Mundijong district water management strategy

Prepared by Urbaqua for

Shire of Serpentine-Jarrahdale:

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Executive Summary

On 29 August 2023, the Western Australian Planning Commission (WAPC)approved the Mundijong District Structure Plan subject to modifications being undertaken. One of the modifications required by the WAPC is the preparation of an updated District Water Management Strategy (DWMS), as follows:

Modification 76 - Modify the District Water Management Strategy to:

- *incorporate and address the inclusion of Urban Expansion Areas within the DSP area.*
- *make the strategy consistent with advice provided in the Department of Water and Environmental Regulation submission, with particular attention to the availability of groundwater for irrigation and in relation to inundation management.*
- *reflect gazettal of Government Sewerage Policy (September 2019).*

This revised district water management strategy responds to this modification requirement including provision of updated flood modelling and mapping and consideration of the latest groundwater availability advice from the Department of Water and Environmental Regulation (DWER). Other relevant modifications that have also been considered in the preparation of this water management strategy are outlined in Table 1 below.

Key components of this water management strategy that respond to the modifications required include:

- A revised study area (Figure 1) that includes the revised District Structure Plan area and surrounding developing land to ensure that water management strategies are consistently applied across the boundaries of development precincts and local structure plan areas (Section 2 and Table 8).
- Updated water management objectives and strategies that reflect contemporary policies and advice from relevant stakeholders (Section 3 and Section 4).
- Updated groundwater information and assessment of future availability for irrigation that reflects current planning and advice from the Department of Water and Environmental Regulation (Section 4 and Appendix B).
- Updated flood modelling and mapping including the whole revised District Structure Plan area and surrounding developing land (Section 4 and Appendix C).
- Development of an updated arterial drainage strategy (Figure 10).
- Updated water and wastewater servicing guidance based on current planning and advice from the Water Corporation (Section 4).

Table 1: Summary of District Structure Plan modifications addressed by this water management strategy

Modification	Wording	Addressed
38 – Local Structure Plans	Incorporate outcomes relating to drainage and inundation arising from the review of the District Water Management Strategy (required under Modification 76) that apply in relation to the guidance of land use and development and to water management within the respective precincts.	This revised District Water Management Strategy provides updated flood modelling and mapping for the whole Mundijong District Structure Plan area and surrounds. Specific water management guidance is provided relevant to individual precincts, summarised in Table 8.
42 – LSP Area D, Watkins Road South	(a) Include the area identified as DIA 2 as part of Precinct D. (b) Include reference in the text to the provision of a primary school at the approximate epicentre of this precinct with its location to be determined in accordance with Liveable Neighbours Element 8 in consultation with the Department of Education to the satisfaction of the WAPC. (c) Insert provision in the text conveying the need for close attention to drainage and water management considerations in relation to the creek that passes through the DIA component of the enlarged precinct, including assessment of potential for inundation and establishment of a foreshore management plan. (d) Include the following under the heading key matters to be addressed – • Verify, retain and protect natural areas; and • Bush fire hazard management.	This revised District Water Management Strategy includes consideration of LSP Area D, Watkins Road South. Specific water management guidance is provided relevant to individual precincts, summarised in Table 8. Guidance provided for LSP Area D, Watkins Road South includes retention of vegetation and wetlands fringing Pruden Creek within a multiple use corridor and adjacent POS.
47 – Development investigation areas	(a) The land identified on the DSP Map as 'DIA1' becoming a separate Local Structure Plan precinct and 'DIA 2' being incorporated with Local Structure Plan Precinct D. (b) Delete section 1.7.1. (c) Create a new subsection titled 1.6.8 – LSP Area H – Cardup South. This should encompass the land identified as DIA1. (d) Under the heading 'key matters to be addressed, include reference in the text to the provision of a centrally-located primary school in this precinct with its location to be determined in accordance with Liveable Neighbours Element 8 in consultation with the Department of Education to the satisfaction of the WAPC.	This revised District Water Management Strategy includes consideration of LSP Areas M1 and M2, corresponding to development investigation areas DIA1 and DIA2. Specific water management guidance is provided relevant to individual precincts, summarised in Table 8. Guidance provided for LSP Area M1, Northern development investigation area

Modification	Wording	Addressed
	(e) Include further provisions under the heading 'key matters to be addressed' as follow – • Allowance for any land requirements associated with a rail crossing / interchange • Possible road widening requirements associated with Soldiers Road, Bishop Road and Bett Road. • Noise mitigation. • Bushfire hazard management. • Verify, retain and protect local natural areas. • Protect wetlands, watercourses and catchments. • Preserve fringing vegetation along roads and waterways. • Consideration of third pipe system.	(DIA1), includes retention of vegetation and wetlands fringing Norman Road Creek within a multiple use corridor and adjacent POS. Guidance provided for LSP Area M2, Southern development investigation area (DIA2), includes retention of vegetation and wetlands fringing Mardella Brook within a multiple use corridor and adjacent POS.
50 – Service Infrastructure Water Supply Wastewater Integrated Water Management Natural Resources (Water Resources) Service Infrastructure	(a) In section 2.2.5, discussion relating to the supply of water pursuant to the provisions of State Planning Policy 2.5 – Rural Planning being deleted. (b) In sections 2.2.5, 2.2.7 and 3.7, text relating to water supply, drainage and wastewater being modified in consultation with the Water Corporation to the satisfaction of the WAPC. (c) In sections 2.2.5 (primarily Integrated Water Management together with some references in Water Supply and Wastewater) and 2.2.7 (Natural Resources – Water Resources), replace text relating to the Waste Water and Drinking Water Strategy with information about work being undertaken on the development of alternative sources of non-drinking water with the aim of utilising this technology, if found to be feasible in a timely manner (while clarifying that, at the time of writing, the feasibility of the technology is not sufficiently proven for implementation), such text being to the satisfaction of the WAPC. (d) In section 2.2.7 incorporate any outcomes relating to drainage and inundation arising from the review of the District Water Management Strategy (required under Modification 76).	This revised District Water Management Strategy provides updated water servicing information for the Mundijong District Structure Plan area and surrounds. Guidance provided reflects the current status of planning for water and wastewater services in Mundijong which no longer includes reference to development of alternative water sources. This revised District Water Management Strategy also provides updated flood modelling and mapping for the whole Mundijong District Structure Plan area and surrounds and establishes an updated arterial drainage strategy for the study area (see Figure 10).
53 – Natural resources	Figure 14 (Existing Landform, Soils and Flood Risk) and Figure 16 (Mundijong Opportunities and Constraints) being updated to show any areas subject to flood risk, as identified in an updated District Water Management Strategy, as required by Modification 76.	This revised District Water Management Strategy provides updated flood modelling and mapping for the whole Mundijong District Structure Plan area and surrounds.

Modification	Wording	Addressed
76 – District water management strategy	Modify the strategy to – • incorporate and address the inclusion of Urban Expansion Areas within the DSP area. • make the strategy consistent with advice provided in the Department of Water and Environmental Regulation submission, with particular attention to the availability of groundwater for irrigation and in relation to inundation management. • reflect gazettal of Government Sewerage Policy (September 2019).	This revised District Water Management Strategy has been prepared for a study area that includes the entire amended District Structure Plan area and adjacent Mundijong Industrial Area. Updated groundwater for irrigation guidance based on the latest advice of the Department of Water and Environmental Regulation is provided. Water servicing guidance provided reflects the current status of planning for water and wastewater services in Mundijong and includes reference to the Government Sewerage Policy (2019). This revised District Water Management Strategy also provides updated flood modelling and mapping for the whole Mundijong District Structure Plan area and surrounds and establishes an updated arterial drainage strategy for the study area (see Figure 10).

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1 INTRODUCTION AND BACKGROUND

This water management strategy has been prepared to demonstrate how water resource protection and management outcomes are intended to be delivered through the *Mundijong District Structure Plan*. This strategy addresses the study area presented in Figure 1 which includes the West Mundijong Industrial Area that will ultimately be removed from the revised District Structure Plan and is therefore not precisely aligned to the Mundijong District Structure Plan area.

It has also been prepared in recognition that the 2021 Mundijong DSP is an update to the 2011 DSP and respects the areas of already approved LSP's and their Local Water Management Strategies within the DSP area.

This water management strategy is delivered in response to draft State Planning Policy 2.9 – Planning for Water, supports the *Mundijong District Structure Plan* (Hames Sharley, 2021) and addresses the requirements of a district water management report (see Chart 1) that are relevant for development in the described planning area. This level of water management report is required to establish a framework for delivery of future planning and development in Mundijong.

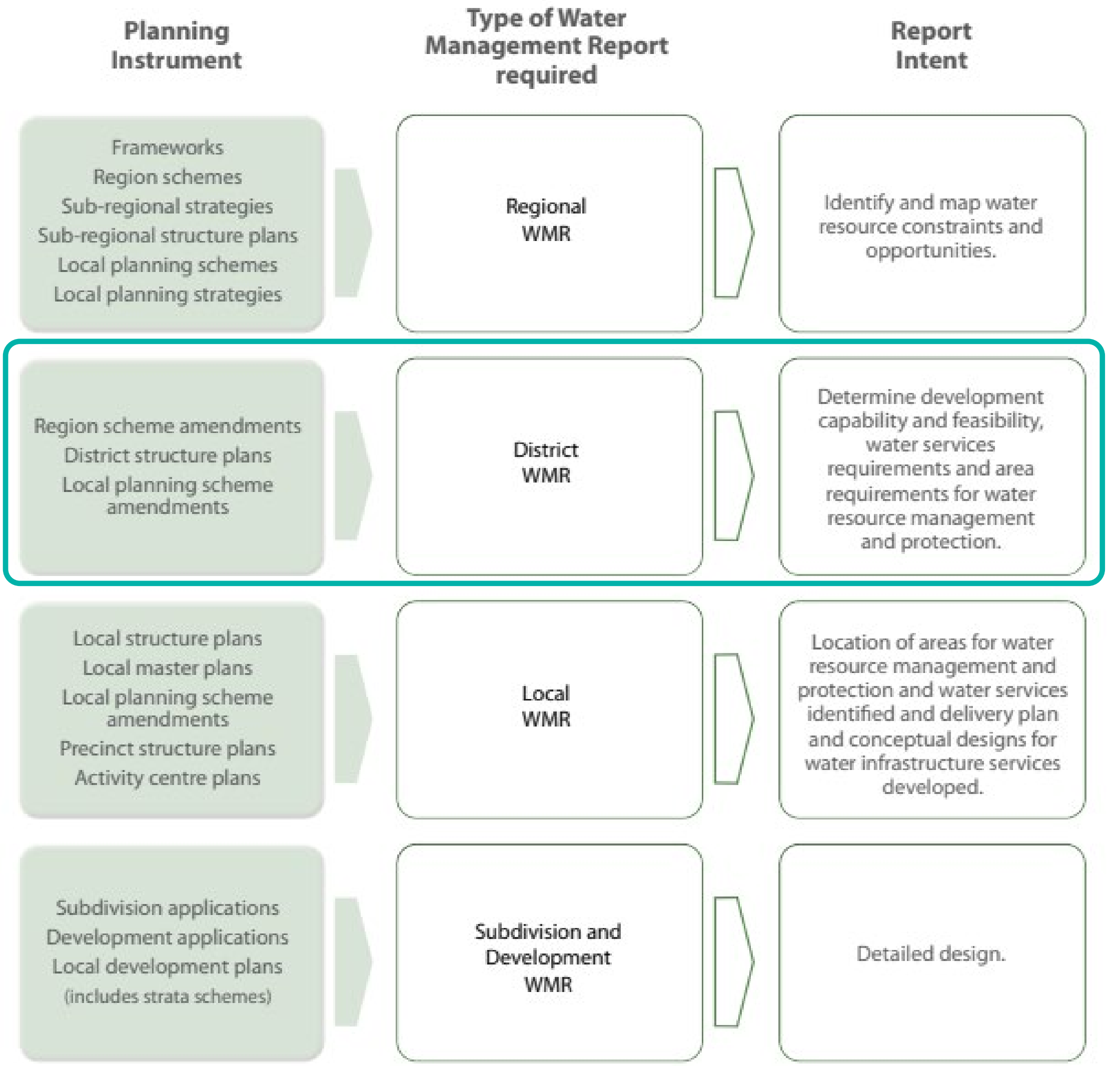
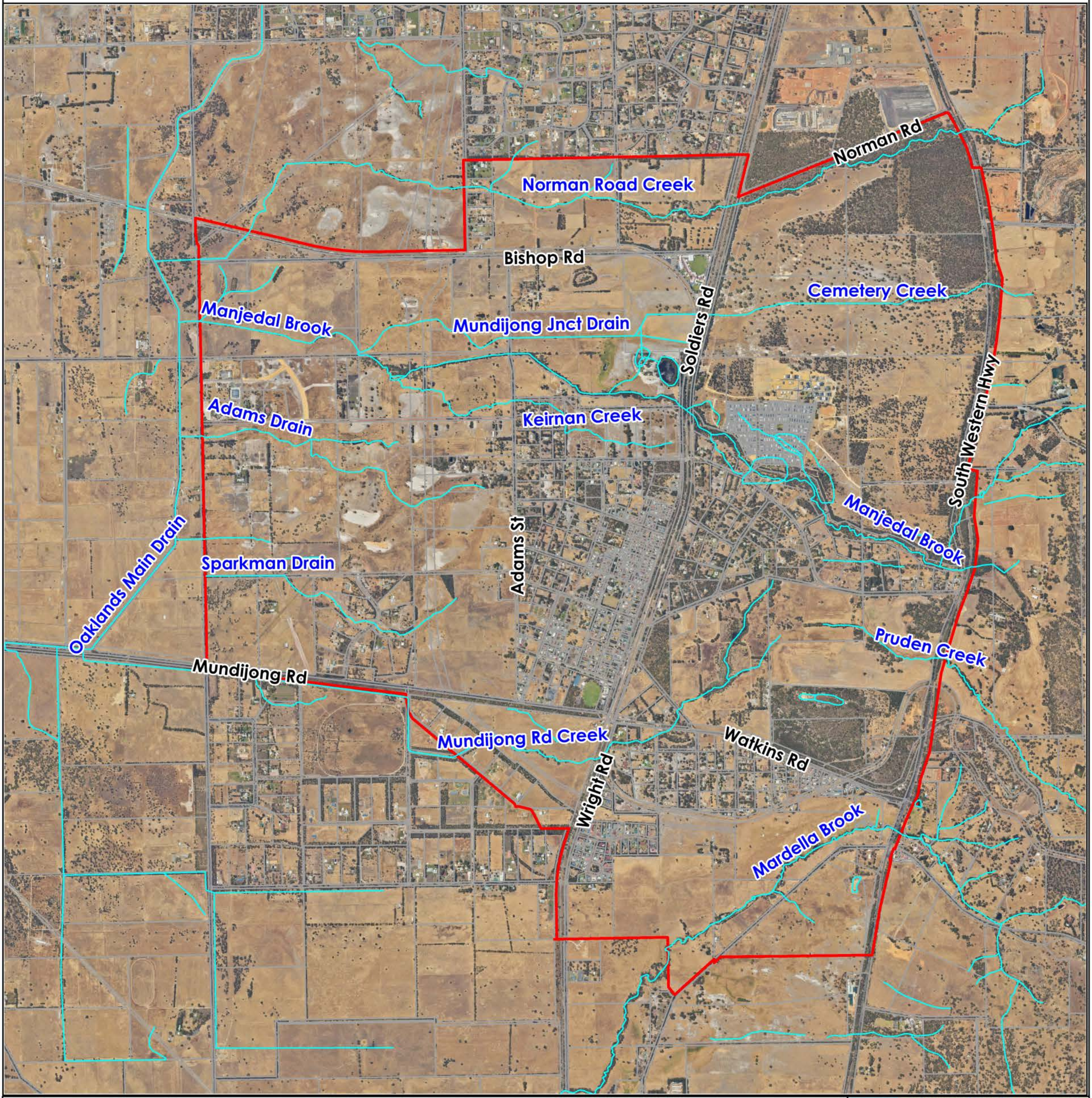


Chart 1: The water management report and planning instrument hierarchy (WAPC, 2021)

Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 1 - Study area location plan



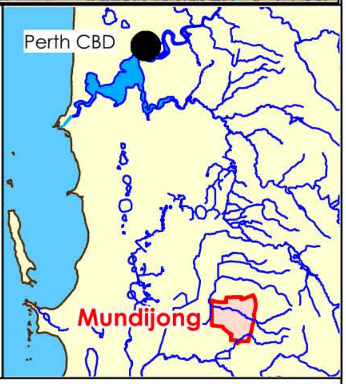
LEGEND:

Study area boundary

Cadastre

Waterways

NOTE: Unnamed waterways have been named for convenience, based on local features or roads.



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1.1 Water management principles

All future land use planning and development proposals will aim to:

- Consider water resources at all stages in the planning process, to integrate water and land use planning, protect important values and optimise total water cycle outcomes.
- Reduce potable water demand, increase water reuse and maximise water use efficiency and use of wastewater and harvested water.
- Design for the small (frequent), minor, then major rainfall events and aim to replicate how water moves through the natural landscape, noting local site conditions.
- Manage rainfall events to minimise runoff throughout the catchment by using multiple low cost 'in-system' management measures to reduce runoff volumes and peak flows.
- Retain and restore existing elements of the natural drainage system, including waterway, wetland and groundwater features, regimes and processes, and integrate these elements into the urban landscape, through multiple use corridors which provide protection to life and property from flooding.
- Minimise pollutant inputs through implementation of appropriate structural and non-structural source controls.
- Enhance social amenity through multiple use corridors, streetscape, lot landscaping and integrating water management measures into the landscape including public spaces to enhance visual, recreational, cultural and ecological values, while minimising development costs.
- Address issues that are relevant to the site and surrounds to a level of detail that is appropriate to the planning decision being made and reflective of the degree of significance of the issue and possible risk to the community and environment.
- At the district level, ensure achievement of both water quantity (pre and post development flows) criteria, and water quality improvement criteria.

1.2 Guiding documents

Preparation of this DWMS has considered the following guiding and technical documents:

- South Metropolitan Peel Sub-Regional Planning Framework (WAPC, 2018)
- *Kep Katitjin – Gabi Kaadadjan Waterwise action plan 3* (DWER, 2024)
- Waangaamaap – Serpentine groundwater allocation statement March 2024 (DWER, 2024)
- *Bindjareb Djilba: A plan for the protection of the Peel-Harvey estuary* (DWER, 2020)
- Peel-Harvey water quality improvement plan *(EPA, 2008)*
- Liveable Neighbourhoods (WAPC, 2015)
- State Planning Policy 2.9: Water Resources (WAPC, 2008)
- Better Urban Water Management (WAPC, 2008)
- Draft State Planning Policy 2.9: Planning for Water (WAPC, 2021)
- Draft Planning for Water Guidelines (WAPC 2021)
- Government Sewerage Policy (Government of Western Australia, 2019)
- Stormwater Management Manual for Western Australia (DoW, 2004–2007)
- Decision Process for Stormwater Management in WA (DWER, 2017)
- Guidelines for district water management strategies (DoW 2013)
- Speciation Separation Distances for Groundwater Controlled Urban Development (IPWEA, 2016)
- Water Resource Considerations when Controlling Groundwater Levels in Urban Development (DoW, 2013)
- South Metropolitan Peel Sub-Regional Water Management Strategy (Urbaqua, 2018)

- Water monitoring guidelines for better urban water management strategies and plans (DoW, 2012)
- Public Parkland Planning and Design Guide WA (Government of WA, 2014)
- Guidance Statement No.33 Environmental Guidance for Planning and Development (EPA, 2008)
- Environmental Factor Guideline - Inland Waters | EPA Western Australia (EPA, 2018)
- Operational policy 4.3 - Identifying and establishing waterways foreshore areas (DoW, 2012)
- Australian Rainfall and Runoff: a guide to flood estimation (Geoscience Australia 2019)
- Code of Practice for urban and peri-urban drainage modelling in Western Australia (Stormwater Western Australia, Institute of Public Works Engineering Australia (WA), Engineers Australia, Hydrology and Water Resources Panel, 2023)
- Mundijong-Whitby District Water Management Strategy (GHD, 2012)

1.3 Key site considerations

Analysis of the site characteristics in Mundijong is provided in Appendix A. Key considerations for water management are summarised below.

1.3.1 Climate considerations

It is important to consider historic, current, and future climate as an integral part of water management investigations and modelling to inform development and validation of strategies. This should include an understanding of the representativeness of local monitoring results and demonstrated understanding of how future changes are likely to impact on the total water cycle.

The climate for the Study Area is typical of the Southwestern region of Western Australia and is characterised by the Köppen Climate Classification as Dry Subtropical featuring mild and wet winters and hot to very hot summers.

The impacts and forecast impacts of climate change will extend periods of very hot conditions, as well as increase significant storm event frequency.

Urban heat mapping of the Study Area provided in Appendix A (Figure 12) demonstrates the importance of water and vegetation in providing cooling for new and existing urban areas.

Urban greening in the study area should focus on retaining existing trees and vegetation wherever possible, maximising trees and vegetation in road reserves, public open spaces and along retained waterways.

The historic townsite has an extensive urban tree canopy, where new development areas are characterised by the general absence of tree canopy.

Water sensitive urban design is a key contributor to the effectiveness of urban greening. It is critical that strategies are implemented to maintain soil moisture through retention and infiltration of stormwater as close to source as possible.

1.3.2 Geotechnical considerations

The physical and topographical conditions for the site influence the hydrological conditions including the ability to retain and infiltrate runoff. A summary is provided in Appendix A based on regional mapping which are also presented in Figure 13 and Figure 14.

The nature of soils, particularly permeability, is a critical element in determining an appropriate drainage strategy. Low permeability soils require consideration of drainage strategies comprising on-site and in-system detention to avoid significant increases in peak flows to existing drainage systems and sensitive receiving water bodies.

Where sandier soils exist, on-site infiltration strategies can be similarly applied to manage peak discharges and should be encouraged in these areas.

Areas of acid sulfate soils cannot be confirmed or discounted at this stage of the development process and will need to be determined by an acid sulfate soils investigation, potentially with sampling within the site. Acid sulfate soils can be managed through appropriate management plans, sampling, and treatment, which is addressed through a DWER approval process that should be undertaken prior to any subdivision.

Further investigations are required to determine the extent of contaminated soil and/or groundwater, particularly where indicated as possible, as a result of current or past land use. A Preliminary Site Investigation (PSI) is recommended at Local Structure Plan stage. This should include consideration of high levels of nutrients (which generally fall outside the Contaminated Sites Act).

1.3.3 Hydrology

As described in Appendix A (Figure 16) there are a number of watercourses and drains discharging through the study area, with the Manjedal Brook and Mardella Creek being the most significant. Natural watercourses in the study area typically drain in an east-west direction from the escarpment.

The Study Area is known to experience regular water logging in the low-lying areas of the study area. This inundation is due to a combination of persistent winter rainfall elevating the shallow water table, which rises to the surface and inundates vast areas of the flat terrain, as well as sparse drainage, with insufficient capacity that does not allow runoff to leave the area. There is also potential for wetlands within the study area to receive additional flood water from outside their natural catchment by overtopping of drains and watercourses.

Development will result in the loss of significant areas of multiple use wetland. The addition of imported fill and subsurface drainage will control groundwater levels and soil wetness and therefore reduce the extent of inundated areas. In addition, improvements to surface water drainage will result in less extensive surface inundation which will be confined to predetermined locations within public open space areas.

Local scale monitoring is required prior to development to ensure that local groundwater and surface water conditions are understood and considered in the development of local structure plans and subdivision designs. This is a requirement for developers in formulating their structure planning proposals.

1.3.4 Services

Water and wastewater are required to be provided through development, noting that wastewater services are not currently available for connection in the Mundijong District Structure Plan area. Development of the Mundijong District Structure Plan area is expected to proceed through the extension and sequential roll-out of existing water and the building of new wastewater services to provide the most efficient and cost-effective way of infrastructure provision.

Wastewater services are soon to be established, noting that Whitby Estate commenced via a non-permanent private pressure main sewer which is planned to be replaced by the permanent solution.

