FLOOD MODELLING REPORT

174 – 176 BROOKVALE ROAD
HAVELOCK NORTH

CIVIL ENGINEERING ▾ SURVEYING ▾ LAND DEVELOPMENT

PROJECT INFORMATION

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1. EXECUTIVE SUMMARY

This Flood Modelling Report has been prepared by Maven Associates to support the Fast Track substantive application for Brookvale Green at 174–176 Brookvale Road, Havelock North, Hawkes Bay. The purpose of this report is to assess existing and post-development flood behaviour across the site and to demonstrate that the proposed development can be implemented without creating adverse upstream or downstream flooding effects, and that flood hazard risks can be appropriately managed through design and consenting controls.

The site comprises approximately 24Ha and is located on the southern side of Brookvale Road, approximately 3.5 km of Havelock North village centre. The site topography generally falls toward the northern boundary and includes two watercourse corridors (one generally through the site and one along/near the northern boundary) which form the primary overland flow paths during major rainfall events.

Flood behaviour has been assessed using a hydraulic model (using TUFLOW software) developed with topographic inputs including survey data and publicly available LiDAR. The model simulates design storm events up to the 100yr ARI event with climate change, including other events as required, with an allowance for climate change consistent with current regulatory guidance applicable in Hawkes Bay. This approach is consistent with Hastings District Council (HDC) Engineering Code of Practice (ECOP) 2020, which specifies a secondary system design storm of 100yr ARI for new developments, while also requiring secondary system performance outcomes, including protection of habitable floors and safe access/egress, to be achieved up to the 50yr ARI event inclusive of climate change. The hydraulic model represents the main overland flow paths and open channels, the Brookvale Road culvert crossings, all stormwater device outlets and culverts that influence flood routing. The internal piped stormwater reticulation within local roads and lots has not been modelled as a detailed pipe network as part of this flood assessment, as the assessment is focused on major-event flood behaviour and primary hydraulic controls relevant to flood effects. Detailed assessment of the primary pipe network may be found in the infrastructure report calculations and sizing of wetland in HEC Report within the Stormwater Management Plan.

The modelling compares pre-development and post-development conditions to understand changes in peak flows, flood extents, and peak water surface levels at key locations within the site and at downstream discharge points. Focus has been placed on the two existing channels and the conveyance of major event flows through/under Brookvale Road, noting that the eastern channel functions as a major overland flow path for the wider upstream catchment during extreme events.

The proposed development incorporates an integrated flood mitigation response through landform design and stormwater management. Key measures include:

- (i) Enlargement of existing cut-off drain along the south-eastern boundary to intercept sheet flows and convey them to watercourse 1;
- (ii) Shaping road corridors to function as secondary flow paths where appropriate;
- (iii) Maintaining and enhancing the two channel corridors for conveyance; and
- (iv) Upgrading the Brookvale Road culverts to reduce flooding within existing Brookvale Road corridor and provide sufficient capacity and freeboard to proposed building platforms. Stormwater detention via a dry pond and wetland are also proposed to manage post-development runoff rates in accordance with HDC's Engineering Code of Practice 2020 and relevant Hawke's Bay Regional Council (HBRC) requirements.

The flood modelling indicates that, with the proposed mitigation measures described above, the development can be implemented without creating any material increase in offsite flood risk. Post-development flood extents and hazard are generally confined to the designated overland flow corridors and stormwater reserves, with developable areas set above design flood levels. Localised increases in peak water level are identified at limited locations, including within the downstream open channel at 163 Brookvale Road and in small, localised areas at 185 Brookvale Road and a localised area within upstream channel within 468 Te Mata Mangateretere Road; however, these increases are limited in extent, do not affect building footprints, and are assessed overall as less than minor. These landowners have been engaged during the design process and owner approval has been received for the identified effects.

Overall, the modelling demonstrates that flood risks associated with the 100yr ARI event with climate change can be appropriately managed for the Brookvale Green proposal through protection of overland flow paths, provision of adequate conveyance and storage, and setting of finished ground and floor levels. The assessment supports the conclusion that the site is suitable for the proposed residential development from a flood hazard perspective for Fast Track approval, subject to implementation of the assessed mitigation measures and conditions requiring minimum finished floor levels, protection of stormwater and overland flow corridors.

2. OVERVIEW

2.1 Design Event Framework and Compliance Basis (HDC ECOP 2020)

This assessment has been prepared with reference to HDC ECOP 2020, particularly Schedule D (Stormwater Drainage), which establishes performance expectations for primary and secondary stormwater systems, climate change considerations, and overland flow path management.

- Assess post-development flood behaviour and demonstrate how adverse flood effects can be avoided, remedied, or mitigated through the proposed landform, overland flow management and stormwater system; and
- Provide a technical basis for design development and relevant approvals, including confirmation of appropriate floor levels/freeboard, conveyance routes, and mitigation requirements.

The assessment has been prepared with reference to relevant guidance and standards, including HDC ECOP 2020, applicable HBRC requirements for stormwater discharges, and current good practice for flood hazard and risk assessment in New Zealand.

2.2 Introduction

The purpose of this assessment is to confirm that flood hazards and overland flow effects for the Brookvale Green development can be appropriately managed, and that development enabled through the Fast Track substantive application will not result in adverse upstream, on-site, or downstream flooding effects.

A hydraulic model has been developed by Maven to assess flood behaviour for the 100-year Annual Recurrence Interval (ARI) rainfall event (with climate change allowance). This report outlines the model development, key results, and conclusions, and should be read in conjunction with the Brookvale Green Fast Track application documentation and the associated civil design information.

2.3 Site Description

The site comprises approximately 24 Ha at 174–176 Brookvale Road, Havelock North, Hawke's Bay. The site is located on the southern side of Brookvale Road, to the east of Arataki Road, and adjoins land to the west which has recently received Fast Track approval (February 2026) for residential development. The site falls generally toward the northern boundary and contains two open watercourse corridors (one generally through the site and one generally along the northern boundary) which function as primary overland flow paths during major rainfall events.

The eastern channel corridor receives flows from a large upstream catchment and conveys major event runoff northward beneath Brookvale Road before continuing through downstream drainage reserves and watercourses. During extreme events, this corridor provides conveyance and local flood storage and is therefore a key constraint and design driver for the proposed development layout.

Downstream of Brookvale Road, flows are conveyed through a combination of open drains, culverts and drainage reserves (including the Crombie Drainage Reserve and downstream receiving watercourses) prior to discharging to the Karamu Stream system. The downstream system includes low-gradient reaches where storage and backwater effects can influence flood extents, particularly during high intensity rainfall events and where culvert capacity is limited or partially blocked.

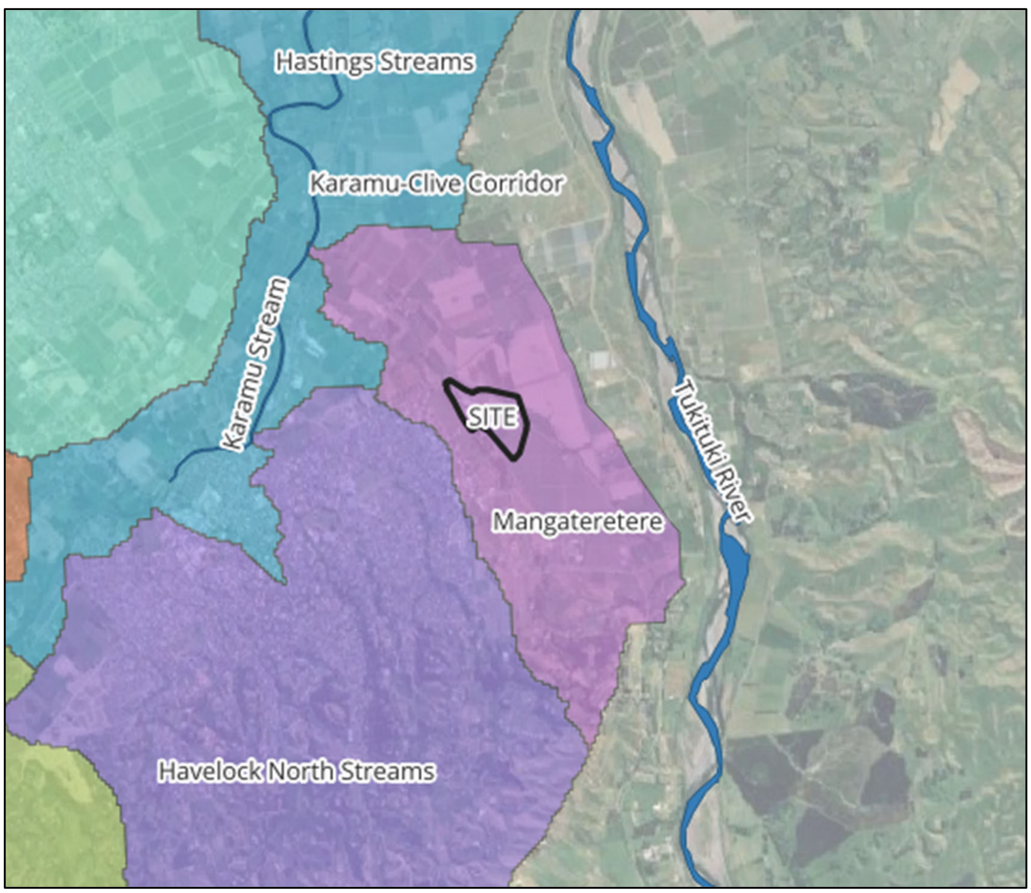


Figure 1 Site locality and indicative catchment context

2.4 Previous Catchment Modelling

2.4.1 Previous Flood Information

Hawke's Bay Regional Council (HBRC) *Hawke's Bay Flood Risk Areas* information has been reviewed as part of the background assessment. Based on this review, the site is identified as not being located within a mapped flood risk study area / in-study area. Accordingly, no HBRC flood model outputs (e.g., flood extents, depths or levels) are available for the site at the time of reporting.

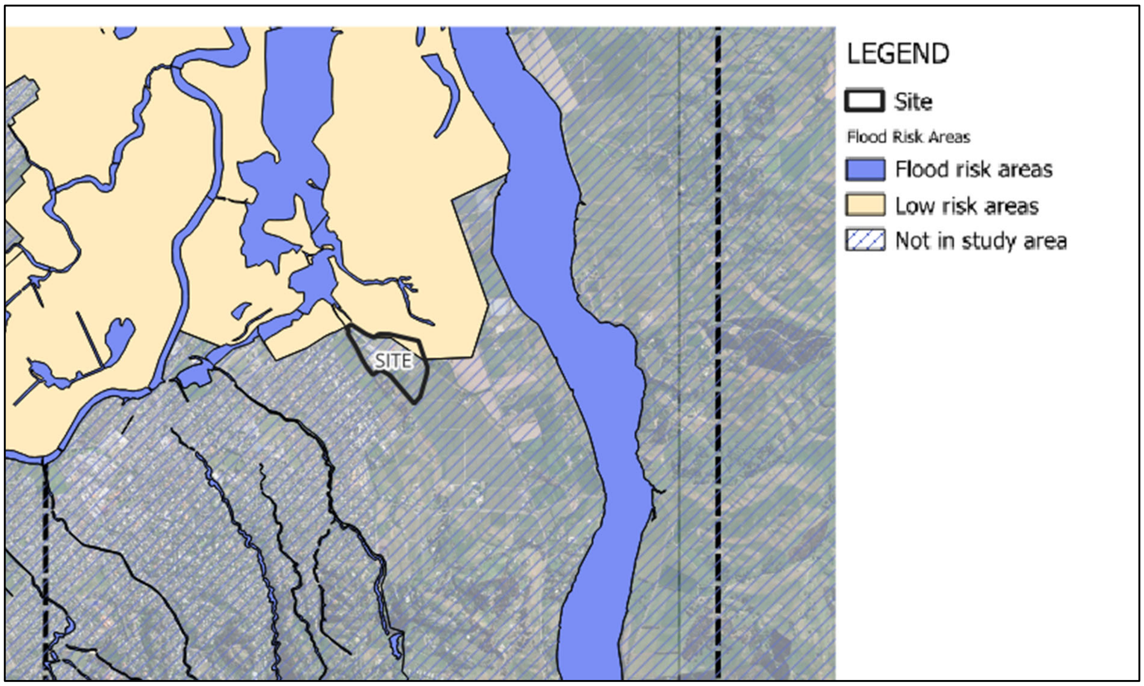


Figure 2 Hawke's Bay Flood Risk Areas, HBRC GIS

This flood modelling assessment has therefore been developed using project-specific topographic data, contemporary modelling tools, and assumptions aligned with HDC and HBRC requirements. The results presented in this report provide the primary basis for assessing flood hazard and flood effects associated with the Brookvale Green proposal for Fast Track consenting purposes.

