate |
| Drainage Pits | Insignificant | Minor | Minor | Moderate |
| Dual use paths | Insignificant | Minor | Minor | Moderate |
| Port Kennedy Foreshore Carpark | Insignificant | Minor | Moderate | Moderate |
| Port Kennedy Foreshore Recreation Area (park) | Insignificant | Minor | Minor | Moderate |
| Port Kennedy Scientific Park | Insignificant | Minor | Moderate | Moderate |
| Residential | Minor | Minor | Moderate | Moderate |
| Roads | Insignificant | Insignificant | Minor | Moderate |
| The Links Kennedy Bay Golf Course | Insignificant | Insignificant | Insignificant | Minor |

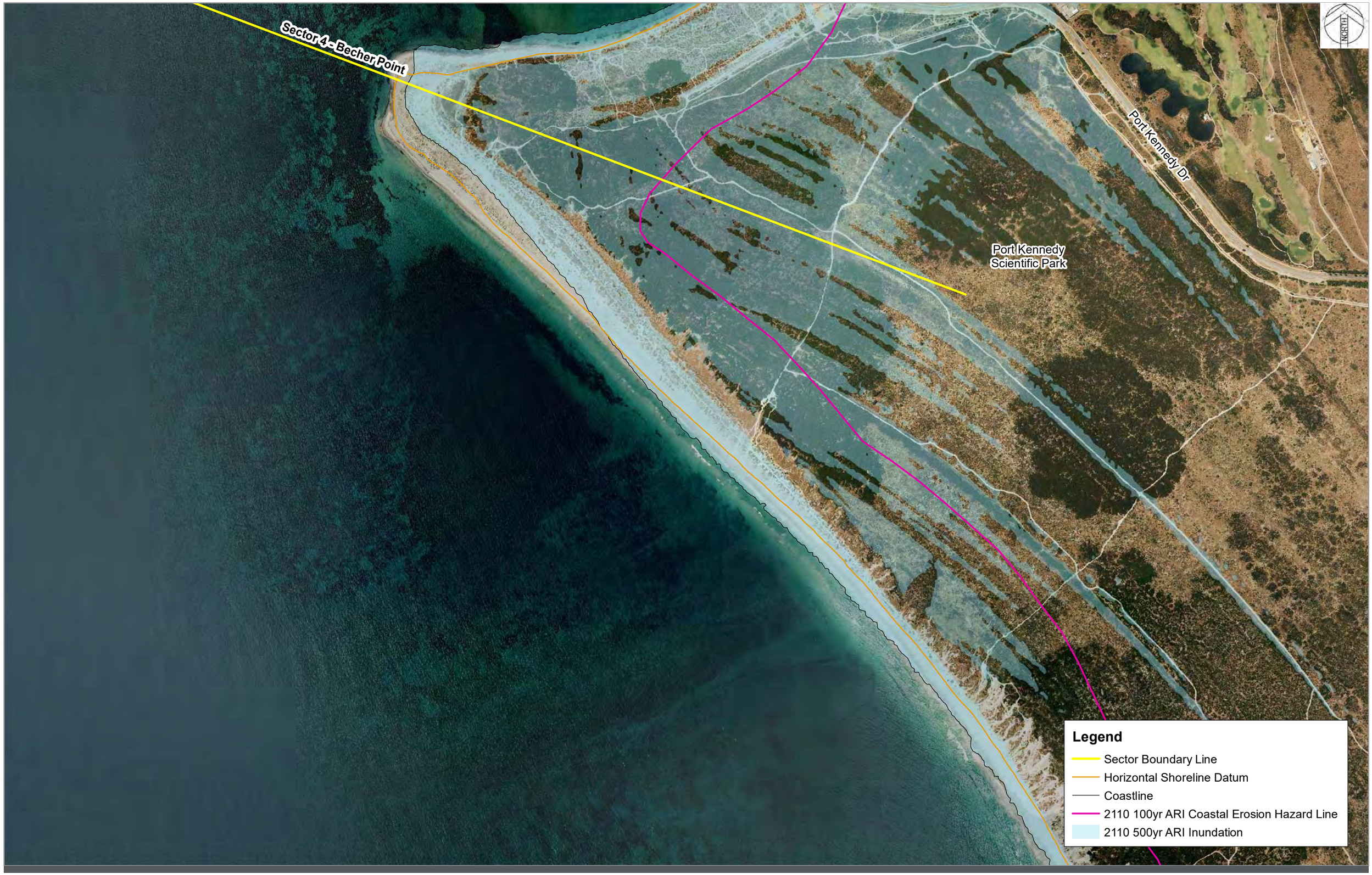
| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Beach | Very High | Very High | High | Moderate |
| Drainage Pipes | Moderate | Moderate | Moderate | Moderate |
| Drainage Pits | Moderate | Moderate | Moderate | Moderate |
| Dual use paths | High | High | High | Moderate |
| Port Kennedy Foreshore Carpark | Moderate | Moderate | Moderate | Moderate |
| Port Kennedy Foreshore Recreation Area (park) | High | Moderate | Moderate | Moderate |
| Port Kennedy Scientific Park | High | High | Moderate | Moderate |
| Residential | Moderate | Low | Low | Low |
| Roads | Moderate | Moderate | Moderate | Moderate |
| The Links Kennedy Bay Golf Course | High | High | High | Moderate |

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | **Risk** | | | |
| **Beach** | Low | Low | Medium | Medium |
| **Drainage Pipes** | Low | Low | Medium | High |
| **Drainage Pits** | Low | Low | Medium | High |
| **Dual use paths** | Low | Low | Low | Medium |
| **Port Kennedy Foreshore Carpark** | Low | Medium | High | High |
| **Port Kennedy Foreshore Recreation Area (park)** | Low | Low | Medium | Medium |
| **Port Kennedy Scientific Park** | Low | Medium | High | High |
| **Residential** | Low | Low | Medium | High |
| **Roads** | Low | Low | Medium | Medium |
| **The Links Kennedy Bay Golf Course** | Low | Low | Low | Low |

| | **Vulnerability** | | | |
|---|---|---|---|---|
| **Beach** | Low | Low | Medium | Medium |
| **Drainage Pipes** | Low | Low | Medium | High |
| **Drainage Pits** | Low | Low | Medium | High |
| **Dual use paths** | Low | Low | Low | Medium |
| **Port Kennedy Foreshore Carpark** | Low | Medium | High | High |
| **Port Kennedy Foreshore Recreation Area (park)** | Low | Low | Medium | Medium |
| **Port Kennedy Scientific Park** | Low | Medium | High | High |
| **Residential** | Low | Low | High | Very High |
| **Roads** | Low | Low | Medium | Medium |
| **The Links Kennedy Bay Golf Course** | Low | Low | Low | Low |

**Sector 5**

| Values | Inundation | | Erosion | |
|---|---|---|---|---|
| | Assets at Risk | Extent | Assets At Risk | Extent |
| **Environmental** | Beach | 6.1 km | Beach | 6.1 km |
| | Coastal / Dune Vegetation | | Coastal / Dune Vegetation | |
| | Port Kennedy Scientific Park | 766,870 $m^2$ | Port Kennedy Scientific Park | 734,000 $m^2$ |
| **Social** | | | Lagoon Park | 10,925 $m^2$ |
| | | | Secret Harbour Surf Lifesaving Club | 1,570 $m^2$ |
| **Economic - Public** | | | Road - Siracusa Ct | 0.1 km |
| | | | Secret Harbour Beach Carpark (Siracusa St) | 1,535 $m^2$ |
| | | | Secret Harbour Beach Carpark (Albenga Pl) | 4,315 $m^2$ |
| | | | Secret Harbour Beach Carpark (Palisades Bvd) | 870 $m^2$ |
| | | | Pedestrian Pathway | 1.2 km |
| **Existing Coastal Controls** | | | | |
| - | | | | |

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City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 5A ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

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City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 5B ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

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## Sector 5 - Erosion

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Possible | Likely | Almost Certain | Almost Certain |
| Coastal/dune vegetation | Possible | Likely | Almost Certain | Almost Certain |
| Drainage Pipes | Rare | Rare | Unlikely | Possible |
| Drainage Pits | Rare | Rare | Unlikely | Possible |
| Lagoon Park | Rare | Rare | Unlikely | Possible |
| Pedestrian pathway | Rare | Unlikely | Possible | Likely |
| Port Kennedy Scientific Park | Rare | Unlikely | Possible | Likely |
| Road (Siracusa Ct) | Rare | Rare | Unlikely | Possible |
| Secret Harbour Beach Carpark (Albenga Pl) | Rare | Rare | Unlikely | Possible |
| Secret Harbour Beach Carpark (Palisades Bvd) | Rare | Rare | Unlikely | Possible |
| Secret Harbour Beach Carpark (Siracusa St) | Rare | Rare | Unlikely | Possible |
| Secret Harbour Surf Lifesaving Club | Rare | Rare | Unlikely | Possible |

| Asset | Consequence of Erosion | | | |
|---|---|---|---|---|
| Beach | Insignificant | Minor | Minor | Minor |
| Coastal/dune vegetation | Insignificant | Minor | Moderate | Moderate |
| Drainage Pipes | Insignificant | Insignificant | Minor | Moderate |
| Drainage Pits | Insignificant | Insignificant | Insignificant | Minor |
| Lagoon Park | Insignificant | Insignificant | Minor | Moderate |
| Pedestrian pathway | Insignificant | Insignificant | Moderate | Moderate |
| Port Kennedy Scientific Park | Insignificant | Insignificant | Minor | Moderate |
| Road (Siracusa Ct) | Insignificant | Insignificant | Insignificant | Minor |
| Secret Harbour Beach Carpark (Albenga Pl) | Insignificant | Insignificant | Insignificant | Moderate |
| Secret Harbour Beach Carpark (Palisades Bvd) | Insignificant | Insignificant | Insignificant | Moderate |
| Secret Harbour Beach Carpark (Siracusa St) | Insignificant | Insignificant | Moderate | Moderate |
| Secret Harbour Surf Lifesaving Club | Moderate | Moderate | Moderate | Moderate |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Beach | High | High | Moderate | Moderate |
| Coastal/dune vegetation | High | High | Moderate | Moderate |
| Drainage Pipes | Moderate | Moderate | Moderate | Moderate |
| Drainage Pits | Moderate | Moderate | Moderate | Moderate |
| Lagoon Park | Moderate | Moderate | Moderate | Moderate |
| Pedestrian pathway | Moderate | Moderate | Moderate | Moderate |
| Port Kennedy Scientific Park | High | High | High | High |
| Road (Siracusa Ct) | Low | Low | Low | Low |
| Secret Harbour Beach Carpark (Albenga Pl) | Moderate | Moderate | Moderate | Moderate |
| Secret Harbour Beach Carpark (Palisades Bvd) | Moderate | Moderate | Moderate | Moderate |
| Secret Harbour Beach Carpark (Siracusa St) | Moderate | Moderate | Moderate | Moderate |
| Secret Harbour Surf Lifesaving Club | Low | Low | Low | Low |

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | **Risk** | | | |
| **Beach** | Low | Medium | Medium | Medium |
| **Coastal/dune vegetation** | Low | Medium | High | High |
| **Drainage Pipes** | Low | Low | Low | Medium |
| **Drainage Pits** | Low | Low | Low | Low |
| **Lagoon Park** | Low | Low | Low | Medium |
| **Pedestrian pathway** | Low | Low | Medium | Medium |
| **Port Kennedy Scientific Park** | Low | Low | Low | Medium |
| **Road (Siracusa Ct)** | Low | Low | Low | Low |
| **Secret Harbour Beach Carpark (Albenga Pl)** | Low | Low | Low | Medium |
| **Secret Harbour Beach Carpark (Palisades Bvd)** | Low | Low | Low | Medium |
| **Secret Harbour Beach Carpark (Siracusa St)** | Low | Low | Medium | Medium |
| **Secret Harbour Surf Lifesaving Club** | Low | Low | Medium | Medium |

| | **Vulnerability** | | | |
|---|---|---|---|---|
| **Beach** | Low | Medium | Medium | Medium |
| **Coastal/dune vegetation** | Low | Medium | High | High |
| **Drainage Pipes** | Low | Low | Low | Medium |
| **Drainage Pits** | Low | Low | Low | Low |
| **Lagoon Park** | Low | Low | Low | Medium |
| **Pedestrian pathway** | Low | Low | Medium | Medium |
| **Port Kennedy Scientific Park** | Low | Low | Low | Medium |
| **Road (Siracusa Ct)** | Low | Low | Low | Low |
| **Secret Harbour Beach Carpark (Albenga Pl)** | Low | Low | Low | Medium |
| **Secret Harbour Beach Carpark (Palisades Bvd)** | Low | Low | Low | Medium |
| **Secret Harbour Beach Carpark (Siracusa St)** | Low | Low | Medium | Medium |
| **Secret Harbour Surf Lifesaving Club** | Low | Low | High | High |

## Sector 5 - Inundation

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Almost Certain | Almost Certain | Almost Certain | Almost Certain |
| Coastal/dune vegetation | Likely | Almost Certain | Almost Certain | Almost Certain |
| Port Kennedy Scientific Park | Likely | Likely | Almost Certain | Almost Certain |

| Asset | Consequence of Inundation | | | |
|---|---|---|---|---|
| Beach | Insignificant | Insignificant | Minor | Minor |
| Coastal/dune vegetation | Insignificant | Insignificant | Insignificant | Minor |
| Port Kennedy Scientific Park | Insignificant | Insignificant | Insignificant | Minor |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Beach | Very High | High | High | Moderate |
| Coastal/dune vegetation | High | High | High | High |
| Port Kennedy Scientific Park | High | High | Moderate | Moderate |

| Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | **Risk** | | | |
| Beach | Low | Low | Medium | Medium |
| Coastal/dune vegetation | Low | Low | Low | Medium |
| Port Kennedy Scientific Park | Low | Low | Low | Medium |

| | Vulnerability | | | |
|---|---|---|---|---|
| Beach | Low | Low | Medium | Medium |
| Coastal/dune vegetation | Low | Low | Low | Medium |
| Port Kennedy Scientific Park | Low | Low | Low | Medium |

**Sector 6**

| Values | Inundation | | Erosion | |
|---|---|---|---|---|
| | Assets at Risk | Extent | Assets At Risk | Extent |
| **Environmental** | Beach | 4.4 km | Beach | 4.4 km |
| | Coastal/Dune Vegetation | | Coastal / Dune Vegetation | |
| **Social** | | | Singleton Foreshore | 1,105 $m^2$ |
| **Existing Coastal Controls** | | | | |
| - | | | | |


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city of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 6A ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

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City of Rockingham

Date
19/02/2018

Size
A3

Scale
1:10,000

0 90 180 270 360m

# SECTOR 6B ASSET VULNERABILITY MAP

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR6B_VULNERABLEASSETS_REV1 01

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## Sector 6 - Erosion

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Possible | Likely | Almost Certain | Almost Certain |
| Coastal/dune vegetation | Possible | Likely | Almost Certain | Almost Certain |
| Drainage Pipes | Rare | Rare | Unlikely | Possible |
| Drainage Pits | Rare | Rare | Unlikely | Possible |
| Singleton Foreshore Park | Rare | Unlikely | Possible | Likely |

| Asset | Consequence of Erosion | | | |
|---|---|---|---|---|
| Beach | Insignificant | Minor | Minor | Minor |
| Coastal/dune vegetation | Insignificant | Minor | Moderate | Moderate |
| Drainage Pipes | Insignificant | Insignificant | Insignificant | Minor |
| Drainage Pits | Insignificant | Insignificant | Insignificant | Minor |
| Singleton Foreshore Park | Insignificant | Insignificant | Insignificant | Minor |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Beach | High | High | High | High |
| Coastal/dune vegetation | High | High | High | Moderate |
| Drainage Pipes | Moderate | Moderate | Moderate | Moderate |
| Drainage Pits | Moderate | Moderate | Moderate | Moderate |
| Singleton Foreshore Park | High | High | High | Moderate |

| Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | **Risk** | | | |
| Beach | Low | Medium | Medium | Medium |
| Coastal/dune vegetation | Low | Medium | High | High |
| Drainage Pipes | Low | Low | Low | Low |
| Drainage Pits | Low | Low | Low | Low |
| Singleton Foreshore Park | Low | Low | Low | Medium |

| | Vulnerability | | | |
|---|---|---|---|---|
| Beach | Low | Medium | Medium | Medium |
| Coastal/dune vegetation | Low | Medium | High | High |
| Drainage Pipes | Low | Low | Low | Low |
| Drainage Pits | Low | Low | Low | Low |
| Singleton Foreshore Park | Low | Low | Low | Medium |

## Sector 6 - Inundation

| Assessment Inputs | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| **Asset** | **Likelihood** | | | |
| Beach | Almost Certain | Almost Certain | Almost Certain | Almost Certain |
| Coastal/dune vegetation | Rare | Rare | Rare | Rare |

| Asset | Consequence of Inundation | | | |
|---|---|---|---|---|
| Beach | Insignificant | Insignificant | Minor | Minor |
| Coastal/dune vegetation | Insignificant | Insignificant | Minor | Minor |

| Asset | Adaptive capacity | | | |
|---|---|---|---|---|
| Beach | High | High | High | High |
| Coastal/dune vegetation | High | High | High | High |

| Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | **Risk** | | | |
| Beach | Low | Low | Medium | Medium |
| Coastal/dune vegetation | Low | Low | Low | Low |

| | Vulnerability | | | |
|---|---|---|---|---|
| Beach | Low | Low | Medium | Medium |
| Coastal/dune vegetation | Low | Low | Low | Low |

# APPENDIX

# K

## RISK MANAGEMENT AND ADAPTATION CHAPTER REPORT

# Risk Management and Adaptation

## City of Rockingham Coastal Hazard Risk Management and Adaptation Plan

59918065

Prepared for

City of Rockingham

29 March 2018

Cardno

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# 1 Introduction

## 1.1 Background

Globally, mean sea level (MSL) has risen since the nineteenth century and is predicted to continue to rise, at an increasing rate, through the twenty first century (Intergovernmental Panel on Climate Change [IPCC], 2014), bringing changes to the Western Australian (WA) coastline over the coming decades. To prepare for sea level rise (SLR) induced coastal hazards, such as coastal erosion and inundation, all levels of government are putting processes in place to ensure that communities understand the risks to values and assets on the coast, and to plan to adapt over time.

Changes to MSL over the past century have been observed for the coastline adjacent to the Perth Metropolitan Area. *Sea Level Change in Western Australia – Application to Coastal Planning* (Department of Transport [DoT], 2010) reviewed information relating to SLR at a local scale and recommended an allowance for SLR be adopted for planning purposes. The WA State Government revised the State Coastal Planning Policy in 2013 to incorporate a projected SLR for WA of 0.9 m between 2010 and 2110 (**Figure 1-1**).

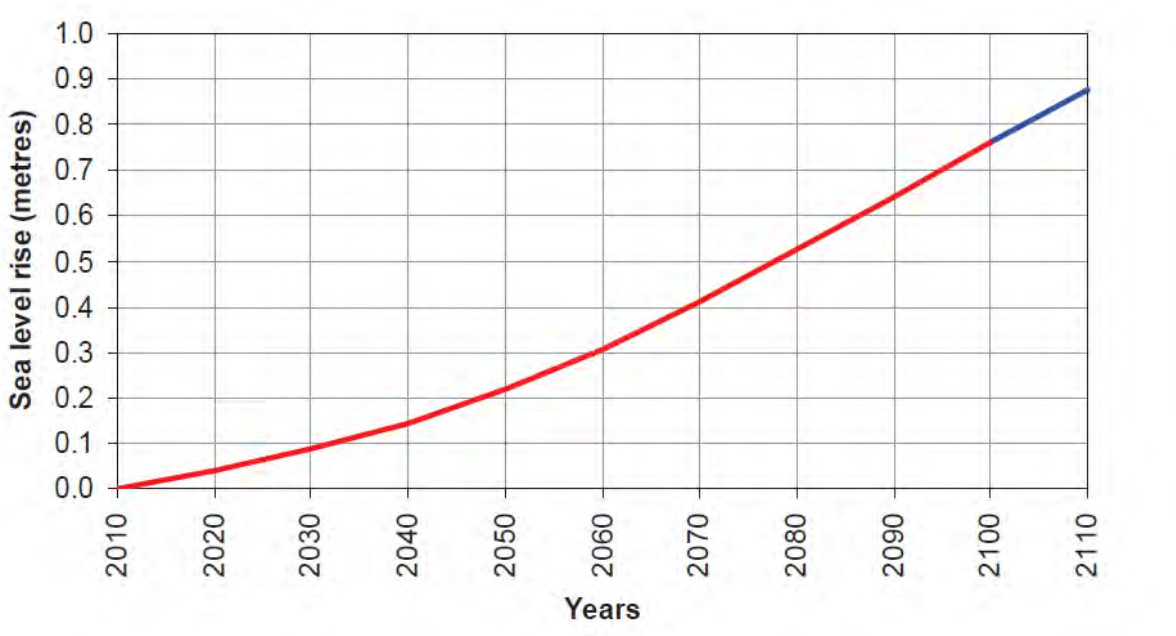


Figure 1-1 Recommended allowance for sea level rise in coastal planning in Western Australia (DoT, 2010).

The Rockingham Local Government Area (LGA) coastline is low lying and sandy, featuring coastal dunes, nearshore reefs, islands and seagrass meadows. For sandy coastlines, increases in local MSL generally result in shoreline recession, with a “rule of thumb” often used, that a 1 cm rise will result in 1 m of landward recession of the shoreline (**Figure 1-2**; CoastAdapt, 2017).

