TE TUPU NGĀTAHI
SUPPORTING GROWTH

Redhills Arterial Transport Network
Assessment of Flooding Effects

December 2022

Version 1.0

WAKA KOTAHI
NZ TRANSPORT AGENCY

New Zealand Government

Document Status

Responsibility	Name
Author	Saleem Akhter
Reviewer	Mike Summerhays, Roger Seyb
Approver	Bridget O'Leary

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Table of Contents

Table of Figures

Table of Tables

Abbreviations

Acronym / Term	Description
AC	Auckland Council
AEE	Assessment of Effects on the Environment
ARI	Average Recurrence Interval
AT	Auckland Transport
AUP:OP	Auckland Unitary Plan Operative in Part
CC	Climate change
CEMP	Construction Environmental Management Plan
FUZ	Future Urban Zone
MfE	Ministry for the Environment
MPD	Maximum Probable Development
NoR	Notice of Requirement (under the Resource Management Act 1991)
PWV	Precipitable water vapour
RCP	Representative Concentration Pathways
RATN	Redhills Arterial Transport Network
RL	Reduced level
RMA	Resource Management Act 1991
SGA	Te Tupu Ngātahi Supporting Growth Alliance
Te Tupu Ngātahi	Te Tupu Ngātahi Supporting Growth
Waka Kotahi	Waka Kotahi NZ Transport Agency

Glossary of Acronyms / Terms

Acronym / Term	Description
AT	Auckland Transport an Auckland Council controlled organisation.
Auckland Council	Means the unitary authority that replaced eight councils in the Auckland Region as of 1 November 2010.
Dry Pond	A permanent pond that is normally dry but during rainfall events temporarily stores stormwater runoff to control discharges. Dry ponds provide limited water quality treatment.
Freeboard	An allowance above the modelled flood level, be it road level or other features (e.g. existing floor level). For buildings freeboard shall be measured from the top water level to the finished floor level. The relevant design manual shall be referred to for the appropriate freeboard and method of calculation.
Lay down areas	An area that has been cleared for the temporary storage of materials and equipment and may include site compounds, stockpiles, sediment retention ponds.
MPD	Maximum Probable Development according to the AUP:OP zonings
Pre-development	Prior to construction of the Project
Post-development	After construction of the Project
Redhills Arterial Transport Network Assessment Package	Two Notices of Requirement (for Don Buck Road and Coatesville-Riverhead Road) and one alteration to an existing designation (Fred Taylor Drive) for the Redhills Riverhead Package of Projects for Auckland Transport.
Stormwater Wetland	Constructed wetlands that temporarily store runoff and support conditions suitable for the growth of wetland plants. Stormwater wetlands provide enhanced water quality treatment of stormwater runoff through vegetation uptake, retention and settling.
Terrain	An elevation model which includes the ground levels based on 2016 LiDAR and the concept design ground levels.
Wet Pond	A permanent pond that has a standing pool of water and provides water quality treatment, and storage of stormwater runoff to reduce the peak water volume from a rainfall event and provide downstream erosion protection.

1 Executive Summary

This report provides an assessment of flood risks associated with the construction, operation and maintenance of the North West – Redhills Arterial Transport Network (**RATN**). The relative location of this site is shown in Figure 1-1 below.

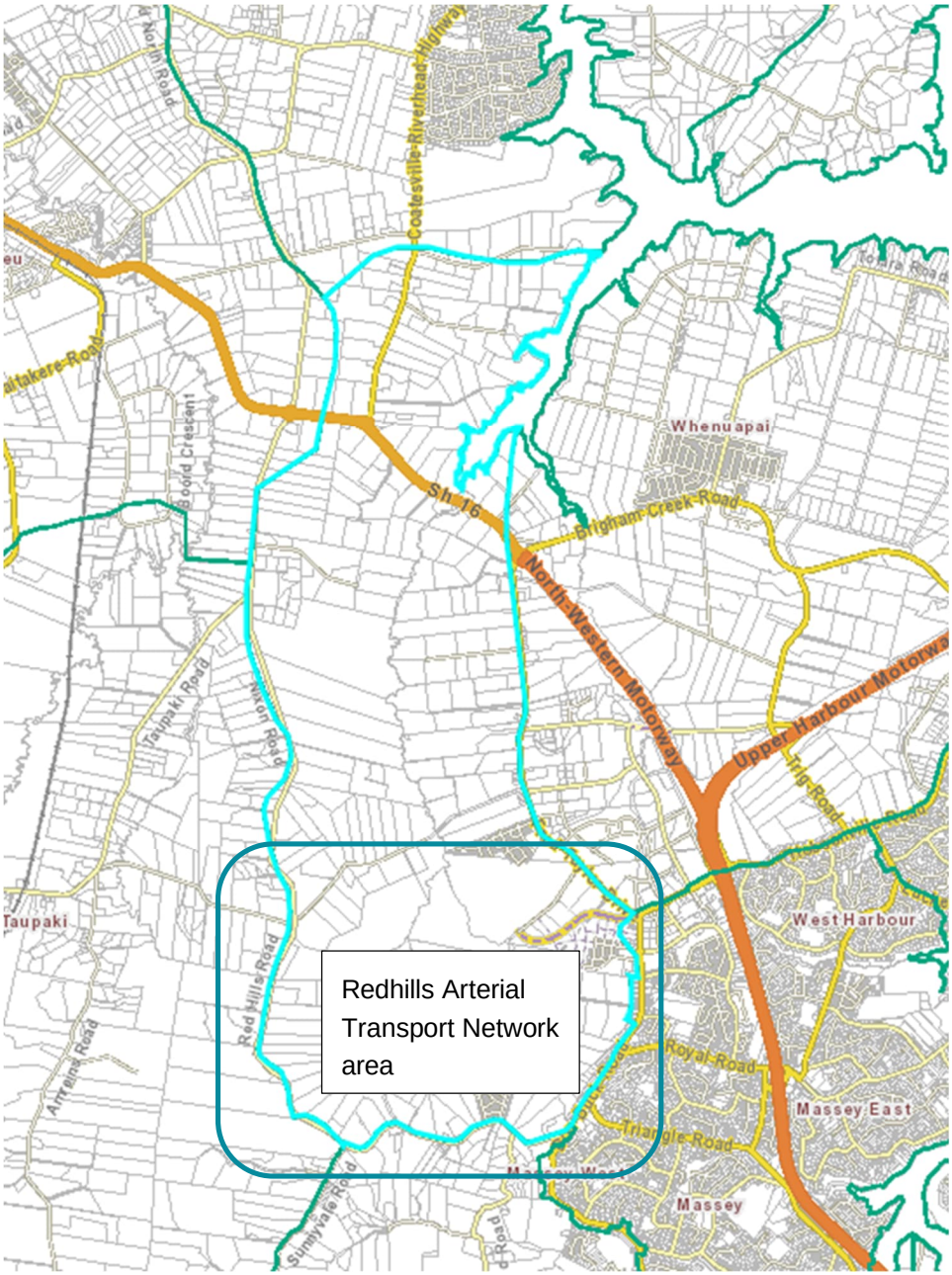

Figure 1-1: Location of the Redhills Arterial Transport Network

Flooding is a natural hazard and has therefore been considered as part of the Redhills Arterial Transport Network Notices of Requirement. The works required for the Redhills Arterial Transport Network have the potential to lead to flooding effects and an assessment of predicted flood effects is provided to demonstrate that these effects can be appropriately mitigated in the future. It is also acknowledged that there will be a subsequent process for seeking regional resource consents which will address a wider range of potential stormwater quantity and quality effects.

In the context of this assessment, flood hazard risk may include changes to:

- the flood freeboard to existing habitable buildings, overland flow paths
- the ability to access property by residents and emergency vehicles
- the level of flooding to roads and flooding arising from the blockage of stormwater drainage
- effects to existing habitable buildings / infrastructure and potential future effects on upstream and downstream properties.

Methodology

The assessment of flooding effects for the Redhills Arterial Transport Network has involved the following steps:

- Desktop assessment to identify potential flooding locations from Auckland Council GeoMaps
- Modelling of the pre-development terrain with Maximum Probable Development (**MPD**) and 100year Average Recurrence Interval (**ARI**) plus climate change rainfall
- Two climate scenarios were modelled, one allowing for 2.1°C of temperature increase and one for 3.8°C of temperature increase. The higher climate change scenario has been used to undertake a sensitivity analysis to understand the increased risk of greater climate change impacts
- Producing flood level maps for the pre-development scenario to show the flood levels and extents (greater than 50 mm) that need to be considered
- Inspection and review of flood maps at key locations such as proposed bridges and major earthworks to ensure allowed for in future design.

While stormwater effects apart from flooding are not assessed, provision is made for the future mitigation of potential stormwater effects (stormwater quantity, stormwater quality and instream structures) by identifying the space required for stormwater management devices (for example ponds) and incorporating land for that purpose into the proposed boundaries. These devices have been designed to attenuate the 100year ARI event by using 10% of the total roading impervious catchment area (proposed and existing) as the required device size – which is sufficient for a device in accordance with Auckland Council and Waka Kotahi guidance[1,2].

The assessment considers that flooding effects will be subject to further assessment at a detailed design stage. It is expected that coordination and integration of the corridor design with future urban development within the Redhills area will be undertaken to confirm and mitigate potential future adverse effects.

Positive Effects

The main positive effects that could be designed allow for:

- existing widened roadway to be above the flood plains
- ability to convey flows without worsening flooding impacts upstream or downstream of the works
- added water quality treatment and attenuation of the total proposed roadway impervious area for Dunlop Road (an existing road) as opposed to just the additional impervious area.,

The scale of these effects will be determined at detailed design stage.

[1] Auckland Council's Stormwater Management Devices in the Auckland Region, Guideline Document 2017/001 (December 2017)
[2] Waka Kotahi NZTA's Stormwater Design Philosophy Statement (May 2010)

Construction phase effects

The potential construction flooding effects can be appropriately managed with the measures set out in Section 6.1 . There may be some temporary construction phase flooding risk associated with temporary works required for the construction of culverts and stormwater management infrastructure. However, the details of the construction approach will be confirmed at detailed design.

