Flood Assessment

Sleepyhead Estate Ohinewai

Ambury Properties Ltd
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Document Control

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1. Introduction

1.1. Sleepyhead Estate

Sleepyhead Estate is a mixed-use master planned community proposed to be located on a site adjacent to State Highway 1 (Waikato Expressway) and the North Island Main Trunk railway at Ohinewai.

Ambury Properties Limited (APL) are the property holding associate of the New Zealand Comfort Group Limited (NZCG), the manufacturer of Sleepyhead, Sleepmaker, Serta, Tattersfield and Design Mobel Beds along with Dunlop Foams and Sleepyhead flooring underlay. They also produce a wide range of related products including pillows, mattresses, drapes, furniture and other soft furnishings. The manufacturing operations are currently based at several locations in Auckland. APL has been investigating options to consolidate all of their manufacturing operations onto one site. It has searched extensively in Auckland and the Waikato for a suitable site.

Figure 1: Proposed Development Site Location

APL has found a suitable property on the corner of Lumsden Road and Tahuna Road, Ohinewai (Allotment 405, Lots 1 and 2 DPS 29288 and Lots 1-3 474347). The property is zoned Rural in the operative and proposed Waikato District Plans.

The proposed NZCG 100,000m^2 factory will be the major industrial anchor for the project. It will be accommodated in a 66ha industrial hub with rail siding access from the North Island Main Trunk railway. The project will also include 8.5ha of commercial development including a service station, local convenience stores and factory outlet shops. 53 hectares of residential land for approximately 1100 new houses will also be provided, together with approximately 55ha of public open space.

1.2. Proposed Re-Zoning

APL has lodged a submission on the proposed Waikato District Plan requesting that the land be rezoned to a mix of industrial, residential and business zone to accommodate the mixed-use community. To support the proposed rezoning, APL are seeking to embed a structure plan for Ohinewai within the (Proposed) Waikato District Plan. The structure plan will provide a framework for the development of the wider site, outlining the location of activities, the indicative road network and the general location of the green spaces that will provide for ecological enhancement, recreation and the management of stormwater.

This flood assessment report has been undertaken in support of the rezoning request.

1.3. Assessment Scenarios

This report provides the model build parameters adopted for the following modelled scenarios along with an assessment of the effects of flooding. All modelling work was carried out by Mike by DHI (v2017 SP1) software package:

- Scenario 1: Pre-Development/Existing Model (ED)
- Scenario 2: Post-Development Model – Sleepyhead Estate (PD)
- Scenario 3: Maximum Probable Development Model (MPD)
- Scenario 4: Emergency Management Plan model (EMP)
- Scenario 5: Sensitivity Model (PDS)

Scenario 1 (pre-development) model has been built on existing impervious coverages and existing landform. These model results establish a baseline understanding of existing flood depths and floodplain extents within and around the site and used to quantify and changes in flood depths or flood extents which may have resulted from the site being developed.

Scenario 2 (Post development – Sleepyhead Estate) model is developed with the Sleepyhead estate set to Maximum Probable Development impervious coverages and landform.

Scenario 3 (Post Development – Sleepyhead Estate + Neighbouring MPD) has been updated to include Maximum Probable Development impervious coverages for the known surrounding sites also seeking plan change.

Scenario 4 (Emergency Management Plan) model has been developed with the Sleepyhead Estate set to Maximum Probable Development impervious coverages and landform to understand the risk to the development as a result of a breach of the stop bank to the west of the site along the Waikato River using a steady state analysis.

Scenario 5 (Sensitivity) model has been updated with different hydrological parameters to understand the sensitivity of flood results with these assumed parameters including curve numbers and initial losses.

2. Purpose of modelling and reporting

The overall purpose of the modelling exercise reporting is to provide guidance to APL and inform Waikato Regional Council (WRC) and Waikato District Council (WDC) on the following matters:

- Identify existing and proposed flood risk areas;
- Provide model results and analysis for the proposed post-development situation;
- Provide assessment of development within the existing 1% AEP floodplain and quantifying if there are any adverse flooding effects on properties upstream or downstream of the proposed development in comparison to the pre-development/existing situation;
- To allow finished flood levels to be set out with adequate flood risk protection; and
- Understand the extent of any residual risk associated with a stop bank breach scenario to inform future Emergency Management Plan provisions.

3. Stakeholder Engagement

3.1. Waikato Regional Council

Woods have been working collaboratively with technical representatives of the Waikato Regional Council (WRC) throughout the modelling process which has been initiated by WRC. The collaborative approach is consistent with the Regional Policy Statement (RPS) for sustainable regional development and managing natural hazard risks by working collaboratively with developers and sharing uninterrupted knowledge sharing.

Key assumptions and decisions have been discussed and agreed with WRC Technical Reviewers along the model build process to support effects assessment. Directions, suggestions and inputs from WRC have been incorporated in the programme which has helped achieve the expected timeframes for APL and achieve a unified outcome for APL and WRC in terms of sustainable development and appropriate assessment of risk to the proposed development.

Four meetings were held, in September and October 2019 and minutes of the meetings have been recorded and shared between Woods and WRC and are included in Appendix C of this report.

3.2. Mercury Energy

Early engagement with Mercury Energy has been undertaken for their comments and understanding their concerns on the flood hazards within the area. Their initial concerns around stop bank breach were noted and the adopted modelling approach as well as scenarios to be modelled were discussed and shared. Memo prepared following the discussion with Mercury Energy has been included in Appendix C of this report. These initial concerns are addressed as part of this flood assessment by completing the Emergency Management Planning modelling as discussed in Section 5.8.

4. Catchment Description

4.1. Site Location and Topography

The proposed development is located to the west of Lake Rotokawau and Lake Waikare. The topography is undulating with heights ranging from 20m RL around Tahuna Road along the southern boundary of the site to approximately 5.5m RL on the margins of Lake Rotokawau in the east.

The proposed development is approximately 1.79sq. km (179ha.) and accounts for approximately 0.86% of the total contributing area of 208 sq.km (20800 ha.) to Lake Waikare. The scale of the project site when compared to the wider catchment contributing to Lake Waikare can be seen in the plan included in Appendix D.

The model extent has been defined to include all areas contributing to Balemi and Tahuna Drains which discharges to Lake Rotokawau and Lake Waikare. This has been based on overland flow path assessment completed using the LiDAR data provided by Waikato Regional Council.

The Waikato River runs along the north of Ohinewai South Road (to the west of Waikato Expressway) and the river flows are contained by the Wool Scourers to Fosters Landing Stop bank. There is very little interaction between the Waikato River and proposed site for events up to 1% AEP which has been tested with modelling. This has also been confirmed as all the tributary streams/overland flow paths discharge to Lake Waikare and Lake Rotokawau only with a hydraulic separation from the Waikato River.

The hydraulic connection between the Waikato River and Lake Waikare exists further downstream at Te Onetea Stream and Rangiriri Spillway which operates only when Lake Waikare has water levels lower than 7mRL.

Balemi and Tahuna Drains were surveyed and included as 1D stream elements in the model and all other overland flow paths are represented within the 2D domain of the model setup. One existing culvert located under Lumsden Road with an upstream catchment area of 0.114 sq.km (11.4ha.), has not been represented in the model. By not including the culvert in the model causes backing up of flows upstream with no downstream conveyance. Given the small upstream catchment, it is considered this can be readily addressed with detailed design at the appropriate development stage. This has been described further in Section 9.2.

A copy of the existing contour plan and proposed earthwork plan for this development can be found in Appendix A.

4.2. Lower Waikato-Waipa Flood Control Scheme

The Lower Waikato-Waipa Flood Control Scheme falls under the Lower Waikato Management Zone and is a comprehensive river control scheme designed to provide flood protection within the floodplains of the Lower Waikato and Waipa rivers. The scheme comprises stop banks, pump stations, floodgates and river channel improvement work which commenced in 1961 and were completed in 1982.

The Lower Waikato River starts at Ngaruawahia and extends to the Waikato Heads. Lake Waikare acts as the first of two flood storage areas and receives flows in certain storm events from the confluence of the Waikato River and the Waipa River at Ngaruawahia.

There is one inlet into Lake Waikare located at the Rangiriri spillway from the Waikato River. The Rangiriri spillway discharges flows from the Waikato River into Lake Waikare when the River reaches 8.8mRL. The Rangiriri spillway, in conjunction with stop banks along the segment of the Waikato River which adjoins the site have been designed to effectively manage floodwaters from the River in a controlled way.