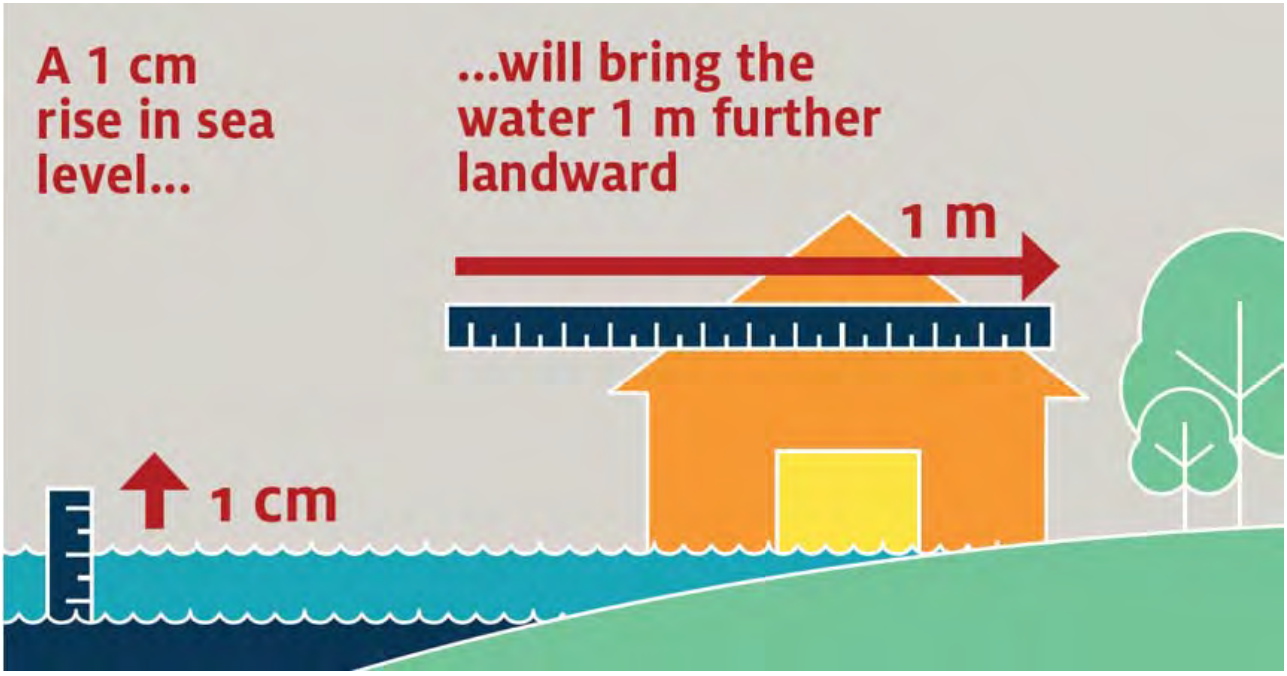


Figure 1-2 Simplified schematic of how sea level rise will impact shorelines (CoastAdapt, 2017).

The City of Rockingham (the City) is developing a Coastal Hazard Risk Management and Adaptation Plan (CHRMAP), with technical input from Cardno, to identify risks and plan to adapt to the potential impacts associated with predicted SLR along their coastline.

The purpose of the CHRMAP process is to:

- Ensure that development and the location of coastal facilities takes into account coastal processes, landform stability, coastal hazards, climate change and biophysical criteria;
- Guide the identification of appropriate areas for the sustainable use of the coast for housing, tourism, recreation, ocean access, maritime industry, commercial and other activities;
- Provide for public coastal foreshore reserves on the coast and ensure access to them; and
- Protect, conserve and enhance coastal zone values, particularly in areas of landscape, biodiversity and ecosystem integrity, indigenous and cultural significance.

## 1.2 Overview of the CHRMAP Process

The key policy governing coastal planning in WA is the *State Planning Policy No. 2.6: State Coastal Planning Policy* (Western Australian Planning Commission [WAPC], 2013a) (SPP2.6). SPP2.6 recommends that management authorities develop a CHRMAP, using a risk mitigation approach to planning, that identifies the hazards associated with existing and future development in the coastal zone. SPP2.6 and the *State Coastal Planning Policy Guidelines* (WAPC, 2013b) contain prescriptive details, for example in relation to scales of assessment, storm event types and SLR allowances.

The WAPC (2014a) has also developed the *Coastal hazard risk management and adaptation planning guidelines* (the CHRMAP Guidelines) which are less prescriptive, but are aimed to ensure that planning is carried out using a risk based approach with due regard given to stakeholder engagement, community consultation and education, and that a full range of adaptation options is considered. An overview of the typical CHRMAP process is shown in **Figure 1-3**.

Coastal planning in accordance with SPP2.6 also needs to take into consideration the requirements of other planning policies, including *Statement of Planning Policy No. 2: Environment and Natural Resources Policy* (WAPC, 2003) and *Statement of Planning Policy No. 3: Urban Growth and Settlement* (WAPC, 2006).

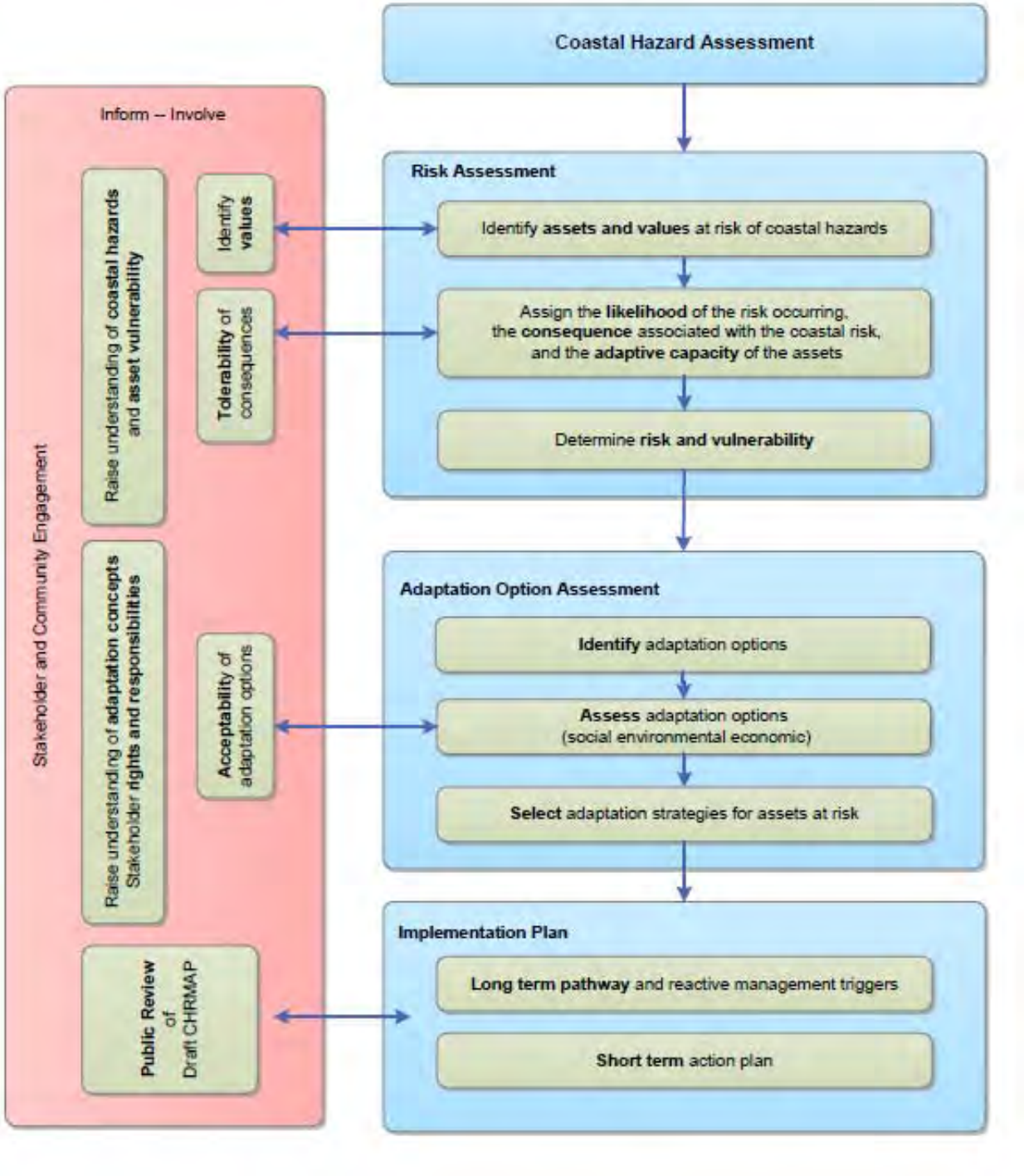


Figure 1-3 CHRMAP methodology flow chart (adapted from the CHRMAP Guidelines (WAPC, 2014a)).

## 1.3 Risk Assessment Outcomes

The risk and vulnerability assessment identified assets, groups of assets and areas potentially vulnerable to coastal erosion and inundation hazards at present and up to the 2110 planning timeframe. In general, coastal erosion hazards lead to the highest vulnerability in the short-term, due to their greater capacity to damage assets. The risk of coastal inundation, however, increases substantially over future planning timeframes and extends across large areas of low-lying land along the City's coastline. Although options for short-term implementation (outlined in **Section 4** of this report) are generally focused on mitigating the threat of coastal erosion, they must consider and account for future hazards associated with coastal inundation.

### 1.3.1 Preliminary Prioritisation

Through the vulnerability assessment process, several assets or groups of assets were identified as being highly or very highly vulnerable by the 2030 planning timeframe. Sectors containing these assets have been prioritised for further assessment and discussion in this report. The options for treatment in these Sectors have been considered in greater detail, to better inform decision making and assist in presenting the options to the community for their consideration. Sectors 2, 3 and 4 were identified as having assets highly vulnerable to coastal erosion within the 2030 planning timeframe. Key assets vulnerable to erosion and their vulnerability timeframes are presented for each of these Sectors in **Tables 1-1** to **1-3**, respectively, below.

Table 1-1 Key assets vulnerable to coastal erosion in Sector 2 and their vulnerability timeframes.

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Vulnerability | | | |
| **Alfred Hines Seaside Home** | High | Very High | Very High | Very High |
| **Coastal/dune vegetation** | Medium | High | Very High | Very High |
| **Commercial area (Railway Tce)** | Low | Very High | Very High | Very High |
| **Drainage Pipes** | Medium | High | Very High | Very High |
| **Mangles Bay Fishing Club** | High | Very High | Very High | Very High |
| **Point Peron Wastewater Treatment Plant** | Medium | High | Very High | Very High |
| **Residential** | Low | High | Very High | Very High |
| **Roads** | Low | High | Very High | Very High |
| **Rockingham Naval Club** | High | High | High | Very High |
| **The Cruising Yacht Club** | High | Very High | Very High | Very High |
| **Underground Storage** | Medium | High | Very High | Very High |

Table 1-2 Key assets vulnerable to coastal erosion in Sector 3 and their vulnerability timeframes.

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Vulnerability | | | |
| **Drainage Pipes** | Medium | High | Very High | Very High |
| **Dual use paths** | Medium | High | High | Very High |
| **Residential** | Low | High | Very High | Very High |
| **Roads** | Medium | High | Very High | Very High |

Table 1-3 Key asset vulnerable to coastal erosion in Sector 4 and their vulnerability timeframes.

| Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Vulnerability | | | |
| **Port Kennedy Foreshore Carpark** | Medium | High | Very High | Very High |

## 1.4 Purpose of this Report

This Risk Management and Adaptation Chapter Report (hereafter called 'the Report') uses the results of the completed risk and vulnerability assessment to identify and assess risk management and adaptation options. It has been written to satisfy Clause 3.5 of the City's Scope.

The Report aims to identify potential responses to the coastal hazard risks for each of the Sectors within the study area, and to provide a preliminary evaluation of the available options, to inform stakeholder and community engagement (see **Figure 1-3** above). The objectives of the adaptation options assessment are:

- To define a range of adaptation measures for each of the City's coastline sectors;
- To carry out a multi-criteria analysis (MCA) as a framework and starting point for stakeholder and community consultation, and to identify options for further assessment;
- To supply relevant information to inform future detailed options assessments for individual sectors;
- To provide preliminary economic information associated with selected adaptation options;
- To provide preliminary recommendations for the implementation of management options and planning responses, with consideration of equity implications; and
- To identify further investigations that may be required.

The adaptation options assessment has been guided by the Project's success criteria (see **Section 2.3**), defined through the City's community engagement process. These success criteria have been used to undertake a preliminary assessment of the acceptability of potential adaptation options.

The Report is structured as follows:

- **Section 1** provides an introduction to the stand-alone chapter report;
- **Section 2** introduces relevant aspects of the statutory planning framework, outlines planning controls and lists the consultation derived community values and success criteria;
- **Section 3** provides a description of the adaptation planning process and the methods used to assess options, including the MCA and economic assessment;
- **Section 4** provides the outcomes of the adaptation options assessment process, discussion of the adaptation options (avoid, accommodate, managed retreat and protect), implications for equity and statutory planning considerations; and
- **Section 5** discusses the key findings of the report and outlines the next steps in the process.

# 2 Adaptation Planning Framework

## 2.1 Statutory Planning Framework

The State Planning Framework is summarised in **Figure 2-1**. The key statutory planning document for the City is Town Planning Scheme No. 2 (TPS2). This applies zones and reserves to land within the City and outlines the permissibility of land uses, the requirements for development and the processes for seeking approval for proposed development. TPS2 was gazetted on 19 November 2004.

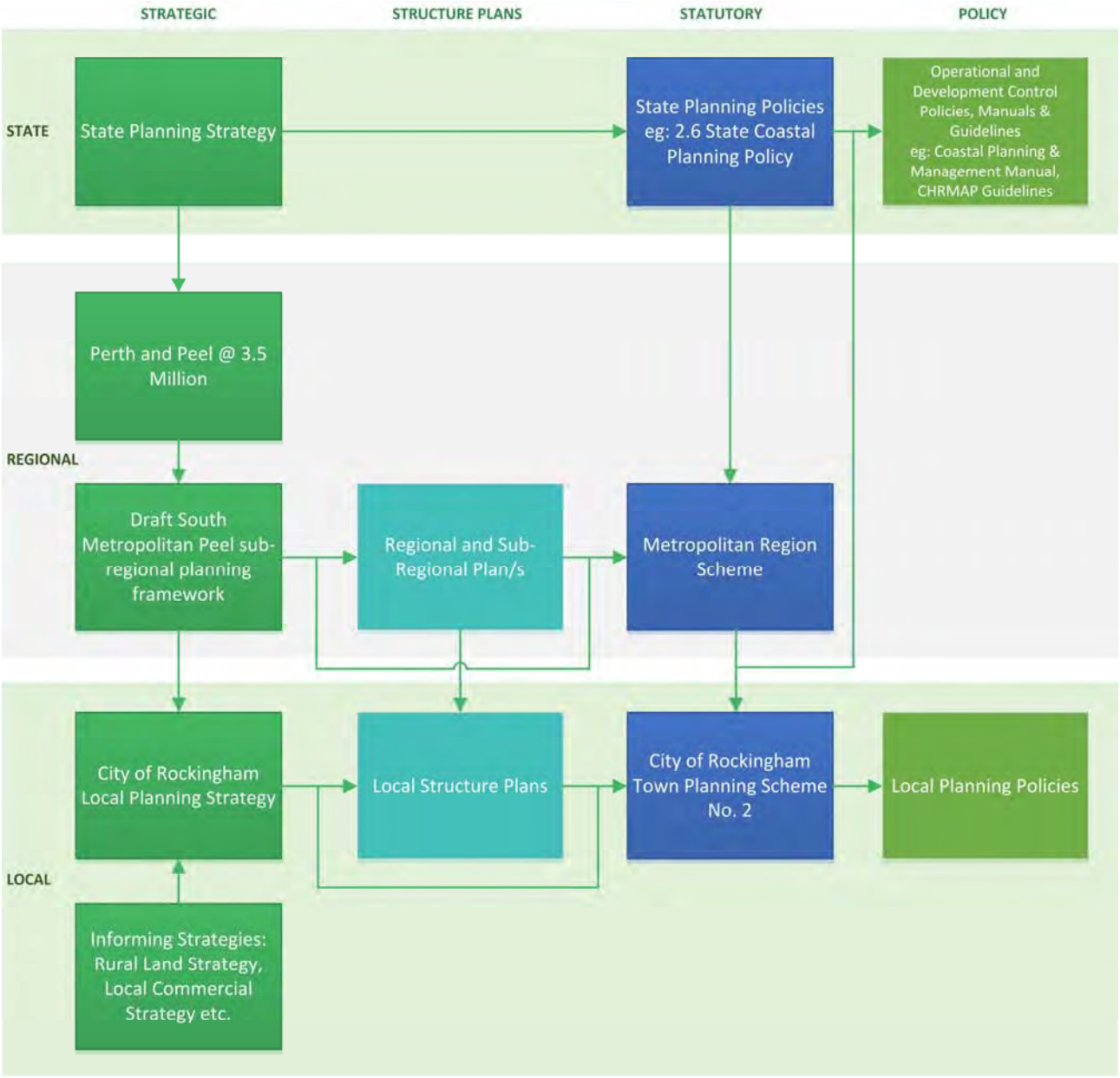


Figure 2-1 Planning context overview

TPS2 was amended in September 2017, to be consistent with the *Planning and Development (Local Planning Scheme) Regulations 2015* (the P&D Regulations, DoPLH, 2017a). Through the review of TPS2, the City identified any aspects of the document that were inconsistent with the intent of regional and state strategies, policies, and statutory requirements, including SPP2.6.

The general objectives of TPS2 are to:

> Optimise the provision of services and facilities for the community;

> Establish the preferred use of land well in advance of development;

- Ensure the coordinated provision of adequate land for development;
- Conserve and enhance features of cultural, historical, environmental and natural significance; and
- Reconcile community needs and aspirations with appropriate land use and development.

State Planning Policies provide the highest level of planning policy control and guidance in Western Australia and are prepared under Part 3 of the *Planning and Development Act 2005* (DoPLH, 2017b). SPP2.6 is an environmental sector policy consistent with the higher order *SPP 2 Environmental and Natural Resources Policy.*

## 2.2 Planning Controls

The risk and vulnerability assessment process identified the key assets and areas vulnerable to coastal erosion and inundation over approximately the next decade to 2030, as well the potential longer-term vulnerability to 2070 and 2110. SPP2.6 and the CHRMAP Guidelines specify the development of a CHRMAP that effectively focuses on two time scales:

- A long-term strategic pathway over the next 100 years for the full study area; and
- Planning for implementation of management actions in the shorter-term (e.g. before 2030) for priority management areas.

There exists a complex set of historical documents, rules and decision making that has led to the present level of development along the coast within WA. Originally, it was assumed that cadastral boundaries enclosed reasonably permanent areas suitable for developing residential and commercial assets ad-infinitum. The notion that the land and assets within these boundaries is now vulnerable (or becoming vulnerable) to coastal hazards, and will potentially become unusable, led to the development of SPP2.6 and the need for careful planning to determine future development directions in coastal areas.

A key aim of SPP2.6 is to ensure recognition that SLR and associated coastal hazards are threatening currently fixed, coastal zone assets and will do so at an increasing rate into the future. SPP2.6 and the CHRMAP Guidelines also seek to commence the process of adjusting community expectations about life in the future, given a diminishing coastal zone. Preliminary estimates of the cost of entirely protecting property and beach amenity throughout the State, into the future, are prohibitively expensive. Hence, SPP2.6 aims to implement responsible long-term planning strategies to develop affordable solutions that satisfy a range of key drivers, including intergenerational equity.

As per SPP2.6 and the CHRMAP guidelines, and the recent *Draft Planned or Managed Retreat Guidelines* (DoPLH, 2017c) the long-term priority is to adopt a strategy hierarchy of:

- *Avoid*;
- *Managed Retreat*;
- *Accommodate*; and, once the options above have been fully investigated,
- *Protect* (to be funded under the beneficiary pays principle).

Ultimately, the aim is to manage retreat from vulnerable areas before assets are threatened. This will require a shift in the strategy from, for example, initial protection to eventual managed retreat. The *Protect* strategy proposes that the beneficiaries fund protection, while the transition from a *Protect* to *Retreat* strategy may trigger funding for removal or relocation under the *Land Administration Act 1997* (DoPLH, 2017d). A number of questions arise out of these strategies, for example:

- Who are the beneficiaries?
- What is a reasonable method for apportioning costs to the beneficiaries?
- Who is disadvantaged by the strategies, how will they be compensated and by who?
- Who is responsible for funding managed retreat, in accordance with the mechanisms described in the *Draft Planned or Managed Retreat Guidelines*?

It is recommended that a comprehensive investigation of the community and visitors be undertaken to identify beneficiaries of any current or proposed protection areas. Further to this, an economic assessment of

mechanisms for recouping costs from beneficiaries (e.g. parking fees, visitor entry fee, increased council rates or levy and other options) is required to inform the future review of the strategy options outlined in this Report.