It is expected that construction works can be carried out in a way that will appropriately manage the risk. Flood risk mitigation measures will be captured in the Construction Environmental Management Plan (**CEMP**) and it is recommended this be included as a condition of the proposed designation.

Operational phase effects

Redhills Arterial Transport Network

The Redhills Arterial Transport Network is near the top of the Redhills catchment therefore flood flows and stormwater effects will be minimised.

There is a minor risk of flooding at locations of bridges, particularly on the main stream reach. Existing overland flow paths can be accommodated although these may be impacted by the future development within the area, with some of the flow reduced by piping.

Potential flooding effects will be appropriately managed and will be negligible up to minor effects subject to the recommended design outcomes and conditions outlined in this Report.

Water quality and attenuation ponds will be optimised to minimise ongoing operational costs and maximise benefit.

The operational flood risks are classified as minor. Operational impacts will aim to be resolved during detailed design by optimising the design of culverts to minimise flood effects upstream and downstream of culvert crossings. Potential flooding effects will be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in this Report.

Sensitivity Analysis

The sensitivity analysis for the potential increased rainfall due to climate change found there was a slight change to the identified flood effects at key locations under a more severe climate change scenario (3.8° temperature change). However, no additional mitigation is required as it is anticipated these effects can be mitigated utilising appropriate design.

2 Introduction

This flooding assessment has been prepared for the North West Redhills Arterial Transport Network Notices of Requirement (**NoRs**) for Auckland Transport (**AT**). The NoRs aim to designate land for future transport corridors as part of Te Tupu Ngātahi Supporting Growth Programme (**Te Tupu Ngātahi**) to enable the construction, operation and maintenance of transport infrastructure in the North West area of Auckland.

An overview of the Redhills Arterial Transport Network is provided in Figure 2-1 below.

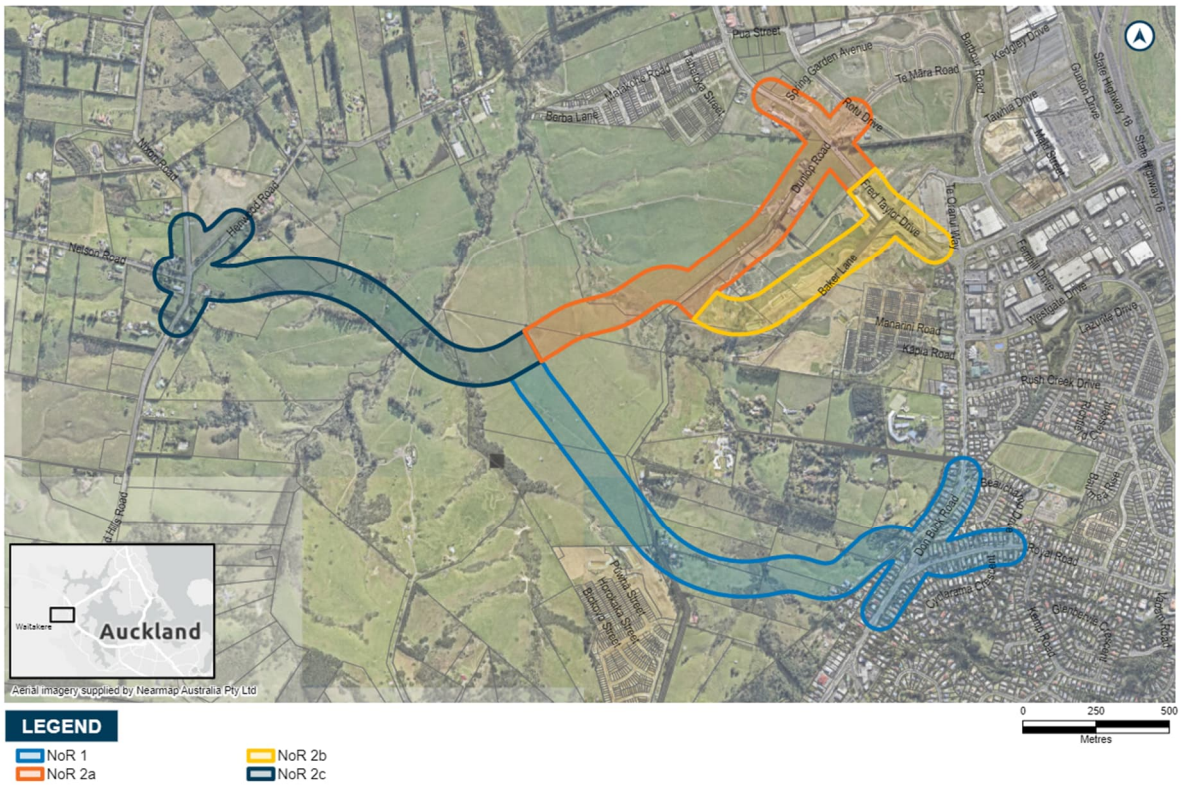

Figure 2-1: Redhills Arterial Transport Network

A brief summary of the Redhills Arterial Transport Network project corridors and corresponding NoRs is provided in Table 2-1 below.

Table 2-1: Redhills Arterial Transport Network Assessment Package Project Summary

Corridor	NOR	Description	Requiring Authority
Redhills North-South Arterial Corridor	**NoR1**	New urban arterial transport corridor and upgrade of Don Buck and Royal Road intersection.	Auckland Transport
Redhills East-West Arterial Corridor – Dunlop Road	**NoR2a**	New urban arterial transport corridor that intersects with Fred Taylor Drive and connects to the remaining East-West corridor (NoR2c) at the intersection with the Redhills North-South arterial corridor.	Auckland Transport

Corridor	NOR	Description	Requiring Authority
Redhills East-West Arterial Corridor – Baker Lane	**NoR2b**	New urban arterial transport corridor that intersects with Fred Taylor Drive and connects to the intersection of the remaining East-West connection and Dunlop Road (NoR2a).	Auckland Transport
Redhills East-West Arterial Corridor – Nixon Road connection	**NoR2c**	New urban arterial transport corridor that intersects with the Redhills East West Arterial Corridor – Dunlop Road. This includes the upgrade of the existing Red Hills Road / Nelson Road / Nixon Road intersection, and the existing Nixon Road / Henwood Road intersection.	Auckland Transport

Please refer to the AEE for further information on these projects, including a project description, key project features and the planning context.

2.1 Purpose and Scope of this Report

This report considers the actual and potential effects associated with the construction, operation and maintenance of the Redhills Arterial Transport Network on the existing and likely future environment as it relates to flooding / stormwater effects and recommends measures that may be implemented to minimise, remedy and / or mitigate these effects.

The key matters addressed in this report are as follows:

- Identify and describe the actual and potential flooding effects of each Project corridor within the RATN
- Recommend measures as appropriate to minimise, remedy or mitigate actual and potential flooding effects (including any conditions / management plan required) for each Project corridor within the RATN
- Present an overall conclusion of the level of actual and potential flooding effects for each Project corridor within the RATN after recommended measures are implemented.

This report draws a distinction between stormwater effects and flood hazard effects, which are a subset of potential stormwater effects.

Stormwater effects are broadly divided into:

- Quantity effects (such as flooding, erosion and changes to hydrology – which may cause effects on stream habitat, baseflow and sediment movement in streams)
- Quality (including the discharge of contaminants – which may cause effects on aquatic fauna, public health and amenity values) and the effects on streams due to the presence of in-stream structures.

These effects are considered through RMA section 13, 14 and 15 consents and are administered by regional councils (or, in the case of Auckland, as regional consents by the Auckland Council as a Unitary Authority).

Provision is made for the future management of the stormwater effects (stormwater quantity, stormwater quality and instream structures) by identifying the space required for stormwater management devices (for example drainage channels and wetlands) and incorporating land for that purpose into the NoRs. In identifying the land required for these devices, preliminary sizing and siting has been undertaken and offset allowances made for construction phase works.

The designation is a land use or district planning mechanism. Hence, the assessment of effects has been limited to flood hazard matters as they are the only matters that would trigger a District Plan consent requirement under the AUP: OP. In presenting information on flood hazard effects, it is therefore acknowledged that there will be a subsequent process for seeking regional council consents.

Flood hazard effects include changes to; the flood freeboard to buildings, the depth of flooding on property, the creation of new overland flow paths, the ability to access property by residents and emergency vehicles and potential flood prone areas caused by blockage of culverts.

2.2 Report Structure

The report is structured as follows:

- Overview of the methodology used to undertake the assessment and identification of the assessment criteria and any relevant standards or guidelines
- Description of the Redhills Arterial Transport Network corridor and project features as it relates to stormwater
- Identification and description of the existing and likely future flooding environment
- Description of the actual and potential adverse flooding effects of construction and operation
- Recommended measures to minimise, remedy or mitigate potential adverse flooding effects
- Overall conclusion of the level of potential adverse flooding effects after recommended measures are implemented.

This report should be read alongside the AEE, which contains further details on the history and context of the RATN. The AEE also contains a detailed description of works to be authorised, likely staging and the typical construction methodologies that will be used to implement this work.

2.3 Preparation for this Report

In preparation of this report several resources were used to support the assessment. These included technical specialist inputs, previous reports, catchment flood models and team workshops.

The AUP:OP was used to identify the existing and likely future environment. Information from the Project Team and SGA Redhills base case model was used to assess the flood water levels and extents of the existing (pre-development) terrain based on the Auckland Council 2016 LiDAR.

3 Assessment Methodology

3.1 Assessment of flooding effects

The assessment of flooding effects has involved the following steps using the Auckland Council and SGA GIS.

- Desktop assessment to identify potential flooding locations, namely:
  - Existing buildings appear to be near / within the existing flood plains
  - Where works are near stream crossings and major overland flow paths
- Flood modelling of the pre-development (without SGA) case, including:
  - Flood modelling of the proposed future land use case using imperviousness based on AUP: OP land zoning with the 100yr ARI plus two climate change rainfall scenarios, being 2.1 and 3.8° temperature increases
  - Identifying potential changes in the predicted flood water levels for the two climate change scenarios to understand the risk of future increased climate change impacts
- Inspection of the flood maps to identify flooding effects, including:
  - At key cross drainage locations such as culverts and bridges to understand predicted water levels for the two climate change scenarios
  - Existing buildings showing potential for flooding by comparing flood extents with the existing building footprints.