Water Corporation undertakes water services planning and allocates funds for infrastructure upgrades on the basis of land use planning information. Where a development proposal requires drinking water headworks infrastructure, for which the Water Corporation has not allocated funds to suit the developer's schedule, prefunding of the works may be necessary.

Wastewater planning for Mundijong District Structure Plan area has been developed based on generalised land use, development and density/yield assumptions from previous iterations of the Mundijong-Whitby DSP. This is now being provided as enabling infrastructure.

Groundwater is used extensively in the study area as a fit for purpose water supply for public open space irrigation, agriculture and commercial/industrial purposes as well as for private uses (garden and stock watering) which are exempt from licensing as discussed in Appendix A.

Existing groundwater licenses within the Mundijong District Structure Plan area are able to draw up to 745 ML/year from the superficial groundwater system and a further 534 ML/year from underlying confined aquifers. The total allocated groundwater resource within the DSP area is therefore 1,279 ML/year.

The ultimate post-development estimated irrigation demand in the Mundijong DSP area is estimated to be 1,481 ML/year, as calculated for water balance modelling presented in Appendix B. This is approximately 200 ML more than the currently allocated groundwater amount and it is likely that this shortfall will require consideration of alternative water sources for irrigation, which may include the use of scheme water where other options are not available.

Recent studies have detected declining groundwater levels in some areas, which are caused by a combination of abstraction and reduced rainfall as a result of climate change (DWER, 2022). These reductions in groundwater levels, particularly in the superficial aquifer, pose a significant risk to the health of the region's wetlands, river systems and riparian vegetation (DWER, 2021). Accordingly, there is a critical need to ensure the sustainable management of our groundwater resources so they can sustain the important social, economic and environmental functions for future generations. It is therefore likely that reductions in groundwater abstraction from licenced areas will be required in future to account for reduced rainfall and recharge based on technical assessments by the Department of Water and Environmental Regulation.

Through the *Waangaamaap — Serpentine groundwater allocation statement* (2024), the Department of Water and Environmental Regulation has reduced allocation limits in line with reductions in rainfall due to climate change and to reflect and maintain currently allocated amounts. Therefore, it is anticipated that current allocations can be traded and transferred to largely satisfy the future water demand for irrigation in Mundijong.

Therefore, it is anticipated that groundwater use within the Mundijong District Structure Plan area should be limited to currently allocated amounts. This will allow for trades and transfers of existing licenses as land uses change and new public open spaces are created but will require development to incorporate strategies to maximise water use efficiency and consider alternative sources, including scheme water, as necessary where availability is insufficient to meet demands.

In addition, it should be noted that the sustainable yield of groundwater from the superficial aquifer in parts of the study area may be significantly restricted due to clay soils. Developments affected by this issue may require numerous shallow, low-yielding bores and/or require a supplementary irrigation source.

2 PROPOSED DEVELOPMENT

2.1 Mundijong District Structure Plan

The rural village of Mundijong and adjoining area of Whitby was rezoned for urban purposes under the Metropolitan Region Scheme in 2006. The original Mundijong/Whitby District Structure Plan was drafted through an Enquiry by Design exercise and approved in March 2011.

The District Structure Plan (Figure 2) is currently being revised to reflect changes in a number of State and local policies and incorporates a significant number of strategic documents (most notably the South Metropolitan and Peel Sub-regional Framework) that have been produced since the District Structure Plan was approved. The Shire has also made some strategic decisions that impact on the District Structure Plan including preparing the local structure plan for the West Mundijong Industrial Area and its consequent removal from the district structure plan.

The updated District Structure Plan estimates a population of 58,000 people and incorporates provision for two new district centres with the opportunity to ultimately link into the Perth urban rail network and promotes the relocation of the existing freight rail line traversing the subject area to its perimeter in conjunction with the construction of the Tonkin Highway extension. It also incorporates the Urban Investigation Areas as indicated by the Sub-regional framework.

Figure 2: Mundijong District Structure Plan

2.2 Vision and objectives for development

Mundijong District Structure Plan (Hames Sharley, 2021) outlines the following vision and objectives for *Mundijong*.

> ***"Mundijong will be a contemporary, connected place reflecting the community's rural character, 'green' values and vibrant village feel, building on the traditional town centre as the civic heart complemented by new sub-regional sports and recreational facilities to service the surrounding districts."***

A Thriving Community of choice

- To be a contemporary, connected place reflecting the community's rural character, 'green' values and village feel.
- A new sub-regional hub of sporting and recreational facilities serving the community and surrounding district.
- Create a vibrant and attractive place that offers a range of lifestyle choices and a liveable environment, supporting a safe, healthy and active community.

Vibrant and Connected District Centres

- The traditional town centre of Mundijong is reinforced as the governance heart with its main street, train station and civic functions complementing the new Whitby town centre.
- Create a strong local employment base which provides for locally available infrastructure and services.
- Ensure as the Shire grows, strong governance will guide well designed growth that makes the most efficient use of existing and planned infrastructure and investment.

A Distinct Sense of Place and Identifiable Character

- Create a distinctive and responsive built form that enhances the sense of place, community identity and character of Mundijong/Whitby.
- A contemporary new District Centre that is well connected and reflective of the community's rural character, green values and vibrant village feel.

A Safe Pedestrian and Interconnected Transit Hub

- Connecting many streets and pedestrian routes leading to a transit hub.
- Reduce reliance on vehicles by creating a pedestrian-oriented community and providing for alternative transport modes.
- Open space areas are provided with passive surveillance.
- A street network and urban environment providing high levels of connectivity and legibility.

A Place that Celebrates its Environmental Assets

- Preserve the existing rural, "leafy green" character of the structure plan area including its scenic values, viewscapes and landscapes.
- Protect and enhance significant natural areas and their buffers, including those with ecological linkage values along railroads, roads and scenic highways.

A Water Sensitive Place

- Maximise the efficient use and reuse of water by conserving water through efficiency and facilitating water reuse and fit-for-purpose use.
- Protect and enhance wetlands, waterways and catchments through appropriate management of water quality and maintenance of hydrology as part of land use change and development.

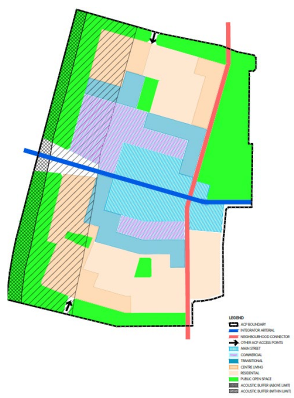
An Innovation Hub

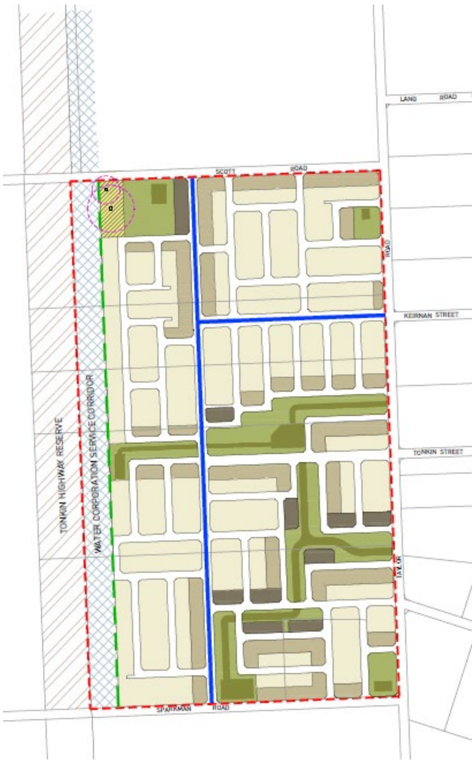
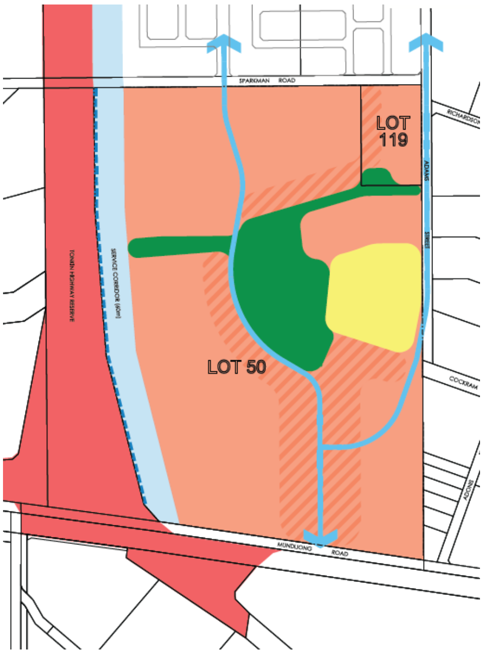
- A local economy supported by the West Mundijong Industrial Precinct to encourage business expansion, job training and economic growth.
- A regional magnet for a young and highly skilled workforce.
- Reduce consumption of non-renewable resources via climate responsive design, efficient use of energy and water and increased use of renewable energy.

2.3 Local structure planning

Several existing local structure plans have been prepared and approved within the Mundijong District Structure Plan area to provide more detailed planning and development guidance. These local structure plans are summarised below in Table 2.

Table 2: Summary of local structure planning in Mundijong

Planning document details	Plan layout
Precinct A – Whitby Local Structure Plan (2012) This Local Structure Plan has been prepared to guide the subdivision and development of land contained within Precinct A of the Mundijong Whitby District Structure Plan. The Local Structure Plan aims to create a residential neighbourhood in line with the Shire's vision for the area, as set out in the Mundijong Whitby District Structure Plan. The Local Structure Plan is bounded to the south by the Manjedal Creek multiple use corridor and includes provision for a second multiple use corridor to accommodate Cemetery Creek.	
Precinct A - Whitby Activity Centre Structure Plan (2021) This activity centre plan provides guidance and structure for development of the district centre at Whitby, located 3km north of Mundijong town centre and 48km from the Perth CBD. It will serve as the primary activity centre within the Mundijong-Whitby district cell and terminus of future passenger rail extension. The Local Structure Plan is bounded to the south by the Manjedal Creek multiple use corridor and and to	

Planning document details	Plan layout
the north by the Cemetery Creek multiple use corridor.	
Precinct E1 – Taylor Road & Adams Street Mundijong Local Structure Plan (2015) This Local Structure Plan applies to the northern portion of Precinct E of the Mundijong Whitby District Structure Plan. The Local Structure Plan includes provision for multiple use corridors to accommodate flows from the existing town centre connecting to Adams Drain via a single crossing of the Tonkin Highway. This LSP is proposed to be superseded by the Mundijong Precincts E1 & E2 Local Structure Plan 2023 version. At the time of writing the E1 and E2 LSP 2024 version has been supported by Council subject to modifications and is with the WAPC for determination. Should the 2024 version be approved by WAPC, this 2015 version will be superseded and longer apply.	
Mundijong Precinct E2 – Lot 50 Cockram St & Lot 119 Sparkman Rd Local Structure Plan (2015) This Local Structure Plan applies to the southern portion of Precinct E of the Mundijong Whitby District Structure Plan. The Local Structure Plan includes provision for a multiple use corridors to accommodate flows from the existing town centre connecting to Sparkman Drain via the Tonkin Highway. This LSP is proposed to be superseded by the Mundijong Precincts E1 & E2 Local Structure Plan 2023 version. At the time of writing the E1 and E2 LSP 2024 version has been supported by Council subject to modifications and is with the WAPC for determination. Should the 2024 version be approved by WAPC, this 2015 version will be superseded and longer apply.	

Planning document details | **Plan layout**

Mundijong Precincts E1 & E2 Local Structure Plan (2023)

Land within the Structure Plan area is zoned urban and is the subject of two previously approved structure plans which cover Precincts E1 and E2 independently. Following the consolidation of landholdings within the E1 and E2 Precincts, this Structure Plan has been prepared to provide a consistent development framework for the combined development precinct to guide the development and delivery of a single, coordinated master-planned community.

The Local Structure Plan increases provision for multiple use corridors to provide for four outlets via the Tonkin Highway.

At the time of writing the E1 and E2 LSP 2024 version has been supported by Council subject to modifications and is with the WAPC for determination. Should the 2024 version be approved by WAPC, this will supersede the 2015 E1 and E2 Local Structure Plans which will no longer apply.

Mundijong Whitby Sub Precinct G1 Local Structure Plan (2024)

The Structure Plan proposes residential development predominately at a R25 density and ranging up to R60, areas for conservation and public open space (POS), two primary schools, one community site and one neighbourhood centre. One existing private school (Court Grammar School, Pre-K to Year 12) is located in the northeastern corner of the Structure Plan area.

The Local Structure Plan includes provision for multiple use corridors to accommodate the Manjedal Brook and Manjedal Junction Drain which provides a connection from Cemetery Creek to Manjedal Brook.

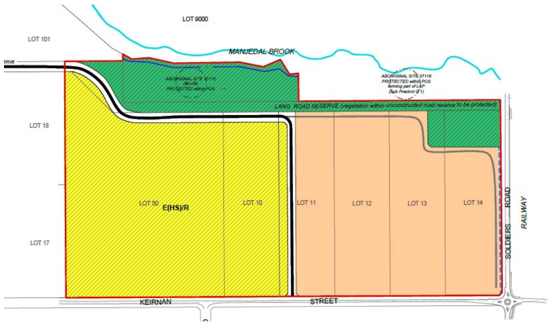
Planning document details	Plan layout

Sub Precinct G2 – Kiernan Street Local Structure Plan (2020)

The main land use of this Local Structure Plan is Residential. The assigned Residential Density Codes accord with the revised DSP for Mundijong which identifies the area on the DSP Map as ‘Low (Suburban): R20-R35’.

The Local Structure Plan is bounded to the north by the Manjedal Creek multiple use corridor.

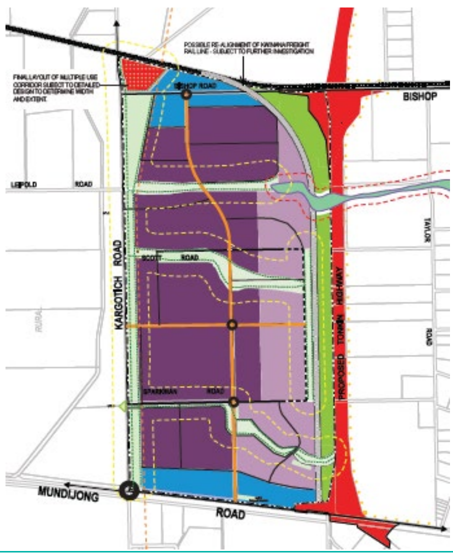
At the time of writing the Sub Precinct G2 – Kiernan Street Local Structure Plan has been approved by the WAPC subject to modifications. The requested modifications are not yet finalised. Should the modifications be completed and endorsed by the WAPC the LSP shall apply.



West Mundijong Industrial Area Structure Plan (2022)

The West Mundijong Structure Plan provides for a general industrial core (279 ha) and supporting light industrial areas (135 ha) for precincts to the east and south. The light industrial areas also provide separation from the core area to adjoining residential areas to the east and south.

The Local Structure Plan includes provision for the Manjedal Creek and two other multiple use corridors linking the Tonkin Highway reserve to Kargotich Road.



2.4 Assessment of risks to water resources

In Mundijong, the following risks to water resources from existing and proposed land uses and land use change have been identified through development of water balance modelling (Appendix B):

Water quality risks to wetland and waterway health:

- Presence and management of existing land uses
- Presence and management of proposed land uses
- Installation of drainage systems potentially mobilising legacy contamination.

Water quantity risks to wetland and waterway health:

- Clearing and development increasing recharge and decreasing evapotranspiration potentially leading to groundwater level rise.
- Filling and draining of the land potentially changing the hydrology of wetlands and waterways.

These risks will need to be understood and addressed as part of local structure planning in order to meet the water management objectives contained in this Strategy (Section 3). Strategies for mitigating these risks are described in Section 4 and should be implemented in accordance with Section 5.

It is noted that these risks will be affected by and, in some cases, worsened by the effects of climate change. Whilst it is not intended to minimise the importance of this increased risk, the primary focus of this report is understanding and managing the risks presented by land uses and land use change. However, where a risk has the potential to be increased by climate change effects and/or where there is an opportunity for management strategies to contribute to mitigation of climate change effects, those issues and opportunities should be identified.

2.5 Assessment of risks to development

Risks to development have been identified through broad-scale water balance modelling (Appendix B) and hydrological modelling (Appendix C) which have assessed the water-related implications of the proposed land use change. Key risks from water resources to future development include:

- Flooding and inundation from small, minor and major flood events and impacts of rising groundwater on system capacity and performance.
- Acid Sulfate Soil risks from changes in groundwater levels including dewatering.
- availability of groundwater for irrigation of future public open space.
- Restricted infiltration of stormwater where inundated by groundwater.
- Impacts to retained vegetation from future groundwater level rise.
- Challenges in managing multiple-front urban development and coordinating drainage aspects.

These risks will need to be understood and addressed as part of local structure planning in order to meet the water management objectives contained in this Strategy (Section 3). Strategies for mitigating these risks are described in Section 4 and should be implemented in accordance with Section 5.

3 WATER MANAGEMENT OBJECTIVES

Water is a basic prerequisite of urban liveability, supporting and sustaining vegetation within streets and open spaces as well as performing the core essential services of providing for drinking water and wastewater needs of the community.

The objectives in Table 3 have been developed to address the site and planning context of Mundijong consistent with the water management principles in draft *State Planning Policy 2.9 – Planning for Water* (WAPC, 2021). The objectives are discussed in detail below and will be achieved through implementation of water sensitive urban design strategies as described in Section 3.

Table 3: Water management objectives

Aim	Objective
Natural areas that are celebrated and supported by blue and green links	• Protect and enhance wetlands, waterways and catchments through appropriate management of water quality and maintenance of hydrology as part of land use change and development. • Protect and enhance significant natural areas and their buffers, and provide for ecological linkages along waterways, railroads, roads and scenic highways.
Streets that are walkable, liveable and adaptive	• Improve amenity and liveability of urban landscapes, including blue-green linkages. • Increase tree canopy coverage and promote cooling. • Achieve a net increase in natural assets (nature positive actions).
Multi-functional and integrated public open space	• Design urban spaces to manage stormwater and flood risks. • Make water infrastructure multi-functional. • Create opportunities for the community to engage with water resources and the environments they sustain.
Efficient and sustainable use of water services	• Provide for equitable access to water and wastewater services • Optimise the use of water, encourage reuse/recycling, and reduce the use of non-renewable energy. • Sustainably manage our groundwater.

4 WATER MANAGEMENT STRATEGY

In order to achieve the water management objectives of this District Water Management Strategy in a manner consistent with the water management principles in section 1.1, the following water management strategies need to be delivered as part of future planning and development of the Mundijong District Structure Plan area.

The strategies are to be incorporated into local structure planning and local water management strategies in accordance with the implementation framework in Section 5.

The water management strategies for the Mundijong District Structure Plan area address:

- Protection of natural areas and water resources
- Provision of blue-green linkages through urban areas
- Multi-functional and integrated public open space
- Fit-for-purpose water supply and wastewater servicing

These key elements are explained further below.

4.1 Protection of natural areas and water resources

Development of the Mundijong District Structure Plan area presents water related risks to the environment and water resources and should aim to deliver natural areas that are celebrated and supported by blue and green links.

Local structure plans must outline the strategy for catchment management, including management of surface water and groundwater hydrology and water quality, with consideration of the following objectives:

- Protect and enhance wetlands, waterways and catchments through appropriate management of water quality and maintenance of hydrology as part of land use change and development.
- Protect and enhance significant natural areas and their buffers, and provide for ecological linkages along waterways, railroads, roads and scenic highways.

4.1.1 Wetland and waterway retention and management requirements

Management strategies for retained wetlands and waterways will need to be informed by environmental assessments and have consideration of management of stormwater and drainage interfaces and landscape including bushfire risk.

Wetland assessments

A site investigation/evaluation is required to be conducted for wetlands and waterways at the local structure planning stage to confirm those which are to be protected.

The guidance document *A methodology for the evaluation of wetlands on the Swan Coastal Plain, Western Australia* (DBCA 2017) and associated information sheet *Wetland identification and delineation: information for mapping and land use planning on the Swan Coastal Plain* (DBCA 2017) should be utilised by proponents and consultants reviewing wetland boundaries and management categories.

Operational policy 4.3 - Identifying and establishing waterways foreshore areas (DoW, 2012) should be applied in identifying and managing foreshore areas whose values are under pressure from land-use changes in the area around them. It aims to ensure that foreshore areas will maintain or improve the environmental, social and economic values of waterways and adjoining land. Foreshores of retained waterways will generally be accommodated within a multiple use corridor.

Wetland and waterway assessments should be undertaken prior to local structure planning to inform proposed open space areas and local structure plan design.

In accordance with the EPA's Guidance Statement 33 *Environmental Guidance for Planning and Development* (2008), all wetlands that are to be protected should be allocated of a minimum 50 metre buffer to maintain wetland values and mitigate impacts from adjacent land uses.

In addition, as part of proposed precinct plans, wetland management plans should be prepared for wetlands to be protected to ensure ongoing maintenance and/or enhancement of wetland values and mitigation of impacts from changes in adjacent land uses.

Managing stormwater

Preliminary stormwater modelling has assumed that wetlands and waterways within precincts may be utilised for minor (20%AEP) and major (1%AEP) flood storage and conveyance. Consistent with water sensitive urban design principles and in accordance *Decision Process for Stormwater Management in WA* (DWER 2017), systems for management of stormwater in more frequent rainfall events will be located outside wetlands and their buffers to minimise hydrological impacts. Any overflow of runoff towards waterways and wetlands will be via overland flow paths across vegetated surfaces.

Ecological water requirements of receiving systems should be a primary consideration within any local water management strategy. Where changes in hydrology are proposed then modelling will need to be undertaken at local structure plan (LWMS) stage to demonstrate that there will be no significant impacts to the ecology of the wetland system. This will need to include detailed analysis of pre-development and post-development water levels and flows into retained wetlands and waterways. As the climate changes, there are options available to consider how to sustain water dependent ecosystems, provided water quality criteria can be assured.

Stormwater systems that utilise wetlands for flood storage will need to be designed to maintain pre-development surface water flow rates, runoff volumes, water levels and shallow groundwater recharge rates for receiving water bodies during frequent rainfall events (up to and including one exceedance per year), unless otherwise established in an approved management strategy or plan and subject to the advice of the relevant agency. As mentioned, this may be considered as part of a response to the changing climate.

Drainage system interface requirements

Open or piped drainage outlets from local drainage systems are required to terminate outside vegetated buffers and foreshores of retained wetlands and waterways.

Invert levels of drainage systems are required to match the natural surface elevation at the edge of the buffer or foreshore and the use of imported or locally reclaimed fill material within the buffer is typically not supported.

Stormwater discharges to wetlands and waterways may require a sediment control pond and/or biofilter prior to discharge, as shown in Figure 3. Where required, these systems are to be located entirely outside the buffer or foreshore. However, it is reasonable to incorporate minor earthworks and small quantities of unmortared rock to stabilise an area immediately downstream of overflows from these systems to assist with transitioning flow from piped or channelised flow into overland flow and protect the area from erosion. Where required, this transition area should not extend into a wetland buffer for more than 5 to 10 metres.

