MOTT MACDONALD

Drury-Opaheke Structure Plan Future Urban Zone

Draft Stormwater Management Plan

12 April 2019

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Contents

Executive summary

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

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

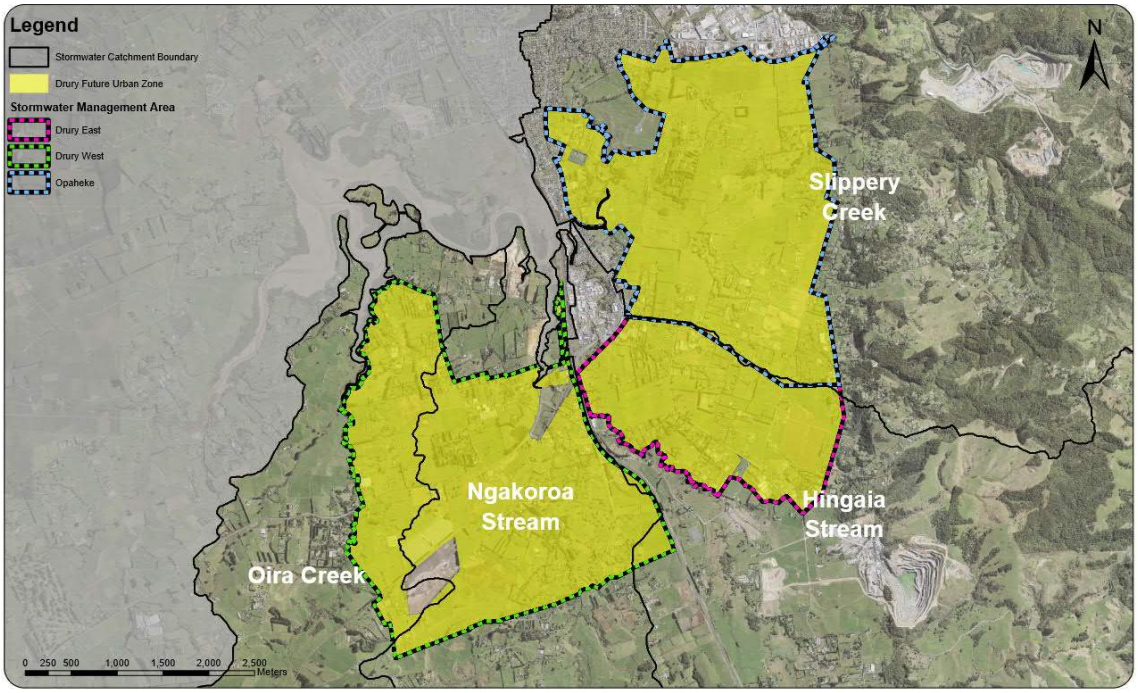


Figure ES 1 Drury Structure Plan Area - Stormwater Management Areas

Constraints and Opportunities

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

Key constraints include:

- Existing flooding of urban areas such as Drury township affecting private and public property. Flood modelling carried out indicates that the motorway and Great South Road will be inundated during a 100 year average recurrence interval (ARI) storm event. This modelling allows for maximum probable development (MPD) and climate change. Other roads will also be inundated. Options to address the flooding are limited as the downstream Drury Creek is a flow constraint. This means that water ponds in the creek and runoff from the contributing

catchments can't discharge freely to the creek resulting in water 'backing up' the streams with a resultant rise in water levels. Hydraulic modelling is ongoing.

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

Key risks include:

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

Key opportunities include:

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

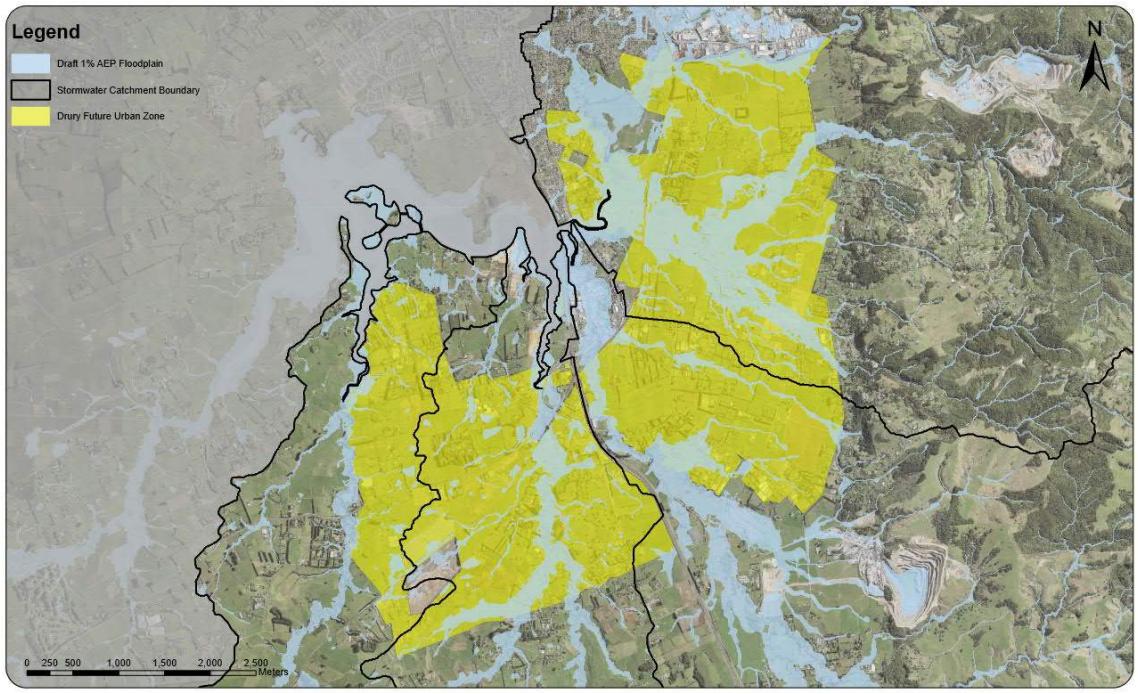


Figure ES 2 Drury Structure Plan Area Floodplains

Outcomes Sought

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

Table ES1: Key Stormwater Management Outcomes Sought

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

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

Stormwater Management Requirements Summary

General

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

Water Quality

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

Minimising and mitigating hydrological change

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

Streams

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

Slippery Creek

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

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

Hingaia Stream

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

Ngakoroa Stream

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

Oira Creek

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

Flood Management

General

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

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

Slippery Creek

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

Hingaia Stream

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

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

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

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

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

Drury West

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

1 Introduction

This document builds on the Preliminary Opaheke-Drury Stormwater Management Plan1 (SMP) and outlines stormwater management requirements for the Drury-Opaheke Future Urban Zone (FUZ). It has been developed in conjunction with the Pukekohe-Paerata SMP prepared by WSP-OPUS and utilises text from that report.

1.1 Purpose of this Stormwater Management Plan

The purpose of this SMP is to:

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

1.2 Scope of this Stormwater Management Plan

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

The scope of this SMP includes:

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

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

1.3 Stormwater Management Outcomes Sought for the Structure Plan Area

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

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

Table 1: Key Stormwater Management Outcomes Sought

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

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

1.4 Report Layout

The report has the following layout:

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

2 Planning Context

2.1 Stormwater Management – The Auckland Context

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

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

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

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

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

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

The focus areas of this outcome include:

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

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

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

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

2.2 Water Sensitivity and Water Sensitive Design

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

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

A water sensitive community will:

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

2.2.1 Water Sensitive Design

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

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

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

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

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

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

2.2.2 Urban Water Principles and Values

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

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

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

2.3 Development Context

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

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

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

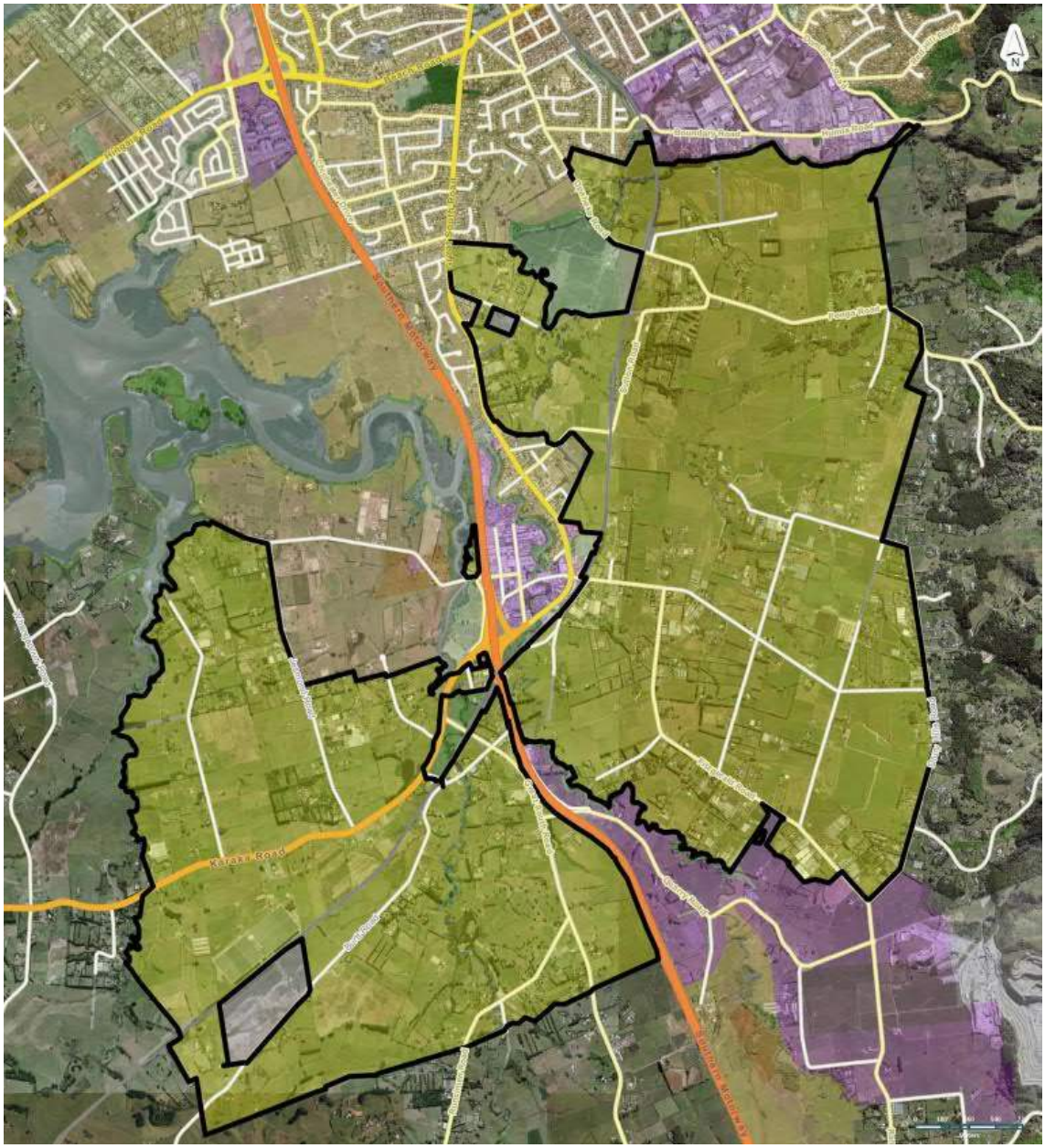


Figure 2 Drury-Opaheke Structure Plan Area

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

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

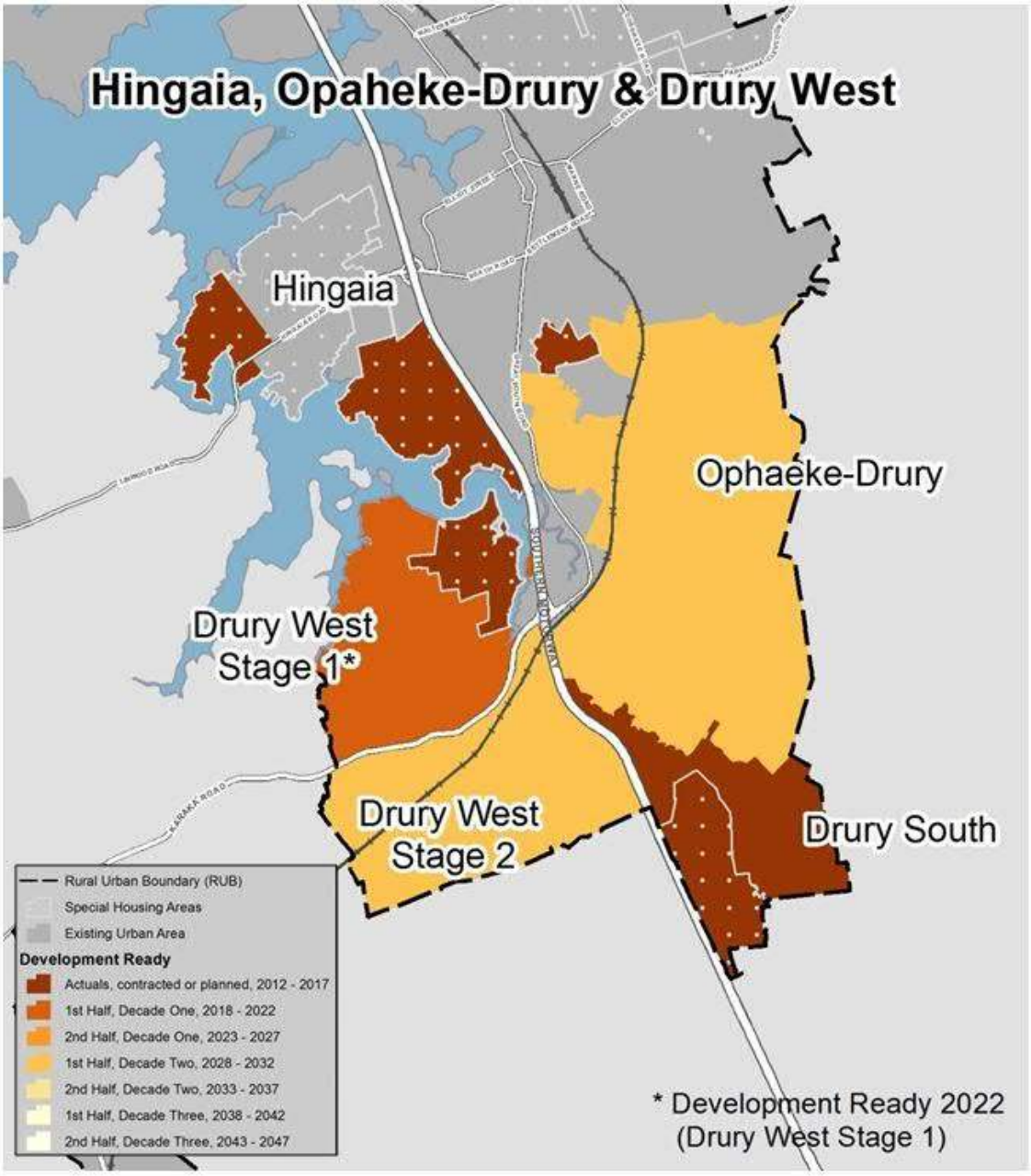


Figure 3 FULSS sequencing for Drury Structure Plan area

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

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

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

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

2.4 Statutory Direction for Integrated Stormwater Management

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

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

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

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

The stormwater related objectives of the NZCPS include:

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

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

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

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

2.4.1 Auckland Unitary Plan Operative in Part

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

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

2.4.1.1 AUPOP Chapter B Regional Policy Statement (RPS)

Indigenous biodiversity (B7.2)

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

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

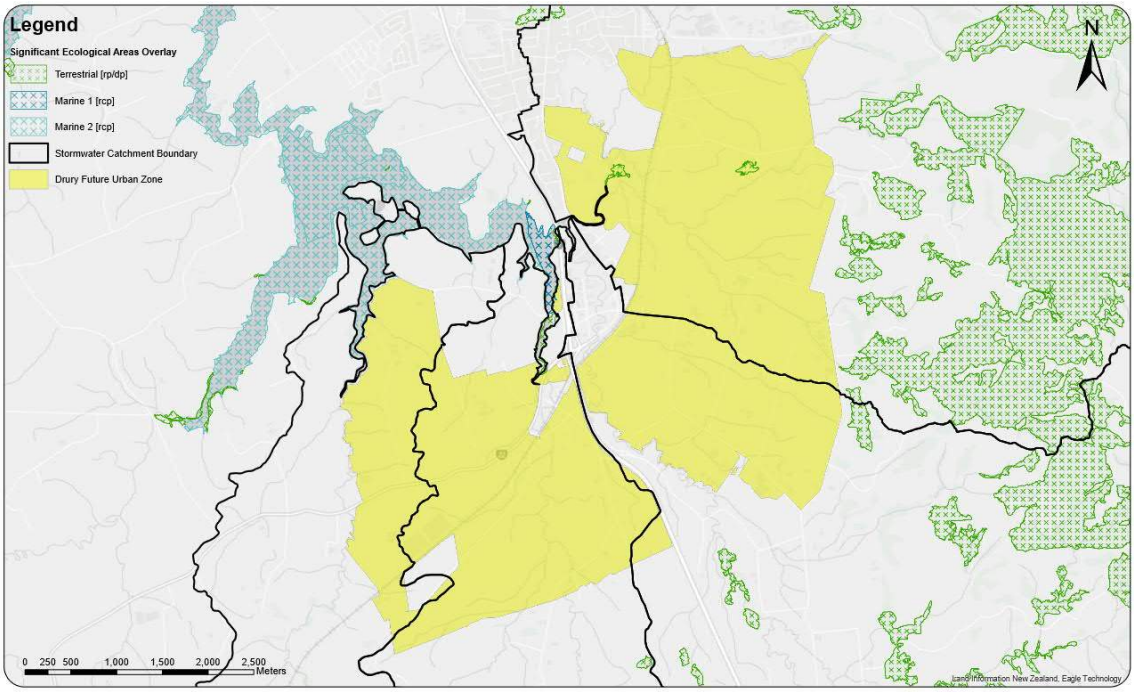


Figure 4 Significant Ecological Areas

Freshwater Systems (B7.3)

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

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

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

Coastal water and freshwater (B7.4)

The objectives seek to:

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

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

Environmental risk – natural hazards and climate change (B10)

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

2.4.1.2 AUPOP Chapter E Auckland Wide

Water quality and integrated management (E1)

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

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

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

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

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

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

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

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

Other relevant stormwater policies include:

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

2.4.1.3 Lakes, rivers, streams and wetlands (E3)

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

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

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

The objectives relevant to this SMP include:

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

2.4.1.4 Natural hazards and flooding (E36)

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

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

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

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

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

2.4.1.5 Overlays

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

High use Aquifer Management Area Overlay (D1)

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

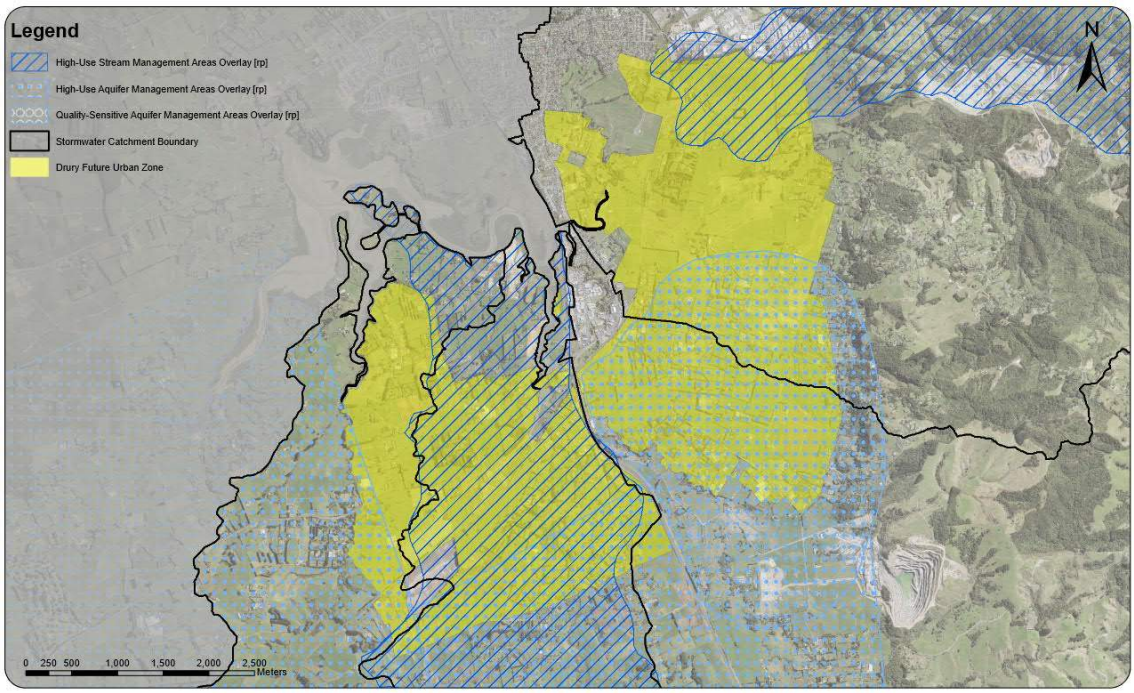


Figure 5 High Use Stream, High Use Aquifer and Quality-Sensitive Aquifer Management Areas,