2.5 Existing Site Land Use and Imperviousness

2.5.1 Existing Development and Impervious Coverage

The site currently includes buildings, yards and accessways associated with existing commercial/rural activities. For modelling purposes, existing impervious coverage has been defined using available aerial photography, site survey information, and reasonable assumptions for roof and paved areas (Figures below provide indicative existing coverage context.

Where spatial landcover datasets were required for the wider catchment, publicly available datasets and local authority information have been used (Land Cover Database version 6.0, Mainland, New Zealand). Assumptions adopted for landcover, imperviousness and infiltration are documented in Section 5 and Appendix A.

The modelled pre-development impervious area within the site extents is approximately 22% of the site area.

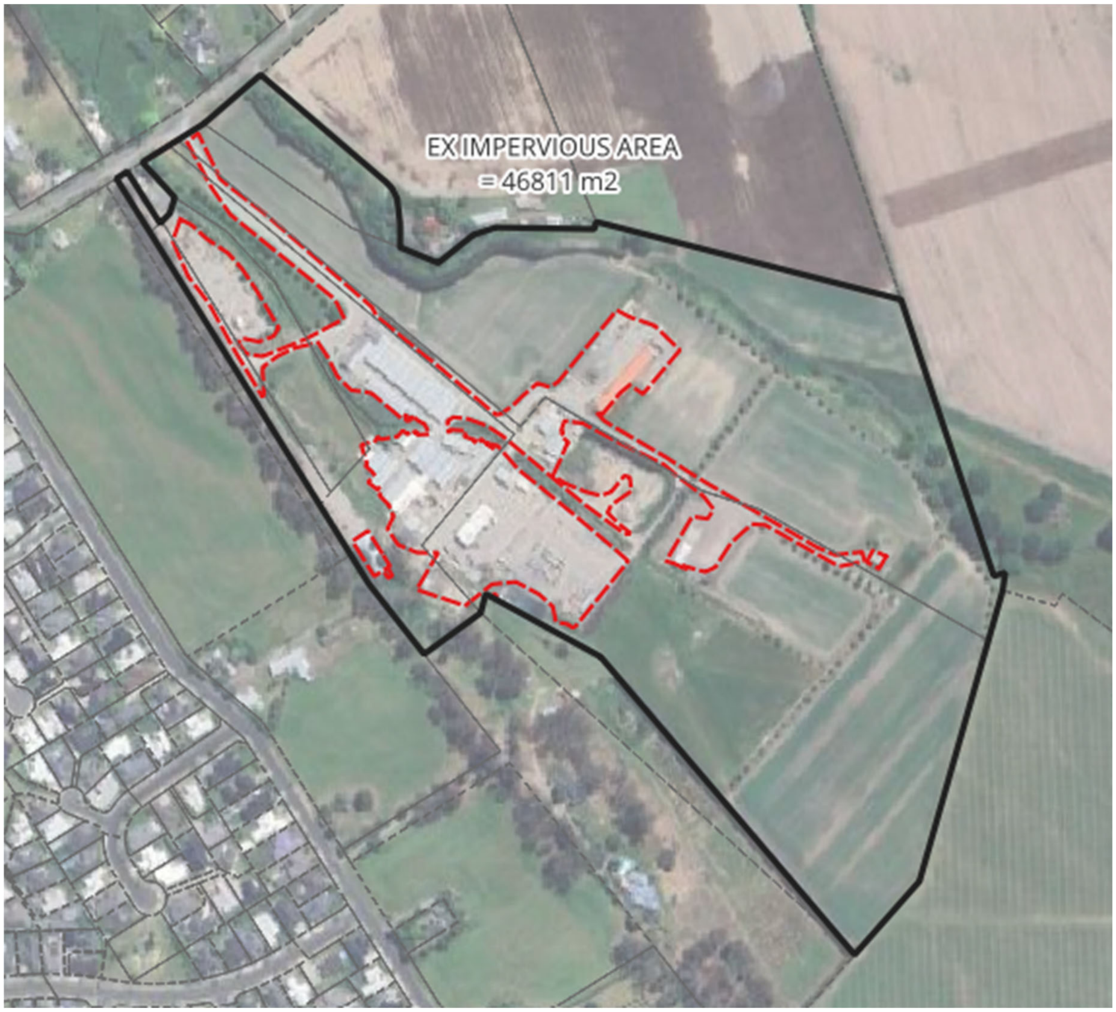


Figure 3 Indicative pre-development impervious coverage (Brookvale Green)

2.6 Proposed Development (Fast Track)

The Brookvale Green proposal comprises a residential development at 174–176 Brookvale Road, Havelock North. The masterplan provides for 203 dwellings together with public roads, open space and stormwater reserves. Flood modelling has been undertaken to inform the landform and stormwater strategy (including conveyance and attenuation) and to demonstrate that flood effects can be appropriately managed for the Fast Track substantive application.

Figure 4 Proposed Brookvale Green Layout

2.6.1 Proposed Flood management objectives

1. Avoid increasing flood risk to people, property, and infrastructure, including downstream effects.

2. Maintain the function of existing overland flow paths and watercourse corridors, including provision for safe conveyance and storage during major events.

3. Ensure stormwater discharges are appropriately managed, including consideration of climate change.

4. Use design and consent conditions (where relevant) to manage residual risk, including minimum finished floor levels/freeboard and protection of critical conveyance routes.

3. MODEL BUILD

A hydraulic model has been prepared to assess flooding for the Brookvale Green proposal. The model build approach, and key inputs are summarised in the following sections.

3.1 Modelling Approach

The following modelling approach has been implemented for the assessment for the 2yr, 10yr, 50yr and 100yr ARI storm events:

1. A catchment wide pre-development model was prepared.
2. A post-development model was prepared.
3. A comparison and impact assessment were undertaken to assess the impact of the proposal downstream for each of the scenarios.
4. A hazard assessment was undertaken

3.2 Data

The following data has been used for the flood model build:

- Design rainfall for Hawke's Bay derived from HIRDS (NIWA) for the adopted duration(s) and ARI(s), including climate change allowance (RCP8.5 2081 to 2100).
- Topographic surface(s): site survey, publicly available Lidar (Hawke's Bay LiDAR 1m DEM (2023-2024), and post-development design surface .
- Representation of existing open channels, overland flow paths, and key hydraulic structures including culverts under Brookvale Road.
- Downstream culverts from HDC Council GIS
- Landcover/roughness and infiltration parameters based on site conditions and available datasets for the wider catchment (from Land Cover Database version 6, S-map drainage - depth, texture, soil order and New Zealand Fundamental - Soil Layer FSL Depth to Slowly Permeable Horizon)
- Blocked culvert sensitivity scenarios as described in section 5.1 for major-event assessment.
- All spatial model inputs and outputs are referenced to the Hawke's Bay 2000 horizontal coordinate system and New Zealand Vertical Datum 2016 (NZVD2016), unless noted otherwise.

3.3 Modelled Catchment Extent

The model extent has been defined to capture the Brookvale Green site and the relevant upstream contributing areas and downstream conveyance routes required to robustly assess flood behaviour at and around the Brookvale Road corridor.

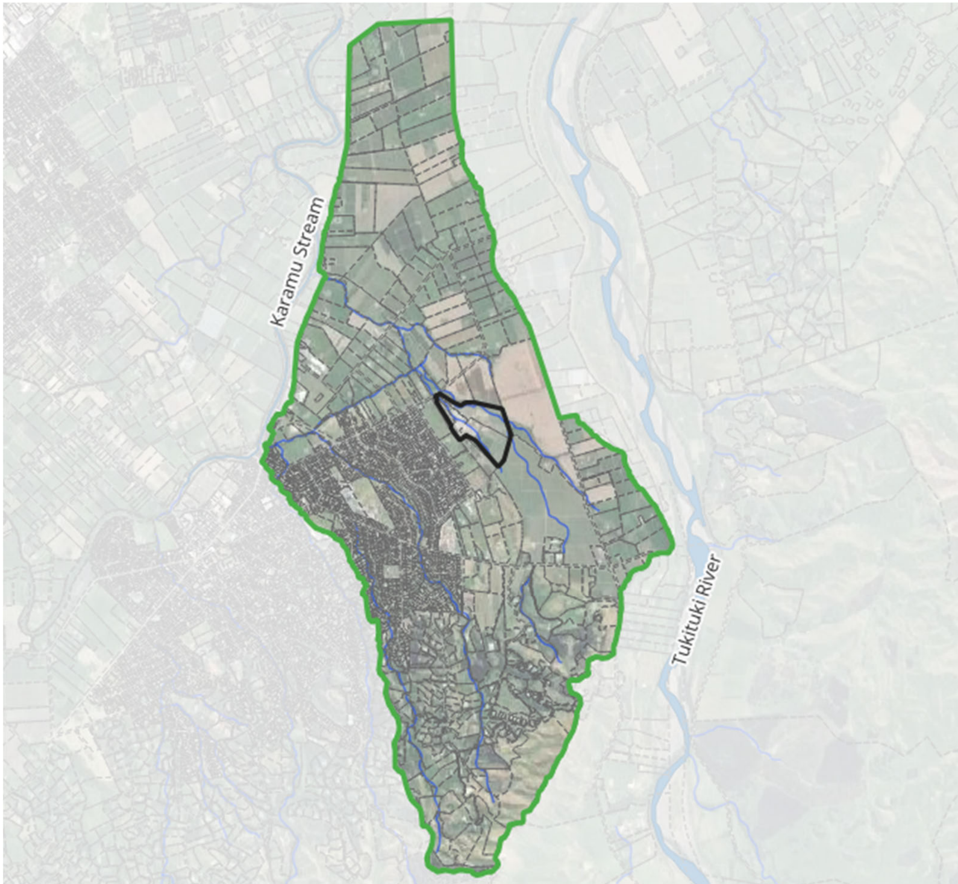


Figure 5 Model extent and indicative catchment boundary (Brookvale Green)

4. HYDROLOGY

Hydrological parameters for the model have been developed using New Zealand standard approaches and local requirements, including rainfall data sourced from NIWA HIRDS and design principles consistent HDC ECOP 2020.

4.1 Design Rainfall

Design rainfall inputs have been derived from NIWA HIRDS for the Brookvale / Havelock North area. A centrally nested temporal rainfall (balanced Nested Storm rainfall profile) has been generated from the rainfall depths of each duration. Table 1 summarises the adopted 24 hour rainfall depth(s) and climate change allowance(s) used in the model.

Storm event	24hr Rainfall depth (mm)	Climate change allowance	Future rainfall depth (mm)
2yr ARI	67.7	RCP8.5 (2100) +18.4%	80.2
10yr ARI	105	RCP8.5 (2100) +20.0%	127
50yr ARI	144	RCP8.5 (2100) +22.2%	176
100yr ARI	162	RCP8.5 (2100) +22.2%	198

Table 1 Design 24-hr rainfall depths HIRDSv4 RCP8.5 (2081-2100)

4.2 Soil Classification

4.2.1 Within Site Extents

A geotechnical assessment for the site (HB Geotech, Geotechnical Assessment Report) has been reviewed to inform flood modelling assumptions and is appended to the substantive application. Key information relevant to the hydrology and hydraulic model is summarised below.