### 2.2.1 Planning Instruments

The following planning instruments are generally consistent with those outlined in the *Draft Planned or Managed Retreat Guidelines* (DoPLH, 2017d). The City should look to incorporate these instruments into their planning framework, and these can be refined as clarity around long-term pathways, financial implications of options and funding arrangements evolve. The planning instruments are as follows:

***Structure Planning***. Local structure plans typically indicate future proposed zoning, and the expectation is that once a structure plan has been implemented to a stage that the boundaries of the proposed zoning are set and not going to be changed, they then be incorporated into the planning scheme as a standard amendment.

In areas where development or redevelopment of coastal land is proposed, all structure plans should properly incorporate the requirements of the City's CHRMAP, to account for coastal hazard risks and ensure an appropriate coastal foreshore reserve is included (see **Section 4.2** for more detail on coastal foreshore reservation). This instrument may have limited effect in the context of the City, given much of the land identified as vulnerable is already developed. There are, however, agreed and draft local structure plans affecting coastal land in the City and each of these should be reviewed to identify any content that conflicts with the principles of coastal adaptation planning, particularly with regards to providing permanent public access to the beach and foreshore. The City will need to consider the implications of any such conflicts, and actions required to avoid the exposure of additional assets to risk from coastal processes where land remains undeveloped.

It is noted that in accordance with Section 27 of the Deemed Provisions of the Planning and Development (Local Planning Schemes) Regulations 2015, the effect of a structure plan is that, where the WAPC has approved a structure plan for an area, the decision maker is to have due regard to, but is not bound by, the structure plan when deciding the application (emphasis added). Currently approved structure plans have a life of 10 years from the date of approval or until 19 October 2025, whichever is the later, unless they have been revoked earlier. The local government or the landowner is able to request the WAPC to revoke approval of a structure plan under a number of circumstances, including when implementation is complete, or if effective implementation is not possible due to change in legislation or a state planning policy.

***Special Control Areas* (SCA)**. SCA's to ensure discretion over any further development proposed in coastal hazard areas and to identify areas likely to require eventual managed retreat. The SCA should show on LPS2 mapping, as required by the P&D Regulations, Schedule 1, Part 5. It is noted that some forms of development cannot be controlled by a SCA, such as works carried out by the State Government under the *Public Works Act 1902*. The City should liaise with the State regarding such development, to ensure it is not incongruous with the long-term pathway set out for the area.

***Notifications on Title***, to inform current and future landholders of coastal hazard risk, as recommended by SPP2.6.

***Time Limited Planning Consent Conditions***, to allow, where appropriate, the temporary use of land in hazard areas until hazards materialise, while ensuring that the City maintains a level of discretion over development in these areas. Time limits could be set using coastal hazard mapping projections. If the consent expires before hazards materialise, the proponent may apply for an extension to the consent. If hazards materialise before the time limit expires, the City would consider requiring the demolition or removal of compromised structures under relevant legislative provisions. Event-based triggers should be incorporated into time limited planning approvals to ensure management action can be taken prior to the time limit expiring, should this be required. It may also be desirable to allow continued use and development for short time periods (e.g. 10 years), with the requirement to seek further approval at the end of these timeframes.

***Interim Coastal Protection***, where development is proposed behind a protected coastline, the lifecycle of the protection mechanism should determine the time limit permitted on planning consents. Maintenance and capital costs of any protection should be funded by the beneficiaries of the protection. The potential for the protection mechanism to negatively affect other areas or existing values of the coastline should also be assessed, such as accelerated erosion 'downstream' of protection structures, or the loss of beach amenity in front of a seawall. The cost to ameliorate or compensate for any negative impacts attributable to the protection

mechanisms should also be borne by those who benefit from the protection. Protection should only be considered as a last resort where all other options have been considered, as per SPP2.6.

***Assessment Criteria***, to ensure consistency when assessing applications for development proposed in hazard areas, for inclusion into a Local Planning Policy.

***Development applications for subdivision and zoning*** beyond existing scheme allowances, within coastal hazard areas, should not be encouraged or approved.

***Theoretical Instruments*** include 'transferable development rights', 'leaseback of land', 'land swaps' and 'rolling easements'. These instruments remain conceptual in the WA planning context and are not provided for under the State's planning framework at present. These concepts require more research to determine how they would be practically implemented, but may be considered by the City in future.

Ultimately the aim of the CHRMAP is to plan for adaption to the effects of SLR and associated coastal hazards. The simplified strategy shifts that are likely to be required in future, as assets currently situated in the eroding coastal zone become unviable, are outlined in **Figure 2-2**.

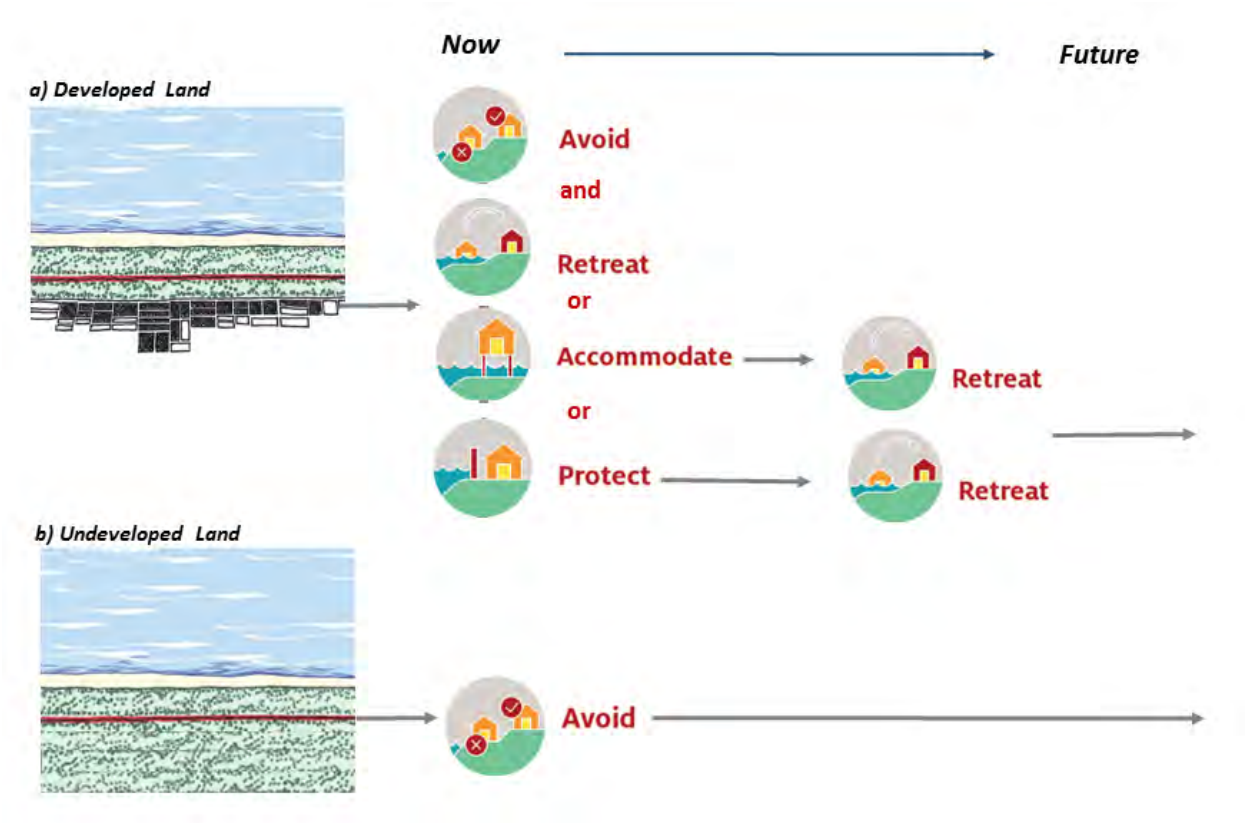


Figure 2-2 Simplified long-term pathways for a) developed land and b) undeveloped land.

## 2.3 Success Criteria

Based on the results of the City's Coastal Values Survey, the following success criteria have been developed to guide the CHRMAP process:

SC1: Conserve natural attributes (e.g. clear water, vegetated dunes and sandy beaches);

SC2: Ensure public safety and access;

SC3: Minimise impacts on existing residential areas;

SC4: Provision and maintenance of public amenities;

SC5: Conserve areas for recreational and passive use;

SC6: Provision of foreshore areas for local economic benefit;

SC7: Provision of access infrastructure (e.g. roads, carparks, paths); and

SC8: Maintenance and preservation of indigenous and cultural heritage sites.

It is noted that legally there is no obligation of the State or Local Governments to either protect public and private assets within the coastal hazard zone, nor to compensate for any losses incurred due to coastal hazards. While SC3 is considered a community aspiration, it must be recognised that assets located in present and future hazardous areas may not be able to attract state or local government funding for protection works.

# 3 Adaptation Planning Process

## 3.1 Adaptation Options

Effective adaptation planning involves the identification and evaluation of options suitable to manage the risk of coastal hazards. In accordance with SPP2.6 and the CHRMAP guidelines (WAPC, 2014a), potential options have been identified under the risk management hierarchy of *Avoid*, *Managed retreat*, *Accommodate* and *Protect*. Protection being the least preferred management option. The range of adaptation and management options were based on WA's CHRMAP guidelines (WAPC, 2014a) and are presented in more detail in **Table 3-1** below.

*Avoid* is seen as the preferred strategy but is generally only applicable to undeveloped coastal land and areas of the coast where intensification of development in hazardous areas might be proposed. This option is underpinned by the implementation of planning controls, which should prevent inappropriate use of land in areas identified as potentially at risk from coastal hazards.


Figure 3-1 Adaptation hierarchy (CoastAdapt, 2017)

*Managed retreat* is a preferred long-term strategy for areas of existing development at risk. This option aims to remove assets from the risk of coastal hazards and is generally the economically responsible approach over the long-term, although it may involve significant expenditure during implementation. Some of the planning mechanisms around implementing *Avoid* and *Managed retreat* options have already been discussed in **Section 2.2**.

*Accommodate* options aim to re-design existing infrastructure to mitigate potential impacts as they occur, and allow for land use of a low risk (for example temporary) nature. This option is rarely applicable to areas, at risk of coastal erosion but is suitable to some areas prone to coastal inundation, where assets can be elevated above flooding to maintain land use in an otherwise hazardous area. The ability for substantial, built assets to be redesigned to accommodate coastal erosion hazards is generally limited.

*Protect* options range from temporary 'soft' protection, such as sand nourishment, to semi-permanent 'hard' protection options, such as groynes and seawalls. It should be noted that no protection option is considered permanent (hence their description as 'interim' protection), and all have associated expense to implement, maintain and remove. This expense and the inability of protection options to permanently mitigate the risks associated with coastal hazards are the primary reasons why these options are considered the least favourable in the preferential planning hierarchy. Hard protection options also have the potential to divert coastal erosion hazards elsewhere, increasing risk for adjacent areas or assets and potentially creating liability for those responsible for the structures.

SPP2.6 Clause (5.5 (iii)) states that the employment of protection options should be sought only where:

> *"sufficient justification can be provided for not avoiding the use or development of land that is at risk from coastal hazards and accommodation measures alone cannot adequately address the risks from coastal hazards, then coastal Protection works may be proposed for areas where there is a need to preserve the foreshore reserve, public access and public safety, property and infrastructure that is not expendable."*

Although protection measures are the least favoured option, particularly as a long-term mitigation measure, they remain the most commonly employed coastal risk mitigation strategy globally. There are several effective

protection techniques that can be employed to manage the risks of coastal erosion in the short- to medium-term (e.g. over 5 to 50 years) as listed in **Table 3-1**.

Table 3-1 Adaptation and management options (adapted from WAPC, 2014a).

| Option Category | Option Name | Option Code | Description |
|---|---|---|---|
| **Avoid** | Avoid development | **AV** | Avoidance of freehold residential or commercial development within the coastal foreshore reserve. |
| **Managed Retreat** | Leave unprotected / repair | **MR1** | Assets are left unprotected and loss is accepted following hazard event. Repairs may be implemented to extend life and for public safety in the short-term. In the case of natural assets, such as beaches and vegetation, allow the impacts of hazards to occur. Drainage infrastructure repaired to ensure operation for future rainfall events. |
| | Remove / relocate | **MR2** | Assets located in the hazard zone are permanently removed or relocated. For residential and commercial property, this option may require voluntary or compulsory acquisition of land. Drainage infrastructure relocated to an area which will not be impacted again within asset life. Drainage to be removed if no other assets are left to service. |
| | Planning controls for managed retreat | **MR3** | Use of planning controls to allow continued use of the current infrastructure until such time that impacts arise, but restrict the development of further infrastructure (densification) as the area/asset is known to be vulnerable. This option also includes mechanisms for ensuring that Local Government, land owners and prospective buyers are made aware of the risk. |
| **Accommodate** | Planning controls to accommodate/identify risk | **AC1** | Indicates to current and future landholders that an asset is at risk from coastal hazards over the planning timeframe. Helps owners to make informed decisions about the level of risk they are/may be willing to accept and that risk management and adaptation is likely to be required at some stage. For areas prone to inundation, planning controls such as minimum finished floor levels (FFL) may be applicable under this category. |
| | Emergency plans and controls | **AC2** | Implement plans for assets/areas that are at risk of coastal erosion. Have procedures in place for before, during and after the events for safety. E.g. signage/barriers to prevent access. |

| | | | |
|---|---|---|---|
| | Redesign to withstand impact | **AC3** | Usually applicable to flood/inundation prone areas (e.g. flood plains) where an area may continue to be inhabited, despite elevated risk, by designing infrastructure to withstand flood events. This option is not generally applicable for coastal erosion hazards. In the context of Rockingham, this option may be applicable to drainage infrastructure, which might require redesign to better accommodate coastal inundation events. Lake Richmond could be redesigned (i.e. weir boards etc.) to limit impact to hydrology, flora and fauna, social criteria and economic benefits. |
| **Protect** | Dune care / sand management | **PR1** | Development of an ongoing program for revegetation and rehabilitation of the dune system.<br><br>Sand fencing to manage wind-blown erosion also falls under this category. |
| | Beach nourishment / sand management | **PR2** | Addition of sand to the beach, dune and/or nearshore area to replace lost material and/or create additional buffer. This option is a temporary measure and can be more effective in association with hard protection options, such as groynes. The sand may be from an external source or from a nearby part of that coastal area (i.e. via sand bypassing or back passing). |
| | Groyne(s) | **PR3** | Construct groynes along the beach to restrict longshore sediment movement and stabilise sections of shoreline. This option is often accompanied by beach nourishment. Hard protection generally diverts erosion issues elsewhere, such as to the down drift side of a groyne, and can have significant impact on coastal ecosystems. |
| | Nearshore reef(s) / breakwater(s) | **PR4** | Construct offshore reef(s)/breakwater(s) or raise existing natural nearshore reef structure to maintain level of protection as sea level rises. Hard protection generally diverts erosion issues elsewhere, such as to beaches either side of the nearshore structures, and can have significant impact on coastal ecosystems. |
| | Seawall(s) | **PR5** | Construct seawall in front of assets or along length of coastline to protect them from coastal hazards. Hard protection generally diverts erosion issues elsewhere, such as to beaches either side of, and directly in front of, a seawall. They can also have significant impact on coastal ecosystems. |
| **Do nothing** | Do nothing | **DN** | Take no action. No limitations on development or implementation of adaptation planning. Accept risk. |

## 3.2 Adaptation Options Assessment Process

Adaptation options were evaluated for each of the defined coastal sectors (also utilising the sub-sectors defined for asset mapping), with multiple options identified as potentially suitable for implementation within each. All options were assessed, for all sectors, through the multi-criteria analysis process. Following this, further detail has been provided and the financial implications have been assessed for priority sectors (see **Section 1.3.1**) and assets or areas likely to require management before 2030.

### 3.2.1 Multi-criteria Analysis

Each of the adaptation options presented in **Table 3-1** has been considered for each of the coastal sectors defined for the CHRMAP. As recommended in the CHRMAP Guidelines (WAPC, 2014a), a multi-criteria analysis has been used as a preliminary step to identify potentially suitable adaptation options for each sector (or sub-sector), as well as to discount unviable options. The analysis uses a broad range of criteria and a simple 'traffic light' rating system to evaluate the acceptability of each option. The assessment considers the effectiveness of options at reducing risk and performing their function in relation to governance, environmental, social and economic aspects. Information gained through the stakeholder and community engagement process has been used to reflect acceptability of options to the community in the assessment. Options have also been assessed in terms of their restriction on future planning and risk management opportunities, with options that allow for a wide range of future strategies generally considered more favourably. The analysis takes into consideration the following criteria:

Preliminary feasibility:

- Effectiveness;
- Governance, legal implications and approval risk; and
- Reversibility / adaptability.

Preliminary acceptability:

- Environmental and social impact; and
- Community acceptability.

Preliminary financial implication:

- Financial gain / avoidance of cost;
- Capital cost; and
- Ongoing cost.

The criteria, and a description to guide the assignment of a rating for each criterion considered, is presented in **Table 3-2**. Ratings have been assigned by taking into account information gathered prior to, and during, the CHRMAP process. This information includes feedback from stakeholder and community consultation, planning considerations (outlined in **Section 2**), previous investigations of the study areas and the outcomes of the coastal hazard assessment and risk assessment process. The analysis has also been guided by coastal engineering, management and planning expertise, and knowledge of other coastal management projects and techniques.

Based on the ratings assigned under each criteria, for a particular adaptation option, a qualitative judgement is then made as to whether that option is recommended, not recommended or requires further investigation. It should be noted that red lights do not necessarily exclude an option, and it still may be recommended that such an option be investigated further. The outcomes of the multi-criteria analysis, for each management unit, are presented and discussed in **Section 4**, below.

Table 3-2 Multi-criteria analysis input ratings and assessment outcome categories.

| | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Outcome |
|---|---|---|---|---|---|---|---|---|---|
| | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Financial Gain / Avoidance of Cost | Capital Cost | Ongoing Cost | Recommendation |
| **Unlikely to be acceptable** | Likely to be ineffective | Not likely to be approved / likely to result in governance or legal risk | Not likely to be reversible. Limits future options once implemented | Likely to have unacceptable negative impacts | Unlikely to meet most success criteria | No financial gain or avoidance of cost | Very expensive | Very expensive | Not recommended |
| **May be acceptable** | May be effective | May not be approved / may present governance or legal risk | Likely to be reversible / adaptable at high costs | Some impacts that could be managed to an acceptable level | Mixed response, may meet some success criteria but not others | Some financial gain / small number of benefactors | Moderately expensive | Moderately expensive | Investigate further / assess against other options |
| **Likely to be acceptable or "No regrets"** | Likely to be effective | Likely to be approved / minimal governance or legal risk | Easily reversible or adaptable for the future. No negative impacts in the future | Not likely to have negative impacts / may have positive impacts | Likely to meet most success criteria | Large financial gain / public benefit | Low cost | Low cost | Recommended |
| **Not Applicable** | | | | | | | | | |

### 3.2.2 Economic Assessment

A high-level economic assessment has been undertaken to assess the costs of potential adaptation options, for comparison with the value of assets at stake and potential cost to remove them. This assessment does not consider the value associated with natural assets, such as direct economic benefit derived due to beach visitation, as well as the significant social and environmental values which are difficult to quantify. Associated economic value for built assets, such as cafes and restaurants, is also not incorporated. A detailed economic analysis, that comprehensively assesses all costs and benefits (direct and indirect) associated with significant changes in coastal areas, should be undertaken before long-term adaptation pathways are selected.

This economic assessment considers asset value and removal cost, to provide an informative comparison with the cost of implementing interim protection options. The estimated value of assets defined for this project were derived from the most current and relevant information. The assessment includes asset value only and does not take into account asset expenditure (maintenance, renewals, replacements, upgrades or land acquisition). The asset value was adjusted to account for inflation at an expected rate of 0.4% per annum, across planning timeframes up to 2070.

#### *3.2.2.1 Unit rates*

The Current Unit Rate ($/m or $/unit) was used to calculate current costs in Net Present Value (NPV) dollars, based on information provided in the Construction Cost Guide (Rawlinsons, 2016) presented in **Table 3-3**.

Table 3-3 Unit Rates

| Asset Type | Unit Rate |
|---|---|
| Boat ramps (#) | $ 50,000.00 |
| Bores (#) | $ 5,000.00 |
| Carparks (m²) | $ 120.00 |
| Clubs (m²) | $ 2,977.50 |
| Commercial (m²) | $ 2,852.20 |
| Factory (m²) | $ 1,252.50 |
| Jetty (/m) | $ 5,600.00 |
| Camps (inc. Alfred Hines Seaside Home) (m²) | $ 501.75 |
| Parks & Recreation (m²) | $ 45 to $ 65 |
| Pipes (m) | $ 198.00 |
| Pits (#) | $ 1,498.00 |
| Residential (m²) | $ 401.87 |
| Restaurants/Cafes (m²) | $ 2,852.50 |
| Road (m²) | $ 275.00 |
| Schools (m²) | $ 2,174.25 |
| Tennis Court (m²) | $ 1,672.50 |
| Underground Storage ($m^2$) | $ 385.00 |

#### *3.2.2.2 Adaption Option Unit Rates*

Costs have been estimated for the construction of coastal protection structures in **Section 4.5**. The unit rates applied for these structures are provided in **Table 3-4**.