3.2 Outcomes based approach

The stormwater and flooding considerations are based on an indicative design designation boundary which incorporate flexibility for design changes to respond to the future environment. The effects assessment is based on being able to meet the requirements of the proposed designation flooding condition and provide any required mitigation within the designation boundary.

The proposed designation flood condition requires the design to achieve the following outcomes:

- No increase in flood levels for existing authorised habitable floors that are already subject to flooding (that is, no increase in flood level where the flood level using the pre-project model scenario is above the habitable floor level)
- No more than a 10% reduction in freeboard for existing authorised habitable floors (that is, if existing freeboard was 500mm, an acceptable change would be to reduce freeboard to 450mm)
- No increase of more than 50mm in flood level on land zoned for urban or future urban development where there is no existing habitable dwelling
- No new flood prone areas (with a flood prone area defined as a potential ponding area that relies on a single culvert for drainage and does not have an overland flow path).

Compliance with the recommended flooding outcomes, secured by the proposed condition, will ensure that potential flooding effects will be negligible up to minor and appropriately managed.

Where the above outcomes can be achieved through alternative measures outside of the designation such as flood stop banks, flood walls and overland flow paths, this may be agreed with the affected property owner and Auckland Council.

This assessment identifies where flood effects require consideration and the types of mitigation measures that could be implemented to address the effect. The designation boundary has been confirmed to provide sufficient land to accommodate those potential mitigation measures identified.

Compliance with these flooding outcomes would be demonstrated through a detailed stormwater design and further flood modelling of the pre-development and post-development 100yr ARI flood levels (with allowances for full development according to the AUP:OP zonings with associated imperviousness and climate change) at the resource consent stage.

3.3 Desktop Assessment

To identify locations considered to be at risk of flooding effects a desktop study was carried out to identify areas where:

- Existing buildings are near / within the existing flood plains
- The project involves carrying out significant work near the stream crossings / major overland flow paths
- The project may alter the existing flood plains, ponding volumes, and natural drainage paths.

The following reference materials were used to perform the desktop study:

- Auckland Unitary Plan Operative in Part
- Auckland Council GIS resources (Auckland GeoMaps)
- Concept Design Drawings
- Flood maps created by the SGA modelling team
- NZTA Stormwater Specification P46
- New Zealand Bridge Manual (SP/M/022) for freeboard allowance.

A full list of references is provided in Section 13.

3.4 Flood Modelling

3.4.1 Stormwater Catchment Overview

The Redhills catchment is approximately 1,366 ha in total area and drains via the Waiteputa and Ngongetepara Streams to the upper reaches of the Waitematā Harbour.

The Redhills Arterial Transport Network area is situated within the Redhills stormwater catchment as shown in Figure 3-1.

The AUP:OP allows for the area between Fred Taylor Drive and Redhills / Nixon Roads to be fully developed in future.

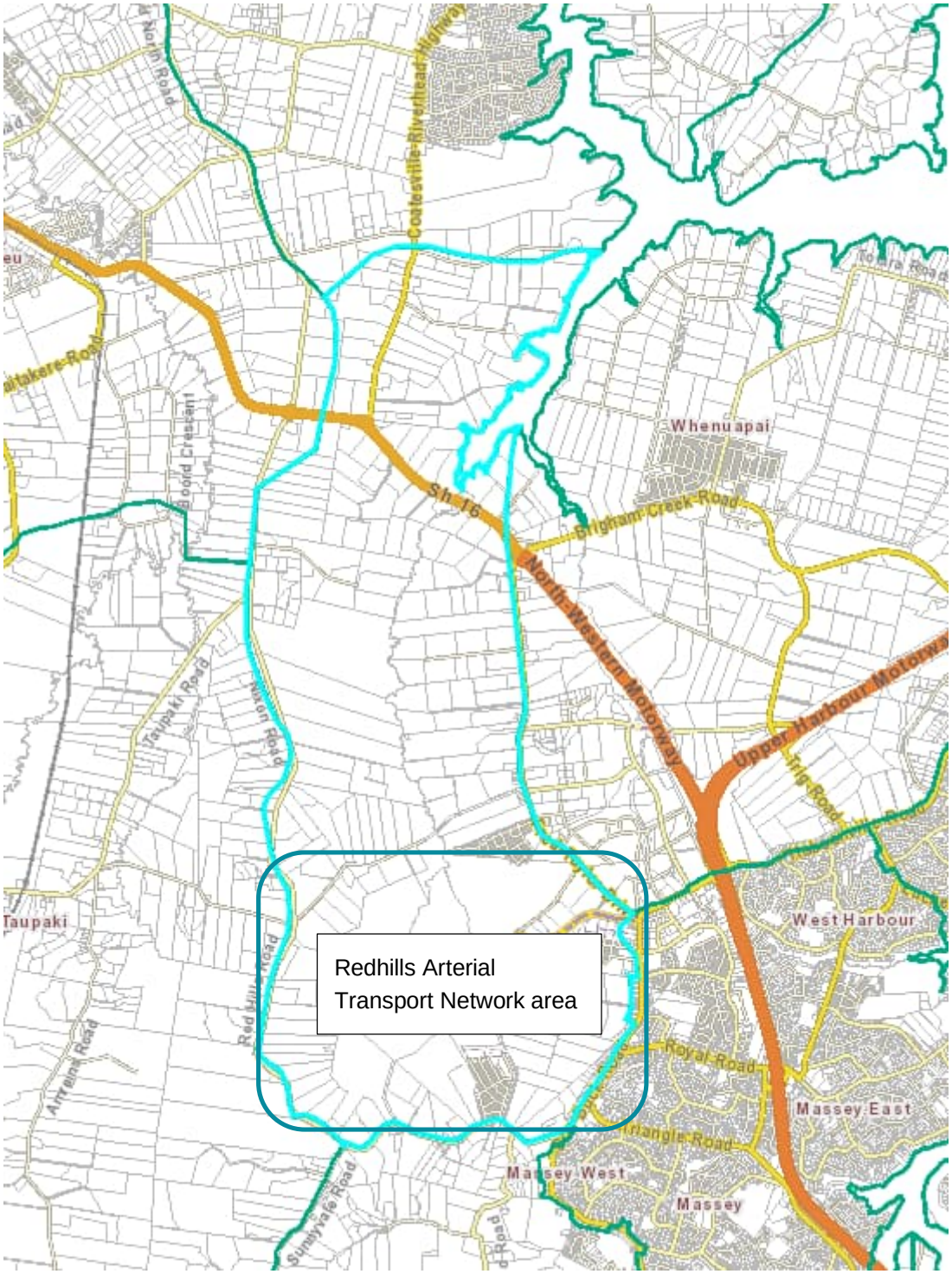

Figure 3-1: Redhills catchment area with Redhills Arterial Transport Network area shown

The assessment in this report is limited to the routes shown in Figure 3-2 below being:

- Nixon Road intersection
- East-West and North-South Arterials
- Dunlop Road
- Baker Lane
- Fred Taylor Drive intersections
- Don Buck Road intersection.

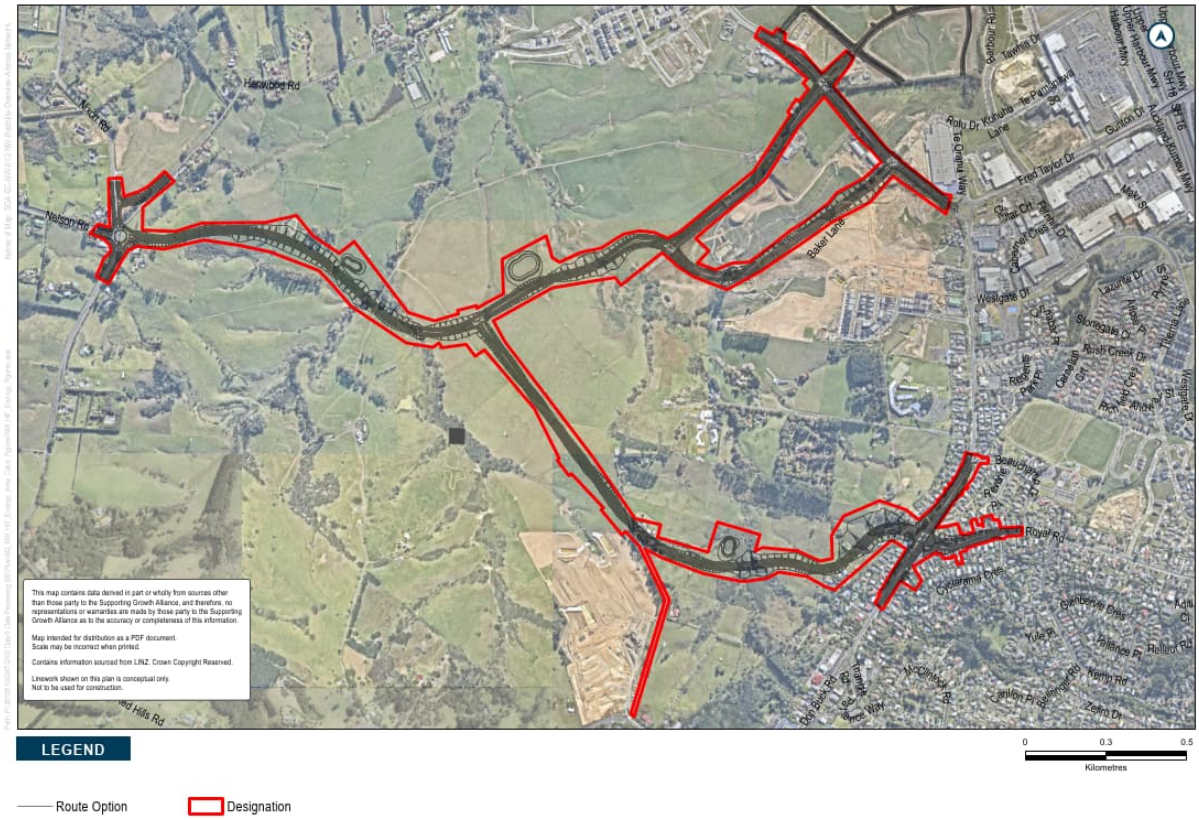

Figure 3-2: Proposed Redhills Arterial Transport Network alignments

3.4.2 Modelling Approach

SGA produced the Redhills catchment model based on the Auckland Council Rapid Flood Hazard Assessment (**RFHA**) approach with any existing road culverts 675mm and greater included in the model which is a higher standard than the AC approach which only includes bridges and culverts with sizes 1200mm and greater. The reason for selecting 675mm is that the risk of blockage and not operating is much greater for pipes 600mm and smaller.