- Groundwater and seepage are variable across the site and over time. During wet conditions (March–April 2026 investigations) groundwater/seepage was commonly encountered at approximately 2.0–4.0m below ground level across much of the site, with shallower levels locally near the eastern channel.
- Perched/transient groundwater may occur where permeable gravels overlie less-permeable silts, leading to local saturation above the fine-grained unit following rainfall. This supports adopting conservative (low) infiltration/soakage assumptions for flood modelling and design, particularly for short-duration, high-intensity storm events.
- Stormwater detention basin area (north-west): groundwater was recorded at approximately 3.55m below ground level following drilling (HA16 piezometer installation), with a highest logged level of approximately 3.15m during a significant rainfall event in April 2026. The proposed basin invert is expected to remain above prevailing groundwater levels; however, seasonal monitoring is being used to confirm winter conditions.
- Soils are predominantly very stiff to hard fine-grained alluvium (sandy silt to clayey silt) over dense to very dense gravels, with localised thicker fine-grained layers in parts of the south-central site. These soil conditions are generally not conducive to high-rate soakage, and infiltration can be limited by fine-grained horizons.
- Localised uncertified fill and organic/weak soils have been identified in historical channel alignments and infilled low areas (including portions of the eastern stream/oxbow and historical pond/channel infill areas). These materials can exhibit higher moisture content, seepage and reduced stability and should be considered in detailed design of diversion works, channel works and any in-channel filling/realignment.
- Where overland flow paths or drainage features are infilled or diverted, subsoil drainage may be required to avoid creating unintended ponding or elevating local groundwater levels. This is relevant to design of flood mitigation earthworks and to ensuring overland flow conveyance routes perform as intended during major events.

Accordingly, the flood model has been set up to avoid relying on soakage for flood mitigation performance, and to treat infiltration as a secondary (and conservative) loss mechanism. Groundwater interactions are not explicitly simulated in the hydraulic model; however, the adopted approach (including conservative infiltration and culvert blockage sensitivity testing) provides an appropriate basis for assessing major-event flood conveyance and hazard pathways for design.

4.2.2 Wider Catchment

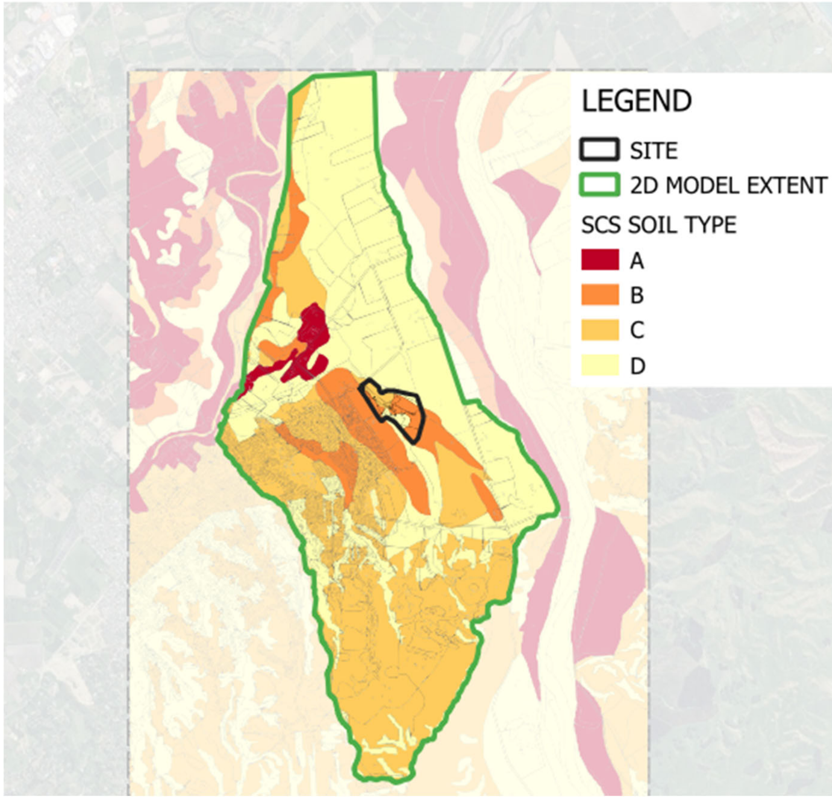


Figure 6 SCS Soil Classification for 2d Model

SCS soil classes have been generated by integrating open soils data (from S-map drainage - depth, texture, soil order and New Zealand Fundamental - Soil Layer FSL Depth to Slowly Permeable Horizon).

The majority of the catchment area uses a soil type of class C with localised areas of class D in low lying stream area and flood plains areas

4.3 LANDCOVER & INFILTRATION INPUTS

Plans and a table showing infiltration and manning values implemented in model may be found in Appendix A.

4.3.1 Pre-development Landcover

<u>Within Site extents - Pre-development impervious coverage</u>

Pre-development landcover and losses have been derived from a combination of site-specific information (Section 2.6) and wider-catchment datasets. Within the site, existing impervious and pervious areas were interpreted from aerial imagery and project information to define an indicative pre-development landcover layer. This layer was then converted to model parameters by assigning representative hydraulic roughness (Manning's *n*) and infiltration/loss values for each landcover class.

Wider catchment

For the upstream contributing catchments outside the site, landcover was sourced from the Land Cover Database (LCDB v6) and used to assign spatially varying roughness and infiltration parameters consistent with the approach summarised above. A map of the adopted landcover classes is provided in Figure 7, with the full parameter tables provided in Appendix A.

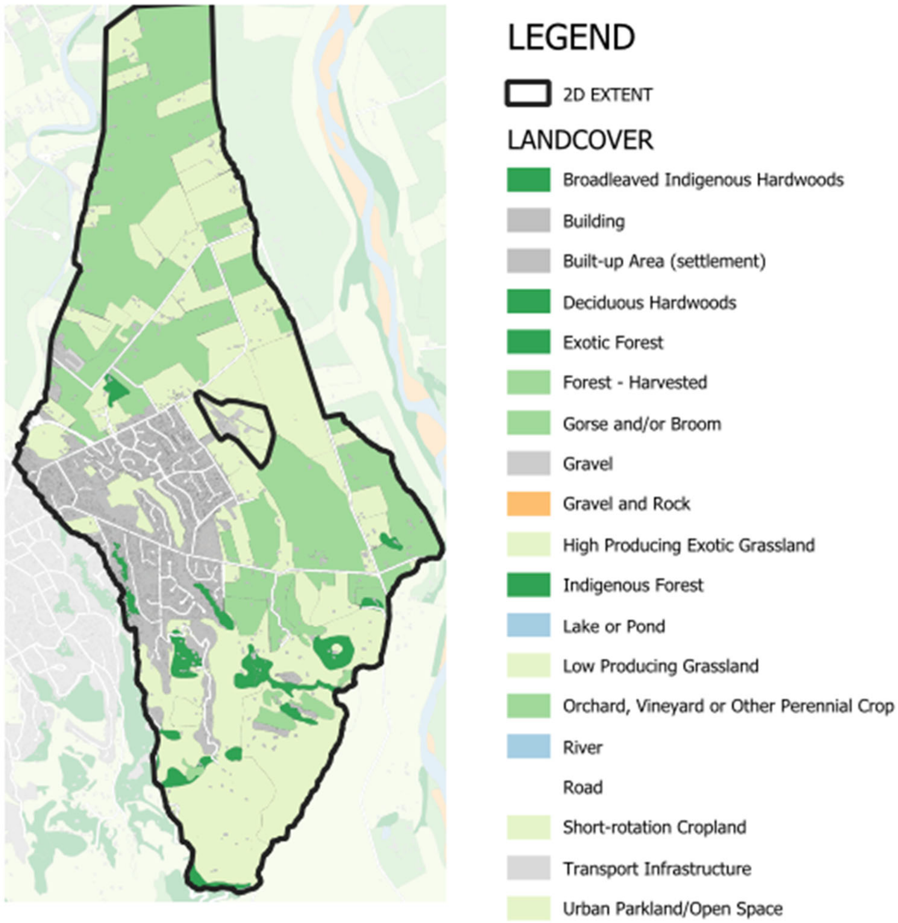


Figure 7 TUFLOW Model landcover layer (source:LCDB v6)

Infiltration

Spatially varying infiltration parameters for the model have been derived based on landcover and indicative soil/permeability information using Auckland TP108 methodology (per section 4.2).

Roughness:

Spatially varying hydraulic roughness (2d_mat) parameters for the catchment were derived from open-source datasets. Roughness values (Manning's 'n') were assigned based on land cover from the Land Cover Database version 6 (LCDB6), supplemented with road parcels and building outlines from LINZ.

For pre-development, manning values vary between 0.02 for roads and impervious areas, 0.12 for forests, and 0.3 for building footprints.

4.3.2 Post-development Landcover

Post-development landcover is based on the proposed Brookvale Green masterplan. Conservative assumptions for hard, impervious surfaces have been applied to residential lots (60%), roads (90%), and stormwater reserves and watercourse channels (0%). Lots and roads have been assigned static surface roughness (Manning's n) values of 0.05 and 0.02, respectively.

To align with the proposed landscaping, the stormwater reserves and watercourse channels have used variable roughness values. These values change based on water depth, reflecting how vegetation resists water flow before eventually bending or becoming fully submerged:

- Upper Stream Bank Mix: Flow resistance peaks at shallow depths (between 0.10 and 0.12 below 0.5m) as water hits dense vegetation, then steadily decreases down to a minimum of 0.08 in deep water (3.0m).
- Bank Face Mix: Flexible vegetation creates initial resistance (between 0.08 and 0.09 below 0.5m) but quickly flattens out under heavier flows, dropping to a lower resistance of 0.045 in deep water (3.0m).
- Eastern Boundary Terrestrial Buffer: Flexible vegetation creates initial resistance (between 0.08 and 0.12 below 1.0m)

4.3.3 Initial Abstraction

Initial abstraction and loss parameters have been adopted consistent with the modelling methodology used (TP108)

- Ia=5mm for pervious area
- Ia=0 for impervious area

4.4 Culverts

This section outlines the culverts represented in the model, with a focus on the Brookvale Road crossings and any other structures that influence conveyance along the site's watercourse corridors. Culvert sizes, inverts and alignment are based on available survey information and available records.

4.4.1 Culvert Blockage Factors

A culvert blockage sensitivity scenario has been assessed to account for potential reductions in hydraulic capacity due to debris, sedimentation, or other maintenance-related factors during major storm events. The adopted blockage assumptions are based on recognised good practice and are intended to be conservative for consenting purposes.

To represent reduced conveyance and residual risk, blockage factors were applied to structures within the TUFLOW model for the 50yr and 100yr ARI design scenarios. Structures were categorised by susceptibility to blockage based on diameter: Category A (≥1500 mm, lower susceptibility) and Category B (<1500 mm, higher susceptibility). No blockage was applied for the 50% and 10yr ARI events, reflecting clear conveyance during smaller, more frequent storms.

For the 50yr ARI event, Category A culverts were modelled with 25% blockage and Category B culverts with 50% blockage. For the 100yr ARI event, Category B culverts were modelled as 100% blocked, while Category A culverts were assigned a 50% blockage to reflect increased debris loading during extreme events.

Notwithstanding these assumptions, secondary flow paths are incorporated to ensure safe overland conveyance if culvert capacity is reduced.

5. HYDRAULICS (TUFLOW)

A TUFLOW model was built to assess the hydraulic characteristics of catchment flows. Details of the model build is summarised in the following sections.

5.1 Geometry

The model geometry includes the following components:

- 2D flow: the 2D model extent generally consists of variable cells sizes ranging from 1m to 5m by using Quadtree and Sub-Grid Sampling techniques.
- Breaklines: breaklines have been applied along roads center line to accurately represent road embankments.
- External boundaries: 2D rainfall region boundaries to distribute spatially variable hyetographs across the catchment.
- Outflow boundaries: where water leaves 2D flow area through downstream boundary conditions.
- Hydraulic structures: Key structures influencing major-event conveyance are represented, including the Brookvale Road culvert crossings, proposed road culverts and outlet controls for the proposed wetland and dry detention basin (modelled as 2D connections).

5.2 Terrain Model

The terrain model was formed by merging the following resources. Model levels are referenced to New Zealand Vertical Datum 2016 (NZVD2016), and horizontal coordinates are referenced to Hawke's Bay 2000.