Quality-sensitive Aquifer Management Area Overlay (D2)

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

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

High-use Stream Management Areas Overlay (D3)

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

Natural Stream Management Areas Overlay (D4)

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

Significant Ecological Areas Overlay (D9)

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

The objectives of the AUPOP seek to:

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

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

2.5 Network Discharge Consent

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

2.6 Local Boards

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

2.6.1 Papakura Local Board

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

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

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

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

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

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

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

2.6.2 Franklin Local Board

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

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

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

2.7 Engagement with Iwi

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

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

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

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

3 Catchment Characteristics, Constraints and Opportunities

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

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

Constraints include:

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

Risks include:

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

Opportunities include:

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

3.1 Land Use

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

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

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

3.2 Topography and Catchments

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

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

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

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

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

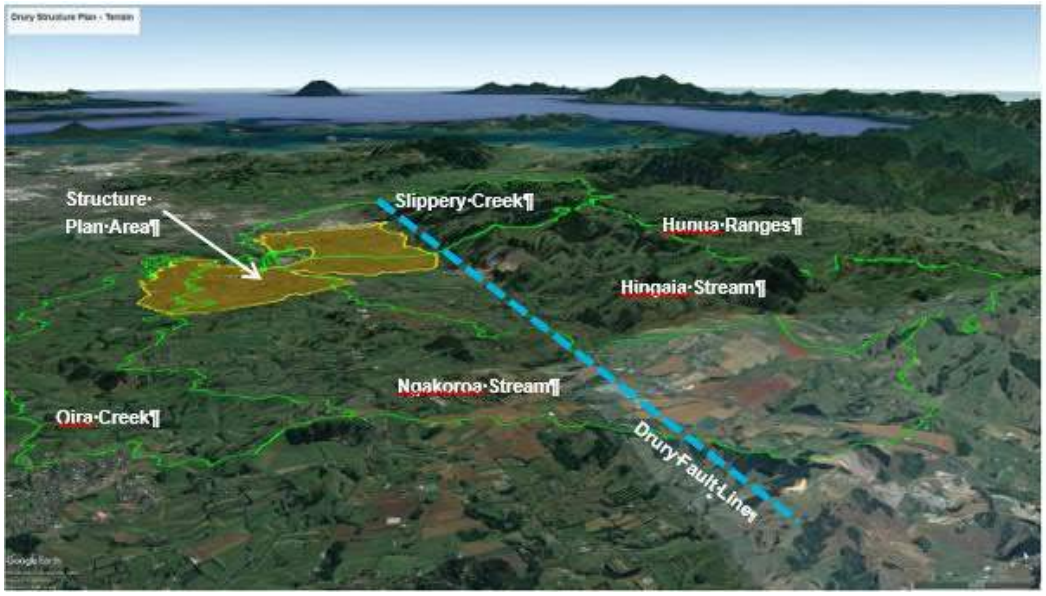


Figure 6 Drury Structure Plan Area - Terrain

3.3 Geology and Soils

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

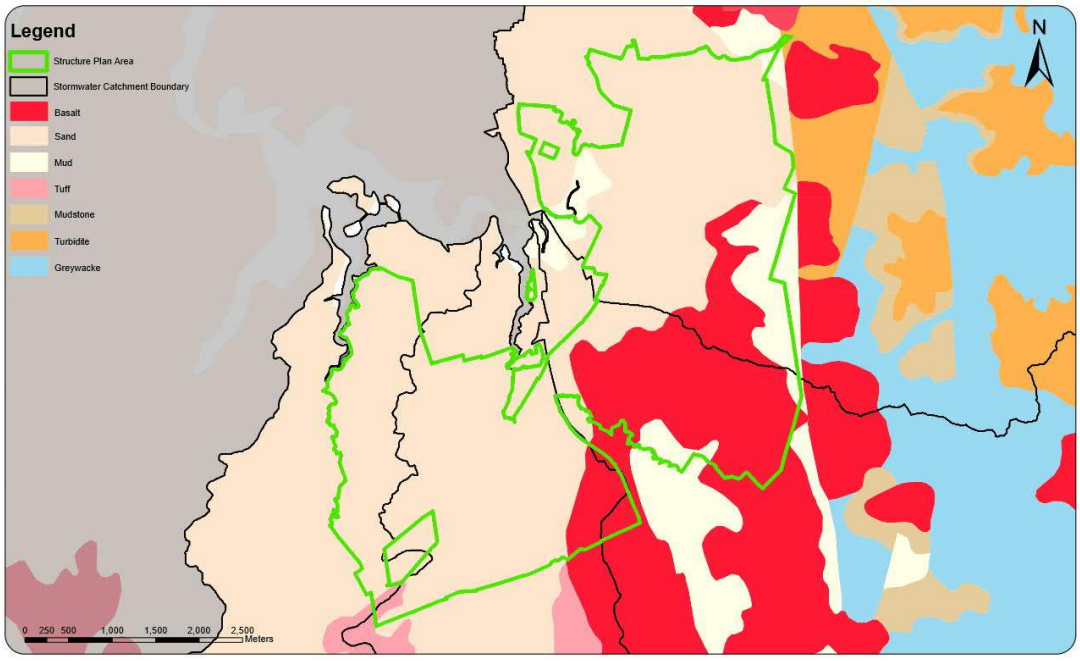


Figure 7 Opaheke-Drury Structure Plan Area - geology

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

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

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

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

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

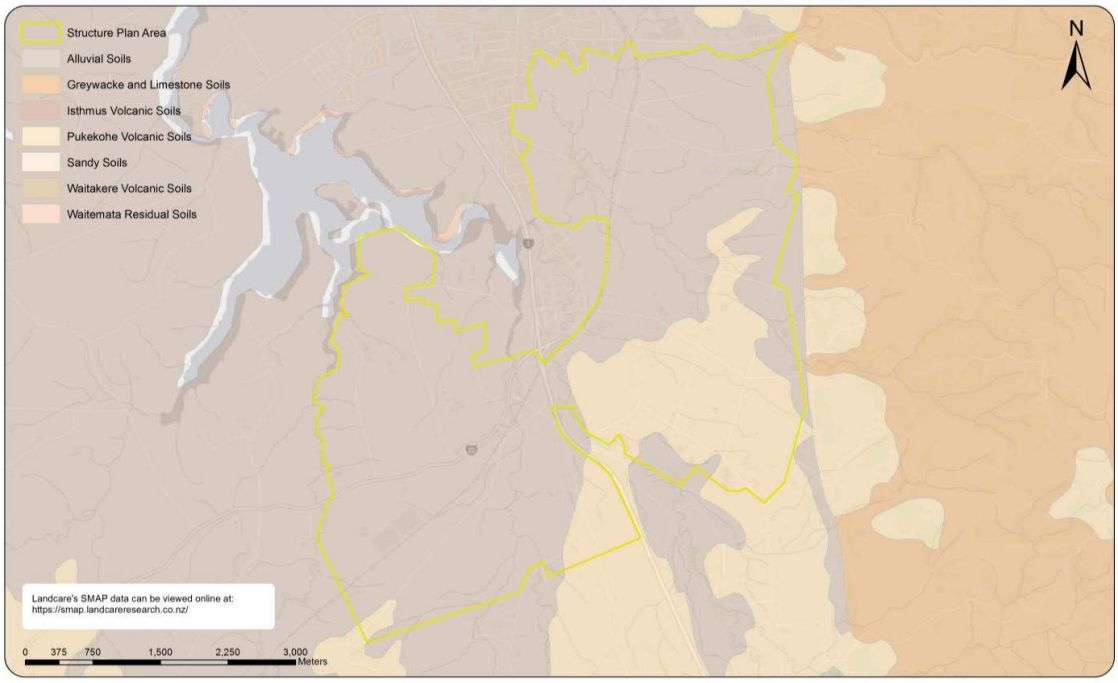
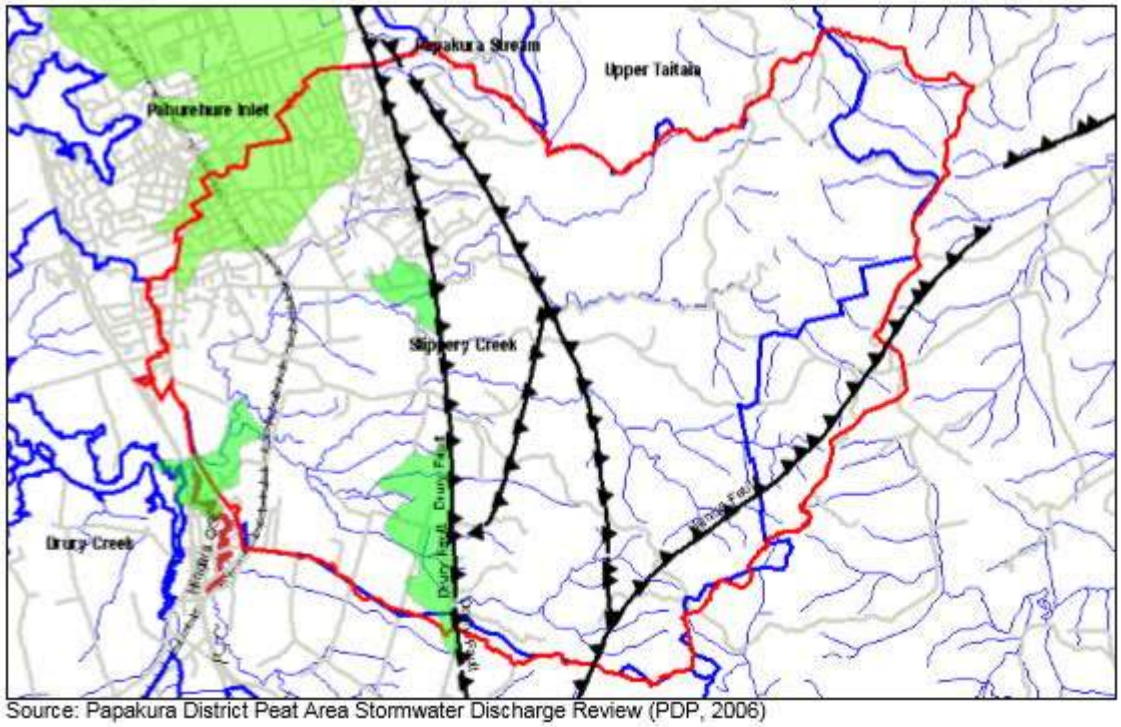


Figure 8 Opahe-Drury Structure Plan Area Soil Types

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

collected geotechnical data at PDC compiled by Pattle Delamore Partners Ltd (2006).