This will ensure that in the event of the Waikato river flooding, floodwater would bypass the site to the north at Rangiriri. Te Onetea Control Gate (located at Rangiriri Spillway) operates when Waikato River level is above Lake Waikare and above 7.0mRL.

There are two outlets from Lake Waikare, which are as follows:

- The Waikare spillway into the Whangamarino Wetland; and
- The Waikare Gate, which operates separately to the Waikare Spillway and discharges flows into the Whangamarino via the Pungarehu Canal

The Waikare spillway operates when the levels in Lake Waikare exceed 7.37 m. The operational level for Lake Waikare is between 5.5 – 5.65mRL as confirmed in WRC's Community Gate operation procedures (3352323) provided by WRC and included in Appendix B.

The gate from Lake Waikare into the Pungarehu Canal is varied daily to manage lake levels but is closed when the Whangamarino control gate at Meremere is closed. The Whangamarino control gate is discussed in the following paragraphs.

The Pungarehu Canal discharges into the Whangamarino Wetlands, which acts as the second of two flood storage areas. The Whangamarino Wetland discharges into the Waikato River through the Whangamarino control gate at Meremere. This gate remains closed to prevent backflow into the Whangamarino Wetland.

As part of the development, flood hazard modelling has been undertaken to quantify the effects of development on Lake Waikare's water levels and flood extents on existing land adjacent to the development.

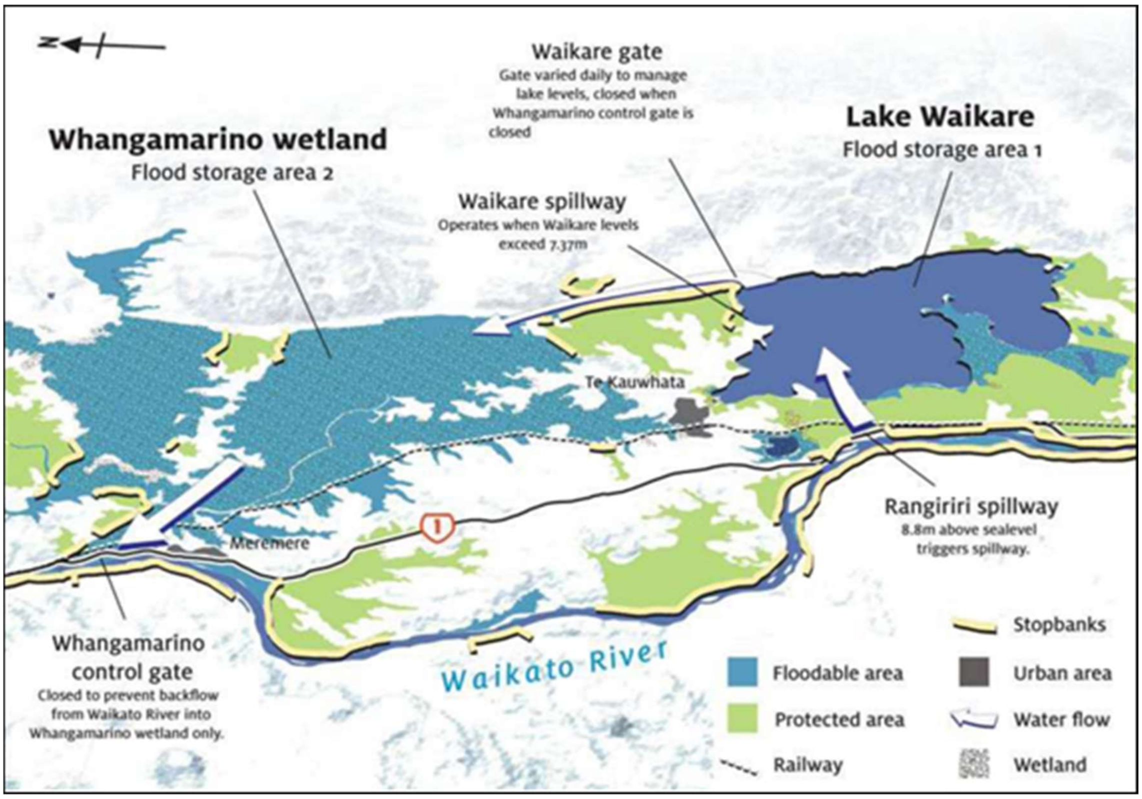

Figure 2: The Lower Waikato Waipa Flood Control Scheme

4.3. Landuse

The catchment is currently classed as rural and the Land Cover Database (v4.1) provided by Landcare Research New Zealand Ltd was used to understand the existing land uses within the model extents. These are primarily pastures and grasslands with some built up areas and settlements. The land uses within the model extent are listed below –

- Broadleaved Indigenous Hardwoods
- Built-up Area (settlement)
- Deciduous Hardwoods
- Exotic Forest
- Flaxland
- Forest – Harvested
- Gorse and/or Broom
- Gravel or Rock
- Herbaceous Freshwater Vegetation
- High Producing Exotic Grassland
- Indigenous Forest
- Lake or Pond
- Low Producing Grassland
- Manuka and/or Kanuka
- River
- Short-rotation Cropland

- Surface Mine or Dump
- Urban Parkland/Open Space

The proposed development focusses on rezoning land uses within the site to a mix of industrial, business, residential and open space with anything outside the site remaining unaffected.

5. Model Build

5.1. Understanding of Existing Flooding

As Waikato Regional Council are in the process of finalising Flood Hazard Mapping for this part of the region, Woods have built a site-specific flood model to:

- Quantify existing flood depths and floodplain extents in the pre-development scenario;
- Quantify post development flood depths and floodplain extents with Sleepyhead Estate impervious coverages and landform in place;
- Allow for finished floor levels to be set out with adequate flood risk protection; and
- Quantify risk to the development by the breach of the stop bank to the west of the site along the Waikato River. This will inform any future Emergency Management Plans (EMPs) to implement on site.

All model runs have been agreed and have been peer reviewed by Mark Pennington of Tonkin and Taylor, as assigned by Rick Liefting from Waikato Regional Council. Peer review meetings have been set up at regular intervals over the course of the model build process to allow for WRC's input into the modelling methodology. Minutes of all meetings are included in Appendix C.

5.2. Modelling Software

The software used for modelling is shown in Table 1. The model developed is a 1D-2D coupled model as detailed below.

Table 1: Modelling Software

Software Type	Mike by DHI
Software Version	V2017
Service Pack	SP2
Model used for Runoff	UHM (as per Waikato stormwater runoff modelling guidelines)
Model used for Hydraulics	Mike 1D
Software used for hydrology	Mike Urban
Software used for modelling streams/channels	Mike 11
Software used for 2D modelling	Mike 21Flexi Mesh (Mike 21FM)
Software used for 1D-2D Coupling	Mike Flood

5.3. Topographical Data

The Waikato LiDAR data provided by WRC has been used for the flood modelling which has been supplemented by on-site cross section survey completed for the Tahuna and Balemi WRC Drains for the pre-development scenario 1.

This data has been overlaid with Woods design terrain surfaces within the site for representing the post-development topography and used for Scenarios 2, 3 and 4. This design surface includes proposed roads, proposed building platforms and adjoining green spaces.

5.4. Asset Data

The River Waikato draft model built by DHI for WRC was reviewed around the site to identify any assets that would need to be included in the model. The River model included the following assets which are related to Lake Waikare –

- Lake Waikare Control Gate
- Te Onetea Control gate
- Rangiriri Spillway
- Whangamarino Control Gate
- Wool Scourers to Fosters Landing Stop bank (along River Waikato near Rangiriri Spillway)

These assets were reviewed for their operations and their performances within the River Waikato River model. The model results showed the 100yr peak water level in excess of 8mRL which is above Lake Waikare Spillway level and is considered inappropriate.

Based on the gate operation procedures provided by WRC, Lake Waikare Control Gate operates between 5.4mRL and 5.7mRL based on seasonal variations and Te Onetea Control Gate are closed when water levels within Lake Waikare exceed 7mRL suggesting there would be no interaction between Lake Waikare and River Waikato.

Based on above criteria and using a constant water level of 8mRL for Lake Waikare where the proposed site discharges, above listed assets were not included in the model.

The Community gate operation procedures provided by WRC are also included in Appendix B.

5.5. Hydrological Model

5.5.1. Method used

The stormwater modelling approach is based on the SCS Unit Hydrograph method, as specified in the Waikato Stormwater runoff modelling guidance (TR2018/02). A normalised 24-hour temporal rainfall and profile has been adopted as specified in TR2018/02. The normalised profile adopted is based on a 2.1°C degrees allowance for future climate change. The profile has been included in Table 2.