Previous modelling results for the area shown on Auckland Council GeoMaps indicates those results to be based on 2009 RFHA using the existing land cover and no climate change effects.

The SGA modelling allows for the area to be developed to the future allowable impervious coverage as per the AUP:OP zoning and the Auckland Council Healthy Waters Impervious coverage memo (refer section 3.4.6 below) along with climate change rainfall.

The two climate change rainfall scenarios modelled for the assessment of effects were based on the Auckland Council TP108 rainfall for the area and were:

- Scenario 1: Without SGA: Future 100year ARI rainfall event with 2.1°C of warming and future land-use
- Scenario 2: Without SGA: Future 100yr ARI rainfall event with 3.8°C of warming and future land-use.

The modelling used the existing terrain (AC 2016 LiDAR). The type and size of cross drainage structures are not fixed and will be assessed further for subsequent regional consenting and design

phases. Changes to these structures may alter the future model outputs and upsizing the crossings may be required to reduce upstream and downstream flood risk.

More details of the Redhills model build approach can be found in SGA North West Local – Redhills Base Case Stormwater Model Build report December 2020 version 0.2.

3.4.3 Climate Change

Climate change is accounted for in the model runs as per the revised Auckland Council (**AC**) Code of Practise (**CoP**) version 3 dated January 2022, which allows for 2.1°C of warming and a 16.8% increase on rainfall. A sensitivity analysis to understand the risk of climate change of warming to 3.8°C – which is an extreme climate change scenario increase (RCP 8.5).

3.4.4 Site Geology

Soil description obtained from the New Zealand Geology Maps indicated three main soil groups in the proposed location of the identified roads. The three main soil groups are as follows (GNS Science, 2018):

- East Cost Bays Formation of Warkworth Subgroup (Waitematā Group)
  - This group have alternating sandstone and mudstone with variable volcanic content and interbedded volcanistic grits. The rock group include alternating sandstone / siltstone
- Late Pilocene to Middle Pleistocene pumiceous river deposits
  - Pumiceous mud, sand and gravel with muddy peat and lignite: rhyolite pumice, including non-welded ignimbrite, tephra and alluvia. The main rock group is sandstone
- Holocene River Deposits
  - Sand, silt mud and clay with local gravels and peat beds

3.4.5 Modelling Outputs

The 100 year future climate change rainfall with 2.1° temperature increase model run predicted the flood extent results to 50mm deep are shown in Figure 3-3 and Figure 3-4 below. This is for the upper catchment area where the RATN is proposed.

Note some of this flood extent may create flows that are less than 2m^3/s therefore they could be classified as overland flow paths and not flood plains although the effects still need to be considered.

The modelling outputs were used to identify the predicted flooding extents and flow rates for the proposed alignment.

For those areas identified as having potential flood effects mitigation measures have been proposed which can be addressed at detailed design stage (e.g. formation levels and widths, bridge size, pond location and culverts).

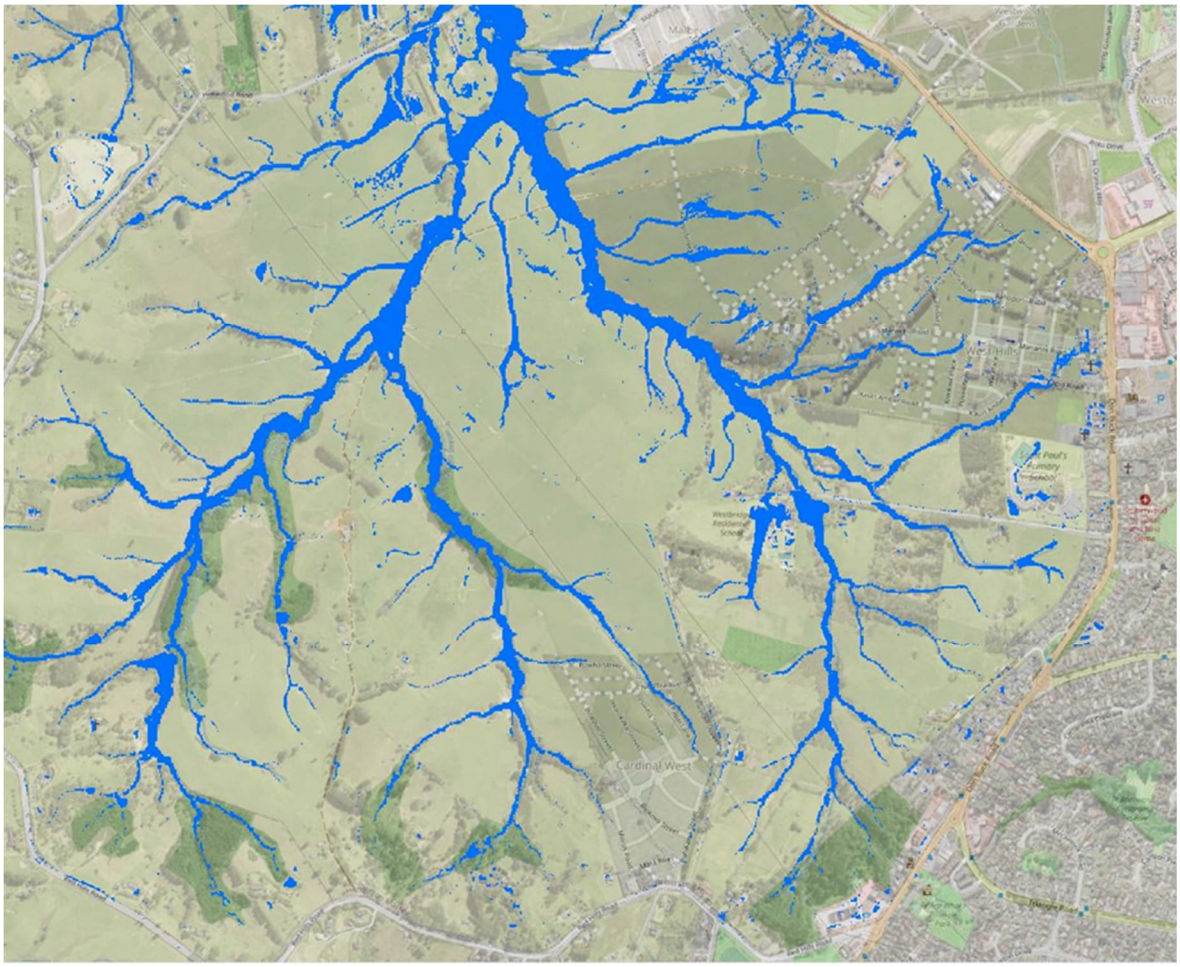

Figure 3-3: Predicted future 100yr ARI with climate change flood extent for the upper reaches of the Redhills catchment (SGA modelling)

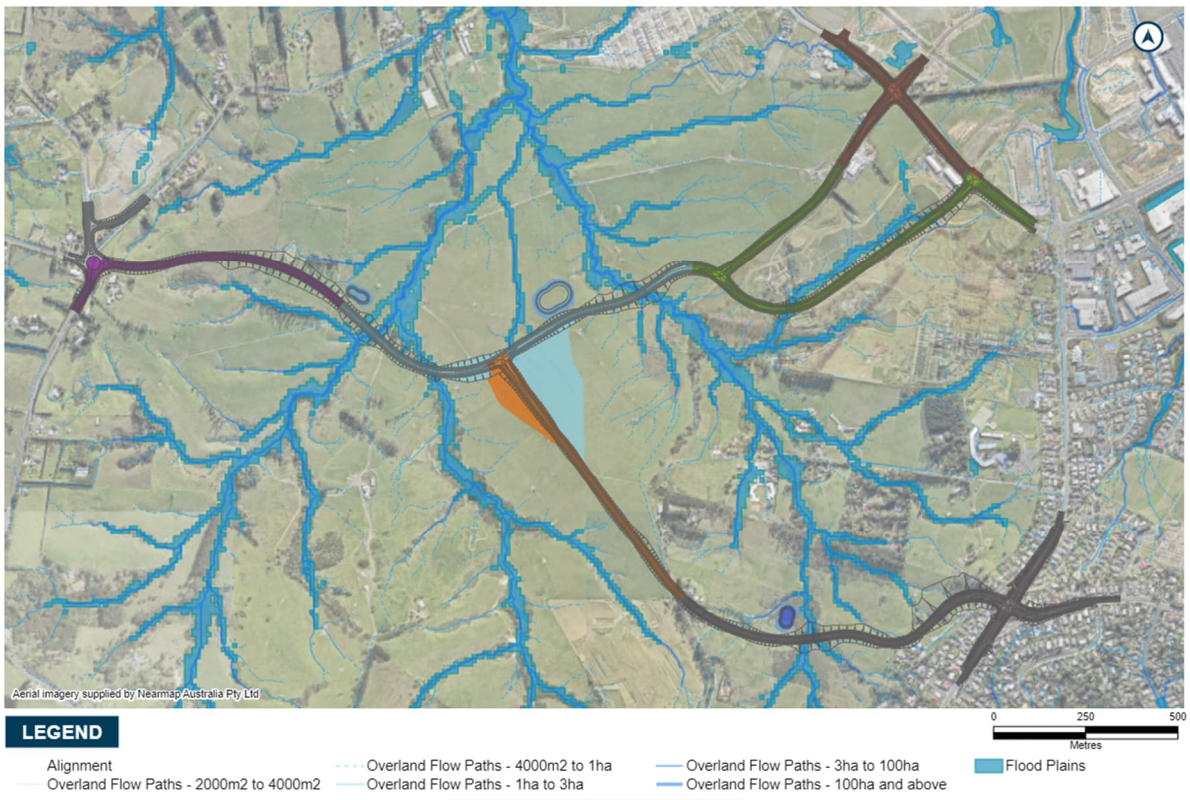

Figure 3-4: Predicted 100yr ARI flood extent with the RATN overlaid

The required freeboard for bridges and culverts that could be used to assess the suitability of the detailed design is set out in Table 3-1.