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

Figure 9 Indicative Slippery Creek Peat Soil Extent

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

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

The geological implications on stormwater management are:

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

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

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

3.4 Existing Hydrological and Stormwater Network

3.4.1 Hydrological Network Overview

The FUZ straddles four stormwater catchments:

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

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

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

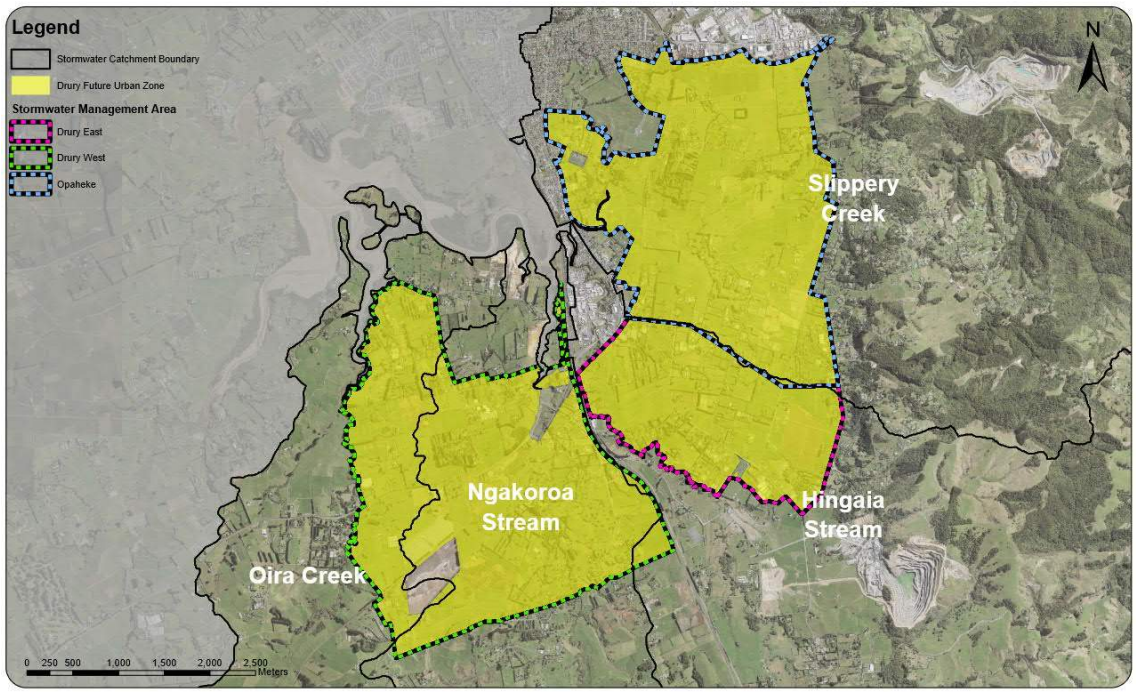


Figure 10 Drury Structure Plan Area - Stormwater Management Areas

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

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

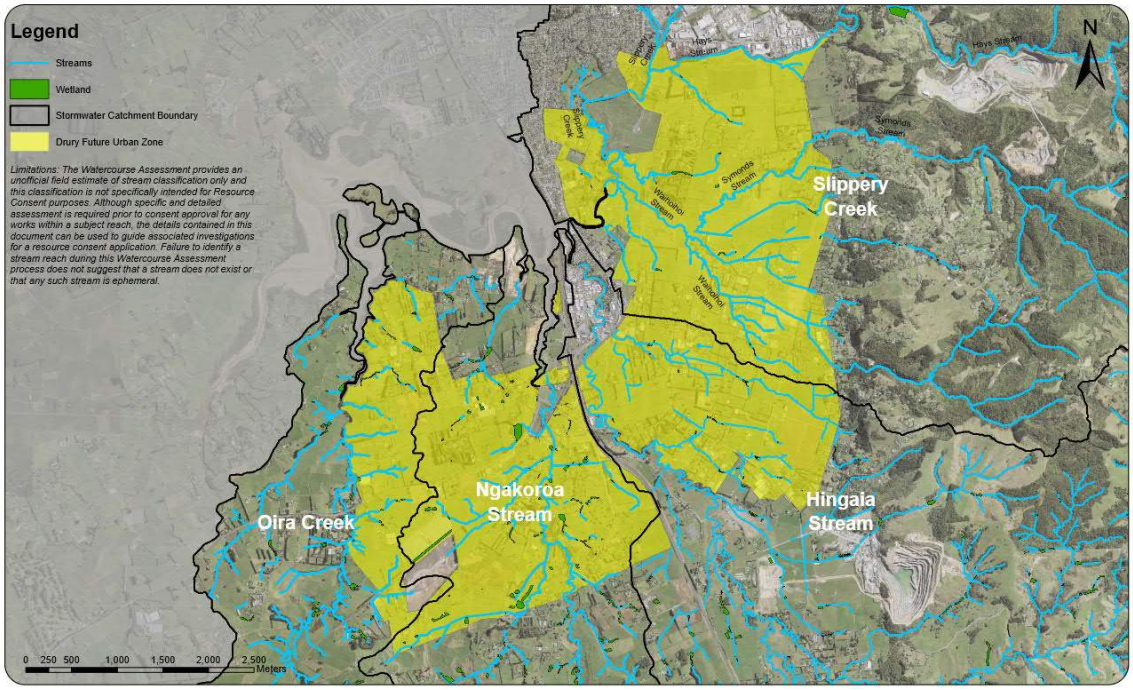


Figure 11 Drury-Opaheke Stormwater Management Plan Streams

3.4.2 Stormwater Network Overview

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

3.4.3 Stormwater Catchments Descriptions

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

3.4.3.1 Slippery Creek Catchment

Key features of the Slippery Creek catchment include:

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

- The low lying and flat downstream terrain coupled with high volumes of rainfall from the large upstream catchment results in significant areas of floodplains in the FUZ. This is discussed further in Section 3.7.1.
- A number of bridges and culverts along the watercourses that influence flooding. The railway embankment is also a flow constraint. .
- The presence of the Hays Creek Dam in the upper catchment which supplies potable water to part of Auckland. The dam impounds nearly 1 million m^3 of water when operating at capacity (Jairaj, 1998). It also acts (inadvertently) as a stormwater attenuation device.

3.4.3.2 Hingaia Stream Catchment

Key features of the Hingaia Stream catchment include:

- Hingaia Stream rises at the crest of the Bombay Hills and flows northwards towards Drury township. Near its midpoint it is joined by Maketu Stream. At the northern end of Drury township, Slippery Creek meets Hingaia Stream. The two streams collectively become Drury Creek (Snelder, 1991).
- Catchment area of 57.5km^2, predominantly rural but with Drury township located at the bottom of the catchment and the recently consented Drury South development (which will comprise industrial and residential landuses) occupying approximately 361ha of the catchment upstream of the Future Urban Zone. Stevenson's quarry is located in the central area of the catchment.
- Waterways within the catchment include permanent streams, intermittent streams, artificial farm drains and amenity ponds, stormwater retention and treatment ponds, and natural wetlands. The streams in the eastern and southern portions of the catchment within the Hunua Ranges and foothills are higher gradient streams while the streams in the western and northern portions of the catchment are lower gradient streams (Golder 2010).
- The land within the FUZ comprises flat to gently rolling landforms, drained by two main tributary branches and bounded by the Hingaia Stream mainstem to the southwest (4Sight Consulting, 2018).
- The stream system is the main drainage system for most of the catchment. Drury Township is reticulated.
- A number of bridges and culverts along the stream and its' tributaries that influence flooding, as well as the railway embankment blocking overland flow (refer Section 3.7).

3.4.3.3 Ngakoroa Stream

Key features of the Ngakoroa Stream catchment include:

- The catchment is drained primarily by the Ngakoroa Stream which discharges to Drury Creek. The Ngakoroa Stream includes a large tributary which splits from the main branch in the Runciman area and extends south for approximately one-third of the catchment.
- Catchment area of 40.1km^2, predominantly rural but with the Auranga SHA located at the bottom of the catchment which is currently under construction.
- The lower 3 km of the main Ngakoroa Stream is dominated by mature willows which provide bank stability however in some areas, these have formed large debris jams and are creating back-waters and pools. In these areas, the willow canopy extends across the full width of the channel.
- Due to the gentle topography of the area, freshwater systems tend to be low order, low energy watercourses connected to large wetland areas. These waterways serve vital

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

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

3.4.3.4 Oira Creek

Key features of the Oira Creek catchment include:

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

3.5 Ecology, Erosion and Water Quality

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

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

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

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

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

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

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

3.5.1 Ecology

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

3.5.2 Erosion

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

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

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

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

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

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

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

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

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

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

Auckland Council are developing a continuous, process-based model for water quality contaminants including sediment (total suspended sediment), spanning the region and developed from a sub-catchment basis – the Freshwater Management Tool (FWMT). The FWMT will be able to resolve sedimentary loading by sub-catchments including Drury Creek,

with expected output on current sediment loading by mid-2019, but with expectations for ongoing revisions to better resolve causes for and behaviour of contaminants across the region's waterways (e.g., improved resolution of causes for erosion and processes transforming sediment instream). This FWMT will complement earlier modelling by Green (2008) in understanding the rates of sediment loss to and delivery by Drury Creek, from which to estimate the effects instream or in-harbour on ecosystem processes and organisms.