Table 2: TP108 Normalised 24-hour Temporal Rainfall Profile

Time [hr: min]	Time Interval [min]	TP-108 Normalised Rainfall Intensity [I/I24]	
		Existing Condition	Future Climate Change
0:00 –	360	0.34	0.33
6:00 –	180	0.74	0.73
9:00 –	60	0.96	0.95
10:00 –	60	1.4	1.40
11:00 –	30	2.2	2.20
11:30 –	10	3.8	3.82
11:40 –	10	4.8	4.86
11:50 –	10	8.7	8.86
12:00 –	10	16.2	16.65
12:10 –	10	5.9	5.95
12:20 –	10	4.2	4.24
12:30 –	30	2.9	2.92
13:00 –	60	1.7	1.70
14:00 –	60	1.2	1.19
15:00 –	180	0.75	0.75
18:00 – 24:00	360	0.4	0.39

5.5.2. Model Extents and Catchment Delineation

Overland flow paths have been generated using the LiDAR data provided to understand the catchment area that discharges to Lake Waikare in the vicinity of the project site. The model has been extended to include all the area that contributes to Lake Waikare to enclose all overland flow path that either discharges towards the project site or share the same discharge location to Lake Rotokawau and Lake Waikare downstream of the project site. The model extent is approximately 50.63 sq.km encompassing the project site and has Lake Waikare and Lake Rotokawau modelled as boundary condition based on discussion with WRC's Technical Reviewers discussed in Section 5.7.2.

The stormwater model consists of subcatchments discharging to modelled nodes which transfer flows to the 2D domain. Subcatchment delineation and model setup are summarised in Table 3 and shown in Figure 4 below.

The extent of the modelled catchments for Scenario 1 and 5 are shown in Figure 3; Scenarios 2 and 3 are shown in Figure 4; Scenario 4 is based on steady state analysis and does not include any hydrology.

The post-development sub-catchments were refined within the site extent and all sub-catchments outside were left unchanged. All models include Lake Waikare water level modelled as tailwater level modelled as open boundary in Mike 21FM.

Table 3: Modelled Stormwater Network

Modelled Scenario	Topography outside proposed site	Topography within proposed site	Climate Change Rainfall	Scenarios modelled
Scenario 1 (Pre-Development)	Existing	Existing	Yes	2yr, 10yr and 100yr
Scenario 2 (Post Development – Sleepyhead Estate)	Existing	Future	Yes	2yr, 10yr and 100yr
Scenario 3 (Post Development – Maximum Probable Development)	Future	Future	Yes	100yr
Scenario 4 (Emergency Management Plan Assessment)	N/A	Future	N/A	Steady State Analysis
Scenario 5 (Sensitivity Model)	Existing	Existing	Yes	100yr

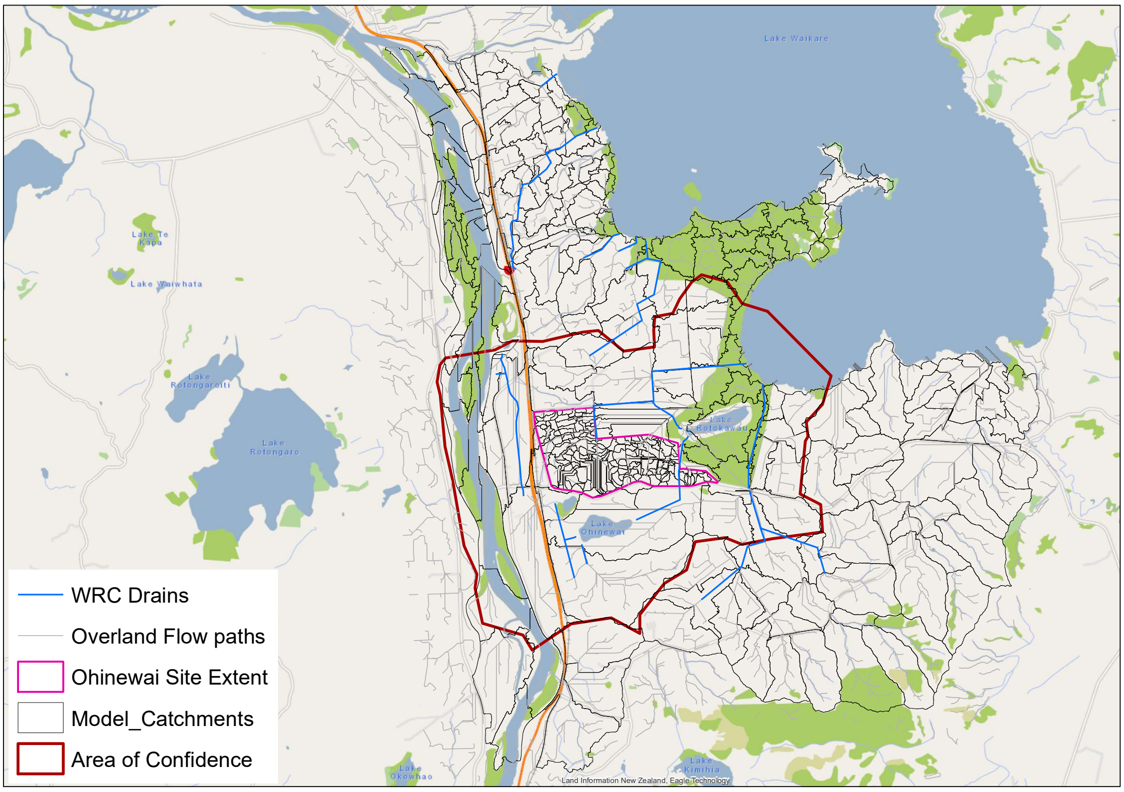

Figure 3: Catchment delineation for Scenario 1 and 5

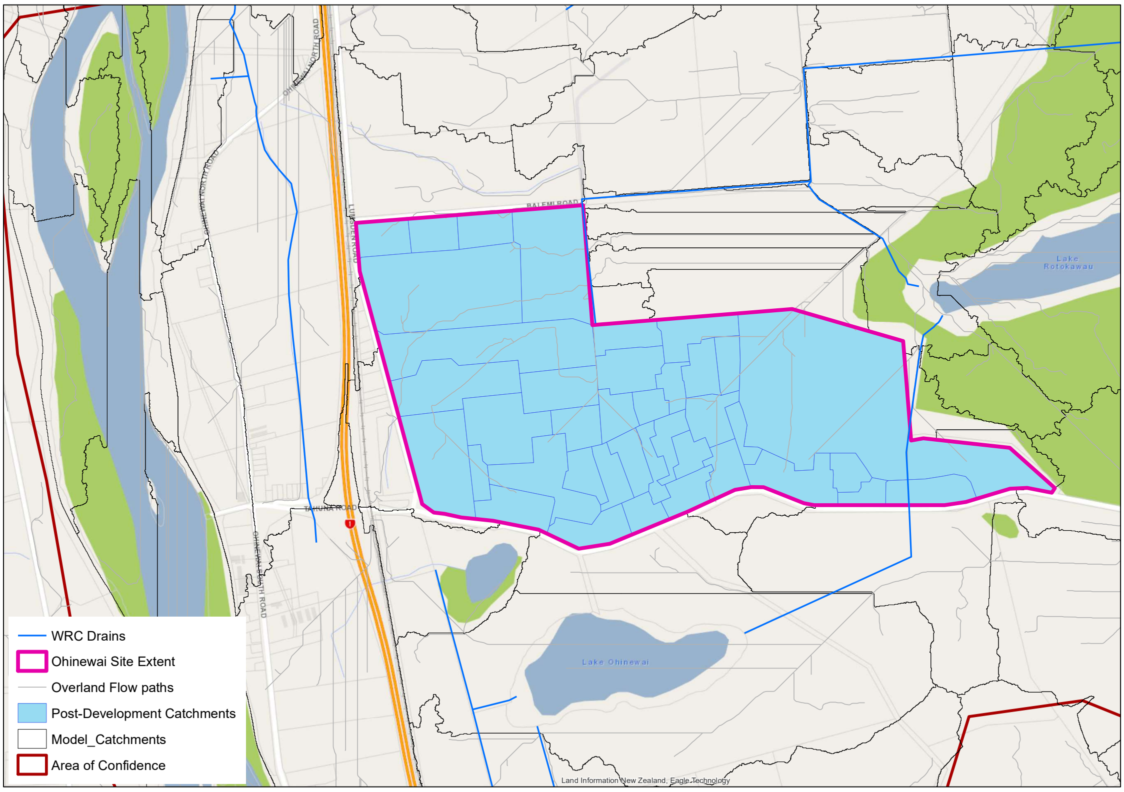

Figure 4: Catchment delineation for Scenario 2 and 3

The sub-catchment delineation is based on topography and land uses are based on following sources. A summary of the hydrological sub-catchments for the modelled scenarios are shown in Table 4.