- Available LiDAR terrain model for (Hawke's Bay LiDAR 1m DEM (2023-2024)
- Maven site survey (including drone and on-site survey)
- Site survey and council records for downstream culvert structures
- Proposed ground level surface

5.3 Boundary Conditions

Rainfall boundaries were applied for each of the rainfall events with the allowance of future climate change (RCP8.5 2081 to 2100).

Two primary downstream boundaries are located approximately 2 km downstream of the site, where the local catchment discharges toward the Karamu Stream system. These locations were selected to minimise downstream boundary influence on the study area while still allowing downstream hydraulic effects to be tested. A long section from the site to the Karamu Stream is provided in Figure 8 and shows the modelled water surface elevations for two pre-development 100yr ARI with climate change tailwater scenarios: a free-flowing downstream condition and a 7 m tailwater level in the Karamu Stream.

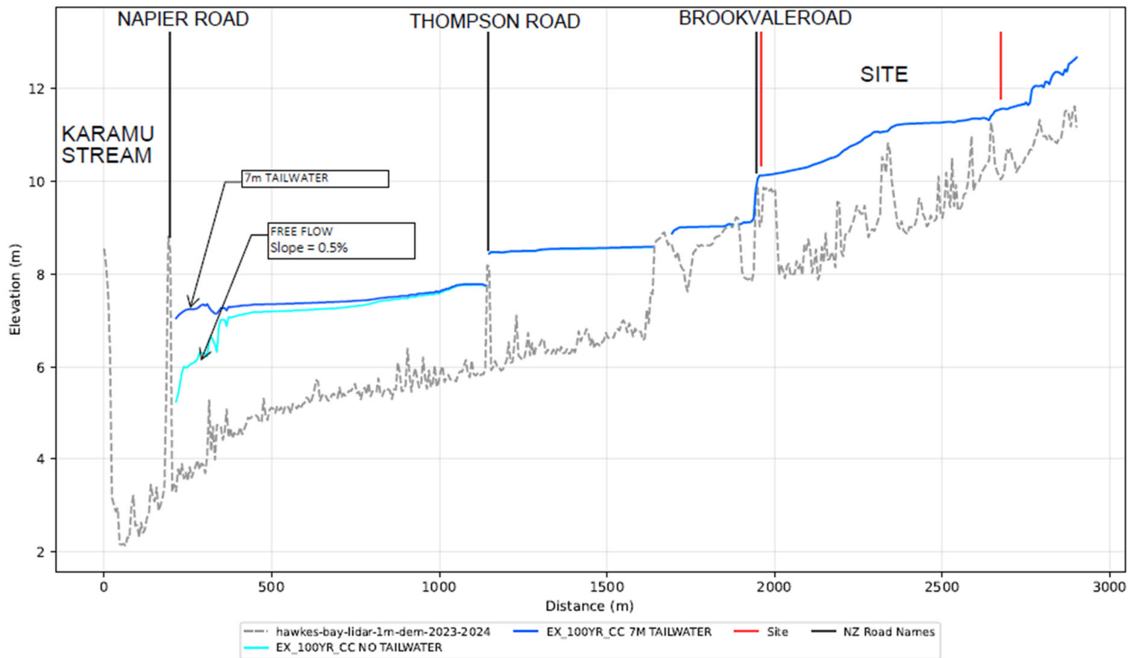


Figure 8 Outflow boundary - Mangateretere

The long-section comparison indicates that the adopted Karamu Stream tailwater condition has only a minor effect on modelled water levels in the downstream reach between Napier Road and Thompson Road, and no material impact further upstream toward the site. On this basis, Karamu Stream tailwater conditions are not expected to influence the flood effects assessment at Brookvale Green. A conservative 7 m tailwater level in the Karamu Stream has therefore been adopted for the assessment.

Another minor downstream boundary has been included approximately 4 km to the north to account for potential overland and sheet flow toward northern low-lying areas during larger events, enabling realistic floodplain outflow beyond the main drainage network.

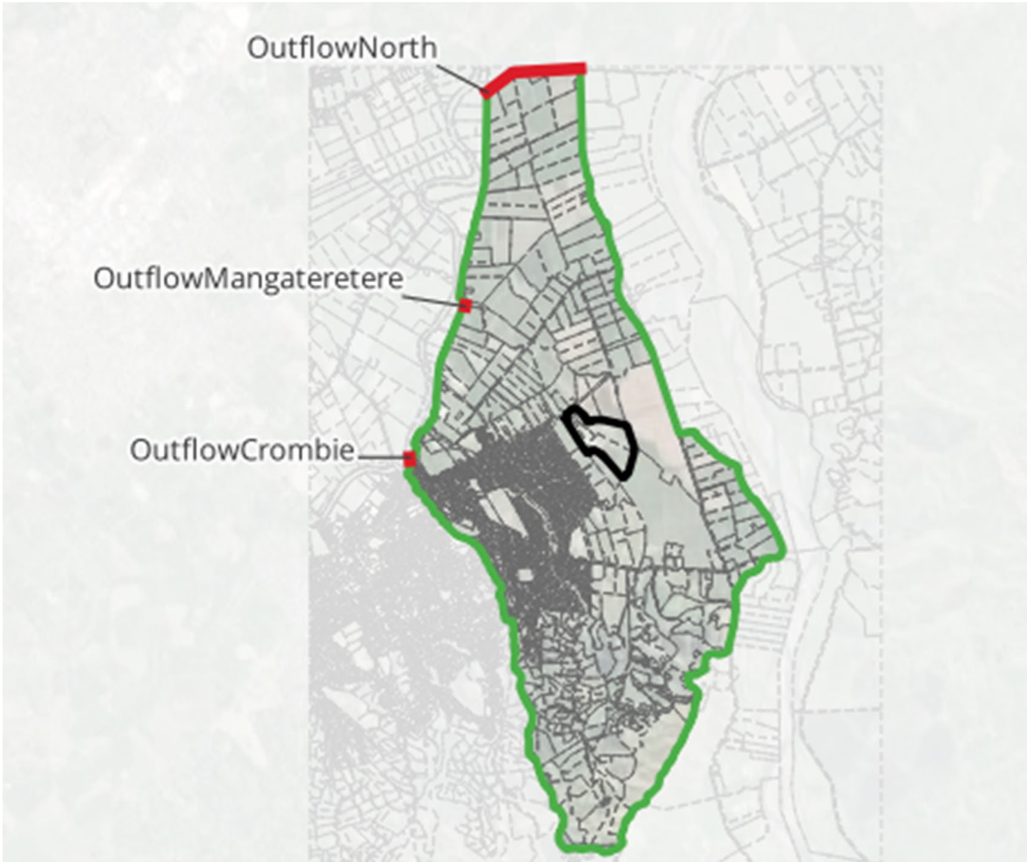


Figure 9 TUFLOW model outflow boundary conditions

The adopted boundary conditions are therefore considered appropriate for the current level of information and purpose of assessment, with the 7 m Karamu Stream tailwater providing a conservative downstream water level assumption that does not materially affect the modelled outcomes at the site.

6. PROPOSED STORMWATER MITIGATION

The proposed flood mitigation strategy combines landform design, protection of overland flow paths, and stormwater management devices to avoid or mitigate adverse flood effects. Key measures are summarised below and reflected in the modelled post-development scenarios.

6.1 Flood Mitigation Measures

To ensure the Brookvale Green proposal does not increase upstream or downstream flood risk, a range of specifically designed mitigation measures have been incorporated into the masterplan and assessed in the flood modelling. These mitigations measures are shown below within Figure 10, and expanded on further in the following sections of the Report.

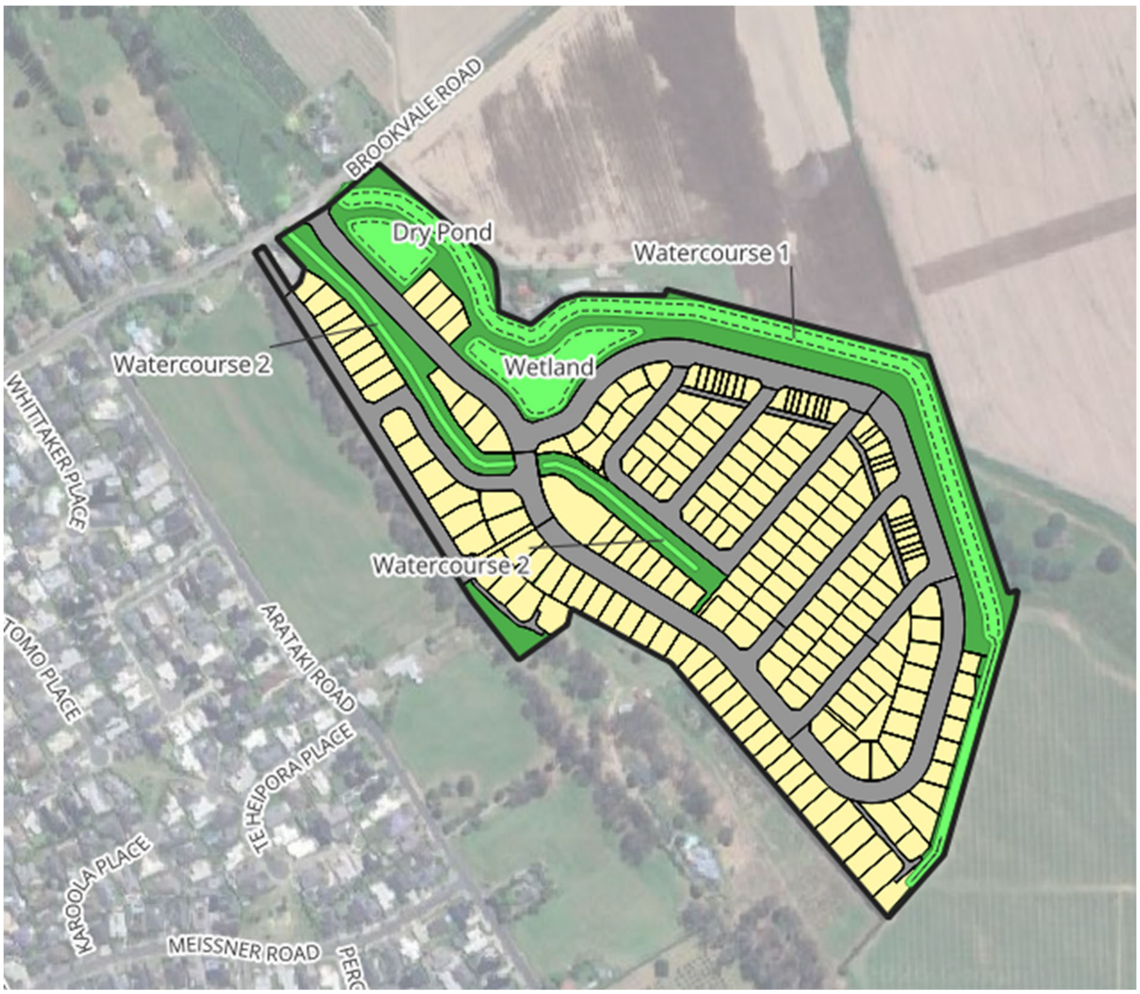


Figure 10 Proposed stormwater / flood mitigation layout

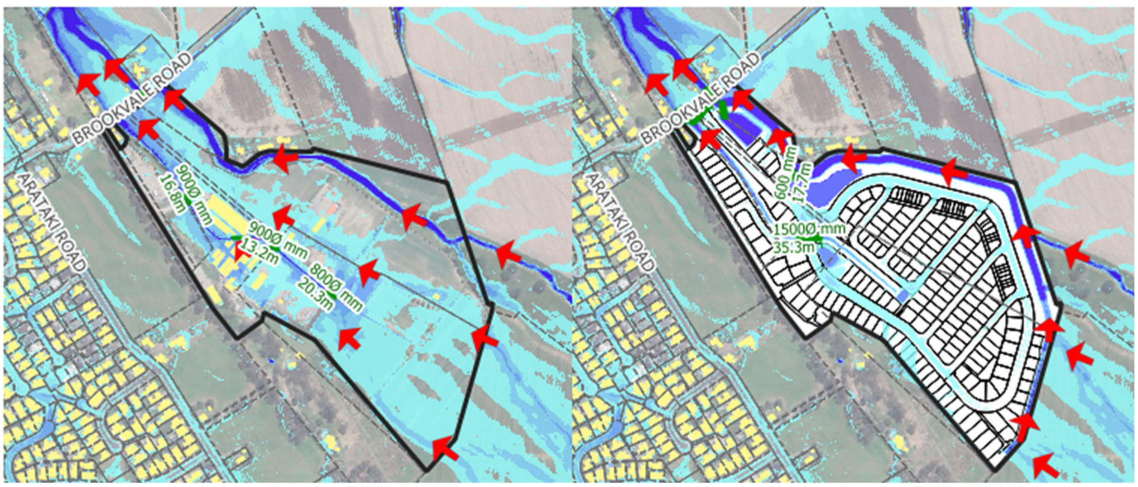
6.1.1 Realignment and Enhancement of the Two Existing watercourse Corridors for Conveyance

Under post-development conditions, primary overland flow is managed within watercourse 1 and watercourse 2 corridors (eastern and internal/western corridors). A cut-off drain along the south-eastern boundary intercepts upstream sheet flows that previously routed toward the internal/western corridor and diverts these flows to the eastern corridor.