Table 3-1: Freeboard allowance for the level of serviceability to traffic (NZ Bridge Manual)

Waterway Structure	Situation	Freeboard	
Bridge	Normal circumstances	From the predicted peak flood water level to the underside of the superstructure	0.6
	Where the possibility that large trees may be carried down the waterway exists		1.2
Culvert	All situations	From the predicted flood water level to the road surface	0.5

3.4.6 Future Development

Development within the Redhills Arterial Transport Network (RATN) area will change catchment hydrology, the terrain, building and property types that are potentially exposed to flooding. The assessment has therefore generally considered effects on potential future development areas. It is anticipated that future developments will take account of flood risk and manage that risk within their development. Figure 3-5 below shows the Auckland Unity Plan: Operative in Part zones for the Redhills Arterial Transport Network area.

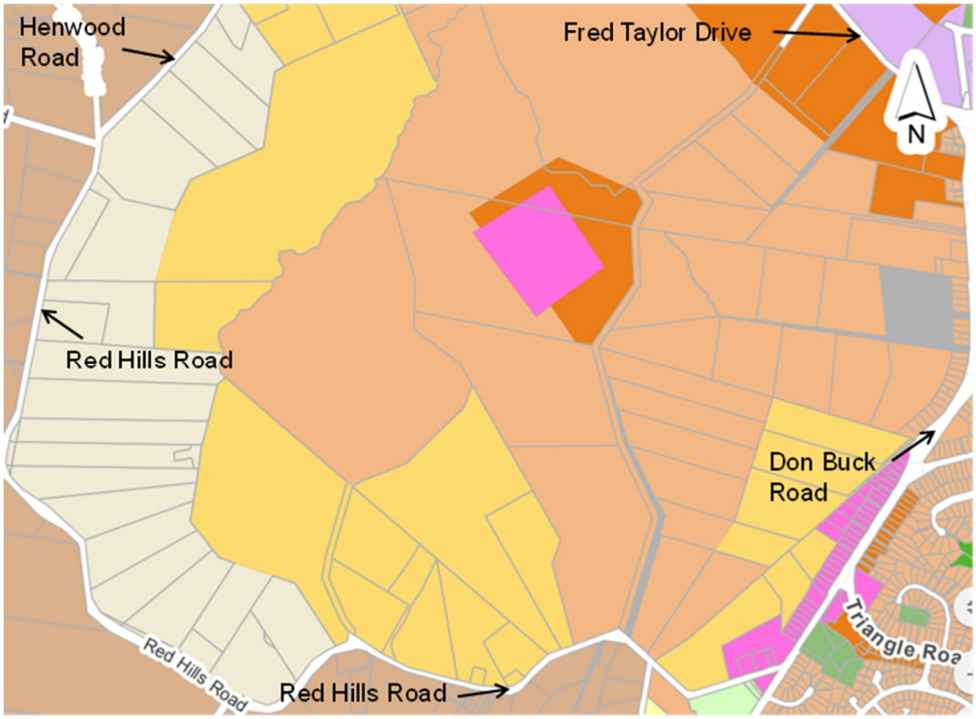

Figure 3-5: Auckland Unitary Plan Zones

According to the AUP:OP the RATN site is located within the following development zones.

- Business – Business Local Centre zone
- Residential – Terrace Housing and Apartment Buildings Zone
- Residential – Mixed Housing Urban Zone
- Residential – Mixed Housing Suburban Zone
- Residential – Single House Zone.

Auckland Council Healthy Waters has provided guidance on the maximum impervious area on the site through their "Land Use Zone Imperviousness for Hydraulic Modelling based on the Auckland Unitary Plan Operative in Part" memo dated 4 Sept 2019 which has been used in the SGA modelling.

Table 3-2 sets out the basis for consideration of the maximum impervious area for future developments within the site.

Table 3-2: AC Healthy Waters recommended maximum impervious coverage based on AUP:OP zonings

Development	Maximum Impervious Area (% of the site area)
Business: Business Local Centre zone	100
Residential: Terrace housing and apartment buildings zone	70
Residential: Mixed housing urban zone	60
Residential: Mixed housing suburban zone	60
Residential: Single house zone	60

3.4.7 Model Limitations

The modelled scenarios use imperviousness assumptions associated with the future land use(s) shown in the Auckland Plan. However, it is possible that significant change in the catchments may take place before or shortly after the corridor is constructed. Therefore, it is anticipated that further modelling will be required during the corridor detailed design phase to take account of catchment characteristics at that time.

Rapid Flood Hazard Assessment models have a relatively coarse terrain grid and do not include stormwater drainage pipes smaller than 600mm diameter. Culverts have been added at selected crossings of the project corridors. However, the results from the models are considered appropriate to assess the relative or overall flooding effects due to the project corridors for the current stage of design.

Generally Redhills Arterial Transport Network is located on elevated terrain (near ridgelines) and it is unlikely that upgrades to existing culverts will be required. However, any new or upgraded culverts will be confirmed at the detailed design stage and will take into account matters such as consent requirements, asset owner requirements, level of service, stream simulation design, fish passage and possible blockage.

Normal modelling limitation set out in the SGA North West Local – Redhills Base Case Stormwater Model Build report December 2020 version 0.2 also apply to this assessment

3.4.8 Sensitivity Analysis

Sensitivity is the degree to which a system is affected, adversely or beneficially, by a given exposure[3]. In this instance the sensitivity of the designation to increased rainfall as a result of climate change has been considered.

The flood model has allowed for 2.1°C of warming and a 16.8% increase on rainfall based on the AC CoP. However, given the uncertainty of climate change effects in the future the assessment has also considered a more severe climate change scenario based on 3.8°C of warming and a 32.7% increase on rainfall.

The results for 3.8°C of warming have been compared to those reported in the flood assessment for 2.1°C of warming and areas where higher rainfall may increase flooding risk have been identified. Further mitigation at these locations has been included where necessary to encourage flood resilience.

In the future it is possible there may be different requirements for climate change, however, at this time a pragmatic approach has been taken and the sensitivity analysis has been prepared to better understand the risk of climate change and enable decision makers to respond to this.

3.5 Stormwater infrastructure

3.5.1 Stormwater devices

While stormwater effects apart from flooding were not fully assessed, provision was made for the future management of potential stormwater effects (stormwater quantity and stormwater quality) by

[3] Intergovernmental Panel on Climate Change. (2007). Climate Change 2007: Contribution of Working Group II to the Fourth Assessment Report. Cambridge, UK: Cambridge University Press.

identifying the space required for stormwater management devices (i.e. attenuation ponds and wetlands) and incorporating land for that purpose into the NORs.

In identifying the land required for these devices, preliminary sizing and siting has been undertaken and extra space allowed for constructing the works. Potential sites are shown as Wetlands 1 to 3 in Figure 3-6 below.

Some key assumptions that were used to identify the amount of land sought for stormwater management works within the designation include the following:

- Wetlands are sized to attenuate 100 year peak flows from the corridor (as of the required stormwater wetland sizing criteria this gives the largest footprint)
- Quality and retention / detention requirements are able to fit within the footprint
- Allowance is made for wetland attenuation storage and hydraulic gradients from corridor inlet to discharge point (typically a minimum of 2.0 to 2.5m vertically)
- Wetland geometry and footprints were modelled to determine the required cut and fill and a 15m buffer added for construction purposes and maintenance access
- A minimum 6m buffer is provided around the corridor earthworks extents to provide space for construction purposes and allow for works such as drainage channels and culvert inlets / outlets and flexibility in the vertical alignment
- Diversion channels are identified where they are needed to prevent upstream flooding.

These allowances are considered appropriate for sizing the devices at this early stage of the design process and also provide some flexibility for future refinement. The design of devices is not discussed further in this report as this is considered a matter that will be developed further for the future regional consents and implementation processes.

The flood model does not account for the flood water storage capacity provided by the proposed wetlands even though they are designed with attenuation capacity for the additional runoff generated by the increased impervious area from the new road infrastructure.

The possible wetland locations are shown in Figure 3-6 below with catchments shown in Figure 3-7.

The road catchments contributing to each wetland are:

- Wetland 1: Road catchment 1
- Wetland 2: Road catchments 2 to 5
- Wetland 3: Road catchment 6.