Table 4: Hydrological Sub-Catchments

Modelled Scenario	Number of Active Sub-catchment
Scenario 1 (Pre-Development)	372
Scenario 2 (Post Development – Sleepyhead Estate)	220
Scenario 3 (Post Development – Maximum Probable Development)	220
Scenario 4 (Emergency Management Plan Assessment)	0
Scenario 5 (Sensitivity Model)	372

A full breakdown of the sub-catchments with hydrological parameters for each of the scenarios has been included in Appendix E – Modelling Inputs.

5.5.3. Pervious and Impervious Coverages

5.5.3.1. Existing Coverage (Existing Development)

The existing catchment is based on Land Cover Database v4.1 and the impervious coverage is represented in the model using a curve number approach as detailed in 4.4.4. below in accordance with Table 5-2 from Waikato Stormwater runoff modelling guidance (TR2018/02).

A full breakdown of pervious and impervious areas can be found in Appendix E – Modelling Inputs.

5.5.3.2. Proposed Coverage – Post Development

For the post-development (Sleepyhead Estate) model - Scenario 2, the sub-catchments within the project site were re-delineated based on the proposed discharge locations and proposed land uses/zonings. The impervious coverages applied are based on the proposed zonings which are predominantly Industrial and Residential.

Note that the post-development scenario is based on a theoretical development as could be expected from the proposed Structure Plan.

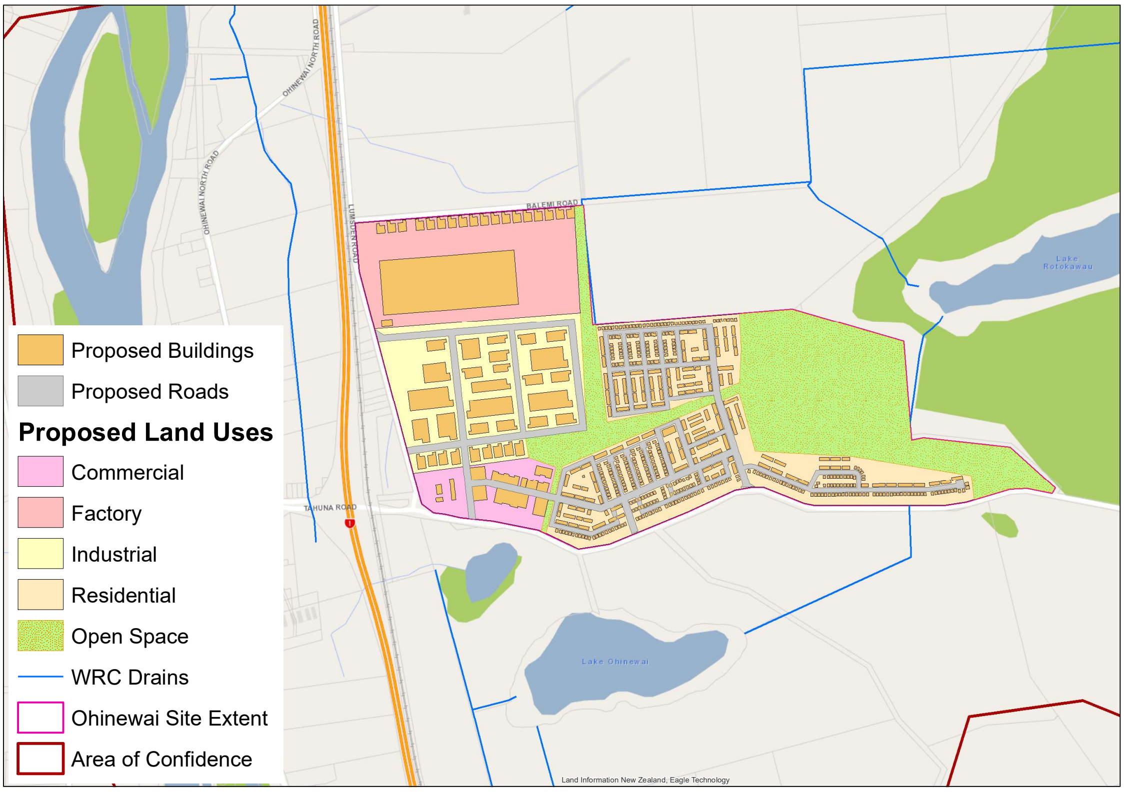

Figure 5: Post-Development – Zoning Plan

A breakdown of the impervious coverages applied for the post-development model is outlined in Table 5. A full breakdown of impervious areas within each sub-catchment can also be found in Appendix E – Modelling Inputs.

Table 5: MPD Coverage Summary Table

Typology	Lot Area (m^2)	Road Area (m^2)	Lot Impervious (m^2)	Road Impervious (m^2)	Impervious Area (m^2)	Pervious Area (m^2)	Weighted Impervious
Factory	306,300		100%		306,300	0	100%
Industrial	263,500	63,700	100%	85%	317,645	9,555	97%
Commercial	83,200	12,900	80%	85%	77,525	18,575	81%
Residential	330,400	131,700	70%	85%	343,225	118,875	74%
Open Space	573,800		0%		0	573,800	0%
Total	**1,557,200**	**208,300**			**1,044,695**	**720805**	
SUM		**1,765,500**	**SUM**		**1,765,500**		

5.5.4. Initial Abstraction

Initial abstraction accounts for losses as a result of storage, interception by vegetation, evaporation and infiltration that occur before runoff begins. The flood modelling has been undertaken by calculating the initial abstraction based on the curve numbers in accordance with Waikato Stormwater runoff modelling guidance (TR2018/02).

5.5.5. Channelization Factors

In all modelled scenarios, as the stormwater runoff is discharging to a modelled pipe, a lag time of 10 minutes was used for all sub-catchments.

5.5.6. Areal Reduction Factors

There are no areal reduction factors applied in the model prepared for Sleepyhead Estate.

5.5.7. Lag Time

The time for concentration adopted for each sub-catchment was 10 minutes for the predevelopment scenarios as there is no existing reticulation system within the model extent and 100% of the flows are conveyed overland. A time of concentration of 10 minutes was also adopted for the sub-catchments within the proposed development site in the post development scenarios. The 10-minute time of concentration adopted is a minimum as per TP108.

A summary of the hydrological calculations can be found in Appendix E.

5.5.8. Hydrological Soil Group and Curve Number

The curve number (CN) has been determined using the SCS Hydrology Method as set out in Waikato Stormwater runoff modelling guidance (TR2018/02). The soil data provided by WRC Soil Risk for FDE layer (https://waikatomaps.waikatoregion.govt.nz/Viewer/?map=1aa9c952a38949a68cbe3ca7aed48270).

These layers provide soil drainage descriptions which are a mixture of 'Very Poorly Drained' soil around the project site and well drained closer to River Waikato. Areas to the south of the project site are generally 'Imperfectly Drained'. Based on this available data, the soil type for modelling purpose is assumed as Type C. The impervious areas within the model (all scenarios) have a CN of 98 and following curve numbers were adopted for pervious coverage based on table 5-2 from TR2018/02 as provided in Table 6. CN of 74 was adopted for the pervious coverage in the post-development model within project site. In discussion and agreement with WRC Technical Reviewer, Sensitivity assessment was completed for curve numbers using the soil Type A curve numbers.