Table 3-4 Unit Rates

| Adaption Option | Construction Unit Rate | Maintenance (1% of construction cost / year) |
|---|---|---|
| Groyne (/m) | $ 10,000 | $100 / year |
| Seawall (/m) | $ 5,000 | $50 / year |
| Breakwater (/m) | $ 15,000 | $150 / year |

Protection options can also include additional asset requirements, to ensure assets function during coastal inundation and erosion events. Examples include non-return valves (tidal gate valves), that are installed for stormwater and drainage flood protection, and sand nourishment placed in conjunction with the construction of protection structures (e.g. buried seawalls). These are additional costs to the asset value and, unless specified in **Section 4.5**, have not been considered as part of the costing information. Options such as these should be considered as part of detailed assessment for potential adaptation options.

# 4 Outcomes

The completed MCA tables are provided in **Appendix A**. These should be read alongside coastal hazard mapping provided as part of the **Coastal Hazard Risk Modelling Chapter Report** and asset mapping provided as part of the **Coastal Hazard Risk Assessment Chapter Report**. Asset mapping required further division of the City's coastal Sectors. These sub-sectors (listed in **Table 4-1**) have also been used for the MCA and in further assessing certain adaptation options (*Protection* and *Managed Retreat* options).

Table 4-1 Defined coastal sectors and their extents

| Coastal Sector | Extents |
|---|---|
| 1 | Municipal Boundary (North) to Wanliss Street |
| 2A | Wanliss Street to Garden Island Causeway |
| 2B | Garden Island Causeway to Boundary Road |
| 3A | Boundary Road to Bent Street |
| 3B | Bent Street to Shelton Street |
| 4A | Shelton Street to Bayeux Avenue |
| 4B | Bayeux Avenue to Becher Point |
| 5A | Becher Point to Secret Harbour Foreshore Park |
| 5B | Secret Harbour Foreshore Park to Turtles Bend |
| 6A | Turtles Bend to Crystaluna Drive |
| 6B | Crystaluna Drive to Municipal Boundary (South) |

## 4.1 Avoid Option

The default recommendation is that the *avoid* option be applied to all presently undeveloped land lying within areas that will potentially be exposed to coastal hazards over the next 100 years. These areas should be defined by coastal erosion and inundation hazard extents at the 2110 planning timeframe. This is considered a default position because long-term management pathways for coastal hazard areas have not yet been defined.

Once long-term pathways have been defined, and responsibilities and funding arrangements for these pathways put in place, it may be acceptable for the City to permit certain types of development in these areas. For example, if an interim protect strategy (under the beneficiary pays principle) is to be in place for a section of coast, funding for this strategy could be aided by allowing additional, time-limited, development on its landward side. Developers and affected landholders would need to be fully cognisant of their responsibilities in contributing to funding the protection and the requirement for eventual managed retreat from the area, once a specified trigger is reached or protection is no longer feasible.

The City should thoroughly investigate and refine long-term pathways to guide the control of development in coastal hazard zones, ensuring responsible management and avoidance of liability. Recommendations for application of the *Avoid* option, and components to its application, are detailed in the following paragraphs.

Coastal Foreshore Reservation: The coastal foreshore provides for storm erosion, beach access, recreation and conservation, tourist attraction and habitat for native flora and fauna. Importantly, it also provides a buffer to mitigate risks to high value built assets such as buildings and infrastructure.

The foreshore reserve should include allowance for physical processes and be established from the current coastline (as defined by the active limit of the shoreline or present day horizontal shoreline datum (HSD)). It should be based on the 2110 coastal erosion hazard line, determined in accordance with SPP2.6. In addition to the allowance for physical processes such as coastal erosion, the foreshore reserve must include land allocation for maintaining the values, functions and equitable use of the coast over a 100 year planning horizon (WAPC, 2013b) (**Figure 4-1**). It should be noted that the 2110 coastal erosion hazard line DOES NOT define the extent of the coastal foreshore reserve. This line defines the potential extent of coastal erosion hazards

over the 100 year planning timeframe. The foreshore reserve boundary should always be landward of the 2110 hazard line.

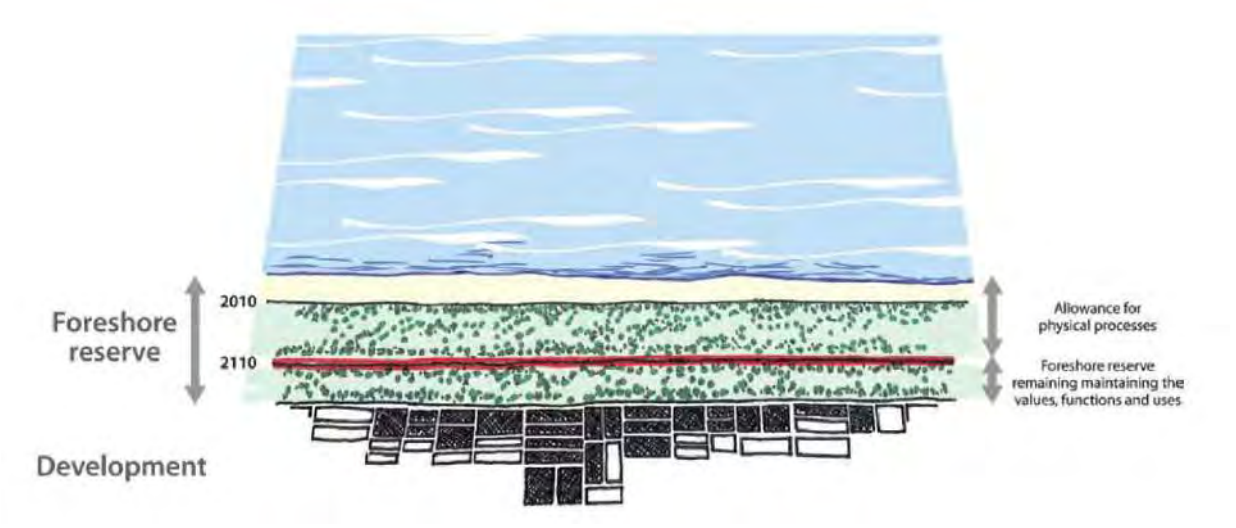


Figure 4-2 Coastal foreshore reserve – sandy coast example (WAPC, 2013b).

Permanent and easy public access to the beach and foreshore reserve is a fundamental coastal planning objective. The coast and coastal recreation reserves are a public asset which should not, now or in the future, become the de facto exclusive domain of private landowners by virtue of the erosion of coastal reserves or due to other coastal processes. Coastal reserves should be wide enough that they can still perform recreation and/or conservation functions (according to the reasons for their initial designation) even if they are affected by coastal erosion or diminution due to SLR. Coastal reserves also need to consider aspects such as the preservation of significant natural features, heritage and landscape values.

In general, permanent development should only be considered landward of the foreshore reserve boundary, however section 7 of Schedule 1 of SPP2.6 provides a number of variations to this, such as public recreation facilities with a finite lifespan and temporary and relocatable developments that are dependent on a coastal location (for example surf lifesaving clubs, tourism related facilities and businesses).

For undeveloped land lying seaward of the 2110 coastal erosion hazard line, plus an additional allowance for coastal foreshore reserve: The 2110 coastal erosion hazard line should be used as the basis for defining a coastal foreshore reserve, in which no major residential or commercial development should take place without further investigation and planning for the economic, social and environmental impacts of proposed development. This recommendation is also consistent with Section 5.2(i) of SPP2.6, which encourages urban development around existing settlements and discourages continuous linear urban development along the coast. It must be reiterated that the 2110 hazard line does not define the extent of the coastal foreshore reserve.

Any proposal for development adjacent to the 2110 coastal erosion hazard line should undertake the necessary investigations to develop a coastal foreshore reserve, between the hazard line and the development, to ensure the function of the coastal foreshore is maintained should the potential coastal hazards be realised over the appropriate planning timeframe (i.e. given the lifespan of the development).

Presently, much of the undeveloped land lying seaward of the 2110 hazard line is contained within the Parks & Recreation Zone under the Metropolitan Region Scheme Reserves. Where possible, it is recommended that this zone be expanded, or added to at a local scale, to contain all undeveloped land lying seaward of the 2110 hazard line. Zones allocated for development landward of and adjacent to the 2110 hazard line should have planning controls to ensure an appropriate coastal foreshore reserve is incorporated (determined on a case by case basis) and foreshore management planning is implemented.

For already developed land lying seaward of the 2110 hazard line for coastal erosion: Any zoning or rezoning of land already lying seaward of the 2110 hazard line needs to be carefully considered due to the potential to trigger a claim for injurious affection. In these instances a Special Control Area should be applied, as described

in **Section 2.2.1**. The *State Coastal Planning Policy Guidelines* (Section 5) provide that infill development can be considered where the parcel of land lies in between existing development and does not extend seaward past the line of existing development. In considering development proposals for such land or subdivision of land seaward of the 2110 hazard line, the City should consider the adaptation and management pathway to be adopted for the area. If the recommended pathway is one of *Managed Retreat*, this land should be controlled to prevent further development or subdivision. If a *Protect* approach has been adopted, and appropriately planned and allowed for, the City may allow such land to be developed or subdivided under the provision that the responsibility for management of the coastal hazard risk is shared with the developer. This responsibility could be shared by way of a Specified Area Rate, which collects additional funds to contribute to the cost of coastal management in the area.

Coastal roads: SPP2.6 states that generally coastal roads should not be developed within the coastal foreshore reserve. Therefore, alignment of any new roads should be landward of the 2110 hazard line and also make an appropriate allowance for a coastal foreshore reserve, determined on a case by case basis. Design of new subdivisions should be robust enough to allow for alternative routes to be taken in the event that a key access route is impacted by coastal processes.

Coastal car parks: SPP2.6 states that coastal carparks should be located landwards of the likely impacts of coastal processes. The design life of the carpark and most up to date coastal hazard line (relevant to that timeframe) should be considered in planning such facilities, along with the availability of suitable land to relocate them in the future, if necessary.

Commercial and Tourist Related Infrastructure: Zoning need not necessarily preclude the development of commercial and tourist related infrastructure within the coastal foreshore reserve. It should however, require that development plans for such infrastructure properly allow for the risks of coastal hazards (as determined in the CHRMAP) over the full lifespan of the proposed development. This should also include an appropriate assessment of social, economic and environmental impacts of the proposed development, and allocation of financial responsibilities, prior to approval.

Public recreation facilities: SPP2.6 is not intended to prevent the development of public recreation facilities such as minor carparks, amenities, pedestrian access, recreational equipment and infrastructure for public safety. Zoning does not need to be adjusted to exclude the development of such infrastructure, however, their full lifespan (generally less than 30 years) should be considered with respect to the appropriate hazard extents.

Temporary development: In some instances, it may be deemed acceptable for development of a temporary nature to be permitted. The City should be indemnified against any future damage to assets in such cases, and a trigger for the removal of the assets should be identified and included as a condition of any approval (with possible memorial on the title to make this known to landowners for as long as necessary).

Scheme provisions and/or a local planning policy relating to temporary private assets should be considered.

Land Records System: It is recommended that the City introduce an easily recognisable alert into its land records system. This will ensure that staff accessing information on any affected land (including road reserves and other Council controlled land within the City), for any reason, can be made aware of the presence of the coastal hazard or any other factor requiring special attention or liaison with another part of the organisation or external agency. This will reduce the risk of works being undertaken by the City that are contrary to any adopted strategy for the land under consideration.

Information on relevant coastal hazards and the implications for property, now and into the future, should also be made available to potential buyers upon making a land purchase enquiry.

Inundation hazards: SPP2.6 the *State Coastal Planning Policy Guidelines* provide prescriptive details for avoiding the threat of coastal erosion hazards, but controlling development to avoid the threat of coastal inundation (S4 allowance) is less defined. This is primarily due to the permanent nature of coastal erosion in affecting the land, compared to the temporary effects of inundation. Potential extents of coastal inundation within the City are considerably greater than those for erosion and must be properly considered. Initially, the City should avoid additional development in areas subject to potential coastal inundation hazards, using similar controls to those proposed for erosion hazard zones (e.g. Special Control Area). Once the City has properly established long-term pathways, it may be acceptable to allow development to continue in some inundation hazard areas, provided constraints are in place to accommodate the risk of coastal inundation. These are discussed further in **Section 4.3** below.

### 4.1.2 Equity Implications for the Avoid Option

The *Avoid* option is generally considered the most equitable, hence its prioritisation on the State's adaptation planning hierarchy. It supports intergenerational equity, by preventing unnecessary costs from being passed to future generations. It also ensures that beach and coastal foreshore access and amenity is provided to the whole community, now and in the future.

The option could be seen to benefit those who already own property in coastal areas (particularly coastal hazard areas) by lowering the supply of such property (e.g. property with coastal views) and therefore increasing its value. This notion should be considered against the potential for these existing landholders to lose their property, or pay a premium for ongoing coastal protection. Similarly, future generations will have less access to premium coastal property due to a lack of supply, and could be seen to lose out in this regard.

Developers and the City may lose out from implementing this option, if coastal land previously earmarked or purchased for development is no longer developable.

## 4.2 Managed Retreat Options

*Managed retreat* is the preferred adaptation pathway for already developed areas under the State's Coastal Planning Policy. Removing assets from hazardous areas eliminates the need to fund expensive ongoing protection, making it the economically responsible approach over the long term. The recently released *Draft Planned or Managed Retreat Guidelines* (DoPLH, 2017c) recommend actions to be undertaken to enact a managed retreat policy, which includes mechanisms to compensate landholders for the acquisition of private property when risk is no longer tolerable. While there is no obligation at any level of Government to compensate landholders for the impacts of coastal hazards and SLR, there is a responsibility to act in the best interests of the community. As such, cost estimates for managed retreat include the value of the affected assets, to account for replacement cost or compensation for acquisition.

Managed retreat can occur by leaving assets unprotected and repairing or removing them when they are impacted (MR1). This is generally recommended for low-value, public assets that can be quickly removed and will not pose a risk to the community if they are damaged. This also avoids potential expense in removing the assets before it is necessary.

Removing or relocating assets before they are impacted (MR2) is the recommended approach for larger assets and infrastructure, including commercial/private property and roads. It is not considered appropriate to allow such infrastructure to be damaged by coastal hazards, as this would cause considerable risk and concern to the community and probably increase the removal cost. To assist the pre-emptive removal of vulnerable assets, it is recommended that planning controls be put in place to facilitate the management pathway (MR3). Key to this is the application of an SCA over vulnerable areas, to control development and identify that retreat from the area is likely to occur at some point in the future. Details around the SCA and other planning controls were outlined in **Section 2.2.1**.

The potential cost of fully adopting the managed retreat option has been estimated based on asset value and removal cost. The assets to be removed have been identified with respect to coastal erosion hazard lines (not inundation extents) up to the 2070 planning timeframe, within each sector. As the hazard lines may be considered conservative (based on current available data), these costs may be inflated above what will realistically be required. The costs are, however, comparable with costings for other adaptation options, which have also been based on hazard line extents. There are several other cost implications that could be associated with managed retreat, and these should be identified through a detailed analysis of the option. It must also be noted that there is considerable uncertainty around the estimated costs, particularly in progressing to future planning timeframes. The upfront cost of implementing managed retreat will be significant and sufficient funding, from any level of government, is highly unlikely to be available in the short term. While managed retreat from vulnerable areas should be the eventual aim throughout the City, realistically, some interim protection will be required while funding for retreat is arranged.

As the average shoreline position is expected to gradually retreat, with intermittent erosion and accretion due to seasonal and storm-based impacts, managed retreat would also take place in a staged approach. The staging of managed retreat would be trigger based, with several key triggers outlined in the *Draft Planned or Managed Retreat Guidelines* (DoPLH, 2017c). These and other appropriate triggers for implementing managed retreat (and other adaptation options) for the City will be discussed in detail in the implementation

plan for this CHRMAP. Where appropriate, the City should look to adopt a managed retreat approach for public assets and minor infrastructure to demonstrate responsible management of the risks associated with coastal hazards.

Managed retreat of assets at the foreshore should avoid coastal erosion impacts and allow the shoreline to recede naturally, maintaining beach amenity and a suitable coastal foreshore reserve. This option does not directly mitigate the risk of coastal inundation, which is projected to become more extensive in the future. Managed retreat would, however, provide space to protect against coastal inundation through the enhancement or reinforcement of natural dune barriers.

### 4.2.1 Sector 2A: Wanliss Street to Garden Island Causeway

Adopting a managed retreat approach in this sector would require the removal of substantial public infrastructure, such as roads and carparks, as well as multiple commercial and residential properties. Potential cost implications are estimated in **Table 4-2** below.

Table 4-2 Sector 2A Managed Retreat Asset Value

| | 2017 | 2030 | 2070 |
|---|---|---|---|
| Asset Value | $4,394,000.00 | $10,659,000.00 | $58,249,000.00 |
| Removal Cost | $571,000.00 | $2,384,000.00 | $3,131,000.00 |
| **Total** | **$4,965,000.00** | **$13,043,000.00** | **$61,380,000.00** |

### 4.2.2 Sector 2B: Garden Island Causeway to Boundary Road

Adopting a managed retreat approach in this sector would require the removal of some public infrastructure, such as roads and carparks, the Point Peron Wastewater Treatment Plant and holiday/recreation camp accommodation buildings. Potential cost implications are estimated in **Table 4-3** below.

Table 4-3 Sector 2B Managed Retreat Asset Value

| | 2017 | 2030 | 2070 |
|---|---|---|---|
| Asset Value | $6,775,000.00 | $14,588,000.00 | $60,883,000.00 |
| Removal Cost | $2,900,000.00 | $10,227,000.00 | $4,736,000.00 |
| **Total** | **$9,675,000.00** | **$24,815,000.00** | **$65,619,000.00** |

### 4.2.3 Sector 3A Boundary Road to Bent Street

Adopting a managed retreat approach in this sector would require the removal of substantial public infrastructure, such as roads and carparks, as well as multiple residential and commercial properties. Potential cost implications are estimated in **Table 4-4** below.

Table 4-4 Sector 3A Managed Retreat Asset Value

| | 2017 | 2030 | 2070 |
|---|---|---|---|
| Asset Value | $1,610,000.00 | $3,117,000.00 | $53,721,000.00 |
| Removal Cost | $103,000.00 | $293,000.00 | $7,222,000.00 |
| **Total** | **$1,713,000.00** | **$3,410,000.00** | **$60,943,000.00** |

### 4.2.4 Sector 3B: Bent Street to Shelton Street

Adopting a managed retreat approach in this sector would require the removal of public infrastructure, such as roads and carparks, as well as residential and commercial properties. Potential cost implications are estimated in **Table 4-5** below.

Table 4-5 Sector 3B Managed Retreat Asset Value

| | 2017 | 2030 | 2070 |
|---|---|---|---|
| Asset Value | $780,000.00 | $1,969,000.00 | $8,355,000.00 |
| Removal Cost | $138,000.00 | $317,000.00 | $852,000.00 |
| **Total** | **$918,000.00** | **$2,286,000.00** | **$9,207,000.00** |

#### 4.2.5 Sector 4B: Bayeux Avenue to Becher Point

Adopting a managed retreat approach in this sector would require the removal of the Port Kennedy Foreshore Carpark, and eventual removal of some residential properties. Potential cost implications are estimated in **Table 4-6** below.

Table 4-6 Sector 4B Managed Retreat Asset Value

| | 2017 | 2030 | 2070 |
|---|---|---|---|
| Asset Value | $545,000.00 | $679,000.00 | $3,250,000.00 |
| Removal Cost | $76,000.00 | $88,000.00 | $621,000.00 |
| **Total** | **$621,000.00** | **$767,000.00** | **$3,871,000.00** |

#### 4.2.1 Equity Implications for Managed Retreat

The *managed retreat* option leads to considerable equity implications. The option is considered fair to the broader community, whose ability to access and use the beach and foreshore is maintained. Those owning residential properties that will be removed will be seen to lose out through the strategy, significantly so if mechanisms for adequate compensation are not put in place.

From an intergenerational equity perspective, the significant short-term costs associated with the option in many areas could be seen to disadvantage current and future generations. These generations would effectively be paying to rectify land mismanagement and inappropriate development, attributable to previous generations. The question of who should be responsible for funding a *managed retreat* approach, at all levels of government, is unresolved.

### 4.3 Accommodate Options

#### 4.3.1 Planning Controls to Identify/Accommodate Risk (AC1)

##### *4.3.1.1 Notification on Title*

Section 5.5(ii) of SPP2.6 specifies that where a coastal hazard is identified it should be disclosed to those likely to be affected. Any approval for subdivision and/or development should include a condition that current and future lot owners be made aware of the coastal hazard risk by providing the following notification on the certificate of title: *VULNERABLE COASTAL AREA – This lot is located in an area likely to be subject to coastal erosion and/or inundation over the next 100 years.*

There exists significant uncertainty in modelling the impacts of coastal hazards up to 100 years into the future. SPP2.6 also requires the modelling of extreme (and therefore unlikely) storm events – 1 in 100-year for coastal erosion and 1 in 500-year for inundation. Given these factors, it is recommended that the City carefully consider the use of the word 'likely' in applying notification to certificates of title. A more appropriate notification may read as follows: *VULNERABLE COASTAL AREA – This lot is located in an area that may be subject to coastal erosion and/or inundation over the next 100 years.*

It is recommended that some form of notification be required in approving subdivision and development applications for all land within the extents of the 2110 coastal erosion and inundation mapping, developed as part of this CHRMAP.