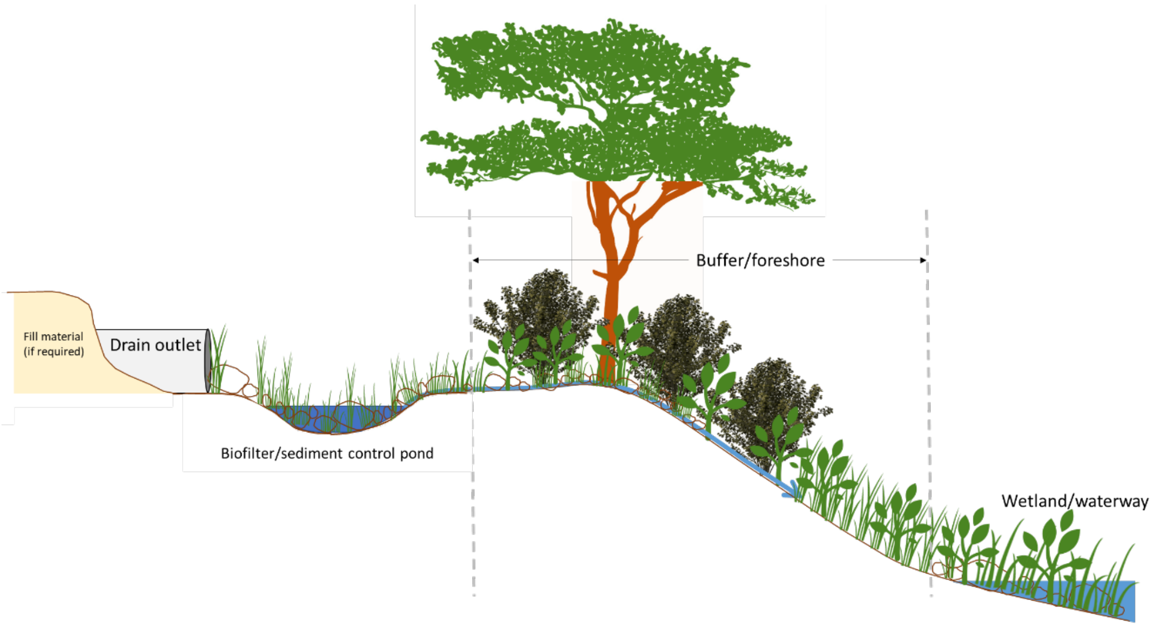


Figure 3: Wetland/waterway interface treatment

Landscaping, bushfire risk and infrastructure

The provision of infrastructure within retained wetlands and their buffers or waterways and their foreshores is generally not supported. However, in some cases, limited infrastructure consistent with the values of the wetland or waterway, designed to provide for community engagement with the environment and foster custodianship, may be permitted. Where proposed, designs developed at local structure plan (LWMS) stage will be required to demonstrate that there will be no significant impacts to the ecology of the wetland system.

Landscaping works within retained wetlands and waterways and their buffers and foreshores should be limited to restoration works such as weed removal and revegetation and limited works for passive recreation such as paths, benches, or bird hides.

It is noted that revegetated wetland buffers and waterway foreshores may be associated with bushfire risk and are generally bushfire prone areas. These areas have implications for bushfire risk management and the design of future land developments in their vicinity. Accordingly, bushfire risk will need to be managed in accordance with *State Planning Policy 3.7 Planning in Bushfire Prone Areas* and it is likely that a bushfire management plan will need to be developed. The bushfire management plan must be developed after identification of the wetland buffer and consider any future wetland restoration and management plans. No bushfire mitigation strategies are to be contained within the wetland buffer or waterway foreshore.

4.1.2 Small event and groundwater management requirements

Management of the risks to development associated with potential future groundwater level rise is likely to require the installation of subsurface drainage systems to manage groundwater levels and may require the use of imported or re-distributed fill. In these areas it is necessary to consider how both small rainfall events and the shallow groundwater system will be managed.

Small rainfall event management at-source

Small rainfall events are to be managed at source (in lots and streets) wherever possible.

All small event stormwater management systems are to be accommodated outside of retained wetlands and their buffers.

Where the depth to groundwater is limited and subsurface drainage systems are required, the design of at-source stormwater infiltration systems should be informed by consideration of the interaction between infiltrated stormwater and the controlled groundwater level. The (surface water and groundwater management) systems should be designed to ensure that they both function appropriately to prevent damage to property and infrastructure and maintain reasonable levels of amenity.

Where it is not feasible to retain or infiltrate small rainfall events at source without impacting amenity, the use of systems such as rainwater tanks, raingardens and detention tanks should be considered as alternatives to more traditional systems. Examples of these types of alternative approaches are shown in Figure 4.

Figure 4: Examples of at-source management of small rainfall events

Controlled groundwater levels

Where it is necessary to manage shallow, or potentially increasing groundwater levels, it may be necessary to install a subsurface drainage system to control or limit groundwater levels. The invert level of an installed subsurface drainage system is typically referred to as the controlled groundwater level and the minimum controlled groundwater level should be determined through consideration of the ecological water requirements of local high value wetland systems and vegetation.

The proposed controlled groundwater level (CGL) for the Mundijong District Structure Plan area is represented by AAMGL. The impacts of using an AAMGL rather than MGL as the CGL near wetlands and important environmental values will require further consideration when detailed modelling is undertaken for the preparation of the local water management strategy for each precinct.

It is generally preferred that subsurface drainage systems are separate from surface water management systems. However, it is accepted that there may be some potential for surface water and groundwater systems to be integrated at an individual precinct level. Where this is proposed it will be necessary to demonstrate that the integrated system design can function effectively for both purposes without loss of performance. For example, where a groundwater drainage system discharges into a combined stormwater and groundwater drain, the groundwater system outlet should be unsubmerged in normal winter baseflow conditions.

4.1.3 Water quality management

The implementation of water sensitive urban design approaches throughout the development is the primary method of water quality management for the Mundijong District Structure Plan area. The selection and design of small event surface water and groundwater quality management strategies is a critical component of this, and the following table provides some preliminary guidance for suitable strategies in different parts of the site.

Table 4: Selection of water quality management strategies

System design element	Water quality management strategies
Groundwater management system	• Conveyance through vegetated swales at discharge points. • Upgrade to treatment in biofiltration areas where legacy contamination has been identified in the subcatchment.
At source water management (public open space)	• No treatment required. • Limit use of fertilizers and pesticides.
At-source water management (residential lots)	• Management of runoff from first 15mm of rainfall in soakwells, raingardens, rainwater tanks, buffer strips etc.
At-source water management (commercial and industrial lots)	• Management of chemicals, materials and equipment to prevent pollution (including bunding of washdown and storage areas). • Treatment of all wastewater prior to discharge (including any runoff from washdown and storage areas). • Management of runoff from first 15mm of rainfall in soakwells, raingardens, rainwater tanks, buffer strips etc.
At source water management (road reserves)	• Management of runoff from first 15mm of rainfall in soakwells, raingardens, rainwater tanks, buffer strips etc.
Additional measures to manage legacy issues	• Site remediation where required. • Avoid locating infiltration systems in areas with known legacy contamination (including elevated nutrients). • Provide additional treatment via biofiltration systems at outlets of subsurface drainage systems.

4.2 Provision of blue-green linkages through urban areas

Development of the Mundijong District Structure Plan area should aim to provide streets that are walkable, liveable and adaptive to the needs of the future community.

Local structure plans must outline the strategy for blue-green linkages, including provision of multiple use corridors and integration of water sensitive urban design at the street scale, with consideration of the following objectives:

- Improve amenity and liveability of urban landscapes, including blue-green linkages.
- Increase tree canopy coverage and promote cooling.
- Achieve a net increase in natural assets (nature positive actions).

4.2.1 Design of multiple use corridors

Arterial drainage conveyance in the Mundijong District Structure Plan area is proposed to be accommodated in a network of living streams and open vegetated swales integrated with multiple use corridors. The dimensions of living streams and swales will vary although the general shapes applied in preliminary modelling presented in Appendix C are shown in Figure 5 and Figure 6.

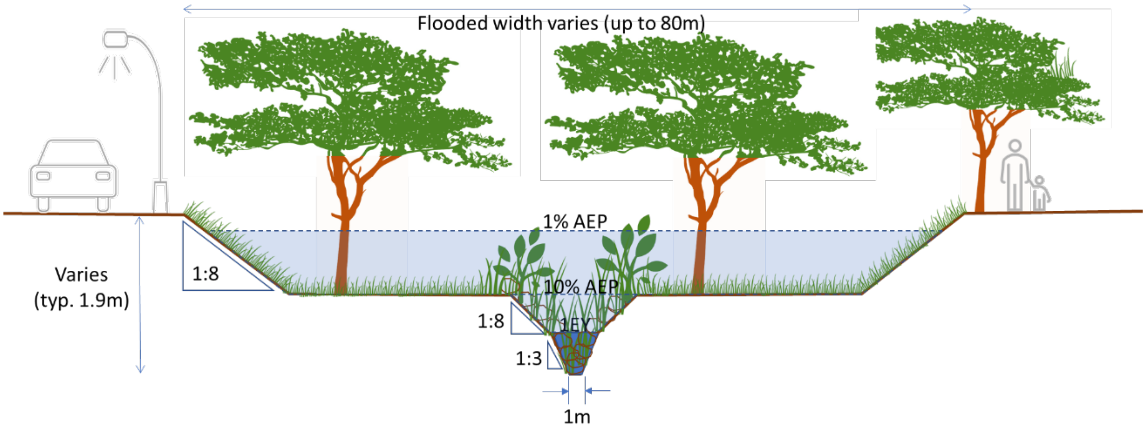


Figure 5: Living stream

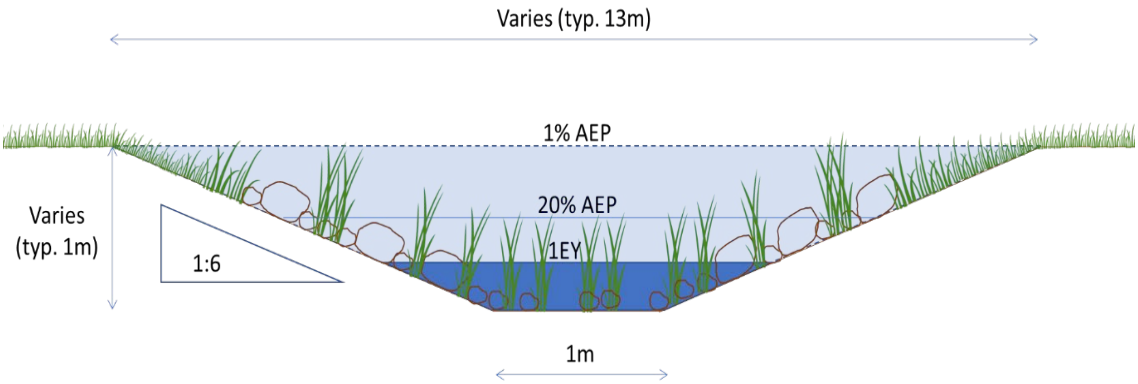


Figure 6: Arterial drainage swale

4.2.2 Local streets and drainage systems

The creation of liveable and adaptive streets is an objective that is strongly aligned with water sensitive cities principles. Within a water sensitive city, water management aims to improve the liveability of a city, providing not only traditional functions (drainage, water supply and sewer) but also additional benefits of the amenity, cooling and ecological health (CRCWSC, 2012).

A key focus of water sensitive cities is to use water to mitigate urban heat effects that increase the risk of illness and mortality, particularly during heatwaves (CRCWSC, 2020). Hard, impervious surfaces (roof, roads, and concrete) absorb more solar radiation and slowly release it into the atmosphere creating an urban heat island. Trees and other vegetation (green infrastructure) cool cities as they absorb less solar radiation and provide shade and evapotranspiration. Shade from tree canopies can reduce temperatures of hard, impervious systems by between 10 and 25°C.

Collection of runoff to create links between blue and green infrastructure provides passive irrigation, reducing the demand on potable and non-potable water sources. These systems can be integrated into the proposed built form through the installation of grates and grills prevent these pits from becoming a tripping hazard or installation of bollards to protect against damage from vehicles. Similarly, using structural cells and wicking beds can protect existing infrastructure (reduce pavement uplift and root intrusion) within road reserves and improve tree growth.

Studies have identified that well designed passive irrigation can increase the rate of canopy of growth (up to 8-10 times higher) (CRCWSC, 2020). Therefore, successful design and implementation of these systems is a considerable component of achieving the objectives of the Mundijong District Structure Plan.

Key considerations for creation of blue-green linkages in streetscape design include:

- Passive watering of street trees by stormwater maximises the beneficial use of water resources and can be easily achieved by directing runoff from road and footpath surfaces towards tree wells surrounded with flush or broken kerbing.
- The use of permeable surfaces maximises groundwater recharge and reduces runoff which in turn can reduce flows to sumps and basins creating opportunities for these assets to be reimagined as multifunctional blue/green urban spaces.
- Co-location of street trees within roadside swales and raingardens designed for collection and infiltration of stormwater improves infiltration performance through the presence of larger root structures and increased evapotranspiration rates.
- Increased vegetation and tree canopy increases interception of stormwater and in-turn helps to alleviate capacity issues within the downstream drainage network.

Raingardens are small, vegetated basins with a flush kerb (or kerb break) that can collect frequent road and pavement runoff. These systems have porous fill material that allows for stormwater to infiltrate either to the underlying aquifer (retention) or to subsoil drainage that connects to the pit and pipe drainage system (detention). Whether the raingarden provides a retention or detention function, these systems assist in reducing flood risk downstream, as well as providing treatment of stormwater prior to entering the downstream system. Directing stormwater to vegetated area including trees also provides passive watering which increases the health and growth rate of the vegetation. Design of these systems is flexible, allowing for consideration of local street design and/or for the retention of existing trees.

Overflow from the raingardens (during minor event) can either cascade to the next entry pit downstream, or dedicated pits can be designed within the raingarden itself (above the invert). This eliminates the risk of localised flooding.

Rain gardens are to be designed, constructed, and implemented in accordance with the Shire of Serpentine Jarrahdale Standard Drawings – Drainage – Rain Gardens 2024. This is to ensure the effective implementation and delivery of rain gardens within the Mundijong District Structure Plan area (See Figure 7 and https://www.sjshire.wa.gov.au/development-services/infrastructure-and-works/infrastructure/standard-drawings/standard-drawings.aspx).

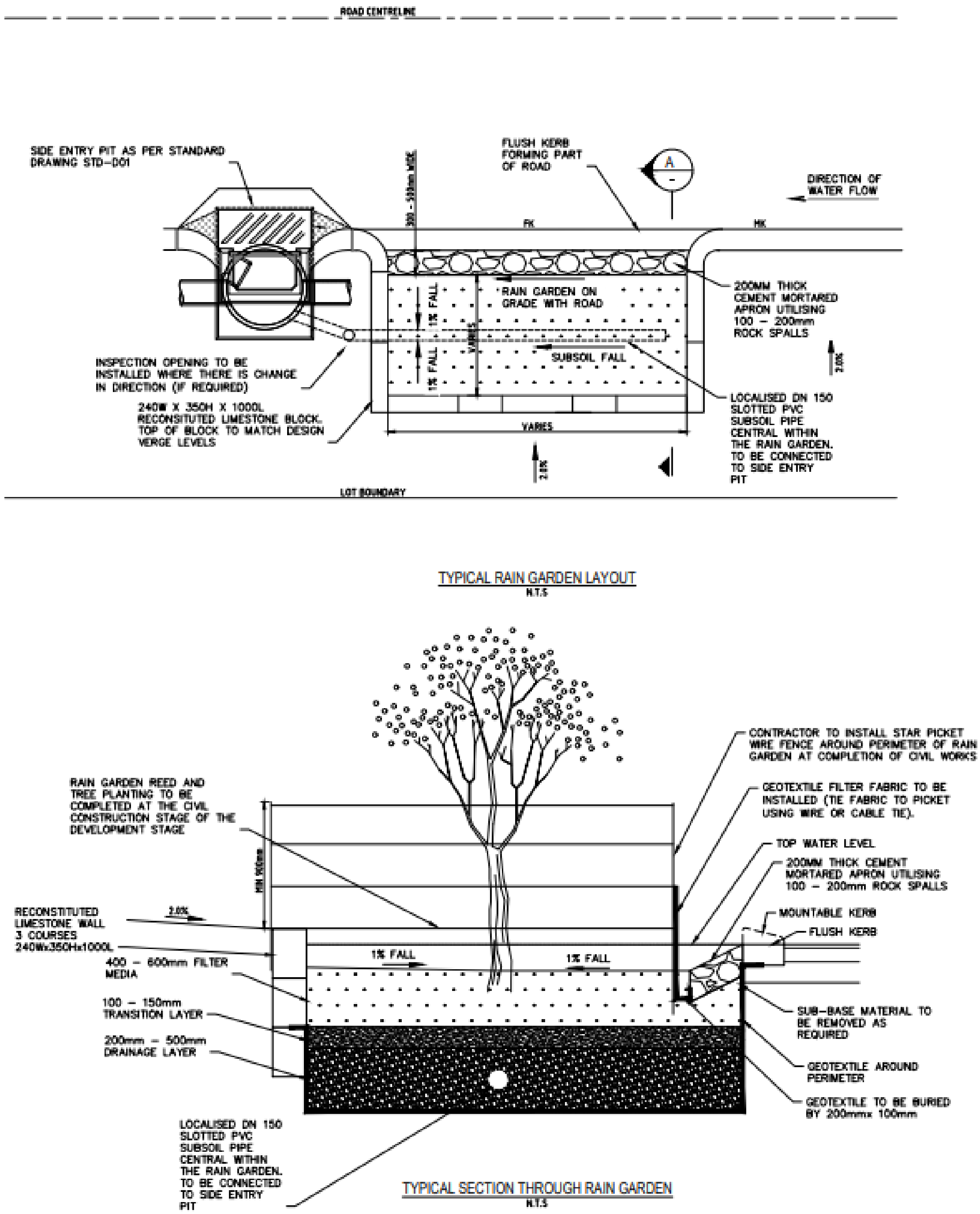


Figure 7: Shire of Serpentine Jarrahdale Standard Drawings – Drainage – Rain Gardens 2024

From a water quality perspective, amended filter media can be installed, and in conjunction with vegetation recommended by Monash (2014), allow for nutrient removal and improvement in water quality discharged downstream. Capturing stormwater runoff within raingardens on steeper slopes assists in reducing gutter flow velocities and associated erosion and safety concerns. These systems also capture sediment and litter.

The flexibility of raingarden design allows for integration into any streetscape design and will assist in delivering liveable communities by reducing hard surfaces and increasing green areas. Raingardens should also include trees to provide shade and evapotranspiration that cools the urban environment.

The intention for raingardens is to capture runoff from impervious areas as close to source as possible. Therefore, raingardens should be considered for most streets within the precinct. These systems should be sized for runoff up to the first 15 mm of rainfall, but not excluded from the streetscape if there only space for smaller systems.

To improve tree growth, meet canopy targets and to protect existing infrastructure, wicking bed and structural cell designs can also be considered (CRCWSC, 2020). Wicking beds rely on soil media for capillary rise within a lined cell. As shown in Figure 8, the subsoil drainage outlet is designed to sit above remainder of the pipe to trap water and facilitate capillary rise. These systems retain soil moisture during extended dry periods experienced in Mundijong.

Structural cells offer the benefit of being trafficable and can be incorporated into most urban streetscapes. These systems feature a frame and deck that supports pavement and provides a void for uncompacted soil media that allows for vegetation growth and stormwater infiltration. As shown in Figure 8, the area for stormwater storage can also be extended to under the pavement, increasing the potential capacity for treatment and integration with streetscape design and amenity. Structure cells combined with a wicking zone to improve tree growth.

Expanding the urban canopy and providing improved street amenity are key aspect of improving the liveability within the precinct. Additionally, many of the drainage sumps within the precinct have been identified as having existing capacity constraints. Raingardens are an ideal solution to both issues as they incorporate a variety of vegetation and reduce runoff into the drainage system, however where space is limited tree pits are a suitable alternative. Tree pits function similarly to raingardens, providing water quality and stormwater detention/retention. However, tree pits are typically smaller and designed for tree planting only. Wicking bed and structural cells designs can also be used for tree pits.

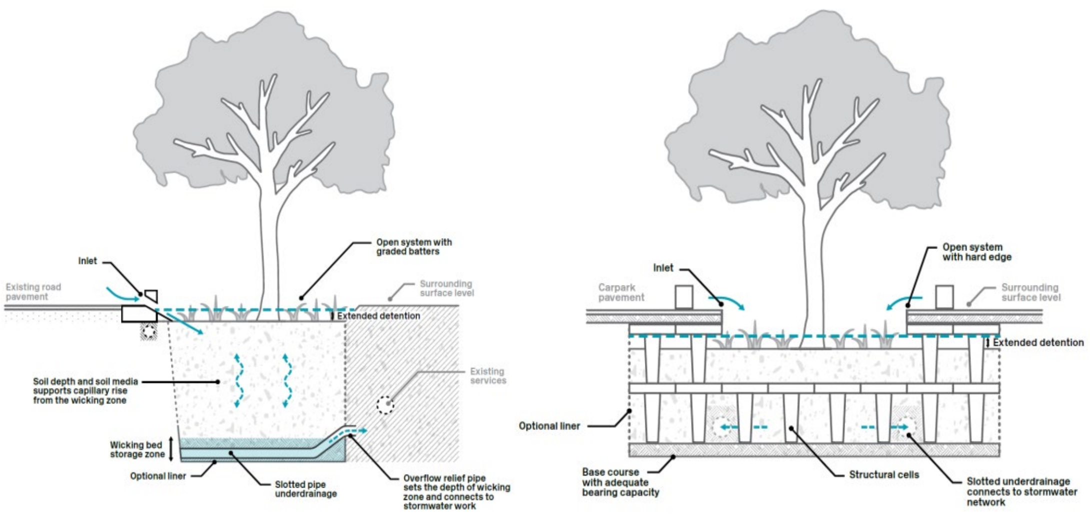


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Figure 8: Wicking bed (left) and structural cell (right) concepts

Raingardens and tree pits require maintenance to inspect tree and vegetation health, remove sediment and litter built up and ensure outlets are not blocked. Effective design can reduce these maintenance requirements, but regular inspection and watering is necessary during tree and vegetation establishment. Ongoing maintenance responsibility may be split between vegetation health (parks staff) and traditional drainage maintenance like blockage removal.

Trees selected for planting within tree pits should generally be local native species and along with the trees, ground cover vegetation should be used to improve ongoing infiltration performance of soil media.

Car parks provide many opportunities for integration of water sensitive urban design to increase capture of rainfall in the catchment, promote urban greening and increase liveability. Key options for car parks include the use of permeable paving, tree pits sited for passive watering and swales or biofilters for on-site management of larger rainfall quantities.

The benefits of integrating these strategies include reduced runoff, improved water quality, increased aquifer recharge and mitigation of urban heat impacts.

Figure 9: Carpark raingarden and swale examples

4.3 Multi-functional and integrated public open space

Development of the Mundijong District Structure Plan area should aim to provide multi-functional and integrated public open space that incorporates effective management of flood risks without compromising sporting and recreational outcomes for the community.

Local structure plans must outline the strategy for delivery of a public open space network, with consideration of the following objectives:

- Design urban spaces to manage stormwater and flood risks.
- Make water infrastructure multi-functional.
- Create opportunities for the community to engage with water resources and the environments they sustain.

4.3.1 Planning for arterial drainage systems

The district arterial drainage system layout has been developed for the Mundijong District Structure Plan area based on natural topography and proposed road layouts. Subcatchments consider the existing topography of the site in combination with existing and proposed roads and may change in future stages of planning and design through further consideration of other factors such as modified road layouts and connections to services.

Detailed surface water modelling is required to support future local structure plans and presented in local water management strategies. This modelling will need to include consideration of the risks associated with surface and groundwater interaction both now and in the future. The establishment of appropriate antecedent conditions in drainage infiltration basins and wetlands functioning as part of the surface water management system will need to consider changing groundwater levels and the performance of subsurface drainage systems under flood conditions.

A post development coupled 1- and 2-dimensional surface water model of the Mundijong District Structure Plan area has been developed using InfoWorks ICM, incorporating proposed local arterial drainage system layouts and subcatchments. This model has been used to determine storage volumes, multiple use corridor dimensions, peak flow rates and top water levels. These critical elements of the proposed arterial drainage system are presented in Appendix C along with technical details of the modelling.

4.3.2 Management of peak flows and flood levels

Overview mapping of the Mundijong arterial drainage strategy is presented in Figure 10. Further details of stormwater modelling procedures and results are provided in Appendix C.

Table 5 provides top water levels, peak flows and the approximate time of the peak flow at several locations throughout the study area.