Table 6: Curve Number and Roughness Summary Table

LCDBv4.1 Land Use	Cover type and hydrologic condition	Curve Number (Soil C)	Manning's M	Curve Number (Soil A)
Broadleaved Indigenous Hardwoods	Bush – bush-weed-grass mixture with bush being the major element - Fair	70	18.9	35
Built-up Area (settlement)	Good condition (grass cover >75%)	74	10	39
Deciduous Hardwoods	Bush - Good	70	6.7	30
Exotic Forest	Bush - Good	70	6.7	30
Flaxland	Pasture, grassland, or range – continuous forage for grazing - Good	74	9.1	39
Forest - Harvested	Bush - Good	70	6.7	30
Gorse and/or Broom	Bush – bush-weed-grass mixture with bush being the major element - Fair	70	18.9	35
Gravel or Rock	Gravel (including right-of-way)	89	37	76
Herbaceous Freshwater Vegetation	Bush – bush-weed-grass mixture with bush being the major element - Fair	70	9.1	35
High Producing Exotic Grassland	Pasture, grassland, or range – continuous forage for grazing - Good	74	20	39
Indigenous Forest	Bush - Good	70	6.7	30
Lake or Pond	Impervious areas	98	23.3	98
Low Producing Grassland	Pasture, grassland, or range – continuous forage for grazing - Good	74	20	39
Manuka and/or Kanuka	Bush – bush-weed-grass mixture with bush being the major element - Fair	70	18.9	35
River	Impervious areas	98	23.3	98
Short-rotation Cropland	Straight row crops - Poor	88	28.6	72
Surface Mine or Dump	Dirt (including right-of-way)	87	37	72
Urban Parkland/Open Space	Good condition (grass cover >75%) - Good	74	47.6	39

5.6. Hydraulic Model

A 1D/2D hydraulic model was developed using Mike by DHI software. Mike Flood modelling software dynamically couples the 1D and 2D elements so that flows can be simulated passing from pipe to terrain.

5.6.1. Manning's Roughness Coefficients

The Manning's coefficients ("M" values) adopted for the models are included in Table 6.

5.7. Boundary Conditions

5.7.1. Rainfall

The 24-hour rainfall depths for the 2-year, 5-year, 10-year and 100-year ARI design storms were obtained from HIRDSv4 rainfall depths (RCP 6.0) based on the centroid of the catchment. To incorporate climate change to 2090, the rainfall depth then had a percentage increase applied to it based on TR2018/02 Table 4-3.

The rainfall depths used for modelling are highly conservative as they are applied to the HIRDSv4 RCP 6.0 rainfall depths rather than historical rainfall depths for this assessment. The rainfall depths and the percentage increases applied have been summarised in Table 7 – Rainfall Data.

Table 7: Rainfall Data

Design Storm Event	Rainfall Depth (Historical) mm	Rainfall Depth (RCP 6.0) (mm)	Percentage Increase in 24-hour design rainfall depth due to climate change	Rainfall Depth + Allowance for Climate Change (Historical) (mm)	Rainfall Depth + Allowance for Climate Change (RCP 6.0) (mm) – USED FOR MODELLING
2-year ARI	60.1	67.2	9%	65.5	**73.2**
5-year ARI	78.7	88.7	11.3%	87.6	**98.7**
10-year ARI	92.9	105	13.2%	105.2	**118.9**
100-year ARI	146	167	16.8%	170.5	**195**

5.7.2. Downstream Boundary Conditions

As shown in Figure 5, the downstream boundary condition is applied along the boundary at Lake Waikare at a constant tailwater level of 8mRL for all scenarios as a worst-case scenario which has been agreed and discussed with WRC Technical Specialists. The 2yr model was rerun with a lower tailwater level of 5.4mRL based on the operating level as per WRC's Community Gate procedures. These model runs were undertaken to assess any effects on neighbouring properties for smaller rainfall events that are more frequent rather than a conservative level for Lake Waikare.

In addition, a constant water level of 10.2mRL was applied along River Waikato as summarised in Table 8 below. These boundary conditions are as agreed and have been provided by technical specialists from WRC.

Table 8: Modelled Boundary Summary Table

Boundary Condition	Scenarios	Reason
Lake Waikare water level set at – 8.00mRL (constant)	All Scenarios 1 - 5	Directed by WRC as the maximum water level that Lake Waikare can achieve before the spillway to the north is operative
River Waikato water level set at – 10.20mRL (constant)	Scenario 4	The 100yr with Climate Change water level was extracted from the DHI Waikato River model and applied at breach locations as described in Section 4.7 below
Lake Waikare water level set at – 5.40mRL (constant)	Scenarios 1 and 2 (2yr)	Operating level as per WRC's Community Gate procedures as the minimum water level that Lake Waikare would operate at

Figure 6: Modelled Boundary Conditions

5.8. Emergency Management Planning

Given the site's location adjacent to the Waikato River and to inform the provision of any future Emergency Management Plan (EMP), modelling was undertaken to understand the residual risk to the development by a potential (but unlikely) breach of the stop bank to the west of the site along the Waikato River.

The following methodology was discussed and agreed with WRC technical specialists –

- The ground levels along the stop bank were compared to the Waikato River water levels based on the DHI model to highlight the spots where the level differences were the highest which would be more prone to failure.
- Three critical locations for the project site were identified based on the water level differences and location of overland flow paths leading to the project site in a breach scenario.
- Maximum water level of 10.2mRL was extracted from the DHI River Waikato model (detailed in Section 7) and applied at the breach locations which were assumed to be approximately 30m wide and set the ground levels along the stop bank.
- Lake Waikare water level was set at a constant level of 8mRL.
- A steady state simulation was run for 24hr with this setup.

The results from this assessment are discussed in Section 9.1 of this report.

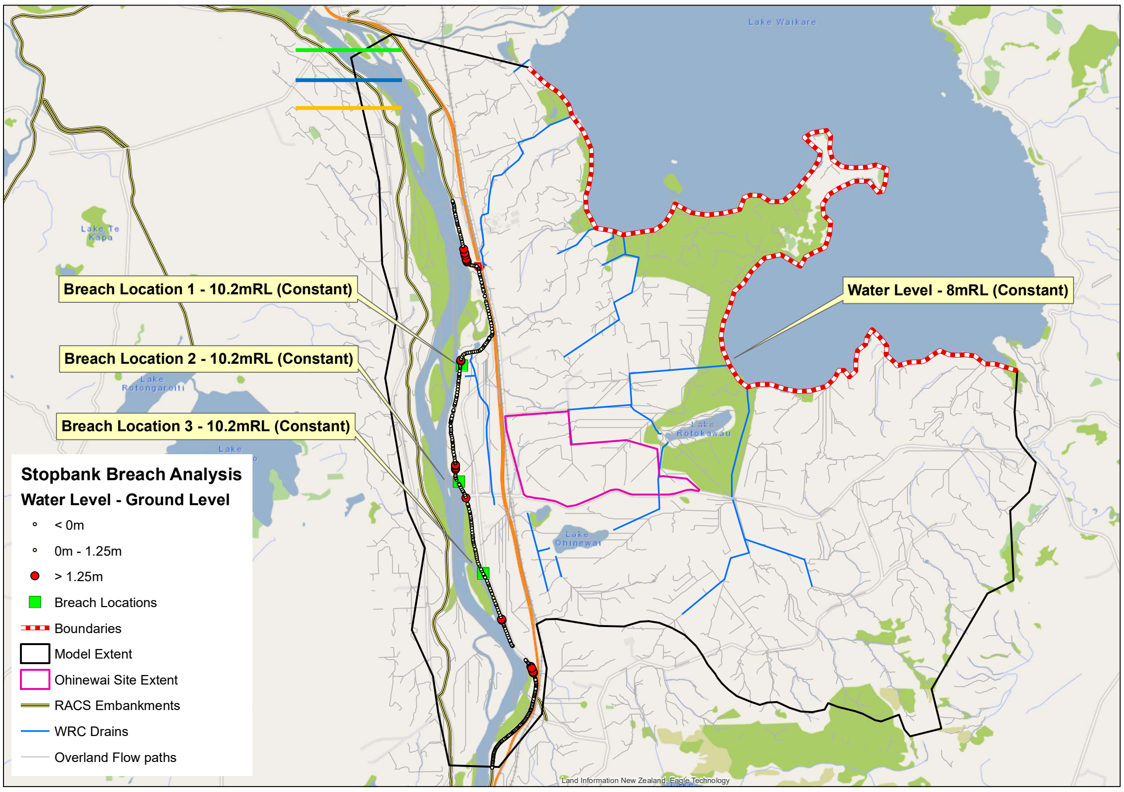

Figure 7: EMP Modelling

6. Modelling Limitations

The flood modelling undertaken represents the flood risk within the modelled extent and are subject to assumptions and limitations outlined below:

- The design storms are in accordance with the Waikato stormwater runoff modelling guideline (TR2018/02) which are based on former Auckland Council's Technical Publication 108 (TP108) The TP108 model has a reported 90% confidence of flow results being within ± 25% of the system being modelled (ARC, 1999).
- The runoff flows calculated by the hydrological model are loaded in the hydraulic model at specified nodes inside the two-dimensional model extents (structured mesh). Inside the two-dimensional model extents, water can flow in all directions from the loading node. The extents of the flow paths may vary based on the location of the loading node, the elevation of the two-dimensional grid cells (from LiDAR data) and other model assumptions. The location of the loading determines the origin of the overland flow path.
- No sedimentation or blockage has been allowed for in any watercourses or culverts.
- This model has been prepared to provide guidance on flood levels and depths within the modelled catchment area for the modelled scenario. The modelling process relies on a range of assumptions and simplifications and is subject to errors and inaccuracies. The compounding effects of the uncertainties in the TR2018/02 Modelling guidance (WRC, 2018), the uncertainties in the contour model and the uncertainties in hydraulic parameters such as roughness could result in the water level varying from the mapped levels.
- Curve Numbers are assumed based on different land uses and soil types and the effect of the variability of these values are tested using Sensitivity assessment.
- The stormwater model for this catchment has been prepared using LiDAR data supplied by WRC (further refined with survey by Woods). The raw LiDAR data is stated to have a standard deviation of

± 0.11m. As a result of the water level variability the lateral extent of flood extent may vary significantly from that shown on the plans. This can have a compounding effect with other uncertainties.