Informing potential purchasers of land within potential hazard areas is important to allow people to make informed decisions about land they may look to purchase and develop. One mechanism for doing this is by

incorporating the requirement that any planning approval issued for development within the areas include a condition requiring that the notification be placed on the title. Such a notification would take the form of a notification under section 70A of the Transfer of Land Act 1893. A Section 70A Notice, as it is commonly known, advises prospective purchasers of a potential hazard or factor that might impact the enjoyment of the property.

Typically, it is only acceptable to place such a notice on a certificate of title if the factor is relatively permanent and would not be evident at all, or would not necessarily be obvious on inspection of the land. Potential erosion or inundation are such factors. The notification could also include the possibility that there may be limitations on the nature of development that may be permitted on the land (as controlled by a SCA). It would not be appropriate to detail those limitations, which might change over time.

Notification on Title outside of Subdivision/Development Approvals: Except when the notification is required as a condition of development or subdivision approval, the landowner's acceptance is required before application to place a notice on a title can be lodged with the Registrar of Titles. Therefore, whilst it is possible to apply to have a Section 70A Notice placed on the title in other circumstances, it can only be with the agreement of the owner. Also, a fee is payable which might make the task cost prohibitive depending on the number of titles involved. Nevertheless, the apparent impractical nature of the process requires further consideration and possibly negotiation with the State Government to, for example, remove the associated fees, in the public interest or redraft the policy to facilitate the intent of this clause.

The sudden placement of notifications on Certificates of Title is likely to raise concerns for affected landholders and prospective developers, and influence decisions to purchase and develop. Community consultation should include a focus on educating the community about the requirement for notifications and gauge the community's response to this mechanism. The City should also seek independent legal advice prior to selecting notification wording and setting up a process for applying notifications to title.

#### *4.3.1.2 Minimum Finished Floor Levels*

Inundation risks can be accommodated in areas prone to inundation (but not coastal erosion) by elevating ground and finished floor levels (FFL) of buildings to a level above potential flood levels. Should the City wish to allow development to occur or continue in areas identified as potentially vulnerable to coastal inundation, they should control the nature of such development by specifying minimum FFL's for buildings and/or ground levels for developments. This control could be maintained through the application of an SCA over the affected land. Only coastal inundation is considered as part of this study. Prior to defining FFLs, it is strongly recommended that the City consider joint probabilities of coastal inundation with rainfall events.

### 4.3.2 Emergency Plans and Controls (AC2)

A key aim of the CHRMAP process is to prepare for unprecedented changes to the coastal zone. Alongside these changes, coastal areas are likely to be impacted by coastal hazards to greater extents than has been experienced in the past. There is likely to be a current lack of preparedness for such impacts and it is recommended that the City update, or put in place, plans and controls in light of the results of the coastal hazard assessment.

It is recommended that emergency plans and controls ensure that action is taken quickly when infrastructure is threatened or damaged by coastal erosion and/or inundation events. They are also critical to ensure public safety is preserved in the event of an extreme event. This option is particularly pertinent if protect options are not in place and/or a managed retreat approach has been selected.

Preparing emergency plans and controls before the infrastructure is impacted will ensure there is a clear plan of action, which can be implemented by the City in the event of a hazardous coastal erosion event. This plan may include, for example, closing the affected public infrastructure and areas and/or otherwise restricting access, putting up signage informing the public of potential hazards and recommended alternative usage areas, and informing any other relevant authorities of implemented changes and restrictions. Responsibilities for repairing or removing damaged infrastructure, including City staff and other relevant authorities (Main Roads, service providers etc.), should be incorporated into the plans.

### 4.3.3 Redesign to Withstand Impact (AC3)

The option to redesign existing infrastructure to withstand the impacts of coastal hazards is not generally considered applicable for coastal erosion, due to its ability to undermine structures. It is, however, a valid management option to accommodate the risk of inundation and is already employed for this purpose throughout Australia (e.g. houses raised on stumps or stilts). Redesigning existing infrastructure as a proactive measure would likely be very expensive and probably unnecessary. However, the building, repair or replacement of all infrastructure in areas that may be subject to coastal inundation should consider the potential hazard, and be designed appropriately (considering the design life of the infrastructure). This could involve elevating the level of roads and paths as they are replaced or refurbished, raising the ground and floor levels of buildings when replaced and generally ensuring replacement or new infrastructure is resistant to the effects of inundation.

#### *4.3.3.1 Lake Richmond*

Lake Richmond plays an important role in the City's drainage system and is recognised as a natural asset with significant environmental value. The water in the lake is currently fresh, and salt water intrusion associated with predicted SLR is likely to pose a threat to its flora and fauna. SLR poses a major threat to the lake, as it could create a permanent increase in the water body's salt load. The lake's hydrology could be artificially altered (redesigned), for example by installing weir boards, to account for changes associated with SLR.

The susceptibility of the lake to coastal inundation should be further investigated in the future, with the likelihood of it being inundated by coastal storm surge at present seen as very low. Inundation levels, while higher than SLR, only occur periodically and for limited durations. Should coastal inundation occur, it may be feasible to 'flush' the lake with fresh stormwater to prevent increases in salinity levels. An assessment including mass balance modelling will need to be undertaken to determine the amount of additional salt load the lake can withstand without impacting the lakes ecosystem. These investigations could be used to set trigger levels and appropriate mitigation measures, as required.

### 4.3.4 Equity Implications for Accommodate Options

Undertaking an *Accommodate* approach in areas where this is feasible could be considered inequitable from an intergenerational perspective. Funding the *accommodation* of coastal hazards, rather than *avoiding* or *retreating* from the hazards in these areas, could be seen as passing the problem on to future generations, given that these hazards are predicted to increase indefinitely. The approach may, however, assist in distributing the substantial 'up front' cost of options such as managed retreat over a longer time period.

## 4.4 Soft Protection Options

Soft protection options do not involve the use of hard infrastructure and provide only temporary or minor protection. Large scale beach renourishment, for example, can provide additional protection for 18 months to 5 years, before the shoreline recedes to its original position. The options can be used as interim measures or on an ongoing basis, but should not be viewed as permanent solutions to deal with rising MSL.

### 4.4.1 Dune Care / Sand Management (PR1)

Sand dunes are naturally formed and maintained by wind-blown sand transport and provide for complex ecosystems, located at the boundary between the marine and terrestrial environment. They are critical for shoreline stabilisation and protection through two primary mechanisms: 1.) providing a natural barrier against wave impact and storm surge inundation, and 2.) providing an erodible sand supply for the beaches fronting them. Dunes have been diminished in many areas throughout the State, due to receding shorelines and development directly inland.

The methods available for dune management and rehabilitation include the following:

- Dune revegetation and vegetation enhancement;
- Sand/wind fencing; and
- Beach entry/access management.

Dune vegetation and revegetation is frequently undertaken along the Perth Metropolitan coastline through dune care programs, usually undertaken by volunteer groups (primarily working under Coastcare). It should

be noted that dune vegetation itself provides minimal protection against coastal erosion, due to the shallow rooted nature of coastal flora. It does however help to capture and retain wind-blown sand, stabilising the dune and helping to maintain it as a natural barrier. Maintenance and installation of coastal dune vegetation is generally recommended, under the assumption that government funding and volunteer input can assist its implementation. If dune vegetation is to be fully funded by the City, it should carefully consider the allocation of resources to the protection method.

Sand fencing is commonly employed to retain wind-blown sand in certain areas of a beach and also to prevent sand from being deposited where it is not wanted, such as on coastal carparks, parks, paths and roads. A careful assessment of wind-blown transport along the City's beaches could be undertaken to determine the suitability and subsequent optimal placement of sand fencing. Sand fencing is relatively inexpensive to install and maintain (although frequent maintenance can be required) and can be highly effective in lowering wind driven erosion. Such fencing could also double as access prevention.

High beach use can rapidly degrade coastal dune vegetation and diminish sand dunes. The provision of designated beach access ways is already in place throughout the City. As discussed above, dunes are critical natural barriers against coastal impact and are under increasing pressure. Protecting the majority of the dune systems with fencing, barriers and signage should be continued and improved wherever possible within the City.

### 4.4.2 Beach Nourishment (PR2)

Beach nourishment (or renourishment) involves the placement of sand on the upper beach profile to increase the sand buffer in front of the dunes and any assets or infrastructure behind. Sand for beach nourishment can be sourced from nearby areas of the coast (such as removing sand from the sand trap at the Point Peron Boating Facility or from the dredging of shipping channels) or it can be imported from outside the coastal system such as from a sand quarry or inland dunes.

Once beach nourishment sand has been placed on the beach, it will be naturally redistributed by coastal processes until the beach has reached an equilibrium profile. Subsequent storm events and calm periods will result in the natural cycle of storm bite and recovery, but the nourished beach buffer can generally be expected to reduce over time and is likely to require eventual renourishment.

Beach renourishment is considered a 'soft' *protection* option and does not guarantee protection of the dunes or assets/infrastructure located landward. During severe storm events or if multiple storm events occur in close succession, the renourished volume can be quickly eroded. For this reason, it is important to monitor areas where beach nourishment has been applied to protect sensitive or important assets.

As beach nourishment generally enhances the natural beach, it maintains or improves beach amenity which usually results in strong support from stakeholders and the community who value this. However, beach nourishment can become prohibitively expensive if very large volumes of sand are required or if it is required repetitively over a long period of time. The fact that nourishment sand is naturally redistributed by coastal processes and is eroded during storm events can lead to a perception among stakeholders and the community that beach nourishment is ineffective and a waste of money. It can also disrupt beach users and annoy the community if its application is required frequently.

Figure 4-3 Beach renourishment occurring to advance the shoreline at C Y O'Connor Beach, North Coogee

An estimated volume and cost (assuming cost of $25/m$^3$) of nourishment sand that would be required to maintain the present shoreline position, in front of assets highly and very highly vulnerable by 2030, has been determined. The nourishment of these areas to 2030 and 2070 has been considered. The costs are in present day dollars and do not factor in inflation or any cost escalation. The costs of sourcing sand, transporting it and placing it as well as the locations which will require sand nourishment will change from year to year. The nourishment volumes are based on beach profiles and shoreline recession rates calculated as part of the coastal hazard assessment for this project. As the hazard lines may be considered conservative (based on current available data), these volumes and costs may be inflated above what will realistically be required. The costs are, however, comparable with costings for other adaptation options, which have also been based on hazard line extents. Estimates for nourishment in priority sectors are provided in **Tables 4-7** to **4-10**, respectively. Sand is a valuable commodity and sourcing high quality material which meets the technical specification in the required quantity is a potential challenge over the long term. The large volumes (and thus cost) of sand nourishment required to protect a large area over the medium-long term are a significant constraint to the adoption of this *protection* option over a significant period of time.

Table 4-7 Indicative nourishment volumes and costs for renourishment concept option for Sector 2A

| Planning Timeframe | Estimated Nourishment Volume (m$^3$) | Estimated Cost |
|---|---|---|
| 2030 | 74,000 | $1.9 m |
| 2070 | 503,000 | $12.6 m |

Table 4-8 Indicative nourishment volumes and costs for renourishment concept option for Sector 3A

| Planning Timeframe | Estimated Nourishment Volume (m$^3$) | Estimated Cost |
|---|---|---|
| 2030 | 125,000 | $3.1 m |
| 2070 | 756,000 | $18.9 m |

Table 4-9 Indicative nourishment volumes and costs for renourishment concept option for Sector 3B

| Planning Timeframe | Estimated Nourishment Volume ($m^3$) | Estimated Cost |
|---|---|---|
| 2030 | 128,000 | $3.2 m |
| 2070 | 868,000 | $21.7 m |

Table 4-10 Indicative nourishment volumes and costs for renourishment concept option for Sector 4B

| Planning Timeframe | Estimated Nourishment Volume ($m^3$) | Estimated Cost |
|---|---|---|
| 2030 | 50,000 | $1.3 m |
| 2070 | 315,000 | $7.9 m |

### 4.4.3 Equity Implications for Soft Protection Options

The results of 'soft' *protection* options are generally seen as equitable, as they maintain or enhance beach amenity, while also providing temporary (and in some cases minor) protection to landward assets. The temporary nature of the options means that significant funds can be exhausted by their application. This has implications for equity (predominantly with beach nourishment), where significant funds are being directed to the protection approach, and diverted away from benefiting other areas of the City's community, for no long-term benefit. Landholders located in current or future hazard areas are direct benefactors of any protection approach, and should contribute to funding such measures accordingly.

Funding ongoing *protection* options, rather than *avoiding* or *retreating* from the hazards in these areas, could be seen as passing the problem on to future generations, given that these hazards are predicted to increase indefinitely. The approach may, however, assist in distributing the substantial 'up front' cost of options such as *managed retreat* over a longer time period.

## 4.5 Hard Protection Options

Hard protection options work to control and/or reconfigure the shoreline by placing significant hard infrastructure on the beach or in the nearshore zone. The options are considered to be interim protection measures as they will eventually require removal, replacement or refurbishment. Hard rock structures (granite or limestone) generally have a maximum design life of 50 years, which may be shortened depending on the extent of SLR in the area. Using hard protection to control long stretches of shoreline will be expensive and the cost to maintain the protection will become increasingly expensive with rising MSL into the future. As such, the options should be carefully considered for interim use, with the intent to eventually manage the retreat of protected assets and avoid the need to control the shoreline over the long term.

The implementation of hard protection options has only been conceptualised and costed where their implementation may be required prior to 2030 (i.e. for assets/areas with high or very high vulnerability by 2030). The costings have assumed options will be designed to provide protection until 2070, to allow for cost comparisons with other options to this timeframe. Costing for hard protection to be implemented after 2030 is considered unnecessary at this stage. The level of hard protection has been based on recession rates associated with calculated hazard lines. As the hazard lines may be considered conservative (based on current available data), these costs may be inflated above what will realistically be required. The costs are, however, comparable with costings for other adaptation options, which have also been based on hazard line extents.

### 4.5.1 Overview of Structures

#### *4.5.1.1 Groynes (PR3)*

Groynes are structures that extend from the rear of the beach and into the surf zone. They work by blocking the sediment that moves along the beach. This results in an increased beach width on the updrift side of the groyne with a similar amount of erosion on the downdrift side.

To counteract the downdrift erosion, multiple groynes (known as a groyne field) are often used. In a groyne field the sand between the groynes is stabilised, and the field is terminated in an area that either has a hard bottom or is allowed to erode. Beach nourishment is also typically undertaken at the time of construction to "fill" the beaches between the groynes.

An example of a groyne is shown below in **Figure 4-4**. This figure shows an aerial view of the Hymus Street timber groyne. In this area the sediment moves towards the west resulting in an increased beach width on the eastern side of the groyne.

The effectiveness of groynes are dependent on a number of factors including the natural sediment movement, foreshore bathymetry and the geometry of the structure.

Depending on the local conditions, groynes can be constructed out of concrete, rock, timber or sand-filled geotextile containers (GSCs). For the majority of the Rockingham coastline, the nearshore wave climate is relatively mild, lending itself to either rock or geotextile groynes.

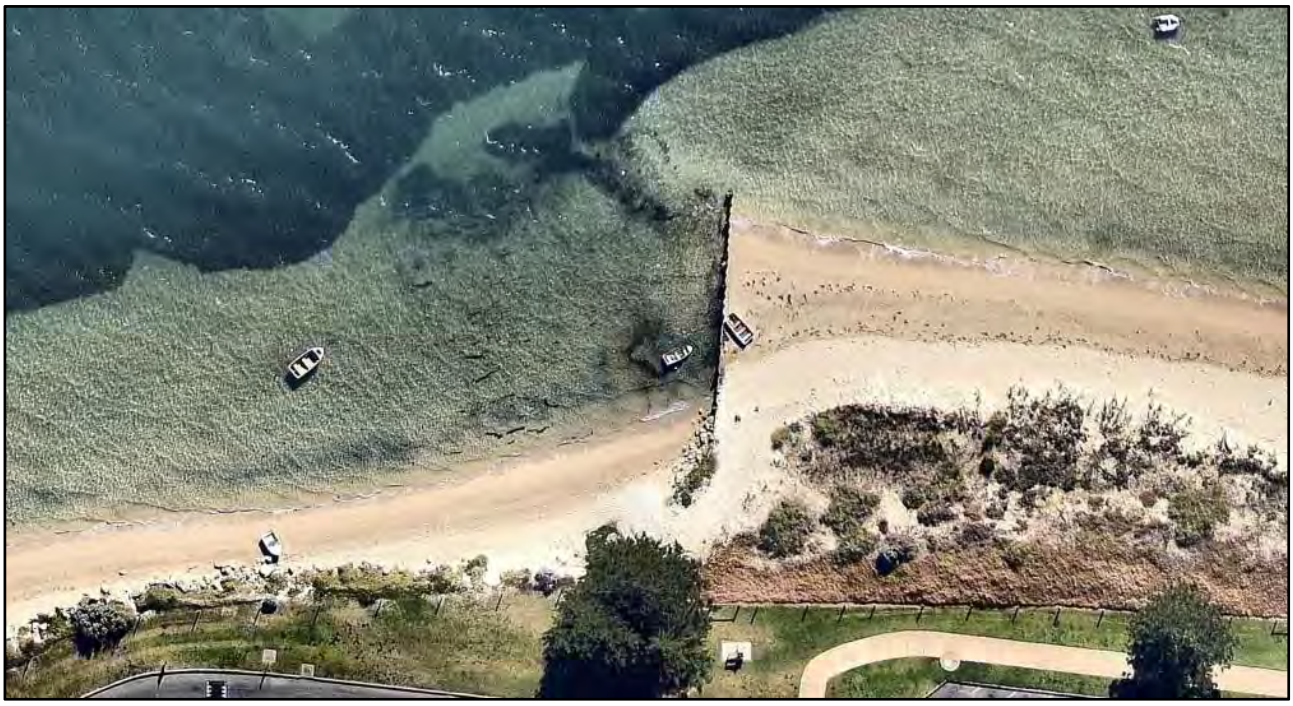

Figure 4-4 Hymus Street timber groyne. (source: Nearmap, 2018)

#### *4.5.1.2 Nearshore Reefs/Breakwaters (PR4)*

Nearshore reefs or breakwaters are structures built offshore of the shoreline to disrupt and dissipate the incoming waves. Waves diffract behind the structure, which results in local realignments of the shoreline and altering the longshore sediment transport rates and directions.

The result of the breakwaters or reefs is the formation of either a tombolo (which is where the shoreline reorients and connects to the breakwater) or a salient (which is similar, but does not connect to the breakwater).

**Figure 4-5** shows an example of offshore breakwaters in Rockingham. In this instance tombolo's have formed, connecting the breakwaters to the shore. Wave diffraction behind the breakwaters can also be seen.

Similar to groynes, breakwaters could be constructed out of concrete, rock or sand filled geotextile bags, depending on the local conditions. In the Rockingham area, breakwaters would likely be made out of rock or geotextile containers.

#### *4.5.1.3 Seawalls (PR5)*

Seawalls are hard structures built on the beach, and act as a last line of defence against coastal erosion. Seawalls are very effective in limiting the extent of erosion, however a drawback is that the presence of a seawall could lead to increased loss of the beach in front of them.

Seawalls can also be used to limit coastal inundation by creating an impermeable barrier between the sea and the land behind the wall, similar to a dyke. An impermeable wall could be made of concrete, steel, or a conventional rock armoured or GSC seawall with an impermeable barrier on the crest.

An example of a seawall is shown below in **Figure 4-6**, showing a buried GSC seawall along the Rockingham Foreshore. Another example of a seawall is shown in **Figure 4-7**, which shows a situation where the beach in front of the seawall has been lost.

Seawalls have been considered where there is high or very high vulnerability to coastal erosion by 2030 and also future high vulnerability due to inundation. Their potential to degrade beach amenity is likely to lower their acceptability to the broader community, unless they perform the dual function of protecting broader areas from intermittent coastal inundation. They have, therefore, not been considered for areas that are only at risk from coastal erosion. Any potential seawalls have been placed such that they would be considered a last line of defence seawall, to minimise impacts to beach amenity at present. These could be designed as buried seawalls to minimise their impact on visual amenity. As MSL rises, these seawalls will have the increasing potential to exacerbate erosion of the beach in front of them and seawalls that are initially buried can easily become exposed.

Figure 4-5 Offshore breakwaters near the northern boundary of the Rockingham LGA (source: Nearmap, 2018)

### 4.5.2 Equity Implications for Hard Protection Options

'Hard' *protection* options have significant associated equity implications. Landholders located in current or future hazard areas are direct benefactors of any protection approach, and should contribute to funding such measures accordingly. Groynes and offshore breakwaters are seen to generally maintain beach amenity for the broader community, although this may be degraded – visually and due to changes in shoreline shape.

Seawalls protect landward assets but often lead to a loss of beach amenity, meaning the broader community who use the beach lose out. If a seawall has the dual function of preventing coastal inundation, as well as coastal erosion, there are likely to be a greater number of benefactors than just those landholders at risk of erosion. This should be considered if such an option is selected, and in apportioning costs.

Because protection structures interrupt and alter the local sediment transport regime, they have the potential to impact the shoreline in areas beyond their desired area of treatment. For example, groynes and marinas often lead to net accretion on one side and net erosion on the other side ('downstream'). These effects can continue for years and even decades after construction. It would not be seen as equitable if the protection of one area leads to negative impacts to another section of coastline that provides value to stakeholders. The potential for such impacts should be assessed if a protection option is to be selected. It would be reasonable to expect that the beneficiaries of the protection measure should be held responsible for any loss of coastal values elsewhere, directly attributable to the protection measure. This may require them to compensate for or remedy any negative impacts.