Indicative volumes are provided for new precinct storages in Table 6. However, it will be necessary to undertake more detailed modelling to determine storage volumes and locations to be accommodated within precincts for reporting at the local structure planning (LWMS) stage.

Dimensions for new culverts beneath the planned Tonkin Highway are provided in Table 7.

Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 10 - Arterial drainage strategy

Table 4: Top water levels, peak flows and timing of peaks at critical locations

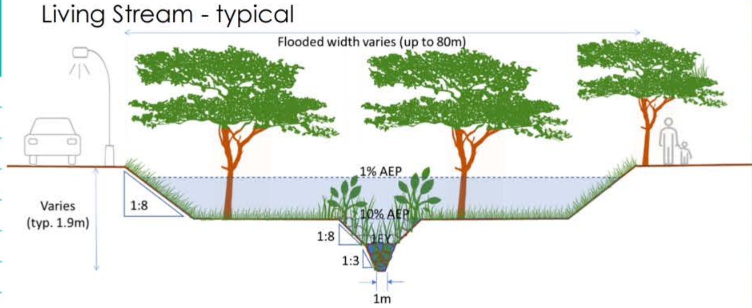
Location	20% AEP (S10-12h)			1% AEP (S5-6hr)		
	Top water level (mAHD)	Peak flow (m3/s)	Time of peak (H:M)	Top water level (mAHD)	Peak flow (m3/s)	Time of peak (H:M)
1. Norman Road Creek at South Western Highway	80.7	1.31	12:14	81.6	7.40	3:44
2. Norman Road Creek at rail crossing	48.1	6.75	13:44	48.5	6.75	4:14
3. Norman Road Creek at Tonkin Highway	24.8	4.38	10:29	26.4	5.21	6:44
4. Cemetery Creek at South Western Highway	93.3	0.71	11:59	93.8	3.98	3:44
5. Cemetery Creek at rail crossing	42.4	4.57	12:44	42.8	4.58	3:29
6. Cemetery Creek at discharge into Manjedal Creek	39.2	3.50	13:14	40.1	3.83	4:29
7. Manjedal Brook at South Western Highway	62.0	2.49	13:29	63.1	10.33	4:44
8. Manjedal Brook at rail crossing	38.3	5.74	17:29	38.7	5.74	5:44
9. Manjedal Brook at Tonkin Highway	25.8	3.68	18:59	26.1	4.64	6:59
10. Manjedal Brook at western boundary	16.6	5.77	19:29	16.9	5.77	9:14
11. Manjedal Brook overflow to Pruden Creek	50.7	0.00	0:29	51.0	0.05	4:59
12. Adams drain at Tonkin Highway	25.1	0.24	10:29	25.8	2.19	3:44
13. Adams drain at western boundary	16.3	3.87	11:29	16.4	3.87	4:44
14. Sparkman drain at Tonkin Highway	25.8	0.38	12:29	26.4	3.82	4:29
15. Sparkman drain at western boundary	17.1	0.69	13:14	17.5	6.86	4:44
16. Pruden Creek at South Western Highway	71.7	0.61	11:59	72.0	3.35	3:29
17. Pruden Creek at Mundijong Road	36.5	9.84	15:44	37.3	9.84	5:29
18. Pruden Creek at rail crossing	33.4	10.65	17:14	37.1	11.87	11:59
19. Pruden Creek at Tonkin Highway	29.5	4.97	17:59	30.7	10.19	5:59
20. Mundijong Road drain at western boundary	18.5	3.28	9:29	18.7	3.29	1:29
21. Mardella Brook at South Western Highway	51.1	2.52	14:59	52.6	13.05	5:59
22. Mardella Brook at Tonkin Highway	43.9	4.11	15:14	47.8	13.28	6:29
23. Mardella Brook at southern boundary	37.6	9.93	16:59	37.6	9.93	6:44

Table 5: Indicative constructed storage volumes

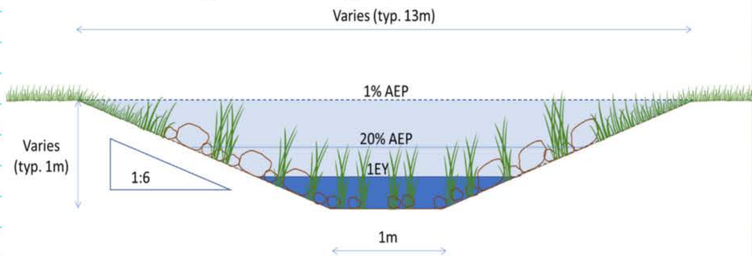
Precinct ID	20% AEP		1% AEP	
	Storage volume (m^3)	Peak discharge rate (m^3/s)	Storage volume (m^3)	Peak discharge rate (m^3/s)
A	10,305	0.09	142,124	3.75
B	1,154	0.01	35,132	1.98
C	2,458	0.04	39,903	1.43
D	1,428	0.13	14,101	3.97
E1	2,780	0.03	19,584	1.24
E2	1,409	0.00	17,566	0.39
E3	628	0.01	11,426	0.46
F	1,586	0.10	11,177	3.74
G1	8,024	0.35	72,838	2.38
G2	67	0.00	9,027	0.55
G3	300	0.01	7,102	0.86
H	2,293	0.08	43,346	3.00
I	78	0.00	23,446	0.83
J	15	0.00	12,286	0.42
K	889	0.02	34,969	0.98
L	1,625	0.11	15,738	1.54
M1	1,743	0.01	42,265	0.79
M2	1,664	0.02	12,985	1.24

Note: additional online storage is provided in multiple use corridors within many precincts

Living Stream - typical



Arterial Drainage Swale - typical



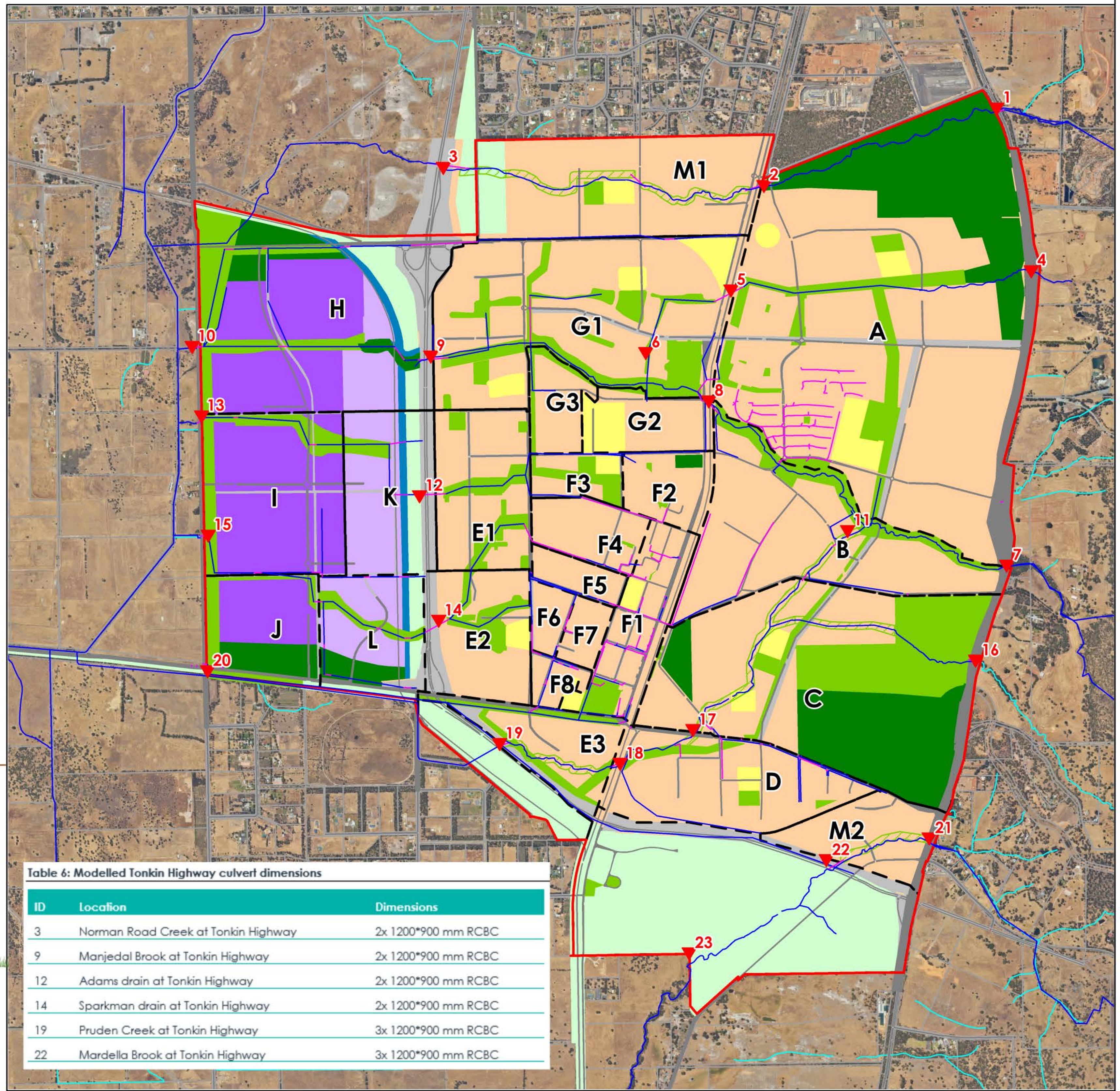


Table 6: Modelled Tonkin Highway culvert dimensions

ID	Location	Dimensions
3	Norman Road Creek at Tonkin Highway	2x 1200*900 mm RCBC
9	Manjedal Brook at Tonkin Highway	2x 1200*900 mm RCBC
12	Adams drain at Tonkin Highway	2x 1200*900 mm RCBC
14	Sparkman drain at Tonkin Highway	2x 1200*900 mm RCBC
19	Pruden Creek at Tonkin Highway	3x 1200*900 mm RCBC
22	Mardella Brook at Tonkin Highway	3x 1200*900 mm RCBC

LEGEND:

Study area boundary
Cadastre
Waterways

District structure plan proposed land uses

Urban development
Education
Rural land
MUC/LPOS
ConservationWetland
light industry
General industry
Future Road
Existing Road
Rail corridor
Precinct boundaries
Additional/alternative multiple use corridors

Post development drainage system

Pipes/culverts
Swales/living streams
Key reporting locations

Data source: Landgate, Created by: HB Projection: MGA: zone 50.

N

0 1,000
metres
Scale 1:35,000 @ A3

urbaqua
land and water solutions

Table 5: Top water levels, peak flows and timing of peaks at critical locations

Location	20% AEP (S10-12h) Top water level (mAHD)	20% AEP (S10-12h) Peak flow (m3/s)	20% AEP (S10-12h) Time of peak (H:M)	1% AEP (S5-6hr) Top water level (mAHD)	1% AEP (S5-6hr) Peak flow (m3/s)	1% AEP (S5-6hr) Time of peak (H:M)
1. Norman Road Creek at South Western Highway	80.7	1.31	12:14	81.6	7.40	3:44
2. Norman Road Creek at rail crossing	48.1	6.75	13:44	48.5	6.75	4:14
3. Norman Road Creek at Tonkin Highway	24.8	4.38	10:29	26.4	5.21	6:44
4. Cemetery Creek at South Western Highway	93.3	0.71	11:59	93.8	3.98	3:44
5. Cemetery Creek at rail crossing	42.4	4.57	12:44	42.8	4.58	3:29
6. Cemetery Creek at discharge into Manjedal Creek	39.2	3.50	13:14	40.1	3.83	4:29
7. Manjedal Brook at South Western Highway	62.0	2.49	13:29	63.1	10.33	4:44
8. Manjedal Brook at rail crossing	38.3	5.74	17:29	38.7	5.74	5:44
9. Manjedal Brook at Tonkin Highway	25.8	3.68	18:59	26.1	4.64	6:59
10. Manjedal Brook at western boundary	16.6	5.77	19:29	16.9	5.77	9:14
11. Manjedal Brook overflow to Pruden Creek	50.7	0.00	0:29	51.0	0.05	4:59
12. Adams drain at Tonkin Highway	25.1	0.24	10:29	25.8	2.19	3:44
13. Adams drain at western boundary	16.3	3.87	11:29	16.4	3.87	4:44
14. Sparkman drain at Tonkin Highway	25.8	0.38	12:29	26.4	3.82	4:29
15. Sparkman drain at western boundary	17.1	0.69	13:14	17.5	6.86	4:44
16. Pruden Creek at South Western Highway	71.7	0.61	11:59	72.0	3.35	3:29
17. Pruden Creek at Mundijong Road	36.5	9.84	15:44	37.3	9.84	5:29
18. Pruden Creek at rail crossing	33.4	10.65	17:14	37.1	11.87	11:59
19. Pruden Creek at Tonkin Highway	29.5	4.97	17:59	30.7	10.19	5:59
20. Mundijong Road drain at western boundary	18.5	3.28	9:29	18.7	3.29	1:29
21. Mardella Brook at South Western Highway	51.1	2.52	14:59	52.6	13.05	5:59
22. Mardella Brook at Tonkin Highway	43.9	4.11	15:14	47.8	13.28	6:29
23. Mardella Brook at southern boundary	37.6	9.93	16:59	37.6	9.93	6:44

Table 6: Indicative constructed storage volumes

Precinct ID	20% AEP		1% AEP	
	Storage volume (m³)	Peak discharge rate (m³/s)	Storage volume (m³)	Peak discharge rate (m³/s)
A	10,305	0.09	142,124	3.75
B	1,154	0.01	35,132	1.98
C	2,458	0.04	39,903	1.43
D	1,428	0.13	14,101	3.97
E1	2,780	0.03	19,584	1.24
E2	1,409	0.00	17,566	0.39
E3	628	0.01	11,426	0.46
F	1,586	0.10	11,177	3.74
G1	8,024	0.35	72,838	2.38
G2	67	0.00	9,027	0.55
G3	300	0.01	7,102	0.86
H	2,293	0.08	43,346	3.00
I	78	0.00	23,446	0.83
J	15	0.00	12,286	0.42
K	889	0.02	34,969	0.98
L	1,625	0.11	15,738	1.54
M1	1,743	0.01	42,265	0.79
M2	1,664	0.02	12,985	1.24

Note: additional online storage is provided in multiple use corridors within many precincts

Table 7: Modelled Tonkin Highway culvert dimensions

ID	Location	Dimensions
3	Norman Road Creek at Tonkin Highway	2x 1200*900 mm RCBC
9	Manjedal Brook at Tonkin Highway	2x 1200*900 mm RCBC
12	Adams drain at Tonkin Highway	2x 1200*900 mm RCBC
14	Sparkman drain at Tonkin Highway	2x 1200*900 mm RCBC
19	Pruden Creek at Tonkin Highway	3x 1200*900 mm RCBC
22	Mardella Brook at Tonkin Highway	3x 1200*900 mm RCBC

It is important to note that modelling assumes that the first 15mm of rainfall (from lots and streets) is retained at source, so this volume is not included in indicative flood detention volumes.

Precinct scale discharge flows presented are not within main waterways and do not include flows generated by upstream subcatchments. Discharge criteria are set for whole subcatchments at the point at which they connect to main waterways as shown in Figure 11.

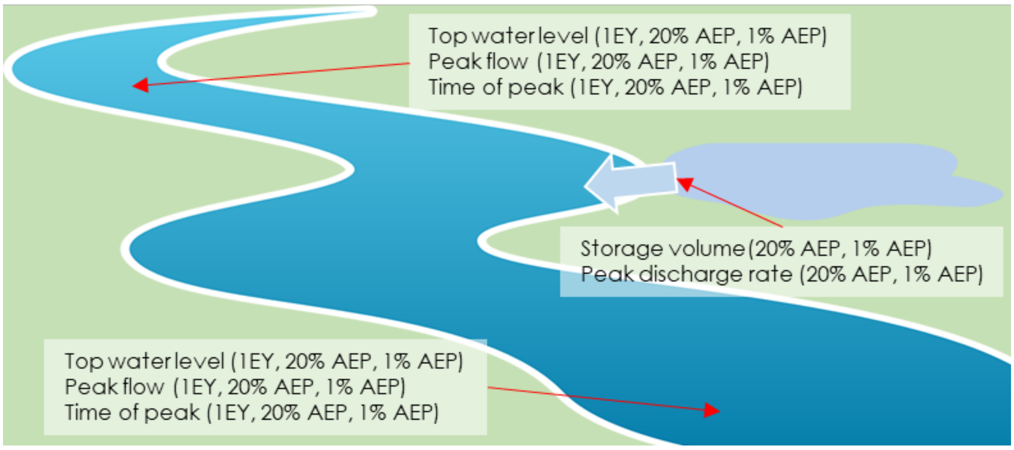


Figure 11: Schematic presentation of information for precincts and main waterways

Detailed surface water modelling will be required to support future local structure plans and presented in local water management strategies. This modelling will need to include consideration of the risks associated with surface and groundwater interaction both now and in the future. The establishment of appropriate antecedent conditions in drainage infiltration basins and wetlands functioning as part of the surface water management system will need to consider changing groundwater levels and the performance of subsurface drainage systems under flood conditions.

Where existing wetlands and waterways are proposed for integration with the arterial drainage system and/or will receive floodwaters during minor or major flood events it is important that the design of the system and its outlets is consistent with protection of natural values. Guidance for the design of drainage system discharges at their interface with wetlands and waterways is provided in section 4.1.1.

Summary of precinct drainage system requirements

Table 8 provides a summary of stormwater and groundwater drainage system requirements for each precinct.

Table 8: Summary precinct drainage requirements

Precinct	Area description	Status	Wetlands and waterways	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
Area A	Whitby	Approved	Vegetation and wetlands fringing Manjedal Brook and Cemetery Creek to be retained within multiple use corridors and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Manjedal Brook and Cemetery Creek to be retained as natural waterways within defined multiple use corridors. Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area B	Keirnan Street	No LSP exists	Vegetation and wetlands fringing Manjedal Brook and its overflow path to be retained within multiple use corridor and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Manjedal Brook to be retained as a natural waterway within defined multiple use corridor. LSP to define additional 50m MUC for overflow discharges from Manjedal Creek, preferably following existing flowpath and retaining fringing vegetation. Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area C	Watkins Road North	No LSP exists	Vegetation and wetlands fringing Pruden Creek and Manjedal Brook overflow path to be retained within multiple use corridor and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	LSP to define additional 50m MUCs for Pruden Creek and overflow discharges from Manjedal Creek, preferably following existing flowpaths and retaining fringing vegetation. Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.

Precinct	Area description	Status	Wetlands and waterways	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
Area D	Watkins Road South	No LSP exists	Vegetation and wetlands fringing Pruden Creek to be retained within multiple use corridor and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Pruden Creek to be retained as a natural waterway within defined multiple use corridor. Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area E (1)	Mundijong West Precinct E1 Taylor Road and Adams Street, Mundijong	Approved	Vegetation and wetlands fringing existing watercourses to be retained within multiple use corridors and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Existing watercourses to be retained within defined multiple use corridors. Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area E (2)	Mundijong West Precinct E2 L50 Cockram Street and L119 Sparkman Road, Mundijong	Approved	Vegetation and wetlands fringing existing watercourses to be retained within multiple use corridors and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Existing watercourses to be retained within defined multiple use corridors. Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area E (3)	Mundijong West Precinct E3	No LSP exists	Vegetation and wetlands fringing Pruden Creek to be retained within multiple use corridor and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Pruden Creek to be retained as a natural waterway within defined multiple use corridor. Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.

Precinct	Area description	Status	Wetlands and waterways	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
Area F (1-8)	Mundijong Town Centre	No LSP exists		Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges from previously undeveloped lots and existing developed lots subdividing to achieve higher densities, to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area G (1)	Mundijong North	Draft	Vegetation and wetlands fringing existing watercourses to be retained within multiple use corridors and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area G (2)	Keirnan Street (West)	Draft		Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area G (3)		No LSP exists		Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area H	North Mundijong Industrial	No LSP exists	Vegetation and wetlands fringing Manjedal Brook and its overflow path to be retained within multiple use corridor and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.

Precinct	Area description	Status	Wetlands and waterways	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
Area I	West Mundijong Industrial	Draft	Vegetation and wetlands fringing existing watercourses to be retained within multiple use corridors and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area J	South-West Mundijong Industrial	No LSP exists	Vegetation and wetlands fringing existing watercourses to be retained within multiple use corridors and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area K	East Mundijong Industrial	No LSP exists	Vegetation and wetlands fringing existing watercourses to be retained within multiple use corridors and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area L	South-East Mundijong Industrial	No LSP exists	Vegetation and wetlands fringing existing watercourses to be retained within multiple use corridors and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.
Area M1	Northern development investigation area	No LSP exists	Vegetation and wetlands fringing Norman Road Creek to be retained within multiple use corridor and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.

Precinct	Area description	Status	Wetlands and waterways	Stormwater management (Small rainfall events)	Stormwater management (Minor and Major rainfall events)	Groundwater management
Area M2	Southern development investigation area	No LSP exists	Vegetation and wetlands fringing Mardella Brook to be retained within multiple use corridor and adjacent POS.	Small rainfall events are to be managed at source (in lots and streets) wherever possible.	Detention storage to be provided to manage discharges to their predevelopment peak flow rates and replace lost floodplain storage.	Subsoil drainage may be installed at or above AAMGL except where local assessment of wetland or waterway health indicates that MGL should be maintained.

4.4 Urban water use

Development of the Mundijong District Structure Plan area is expected to proceed through the extension and sequential roll-out of existing water and the building of new wastewater services to provide the most efficient and cost-effective way of infrastructure provision.

As Mundijong is a priority growth area for Western Australia, the Water Corporation are currently working with developers to deliver a permanent sewer solution.

Local structure plans must outline the strategy for the provision of drinking water, wastewater and irrigation of public open space with consideration of the following objectives:

- Provide for equitable access to water and wastewater services
- Optimise the use of water, encourage reuse/recycling, and reduce the use of non-renewable energy.
- Sustainably manage our groundwater.

4.4.1 Drinking water

All urban development is required to connect to scheme water for drinking water purposes. Consultation with the Water Corporation will be necessary to identify the infrastructure requirements, costs and timeframes associated with connection to the Integrated Water Supply System (IWSS). Conventional headworks charges will be payable at time of connection.

4.4.2 Wastewater servicing

Development within the Mundijong District Structure Plan area should comply with the requirements of the Government Sewerage Policy (2019).

Consultation with the Water Corporation will be necessary to identify the infrastructure requirements, costs and timeframes associated with connection to sewerage. As mentioned above, the Water Corporation are working to deliver the sewer solution for Mundijong as soon as possible, to help developers address the housing crisis currently affecting Western Australia.

4.4.3 Irrigation requirements for public open space and schools

An appropriate fit-for-purpose water source for efficient irrigation of public open spaces and schools must be confirmed and secured at the local structure plan/local water management strategy stage of planning.

Groundwater is used extensively in the study area as a fit for purpose water supply for public open space irrigation, agriculture and commercial/industrial purposes as well as for private uses (garden and stock watering) which are exempt from licensing as discussed in Appendix A.

Existing groundwater licenses within the Mundijong District Structure Plan area are able to draw up to 745 ML/year from the superficial groundwater system and a further 534 ML/year from underlying confined aquifers. The total allocated groundwater resource within the DSP area is therefore 1,279 ML/year.

The post development groundwater abstraction demand within the Mundijong District Structure Plan area is estimated to be 1,481 ML/year, as calculated in Appendix B and discussed further in Appendix A. The ultimate post-development estimated demand in the Mundijong DSP area is therefore less than the currently allocated groundwater amount.

As land is developed, it is expected that privately held licenses for irrigation will be transferred to developers to facilitate development and subsequently handed over to the Shire for ongoing irrigation of newly created public open spaces.

Therefore, based on the currently allocated groundwater in the Mundijong District Structure Plan area it is anticipated that the future water demand for irrigation in Mundijong can continue to be supplied from groundwater. Therefore, the proposed water source for irrigation of public open spaces and schools throughout the Mundijong District Structure Plan area is groundwater.