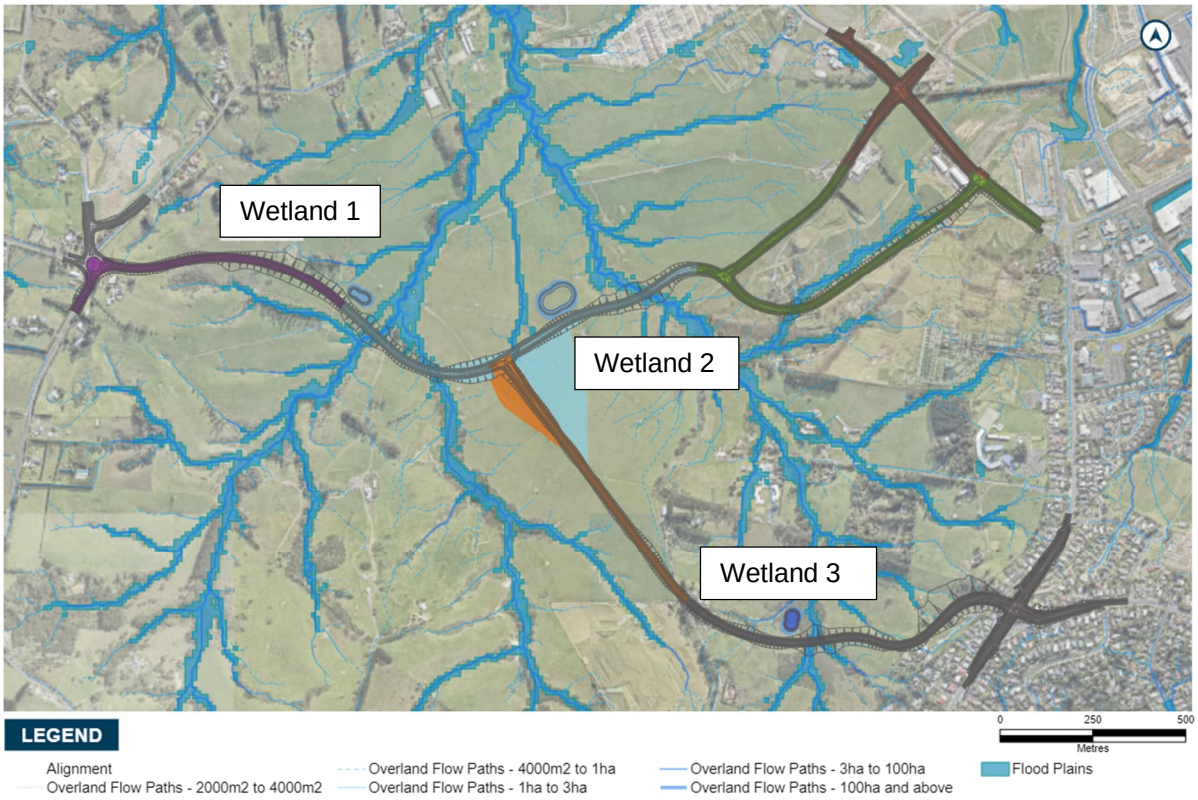

Figure 3-6: Possible wetland locations

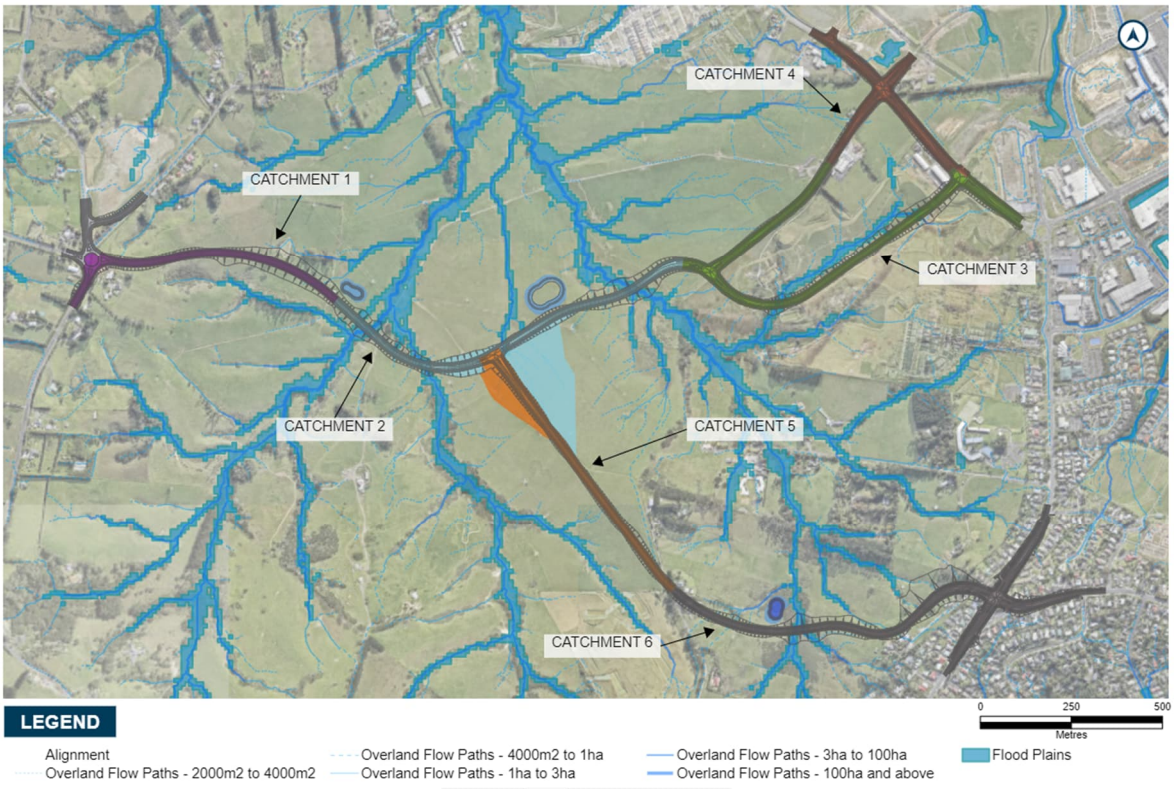

Figure 3-7: Wetland catchments

3.5.2 Stormwater bridges and culverts

Stormwater bridges and culverts have been assessed on the alignment of the main streams and overland flow paths as shown in Figure 3-3 and Figure 3-4 above.

Figure 3-8 below indicates potential bridge and culvert locations based on predicted overland flow paths from modelling.

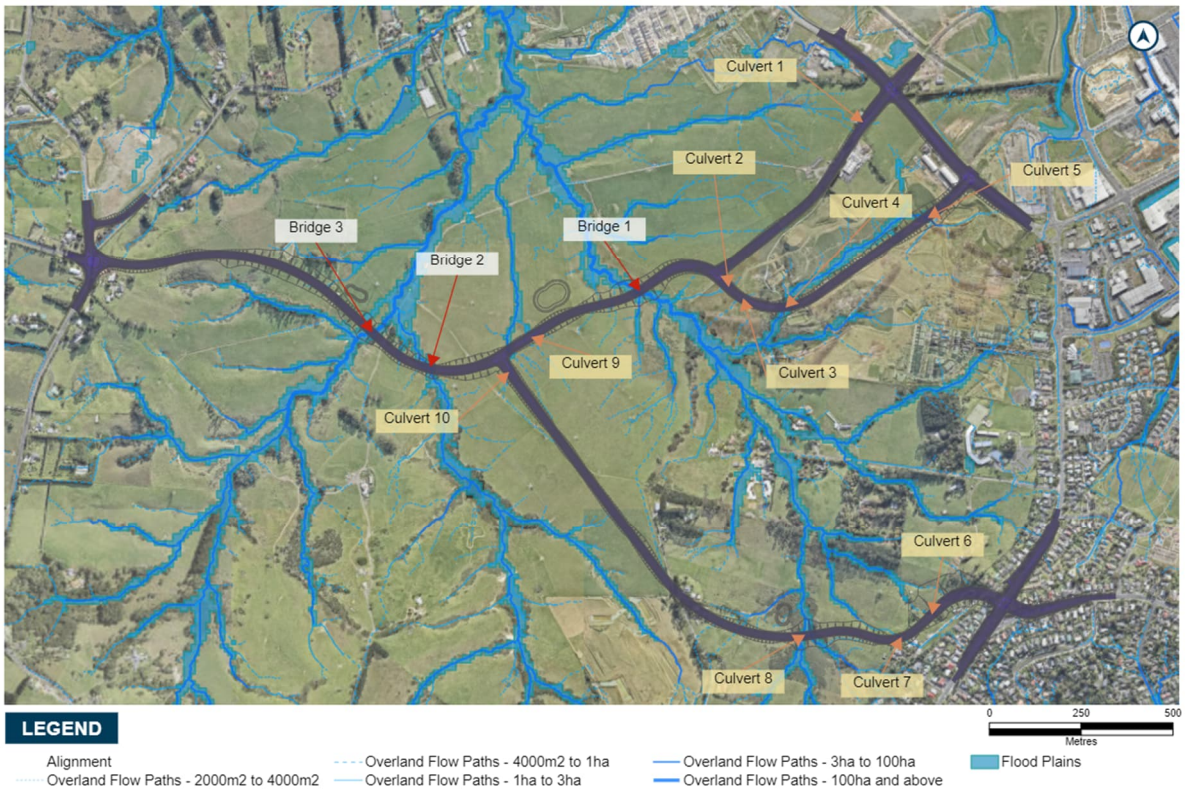

Figure 3-8: Potential bridge and culvert locations

The flows and water levels at the potential bridge and culvert sites shown in Figure 3-8: Potential bridge and culvert locations above have been assessed for the two climate change scenarios; 100yr future climate change rainfall with 2.1°C of temperature increase, and 100yr future climate change rainfall with 3.8° temperature increase. The results are shown in Table 3-3 below.

These results can then be used in the detailed design phase to assess road level based on freeboards above predicted flood levels and bridge / culvert openings can be sized to achieve flood neutrality upstream and downstream of the bridge or culvert.

Table 3-3 shows that although the predicted flow rates increase from the 2.1 to 3.8° temperature increase scenario the predicted water levels do not change dramatically.

Table 3-3: Bridge and culvert information

	100yr future flow (m3/s)		100yr future water level (m)	
Structure	2.1° temperature increase	3.8° temperature increase	2.1° temperature increase	3.8° temperature increase
Culvert 1	0.21	0.41	53.98	53.99
Culvert 2	0.37	0.51	36.51	36.53
Culvert 3	0.19	0.25	36.82	36.83
Culvert 4	5.95	8.29	33.28	33.37
Culvert 5	1.40	1.96	47.04	47.07
Culvert 6	0.59	0.75	57.21	57.24
Culvert 7	0.16	0.29	51.56	51.59
Culvert 8	11.32	15.48	41.80	41.94
Culvert 9	0.63	0.87	32.79	32.80
Culvert 10	1.78	2.37	32.18	32.21
Bridge 1	47.13	64.40	26.03	26.35
Bridge 2	27.79	37.03	29.59	29.84
Bridge 3	44.46	58.34	27.72	28.06

4 Summary of Modelling Results

A summary of the operational effects for each of the corridors is set out in Table 4-1 below and discussed in more detail in Section 7. The Redhills Arterial Transport Network will result in negligible to minor flooding effects as the detailed design phase can resolve all issues from a flood neutrality (quantity) and water quality perspective, achieving the outcomes set out in Section 3.2.

Indicative mitigation measures have been provided in Section 7 which will minimise flooding effects and help enable the outcomes.

The outcomes set out in Section 3.2 will form part of the designation conditions and compliance with those conditions will ensure the residual flood effects for all NoRs will be negligible up to minor.