To accommodate the increased flows the eastern corridor has been widened and enhanced to increase conveyance capacity. Both corridors are retained and upgraded as stormwater reserve/open space corridors, providing for major-event conveyance. The proposed landform and stormwater strategy is intended to confine floodwaters within these corridors while elevating developable areas above the modelled floodplain.

The eastern corridor has also been realigned along the north-eastern boundary to accommodate the proposed lot layout and to improve connectivity and alignment with the existing and proposed road culverts and downstream channel beyond Brookvale Road. This has improved the conveyance of flow over Brookvale Road, providing positive resilience effects.

Road corridors are shaped to provide secondary (exceedance) flow paths where required, directing overland flows safely back toward the watercourse corridors and away from building platforms.



6.1.2 Proposed Wetland

The proposed wetland provides primary attenuation of post-development runoff, with extended detention and a controlled outlet to limit discharge to downstream networks.

As outlined in the Infrastructure Report, the wetland forms the key attenuation device, designed to achieve post-development flows consistent with the required pre-development conditions in accordance with HDC ECOP.

The wetland is modelled as a storage with controlled discharge, demonstrating reduced peak flows and improved downstream performance.

Detailed sizing and outlet design are provided in the Civil Design (Infrastructure) Report and supporting calculations.

6.1.3 Proposed Brookvale Road Culvert Upgrades

At the watercourse 1 outlet beneath Brookvale Road, the existing 1.4 m × 1.1 m box culvert is retained, with a new twin 2.5 m × 1.0 m box culverts proposed adjacent to increase conveyance capacity.

At the watercourse 2 channel outlet beneath Brookvale Road, the existing 400 mm and 800 mm culverts are replaced with a single 2.0 m × 1.0 m box culvert to improve hydraulic performance.

These upgrades have been incorporated into the hydraulic modelling and support improved conveyance under post-development conditions. These upgrades provide for improved roadway performance in flood events, improves resilience against future rainfall events, and reduces the risk of asset damage that otherwise exists with the undersized culverts which currently exist.

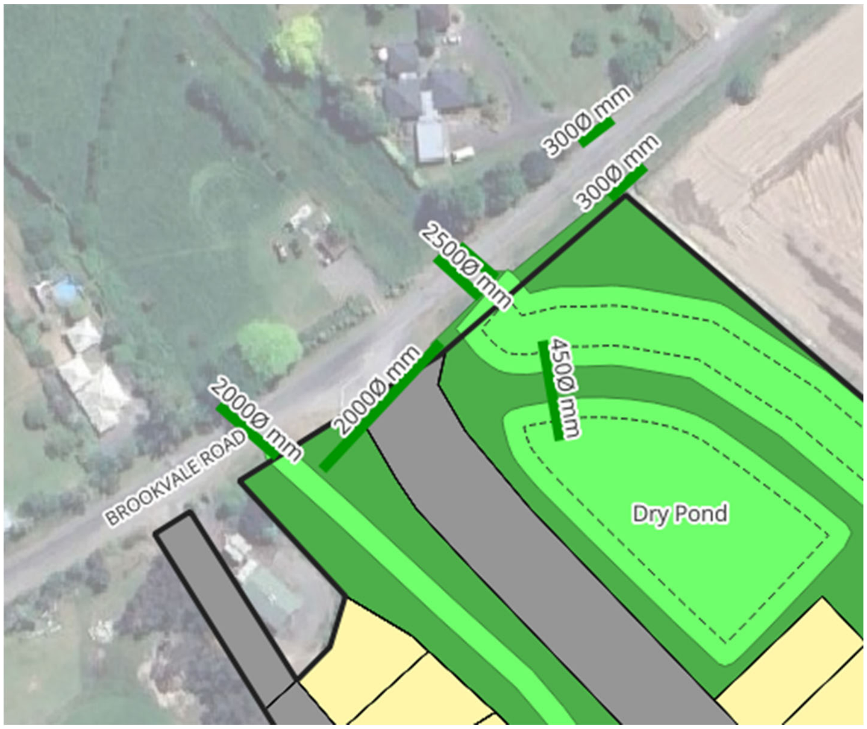


Figure 11 Proposed Brookvale Road Culverts

6.1.4 Proposed Dry Pond

Under the culvert blockage sensitivity scenario (refer Section 5.1), the proposed dry detention pond has been specifically configured to function as a peak flow diversion and mitigation measure during extreme events.

The dry detention pond and localised realignment at the downstream end of the eastern corridor are required to manage increased post-development flows. Peak flow diversion to the dry pond reduces discharge at the Brookvale Road crossing, while the realignment at the culvert outlet improves downstream conveyance and avoids directing flows toward 185 Brookvale Road.The dry pond is not intended to operate as a conventional attenuation device for frequent storms; rather, it is designed to remain largely offline under normal and moderate conditions and to activate only under major-event exceedance conditions.

The system is configured such that:

- The dry pond is triggered during the 100yr ARI event with climate change, in combination with a culvert blockage scenario, where upstream conveyance is reduced and overland flow paths become critical.

- A spillway control level set at RL 10.1 m defines the activation threshold of the dry pond.
- Once upstream water levels exceed RL 10.1 m, flow is diverted into the dry pond which has a storage volume of approximately 3,800 m3 below the spillway, temporarily storing excess runoff that would otherwise contribute to peak discharge and downstream surcharge conditions.

6.1.5 Required Finished Floor Levels

As per the HBRC Waterway Guidelines for Stormwater Management, habitable building floor levels are required to include a contingency freeboard above the 100yr ARI flood level. In accordance with NZS 4404:2010 , 4.3.5.2, a minimum freeboard of 0.5 metres above the computed top water level for the 100yr ARI with climate change (blocked scenario) design stormwater event is required for habitable dwellings, including attached garages.

7. MODEL SCENARIOS

Modelled scenarios include events selected to support the major-event (secondary system) consenting assessment, with reference to HDC ECOP 2020 Schedule D. For new developments, ECOP specifies the 100yr ARI event with climate change as the secondary design storm (and requires assessment of 100-year effects), while also setting secondary-system performance expectations up to the 50yr ARI event (inclusive of climate change) for habitable floor protection and safe access/egress. Accordingly, the primary focus of this report is the 100yr ARI event with climate change allowance for pre- and post-development scenarios (including a culvert blockage sensitivity test). This modelling assessment does not include the internal piped stormwater network, however, 10yr and 2yr ARI models have been included for reference.

Scenario	Condition	Event	Notes
1	Pre-development (unblocked)	100yr ARI + climate change	Existing terrain and existing culverts.
2	Pre-development (blocked)	100yr ARI + climate change	Key culverts partially blocked per Section 5.1 (blockage sensitivity).
3	Post-development (unblocked)	100yr ARI + climate change	Proposed terrain, stormwater devices, and proposed culvert upgrades.
4	Post-development (blocked)	100yr ARI + climate change	Sensitivity check with partial culvert blockage per Section 5.1.
5	Pre-development (unblocked)	50yr ARI + climate change	Existing terrain and existing culverts.
6	Pre-development (blocked)	50yr ARI + climate change	Key culverts partially blocked per Section 5.1 (blockage sensitivity).
7	Post-development (unblocked)	50yr ARI + climate change	Proposed terrain, stormwater devices, and proposed culvert upgrades.

8	Post-development (blocked)	50yr ARI + climate change	Sensitivity check with partial culvert blockage per Section 5.1.
9	Pre-development (unblocked)	10yr ARI + climate change	Existing terrain and existing culverts.
10	Post-development (unblocked)	10yr ARI + climate change	Proposed terrain, stormwater devices, and proposed culvert upgrades.
11	Pre-development (unblocked)	2yr ARI + climate change	Existing terrain and existing culverts.
12	Post-development (unblocked)	2yr ARI + climate change	Proposed terrain, stormwater devices, and proposed culvert upgrades.

Table 2 Modelled scenarios summary (Brookvale Green)

8. FLOOD RESULT MAPS

The model result maps are provided in APPENDIX B, including maximum flood depth maps and peak flow maps (pre- and post-development). Flood level difference maps between post-development and pre-development conditions are provided in APPENDIX C.

9. MODEL RESULTS

This section summarises the key flood modelling results and assesses the potential impact of the Brookvale Green proposal on flood behaviour within the site and at relevant downstream locations. Results are reported for pre-development and post-development scenarios (including culvert blockage sensitivity), with supporting maps provided in the appendices.

9.1 PREDEVELOPMENT

9.1.1 Existing Site Flow Paths

Under pre-development conditions, flooding is primarily associated with the two watercourse corridors and adjacent low-lying areas.

The site drains to two primary open watercourse corridors which also convey runoff from a wider upstream catchment (as shown in figure 10).

- Watercourse 1: A significant upstream contributing catchment discharges to this corridor, which runs along/near the site's northeastern boundary and passes under Brookvale Road via the existing box culvert (1.4m x 1.1m). Approximately half the upstream flow is conveyed via this watercourse.

- Watercourse 2: This corridor runs through the site and receives local catchment runoff (including from proposed development areas), providing conveyance to downstream discharge points, including through Brookvale Road culvert (400mm and 800mm). During major events, overland sheet flow also occurs adjacent to (and converges into) the internal corridor. Existing topography indicates that approximately half of the overland flow is conveyed via a combination of the internal corridor and adjacent sheet flow, with the remaining half reporting to the eastern corridor (approximately mid-way along the corridor).

9.1.2 Brookvale Road Corridor

Hydraulic modelling indicates that Brookvale Road provides effective conveyance for frequent events, with the road not overtopping during the 2-year event. Overtopping is predicted to occur in the 10-year event and larger events, with exceedance flows routing along the Brookvale Road corridor and into adjacent overland flow paths where culvert capacity is exceeded and/or backwater conditions develop. Flood extents and depths for these scenarios are shown on the result maps in Appendix B.

9.2 Impact Assessment

Potential changes in peak flows and peak water surface elevations have been assessed by comparing pre- and post-development scenarios at representative locations within and downstream of the site. Impacts were generally identified within the Brookvale Road corridor adjacent to the site and also within the two downstream neighbour properties 163 and 185 Brookvale Road. Impacts are summarised below and further discussed in the following sections.