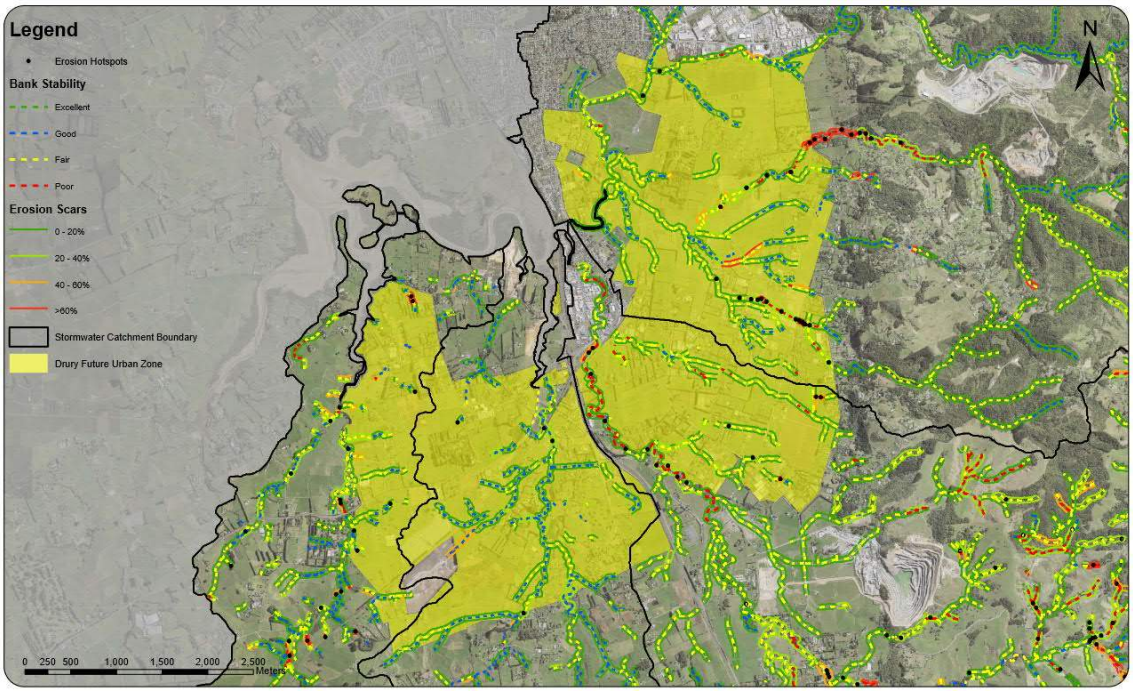


Figure 12 Erosion Issues within the FUZ

3.5.3 Water Quality

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

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

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

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

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

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

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

3.6 Receiving Environment

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

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

The Manukau Harbour and the aquifers are discussed below.

3.6.1 Manukau Harbour

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

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

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

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

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

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

Development of areas (such as the FUZ), which discharge to low energy estuarine receiving environment pose higher environmental risk to marine receiving environments because

contaminants (typically sediment, trace metals, hydrocarbons and trace organics) rapidly accumulate in these zones with minimal mixing and dispersal from coastal processes, subsequently affecting marine health (Huls & Chin, 2016).

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

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

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

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

3.6.2 Aquifers

The following aquifers lie beneath the catchments:

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

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

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

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

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

Development of the FUZ must consider aquifer recharge.

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

3.7 Flooding and Coastal Inundation

3.7.1 Flooding

3.7.1.1 Historical Flooding

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

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

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

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

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

Catchment Interactions

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

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

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

3.7.1.2 Hydrological and Hydraulic Modelling

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

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

Three stormwater models were used. These are the:

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

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

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

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

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

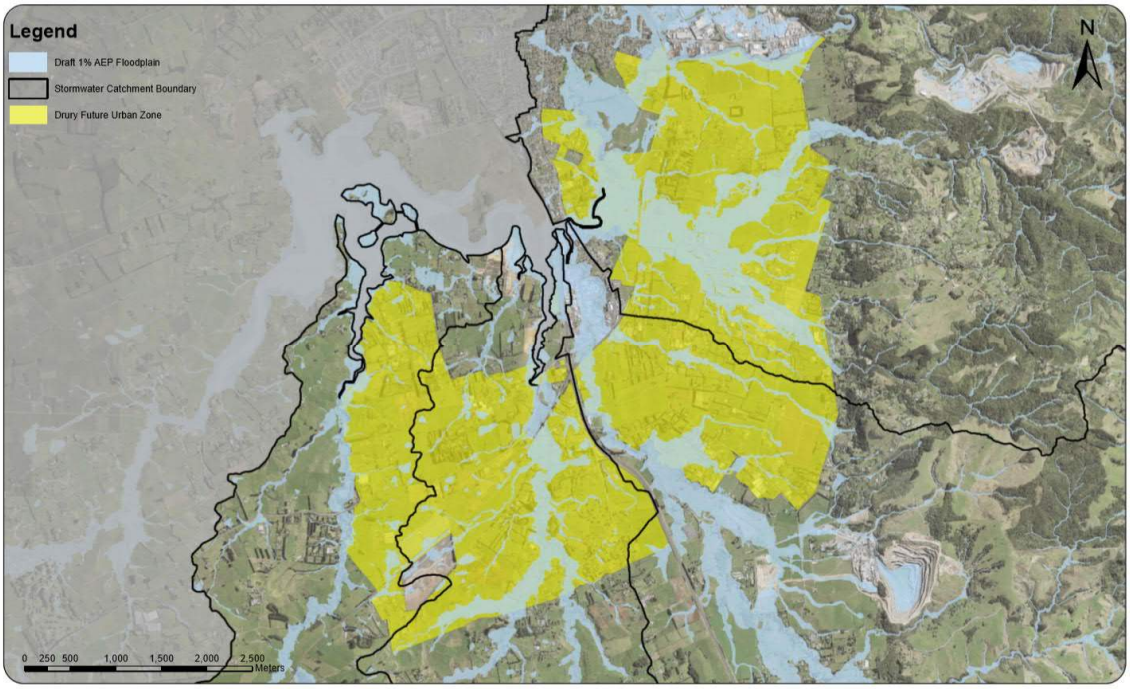


Figure 13 Drury-Opaheke Stormwater Management Plan – Predicted 100 year ARI Floodplains

3.7.1.3 Floodplains

Slippery Creek

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

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

Figure 14 below shows the floodplain depths thematically.

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

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

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

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

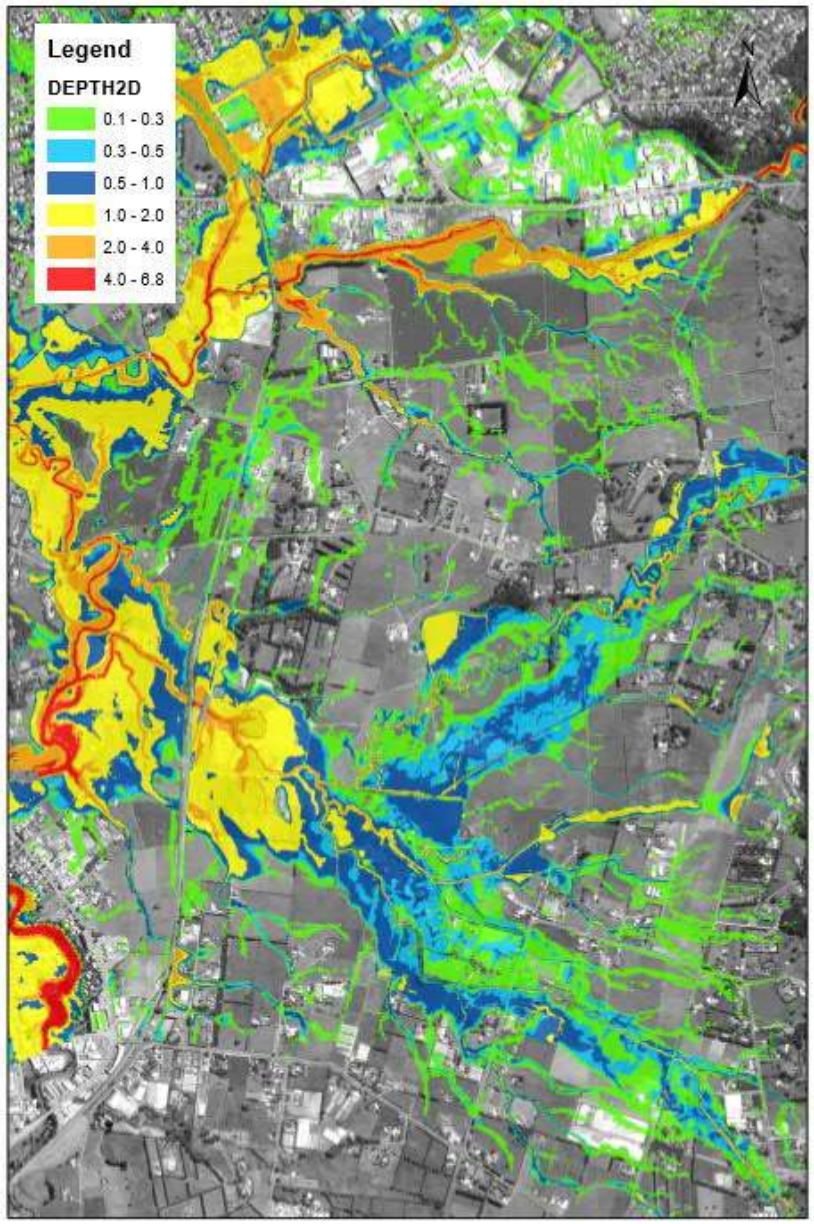


Figure 14 Slippery Creek Flood Depths

Hingaia Stream Catchment

The predominantly rural 57.5 km² Hingaia Stream catchment is predicted to produce over 10,500,000m^3 of runoff in a future 100 year ARI rainfall event with climate change and contains

one of the deepest floodplains in the Auckland Region. Approximately 366 Ha of the Hingaia Stream catchment falls within the Structure Plan Area. Approximately 54ha or 15% of the structure plan area within this catchment is predicted to be within the floodplain.