However, it should be noted that the sustainable yield of groundwater from the superficial aquifer in parts of the study area may be significantly restricted due to clay soils. Developments affected by this issue may require numerous shallow, low-yielding bores and/or require a supplementary irrigation source.

In addition, it is noted that this assessment has assumed that all existing groundwater licenses in the DSP area will be ultimately transferred for development of the land. Any licenses that are retained for continuing commercial purposes within the DSP area, or new commercial or industrial land uses that obtain access to groundwater for other purposes, will reduce the amounts available for transfer and may result in a future shortfall.

Measures should be implemented to minimise the water use (efficient irrigation of public open space) within the Mundijong District Structure Plan area including:

- Prioritisation of turf in sport/active public open spaces areas, minimising turf in recreation/passive public open spaces.
- Limiting the use of irrigation to turfed areas of public open spaces only (with all other areas to be irrigated for establishment only, including garden beds, streetscapes, verges and street trees).
- Incorporation of non-irrigated landscaping including retention of native vegetation, soft landscaping, and nature play areas.

5 IMPLEMENTATION

The success of the water management strategies relies on effective implementation during subsequent planning, management, construction and maintenance. The framework for implementation is outlined in this Section.

5.1 Development controls

It is strongly recommended that proponents meet with the Shire of Serpentine-Jarrahdale to discuss proposed water management strategies and to gain further guidance on site-specific requirements at commencement of any water management strategy or plan.

All development in Mundijong shall be supported by submission of a water management report or detailed stormwater management plan (including engineering and landscaping) that will be assessed and approved by the Shire of Serpentine Jarrahdale. The type of document is dependent on the scale and complexity of the proposed development and will need to demonstrate compliance with strategies set out in this document including implementation of:

- connection to water and wastewater services
- on-site stormwater management requirements
- groundwater management requirements
- water efficiency measures

Water Management reports are required to demonstrate that designs achieve the objectives, strategies and design criteria outlined in this district water management strategy and any future local water management strategy. Any water management report should be prepared in consultation with the Shire of Serpentine-Jarrahdale and DWER and submitted to these agencies for approval.

Water management reports are based on local site investigations appropriate to the proposal and level of risk to water resources. The water management report should be consistent with the requirements of the Department of Water and Environmental Regulation's *Urban water management plans: Guidelines for preparing plans and for complying with subdivision conditions* (DoW, 2008b).

Specifically, the water management report should include detailed engineering designs (drainage and wastewater) and any landscaping designs relating to water quality improvement or water efficiency improvement. The water management report will also include a framework for implementing the water management strategies and plans through the construction and post-development phases of the project.

Proponents of development should demonstrate that their proposals and designs are consistent with the strategies and design criteria presented in this strategy, as well as satisfying other requirements of other relevant agencies.

5.2 Review of District Water Management Strategy

It is intended that the District Water Management Strategy be reviewed within ten years or earlier if deemed necessary until development has occurred consistent with the Mundijong District Structure Plan.

5.3 Monitoring strategy

Monitoring and site investigations should always be targeted at addressing a specified problem. For instance, if the problem is shallow groundwater, then the monitoring program should be targeted to understanding groundwater levels in particularly low-lying or vulnerable parts of the site. If the problem is around understanding a sensitive wetland, then the monitoring program should be targeted to capture information about the wetland including both surface and groundwater inputs and outputs. Finally, in some circumstances minimal monitoring may be acceptable, provided targeted site investigation is undertaken and correlated to already available data from the nearest long-term monitoring site.

Early consultation is recommended to assist with definition of monitoring and investigation work.

5.3.1 District monitoring program

Implementation of a district scale monitoring program, funded through developer contributions and coordinated by the Shire, is proposed for the Mundijong District Structure Plan area.

This program is likely to include the following elements to be undertaken during and post-development:

- Ongoing assessment of surface and groundwater systems (including wetlands and native vegetation) health.
- Triggers for early warning for arising issues enabling adaptive management of surface and groundwater management systems.
- Review of the performance of water quality and quantity management systems and propose design adjustments where necessary.

It is noted that precinct scale monitoring to provide detailed local scale information for design purposes will also be required in addition to this district scale monitoring in accordance with the usual requirements for developments which are outlined below.

5.3.2 Predevelopment monitoring

In low-lying shallow groundwater and clay soil environments such as those prevalent in the study area there is a need to fully understand the seasonal, inter-annual and long-term variability of the local groundwater system and the following questions need to be answered:

Does the local groundwater level reflect the district or regional scale superficial aquifer or is there a localised perching effect due to low in-situ soil permeability and/or the presence of impermeable materials in the soil profile?

- Localised perching can be permanent or seasonal depending on the extent and level of the impermeable layer. It is critical to develop an understanding of the relationship between the local groundwater system and the geotechnical conditions.
- Local wetlands and waterways may be sustained by a local perched groundwater system or the district or regional scale superficial groundwater system
- Shallow perched groundwater systems are sensitive to changes to the pre-developed water balance, such as a focus on ‘at source’ infiltration, or importation of irrigation water.
- Poorly draining in-situ soils can limit the ability for water to enter the groundwater system. It is important to understand the extent to which locally generated stormwater contributes to the groundwater system or runs off.

How close to the surface does the pre-development groundwater rise during winter?

- Conditions that are likely to be experienced frequently can impact on the amenity and liveability of the subdivision, reducing the functionality of public open spaces as well as being potentially damaging to infrastructure.
- Less frequent occurrences that may not have occurred at all in recent history remain important to understand how groundwater will behave under them so that the urban form can be designed appropriately.

To answer these questions groundwater level monitoring needs to be undertaken and capture at least two winters locally so that this data can be correlated to the nearest available longer-term record and the long-term patterns can be understood.

Where there is a locally perched groundwater system it is important to consider the extent to which local groundwater levels may be disconnected from the regional groundwater system on a seasonal, annual or inter-annual basis. Monitoring programs should be tailored to include this consideration potentially using paired deep and shallow bores.

Where subsoil drainage is likely to be used to manage a shallow groundwater system the following additional questions will need to be considered:

What level is acceptable for installation of subsurface drainage (CGL)?

- The definition of an acceptable CGL should be undertaken consistent with *Water resource considerations when controlling groundwater levels in urban development* (DWER, 2013) in consultation with the Shire of Serpentine-Jarrahdale and for approval by DWER in their role as water resource managers.
- This process generally considers the impact to the regional or district scale superficial aquifer and the wetlands and watercourses that it sustains and may require significant additional monitoring and investigation work.
- There is also a risk of impacts to local wetlands and watercourses as well as potential for significant groundwater export from locally perched systems and these effects need to be fully understood to be managed.

What is the potential water quality impact from stormwater and groundwater that will be discharged from the drainage system?

- It is critical to gain an understanding of the in-situ soil and groundwater quality that will be mobilised by the system so that an appropriate level of treatment can be provided.
- Where historic land uses indicate a risk of contamination or there is a known contaminated site present within or in proximity to the site, additional investigations will be necessary.
- Additionally, it is necessary to understand water quality in the receiving environment so that any impacts in the future can be properly identified and understood.

To answer these questions, surface water and groundwater quality information needs to be collected. The data must be sufficient to provide an understanding of seasonal trends and recent enough to capture the current status of the site and surrounding land uses. Generally, this will require sampling to be undertaken on at least four to six occasions timed to provide at least one sample per season.

5.3.3 Establishment of trigger values

Site specific trigger values should be established following completion of any predevelopment monitoring program. Trigger values should be established applying procedures consistent with *ANZG (2018)* using local reference data where possible to derive the 80th percentile and applying default trigger values from regional reference data as a fall-back.

5.3.4 Post-development monitoring

The key objectives of post-development monitoring are to:

- Determine the quantity and quality of groundwater and surface water on site and downstream of the site post-development.
- Ascertain whether the quantity and quality of groundwater and surface water has significantly changed post-development.
- Establish the performance of water quality systems that have been installed by the developer and to determine whether they are successful. Where water quality systems are found to be less effective than is desirable, they will act as 'lessons learnt' for future subdivisions.

5.3.5 Monitoring specification

Post-development monitoring should commence 2 years after each stage of clearance and continue for a duration of a minimum of 3 years. This is to be applied up until the full completion of all stages of development.

Surface water

Surface water monitoring sites should be selected to address the key objectives of post-development monitoring outlined above. Monitoring should include but not necessarily be limited to:

- Flow
- Quality
- Visual inspection and photographic record of drainage outlets and water quality treatment systems. Any outflows observed at these locations during inspection should be sampled opportunistically to coincide with other sampling.
- Visual inspection and photographic record of overland flowpaths to detect the occurrence of any maintenance and management issues such as the deposition of waste, sediment, and the presence of mosquitoes or algal growth.

The specific methodology for flow data collection may vary from site to site and does not necessarily include continuous monitoring. However, flow monitoring should be undertaken with site specific consideration of an appropriate methodology for estimation of contaminant loads to receiving environments.

Surface water sampling should be undertaken fortnightly from August to October (i.e. six fortnightly monitoring events) to capture peak winter baseflows, and once in March to capture the first baseflows post-summer.

Surface water samples should be submitted to a NATA-accredited laboratory in accordance with Australian Standards and analysed for the following parameters:

- In situ pH, electrical conductivity (EC), dissolved oxygen, and temperature

- pH
- Total suspended solids (TSS)
- Total nitrogen (TN) and total dissolved nitrogen (TDN)
- Ammonia (NH4)
- Nitrate and nitrite (Nox-N)
- Total phosphorous (TP)
- Filterable reactive phosphorous (FRP)

The following additional parameters should be included in the laboratory analysis annually:

- Major anions (chloride, bromide and sulphate)
- Major cations (calcium, magnesium, sodium and potassium)
- Iron (Fe) and aluminium (Al)

Groundwater

Groundwater monitoring sites should be selected to address the key objectives of post-development monitoring outlined above. Monitoring should include but not necessarily be limited to:

- Levels
- Quality

Monitoring of groundwater levels and the collection of groundwater samples should be undertaken on a quarterly basis.

Groundwater samples should be submitted to a NATA-accredited laboratory in accordance with Australian Standards and analysed for the following parameters:

- In situ pH, electrical conductivity (EC), dissolved oxygen, and temperature
- pH
- Total suspended solids (TSS)
- Total nitrogen (TN) and total dissolved nitrogen (TDN)
- Ammonia (NH4)
- Nitrate and nitrite (Nox-N)
- Total phosphorous (TP)
- Filterable reactive phosphorous (FRP)

The following additional parameters should be included annually:

- Major anions (chloride, bromide and sulphate)
- Major cations (calcium, magnesium, sodium and potassium)
- Iron (Fe) and aluminium (Al)

5.3.6 Reporting

The Shire of Serpentine-Jarrahdale should be advised of any trigger value exceedances immediately. The Shire of Serpentine-Jarrahdale requires annual reports to be provided for all post development monitoring programs. Monitoring data should be provided in electronic format, preferably as an excel spreadsheet. Reports should include:

- Summary tables, graphs and maps presenting spatial and temporal variations of flow and quality.

- Estimation of contaminant loads to the downstream environment based on collected water quality and flow data.
- Discussion of findings including investigations undertaken in response to trigger value exceedances.
- Recommendations for modified monitoring regime and/or trigger values where required.
- Presentation of site inspection findings including photographs and field notes
- Groundwater bore construction logs.

5.4 Action plan

Table 9: Actions and responsibilities for implementation of the strategy

Action	Responsibility	Timing
Development of water management documents	Proponents of development	As part of the planning and development process
Assessment of DWMS and LWMS documents	DWER in consultation with the Shire of Serpentine-Jarrahdale	In accordance with statutory planning process timeframes
Assessment of UWMP documents and subdivision designs	Shire of Serpentine-Jarrahdale in consultation with DWER	In accordance with statutory planning process timeframes

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Appendix A Site context

The existing environmental conditions and land uses in the Study Area define opportunities and constraints for water management. A summary of these conditions is provided in this Appendix.

Existing land use

The Study Area is located approximately 38 km southeast of the Perth CBD, in the Shire of Serpentine-Jarrahdale. The area is bounded by the Tonkin Highway Reserve to the west, rural residential land to the north, the South Western Highway to the east and Mundijong Road, Lampiter Drive and Wright Road to the south.

The Study Area has a mix of existing urban and peri-urban land in and around the existing townsite and in the newly developed Whitby Town area, and rural land surrounding. There are some areas of remnant vegetation including areas set aside as Regional Parks and Recreation under the Metropolitan Region Scheme (MRS). This includes the new 65 hectare regional open space at Kiernan Park.

Implications for future development

Land uses and land use change present water related risks to the environment and water resources. Land uses in the Mundijong District Structure Plan that have the potential to impact on water resources are as follows.

- District and neighbourhood centres (high density urban residential and commercial)
- Schools and community facilities
- Urban and suburban neighbourhoods
- Remaining rural land and smallholdings
- Industrial and light industrial land
- Parkland and district sporting fields

Climate

The climate for the Study Area is typical of the Southwestern region of Western Australia and is characterised by the Köppen Climate Classification as Dry Subtropical featuring mild and wet winters and hot to very hot summers. Most of the rainfall is experienced in the winter between May and September and the driest months are between December and March as shown in Chart 2.

Evaporation data show evaporation exceeds rainfall between September and April, and from May to August rainfall exceeds evaporation as shown in Chart 3.

The rainfall record at the nearest Bureau of Meteorology weather station (Cardup station no. 9237, approximately 5.8km from the Study Area) has an annual average rainfall of 858.7 mm since 1970. The average has decreased since 2000, although no data has been collected at this site since 2012, recording an average of 774.3 mm, a 10% decrease in rainfall as observed in Chart 4. Rainfall data for an alternative site approximately 7.4km from the Study Area (Serpentine, station no. 9039) is presented in Chart 5 showing an annual average of 913.4mm since 1905 declining to 743.2mm since 2000, a 19% decrease.

Decreasing rainfall is noted in the *Selection of future climate projects for Western Australia* (DoW, 2015). Mean annual rainfall decreases projected by DWER, based on the 1961-1990 baseline, varies between -4% (wet scenario) and -25% (dry scenario) by 2050. This extends to -7% (wet) and -47% (dry) by 2090.

Increasing urban heat due to climate change has also been recognised as a significant issue for the Perth region linked to loss of urban canopy and increasing populations. Chart 6 shows the increases that have been observed in mean maximum temperatures recorded at the nearest Bureau of Meteorology temperature station (Karnet station no. 9111).

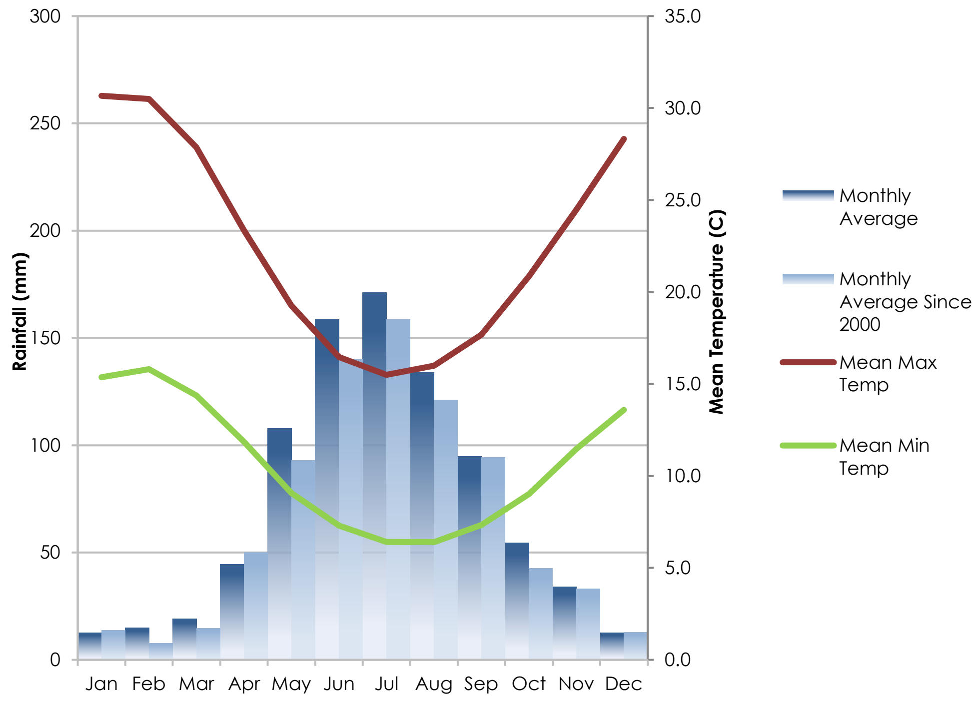


Chart 2: Climate summary data (BoM station no. 9237, BoM, 2024)

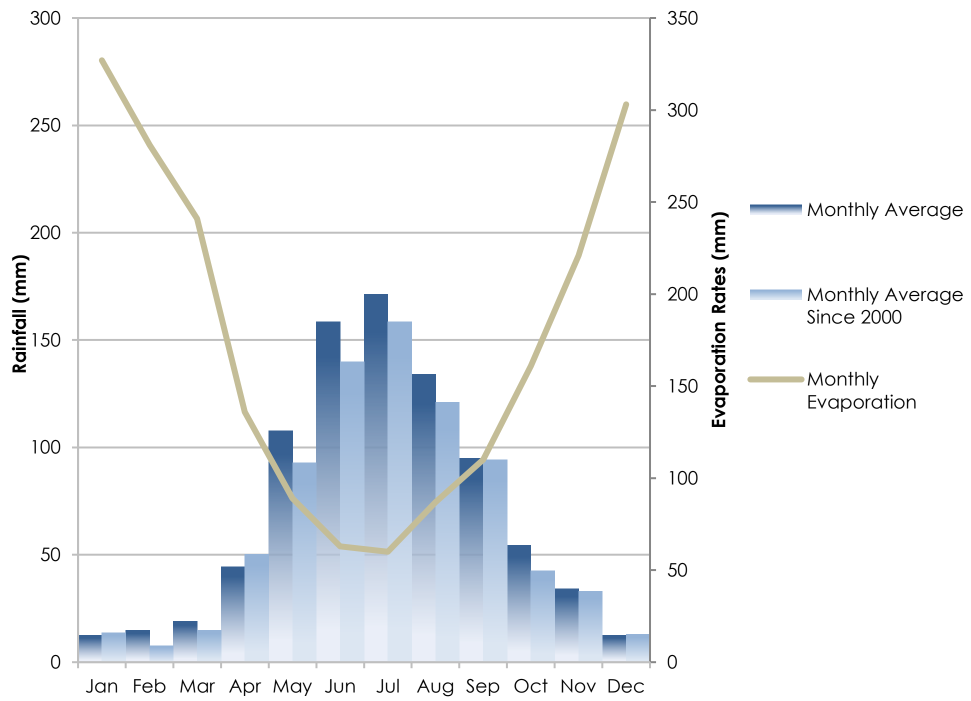


Chart 3: Climate summary data (BoM station no. 9237, BoM, 2024)

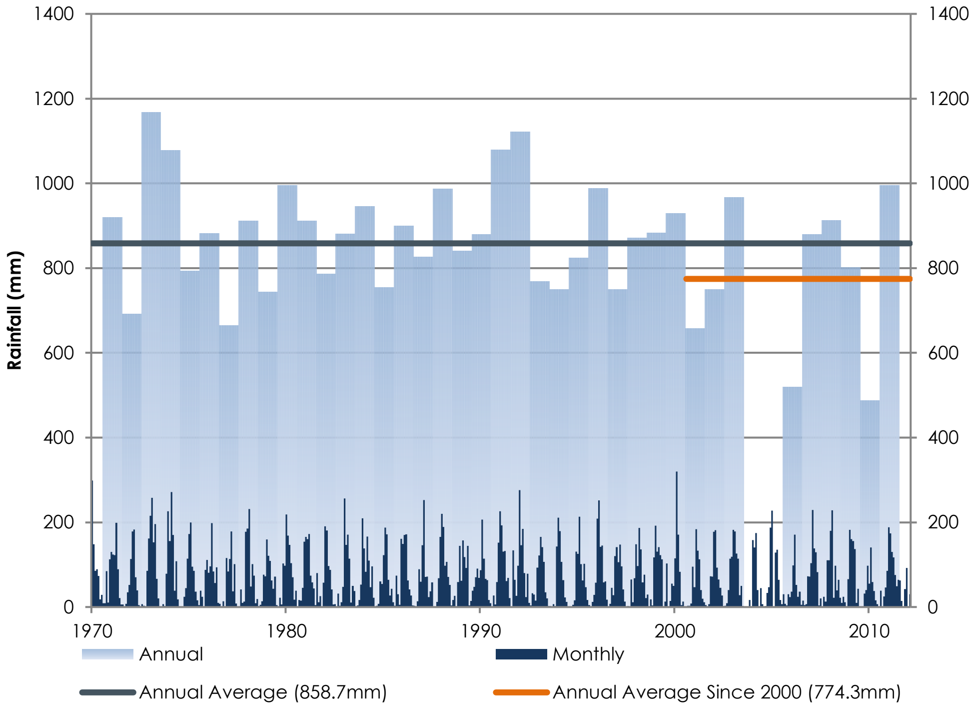


Chart 4: Rainfall summary data (BoM station no. 9237, BoM, 2024)

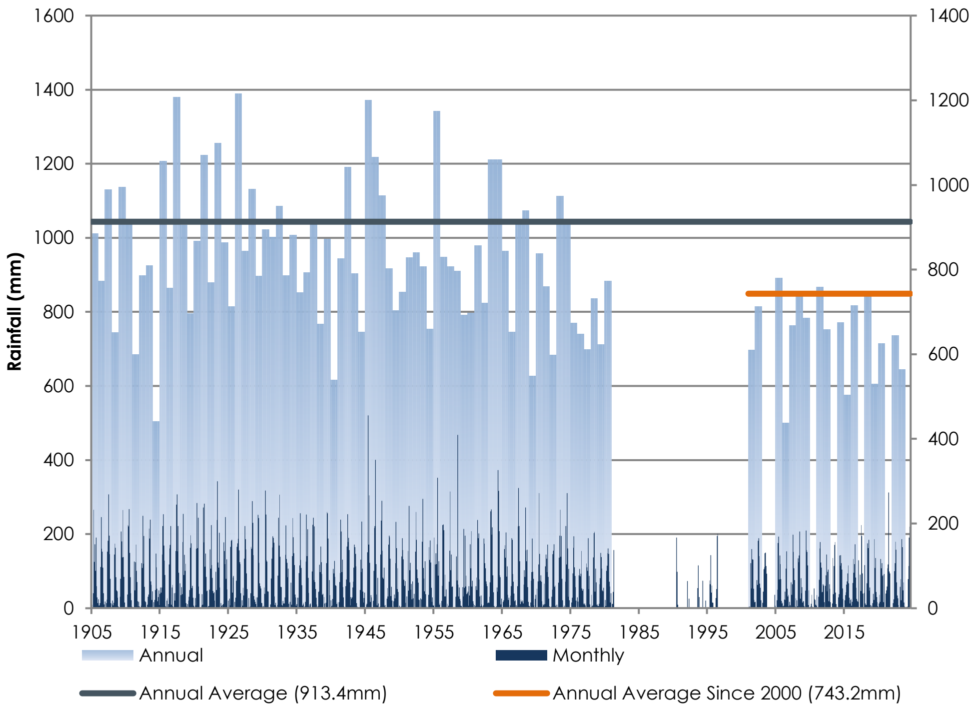


Chart 5: Rainfall summary data (BoM station no. 9039, BoM, 2024)

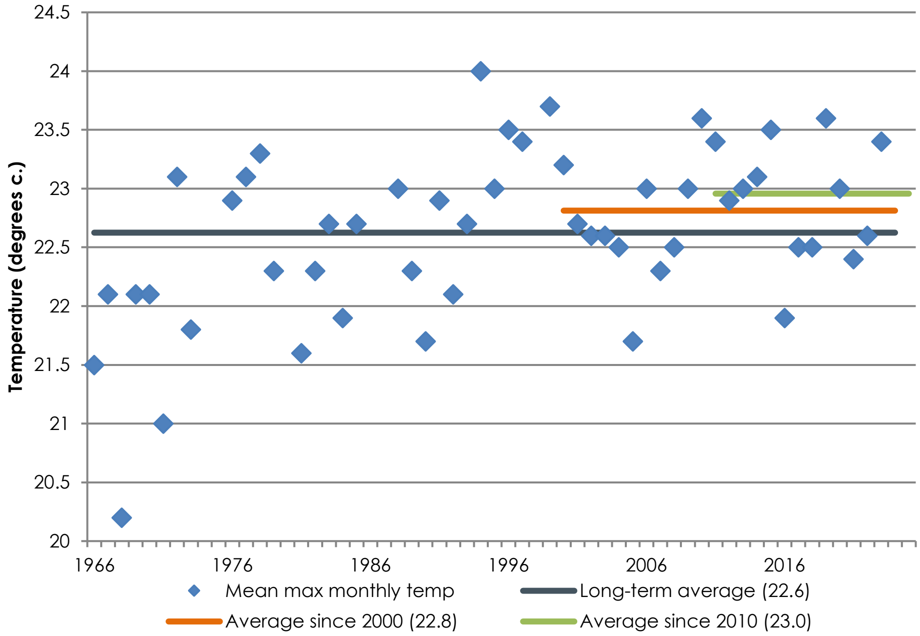


Chart 6: Mean maximum temperature data (BoM station no. 9111, BoM, 2024)

Urban greening is an important way that mitigation of urban heat impacts can be achieved. In recognition of this, the Urban Greening Grant Program was created to expand tree canopy and vegetative cover in high urban heat risk areas in 33 Local Governments within the Boorloo (Perth) and Bindjareb (Peel) regions. Funded by the Department of Water and Environmental Regulation (DWER) and delivered collaboratively with WALGA, the program provides a total of $3.75 million (ex GST) to support additional planting or to bring forward future tree planting in winter 2024 and winter 2025. A UHI rating of 3 or above, based on WALGA mapping available online, has been specified as a criterion for grant eligibility.