Location	Principal impact	Indicative magnitude	Overall effect
Brookvale Road corridor	Reduced overtopping flows due to culvert upgrades and improved conveyance.	Approx. 7.2 m3/s reduction for 10yr, 13.6. m3/s for 50yr, 15.0 m3/s for 100yr; blocked reductions of 11.5 m3/s for 50yr and 8.4 m3/s for 100yr.	Beneficial overall, with lower hazard and reduced exceedance flows. Improved resilience and reduced asset liability/costs.
163 Brookvale Road	Localised increase in peak water level largely confined within the open channel; decrease across southern portion of the property.	Up to approx. 80 mm increase in-channel; approx. 100 mm decrease near existing shed.	Less than minor, positive overall effects.
185 Brookvale Road	Localised increases along south-eastern boundary swale and rear-yard depression, with reductions across eastern portion of the property.	Approx. 20 mm increase locally; reductions of about 16 mm for 100yr and 100 mm for 50yr in other areas.	Less than minor, positive overall effects.
468 Te Mata Mangateretere Road	Localised increases in a 150m long section of channel. Water levels still contained within the channel	Approx 500mm increase in within the channel during 100yr storm for a 60min duration.	Less than minor
Upstream properties	Generally reduced peak water levels due to cutoff drain and improved conveyance,	Minor beneficial changes	Generally beneficial overall.

Table 3 Summary of modelled flood impacts

9.2.1 Brookvale Road Corridor

Hydraulic modelling indicates that overtopping flows across Brookvale Road adjacent to the site are reduced under post-development conditions, due to the proposed culvert upgrades.

For the unblocked scenario, overtopping is effectively eliminated for frequent events (2-year), and significantly reduced for larger events, with reductions of approximately 7.2 m^3/s (10-year), 13.6 m^3/s (50-year), and 15.0 m^3/s (100-year).

Under blocked conditions, overtopping flows are also reduced, with decreases of approximately 11.5 m^3/s for the 50-year event and 8.4 m^3/s for the 100-year event.

Overall, the upgraded culvert configuration improves conveyance beneath Brookvale Road and reduces the magnitude of exceedance flows, thereby lowering flood hazard and the extent of uncontrolled flow routing across the road corridor.

These improvements provide for increased asset resilience, and reduces the risk of damage and maintenance being required to Brookvale Road which currently exists with the undersized culvert network.

9.2.2 Downstream properties

Model results show small increases in peak water depth occur within the open channel located on the downstream property at 163 Brookvale Road because of the proposed Brookvale Road culvert upgrades. For the 100yr ARI event with climate change under the culvert blockage sensitivity scenario, the peak water depth increases are largely confined within the channel, with increases of up to approximately 60 mm. Further downstream, a broader area experiences minor increases generally in the order of 6 mm. Site topographical survey has been conducted to determine the existing finished floor levels of the dwellings adjacent the channel to allow impact assessments which are further discussed in sections below.

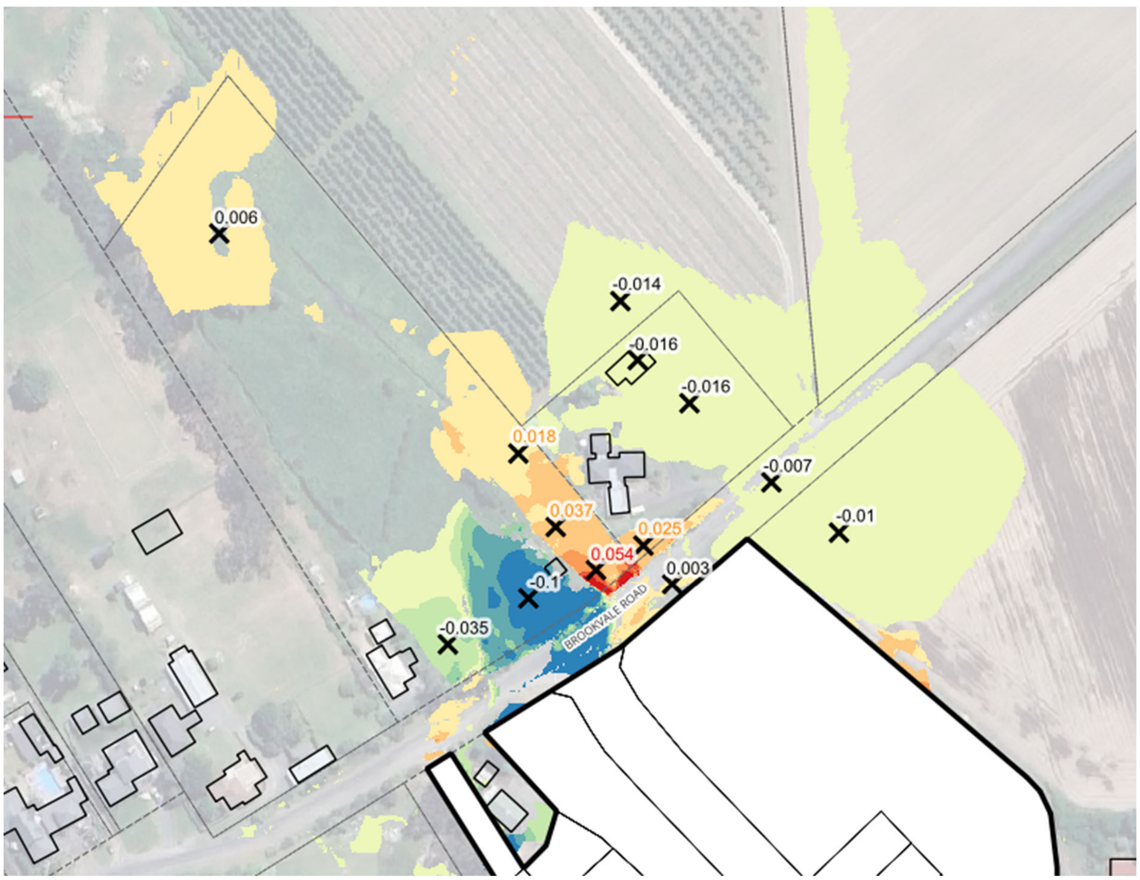


Figure 12 100yrCC Blocked Peak water level change for 100yrCC (red = increase, blue/ green = decrease)

Cross section assessments have been undertaken as locations shown in figure 13 below and discussed in the following sections.

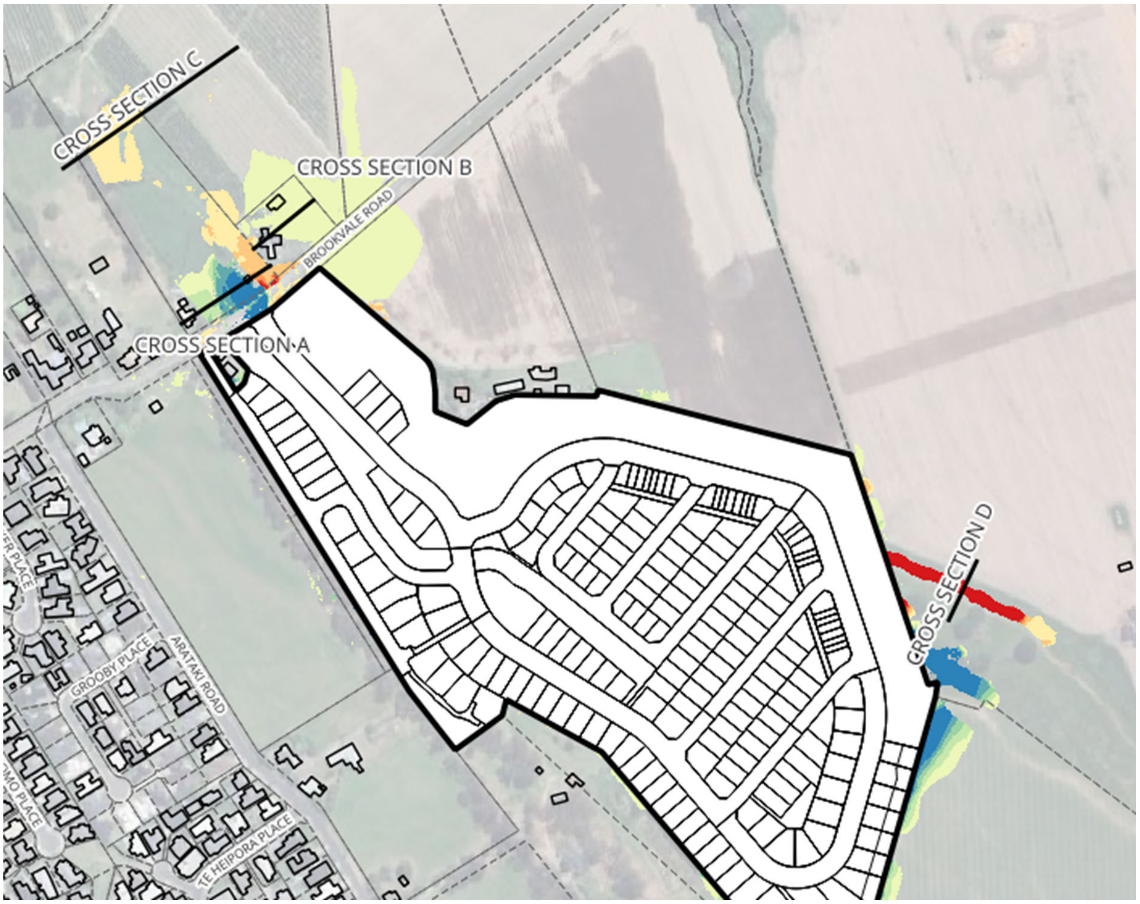


Figure 13 Downstream neighbour cross section locations

9.2.3 163 Brookvale Road

Cross section A as shown in figures 13 and 14 show peak 100yr (blocked scenario) water level across the property. Increases in water level are confined to the existing open channel along the north eastern boundary (approximately 50mm increase). A decrease in flow and peak water level is shown across the southern portion of the property where the existing shed is located, with a decrease in 100yr ARI peak water level of approximately 90 to 100 mm. As water levels next to the shed footprint decrease and there are no building footprints within the areas where increased water depths are predicted, the potential effect from the development is considered beneficial to the property. The owner of 163 Brookvale Road has been engaged during the design process and owner approval has been received for the identified downstream effects.

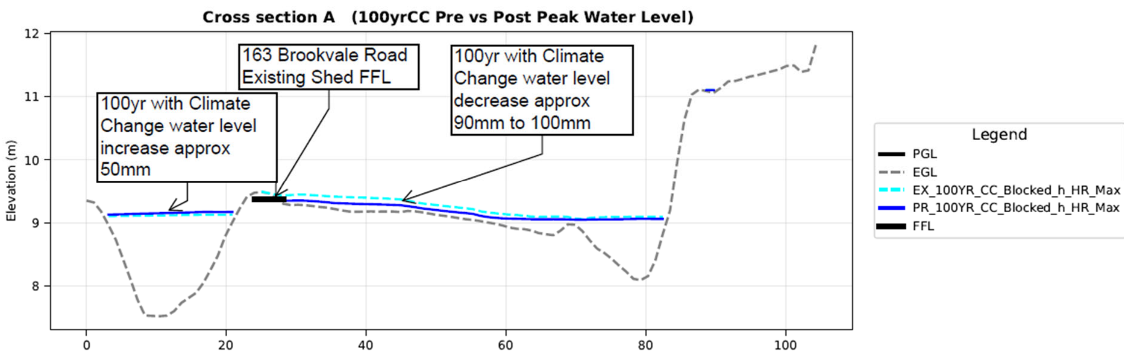


Figure 14 Cross section A showing pre and post 100yrCC flooding at 163 Brookvale Road

9.2.4 185 Brookvale Road

Cross section B (per figures 13 and 15) shows peak 100yr water level across the 185 Brookvale Road property. Model results indicate localised minor increases in peak water depth at 185 Brookvale Road for the 100yr ARI event. Increases are predicted along the south-eastern boundary, which currently functions as a roadside swale, and within a localised depression area in the rear yard where a temporary increase in peak water depth of approximately 20 mm is predicted. Conversely, a reduction in flow is predicted across the eastern portion of the property, with decreases of approximately 16 mm for the 100yr ARI event with climate change and approximately 100 mm for the 50yr ARI event with climate change . As there are no building footprints within the areas where increased water depths are predicted, the potential adverse effect is considered less than minor, and overall the results are positive, with reduced sheet flows occurring over the site, including the outbuilding. The owner of 185 Brookvale Road has been engaged during the design process and owner approval has been received for the identified downstream effects.