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

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

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

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

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

Drury West

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

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

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

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

3.7.1.4 Structures Assessment

A hydraulic assessment of the major structures (bridges and major culverts) within and downstream of the FUZ has been carried out. One of the purposes of the assessment was to

determine how structures would 'cope' under different land uses and storm events. The structures were assessed for the following scenarios:

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

Figure 15 shows most of the structures that were assessed.

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

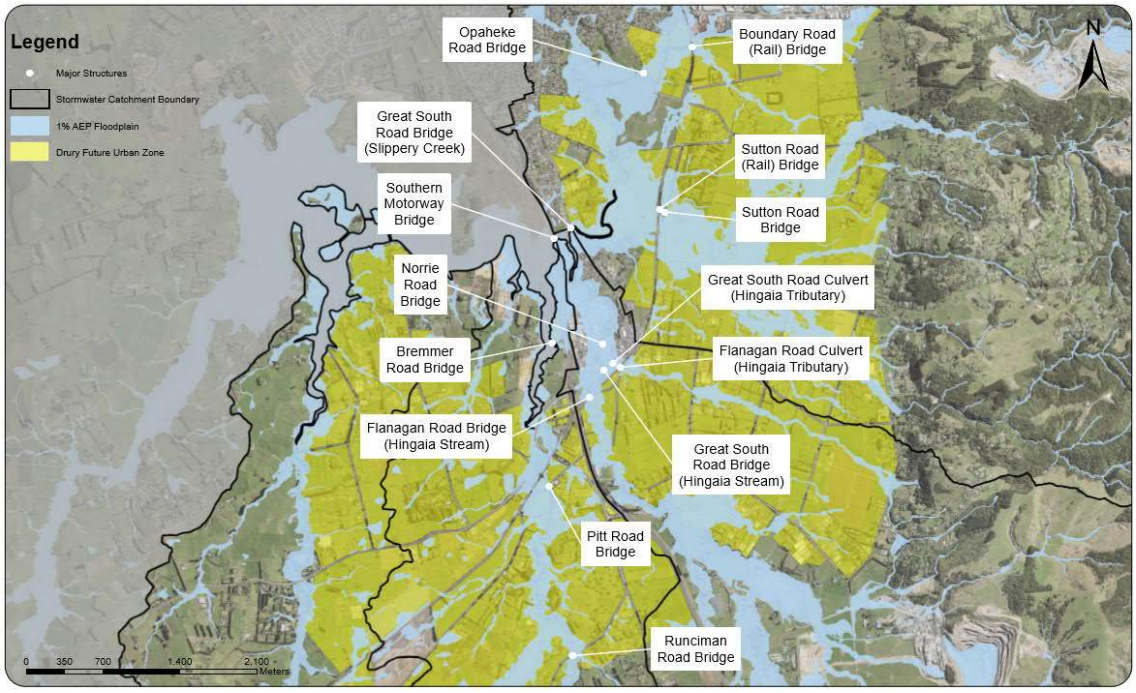


Figure 15 Structures Assessed within FUZ

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

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

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

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

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

Table 3: Level of Service of Structures

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

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

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

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

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

3.7.1.6 Flood Prone Areas

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

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

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

3.7.1.7 Overland Flowpaths

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

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

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

3.7.1.8 Drury Estuary as a Flow Constraint

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

3.7.2 Coastal Inundation

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

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

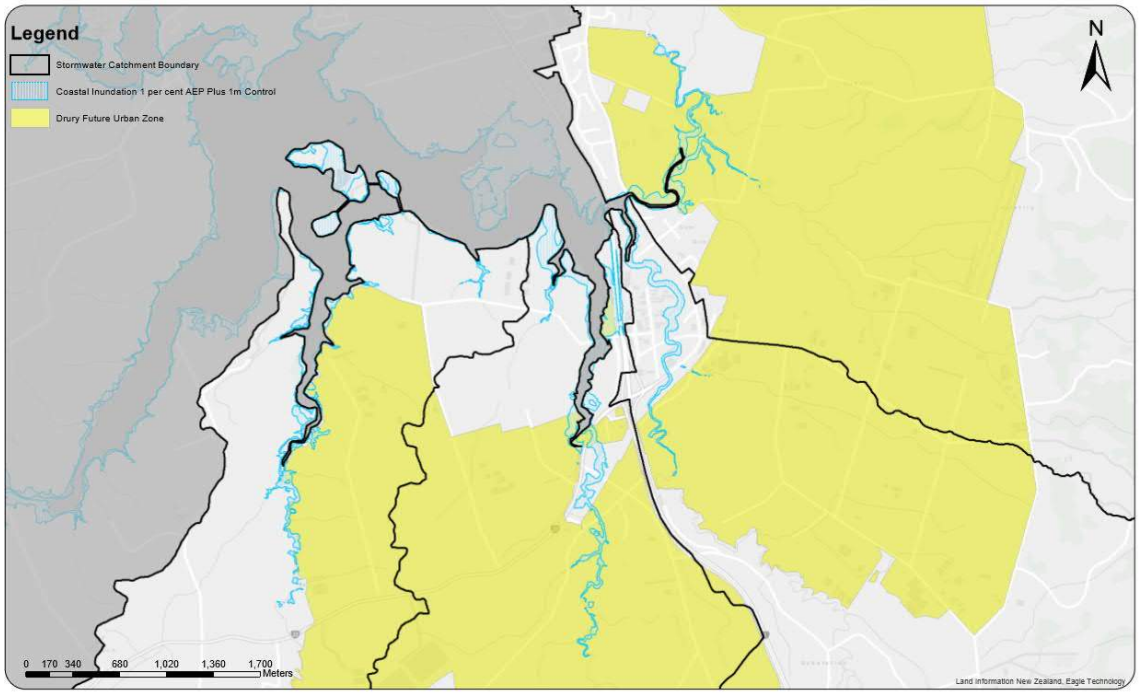


Figure 16 Drury-Opaheke Structure Plan Area - Coastal Inundation (1% AEP plus 1m control)

3.7.3 Hays Creek Dam

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

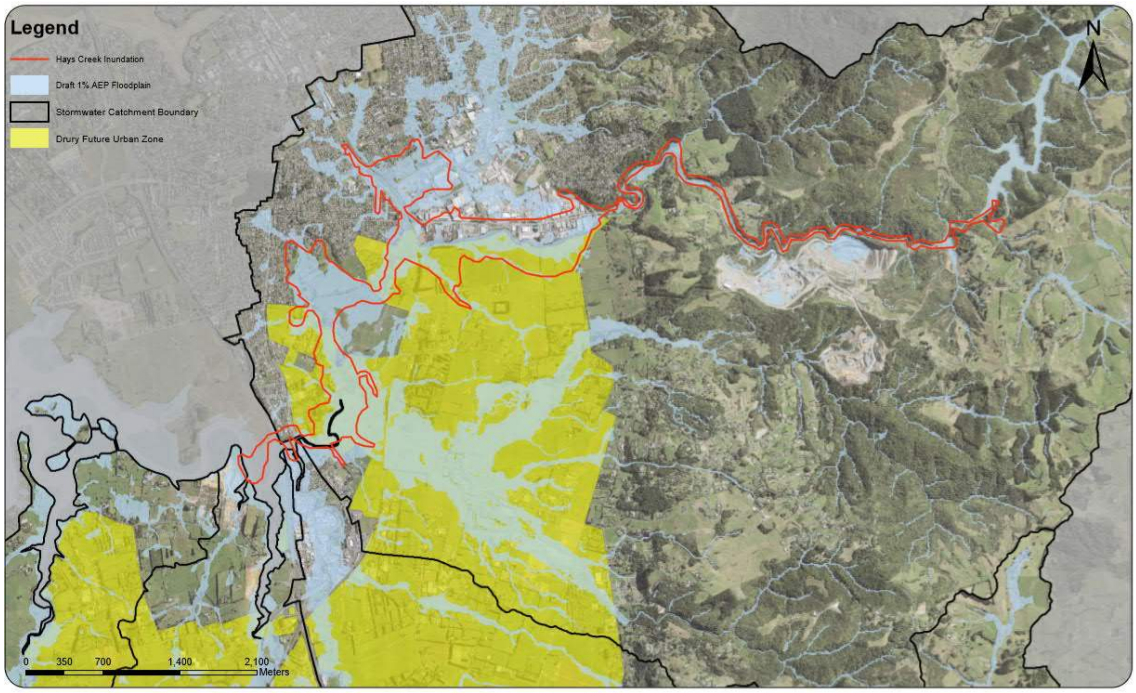


Figure 17 Hays Creek Dam Inundation Floodplain

3.8 Knowledge Gaps

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

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

4 Implementing Integrated Stormwater Management

4.1 Introduction

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

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

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

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

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

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

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

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

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

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4.2 Stream Management and Enhancement

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

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

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

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

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

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

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

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

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

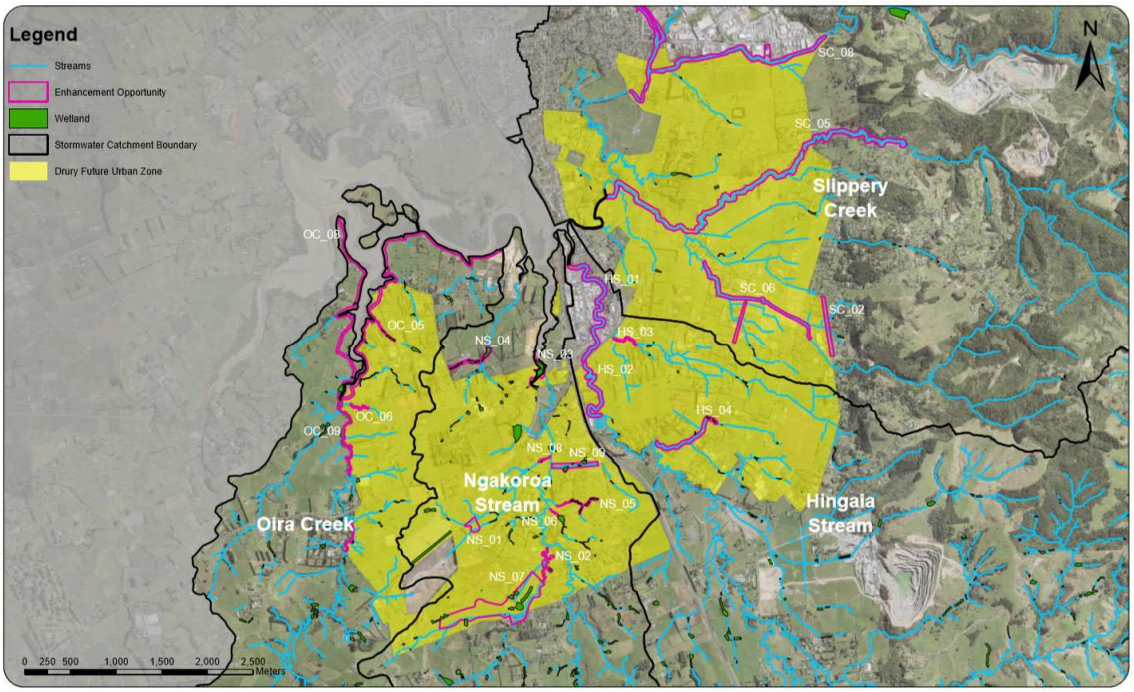

Figure 18 Enhancement Opportunities

4.2.1 Slippery Creek

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

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

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

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

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

Source: Slippery Creek Watercourse Assessment Report

Three EO's were identified within the FUZ.