To assist with Urban Greening Grant applications, WALGA have developed urban heat index (UHI) mapping and a UHI rating of 3 or above has been specified as a criterion for grant eligibility. The mapping can be accessed online at: <<https://walga.maps.arcgis.com/apps/mapviewer/index.html?webmap=2451df5130f74a9d92c08cd3b9ba6940>>

Urban heat mapping of the Study Area is presented in Figure 12 showing the significant heating influence of cleared pasture areas. Cooler parts of the study area can be seen associated with the presence of water and vegetation, particularly along the Manjedal Creek and into the hills to the east. The existing townsite is also cooler than surrounding land due to the presence of trees and vegetation along road reserves and within large residential lots.

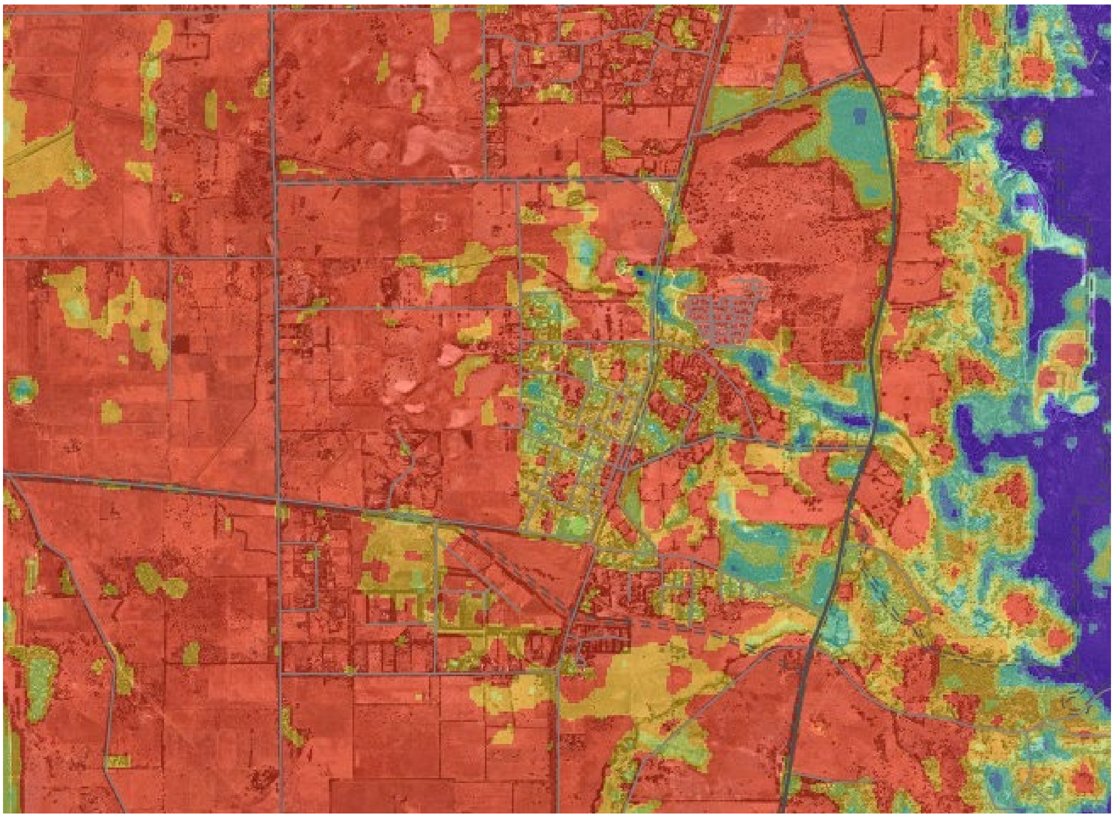


Figure 12: Urban Heat Mapping

Implications for future development

It is important to consider historic, current, and future climate as an integral part of water management investigations and modelling to inform development and validation of strategies. This should include an understanding of the representativeness of local monitoring results and demonstrated understanding of how future changes are likely to impact on the total water cycle.

Urban greening in the study area should focus on retaining existing trees and vegetation wherever possible, maximising trees and vegetation in road reserves, public open spaces and along retained waterways.

Water sensitive urban design is a key contributor to the effectiveness of urban greening. It is critical that strategies are implemented to maintain soil moisture through retention and infiltration of stormwater as close to source as possible.

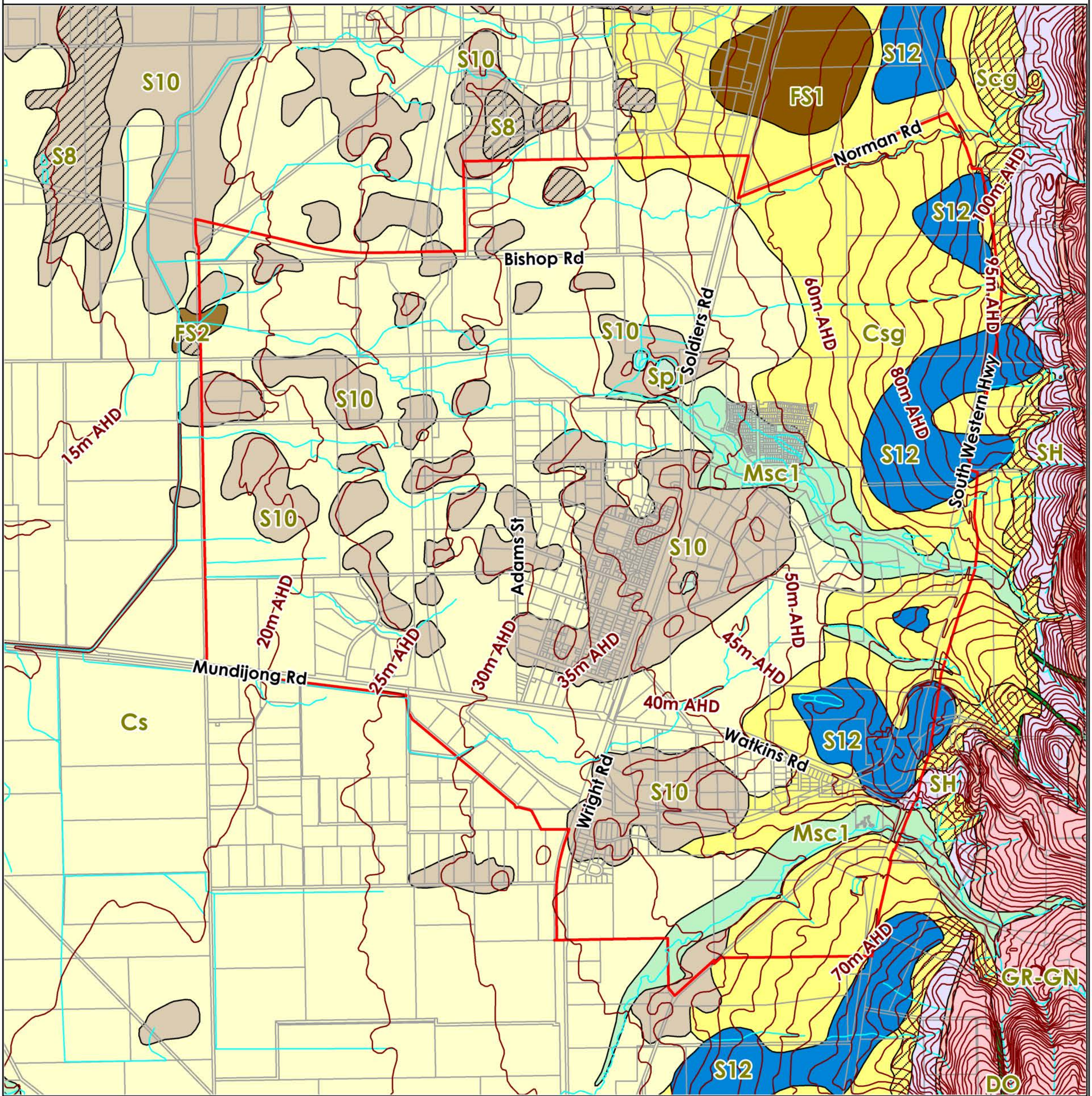
Topography, geology, and soils

The physical and topographical conditions for the site influence the hydrological conditions including the ability to retain and infiltrate runoff. A summary is provided below based on regional mapping which are also presented in Figure 13 and Figure 14.

Topography

The majority of the Study Area, situated on the Swan Coastal Plain, is relatively flat and low-lying. To the east, the study area rises gently to begin with, into the foothills of the Darling Scarp and then rises more steeply up onto the Darling Plateau.

Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 13 - Topography and soils

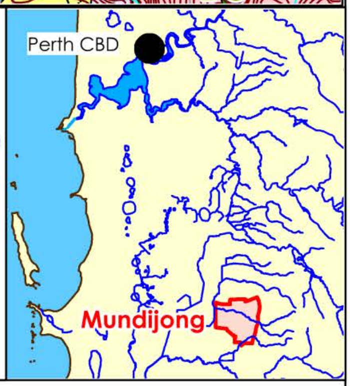


LEGEND:

- Study area boundary
- Cadastre
- Watercourse
- 5m elevation contours

Surface geology

- Cs - Sandy Clay
- S10 - Bassendean Sand over Guildford Formation
- S8 - Bassendean Sand
- Csg - Gravelly Sandy Clay (Colluvium)
- Scg - Gravelly Clayey Sand (Colluvium)
- S12 - Yoganup Formation Sand
- FS1 - Ironstone Gravel
- FS2 - Ironstone
- Sp1 - Peaty Sand (Swamp Deposits)
- Msc1 - Clayey Sandy Silt (Alluvial)
- SH - Armadale Shale
- GR-GN - Granites and Gneisses
- DO - Dolerite



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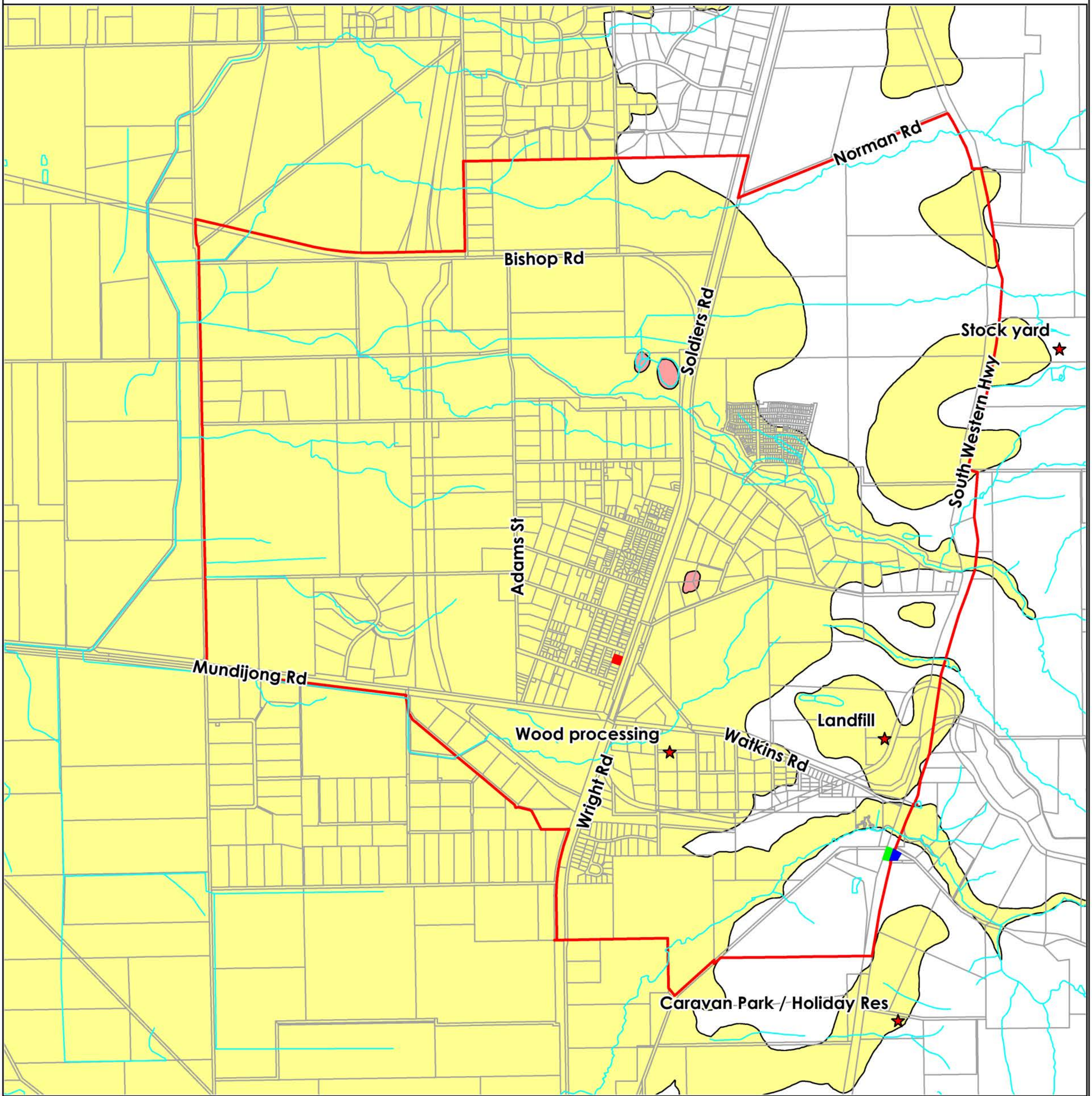
Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 14 - Acid sulfate soils and contamination



LEGEND:

Study area boundary

Cadastre

Watercourse

Acid sulfate soil risk

High to moderate risk

Moderate to low risk

Registered Contaminated Sites

Contaminated - remediation required

Contaminated - restricted use

Remediated for restricted use

Other potentially contaminating activity

Data source: Landgate, Created by: HB Projection: MGA: zone 50.

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Ground elevations at the site slope from the western boundary to the north west point of the site from approximately 25 mAHD to 75 mAHD, reaching a high point of 96 mAHD along the Eastern Boundary (Figure 13).

Regional soil mapping

The surface geology of the Study Area, shown in Figure 13, has been classified as Bassendean Sand over Guildford Clay (S10). and Bassendean Sand (S8) (Gozzard, 1986) as follows:

- S10: This unit, found on the majority of the Study Area, includes a thin layer of Bassendean Sand (S8 as described below) over Guildford formation which includes sandy and pebbly soils with varying clay content.
- S8: Bassendean Sands are described as white to pale grey at surface, yellow at depth, fine to medium-grained, moderately sorted, subangular to subrounded, minor heavy minerals of aeolian origin.

Acid sulphate soils

Most of the Study Area is classified as having moderate to low risk of developing Acid Sulphate Soils (ASS) within the first 3 m from the natural surface with three relatively small areas of high to moderate risk developing Acid Sulphate Soils (ASS) within the first 3 m from the natural surface based on regional mapping shown in Figure 14. These areas are wetlands west of Soldiers Road and a wetland east of Robertson Road and north of Evelyn Street adjacent to Manjedal Brook.

Previous site investigations, undertaken by Cardno in 2007, confirmed that at the wetlands west of Soldiers Road suitable conditions persist for ASS development. There was also evidence of ASS oxidation with the presence of an oily bacterial scum and rust-staining. This was thought to result from acidic water mixing with water of a higher pH, precipitating a rust-red scum containing iron and it is possible ASS are located within 3.0m of the natural soil surface in this area.

Contamination

Two registered contaminated sites are present within the Study Area. One of these sites, comprised of two adjacent parcels, is currently registered as "Contaminated – Remediation Required" (ID number 75499 and 76894) under the *Contaminated Sites Act 2003*. The Basic Summary of Records for both parcels state there are hydrocarbons (such as from petrol and diesel) present in groundwater as a plume extending beneath the site and is likely to migrate offsite in a southerly direction to affect adjoining land.

The second registered contaminated site is comprised of one private parcel (ID number 12570 currently classified "Contaminated – Restricted Use") and an adjacent parcel of South Western Highway road reserve (ID number 20134 currently classified "Remediated for Restricted Use"). The basic summary of records for the private parcel states that there are hydrocarbons (such as from petrol/oil/diesel) are present in groundwater beneath the forecourt and extending to the west/northwest of the site. Light non-aqueous phase liquid (LNAPL) (e.g. pure petrol or diesel) is present in the vicinity of former tank infrastructure. Hydrocarbon-impacted soil is present in the smear zone of the seasonally fluctuating impacted groundwater. Contamination from this parcel has migrated into the adjacent South Western Highway road reserve.

In addition to registered contaminated sites, there are other sites where potentially contaminating activities have occurred in the past, including a former landfill site and wood processing plant.

Registered contaminated sites and potential historical contamination sources are presented in Figure 14.

Implications for future development

The nature of soils, particularly permeability, is a critical element in determining an appropriate drainage strategy. Low permeability soils require consideration of drainage strategies comprising on-site and in-system detention to avoid significant increases in peak flows to existing drainage systems and sensitive receiving water bodies.

Where sandier soils exist, on-site infiltration strategies can be similarly applied to manage peak discharges and should be encouraged in these areas.

Areas of acid sulfate soils cannot be confirmed or discounted at this stage of the development process and will need to be determined by an acid sulfate soils investigation, potentially with sampling within the site. Acid sulfate soils can be managed through appropriate management plans, sampling, and treatment, which is addressed through a DWER approval process that should be undertaken prior to any subdivision.

Further investigations are required to determine the extent of contaminated soil and/or groundwater, particularly where indicated as possible, as a result of current or past land use. A Preliminary Site Investigation (PSI) is recommended at Local Structure Plan stage. This should include consideration of high levels of nutrients (which generally fall outside the Contaminated Sites Act).

Hydrology

The part of the catchment that lies within the Darling Scarp is hilly with steep grades and well-defined watercourses. The lower (western) section of the catchment is the Swan Coastal Plain, which is predominantly low lying with a gently undulating to flat surface and extensive areas of Palusplain, largely classified as multiple use wetlands.

Vegetation and wetlands

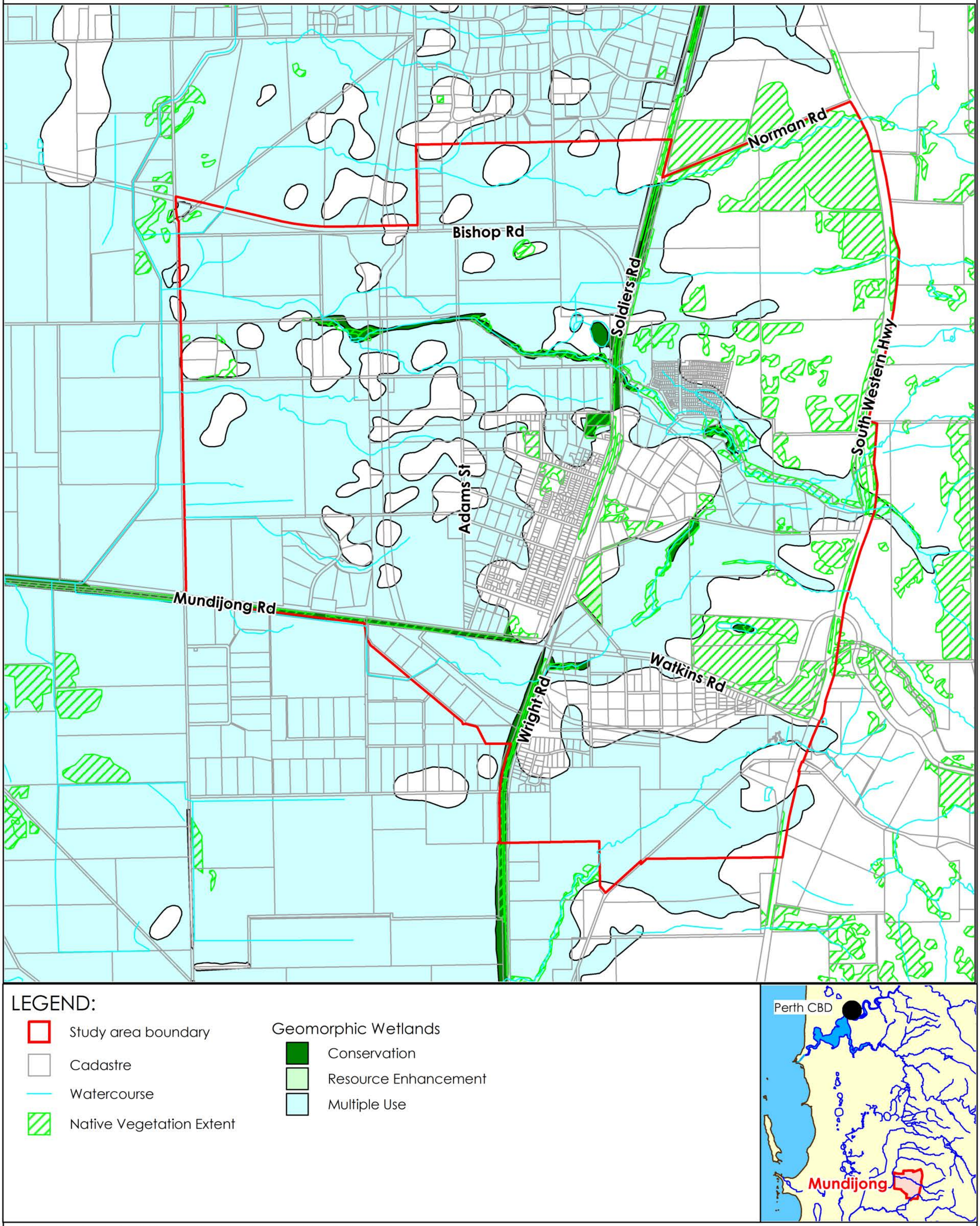
Figure 15 presents mapping of geomorphic wetland classifications and remnant native vegetation.

As noted above, much of the study area is covered with extensive areas of Palus plain which is mostly classified as multiple use wetland although there are areas of conservation category associated with remnant vegetation along road reserves and waterways and one resource enhancement area also associated with remnant vegetation adjacent to Roman Road.

In addition to the extensive Palusplain areas, there are a small number of basin type Sumplands, two of which are conservation category. These are located adjacent to Soldiers Road, to the north of Manjedal Brook and in Watkins Rd Nature Reserve.