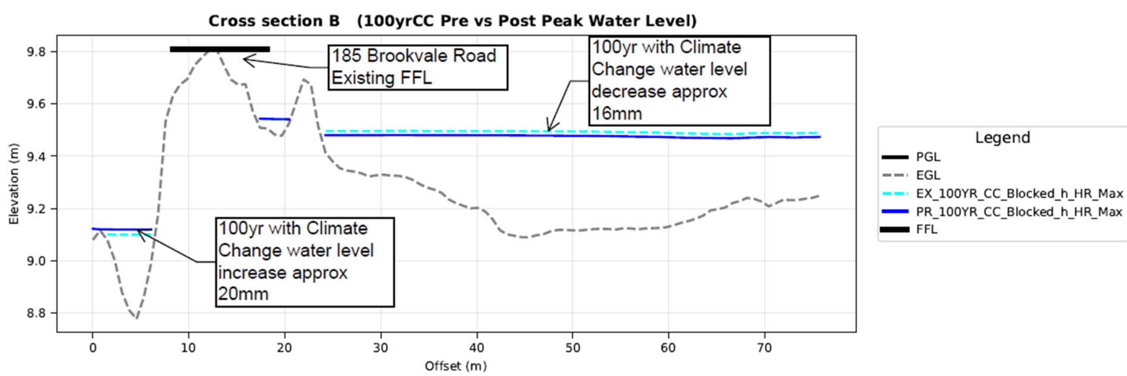


Figure 15 Cross section B showing pre and post 100yrCC flooding at 185 Brookvale Road FFL

9.2.5 Upstream properties

The upstream comparison indicates that post-development conditions generally result in decreases in peak water level across upstream properties, reflecting the cut-off drain along the south-eastern boundary, overland flow path easements along the western boundary, and improved conveyance provided by the proposed flood mitigation measures and Brookvale Road culvert upgrades. These changes reduce the extent and depth of overland sheet flow along the site boundary and are therefore generally beneficial for upstream properties. One localised exception is identified within the channel at 468 Te Mata Mangateretere Road, where post-development planting within the proposed diversion channel results in increased hydraulic roughness and a temporary tailwater effect. This localised channel effect is addressed separately in Section 9.2.6.

9.2.6 468 Te Mata Mangateretere Road

At 468 Te Mata Mangateretere Road, the model results indicate a localised increase in water level within the upstream channel located inside the property boundary. Cross section D (per figures 13 and 16) shows peak 100yr water level within the channel. This increase is associated with the proposed planting within the diversion channel. The planting increases hydraulic roughness, slows flow velocities through the channel, and creates a local tailwater effect upstream. Under existing conditions, the modelled channel flow depth is approximately 1.1 m to 1.5 m. Under post-development conditions, the modelled depth increases to approximately 1.2 m to 2.0 m, representing an increase of up to approximately 500 mm in the affected reach. The increase remains contained within the existing channel banks and does not result in breakout flow or inundation of adjacent land outside the channel corridor.

For the 100yr ARI event with climate change under the blocked culvert sensitivity scenario, the duration of the increase above the pre-development maximum depth is approximately 60 minutes. The effect is therefore temporary, limited to the peak period of the design event, and remains confined within the channel. On this basis, the increase in water level is considered manageable and does not result in a material increase in flood risk to the adjoining parts of the property. The owner of 468 Te Mata Mangateretere Road has been engaged during the design process and owner approval has been received for the identified channel water-level effects.

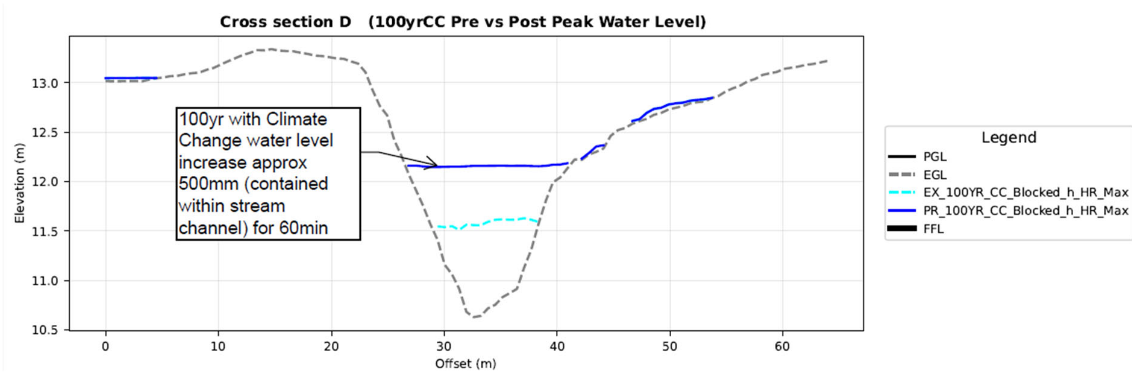


Figure 16 Cross section D showing pre and post 100yrCC flooding within 468 Te Mata Mangateretere Road channel

9.2.7 Downstream Peak flows

Downstream peak flow comparison for the six locations shown in Figure 17 are shown below, which includes 6 downstream cross sections and the road culverts beneath Davidson Road and Romanes Drive.

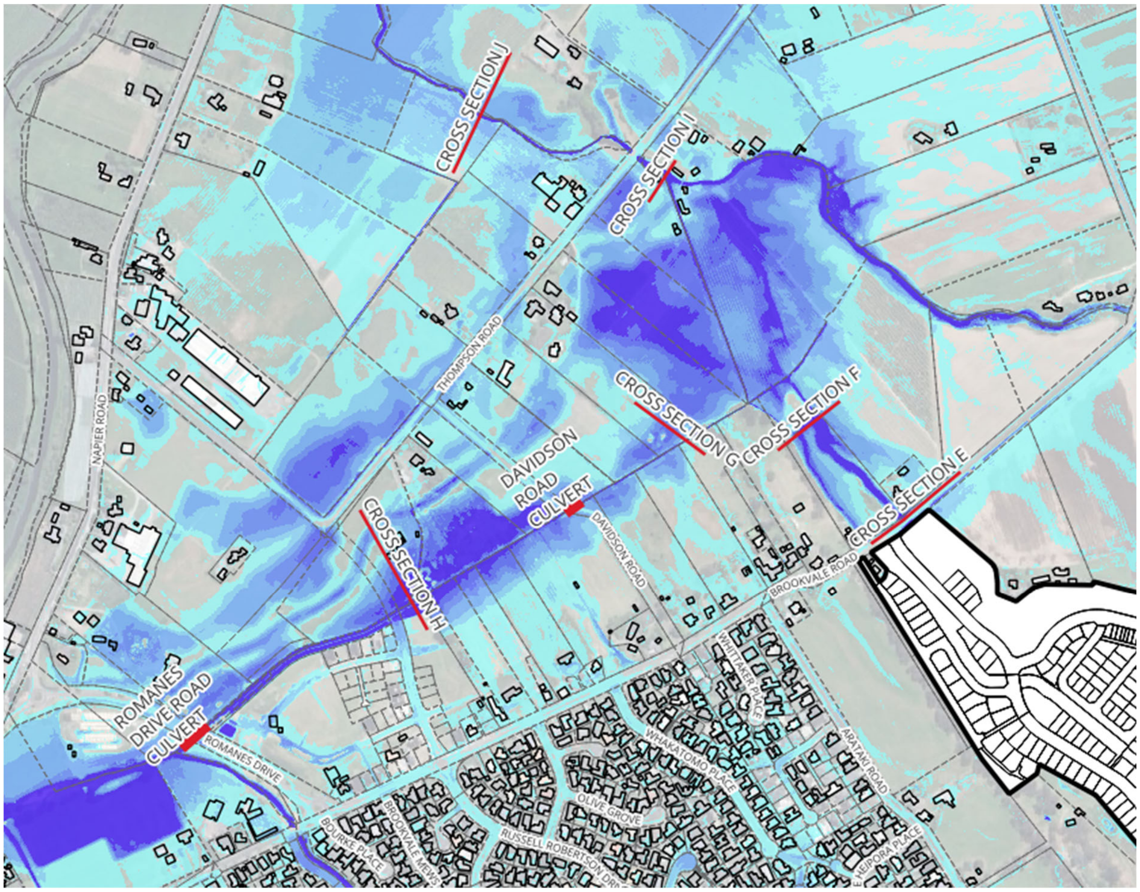


Figure 17 Downstream Peak flow cross section Locations

Cross section E shows that peak flows across the Brookvale Road carriageway adjacent to the site decrease for all assessed storm events, with overtopping eliminated for the 10-year ARI event. Cross section F shows only minor increases in peak flow, which is consistent with the afflux plans showing no material increase north of this location. Additional downstream cross sections G through J show no material increases in peak flow. Similarly, peak flow comparisons for the existing culverts beneath Davidson Road (300mm) and Romanes Drive (1650mm) show no material increase. A review of the wider catchment indicates that any peak flow increases further north are negligible due to the confluence with other catchments.

Cross section	Scenario	Pre	Post	Difference m3/s	Percentage
E	2yr ARI + climate change	0.0	0.0	0.0	0%
	10yr ARI + climate change	7.5	0.3	-7.2	-96%
	50yr ARI + climate change (unblocked)	21.8	8.2	-13.6	-62%
	50yr ARI + climate change (blocked)	24.0	12.5	-11.5	-48%
	100yr ARI + climate change (unblocked)	29.4	14.4	-15.0	-51%
	100yr ARI + climate change (blocked)	33.3	24.9	-8.4	-25%
F	2yr ARI + climate change	5.2	5.9	0.7	13%
	10yr ARI + climate change	14.1	15.5	1.4	10%
	50yr ARI + climate change (unblocked)	28.0	29.8	1.8	6%
	50yr ARI + climate change (blocked)	28.0	29.6	1.6	6%
	100yr ARI + climate change (unblocked)	34.7	35.5	0.7	2%
	100yr ARI + climate change (blocked)	34.7	35.5	0.7	2%
G	2yr ARI + climate change	0.7	0.7	0.0	0%
	10yr ARI + climate change	2.6	2.7	0.1	3%
	50yr ARI + climate change (unblocked)	11.5	11.6	0.1	1%
	50yr ARI + climate change (blocked)	12.8	13.0	0.1	1%
	100yr ARI + climate change (unblocked)	16.0	16.0	0.0	0%
	100yr ARI + climate change (blocked)	18.5	18.4	-0.1	-1%
H	2yr ARI + climate change	1.9	1.9	0.0	-1%
	10yr ARI + climate change	2.3	2.3	0.0	0%
	50yr ARI + climate change (unblocked)	9.2	9.1	-0.1	-1%
	50yr ARI + climate change (blocked)	11.3	11.3	-0.1	-1%
	100yr ARI + climate change (unblocked)	14.3	14.2	-0.1	-1%
	100yr ARI + climate change (blocked)	18.4	18.3	0.0	0%
I	2yr ARI + climate change	0.1	0.2	0.0	0%
	10yr ARI + climate change	2.1	2.2	0.0	1%
	50yr ARI + climate change (unblocked)	7.9	8.0	0.1	1%
	50yr ARI + climate change (blocked)	8.1	8.2	0.0	0%
	100yr ARI + climate change (unblocked)	10.3	10.3	0.0	0%
	100yr ARI + climate change (blocked)	10.9	10.9	0.0	0%

Cross section	Scenario	Pre	Post	Difference m3/s	Percentage
J	2yr ARI + climate change	2.1	2.1	0.0	0%
	10yr ARI + climate change	4.0	4.0	0.0	1%
	50yr ARI + climate change (unblocked)	15.2	15.4	0.2	1%
	50yr ARI + climate change (blocked)	16.5	16.5	0.0	0%
	100yr ARI + climate change (unblocked)	24.2	23.9	-0.3	-1%
	100yr ARI + climate change (blocked)	29.4	29.0	-0.4	-1%
Davidson Road Culvert (300mm)	2yr ARI + climate change	0.2	0.2	0.0	0%
	10yr ARI + climate change	0.1	0.1	0.0	0%
	50yr ARI + climate change (unblocked)	0.1	0.1	0.0	0%
	50yr ARI + climate change (blocked)	0.1	0.1	0.0	0%
	100yr ARI + climate change (unblocked)	0.1	0.1	0.0	0%
	100yr ARI + climate change (blocked)	0.0	0.0	0.0	0%
Romanes Drive Culvert (1650mm)	2yr ARI + climate change	2.6	2.6	0.0	0%
	10yr ARI + climate change	3.4	3.4	0.0	0%
	50yr ARI + climate change (unblocked)	4.5	4.5	0.0	0%
	50yr ARI + climate change (blocked)	3.4	3.4	0.0	0%
	100yr ARI + climate change (unblocked)	4.4	4.4	0.1	1%
	100yr ARI + climate change (blocked)	2.1	2.1	0.0	1%

Table 4 Peak flow comparison at cross sections E and F

9.3 Flood Hazard and Risk Discussion

9.3.1 Within Site

Flood depth and extent mapping has been prepared for the adopted design events, including the 100yr ARI event with climate change allowance and the culvert blockage sensitivity scenarios. The resulting flood hazard maps are provided in Appendix D.