Funding interim *protection* options, rather than *avoiding* or *retreating* from the hazards in these areas, could be seen as passing the problem on to future generations, given that these hazards are predicted to increase indefinitely. This should be carefully considered because although the cost of protection may be less than that for managed retreat in the short-term, eventual *managed retreat* is likely to be required at some point in the future. Cost implications could be considerably greater at this point and significant funding will have been 'used up' in maintaining the interim protection measures.

Figure 4-6 Buried GSC seawall along the Rockingham Foreshore

Figure 4-7 Exposed seawall where the beach in front of the seawall has been lost

### 4.5.3 Sector 2A: Wanliss Street to Garden Island Causeway

The MCA (**Appendix A**) found that groynes, offshore breakwaters and seawalls all warrant further assessment in Sector 2A. The key vulnerable assets in the sector include:

- The Alfred Hines Seaside Home;
- Coastal dunes and their vegetation;
- The Railway Terrace Commercial area;
- Drainage pipes and underground storage;
- Mangles Bay Fishing Club;
- Residential properties and road infrastructure at the Esplanade, near Hymus Street;
- Residential properties and road infrastructure between Bell Street and Fisher Street; and
- The Cruising Yacht Club.

#### *4.5.3.1 Groyne(s) (PR3)*

**Appendix B** includes a concept map of how groynes could be used to provide protection in this sector. It should be noted that groynes almost always require coincident renourishment to "fill" the beach compartments they create. The groyne fields shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The expected staging of groyne construction generally reflects the timing with which assets and areas become vulnerable to coastal erosion. The concept map shows an indicative future shoreline which has been based on estimated net sediment transport directions, however the shoreline between groynes would be dynamic, based on prevailing metocean conditions.

An indicative cost for the groyne field as shown in the concept map (17 groynes total) is presented in **Table 4-11** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming each groyne is 50m long at a cost of $10,000/m (per **Table 3-5**). The costs have been separated into two stages and include an indicative estimate of the cost of renourishment (assumed $25/m$^3$ total cost) for each stage, required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-11 Indicative costs for two stage groyne protection concept for Sector 2A

| Stage | Number of Groynes | Groyne Cost | Maintenance Cost to 2070 | Associated Renourishment Cost to 2070 | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| 1 | 7 | $3.5 m | $1.75 m | $4.5 m | $135k | $9.89 m |
| 2 | 10 | $5 m | $2.5 m | $6.4 m | $50k | $13.95 m |
| | | | | | **TOTAL** | **$23.84 m** |

The effectiveness of groynes along this relatively sheltered section of coast is uncertain due to low expected gross sediment transport rates and would require further investigation. In addition, the section of coast between the two jetties has relatively deep water located quite close to shore, which may limit the practical length of groynes and reduce the efficacy of the option. The optimum number of groynes, groyne lengths, groyne spacing, construction staging and coincident renourishment requirements for any groyne protection option require a detailed engineering study, which should be undertaken if this option is favoured. One issue to note with groynes in this sector is the existence of nearshore seagrass assemblages, meaning appropriate environmental considerations, approvals and/or controls are likely to be required.

Groynes do not directly mitigate potential future inundation hazards, but will allow, or assist in, the maintenance of a natural dune barrier to protect against the threat.

#### *4.5.3.2 Nearshore Reef(s)/Breakwater(s) (PR4)*

**Appendix B** includes a concept map of how nearshore breakwaters could be used to provide protection in this sector. It should be noted that nearshore breakwaters usually require coincident renourishment to limit erosion in between adjacent breakwaters. The nearshore breakwaters shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The expected staging of breakwater construction generally reflects the timing with which assets and areas become vulnerable to coastal erosion. The concept map shows an indicative future shoreline which has been based on anticipated shoreline response, also assuming renourishment sand is added behind the breakwaters.

An indicative cost for the breakwaters as shown in the concept map (11 breakwaters total) is presented in **Table 4-12** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming each breakwater is 60m long at a cost of $15,000/m (per **Table 3-5**). The costs have been separated into two stages and include an indicative estimate of the cost of renourishment (assumed $25/m$^3$ total cost) for each stage required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-12 Indicative costs for two stage nearshore breakwater protection concept for Sector 2A

| Stage | Number of Breakwaters | Breakwater Cost | Maintenance Cost to 2070 | Associated Renourishment Cost to 2070 | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| 1 | 6 | $9 m | $4.5 m | $3.4 m | $160k | $13.44 m |
| 2 | 5 | $7.5 m | $3.75 m | $4.8 m | $50k | $11.25 m |
| | | | | | **TOTAL** | **$24.69 m** |

The section of coast between the two jetties has relatively deep water located close to shore, which may restrict the distance offshore that the structures could be feasibly built, limiting their efficacy. The optimum breakwater size, spacing, construction staging and coincident renourishment requirements for any breakwater protection option require a detailed engineering study, which should be undertaken if this option is favoured. Similar to groynes (and potentially more so), an issue to note with nearshore breakwaters in this sector is the existence of seagrass assemblages, meaning appropriate environmental considerations, approvals and controls are likely to be required.

Offshore breakwaters do not directly mitigate potential future inundation hazards, but will allow, or assist in, the maintenance of a natural dune barrier to protect against the threat.

#### *4.5.3.3 Seawall(s) (PR5)*

**Appendix B** includes a concept map of how seawalls could be used to provide protection in this sector. It was assumed that all seawalls would be constructed as a "last line of defence" where they remain buried most of the time except during extreme events and, therefore, no renourishment is considered. The seawalls shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The staging of seawall construction should generally reflect the timing with which assets and areas become vulnerable to coastal erosion and inundation. The seawalls in the concept map have been shown as joining with the existing boat ramps. This assumes that these boat ramps will be retained and adapted to future sea levels, such that they form part of the protection in this area.

An indicative cost for the seawalls as shown in the concept map (two stages) is presented in **Table 4-13** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming a cost of $5,000/m of seawall (per **Table 3-5**).

Table 4-13 Indicative costs for seawall protection concept for Sector 2A

| Stage | Total Length of Seawall | Seawall Cost | Maintenance Cost to 2070 | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|
| 1 | 700 m | $3.5 m | $1.75 m | $50k | **$5.3 m** |
| 2 | 800 m | $4.0 m | $2.0 m | $20k | **$6.02 m** |
| | | | | TOTAL | **$11.32 m** |

The optimum seawall layout, cross-section, construction staging and renourishment requirements for any seawall protection option require a detailed engineering study, which should be undertaken if this option is favoured. It must be noted that seawalls provide protection to assets on their landward side, but not to those in front of them (i.e. beaches). They can increase coastal erosion in front of them (through wave reflection), making it more expensive or unfeasible to maintain a useable beach in the area.

Unlike offshore breakwaters and groynes, seawalls can be employed to directly mitigate the threat of coastal inundation. This is pertinent in this sector, where vulnerability to assets associated with inundation is predicted to increase over future planning timeframes.

#### *4.5.3.4 Rockingham Foreshore Master Plan*

A master plan has been prepared for the Rockingham Foreshore, with an associated CHRMAP (MRA, 2015) that encompasses the majority of Sector 2A. The CHRMAP contains a greater level of detail on specific management options for the coastline and also considers the design of the redevelopment. As such it should be referred to, alongside the overall CHRMAP, when refining plans for development and future management of the foreshore.

Management approaches for the foreshore presented in the Master Plan CHRMAP are generally consistent with those proposed in this CHRMAP, with the exception of the section of coast in front of Bell and Churchill Parks. The Master Plan CHRMAP has proposed the use of protection structures, such as seawalls, to mitigate hazards in this area in the short term. In the longer term, protection options that retain the beach, such as beach nourishment, have been proposed. Based on the outcomes of the overall CHRMAP, the incorporation of seawall protection should be carefully considered for the following reasons:

1. Vulnerability of the parks and associated foreshore assets was not deemed high enough to warrant significant management (such as hard protection structures) before 2030. The foreshore redevelopment is likely to occur before this. However, it is worthwhile considering the incorporation of hazard management into any redevelopment to lower overall construction costs and proactively manage risk; and
2. The value attributed to the beach is very high in this area and seawalls have the potential to exacerbate erosion of the beach during storm events and with rising MSL.

Furthermore, the use of beach nourishment has not been considered appropriate as a long term management technique (in its own right) in the overall CHRMAP, due to its temporary nature and considerable associated ongoing expense. Rather, nourishment could be useful as an interim protection measure, while more permanent long term solutions are arranged.

### 4.5.4 Sector 3A Boundary Road to Bent Street

The MCA (**Appendix A**) found that groynes and seawalls warrant further assessment in Sector 3A. It was not considered an appropriate option to install offshore breakwaters in this sector, due to their potential impact on sensitive marine ecosystems. The key vulnerable assets in the sector include:

- Drainage pipes;
- Dual use paths; and
- Residential properties and road infrastructure at the south side of Mersey Point.

#### *4.5.4.1 Groyne(s) (PR3)*

**Appendix B** includes a concept map of how groynes could be used to provide protection in Sector 3A. It should be noted that groynes almost always require coincident renourishment to "fill" the beach compartments they create. The groyne fields shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The expected staging of groyne construction generally reflects the timing with which assets and areas become vulnerable to coastal erosion. The concept maps show an indicative future shoreline which has been based on estimated net sediment transport directions, however the shoreline between groynes would be dynamic, based on prevailing metocean conditions.

An indicative cost for the groyne field as shown in the concept map (14 groynes total) is presented in **Table 4-14** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming each groyne is 50m long at a cost of $10,000/m (per **Table 3-5**). The costs have been separated into three stages and include an indicative estimate of the cost of renourishment (assumed $25/m$^3$ total cost) for each stage, required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-14 Indicative costs for three stage groyne protection concept for Sector 3A

| Stage | Number of Groynes | Groyne Cost | Maintenance Cost to 2070 | Associated Renourishment Cost to 2070 | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| 1 | 4 | $2 m | $1 m | $3.8 m | $120 k | $6.92 m |
| 2 | 8 | $4 m | $2 m | $7.6 m | $40 k | $13.64 m |
| 3 | 2 | $1 m | $500 k | $1.9 m | $10 k | $3.41 m |
| | | | | | **TOTAL** | **$23.97 m** |

The optimum number of groynes, groyne lengths, groyne spacing, construction staging and coincident renourishment requirements for any groyne protection option require a detailed engineering study, which should be undertaken if this option is favoured. One issue to note with groynes in this sector is the existence of sensitive nearshore marine habitat (including areas designated as Wildlife Conservation Areas within the Shoalwater Islands Marine Park), meaning appropriate environmental considerations, approvals and/or controls would be required. It should be noted that the south side of Mersey Point, where there is an existing seawall, is currently experiencing erosion issues and this area should be the first considered for any protection strategy.

Groynes do not directly mitigate potential future inundation hazards, but will allow, or assist in, the maintenance of a natural dune barrier to protect against the threat.

#### *4.5.4.2 Seawall(s) (PR5)*

**Appendix B** includes a concept map of how seawalls could be used to provide protection in this sector. It was assumed that all seawalls would be constructed as a "last line of defence" where they remain buried most of the time except during extreme events and, therefore, no renourishment is considered. The seawalls shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The staging of seawall construction should generally reflect the timing with which assets and areas become

vulnerable to coastal erosion and inundation. The seawall in the concept map has been shown as joining with the existing boat ramp. This assumes that this boat ramp will be retained and adapted to future sea levels, such that it forms part of the protection mechanism.

An indicative cost for the seawalls as shown in the concept maps (three stages) is presented in **Table 4-15** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming a cost of $5,000/m (per **Table 3-5**).

Table 4-15 Indicative costs for seawall protection concept for Sector 3A

| Stage | Total Length of Seawall | Seawall Cost | Maintenance Cost to 2070 | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|
| 1 | 500 m | $2.5 m | $1.25 m | $50k | **$3.8 m** |
| 2 | 700 m | $3.5 m | $1.75 m | $20k | **$5.27 m** |
| 3 | 700 m | $3.5 m | $1.75 m | $20k | **$5.27 m** |
| | | | | TOTAL | **$14.34 m** |

The optimum seawall layout, cross-section, construction staging and renourishment requirements for any seawall protection option require a detailed engineering study, which should be undertaken if this option is favoured. It should be noted that the south side of Mersey Point, where there is an existing seawall, is currently experiencing erosion issues and this area should be the first considered for any protection strategy.

It must be noted that seawalls provide protection to assets on their landward side, but not to those in front of them (i.e. beaches). They can increase coastal erosion in front of them (through wave reflection), making it more expensive or unfeasible to maintain a useable beach in the area.

Unlike offshore breakwaters and groynes, seawalls can be employed to directly mitigate the threat of coastal inundation. This is pertinent in this sector, where vulnerability to assets associated with inundation is predicted to increase over future planning timeframes.

### 4.5.5 Sector 3B: Bent Street to Shelton Street

The MCA (**Appendix A**) found that groynes, offshore breakwaters and seawalls all warrant further assessment in Sector 3B. The key vulnerable assets in the sector include:

- Drainage pipes;
- Dual use paths;
- Residential properties and road infrastructure along Safety Bay Road, near June Road; and
- Residential properties and road infrastructure along Warnbro Beach Road – from Safety Bay Road to Short Street, near View Road, to the north of Michael Road, and at its south just before Shelton Street.

#### *4.5.5.1 Groyne(s) (PR3)*

**Appendix B** includes a concept map of how groynes could be used to provide protection in Sector 3B. It should be noted that groynes almost always require coincident renourishment to "fill" the beach compartments they create. The groyne fields shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The expected staging of groyne construction generally reflects the timing with which assets and areas become vulnerable to coastal erosion. The concept maps show an indicative future shoreline which has been based on estimated net sediment transport directions, however the shoreline between groynes would be dynamic, based on prevailing metocean conditions.

An indicative cost for the groyne field as shown in the concept map (22 groynes total) is presented in **Table 4-16** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming each groyne is 50m long at a cost of $10,000/m (per **Table 3-5**). The costs have been separated into two stages and include an indicative estimate of the cost of renourishment (assumed $25/m$^3$ total cost) for each stage, required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-16 Indicative costs for two stage groyne protection concept for Sector 3B

| Stage | Number of Groynes | Groyne Cost | Maintenance Cost to 2070 | Associated Renourishment Cost to 2070 | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| 1 | 7 | $3.5 m | $1.75 m | $5.9 m | $135k | $11.29 m |
| 2 | 15 | $7.5 m | $3.75 m | $12.7 m | $75k | $24.03 m |
| | | | | | **TOTAL** | **$35.32 m** |

The optimum number of groynes, groyne lengths, groyne spacing, construction staging and coincident renourishment requirements for any groyne protection option require a detailed engineering study, which should be undertaken if this option is favoured.

Groynes do not directly mitigate potential future inundation hazards, but will allow, or assist in, the maintenance of a natural dune barrier to protect against the threat.

#### *4.5.5.2 Nearshore Reef(s)/Breakwater(s) (PR4)*

**Appendix B** includes a concept map of how nearshore breakwaters could be used to provide protection in Sector 3B. It should be noted that nearshore breakwaters usually require coincident renourishment to limit erosion in between adjacent breakwaters. The nearshore breakwaters shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The expected staging of breakwater construction generally reflects the timing with which assets and areas become vulnerable to coastal erosion. The concept maps show an indicative future shoreline which has been based on anticipated shoreline response, also assuming renourishment sand is added behind the breakwaters.

An indicative cost for the breakwaters as shown in the concept map (13 breakwaters total) is presented in **Table 4-17** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming each breakwater is 60m long, at a cost of $15,000/m (per **Table 3-5**). The costs have been separated into two stages and include an indicative estimate of the cost of renourishment (assumed $25/m$^3$ total cost) for each stage, required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-17 Indicative costs for two stage nearshore breakwater protection concept for Sector 3B

| Stage | Number of Breakwaters | Breakwater Cost | Maintenance Cost to 2070 | Associated Renourishment Cost to 2070 | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| 1 | 4 | $3.6 m | $1.8 m | $4.4 m | $140k | $9.97 m |
| 2 | 9 | $8.1 m | $4.05 m | $9.5 m | $90k | $21.77 m |
| | | | | | **TOTAL** | **$31.74 m** |

The southern section of Sector 3B has relatively deep water located close to shore, which may restrict the distance offshore that the structures could be feasibly built, limiting their efficacy. The optimum breakwater size, spacing, construction staging and coincident renourishment requirements for any breakwater protection option require a detailed engineering study, which should be undertaken if this option is favoured. An issue to note with nearshore breakwaters in the northern part of this sector is the existence of seagrass assemblages, meaning appropriate environmental considerations, approvals and/or controls are likely to be required.

Offshore breakwaters do not directly mitigate potential future inundation hazards, but will allow, or assist in, the maintenance of a natural dune barrier to protect against the threat.

#### *4.5.5.3 Seawall(s) (PR5)*

**Appendix B** includes a concept map of how a seawall could be used to provide protection in this sector. It was assumed that any seawall would be constructed as a “last line of defence” where it remains buried most of the time except during extreme events and, therefore, no renourishment has been considered. The seawall shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The staging of seawall construction should generally reflect the timing with which assets and areas become vulnerable to coastal erosion and inundation. The seawall in the concept map has been shown as joining with the existing boat ramp. This assumes that this boat ramp will be retained and adapted to future sea levels, such that it forms part of the protection mechanism.

An indicative cost for the seawall as shown in the concept map (two stages) is presented in **Table 4-18** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming a cost of $5,000/m (per **Table 3-5**).

Table 4-18 Indicative costs for seawall protection concept for Sector 3B

| Stage | Total Length of Seawall | Seawall Cost | Maintenance Cost to 2070 | Allowance for Design Work Required | TOTAL |
|---|---|---|---|---|---|
| 1 | 350 m | $1.75 m | $875 k | $50k | **$2.67 m** |
| 2 | 650 m | $3.25 m | $1.62 m | $20k | **$4.89 m** |
| | | | | TOTAL | **$7.56 m** |

The optimum seawall layout, cross-section, construction staging and renourishment requirements for any seawall protection option require a detailed engineering study, which should be undertaken if this option is favoured.

Seawalls provide protection to assets on their landward side, but not to those in front of them (i.e. beaches). They can increase coastal erosion in front of them (through wave reflection), making it more expensive or unfeasible to maintain a useable beach in the area.

Unlike offshore breakwaters and groynes, seawalls can be employed to directly mitigate the threat of coastal inundation. This is pertinent in this sector, where vulnerability to assets associated with inundation is predicted to increase over future planning timeframes.

It should be noted that there is presently a section of buried rock seawall just north of the beach access ramp at Waikiki. The seawall in this area, although effective in protecting assets on its landward side, will have the potential to exacerbate erosion of the beach in front of it and either side of it as sea level rises in the future. The area adjacent to the seawall is not prone to inland coastal inundation, so it only serves to protect assets directly behind it. For these reasons, as identified through the MCA, the continued use of a seawall to manage coastal hazards in this area (beyond the lifespan of the existing structure) has not been recommended.

### 4.5.6 Sector 4B: Bayeux Avenue to Becher Point

The MCA (**Appendix A**) found that groynes, offshore breakwaters and seawalls all warrant further assessment in Sector 4B. The key vulnerable asset in the short-term in this sector is the Port Kennedy Foreshore Carpark.

#### *4.5.6.1 Groyne(s) (PR3)*

**Appendix B** includes a concept map of how groynes could be used to provide protection in Sector 4B. It should be noted that groynes almost always require coincident renourishment to “fill” the beach compartments they create. The groyne fields shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The expected staging of groyne construction generally reflects the timing with which assets and areas become vulnerable to coastal erosion. The concept has assumed that the Port Kennedy Boat Ramp will be retained and adapted to future changes in shoreline and mean sea level, which may include retreat of the boat ramp from its current position or armouring of the boat ramp and adjacent carpark. These costs have not been included in the costing for this option.

An indicative cost for the groyne field as shown in the concept map (2 groynes total) is presented in **Table 4-19** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming each groyne is 50m long at a cost of $10,000/m (per **Table 3-5**). The total includes an indicative estimate of the cost of renourishment (assumed $25/m$^3$ total cost) required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-19 Indicative costs for single stage groyne protection concept for Sector 4B

| Stage | Number of Groynes | Groyne Cost | Maintenance Cost to 2070 | Associated Renourishment Cost to 2070 | Allowance for Design Work Required | TOTAL |
|---|---|---|---|---|---|---|
| 1 | 2 | $1 m | $500 k | $5.9 m | $110k | **$7.51 m** |

The optimum number of groynes, groyne lengths, groyne spacing, construction staging and coincident renourishment requirements for any groyne protection option require a detailed engineering study, which should be undertaken if this option is favoured.

Groynes do not directly mitigate potential future inundation hazards, but will allow, or assist in, the maintenance of a natural dune barrier to protect against the threat.

#### *4.5.6.2 Nearshore Reef(s)/Breakwater(s) (PR4)*

**Appendix B** includes a concept map of how a nearshore breakwater could be used to provide protection in Sector 4B. It should be noted that nearshore breakwaters usually require coincident renourishment to limit erosion in between adjacent breakwaters. The nearshore breakwater shown in the concept map could be constructed when a defined trigger is reached. The concept map shows an indicative future shoreline which has been based on anticipated shoreline response, also assuming renourishment sand is added behind the breakwaters. The concept has assumed that the Port Kennedy Boat Ramp will be retained and adapted to future changes in shoreline and mean sea level, which may include retreat of the boat ramp from its current position or armouring of the boat ramp and adjacent carpark. These costs have not been included in the costing for this option.