The hydrological characteristics of the Manjedal Brook and other surface waterways play an important role in supporting these wetlands and remnant vegetation. It is therefore important to preserve connectivity, flow rates and hydroperiods associated with these natural features.

Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 15 - Vegetation and wetlands



Data source: Landgate, Created by: HB Projection: MGA: zone 50.

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Surface water and drainage

Erosive processes principally related to runoff from the escarpment have defined step valleys in the upper reaches of the catchments. Reduced velocities as runoff reaches the floodplain have resulted in wide flat floodplains along the lower reaches of the catchment.

As shown in Figure 16 there are a number of watercourses and drains discharging through the study area, with the Manjedal Brook and Mardella Creek being the most significant. Natural watercourses in the study area typically drain in an east-west direction from the escarpment.

Manjedal Brook enters the study area after traversing the South Western Highway and then draining in a west-nor-westerly direction, skirting Mundijong townsite, and flowing parallel to

Keirnan Street. Manjedal Brook is crossed by Robertson Road, the Southern Railway, Soldiers Road and finally Taylor Road before draining out of the study area at the Tonkin Highway Reserve.

Mardella Creek also enters the study area via the South Western Highway and drains in a south westerly direction adjacent to Shanley Road before leaving the study area to the south.

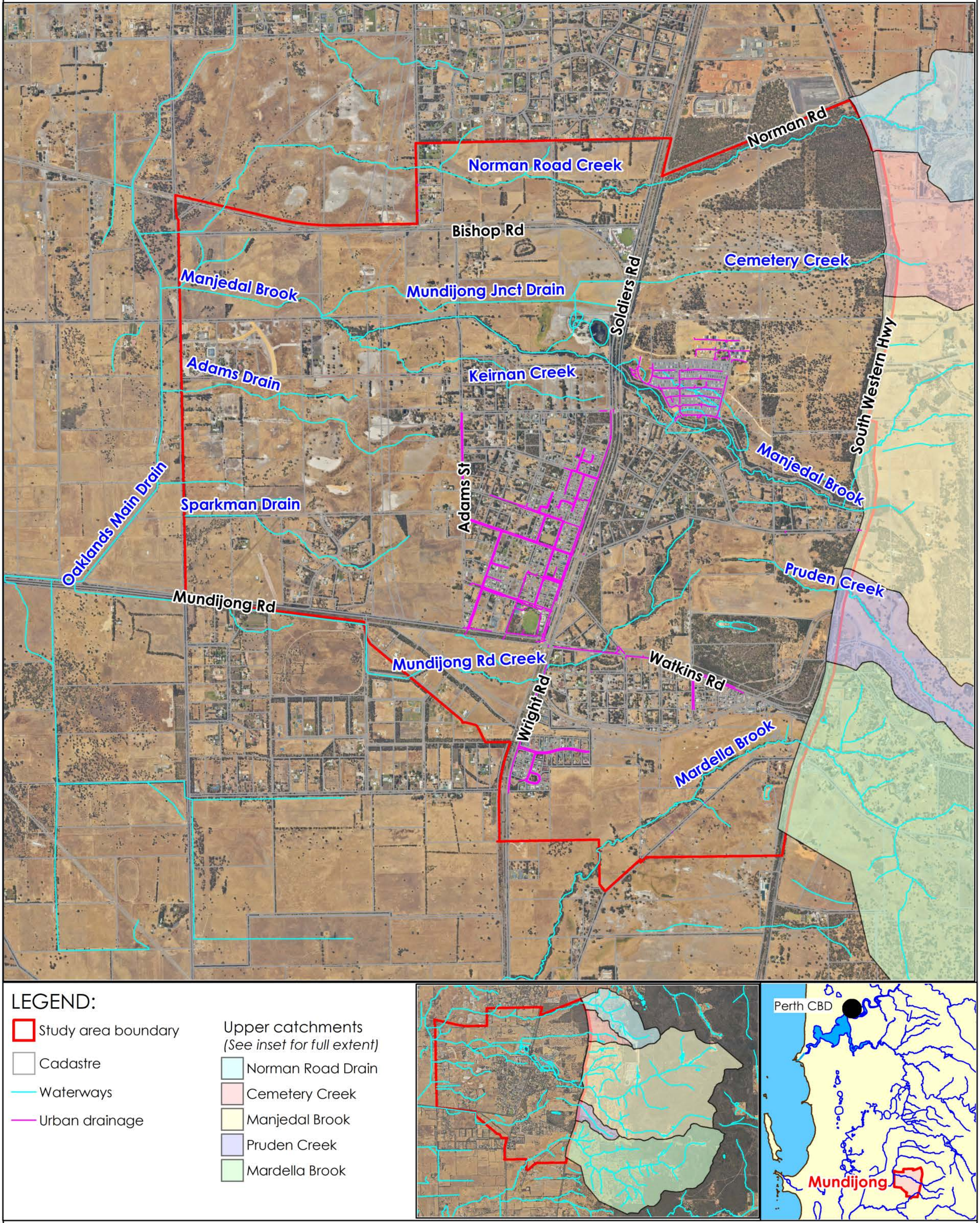
Other minor watercourses draining through the site include:

- A small modified natural creek enters the study area at the South Western Highway south of Norman Road and flows through the Norman Road bushland before crossing Robertson Road, the Southern Railway, Soldiers Road and exits the study area at Hopkinson Road.
- Another highly modified creek/drain enters the study area at the South Western Highway south of Whitby Cemetery. This creek/drain discharges in a westerly direction through an incised channel before crossing Robertson Road, the Southern Railway, Soldiers Road and finally Taylor Road before draining out of the study area at the Tonkin Highway Reserve.
- A small creek enters the study area at the South Western Highway north of Pruden Road. The creek is poorly defined and meanders across rural land between Watkins Road and Evelyn St/ Galvin Road. This creek drains through two farm dams before crossing Roman Road, Watkins Road, Hicks Street, Wright Road, and the Southern Railway and ultimately turns northwards to form a more formalised rural drain alongside Webb Road before discharging into Mundijong Road drain.
- Several small rural drains are also present in the western portion of the study area, all draining in a westerly direction towards the Oaklands Main Drain which lies just outside the study area and drains southwards towards the Birrega Main Drain and Serpentine River.

The Study Area is known to experience regular water logging in the low-lying areas of the study area. This inundation is due to a combination of persistent winter rainfall elevating the shallow water table, which rises to the surface and inundates vast areas of the flat terrain, as well as sparse drainage, with insufficient capacity that does not allow runoff to leave the area. There is also potential for wetlands within the study area to receive additional flood water from outside their natural catchment by overtopping of drains and watercourses.

There are several local depressions east and west of the South Western Highway, which result in local perching of surface water after a large rainfall event.

Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 16 - Surface water and drainage



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Groundwater

As noted above, large parts of the Study Area are low-lying and frequently water-logged with shallow perched groundwater and rejected recharge.

Typically, in these areas, winter rainfall is stored at the surface in wetlands and local depressions with very little leaving the landscape via shallow poorly defined surface waterways. This surface storage allows recharge of the local superficial groundwater system to occur slowly over several months of the year and is coupled with evapotranspiration as the major elements of the local water balance which is discussed further in Appendix B.

Figure 17 presents the Annual Average Maximum Groundwater Level (AAMGL) from modelling undertaken by DWER for the Lower Serpentine Hydrological Studies.

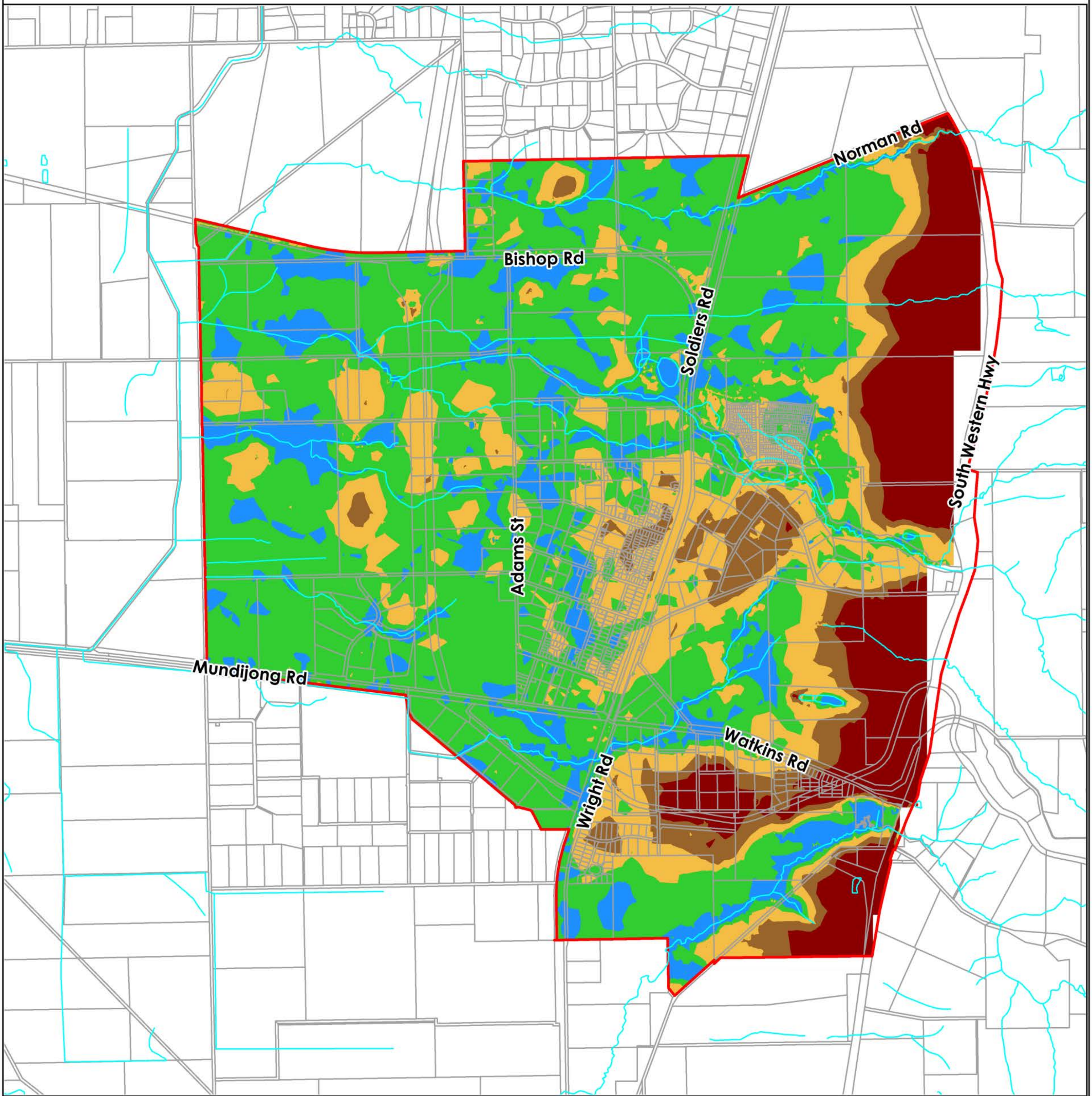
Water quality

There is limited surface water quality data available within the study area. The SMEC Mundijong- Whitby DSP Environmental Study (2008) collected samples on the 30th October 2007 from four sites along Manjedal Brook and one from a wetland on the western side of Soldiers Road. Table 10 summarises the results.

Table 10: Water Quality Results (SMEC, 2008)

Variable	Range	Comments
pH	6.89-8.25	Meets ANZECC water quality objectives
Electrical Conductivity	343 – 1150 µs/cm	Lower conductivity values are often associated with seasonal rainfall
Salinity	0.14 – 0.58 ppt	fresh to slightly brackish
Turbidity	5.30 – 25.8 NTU	
ORP	170-286 mV	
Dissolved Oxygen	82.7 – 138.6%	should avoid falling below 5mg/L to avoid stress to aquatic species
Heavy Metals		Within ANZECC Drinking Water Guideline Values 2004
Total Phosphorus	0.01 to 0.03 mg/L	Meets ANZECC water quality objectives
Reactive Phosphorus	<0.01 mg/L	Meets ANZECC water quality objectives
Total Nitrogen	0.35 mg/L (average) 2.1 mg/L (max)	All but site 3 meets ANZECC water quality objectives
Total Kjeldahl Nitrogen	0.2 – 0.7 mg/L	
Ammonia	>0.105 – 0.118 mg/L	Above ANZECC trigger values
Nitrite and Nitrate (NO_x)	<0.010 - 1.380 mg/L	Mostly less than ANZECC trigger values

Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 17 - Groundwater



LEGEND:

- Study area boundary
- Cadastre
- Watercourse

Depth to modelled AAMGL

- >5m
- 3-5m
- 1-3m
- 0-1m
- 0m

Data source: Landgate, Created by: HB Projection: MGA: zone 50.

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The EPA's 2008 Peel-Harvey water quality improvement plan *(WQIP)* addresses catchment management measures and control actions for phosphorus. It was developed to meet the objectives of the *Environmental protection (Peel Inlet-Harvey Estuary) policy 1992* (Government of Western Australia 1992), with the following aim:

- improve water quality by reducing phosphorus discharges from the catchment through changes to agricultural and urban practices and land use planning

The WQIP establishes that the river flow objective for tidal reaches of Serpentine, Murray and Harvey Rivers to maintain current flow variability.

The WQIP also sets aspirational objectives within the catchment to protect wetlands and floodplains (to mimic natural inundation and drying patterns) and minimise the effect of damming on water quality (to mimic natural frequency, duration and seasonal flow).

Bindjareb Djilba: A plan for the protection of the Peel-Harvey estuary (DWER, 2020) collates actions across the estuary and its catchment and asks for many groups to work together to protect the Peel-Harvey estuary for future generations. Actions are grouped into four work areas: Catchment; Estuary; Plans, Policy and Partnerships; and Measuring Progress.

Catchment actions (C) include the following actions aimed at reducing diffuse and point sources of urban nutrients that directly relate to this District Water Management Strategy:

- Action C9: Assist householders to improve water use efficiency in urban gardens and minimise nutrient export risk through Waterwise education programs (aligned with Waterwise Perth).
- Action C10: Public open space managers to reduce the application of nutrients (fertiliser and others) and export risk and improve water efficiency in public open space (aligned with Waterwise Perth).
- Action C11: Public open space managers to evaluate the use of soil amendment to reduce phosphorus losses.
- Action C12: Upgrade existing stormwater systems in priority areas according to water-sensitive design principles (aligned with Waterwise Perth).

Implications for future development

Development will result in the loss of significant areas of multiple use wetland. The addition of imported fill and subsurface drainage will control groundwater levels and soil wetness and therefore reduce the extent of inundated areas. In addition, improvements to surface water drainage will result in less extensive surface inundation which will be confined to predetermined locations within public open space areas.

An understanding of the pre- and post-development water balance, as presented in Appendix B, is critical to inform development of water management strategies. Some variables also have the potential to significantly influence results, and these must be understood, assessed and documented.

Local scale monitoring is required prior to development to ensure that local groundwater and surface water conditions are understood and considered in the development of local structure plans and subdivision designs.

Water and wastewater services

Drinking water supply

Water is currently supplied to Mundijong via an offtake from the Serpentine Trunk Main at Wright Road, approximately 5.5 km to the south of the town. The Water Corporation has progressively replaced sections of this distribution main to address water pressure problems in Mundijong. The medium-term water scheme planning for Mundijong is to supply water from a new high-level tank. The Sub-regional Planning Framework identifies conceptual water supply planning from the eastern Serpentine sector where major water storage reservoirs will be necessary in the escarpment near Byford Tank (Byford) and Mundijong Reservoir (Jarrahdale) to serve long-term urban development in these areas (WAPC, 2018).

The tank will supply southwards to Mundijong via large distribution mains to the proposed Mundijong Gravity zone. Some sections of the future distribution mains may need to be laid in stages as part of supply to Mundijong subdivisions as an interim solution while the area is still being supplied with water from the trunk main to the south. These mains would the later be used to supply water from the north through the ultimate scheme. As per the Sub-regional Planning Framework (WAPC, 2018), an indicative water main is planned to connect the Mundijong area with Rockingham, known as the Mundijong-Tamworth Hill Trunk Main.

Water Corporation undertakes water services planning and allocates funds for infrastructure upgrades on the basis of land use planning information. Where a development proposal requires drinking water headworks infrastructure, for which the Water Corporation has not allocated funds to suit the developer's schedule, prefunding of the works may be necessary. Connection to a reticulated scheme water supply is not always possible for rural residential areas. State planning policy 2.5: rural planning policy (2016) recognises that there may be alternative service delivery models proposed and provides the following guidance (Essential Environmental, 2016):

- where lots with an individual area of four hectares or less are proposed and a reticulated water supply of sufficient capacity is available in the locality, the precinct will be required to be serviced with reticulated potable water by a licenced service provider, including water for firefighting. Should an alternative to a licenced supply be proposed it must be demonstrated that a licenced supply is not available; or
- where a reticulated supply is demonstrated to not be available, or the individual lots are greater than four hectares, the WAPC may consider a fit-for purpose domestic potable water supply, which includes water for firefighting. The supply must be demonstrated, sustainable and consistent with the standards for water and health; or
- the development cannot proceed if an acceptable supply of potable water cannot be demonstrated.

Groundwater availability and use

An appropriate fit-for-purpose water source for irrigation of public open spaces and schools must be confirmed and secured at the local structure plan/local water management strategy stage of planning.

Groundwater is used extensively in the study area as a fit for purpose water supply for public open space irrigation, agriculture and commercial/industrial purposes as well as for private uses (garden and stock watering) which are exempt from licensing. Table 11 provides a summary of current groundwater licenses within the Study Area.

As shown in Table 11, existing groundwater licenses within the Mundijong District Structure Plan area are able to draw up to 745 ML/year from the superficial groundwater system and a further

534 ML/year from underlying confined aquifers. The total allocated groundwater resource within the DSP area is therefore 1,279 ML/year.

Table 11: Summary of groundwater licences within the Study Area

Groundwater area	Groundwater subarea	Aquifer	Number of licenses	Licenced amount (kL)
Serpentine	Byford 3	Perth – Superficial Swan	11	745,125
Serpentine	Byford 3	Perth – Leederville	47	394,280
Serpentine	Byford 3	Perth – Cattamarra Coal Measures	2	131,970
Serpentine	Byford 3	Combined – Fractured Rock West	1	7,700
Total allocated groundwater resource			61	

Groundwater availability reporting and licensing is based on groundwater management areas and subareas proclaimed under the *Rights in Water and Irrigation Act 1914* which have been defined by the Department of Water and Environmental Regulation based on natural catchment boundaries in some cases and administrative boundaries in others. The Study Area lies entirely within the Byford 3 Subarea of the Serpentine Groundwater Area.

An allocation limit is the annual volume of water set aside for consumptive use from a water resource. This includes water available for licensing and water for uses exempt from licensing (including stock and domestic 'backyard' bores). Exempted groundwater use within the study area is expected to be significant but there is little reliable consumption information available. This is discussed further in relation to the water balance modelling presented in Appendix B.

Allocation limits have been set for all aquifers present and water remains available for allocation in all aquifers. However, recent studies have detected declining groundwater levels in some areas, which are caused by a combination of abstraction and reduced rainfall as a result of climate change (DWER, 2022). These reductions in groundwater levels, particularly in the superficial aquifer, pose a significant risk to the health of the region's wetlands, river systems and riparian vegetation (DWER, 2021). Accordingly, there is a critical need to ensure the sustainable management of our groundwater resources so they can sustain the important social, economic and environmental functions for future generations. It is therefore likely that reductions in groundwater abstraction from licenced areas will be required in future to account for reduced rainfall and recharge based on technical assessments by the Department of Water and Environmental Regulation.

The post development groundwater abstraction demand within the Mundijong District Structure Plan area is estimated to be 1,481 ML/year, as calculated for water balance modelling presented in Appendix B. Modelling has applied the current Department of Water and Environmental Regulation waterwise irrigation rate of 6,750 kl/ha, and has estimated the amount of public open space and school requiring irrigation by applying % areas shown in Table 12.

As land is developed, it is expected that privately held licenses for irrigation will be transferred to developers to facilitate development and subsequently handed over to the Shire for ongoing irrigation of newly created public open spaces.

Table 12: Summary of applied irrigation rates

POS category	Irrigation rate	% irrigated
Sport spaces	6,750 kL/ha	100%
Multiple use corridors	6,750 kL/ha	10%
Local open spaces	6,750 kL/ha	50%
Schools	6,750 kL/ha	30%

The ultimate post-development estimated irrigation demand in the Mundijong DSP area is therefore approximately 200 ML more than the currently allocated groundwater amount. It is likely that this shortfall will require consideration of alternative water sources for irrigation, which may include the use of scheme water where other options are not available.

Through the *Waangaamaap — Serpentine groundwater allocation statement* (2024), the Department of Water and Environmental Regulation has reduced allocation limits in line with reductions in rainfall due to climate change and to reflect and maintain currently allocated amounts. Therefore, it is anticipated that current allocations can be traded and transferred to largely satisfy the future water demand for irrigation in Mundijong.

However, it should be noted that the sustainable yield of groundwater from the superficial aquifer in parts of the study area may be significantly restricted due to clay soils. Developments affected by this issue may require numerous shallow, low-yielding bores and/or require a supplementary irrigation source.

In addition, it is noted that this assessment has assumed that all existing groundwater licenses in the DSP area will be ultimately transferred for development of the land. Any licenses that are retained for continuing commercial purposes within the DSP area, or new commercial or industrial land uses that obtain access to groundwater for other purposes, will reduce the amounts available for transfer and may result in a larger future shortfall.

Based on current allocation limits and availability, it appears that there is sufficient groundwater allocation available to provide for around 86% of the future public open space irrigation demands in Mundijong with the remainder to be supplied from scheme water or other alternative sources. However, it is important to note that allocation limits may be further reduced in response to climate change impacts and other groundwater management issues. At the same time, sustainable yield from the superficial aquifer in the study area may be restricted due to clay soils. Developments affected by this issue may require numerous shallow, low-yielding bores and/or require a supplementary irrigation source.

Wastewater

Mundijong is situated within the Water Corp's Byford Wastewater Scheme Catchment Area. The Corporation's wastewater scheme planning for the catchment has required a range of major headworks items to be constructed.

Private and temporary wastewater infrastructure and a pump station have been installed to serve the Whitby development area. Land has also been purchased in Scott Road, adjacent to the future Tonkin Highway extension to accommodate an additional wastewater pump station, as reflected on the Mundijong District Structure Plan map. This is in the final stages of approval for construction. As an interim measure, wastewater will be pumped from Mundijong to Byford via a 'Type 90 Wastewater Pump Station (WWPS), having a 20-30m radius odour buffer. The longer term solution will be for the site to accommodate a 'Type 350' WWPS, having a 50m radius odour buffer. According to Water Corporation, the ultimate designed facility is to accommodate a ‘Type 1000’ WWPS located on the western side of the Tonkin Highway reserve, which will collect wastewater from the Byford pump stations via dual 600mm diameter wastewater pressure mains, through to the East Rockingham Waste Water Treatment Plan (WWTP), requiring a minimum 150m radius odour buffer.

Wastewater planning for Mundijong District Structure Plan area has been developed based on generalised land use, development and density/yield assumptions from previous iterations of the Mundijong-Whitby DSP. This identified the need for major gravity mains running east to west (downhill) through the development area and a large collector sewer along the western edge of the urban development area, accommodated within existing and future road reserves together with other domestic services. The width of road reserves and the size of these mains will need to be reviewed in more detail as more detailed structure planning progresses for the various precincts.

An interim wastewater strategy for this area is to convey wastewater from Mundijong and Byford northwards by pressure mains to the Waterworks Rd Main pump station (at the corner of Tonkin Highway and Armadale Rd, Westfield) and then onwards to the Woodman Point WWTP. Initial sewer flows from developments in the Mundijong area is being pumped northwards through the Byford sub-catchment via the Byford pump station, subject to capacity limits.