Based on the post-development model results, flood hazard on the proposed internal roads was assessed using modelled depth and velocity, with hazard categories assigned in accordance with the Australian Rainfall and Runoff 2016 (ARR 2016) guidance. The ARR hazard classification defines six categories:

- H1: Generally safe for vehicles, people, and buildings.
- H2: Unsafe for small vehicles.
- H3: Unsafe for vehicles, children, and the elderly.
- H4: Unsafe for vehicles and people.
- H5: Unsafe for vehicles and people. All building types are vulnerable to structural damage, and some less robust building types are vulnerable to failure.
- H6: Unsafe for vehicles and people. All building types are considered vulnerable to failure.

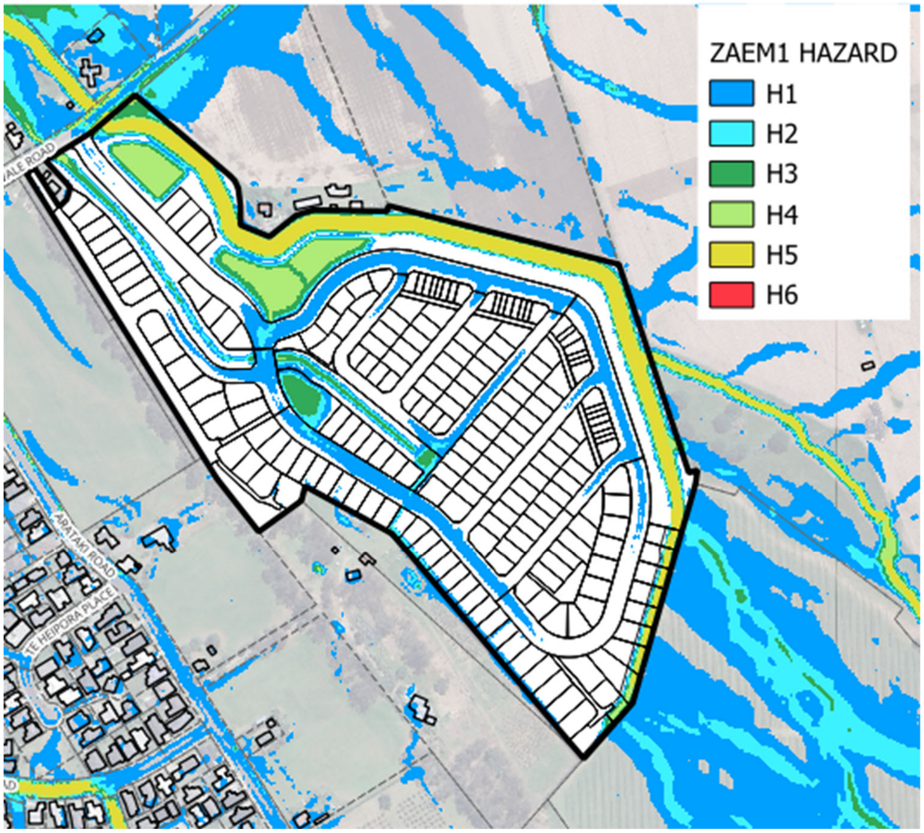


Figure 18 Post development 100yrCC flood hazards

As shown in Figure 17, the assessed flood hazard on the proposed internal roads is predominantly within category H1, with only small, localised portions of roadway falling within category H2. These locations are adjacent to the stormwater ponds, and refinement of terrain and spillway design during detailed design is expected to further reduce local flooding depths. While H2 represents a mild hazard for small vehicles, the affected area is limited in extent and emergency vehicle access is expected to remain available during extreme events. On this basis, the overall flood risk within the internal road system is considered minor and acceptable for the purpose of the Fast Track assessment. In addition, internal cross-sections extracted from the model show that flow is generally contained within the road corridor. Overall, the internal hazard is considered acceptable and generally safe in terms of the adopted hazard categorisation.

9.3.2 Brookvale Road Carriageway

Flood hazard along the Brookvale Road carriageway has also been reduced under the post-development scenario. For the 2yr ARI event, model results indicate no change from existing conditions, with Brookvale Road remaining below overtopping threshold. For the 10yr ARI event with climate change overtopping is generally removed and for larger events, overtopping cannot be fully removed; however, the proposed mitigation measures generally reduce hazard classification within the Brookvale Road in front of the site from H2 to H1 (including 50yr, 50yr blocked scenarios and reduces the extent of the H2 hazard within the carriage way for the 100yr blocked and unblocked scenarios. This represents an improvement in safety and trafficability along the carriageway, notwithstanding that exceedance flow will still occur during larger storm events.

10. CONCLUSION

This Flood Modelling Report has been prepared by Maven Associates to support the Fast Track substantive application for Brookvale Green at 174–176 Brookvale Road, Havelock North, Hawke's Bay. The report assesses flood behaviour, flood hazard and potential upstream and downstream effects for pre-development and post-development scenarios using a hydraulic model (TUFLOW), including the 100yr ARI event with climate change allowance and a culvert blockage sensitivity check.

The modelling indicates that, with the proposed mitigation measures in place, the development can be implemented without creating any material increase in offsite flood risk. Overall, adverse offsite effects are assessed as less than minor. Flooding during the modelled major event remains generally confined to the existing watercourse and overland flow corridors and to designated stormwater reserve areas, while proposed developable areas are raised above the modelled floodplain and protected through minimum finished floor levels.

Localised increases in peak water level are identified at limited locations, principally within the downstream open channel at 163 Brookvale Road and in small localised areas at 185 Brookvale Road and the upstream channel within 468 Te Mata Mangateretere Road. These landowners have been engaged during the design process and owner approval has been received for the identified effects. At 163 Brookvale Road, increases are largely confined to the existing channel corridor, while other parts of the property experience reduced flood levels, which create a net positive effect. At 185 Brookvale Road, the increases are minor and localised to the south-eastern boundary swale and a rear-yard depression, with no building footprints affected. Again, we view this as a net positive effect to the property. On this basis, the identified increases do not constitute a materially adverse effect and are considered acceptable in the context of the overall reduction in flood levels and improved conveyance achieved by the proposal.At 468 Te Mata Mangateretere Road, the model results indicate a temporary localised increase in water level within the upstream channel, the increase is localised and contained within the existing channel banks, the identified increase does not constitute a materially adverse effect.

Flood hazard mapping (depth and depth–velocity as applicable) has been prepared for the adopted design event(s) and is provided in Appendix D. Areas of higher depth and/or velocity are generally limited to the northern and central channel corridors and associated flood storage areas, which are retained within open space/stormwater reserve designations and excluded from building development. Developable areas are proposed to be located outside (or set above) the modelled floodplain and hazard areas, consistent with the intended land use outcomes and relevant HDC and HBRC requirements.

Residual flood risk can be appropriately managed through consent and detailed design requirements. These include confirmation and implementation of minimum finished floor levels, legal protection and ongoing maintenance access for overland flow paths and stormwater corridors and implementation of proposed stormwater mitigation measures Subject to these matters being secured through the subsequent design and approval process, the Brookvale Green proposal is considered suitable to proceed from a flood hazard and flood effects perspective.

11. LIMITATIONS

This report has been prepared to support the Brookvale Green Fast Track application at a resource consent level of detail, based on the information available at the time of assessment.

Scope

The assessment evaluates flood behaviour and effects for pre- and post-development scenarios, including the 100yr ARI event with climate change. It is suitable for consent purposes but does not represent final detailed design.

Model coverage

The hydraulic model represents overland flow paths, open channels, stormwater device outlets, culverts and key hydraulic structures that control flood routing through and downstream of the site. All proposed stormwater device outlets and culverts relevant to the flood assessment have been modelled, including the proposed twin 1.0 m box culvert beneath the entrance road connecting the two watercourses.

Data and assumptions

Results are based on available survey, LiDAR, GIS data, and standard hydrological assumptions (including HIRDS rainfall, landcover, and infiltration). Unless noted otherwise, model spatial data are referenced to the Hawke's Bay 2000 horizontal coordinate system and New Zealand Vertical Datum 2016 (NZVD2016). These inputs simplify actual conditions and may be refined with further data.

Proposed kerbs in Brookvale Road

The proposed kerb and channel works along Brookvale Road have not been explicitly represented in the TUFLOW model, as they do not materially influence the predicted flood behaviour for the modelled events. This approach is considered appropriate as no change to road levels or crest controls: The proposed works involve the addition of kerb and channel only, with no modification to the existing road levels or longitudinal profile, which remain the governing hydraulic control for overland flow conveyance.

Boundary conditions

Downstream boundary conditions include a sensitivity assessment of Karamu Stream tailwater effects. A 7 m Karamu Stream tailwater has been adopted for the assessment, with the Figure 8 long-section comparison showing only minor effects between Napier Road and Thompson Road and no material impact further upstream toward the site.

Mitigation and structures

Proposed mitigation measures and culvert performance (including blockage scenarios) are modelled based on current design information and assumptions. Final performance will depend on detailed design and construction.

Model uncertainty

Model outputs provide an estimate of flood behaviour. Actual flood levels and extents may vary due to natural variability and model assumptions.

Use of report

This report is prepared specifically for the Brookvale Green Fast Track application and should not be relied upon for detailed design or other purposes without further verification.

12. APPENDICES

APPENDIX A – TUFLOW MODEL PARAMETERS

LANDCOVER / INFILTRATION AND MANNING USED FOR 2d_Soil layer and 2d_mat layer

Landcover Name	% Impervious	CN (Group A)	CN (Group B)	CN (Group C)	CN (Group D)	Manning's n
Broadleaved Indigenous Hardwoods	0	39	61	74	80	0.12
Building	100	98	98	98	98	0.3
Built-up Area (settlement)	60	74.4	83.2	88.4	90.8	0.1
Deciduous Hardwoods	0	30	55	70	77	0.1
Exotic Forest	0	30	55	70	77	0.11
Forest - Harvested	5	41.95	62.85	75.2	80.9	0.05
Gorse and/or Broom	0	39	61	74	80	0.1
Gravel	100	98	98	98	98	0.05
Gravel and Rock	30	56.7	72.1	81.2	85.4	0.035
High Producing Exotic Grassland	2	40.18	61.74	74.48	80.36	0.1
Indigenous Forest	0	30	55	70	77	0.12
Lake or Pond	100	98	98	98	98	0.025
Low Producing Grassland	2	40.18	61.74	74.48	80.36	0.05
Orchard, Vineyard or Other Perennial Crop	5	41.95	62.85	75.2	80.9	0.1
River	100	98	98	98	98	0.035
Road	90	92.1	94.3	95.6	96.2	0.02
Short-rotation Cropland	2	67.62	78.4	85.26	89.18	0.05
Transport Infrastructure	98	96.82	97.26	97.52	97.64	0.02
Urban Parkland/Open Space	10	44.9	64.7	76.4	81.8	0.035

APPENDIX B - RESULTS - FLOOD MAPS & PEAK FLOW MAPS

APPENDIX C - RESULTS – FLOOD LEVELS COMPARISON

APPENDIX D - RESULTS - FLOOD HAZARD MAPS