Table 5: Slippery Creek Enhancement Opportunities

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

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

Source: Slippery Creek Watercourse Assessment Report

4.2.2 Hingaia Stream

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

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

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

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

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

Source: Hingaia Stream Watercourse Assessment Report

Three Enhancement Opportunities were identified within the FUZ.

Table 7: Hingaia Stream Enhancement Opportunities

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

Source: Hingaia Stream Watercourse Assessment Report

4.2.3 Ngakoroa Stream

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

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

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

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

Source: Ngakoroa Watercourse Assessment Report

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

Table 9: Ngakoroa Stream Enhancement Opportunities

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

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

Source: Ngakoroa Watercourse Assessment Report

4.2.4 Oira Creek

Management Zone 1 is located within the FUZ.

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

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

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

Source: Oira Catchment Watercourse Assessment Report

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

Table 11: Oira Creek Enhancement Opportunities

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

Source: Oira Creek Watercourse Management Report

4.2.5 Riparian Planting

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

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

Modern best practice water sensitive design development approach management of stream corridors and overland flow paths by incorporating their form and function into developmental designs at the very early stage of the development process. A clear plan established at an early stage allows these corridors to be designed to maximise their value to both future urban communities and its supporting natural environment. Once the values are defined and

accounted for, intensification and urban development of the surrounding urban developments can strategically take place on the land surrounding these corridors. These approaches are outlined in the Auckland Council GD04 Water Sensitive Design Manual.

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

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

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

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

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

4.3 Minimising and Mitigating Hydrological Change

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

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

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

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

requiring mitigation where more than 50% of the site is being redeveloped. In this way, flows from the existing development is managed, as well as that from new development.

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

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

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

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

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

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

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

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

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

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

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

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

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

4.3.1 Ongoing Auckland Council Stream Erosion Studies

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

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

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

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

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

4.4 Stormwater Treatment

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

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

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

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

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

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

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

4.5 Flood Risk Management

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

Table 12 Flood Risk Management Hierarchy

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

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

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

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

4.5.1 General

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

4.5.2 Slippery Creek Catchment

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

4.5.2.1 Potential Interventions

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

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

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

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

4.5.3 Hingaia Stream Catchment

The general management approach will be to pass flows forward.

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

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

4.5.3.1 Potential Interventions

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

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

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

4.5.4 Drury West

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

4.6 Applying Water Sensitive Design in the Future Urban Zone

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

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

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

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

Table 13: Water Sensitive Design Toolbox

Key Principles

Working with the existing landform - minimising cutting and filling that effects infiltration and changes the natural flowpaths, as far as practicable.
Minimise impervious surfaces and land disturbance thereby retaining the natural infiltration capacity of the soil
Apply exemplar erosion and sediment control measures (including small site development) to minimise the impact on the downstream receiving environment
Disconnection of impervious surfaces from the receiving environment to encourage infiltration and attenuation prior to discharge to the stormwater system
Utilise soakage into basaltic soils – directly via pervious surfaces or using soakage devices coupled with stormwater treatment.
Utilise soakage into peat soils
Utilise soakage in high use aquifer managements areas and high use stream management areas.
Avoid soil compaction or undertake cultivation to include organics and restore damage to maximise permeability
Re-vegetation/planting to reduce runoff and erosion and maximise biodiversity
Use inert building materials
Capture and reuse of rainwater for buildings and landscapes – the reuse component diverts stormwater first flush to wastewater (toilet flushing) or to ground for infiltration.