7. Waikato Regional Council Flood Hazard Model Comparison

For the purpose of validation, the prepared flood models were compared against the results from the Flood Hazard Model (Waikato River model) prepared by DHI for WRC. This model was prepared for understanding the flood risk from the Waikato River and performances of the Drainage scheme operated by WRC which includes –

- Waikato River
- Lake Taupo
- Lake Waikare
- Whangamarino Wetlands

This model has Lake Waikare modelled as a 1D storage element with overflowing weirs connected River Waikato (which operates with control gates). This model focuses on fluvial flooding only and excludes pluvial flooding. This pluvial flooding is assessed with the local model built by Woods to understand the risk of flooding to the proposed site.

The peak water level attained by Lake Waikare in the River Waikato model was approximately 8.5mRL which is significantly higher than the maximum water level that can be expected which is less than 8mRL. Thus, in discussion with WRC it was agreed to use the local model for effects assessment and the River model be used for understanding the stop breach assessment to highlight risk to the proposed site from stop bank failure.

8. Model Scenarios and Simulations

The flood assessment models the 2, 10, and 100-year ARI design events. The multiple iterations were undertaken to gain the full understanding of hydrology and hydraulic behaviours of the catchment amongst various rainfall events. The modelling undertaken is based on unmitigated scenarios and therefore does not consider stormwater management devices such as rain tanks, raingardens etc.

The modelled scenarios are summarised as follows:

- **Scenario 1** (pre-development) – modelled with existing stormwater infrastructure and impervious coverage and existing landform
- **Scenario 2** (post-development – Sleepyhead Estate) – modelled with existing stormwater infrastructure and post development impervious coverage and proposed landform within the site
- **Scenario 3** (post-development - MPD) – modelled with existing stormwater infrastructure and post development impervious coverage and proposed landform within the site. The model also includes a catchment wide 2% imperviousness based on a building coverage rule of 2% for Rural zonings. As there is the potential for land use changes as a result of submissions to the Proposed Waikato District Plan, proposed developments within the model extent were also included as following:
    - Ohinewai Lands Ltd, Ohinewai (*30ha of residential*) – 70% Imperviousness
    - 51-57 Ohinewai South Road, Ohinewai (*Countryside Living*) – 10% Imperviousness
    - 97-193 Ohinewai South Road, Ohinewai (*Industrial*) – 95% Imperviousness
    - Shand Properties, Ohinewai (*Country living*) – 100% Imperviousness
    - 249 Ohinewai North Road, Ohinewai (*Industrial*) – 90% Imperviousness
    - 354 Lumsden Road, Ohinewai (*Industrial*) – 90% Imperviousness

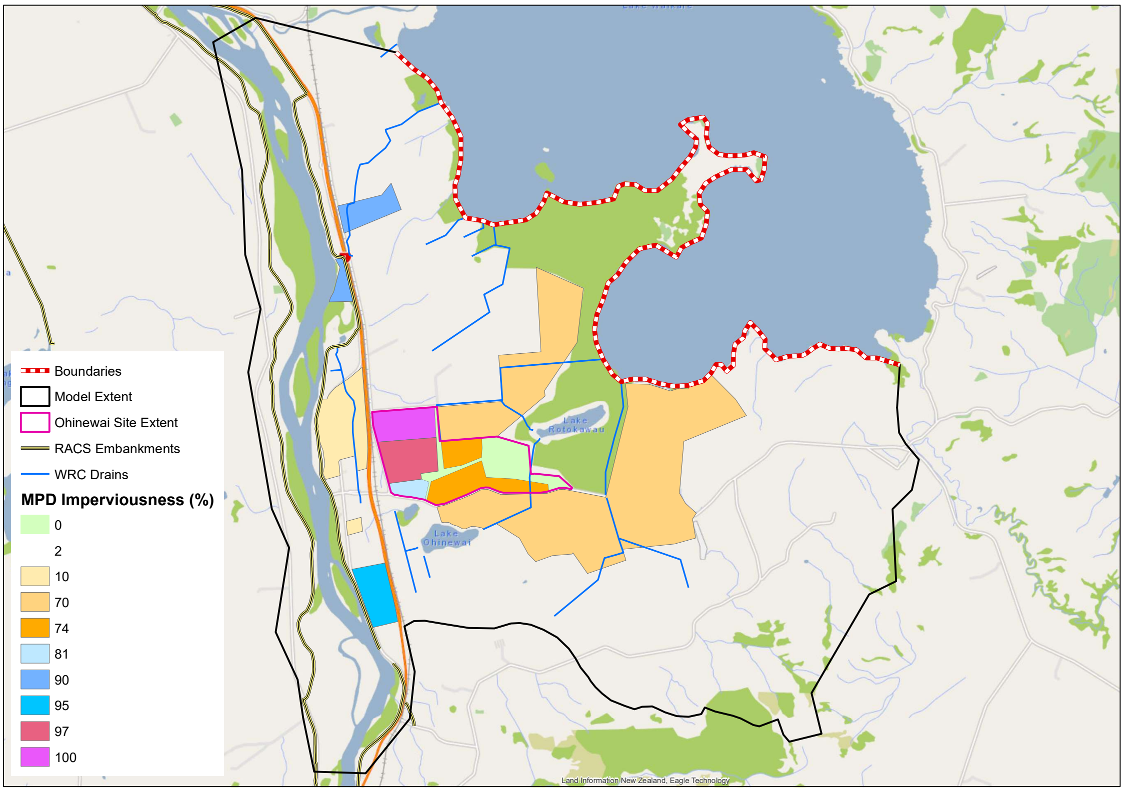

Figure 8: MPD Imperviousness (%)

- **Scenario 4** (post-development – Emergency Management Plan) – modelled with existing stormwater infrastructure and post development proposed landform within the site. This scenario is run as steady state as detailed in section 4.7 with no hydrological inputs.
- **Scenario 5** (Sensitivity Model) – modelled with existing stormwater infrastructure and impervious coverage and existing landform. With the limitations associated with the use of Curve Number approach (as noted in TR2018/02 Section 5.2) a sensitivity scenario has been modelled to understand the variability in modelling results in the vicinity of the proposed site compared to the Post Development model outputs. Curve Numbers associate with Soil Type C has been used for all Scenario 1 and tested for values against Curve Numbers with Soil Type A to understand the sensitivity of model and results for Curve Numbers.

A simulation matrix for all modelled scenarios is summarised in Table 9. A complete set of modelling results for all scenarios can be found in Appendix F.

Table 9: Simulation matrix

Scenario	Description	Land use	Landform	Rainfall
1	Pre-development	ED	Existing	Future 2yr Future 10yr Future 100yr
2	Post-development (Sleepyhead Estate)	MPD Within Sleepyhead Estate + ED Contributing Catchment	Existing with Design surface within site	Future 2yr Future 10yr Future 100yr
3	Post-development (Maximum Probable Development)	MPD Sleepyhead Estate + Surrounding Plan Change Area	Existing with Design surface within site	Future 100yr
4	Post-development (Emergency Management Plan)	n/a	Existing with Design surface within site	Steady State
5	Sensitivity model	ED	Existing	Future 100yr

The pre and post development model scenarios were also revised to understand the effect of the proposed development on the receiving environmental when the Lake Waikare has a water level within its regular operating level of 5.4 – 5.65mRL as confirmed in the Operations Procedure (provided in Appendix B). These two scenarios were run for the 2yr with a boundary condition of 5.4mRL as detailed in Table 10 below.