Table 4-1: Summary of flood modelling results

Corridor name	Location	Potential effect without mitigation	Potential effect with implementation of the recommended flooding outcomes
Redhills North-South Arterial Corridor	There are no existing buildings predicted to be affected by flooding that could be further affected by the proposed infrastructure works. Increased runoff and water quality due to impervious road area can be accommodated within proposed wetland sites.	Increased runoff and greater potential environmental pollution effects.	Improvement due to attenuation of road surface runoff and treatment.
Redhills East-West Arterial Corridor – Dunlop Road			
Redhills East-West Arterial Corridor – Baker Lane			
Redhills East-West Arterial Corridor – Nixon Road connection	Houses affected by construction will be removed and are near the top of the catchment therefore no flooding effects.		

5 Positive Effects

The main positive effects that could be designed for are:

- proposed roadways to be above the flood plains
- ability to convey flows without worsening flooding impacts upstream or downstream of the works
- added water quality treatment and attenuation of the total roadway impervious area of Dunlop Road (an existing road that is proposed to be widened) as opposed to just the additional roadway area.

6 Construction Effects

Construction effects apply to the entire project, however are more likely at locations within or adjacent to overland flows or flood prone areas. The proposed construction works which could result in flooding effects include:

- Construction of new culvert crossings or upgrading of existing culvert crossings
- Installation of diversion drains / realignment of existing overland flow paths
- Construction of new attenuation ponds or upgrading of existing attenuation ponds
- Temporary use of lay down areas.

The potential effects of these are:

- Bulk earthworks to complete the contouring for new landscape features e.g. attenuation ponds and new or upgraded culverts require a dry works area and can alter overland flow paths or generate erosion and sediment effects

- The siting of attenuation ponds within an existing overland flow path can obstruct runoff and result in flows being diverted towards existing properties due to the need for embankments.

Section 6.1 below describes methods for minimising / mitigating these potential effects.

6.1 Recommended Measures to Minimise, Remedy or Mitigate Construction Effects

The management and mitigation measures for construction effects are outlined below:

General

- Carrying out earthworks during the summer / dry months to reduce the risk of flooding
- Locating lay down areas outside of predicted overland flow paths and flood plains, where possible
- Managing the overland flow paths to make sure flows are not diverted toward existing buildings or properties
- Construction Environmental Management Plans (CEMP) be developed prior to construction in conjunction with an experienced Stormwater Engineer and shall consider the effects of temporary works, earthworks, storage of materials, temporary diversion and drainage on flow paths, flow levels and velocities. Including (but not limited to):
  - Siting construction yards and stockpiles outside the predicted flood plains
  - Diverting overland flow paths away from area of work
  - Minimizing the physical obstruction to flood flows at the road sag points
  - Staging and programming to provide new drainage prior to raising road design levels and carry out work when there is less risk of extreme flood events
  - Actions to take in response to heavy rain warnings which may include reducing the conveyance of materials and plant that are considered necessary to be stored or sited within the predicted flood plain or significant overland flow path.

Construction of new and existing culvert crossings and stormwater wetlands and ponds:

- Existing culvert extensions should be done prior to commencement of bulk earthworks to allow for the passage of clean water across the site
- Installing temporary diversions to allow flows to be maintained while new culverts and ponds are constructed
- For larger embankments requiring a longer duration of works or for overland flow paths with more regular and higher flow rates diversions should be installed prior to works commencing
- Where no diversion is required a 6m working clearance between any earthworks and designation boundary should be adopted to accommodate access and materials
- For larger diameter pipes (> 600mm in size) a working clearance of ±20m from the upstream extent and ±15m from the downstream extents should be provided.

7 Operational Effects

There are a range of operational effects particularly from proposed crossings. Future detailed design will be subject to a separate flooding assessment at the resource consent stage. For the project the assessment of operational flooding effects considered:

- New culvert crossings (≥ 600 mm diameter)

- Areas where the new road embankment encroaches onto predicted flood plain and flood prone land
- The potential of flooding on existing properties due to the new project corridor.

The effects of these are:

- Increasing impervious areas resulting in increased runoff and potentially increased flood levels
- Altering existing overland flow paths resulting in flows being redirected on a different alignment
- Obstructing an existing overland flow path resulting in ponding at existing low points or newly created depressions along the corridor
- Improving flows under the road reducing upstream flood levels and increasing flood levels at properties further downstream.

The mitigation measures set out in Section 7.1 have been designed to assist in minimising flood effects. There are a range of potential mitigation measures that can be applied and additional modelling during detailed design will consider which measures are most appropriate to ensure adverse flood effects are minimised, remedied or mitigated. The detailed design would then need to demonstrate compliance with outcomes set out in Section 3.2 as required by an appropriate designation condition.

7.1 Recommended Measures to Minimise, Remedy or Mitigate Operational Effects

It is recommended that during detailed design additional flood modelling is carried out and mitigation measures implemented as required to achieve the outcomes set out in Section 3.2. Compliance with these outcomes will be required as a designation condition. Based on the interim design potential mitigation measures have been identified in order to show that the feasibility to meet these outcomes has been considered.

Mitigation measures which may be implemented include:

- Creating new overland flow path diversions to discharge to nearby overland flow paths or streams to mitigate ponding and decrease flood levels at affected properties. This is where existing predicted overland flow paths run parallel to the proposed roads and do not cross under the road
- Increasing culvert sizes so that the upstream and downstream water level differences do not increase by more than 0.5m on land zoned for urban development or 0.05m for existing floors at risk of flooding (none identified at this stage)
- Upgrading culverts by adding smaller culverts to create a balance between the flood level differences upstream and downstream
- Installing drains at the toe of embankment sloping towards the culverts can also allow for additional storage to decrease the velocity and peak flow through the culvert crossings.

8 NoR1: Redhills North-South Arterial Corridor

8.1 Catchment Characteristics

The corridor is located near the top of the catchment and as such on the Waiteputa Stream. The flood modelling predicts there will be minor flooding as it is near the top of the catchment. Auckland Council GeoMaps does not show greater flood extent than identified in the modelling.

8.2 Existing and Likely Future Environment

8.2.1 Planning Context

Within the Project area there are a range of zones under the AUP:OIP which influence the existing and likely future land use patterns for assessment purposes.

Table 8-1 below provides a summary of the existing and likely future environment as it relates to the North-South Arterial Corridor within the RATN.

Table 8-1: North-South Arterial Corridor Existing and Likely Future Environment

Land use today	Zoning	Likelihood of Change for the environment[4]	Likely Future Environment[5]
Rural	Residential – Mixed Housing Suburban	High	Urban
	Residential – Mixed Housing Urban		
	Residential – Terrace Housing and Apartment Building Zone		
	Business – Local Centre Zone		
Residential	Business – Local Centre Zone	Moderate	Urban
	Residential – Mixed Housing Urban	Low	
	Residential – Terrace Housing and Apartment Building Zone		
Business	Business – Local Centre Zone	Low	Urban

[4] Based on AUP:OP zoning/policy direction

[5] Based on AUP:OP zoning/policy direction

Land use today	Zoning	Likelihood of Change for the environment[4]	Likely Future Environment[5]
Special Purpose	Special Purpose – School Zone	Low	Special Purpose

Please refer to the AEE for further information on the planning context.

8.3 Proposed works

Two road stormwater catchments (Catchment 1 & 2 shown on Figure 3-7) is created along the transport corridor and runoff from the catchment flows into two proposed stormwater wetland (Wetland 1 & 2 shown on Figure 3-6) for treatment and attenuation.

8.4 Assessment of Flooding Effects and Measures to Minimise, Remedy or Mitigate Actual or Potential Adverse Effects

8.4.1 Positive Effects

The corridor crosses an existing flood prone areas although no increased flooding risks are anticipated. The proposed road is above the existing alignment and predicted flood plain, therefore improving freeboard and reducing any potential flood risk.

8.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 6 above.

The proposed upgraded Stormwater Wetlands 1 and 2 are located outside of the predicted flood plain and overland flow paths.

8.4.3 Recommended Measures to Minimise, Remedy or Mitigate Construction Effects

Resource consents for diversion and discharge of stormwater and stream works will be sought as part of future resource consent processes.

The potential flooding effects during construction will be considered by, and managed through, flood risk mitigation measures to be set out in the Construction Environmental Management Plan (**CEMP**).

All other mitigation measures as set out in in Section 6.1 apply.

8.4.4 Assessment of Operational Effects

The flood modelling results are shown in Table 3-3 which show little difference between 100 year future climate change 2.1 and 3.8° temperature increase predictions for water levels and flow rates .

8.4.5 Recommended Measures to Minimise, Remedy or Mitigate Operational Effects

Wetland 1 will provide treatment and attenuation along with appropriately sized bridge and culverts openings to reduce flood neutrality issues.

Further assessment at the detailed design stage can be used to confirm the preferred mitigation.

Compliance with the recommended flooding outcomes set out in Section 3.2, to be included in the designation conditions, will ensure that potential flooding effects will be negligible up to minor and appropriately managed.

8.5 Conclusions

The corridor is near the top of catchments and there is little difference between the 100 year future with climate change events for the 2.1 and 3.8° temperature rise.

No potential flooding risks during operations are anticipated.

9 NoR R2a: Redhills East-West Arterial Corridor – Dunlop Road

9.1 Catchment Characteristics

The corridor is located near the top of the catchment on the Ngongetepara Stream. The flood modelling predicts there will be minor flooding as it is near the top of the catchment. Auckland Council GeoMaps does not show greater flood extent than identified in the modelling.

9.2 Existing and Likely Future Environment

9.2.1 Planning Context

Within the Project area there are a range of zones under the AUP:OIP which influence the existing and likely future land use patterns for assessment purposes.

Table 9-1 below provides a summary of the existing and likely future environment as it relates to the Dunlop Road Corridor within the RATN.

Table 9-1: Dunlop Road Corridor Existing and Likely Future Environment

Land use today	Zoning	Likelihood of Change for the environment[6]	Likely Future Environment[7]
Rural	Residential – Mixed Housing Urban	High	Urban
	Residential – Terraced Housing and Apartment Zone		
	Business – Local Centre		
Business	Business – Mixed Use Zone	Low	Urban
	Business – Light Industry		
Residential	Residential – Mixed Housing Urban	Low	Urban
	Residential – Terraced Housing and Apartment Zone		

Please refer to the AEE for further information on the planning context.