An indicative cost for the breakwater as shown in the concept map is presented in **Table 4-20** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming the breakwater is 60m long at a cost of $15,000/m (per **Table 3-5**). The total includes an indicative estimate of the cost of renourishment (assumed $25/m$^3$ total cost) required to counteract coastal erosion due to sea level rise, out to 2070.

Table 4-20 Indicative costs for nearshore breakwater protection concept for Sector 4B

| Stage | Number of Breakwaters | Breakwater Cost | Maintenance Cost to 2070 | Associated Renourishment Cost to 2070 | Allowance for Design Work Required | TOTAL |
|---|---|---|---|---|---|---|
| 1 | 1 | $0.9 m | $450 k | $4.43 m | $110k | **$5.89 m** |

The vulnerable area in this sector has relatively deep water located close to shore, which may restrict the distance offshore that a breakwater could be feasibly built, limiting their efficacy. The optimum breakwater size, spacing, construction staging and coincident renourishment requirements for any breakwater protection option require a detailed engineering study, which should be undertaken if this option is favoured.

Offshore breakwaters do not directly mitigate potential future inundation hazards, but will allow, or assist in, the maintenance of a natural dune barrier to protect against the threat.

#### *4.5.6.3 Seawall(s) (PR5)*

**Appendix B** includes a concept map of how a seawall could be used to provide protection in this sector. It was assumed that any seawall would be constructed as a “last line of defence” where it remains buried most of the time except during extreme events and, therefore, no renourishment has been considered. The seawall shown in the concept map could be constructed in stages, which would be based on defined triggers being reached. The staging of seawall construction should generally reflect the timing with which assets and areas become vulnerable to coastal erosion. The seawall in the concept map has been shown as joining with the existing boat ramp. This assumes that this boat ramp will be retained and adapted to future sea levels, such that it forms part of the protection mechanism.

An indicative cost for the seawall as shown in the concept map (two stages) is presented in **Table 4-21** below. The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming a cost of $5,000/m (per **Table 3-5**).

Table 4-21 Indicative costs for seawall protection concept for Sector 4B

| Stage | Total Length of Seawall | Seawall Cost | Maintenance Cost to 2070 | Allowance for Design Work Required | TOTAL |
|---|---|---|---|---|---|
| 1 | 250 m | $1.25 m | $625 k | $50k | **$1.92 m** |
| 2 | 300 m | $1.5 m | $750 k | $20k | **$2.27 m** |
| | | | | TOTAL | **$4.2 m** |

The optimum seawall layout, cross-section, construction staging and renourishment requirements for any seawall protection option require a detailed engineering study, which should be undertaken if this option is favoured.

Seawalls provide protection to assets on their landward side, but not to those in front of them (i.e. beaches). They can increase coastal erosion in front of them (through wave reflection), making it more expensive or unfeasible to maintain a useable beach in the area.

Unlike offshore breakwaters and groynes, seawalls can be employed to directly mitigate the threat of coastal inundation. This is pertinent in this sector, where vulnerability to assets associated with inundation is predicted to increase over future planning timeframes.

## 4.6 Stormwater Drainage Adaptation

The City's stormwater and drainage network includes enclosed pipe, gullies and waterway infrastructure. These stormwater and drainage assets form a network of waterways, drains and pipes that transport water collected from road and land surfaces and direct them predominately to the ocean and Lake Richmond. SLR, inundation, groundwater swelling events and the increase in population place increasing demands on the network.

Stormwater and drainage infrastructure is intended to extract the stormwater to provide flood prevention and protection, pollution control and rapidly convey road subsoil drainage to lower areas to enable a return to service. One of the stormwater system's major uses is to mitigate flooding caused by large rainfall events by managing stormwater runoff and preventing local flooding of public spaces, transport corridors and properties.

Pipe networks are sized typically to 5 or 10yr ARI events. The Adaptation of drainage infrastructure was assessed for up to the 10yr ARI event only. Once the capacity of the pipe drainage infrastructure has been reached, it is acceptable to utilise roads as floodways and these have been assessed accordingly as part of the process.

### 4.6.1 Stormwater Infrastructure Adaptation Options

Adaptation options applied to stormwater and drainage assets are:

- *Protect / Repair*– Drainage infrastructure repaired to ensure operation for future rainfall events. Add to or modify existing infrastructure, or improve the materials of construction in response to SLR flood predictions to minimise the effect of changed area inundation on network performance. As a minimum, the current level of service will be maintained. This is unlikely to include significant adjustments to spatial geometry of networks

  A main consideration for stormwater assets and drainage is the use of tidal gate valves or large non-return valves at the drainage outlets to avoid further inundation during flood events. Floodgates are essentially non-return valves used extensively throughout Australia in coastal, riverine and coastal environments by water authorities, Councils and hydraulic engineers.

- *Relocate* – Drainage infrastructure relocated to an area which will not be impacted again within asset life. Drainage to be removed if no other assets are left to service. Partial or full replacement of sections of infrastructure consistent with SLR flood predictions, with level of service based on current level of service. This is likely to include adjustment to spatial geometry of networks

- *Accommodate* – Add additional infrastructure (e.g. pump stations), improve the materials of construction, or modify maintenance processes to adapt to increased water inflow, reduced working hydraulic head or

rising ground water levels consistent with SLR flood predictions. This may also include an adjustment to the level of service. This is unlikely to include significant changes to the spatial geometry of network.

General factors affecting both planning and implementation of all of the above adaptation options include the:

- Depth of the drainage or stormwater pipeline or culvert asset;
- Construction access and laydown/staging availability, including control;
- Greenfield / brownfield location;
- Ground conditions (presence of rock, weak soils, acid sulphate soils or ground saturation, heaving/swelling);
- Influence of other infrastructure influencing stormwater and drainage performance;
- Emerging technologies causing demand adjustment from baseline performance expectations; and
- Changes in level of service expectations within adaptation planning horizons.

Factors that may influence implementation of the above adaptation considerations include:

- Area type (population density);
- Available corridor width for change;
- Major road crossings;
- Waterways crossings;
- Requirements for tunnelling / horizontal directional drilling; and
- Cultural heritage or environmental management requirements.

### 4.6.2 Adaptation Options Costs

To protect drainage infrastructure and ensure operation, each adaptation option, protect/repair, relocate and accommodate, has been assessed and indicative costs provided.

The costs are in present day dollars (they do not factor in inflation or escalation of costs) and were estimated assuming:

- Protection – tide gate valve at all outlets at a cost of $15,000 per unit including installation.
- Relocate – Replacement cost of all drainage infrastructure including removal, replacement and excavation costs (not including land acquisition) based on:
  - Drainage pits - $ 2,293/pit
  - Drainage pipes - $ 317/m
  - Underground Storage $ 385/$m^2$
- Accommodate – Installation of a pump station and additional pipe network (costs include excavation and material costs only) to inter connect all drainage based on:
  - Pump station $ 100,400
  - Drainage pits $ 1,498/pit
  - Drainage pipes $ 198/m

Design works assumed to be 10% of infrastructure costs.

Costs do not include studies that may need to be undertaken to ensure adaptation measure will work.

### 4.6.3 Sector 2A: Wanliss Street to Garden Island Causeway

The key vulnerable drainage assets in sector 2A until 2070 are presented in **Table 4-22**.

Table 4-22 Drainage assets impacted by Erosion 2030 and 2070 for Sector 2A

| 2030 | | | | 2070 | | | |
|---|---|---|---|---|---|---|---|
| Drainage pits (no.) | Outlets (no.) | Drainage Pipes (m) | Underground Storage (m2) | Drainage pits (no.) | Outlets (no.) | Drainage Pipes (m) | Underground Storage (m2) |
| 28 | 5 | 864 | 1000 | 109 | 9 | 2552 | 2520 |

Indicative costs of adaptation are presented in **Tables 4-23** and **4-24**.

Table 4-23 Indicative costs for drainage asset adaption concept for Sector 2A until 2030

| Adaptation Option | Drainage Pits Cost | Drainage Pipes Cost | Underground Storage Cost | Additional Infrastructure cost | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| Protect | - | - | - | $ 75,000 | $ 7,500 | $ 82,500 |
| Relocate | $ 64,204 | $ 274,205 | $ 385,000 | - | $ 72,340 | $ 795,749 |
| Accommodate[1] | $10,486 | $71, 280 | - | $100,400 | $ 18,216 | $ 200,382 |

1- An additional 685m of pipes and 14 pits required for accommodation option.

Table 4-24 Indicative costs for drainage asset adaption concept for Sector 2A until 2070

| Adaptation Option | Drainage Pits Cost | Drainage Pipes Cost | Underground Storage Cost | Additional Infrastructure cost | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| Protect | - | - | - | $ 135,000 | $ 13,500 | $ 148,500 |
| Relocate | $ 249,937 | $ 808,984 | $ 970,200 | - | $ 202,912 | $ 2,232,033 |
| Accommodate[1] | $34,454 | $ 230,670 | - | $100,400 | $ 36,552 | $ 402,076 |

1- An additional 1165m of pipes and 23 pits required for accommodation option.

There is significant drainage assets within Sector 2A that leads to protection or accommodating adaptation options as being the most cost effective. It should be noted that protect will also require additional maintenance to ensure that the outlet remains operational. The optimum solution for either adaptation option requires a detailed engineering study, which should be undertaken for the favoured option.

### 4.6.4 Sector 3A Boundary Road to Bent Street

The key vulnerable drainage assets in sector 3A until 2070 are presented in **Table 4-25**.

Table 4-25 Drainage assets impacted by Erosion 2030 and 2070 for Sector 2A

| 2030 | | | | 2070 | | | |
|---|---|---|---|---|---|---|---|
| Drainage pits (no.) | Outlets (no.) | Drainage Pipes (m) | Underground Storage (m2) | Drainage pits (no.) | Outlets (no.) | Drainage Pipes (m) | Underground Storage (m2) |
| 9 | 5 | 635 | - | 86 | 5 | 2370 | - |

Indicative costs of adaptation are presented in **Table 4-26** and **Table 4-27**.

Table 4-26 Indicative costs for drainage asset adaption concept for Sector 3A until 2030

| Adaptation Option | Drainage Pits Cost | Drainage Pipes Cost | Underground Storage Cost | Additional Infrastructure cost | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| Protect | - | - | - | $ 75,000 | $ 7,500 | $ 82,500 |
| Relocate | $ 20,637 | $ 201,295 | - | - | $ 22,193 | $ 244,125 |
| Accommodate[1] | $ 20,972 | $ 135,630 | - | $100,400 | $ 25,700 | $ 282,702 |

1- An additional 685m of pipes and 14 pits required for accommodation option

Table 4-27 Indicative costs for drainage asset adaption concept for Sector 3A until 2070

| Adaptation Option | Drainage Pits Cost | Drainage Pipes Cost | Underground Storage Cost | Additional Infrastructure cost | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| Protect | - | - | - | $ 75,000 | $ 7,500 | $ 82,500 |
| Relocate | $ 197,198 | $ 751,290 | - | - | $ 94,848 | $ 1,043,336 |
| Accommodate[1] | $ 20,972 | $ 135,630 | - | $100,400 | $ 25,700 | $ 282,702 |

1- An additional 685m of pipes and 14 pits required for accommodation option

The five drainage outlets service a much larger stormwater network and are imperative to maintain the effectiveness of the drainage system. The costs associated with providing tide gate valves and maintenance to ensure this larger drainage network remains effective may out way the relocation or accommodating options for Sector 3A. The optimum solution for either adaptation option requires a detailed engineering study, which should be undertaken for the favoured option.

### 4.6.5 Sector 3B: Bent Street to Shelton Street

The key vulnerable drainage assets in sector 3B until 2070 are presented in **Table 4-28**.

Table 4-28 Drainage assets impacted by Erosion 2030 and 2070 for Sector 2A

| 2030 | | | | 2070 | | | |
|---|---|---|---|---|---|---|---|
| Drainage pits (no.) | Outlets (no.) | Drainage Pipes (m) | Underground Storage (m2) | Drainage pits (no.) | Outlets (no.) | Drainage Pipes (m) | Underground Storage (m2) |
| 3 | 3 | 83 | - | 29 | 6 | 791 | - |

Indicative costs of adaptation are presented in **Table 4-29** and **Table 4-30**.

Table 4-29 Indicative costs for drainage asset adaption concept for Sector 3B until 2030

| Adaptation Option | Drainage Pits Cost | Drainage Pipes Cost | Underground Storage Cost | Additional Infrastructure cost | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| Protect | - | - | - | $ 45,000 | $ 4,500 | $ 49,500 |
| Relocate | $ 6,879 | $ 26,311 | - | - | $ 3,319 | $ 36,509 |
| Accommodate | $ 13,482 | $ 87,120 | - | $100,400 | $ 20,100 | $ 221,102 |

1- An additional 440m of pipes and 9 pits required for accommodation option

Table 4-30 Indicative costs for drainage asset adaption concept for Sector 3B until 2070

| Adaptation Option | Drainage Pits Cost | Drainage Pipes Cost | Underground Storage Cost | Additional Infrastructure cost | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| Protect | - | - | - | $ 90,000 | $ 9,000 | $ 99,000 |
| Relocate | $ 66,497 | $ 250,747 | - | - | $ 31,724 | $ 348,968 |
| Accommodate[1] | $34,454 | $ 227,700 | - | $100,400 | $ 26,215 | $ 388,769 |

1- An additional 1150m of pipes and 23 pits required for accommodation option

The drainage pits and associated pipes impacted in Sector 3B to 2030 are minimal and can be relocated to ensure a functioning drainage system. Following this, should observations beyond 2030 show that the outlets are being impeded by erosion consideration to protect the outlets should be considered. Both options at either time period will require detailed engineering design to be undertaken.

### 4.6.6 Sector 4B: Bayeux Avenue to Becher Point

The key vulnerable drainage assets in sector 4B until 2070 are presented in **Table 4-31**.

Table 4-31 Drainage assets impacted by Erosion 2030 and 2070 for Sector 4B

| 2030 | | | | 2070 | | | |
|---|---|---|---|---|---|---|---|
| Drainage pits (no.) | Outlets (no.) | Drainage Pipes (m) | Underground Storage (m2) | Drainage pits (no.) | Outlets (no.) | Drainage Pipes (m) | Underground Storage (m2) |
| 4 | - | 110 | - | 9 | - | 244 | - |

Indicative costs of adaptation are presented in **Table 4-32** and **Table 4-33**.

Table 4-32 Indicative costs for drainage asset adaption concept for Sector 4B until 2030

| Adaptation Option | Drainage Pits Cost | Drainage Pipes Cost | Underground Storage Cost | Additional Infrastructure cost | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| Protect | - | - | - | - | - | - |
| Relocate | $ 9,172 | $ 34,870 | - | - | $ 4,404 | $ 48,446 |
| Accommodate | $ 1,498 | $ 1,980 | - | $100,400 | $ 10,387 | $ 114,256 |

1- An additional 10m of pipes and 1 pit required for accommodation option

Table 4-33 Indicative costs for drainage asset adaption concept for Sector 4B until 2070

| Adaptation Option | Drainage Pits Cost | Drainage Pipes Cost | Underground Storage Cost | Additional Infrastructure cost | Allowance for Design Work Required | Total Stage Cost |
|---|---|---|---|---|---|---|
| Protect | - | - | - | - | - | - |
| Relocate | $ 20,637 | $ 77,348 | - | - | $ 9,798 | $ 107,783 |
| Accommodate | $ 1,498 | $ 1,980 | - | $100,400 | $ 10,387 | $ 114,256 |

1- An additional 10m of pipes and 1 pit required for accommodation option

Stormwater in Sector 4B is disposed of via infiltration through manholes. Prior to the stormwater system being impacted, the carpark will be impacted by erosion first. At the time of relocating the carpark, a suitable stormwater system should be installed outside the future predicted impact area.

# 5 Discussion

The full results of the MCA, applied to each coastal sector (and sub-sector), are provided in **Appendix A**. Through the MCA, various options have been either recommended, not recommended or identified as requiring further investigation for each sector. Implementation of *Avoid, Accommodate* and some 'soft' *Protection* options have been discussed with respect to the City's entire coastline. *Managed Retreat* and *Protect* options have been outlined for priority sectors, where some implementation of the options may be required prior to 2030. These are Sectors 2, 3 and 4 (specifically 4B).

In general, the proposed adaptation options provide technical mitigation approaches for adapting to the effects of landward migration of the shoreline, due to future SLR and associated coastal erosion and inundation (**Section 4**). A summary of the range of planning instruments available to effect changes in the character and use of the coastal zone has been provided in **Section 2**.

In general, options recommend that:

- Where there is currently no existing development seaward of the predicted 2110 coastal erosion hazard line, planning controls and coastal zone boundaries be adjusted to preclude development within the zone;
- Where high value natural and social assets exist seaward of the 2110 coastal erosion hazard line, adaptation options and pathways which maintain the present values of these assets should be favoured;
- Where public built assets exist seaward of the 2110 coastal erosion hazard line, managed retreat options should be considered; and/or
- Where private land and dwellings are located seaward of the 2110 coastal erosion hazard line, options to retreat or protect should be considered.

General coastal planning principles (**Section 6.1**) and acknowledgement of the uncertainty in the hazard lines (**Section 6.2**) will need to be conveyed during the next opportunity to engage with the community, where the aim should be to elicit community consensus on the priorities and content of the City's CHRMAP.

## 5.1 General Coastal Planning Principles

With a view to achieving the planning objective of ensuring permanent and easy public access to the beach and coastal recreation (foreshore) reserves, some guiding principles are proposed. These could form the basis for drafting scheme and/or policy provisions relating to the definition of coastal foreshore reserves.

- The coast and coastal foreshore reserves are a public asset that should not, now or in the future, become the de facto exclusive domain of private landowners by virtue of the erosion of coastal reserves or other coastal processes;
- Foreshore reserves should be wide enough that they can still perform recreation and/or conservation functions (according to the reasons for their initial designation) even if they are affected by coastal erosion or diminution due to SLR;
- Privatisation of coastal land at risk of coastal erosion or inundation, now or in the future, through freehold or long-term leasehold subdivision should be avoided;
- Permanent structures, including buildings, should not be permitted on land at risk of coastal erosion or significant inundation; and
- Redevelopment of land at risk of coastal erosion or inundation with permanent structures (e.g. houses) should not be permitted within the at-risk parts of a site.

## 5.2 Uncertainty and Adaptive Management

The coastal hazard lines derived during the coastal hazard assessment are subject to a number of assumptions that introduce uncertainty into the predicted location of each hazard line, at each planning time frame. The CHRMAP process recognises this and utilises adaptive management techniques to continually monitor, assess and revise plans as new information comes to light in the future. The confounding aspects of hazard line predictions for variable SLR and climate change scenarios and the complex coastal planning instruments will require a careful, balanced consideration when prioritising implementation of proposed

adaptation options. The general principles discussed above and acceptance of the uncertainty in the hazard lines are intended to provide a reasonable overview to inform the community, that will be important to guide the development of long-term management pathways.

As the shoreline is dynamic and new information is constantly being collected, there may be opportunity to revise hazard line extents prior to the next formal review of the CHRMAP. A review of hazard lines may be appropriate if significant new information becomes available, such as a change to State endorsed SLR predictions or the addition of collected shoreline movement or metocean datasets that contradict existing information/predictions. It is important that any hazard line revisions are made for an entire sediment cell (at least the Secondary Sediment Cell as defined by Stul et al, 2015) containing the area of interest, as stipulated in Section 4 of SPP2.6.

With regard to this, CHRMAPs have often been produced in the past for specific development sites or areas of interest, which are not compliant with the requirements of SPP2.6 (due to not considering entire sediment cels) or consistent with the intent of the CHRMAP process. The City should avoid condoning the preparation of individual CHRMAPs (which are also unlikely to be endorsed by the WAPC), but rather require the recalculation of hazard line extents for its consideration and incorporation into its overall CHRMAP and risk management database. The calculation of hazard lines should be accompanied by an explanation of the reason for the proposed revision and a full description of calculations undertaken to achieve hazard extents, in line with the methodology stipulated in SPP2.6. The City may then choose to adopt the new hazard lines and incorporate them by amending mapping in their local planning scheme. A reassessment of risk and vulnerability levels for that area, using the assessment spreadsheets provided as part of this CHRMAP, may also then be appropriate.

Rather than using site-specific CHRMAPs, foreshore/coastal management plans and structure plans should be used to increase the level of detail for management of specific sites and ensure the outcomes of the City's CHRMAP are incorporated into planned development. A key purpose of the CHRMAP process is to empower and guide local government agencies to control coastal development and ensure it is carried out in a responsible manner. It is reiterated that hazard line extents contain conservative assumptions, which are necessary given future uncertainty and the need to avoid inappropriate, permanent development. Such development has been identified to already exist within the City and will require expensive management over the next 100 years. The City should be wary of proponents wishing to revise hazard extents based on different interpretations of prescriptive methods in SPP2.6, with the aim of maximising the development potential for their area of interest.

Alongside the recommended adaptation pathways that will underpin implementation over the next decade, recommendations will be made for further investigation and specific monitoring programs. This will help refine and guide the adaptation pathways into the future. A key aim will be to make recommendations that will help reduce the uncertainty in the coastal process hazards, prior to subsequent future updates of the City's CHRMAP.