Table 10: Additional Simulations

Scenario	Description	Land use	Landform	Rainfall
1_LTW	Pre-development with a lower tailwater level for Lake Waikare at 5.40mRL	ED	Existing	Future 2yr
2_LTW	Post-development (Sleepyhead Estate) with a lower tailwater level for Lake Waikare at 5.40mRL	MPD Within Sleepyhead Estate + ED Contributing Catchment	Existing with Design surface within site	Future 2yr

Note: ED = Existing Development; MPD = Maximum Probable Development

9. Flood Model Results

Results from Mike by DHI models for all scenarios have been exported to GIS files to reflect the extents of flooding for each modelled scenario. Peak water level rasters were also generated for each modelled scenario to compare the differences in water levels outside the site.

It is important to note that all the modelling flood extents shown in the report have been filtered for flood depths less than 50 mm.

A complete set of modelling results for all scenarios can be found in Appendix F.

9.1. Result Comparison

A comparison of the model results against the pre-development scenario has been undertaken for the 2, 10 and 100-year rainfall event. The results compare the maximum water levels and flood extents.

Model results at key locations shown in Figure 9.

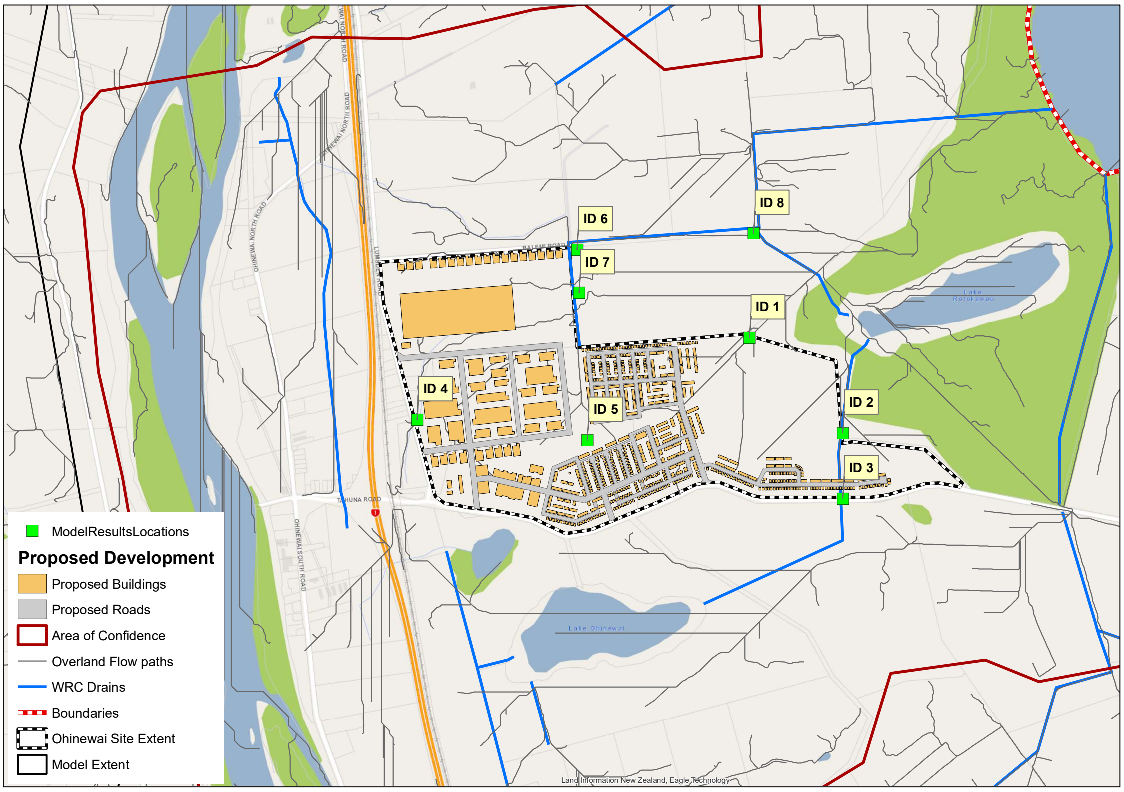

Figure 9: Key Locations

Results are key locations are tabulated in Tables 11 – 13.

Table 11: Model Results – 100yr with CC

Location ID	Scenario 1 Pre-Development Model	Scenario 2 Post Development (Sleepyhead Estate)	Scenario 3 Post Development (MPD Model)	Scenario 4 Emergency Management Plan Model	Scenario 5 Sensitivity Model
1	8.00	8.00	8.00	8.00	8.00
2	8.00	8.00	8.00	8.00	8.00
3	8.00	8.00	8.00	8.00	8.00
4	*8.80	*9.55	*9.55	*10.56	*8.70
5	8.00	8.00	8.00	8.00	8.00
6	8.00	8.00	8.00	8.00	8.00
7	8.00	8.00	8.00	8.00	8.00
8	8.00	8.00	8.00	8.00	8.00

**Due to model representation - discussed in section 8.1.1*

Table 12: Model Results – 10yr with CC

Location ID	Scenario 1 Pre-Development Model	Scenario 2 Post Development (Sleepyhead Estate)
1	8.00	8.00
2	8.00	8.00
3	8.00	8.00
4	*8.65	*8.95
5	8.00	8.00
6	8.00	8.00
7	8.00	8.00
8	8.00	8.00

**Due to model representation - discussed in section 8.1.1*

Table 13: Model Results – 2yr with CC

Location ID	Scenario 1 Pre-Development Model	Scenario 2 Post Development (Sleepyhead Estate)
1	8.00	8.00
2	8.00	8.00
3	8.00	8.00
4	*8.60	*8.70
5	8.00	8.00
6	8.00	8.00
7	8.00	8.00
8	8.00	8.00

**Due to model representation - discussed in section 8.1.1*

The model results indicate that there is no increase in water levels or flood extents in neighbouring properties with the proposed development in comparison to the pre-development model with exception of location 4 as detailed in Section 8.1.1 below. This holds true for all the scenarios modelled.

This is a result of total site area within the proposed development (1.79sq. km) being insignificant when compared to the downstream floodplain extents (34.66 sq. km) and total the total contributing area to Lake Waikare (208 sq. km).

The results for additional model runs completed with a lower tailwater level of 5.40mRL for lake Waikare are tabulated in Table 14 below.

The 2yr model runs with lower boundary conditions of 5.4mRL show that there are increases in water levels at locations 4 and 5. The increase in water level at Location 4 is detailed in Section 9.1.1 and the increase in water level is observed at Location 5 which is within the proposed site only.

Table 14: Model Results – Lower Tailwater level Scenario

Location ID	Scenario 1 Pre-Development Model	Scenario 2 Post Development (Sleepyhead Estate)	Water Level Difference
1	5.71	Does not Flood	n/a
2	5.86	5.86	0
3	Does not Flood	Does not Flood	0
4	*8.60	*8.69	*0.09
5	6.29	6.93	**0.64
6	7.29	7.14	-0.15
7	6.42	Does not Flood	n/a
8	5.71	5.40	-0.31

**Due to model representation - discussed in section 8.1.1*

***Location within the proposed development site – Therefore no effect*

9.1.1. Lumsden Road Overland flow path

The overland flow path located around Lumsden Road at location 4 shown in Figure 9 exhibits ponding behind Lumsden Road for pre and post development scenarios. This is caused by the model representation in this area which does not include the culvert under the existing road. This results in 'no flows' through the culvert and flows backing upstream with no downstream conveyance. This culvert under Lumsden Road will be addressed at detail design stage and designed to maintain the predevelopment flood levels.

9.2. Emergency Management Plan Model Results

A flood model has been completed for quantifying the risk of stop bank breach for the proposed site. This assessment has been done as recommended by WRC, and to also assess risks from natural hazards to future built form and community.

The assessment has been undertaken using a steady state analysis with a constant water level of 8mRL at Lake Waikare and 10.2mRL (extracted from River Waikato 100yr Climate Change model). This steady state analysis provides a conservative assessment of the risks and hazards and has been modelled in consultation with WRC.

The findings are summarised as follows.

- There were 3 locations identified for possible breach based on water level differences and overland flow paths leading towards the proposed site. Effect of each breach location is as follows:
    - Breach Location 1 (Ohinewai North Road): Breach flows from this location enter the proposed site from the north - western boundary corner and flooding is observed along Balemi Drain and encroaching the factory. The flood depths vary from 0.95m along the western boundary to 0.1m along the eastern boundary at Balemi Drain as shown in Figure 9 below.
    - Breach Location 2 (Ohinewai Landing Road): Breach flows are contained within the area to the west of State Highway 1 and do not affect the proposed site
    - Breach Location 3 (Ohinewai South Road): Breach flows are directed along the flow path towards Lake Ohinewai and do not affect the proposed site
- Within the proposed site –
    - Model results have been extracted from four locations within the Sleepyhead estate development site. These locations can be found in Figure 10.