[6] Based on AUP:OP zoning/policy direction

[7] Based on AUP:OP zoning/policy direction

9.3 Proposed works

Two road stormwater catchments (Catchment part 2 & 4 shown on Figure 3-7) is created along the transport corridor and runoff from the catchment flows into one proposed stormwater wetland (Wetland 2 shown on Figure 3-6) for treatment and attenuation.

9.4 Assessment of Flooding Effects and Measures to Minimise, Remedy or Mitigate Actual or Potential Adverse Effects

9.4.1 Positive Effects

The corridor crosses an existing flood prone areas although no increased flooding risks are anticipated. The proposed road is above the existing alignment and predicted flood plain, therefore improving freeboard and reducing any potential flood risk.

9.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 6 above.

The proposed upgraded Stormwater Wetland 2 is located outside of the predicted flood plain and overland flow paths.

9.4.3 Recommended Measures to Minimise, Remedy or Mitigate Construction Effects

Resource consents for diversion and discharge of stormwater and stream works will be sought as part of future resource consent processes.

The potential flooding effects during construction will be considered by, and managed through, flood risk mitigation measures to be set out in the Construction Environmental Management Plan (**CEMP**).

All other mitigation measures as set out in in Section 6.1 apply.

9.4.4 Assessment of Operational Effects

The flood modelling results are shown in Table 3-3 which show little difference between 100 year future climate change 2.1 and 3.8° temperature increase predictions for water levels and flow rates.

9.4.5 Recommended Measures to Minimise, Remedy or Mitigate Operational Effects

Wetland 1 will provide treatment and attenuation along with appropriately sized bridge and culverts openings to reduce flood issues.

Further assessment at the detailed design stage can be used to confirm the preferred mitigation.

Compliance with the recommended flooding outcomes set out in Section 3.2, to be included in the designation conditions, will ensure that potential flooding effects will be negligible up to minor and appropriately managed.

9.5 Conclusions

The corridor is near the top of catchments and there is little difference between the 100yr future with climate change events for the 2.1 and 3.8° temperature rise.

No potential flooding risks during operations are anticipated.

10 NoR R2b: Redhills East-West Arterial Corridor – Baker Lane

10.1 Catchment Characteristics

The corridor is located near the top of the catchment and as such on the Ngongetepara Stream. The flood modelling predicts there will be minor flooding as it is near the top of the catchment. Auckland Council GeoMaps does not show greater flood extent than identified in the modelling.

10.2 Existing and Likely Future Environment

10.2.1 Planning Context

Within the Project area there are a range of zones under the AUP:OIP which influence the existing and likely future land use patterns for assessment purposes.

Table 10-1 below provides a summary of the existing and likely future environment as it relates to the Baker Lane Corridor within the RATN.

Table 10-1: Baker Lane Corridor Existing and Likely Future Environment

Land use today	Zoning	Likelihood of Change for the environment[8]	Likely Future Environment[9]
Rural	Residential – Mixed Housing Urban	High	Urban
	Residential – Terraced Housing and Apartment Zone		
Business	Business – Mixed Use Zone	Low	Urban
	Business – Light Industry		
Residential	Residential – Mixed Housing Urban	Low	Urban
	Residential – Terraced Housing and Apartment Zone		
Special Purpose	Special Purpose – School Zone	Low	Special Purpose

Please refer to the AEE for further information on the planning context.

[8] Based on AUP:OP zoning/policy direction

[9] Based on AUP:OP zoning/policy direction

10.3 Proposed works

One road stormwater catchment (Catchment 3 shown on Figure 3-7) is created along the transport corridor and runoff from the catchment flows into one proposed stormwater wetland (Wetland 2 shown on Figure 3-6) for treatment and attenuation.

10.4 Assessment of Flooding Effects and Measures to Minimise, Remedy or Mitigate Actual or Potential Adverse Effects

10.4.1 Positive Effects

The corridor crosses an existing flood prone areas although no increased flooding risks are anticipated. The proposed road is above the existing alignment and predicted flood plain, therefore improving freeboard and reducing any potential flood risk.

10.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 6 above.

The proposed upgraded Stormwater Wetland 2 is located outside of the predicted flood plain and overland flow paths.

10.4.3 Recommended Measures to Minimise, Remedy or Mitigate Construction Effects

Resource consents for diversion and discharge of stormwater and stream works will be sought as part of future resource consent processes.

The potential flooding effects during construction will be considered by, and managed through, flood risk mitigation measures to be set out in the Construction Environmental Management Plan (CEMP).

All other mitigation measures as set out in in Section 6.1 apply.

10.4.4 Assessment of Operational Effects

The flood modelling results are shown in Table 3-3 which show little difference between 100yr future climate change 2.1 and 3.8° temperature increase predictions for water levels and flow rates.

10.4.5 Recommended Measures to Minimise, Remedy or Mitigate Operational Effects

Wetland 1 will provide treatment and attenuation along with appropriately sized bridge and culverts openings to reduce flood neutrality issues.

Further assessment at the detailed design stage can be used to confirm the preferred mitigation.

Compliance with the recommended flooding outcomes set out in Section 3.2, to be included in the designation conditions, will ensure that potential flooding effects will be negligible up to minor and appropriately managed.

10.5 Conclusions

The corridor is near the top of catchments and there is little difference between the 100yr future with climate change events for the 2.1 and 3.8° temperature rise.

No potential flooding risks during operations are anticipated.

11 NoR R2c: Redhills East-West Arterial Corridor – Nixon Road connection

11.1 Catchment Characteristics

The corridor is located near the top of the catchment and as such on the Ngongetepara Stream. The flood modelling predicts there will be minor flooding as it is near the top of the catchment. Auckland Council GeoMaps does not show greater flood extent than identified in the modelling.

11.2 Existing and Likely Future Environment

11.2.1 Planning Context

Within the Project area there are a range of zones under the AUP:OIP which influence the existing and likely future land use patterns for assessment purposes.

Table 11-1 below provides a summary of the existing and likely future environment as it relates to the Nixon Road Connection within the RATN.

Table 11-1: Nixon Road Connection Existing and Likely Future Environment

Land use today	Zoning	Likelihood of Change for the environment[10]	Likely Future Environment[11]
Rural	Residential – Single House	High	Urban
	Residential – Mixed Housing Suburban		
	Residential – Mixed Housing Urban		
	Residential – Terraced Housing and Apartment Zone		

Please refer to the AEE for further information on the planning context.

11.3 Proposed works

Two road stormwater catchment (Catchments 5 and 6 shown on Figure 3-7) are created along the transport corridor and runoff from the catchment flows into one proposed stormwater wetland (Wetland 1 and 2 shown on Figure 3-6) for treatment and attenuation.

[10] Based on AUP:OP zoning/policy direction
[11] Based on AUP:OP zoning/policy direction

11.4 Assessment of Flooding Effects and Measures to Minimise, Remedy or Mitigate Actual or Potential Adverse Effects

11.4.1 Positive Effects

The corridor crosses an existing flood prone areas although no increased flooding risks are anticipated. The proposed road is above the existing alignment and predicted flood plain, therefore improving freeboard and reducing any potential flood risk.

11.4.2 Assessment of Construction Effects

Potential construction effects have been described in Section 6 above.

The proposed upgraded Stormwater Wetlands 2 and 3 are located outside of the predicted flood plain and overland flow paths.

11.4.3 Recommended Measures to Minimise, Remedy or Mitigate Construction Effects

Resource consents for diversion and discharge of stormwater and stream works will be sought as part of future resource consent processes.

The potential flooding effects during construction will be considered by, and managed through, flood risk mitigation measures to be set out in the Construction Environmental Management Plan (**CEMP**).

All other mitigation measures as set out in in Section 6.1 apply.

11.4.4 Assessment of Operational Effects

The flood modelling results are shown in Table 3-3 which show little difference between 100yr future climate change 2.1 and 3.8° temperature increase predictions for water levels and flow rates.

11.4.5 Recommended Measures to Minimise, Remedy or Mitigate Operational Effects

Wetland 1 will provide treatment and attenuation along with appropriately sized bridge and culverts openings to reduce flood neutrality issues.

Further assessment at the detailed design stage can be used to confirm the preferred mitigation.

Compliance with the recommended flooding outcomes set out in Section 3.2, to be included in the designation conditions, will mean that potential flooding effects will be negligible up to minor and appropriately managed.

11.5 Conclusions

The corridor is near the top of catchments and there is little difference between the 100yr future with climate change events for the 2.1 and 3.8° temperature rise. No potential flooding risks during operations are anticipated.

12 Conclusion

The assessment reviewed the flood risk for:

- NoR 1 Redhills North-South Arterial Corridor
- NoR 2a Redhills East-West Arterial Corridor – Dunlop Road
- NoR 2b Redhills East-West Arterial Corridor – Baker Lane
- NoR 2c Redhills East-West Arterial Corridor – Nixon Road connection.

The assessment found that there was unlikely to be an increased risk from flood effects during construction and flood effects will be managed as set out in Section 6.1.

The assessment identified during operations likely positive effects based on the vertical elevation of the future design.

Potential flooding effects can be appropriately managed and will be negligible up to minor subject to the recommended design outcomes and conditions outlined in set out in Section 3.2 of this report being met. Additional modelling of the final design at a detailed design stage will be used to confirm that flood effects are minimised, remedied or mitigated as appropriate.

The sensitivity analysis for the potential increased rainfall due to climate change found there was no change to the identified flood risk at key locations under a more severe climate change scenario (3.8 degree temperature change).

13 References

Auckland Council (Nov 2011) Auckland Council Stormwater Modelling Specification

Auckland Council GeoMaps (accessed 2021)

Te Tupu Ngātahi flood model: SGA North West Local – Redhills Base Case Stormwater Model December 2020 version 0.2

New Zealand Transport Agency (April 2016) NZTA P46 Stormwater Specification

New Zealand Transport Agency (2013) Bridge Manual SP/M/022 third edition