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

Key Principles

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

Key Principles

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

Key Principles

	Primary Stormwater Conveyance
	Secondary Stormwater Conveyance

5 Next Steps

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

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

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

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

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

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

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

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

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

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

6 References

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Appendices

A. Catchment Characteristics and Constraints Mapping

A.1 Figure 11: Streams

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

A.3 Figure 13: Flooding

A.4 Figure 19: Enhancement Opportunities

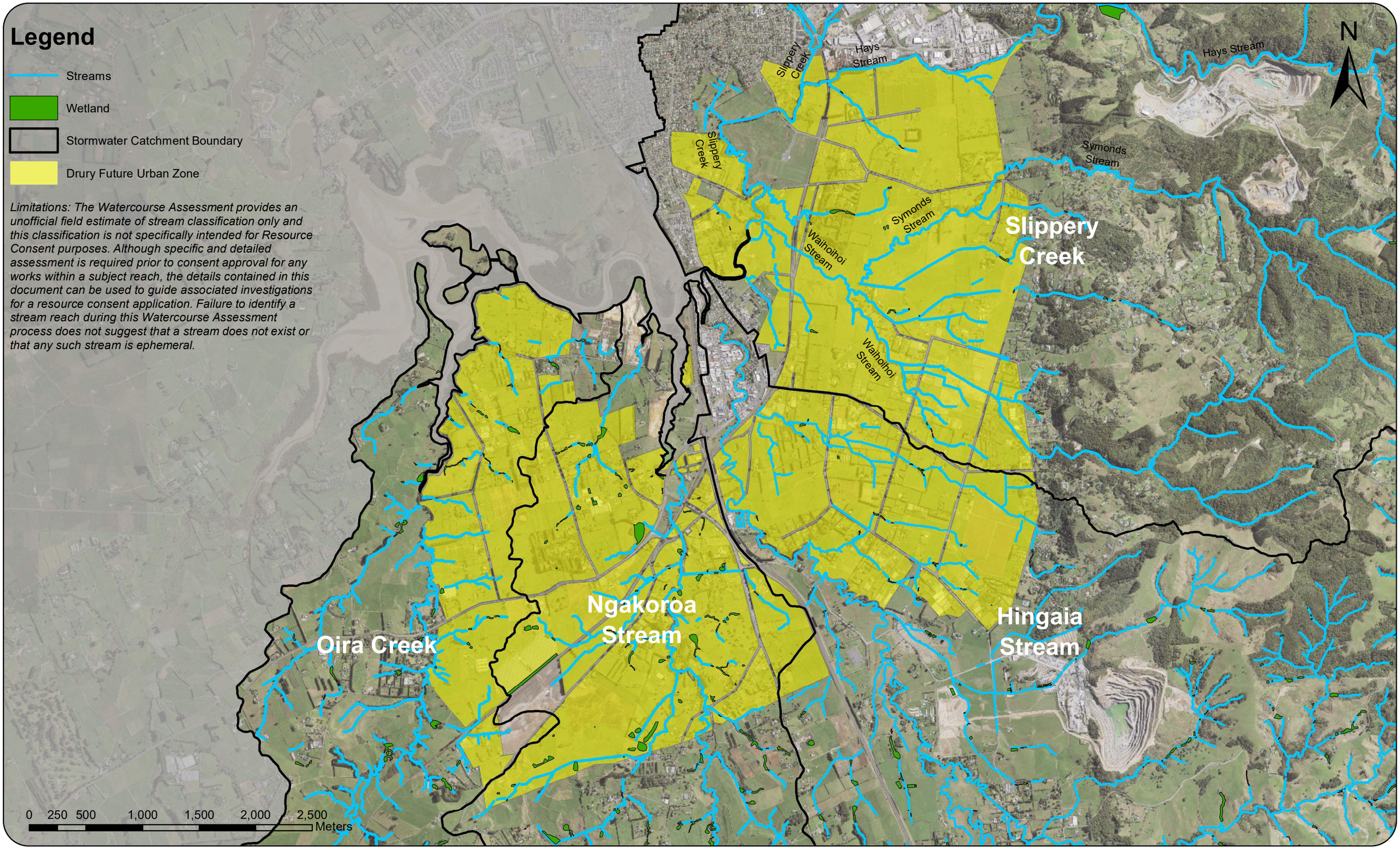

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Figure 11: Streams

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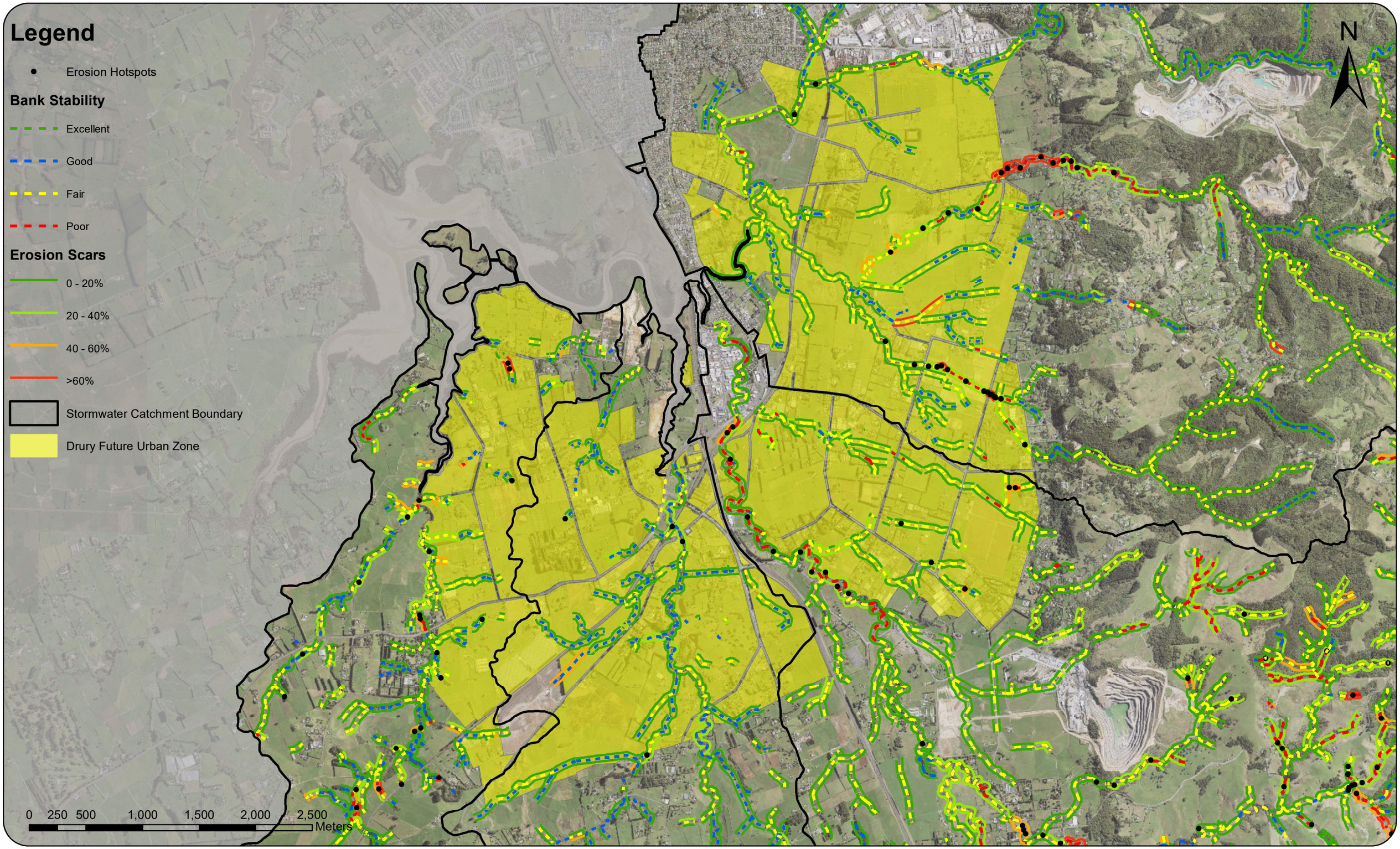

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Figure 12: Ecology, Erosion and Water Quality

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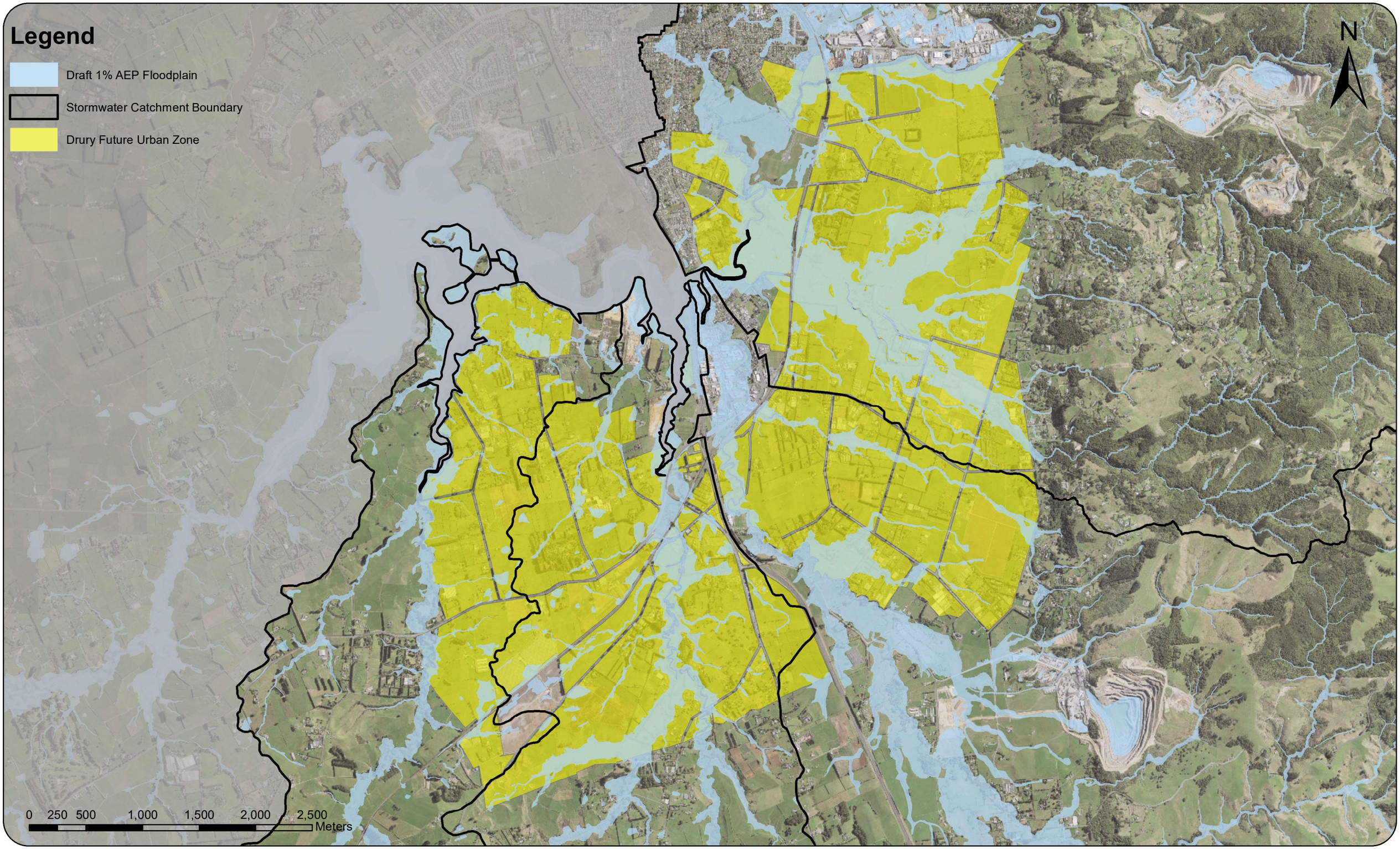

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Figure 13: Flooding

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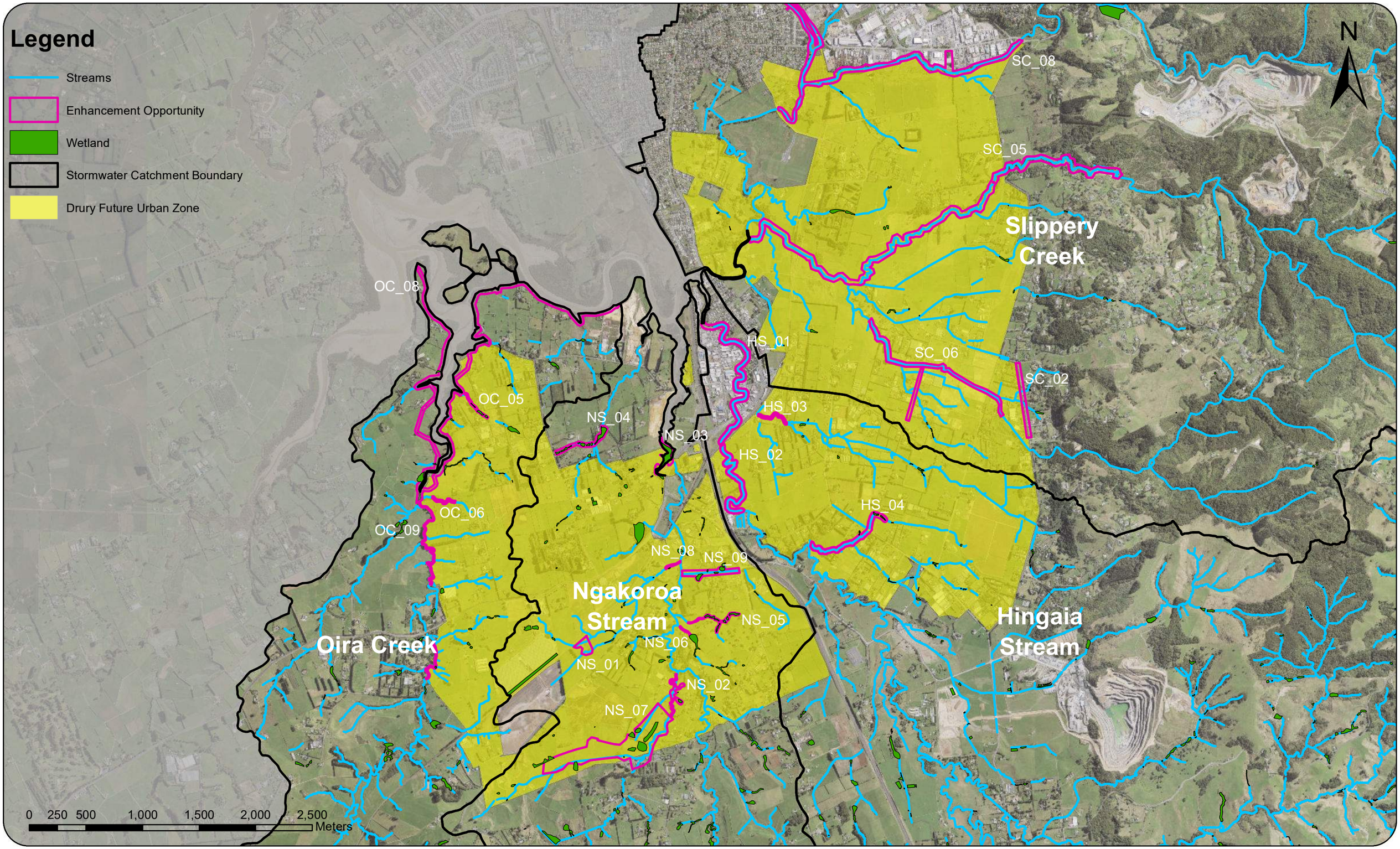

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Figure 18: Enhancement Opportunities

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