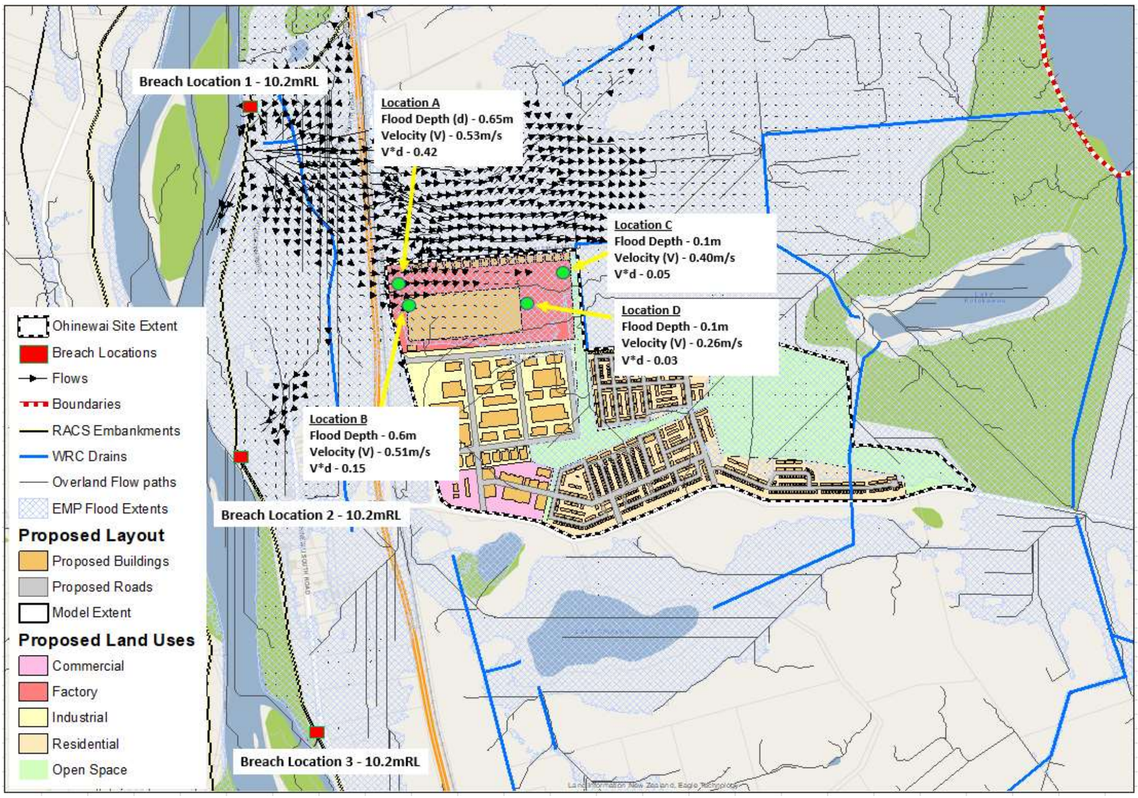

Figure 10: EMP Scenario Flood Extents

- The model predicts flood depths of up to 650 mm encroaching at the north western boundary (location A), with flood depths of 600 mm at location B and 100 mm at locations C and D.
- Depth and velocity products have been formulated for the part of the site that is inundated in the EMP scenario. These four locations have been assessed against the Austroads safety criteria for vehicles crossing a floodway. The Austroads Safety Criteria is outlined in Figure 11.

Table 3.2: The proposed draft *interim criteria* for stationary vehicle stability

Class of vehicle	Length (m)	Kerb weight (kg)	Ground clearance (m)	Limiting still water depth with zero velocity	Limiting high velocity flow depth (3 m/sec)	limiting velocity (m/sec) at low depth	Equation of stability
Small passenger	< 4.3	< 1250	< 0.12	0.3	0.1	3.0	DxV < 0.3
Large passenger	> 4.3	> 1250	> 0.12	0.4	0.15	3	DxV < 0.45
Large 4WD	> 4.5	> 2000	> 0.22	0.5	0.2	3	DxV < 0.6

Source: Shand et al. (2011).

Figure 11: AustRoads floodway safety criteria

- The model results show that locations A & B would not be accessible during catastrophic events (greater than the 100 year + climate change event) where the stop banks have breached. Locations C & D are accessible for small passenger vehicles when the velocity is stationary. It is important to note that overall the factory remains accessible from the south. The depth and velocity locations are summarised in Table 15.

Table 15: EMP Model Results - Safety Criteria

Location ID	Depth (m)	Velocity (m/s)	Depth x Velocity Product	Stability
A	0.65	0.53	0.42	Not trafficable
B	0.60	0.51	0.15	Not trafficable
C	0.10	0.40	0.05	Trafficable by small passenger vehicles
D	0.10	0.26	0.03	Trafficable by small passenger vehicles

  - It is proposed that evacuation plan will be drafted at detailed design of the factory to ensure that employees are provided safe egress to higher ground. As previously stated safe egress is possible from the south of the proposed factory site.
  - Proposed roads are clear of any flooding which would assist in the evacuation from the factory site.
  - There is no risk of flooding to the residential and commercial zones
- Outside the proposed site following flooding is observed –
  - State Highway 1
  - North Island Main Trunk railway
  - All properties along Ohinewai North Road and Ohinewai South roads

9.3. Maximum Probable Development Model

The 100yr model results were compared to understand the differences in flood extents and water levels between Scenarios 2 and 3 to understand the effects of proposed wider development. The results confirm that there is no increase in water levels or flood extents within the proposed site or any of the neighbouring sites primarily as the total effective impervious contribution is approximately 12% (6.27 sq. km) of the modelled 2D domain extent (50.63 sq. km) and 3% when compared to the total contributing area discharging to Lake Waikare (208 sq. km).

9.4. Sensitivity Model

The 100yr model results were compared to understand the differences in flood extents and water levels between Scenarios 1 and 5 to understand the effects of different curve numbers assumed for calculating the hydrological parameters. The results confirm that there is no increase in water levels or flood extents within the proposed site and there is 0.1m variability in water levels and depths at location 4 with curve number which would be managed with designing of the culvert under Lumsden Road as suggested in Section 8.1 above.

10. Conclusion

This report sets out the methodology and outcomes for the Ohinewai Sleepyhead Estate model build and effects assessment.

Flood modelling has been undertaken for the following scenarios:

- Scenario 1: Pre-Development/Existing Model (ED)
- Scenario 2: Post-Development Model (PD)
- Scenario 3: Maximum Probable Development Model (MPD)
- Scenario 4: Emergency Management Plan model (EMP)
- Scenario 5: Post-Development Sensitivity Model (PDS)

Modelling indicates that the proposed development has no adverse effects on neighbouring properties and achieves hydraulic neutrality for all modelled scenarios except for Location 4.

The overland flow path located around Lumsden Road at location 4 below exhibits ponding behind Lumsden Road for pre and post development scenarios. This is caused by the model representation in this area which has road levels intercepted by the LiDAR data without accounting for the culverted structure. This results in 'no flows' through the culvert and flows backing upstream with no downstream conveyance. This culvert under Lumsden Road will be revisited at detail design stage and designed appropriately to maintain the predevelopment flood levels and achieve neutrality.

Stop bank breach modelling has been carried out as per Waikato Regional Council's Regional Policy Statement around managing natural hazards and understanding residual risk. The model results show three breach locations in the stop banks along the Waikato River. The northern most breach at Ohinewai North Road affects the proposed foam factory location, with around 650 mm of flooding predicted at the north western property boundary. It should be noted that the rest of the site remain unaffected by the stop bank breach scenario. An assessment of the proposed depths and velocities against the Austroads Floodways Safety Criteria shows that the north western property boundary is not trafficable by large passenger vehicles. Safe egress from the site is possible to the south of the site, which remains unaffected in the breach scenario.

Modelling of Maximum Probable Development scenario indicates that there is no increase in water levels or flood extents within the proposed site or any of the neighbouring sites.

This is a result of total site area within the proposed development (1.79sq. km) being insignificant when compared to the downstream floodplain extents (34.66 sq. km) and total the total contributing area to Lake Waikare (208 sq. km).

List of References

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