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APPENDIX

# A

## MULTI-CRITERIA ANALYSIS TABLES

# APPENDIX

# B

## ADAPTATION OPTIONS CONCEPT DESIGNS

# APPENDIX

# L

## MULTI-CRITERIA ANALYSIS TABLES

## Sector 1: Municipal Boundary (North) to Wanliss Street

## Primary Coastal Hazard(s): Erosion

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Beach | Low | Medium | High | Very High |
| Coastal dune/vegetation | Low | Medium | Very High | Very High |
| Phoebe Hymus Carpark | Low | Medium | Medium | Very High |
| Road (Rockingham Beach Rd) | Low | Medium | Medium | Very High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| Managed Retreat | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | | | | | | | | | Do not recommend |
| | | | Drainage Infrastructure | | | | | | | | | Further assessment |
| | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | | | | | | | | | Further assessment |
| | | | Drainage Infrastructure | | | | | | | | | Recommend |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Recommend |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Do not recommend |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 2A: Wanliss Street to Garden Island Causeway

## Primary Coastal Hazard(s): Erosion and Inundation

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Alfred Hines Seaside Home | High | Very High | Very High | Very High |
| Coastal/dune vegetation | Medium | High | Very High | Very High |
| Commercial area (Railway Tce) | Low | Very High | Very High | Very High |
| Drainage Pipes | Medium | High | Very High | Very High |
| Mangles Bay Fishing Club | High | Very High | Very High | Very High |
| Residential | Low | High | Very High | Very High |
| Roads | Low | High | Very High | Very High |
| The Cruising Yacht Club | High | Very High | Very High | Very High |
| Underground Storage | Medium | High | Very High | Very High |

| Inundation Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| All Parks & Recreation areas | Medium | Medium | High | Very High |
| Catalpa Park Carpark | Medium | Medium | Medium | High |
| Dual use path | Medium | Medium | Medium | Very High |
| Jetty abutments (Val St and Fisher St) | Medium | Medium | Medium | Medium |
| Residential | Medium | High | Very High | Very High |
| Roads | Medium | Medium | High | Very High |
| Underground Storage | Medium | Medium | Very High | Very High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| Managed Retreat | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | | | | | | | | | Do not recommend |
| | | | Drainage Infrastructure | | | | | | | | | Further assessment |
| | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | | | | | | | | | Further assessment |
| | | | Drainage Infrastructure | | | | | | | | | Recommend |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Further assessment |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| | | | Lake Richmond | | | | | | | | | Further assessment |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Further assessment |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 2B: Garden Island Causeway to Boundary Road

## Primary Coastal Hazard(s): Erosion and Inundation

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Coastal/dune vegetation | Medium | High | Very High | Very High |
| Drainage Pipes | Medium | High | Very High | Very High |
| Point Peron Wastewater Treatment Plant | Medium | High | Very High | Very High |
| Roads | Low | High | Very High | Very High |
| Rockingham Naval Club | High | High | High | Very High |

| Inundation Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Department of Defence Land | Medium | Medium | High | Very High |
| Point Peron Camp School | Medium | Medium | Very High | Very High |
| Point Peron Wastewater Treatment Plant | Medium | Medium | Very High | Very High |
| Roads | Medium | Medium | High | Very High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| Managed Retreat | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | | | | | | | | | Do not recommend |
| | | | Drainage Infrastructure | | | | | | | | | Further assessment |
| | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | | | | | | | | | Further assessment |
| | | | Drainage Infrastructure | | | | | | | | | Recommend |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Recommend |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Do not recommend |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 3A: Boundary Road to Bent Street

## Primary Coastal Hazard(s): Erosion and Inundation

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Drainage Pipes | Medium | High | Very High | Very High |
| Dual use paths | Medium | High | High | Very High |
| Residential | Low | High | Very High | Very High |
| Roads | Medium | High | Very High | Very High |

| Inundation Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| All Parks & Recreation areas | Medium | Medium | High | Very High |
| Dual use paths | Medium | Medium | High | Very High |
| Mersey Point Carpark | Medium | Medium | Medium | High |
| Residential | High | High | Very High | Very High |
| Safety Bay Foreshore Carparks (6 total) | Medium | Medium | High | High |
| Safety Bay Yacht Club | Medium | Medium | High | Very High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Not applicable |
| Managed Retreat | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | | | | | | | | | Do not recommend |
| | | | Drainage Infrastructure | | | | | | | | | Further assessment |
| | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | | | | | | | | | Further assessment |
| | | | Drainage Infrastructure | | | | | | | | | Recommend |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Further assessment |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Further assessment |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 3B: Bent Street to Shelton Street

## Primary Coastal Hazard(s): Erosion and Inundation

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Vulnerability | | | |
| Drainage Pipes | Medium | High | Very High | Very High |
| Dual use paths | Medium | High | High | Very High |
| Residential | Low | High | Very High | Very High |
| Roads | Medium | High | Very High | Very High |

| Inundation Risk Assessment | 2017 | 2030 | 2070 | 2110 |
|---|---|---|---|---|
| | Vulnerability | | | |
| All Parks & Recreation areas | Medium | Medium | High | Very High |
| Dual use paths | Medium | Medium | High | Very High |
| Residential | High | High | Very High | Very High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Not applicable |
| | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | | | | | | | | | Do not recommend |
| | | | Drainage Infrastructure | | | | | | | | | Further assessment |
| Managed Retreat | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | | | | | | | | | Further assessment |
| | | | Drainage Infrastructure | | | | | | | | | Recommend |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Recommend |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Further assessment |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 4A: Shelton Street to Bayeux Avenue

## Primary Coastal Hazard(s): Erosion

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| **Beach** | Low | Medium | High | Very High |
| **Coastal/dune vegetation** | Low | Medium | Very High | Very High |
| **Drainage Pipes** | Low | Medium | High | High |
| **Drainage Pits** | Low | Medium | Medium | High |
| **Dual use paths** | Medium | Medium | Medium | High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Not applicable |
| | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | | | | | | | | | Do not recommend |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| Managed Retreat | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | | | | | | | | | Further assessment |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Recommend |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Do not recommend |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 4B: Bayeux Avenue to Becher Point

## Primary Coastal Hazard(s): Erosion and Inundation

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Beach | Low | Medium | High | Very High |
| Coastal/dune vegetation | Low | Medium | Very High | Very High |
| Drainage Pipes | Low | Medium | High | High |
| Drainage Pits | Low | Medium | Medium | High |
| Port Kennedy boat ramp | Low | Medium | Very High | Very High |
| Port Kennedy Foreshore Carpark | Medium | High | Very High | Very High |
| Port Kennedy Foreshore Recreation Area (park) | Low | Medium | High | Very High |

| Inundation Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Port Kennedy Foreshore Carpark | Low | Medium | High | High |
| Port Kennedy Scientific Park | Low | Medium | High | High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| Managed Retreat | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | | | | | | | | | Do not recommend |
| | | | Drainage Infrastructure | | | | | | | | | Further assessment |
| | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | | | | | | | | | Further assessment |
| | | | Drainage Infrastructure | | | | | | | | | Recommend |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Recommend |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Further assessment |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 5A: Becher Point to Secret Harbour Foreshore Park

## Primary Coastal Hazard(s): Erosion and Inundation

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Beach | Low | Medium | Medium | Medium |
| Coastal/dune vegetation | Low | Medium | High | High |

| Inundation Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Beach | Low | Low | Medium | Medium |
| Coastal/dune vegetation | Low | Low | Low | Medium |
| Port Kennedy Scientific Park | Low | Low | Low | Medium |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| Managed Retreat | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Not applicable |
| | | | Residential and commercial property. | | | | | | | | | Not applicable |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Not applicable |
| | | | Residential and commercial property. | | | | | | | | | Not applicable |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Not applicable |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Not applicable |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Do not recommend |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 5B: Secret Harbour Foreshore Park to Turtles Bend

## Primary Coastal Hazard(s): Erosion

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Beach | Low | Medium | Medium | Medium |
| Coastal/dune vegetation | Low | Medium | High | High |
| Secret Harbour Surf Lifesaving Club | Low | Low | High | High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Do not recommend |
| | | | Residential and commercial property. | | | | | | | | | Not applicable |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| Managed Retreat | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Further assessment |
| | | | Residential and commercial property. | | | | | | | | | Not applicable |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Not applicable |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Do not recommend |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Further assessment |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Do not recommend |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 6A: Turtles Bend to Crystaluna Drive

## Primary Coastal Hazard(s): Erosion

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Beach | Low | Medium | Medium | Medium |
| Coastal/dune vegetation | Low | Medium | High | High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| Managed Retreat | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Not applicable |
| | | | Residential and commercial property. | | | | | | | | | Not applicable |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Not applicable |
| | | | Residential and commercial property. | | | | | | | | | Not applicable |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Not applicable |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Not applicable |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Do not recommend |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

## Sector 6B: Crystaluna Drive to Municipal Boundary (South)

## Primary Coastal Hazard(s): Erosion

## Key Vulnerable Assets and Timeframes

| Erosion Risk Assessment | | | | |
|---|---|---|---|---|
| | 2017 | 2030 | 2070 | 2110 |
| | Vulnerability | | | |
| Beach | Low | Medium | Medium | Medium |
| Coastal/dune vegetation | Low | Medium | High | High |

| Option Category | Option Code | Option Name | Applicable Assets / Areas | Preliminary Feasibility | | | Preliminary Acceptability | | Preliminary Financial Implication | | | Recommendation |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Effectiveness | Legal / Approval Risk | Reversibility / Adaptability | Environmental / Social Impact | Community Acceptability | Economic gain / Avoidance of Cost | Capital Cost | Ongoing Cost | |
| Avoid | AV | Avoid development | Presently undeveloped land within the coastal foreshore reserve. | | | | | | | | | Recommend |
| Managed Retreat | MR1 | Leave unprotected / repair | Minor public infrastructure - e.g. benchs, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Not applicable |
| | | | Residential and commercial property. | | | | | | | | | Not applicable |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| | MR2 | Remove / relocate | Minor public infrastructure - e.g. benches, paths, amenities. | | | | | | | | | Recommend |
| | | | Major public infrastructure - e.g. buildings, roads, carparks. | | | | | | | | | Not applicable |
| | | | Residential and commercial property. | | | | | | | | | Not applicable |
| | | | Drainage Infrastructure | | | | | | | | | Not applicable |
| | MR3 | Planning controls for managed retreat | Residential and commercial property. | | | | | | | | | Recommend |
| Accommodate | AC1 | Planning controls to identify/accommodate risk | Residential and commercial property. | | | | | | | | | Not applicable |
| | AC2 | Emergency plans and controls | All areas. | | | | | | | | | Recommend |
| | AC3 | Re-design to withstand impact | Built assets. | | | | | | | | | Not applicable |
| Protect | PR1 | Dune care / sand management | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Recommend |
| | PR2 | Beach Nourishment | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR3 | Groyne(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR4 | Nearshore Reef(s) / Breakwater(s) | Beach and dunes - protective buffer to landward assets. | | | | | | | | | Do not recommend |
| | PR5 | Seawall(s) | Protective buffer to landward assets. | | | | | | | | | Do not recommend |
| Do Nothing | DN | Do Nothing | All areas. | | | | | | | | | Do not recommend |

# APPENDIX

# M

## ADAPTATION OPTIONS CONCEPT DESIGNS


Aerial imagery supplied by City of Rockingham (February 2017)
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city of Rockingham

Date
7/02/2018

Size
A3

Scale
1:4,500

0 40 80 120 160m

# SECTOR 2A-1 ADAPTATION OPTIONS - BREAKWATER CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR2A-1_ADAPTATION_BREAKWATER_REV1 01

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Date
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A3

Scale
1:4,500

# SECTOR 2A-2 ADAPTATION OPTIONS MAP - BREAKWATER CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 40 80 120 160m

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city of Rockingham

Date
7/02/2018

Size
A3

Scale
1:4,500

0 40 80 120 160m

# SECTOR 2A-1 ADAPTATION OPTIONS - GROYNE CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

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city of Rockingham

Date
8/02/2018

Size
A3

Scale
1:4,500

# SECTOR 2A-2 ADAPTATION OPTIONS MAP - GROYNE CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 40 80 120 160m

59918065-GS-001-SECTOR2A-2_ADAPTATION_GROYNE_REV1 01

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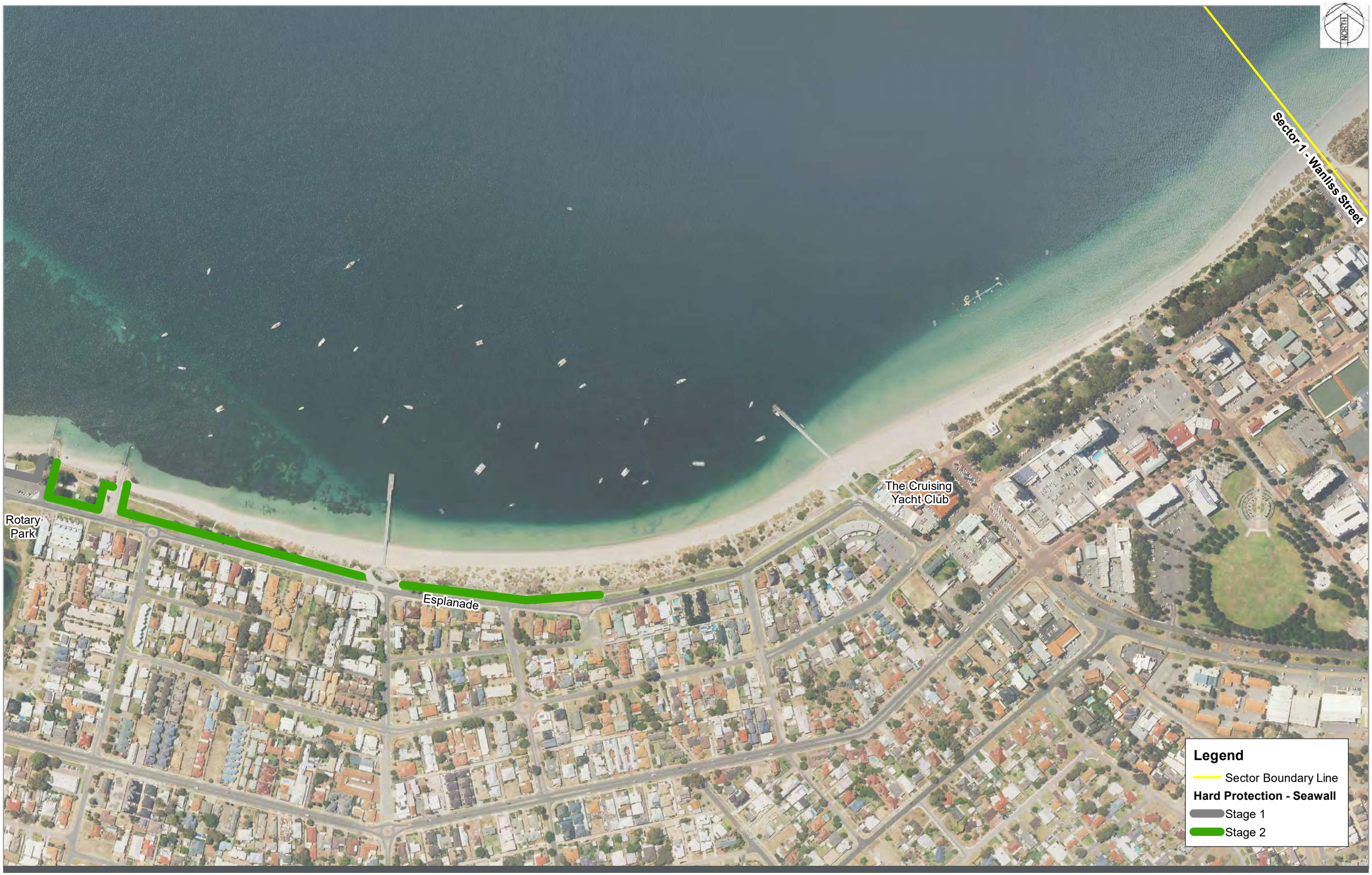


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city of Rockingham

Date
2/03/2018

# SECTOR 2A-1 ADAPTATION OPTIONS MAP - SEAWALL CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

Size
A3

Scale
1:4,500

0 40 80 120 160m

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City of Rockingham

Date
2/03/2018

Size
A3

Scale
1:4,500

# SECTOR 2A-2 ADAPTATION OPTIONS MAP - SEAWALL CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 40 80 120 160m

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Size
A3

Scale
1:7,500

0 70 140 210 280m

# SECTOR 3A-1 ADAPTATION OPTIONS - GROYNE CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

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Lions Park

Rockingham Wild Encounters

NORTH

**Legend**

- Indicative Future Shoreline

**Hard Protection - Groyne**

- Stage 1
- Stage 2

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Date
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Size
A3

Scale
1:5,000

# SECTOR 3A-2 ADAPTATION OPTIONS - GROYNE CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 40 80 120 160m

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City of Rockingham

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A3

Scale
1:5,000

# SECTOR 3A-2 ADAPTATION OPTIONS - SEAWALL CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 40 80 120 160m

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City of Rockingham

Date
9/02/2018

Size
A3

Scale
1:5,000

0 40 80 120 160m

# SECTOR 3B-1 ADAPTATION OPTIONS - BREAKWATER CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

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Date
8/02/2018

# SECTOR 3B-2 ADAPTATION OPTIONS - BREAKWATER CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

Size
A3

Scale
1:5,000

0 40 80 120 160m

59918065-GS-001-SECTOR3B-2_ADAPTATION_BREAKWATER_REV1 01

DATE PLOTTED:8/02/2018 11:03:35 AM BY: RICCARDO.DIVITA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\Adaptaion Options\59918065-GS-001-Sector3B-2_Adaptation_Breakwater_Rev1.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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city of Rockingham

Date
9/02/2018

Size
A3

Scale
1:5,000

# SECTOR 3B-1 ADAPTATION OPTIONS - GROYNE CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 40 80 120 160m

59918065-GS-001-SECTOR3B-1_ADAPTATION_GROYNE_REV1 01

DATE PLOTTED:9/02/2018 1:28:24 PM BY: RICCARDO.DIVITA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\Adaptation Options\59918065-GS-001-Sector3B-1_Adaptation_Groyne_Rev1.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
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city of Rockingham

Date
8/02/2018

Size
A3

Scale
1:5,000

# SECTOR 3B-2 ADAPTATION OPTIONS - GROYNE CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 40 80 120 160m

59918065-GS-001-SECTOR3B-2_ADAPTATION_GROYNE_REV1 01

DATE PLOTTED:8/02/2018 11:00:55 AM BY: RICCARDO.DIVITA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\Adaptation Options\59918065-GS-001-Sector3B-2_Adaptation_Groyne_Rev1.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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City of Rockingham

Date
2/03/2018

Size
A3

Scale
1:5,000

# SECTOR 3B-1 ADAPTATION OPTIONS - SEAWALL CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 40 80 120 160m

59918065-GS-001-SECTOR3B-1_ADAPTATION_SEAWALL_REV2 01

DATE PLOTTED: 2/03/2018 3:13:22 PM BY: COLIN.HART
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\Adaptaion Options\59918065-GS-001-Sector3B-1_Adaptation_Seawall_Rev2.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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City of Rockingham

Date
9/02/2018

Size
A3

Scale
1:2,500

# SECTOR 4B-1 ADAPTATION OPTIONS - BREAKWATER CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

0 20 40 60 80m

59918065-GS-001-SECTOR4B-1_ADAPTATION_BREAKWATER_REV1 01

DATE PLOTTED:9/02/2018 4:23:02 PM BY: RICCARDO.DIVITA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\Adaptation Options\59918065-GS-001-Sector4B-1_Adaptation_Breakwater_Rev1.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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city of Rockingham

Date
9/02/2018

Size
A3

Scale
1:2,500

0 20 40 60 80m

# SECTOR 4B-1 ADAPTATION OPTIONS - GROYNE CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR4B-1_ADAPTATION_GROYNE_REV1 01

DATE PLOTTED:9/02/2018 4:23:46 PM BY: RICCARDO.DIVITA
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\D\drawings\GIS\Workspaces\Adaptaion Options\59918065-GS-001-Sector4B-1_Adaptation_groyne_Rev1.mxd


Aerial imagery supplied by City of Rockingham (February 2017)
Coordinate System: GDA 1994 MGA Zone 50

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City of Rockingham

Date
2/03/2018

Size
A3

Scale
1:2,500

0 20 40 60 80m

# SECTOR 4B-1 ADAPTATION OPTIONS - SEAWALL CONCEPT

COASTAL HAZARD RISK MANAGEMENT AND ADAPTATION PLANNING
CITY OF ROCKINGHAM

59918065-GS-001-SECTOR4B-1_ADAPTATION_SEAWALL_REV2 01

DATE PLOTTED:2/03/2018 3:25:57 PM BY: COLIN.HART
FILE: V:\Jobs\59918065_Rockingham_CHRMAP\Drawings\GIS\Workspaces\Adaptation Options\59918065-GS-001-Sector4B-1_Adaptation_Seawall_Rev2.mxd

## About Cardno

Cardno is an ASX200 professional infrastructure and environmental services company, with expertise in the development and improvement of physical and social infrastructure for communities around the world. Cardno's team includes leading professionals who plan, design, manage and deliver sustainable projects and community programs. Cardno is an international company listed on the Australian Securities Exchange [ASX:CDD].

## Contact

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