Social and heritage values

16 Aboriginal heritage sites have been identified within the Study Area, with a further five located in close proximity, as shown in Figure 18. The sites have been the subject of numerous cultural heritage surveys and reports. Of the 16 known sites within the Study Area, detailed site information, a description of the condition of the site and an analysis of its significance is available for eight of the sites (SMEC, 2008).

Detailed heritage surveys of the north east sector of the Study Area between South West Highway and Reilly Road, carried out on behalf of Cardno BSD (Robert Day, 2005), found no Aboriginal heritage sites in the area. Therefore, it is not expected that Aboriginal heritage issues are likely to constrain any proposed development in that area.

The significance of each Aboriginal heritage site has been described by the Blockley and Greenfield (1995), O’Connor & Quatermaine (1989) and Blockley (1996). Site SO2329, on Soldiers Rd is a stratified archaeological site that conforms to the general pattern and nature of other sites located on the Swan Coastal plain, suggesting that Aboriginal habitation of the Swan Coastal Plain was mainly concentrated along the eastern interface with the Darling Scarp.

It is recommended that Shire of Serpentine-Jarrahdale consult with the South West Land & Sea Council (SWLASC) in relation to all matters pertaining to Aboriginal heritage sites identified in this report should they be subject to disturbance as a result of Mundijong District Structure Plan.

It is also recommended that further ethnographical and archaeological surveys are undertaken in the southeast of the study area, should this area be subject to development under that Structure Plan, as previous surveys were unable to locate this site and assess its significance.

The Whitby Falls Hostel, which is a state registered heritage place is also located adjacent to the Study Area, as shown in Figure 18. The Heritage Council’s online InHerit system provides the following information about the site:

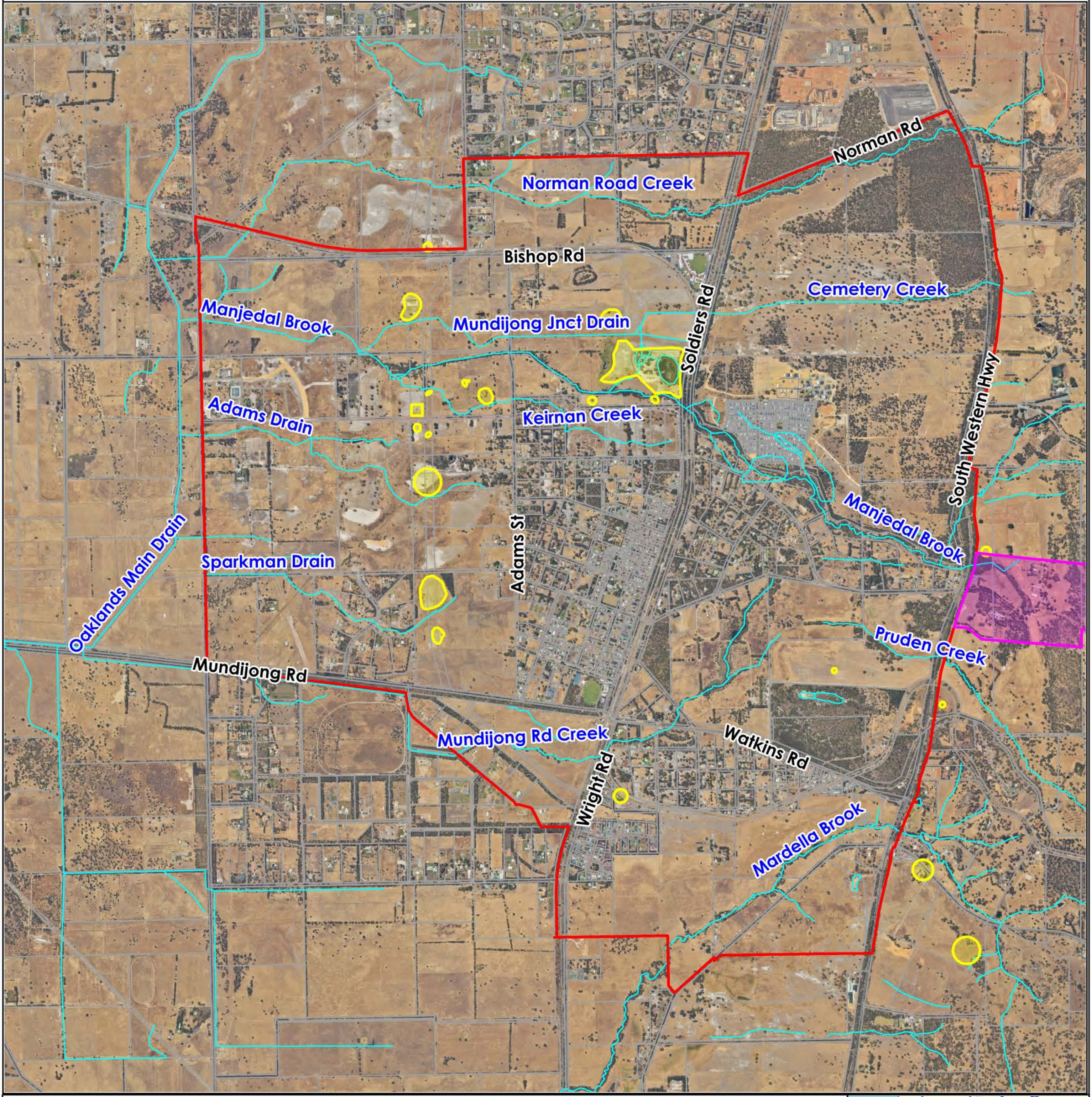
In 1846, Cockburn Sound Location 23 was surveyed and became a key centre for activity. Originally known as "Mundajill", it was renamed "Whitby Falls Estate" in 1848 by Henry Mead who purchased the property.

In 1897, the homestead was sold by a subsequent owner to the Government for use as a lunatic asylum. The cool room, egg room and hen houses were built by the inmates in the 1930's.

In 1976, the original hostel (residence) was demolished. The hostel was and remains largely self-sustaining from the animals and food produced on the property.

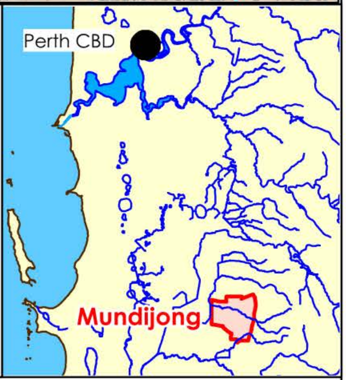
A Series of brick buildings remains below the hills and Whitby Falls- a prominent landmark for the district. Manjedal Brook flows through the property.

Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 18 - Heritage sites



LEGEND:

- Study area boundary
- Cadastre
- Waterways
- Aboriginal Heritage Places (DPLH)
- Heritage Council state registered places



Data source: Landgate, Created by: HB Projection: MGA: zone 50.

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0 800 metres

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urbaqua land and water solutions

Appendix B Conceptual water balance modelling

Conceptually, a simplified water balance can be utilised to estimate the water needs for the environment and consider the influences of various major hydrological processes and the ways that they will change in future.

The hydrological processes which need to be considered for a conceptual water balance are rainfall, evapotranspiration, surface water runoff, streamflow and infiltration, groundwater abstraction, lateral groundwater flow, leakage to and from deeper aquifers and infiltration of irrigation water (both returned groundwater and imported scheme water).

In the Study Area, there is substantial interaction between the superficial aquifer and shallow seasonal streams, rural drains, and wetlands. In this area the groundwater flux equation below (and represented graphically in Figure 19 should be satisfied.

$$RE + \Delta D - EVT - \Delta L - \Delta H - Ag + Irr = \Delta Vgw$$

Where:

- RE = gross recharge from rainfall
- ΔD = net drainage into the site (surface storage)
- EVT = evapotranspiration
- ΔL = net leakage to confined aquifers
- ΔH = net horizontal groundwater flow out of the DSP area
- Ag = groundwater abstraction
- Irr = Re-infiltration of irrigation using groundwater and/or imported scheme water
- ΔVgw = change in superficial groundwater storage

In a stable system, where there is no observed change in superficial groundwater storage, the equation above would approximately equal zero on an annual timestep.

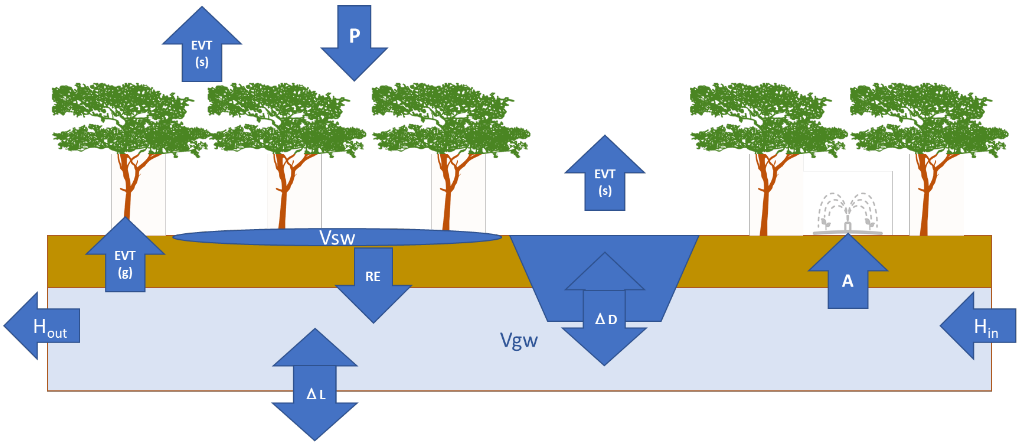


Figure 19: Conceptual water balance

In the future, with a changing climate and increased development in the study area, several of the hydrological processes identified above may change significantly to affect streamflows and superficial groundwater levels. The key changes that need to be considered are:

- Changing precipitation rates and patterns resulting from climate change
- Changing evapotranspiration from reduced vegetation cover and climate change
- Increased runoff conveyance

- Changing abstraction rates and locations

Hydrological processes

As noted previously, the hydrological processes which need to be considered to develop a conceptual water balance are evapotranspiration, surface water runoff, streamflow and infiltration, groundwater abstraction, lateral groundwater flow, leakage to and from deeper aquifers and infiltration of irrigation water (both returned groundwater and imported scheme water). These processes are considered in more detail below, drawing on information available from previous studies and monitoring to develop a numerical assessment of the broadscale conceptual water balance.

Evapotranspiration

Evapotranspiration is applied as a collective term for several different processes which include:

- interception of rainfall by leaves.
- evaporation of rainfall from impervious and vegetated surfaces.
- evaporation from open surface water bodies.
- evaporation from soils.
- uptake and transpiration of water from unsaturated soils by shallow rooted vegetation.
- evaporation from shallow groundwater (incl. surface expressions of groundwater).
- uptake and transpiration of groundwater by deep-rooted vegetation and trees.

In groundwater modelling, evaporation from shallow groundwater systems and uptake and transpiration of groundwater by deep-rooted vegetation and trees are typically grouped as groundwater evapotranspiration. Surface evapotranspiration processes, meanwhile, are usually accounted for through estimation of gross recharge rates for different surface types.

The change in groundwater evapotranspiration resulting from development can be significant, resulting from increased areas of impervious surfaces preventing evaporation from parts of the underlying groundwater system and clearing of trees and other deep-rooted vegetation reducing groundwater uptake and transpiration.

Evapotranspiration can be estimated in different ways for different parts of the site.

In areas of bare soil and/or shallow rooted vegetation, groundwater evaporation can be determined by the Penman-Monteith evaporation rate and the extinction depth. Applying this method, the evaporation rate from the water table is equal to the corrected pan evaporation rate where the water table intersects ground level and zero at the extinction depth. A pan evaporation factor of 0.75 is applied to estimate the Penman-Monteith evaporation rate for open waterbodies and extinction depths of 0.5m and 1.45m are recommended for bare soils and grass respectively.

In areas with deep-rooted vegetation, evapotranspiration can be approximated as pan evaporation multiplied by a vegetation factor. Marillier et al (2012) applied a vegetation factor of 1.0 reducing to 0.1 in the summer months December to February) when plants are likely to transpire less, and these rates have been applied in this study. The study area has 11% coverage of native vegetation which is considered 'deep rooted for this purpose.

For estimation of evapotranspiration, monthly groundwater levels for 1975-24 were prepared and monthly evapotranspiration for areas of land with <1.45m, 1-1.45m, 0.5-1m 0-1.0m depth to groundwater was calculated. Monthly inundated areas were also used to calculate direct evaporation. Average monthly depth to groundwater maps are shown in Figure 20.

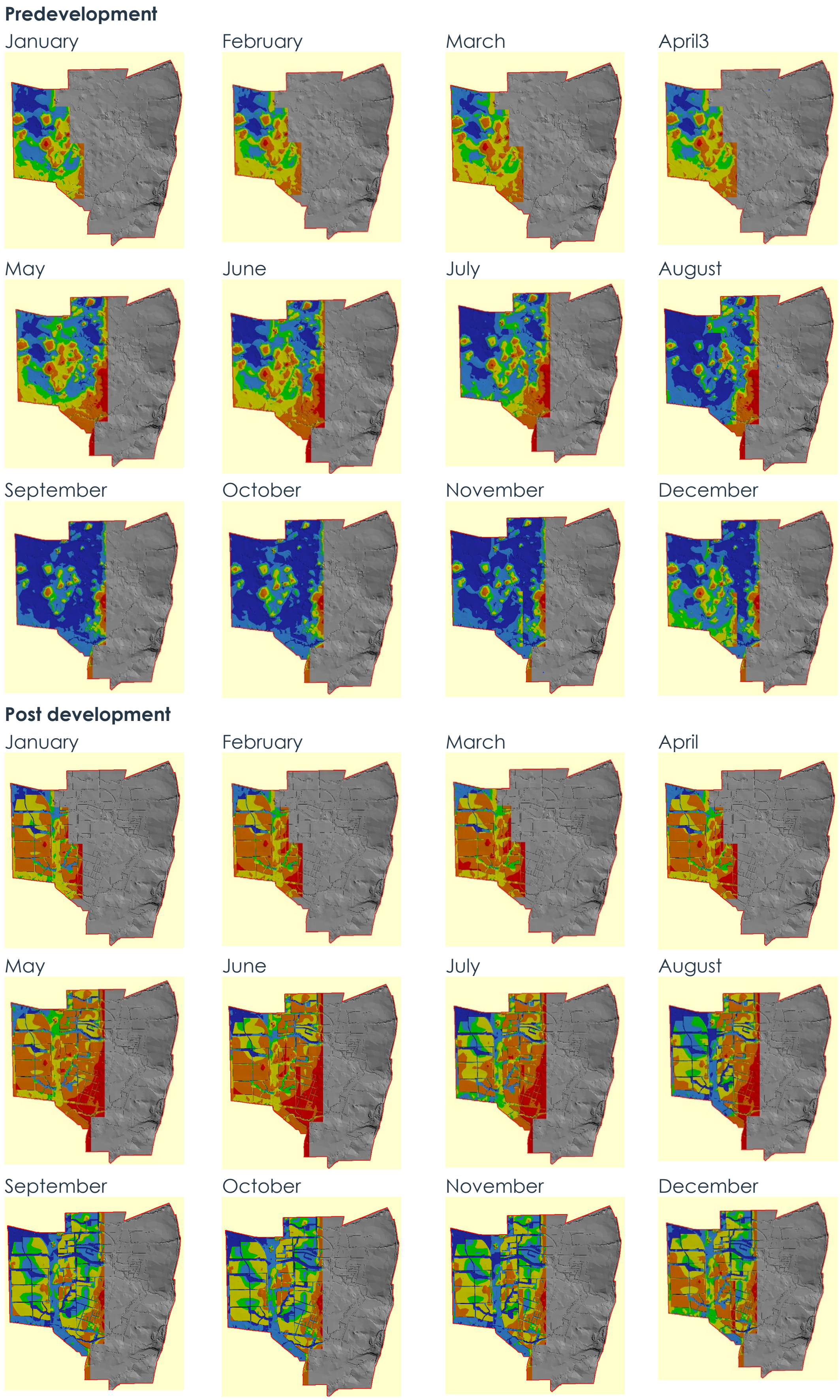


Figure 20: Average monthly depth to groundwater (1975-24)

The predevelopment groundwater evapotranspiration rate is estimated to be 269mm/year (7,367 ML/year).

The principal mechanisms that may be expected to result in changes to evapotranspiration rates are:

- climate change reducing precipitation
- filling of land, reducing groundwater evaporation
- clearing of vegetation causing reduced evapotranspiration
- climate change causing increased pan evaporation rates
- climate change causing vegetation to transpire at different rates and with different seasonal patterns

The Mundijong District Structure Plan proposes to retain the majority of remnant vegetation and native vegetation coverage is expected to remain relatively unchanged at approximately 10%. The application of fill to provide for development however, is expected to reduce groundwater evaporation, resulting in a post development groundwater evapotranspiration rate of 246mm/year (6,745ML/year).

Recharge

Recharge, in broad terms, is the proportion of rainfall that infiltrates into the ground and reaches the water table. There are several different terms used to describe recharge, each of which either include or exclude various hydrogeological processes. The terms most frequently encountered are:

- **Potential recharge** (also sometimes referred to as deep drainage) is the amount of rainfall that infiltrates beyond the rootzones of most vegetation and therefore is equal to rainfall minus runoff and surface evapotranspiration processes.
- **Gross recharge** is the amount of rainfall that reaches the water table after interflow losses and therefore is equal to the potential recharge minus interflow lost horizontally through the unsaturated zone.
- **Net recharge** is the net amount of water that is contributed to the water table over the timestep considered and therefore is equal to gross recharge minus evapotranspiration and other losses including abstraction, vertical leakage and drainage from groundwater into surface water systems. In a steady state system, net recharge is expected to be close to zero on an annual timestep but will vary seasonally.

Gross recharge has been estimated for the purposes of this study by applying published recharge rates for existing and proposed land uses. The gross recharge rates applied in this calculation are presented in Table 13 below

Table 13: Summary of gross recharge rates

Land use category	Gross recharge	Reference
Native vegetation (Banksia)	0.38	Xu et al (2009)
Pasture	0.45	Xu et al (2009)
Lake/wetland	-0.85	Xu et al (2009)
Market garden/parkland	0.4	Xu et al (2009)
Urban - industrial	0.7	Xu et al (2009)
Urban - residential	0.6	Xu et al (2009)

Application of these rates results in a gross recharge volume of 9,474 ML/yr (345 mm or 46% of total rainfall).

In this Study Area, groundwater is close to the surface. As a result, part of the gross recharge is rejected from the Superficial Aquifer because it is full (referred to as 'rejected recharge' in the literature) and ponds on the surface. This contributes to additional EVT and surface runoff.

The principal mechanisms that may be expected to result in changes to net recharge are:

- climate change reducing precipitation
- filling of land, changing soil conditions
- construction of impervious surfaces increasing runoff
- construction of urban drainage systems
- clearing of vegetation causing reduced evapotranspiration
- changed abstraction resulting from changing land uses

Following development, recharge in the Study Area is expected to increase to 11,911 ML/yr (434 mm or 58% of total rainfall).

Drainage

Drainage includes direct surface runoff from catchments within the Study Area, streamflow and baseflow from upstream catchments where the baseflow is formed from a combination of interflow where groundwater recharge by infiltrated rainwater is limited by an underlying impervious layer (aquitard) and drainage of groundwater where the groundwater level is sufficiently shallow.

In this Study Area, significant streamflows and baseflows enter from upstream catchments whilst conveyance out of the Study Area is limited to a few small rural drains, leading to frequent overflows into surrounding rural land where the water accumulates with the 'rejected recharge' noted above, and is stored in local depressions to slowly infiltrate or evaporate.

SQUARE modelling undertaken by DWER and presented in *Lower Serpentine hydrological studies – conceptual model report* (Marillier et al, 2012) provided estimates of inflow and outflows for the Manjedal Brook that are provided in Table 14.

Table 14: Streamflow and baseflow estimates (Marillier et al, 2012)

Manjedal Brook (includes Oaklands drain from Byford)		
Streamflow in	4.8	GL
Baseflow in	2.4	GL
Streamflow out	18.1	GL
Baseflow out	9.4	GL
Net outflow	13.3	GL
Net baseflow	7	GL

However, inflows and outflows for the Manjedal Brook reported by Marillier et al (2012) include contributions from the Oaklands drain which is a large rural drain serving both Byford and Cardup to the north. If a direct proportional distribution of flows by catchment area is applied, then a net outflow from the Study Area of 4.6 GL/year and a net baseflow from the Study Area of 2.4 GL/year would be estimated.

However, as previously noted, outflows from the Study Area are limited to a few small rural drains and surface storage of drainage and rejected recharge occurs. Therefore, it is expected that the actual net drainage will be substantially smaller, and the water balance can be applied to consider the net drainage component further. Assuming a stable system, with no long term groundwater level decline or reduction in surface storage, which is consistent with groundwater monitoring within the Study Area, the necessary net drainage component would be a net inflow of 0.7 GL.

The principal mechanisms that may be expected to result in changes to net drainage are:

- climate change reducing precipitation
- filling of land, reducing surface storage
- construction of impervious surfaces increasing runoff
- construction of urban drainage systems
- clearing of vegetation causing reduced evapotranspiration
- changed abstraction resulting from changing land uses

Predictions for post development net drainage, and implications for development are discussed below with the summary of water balance results.

Groundwater abstraction

Licensed superficial aquifer groundwater abstraction volumes from the DWER water licensing database have been included in the broadscale water balance for this study. Existing licenses allow for a draw of up to 745 ML/year. To estimate the post development demand, licenses held on private lots where development is proposed are assumed to cease, replaced by new licenses for irrigation of new public open spaces. The rates of irrigation assumed for various types of public open spaces are provided in Table 15. Existing licenses held by the Department of Education and Shire of Serpentine Jarrahdale are assumed to remain in place.

The post development groundwater abstraction demand is estimated to be 1,481 ML/year.

Table 15: Summary of applied irrigation rates

POS category	Irrigation rate	% irrigated
Sport spaces	6,750 kL/ha	100%
Multiple use corridors	6,750 kL/ha	10%
Local open spaces	6,750 kL/ha	50%
Schools	6,750 kL/ha	30%

Most of the licensed groundwater use is for irrigation purposes and it is estimated that approximately 20% of water used for irrigation is assumed to return to the water table resulting in an existing return of 149 ML and a future return of 296 ML.

It should be noted that, whilst an increase in groundwater demand is estimated, it is likely that alternative resources will be used for some of this demand, such as the underlying Leederville Aquifer and potentially scheme water, where alternative sources are not available. It is therefore assumed that the current licensed abstraction rate will continue unchanged.

The use of private unlicensed 'backyard' bores for garden irrigation on residential properties is widespread in Western Australia. It has been estimated that approximately 30% of households in Perth have a garden bore and the average bore pumps about 800 kL/yr (Davidson and Yu, 2006). More recent analysis by DWER suggests that groundwater use from garden bores varies according to block size as summarised in Table 16. These rates have been applied to rural and urban lots in the existing Study Area at the rates indicated in Table 16.

Table 16: Indicative water usage rates for domestic groundwater bores

Block size	Estimated annual usage (DWER)	Proportion modelled
Urban block (<1,000 m^2)	300 to 420 kL / property	50%
Rural block (<5,000 m^2)	970 kL / property	30%
Rural block (>5,000 m^2)	3040 kL / property	10%

Following development, whilst uptake may be consistent with current rates it is expected that usage will be lower, associated with smaller lot sizes and compliance with waterwise messaging which emphasises the need for conservation and efficiency. Assuming compliance with current sprinkler restrictions and waterwise advice, a future average usage rate of 240 kL/yr/dwelling may be expected.

The total current unlicensed groundwater demand is estimated to be 925 ML/year reducing to 489 ML/year following development.

There is significant uncertainty regarding the potential return to the aquifer of groundwater used for garden irrigation. If the rate applied to commercial irrigation were similarly applied to garden irrigation, the estimated returns would be 185 ML prior to development and 98 ML after development. However, it is considered unlikely that this level of return is realistic, and so this potential return has been excluded from modelling.

Groundwater leakage to and from confined aquifers

A standardised leakage rate has been calculated using Darcy's Law based on a typical head difference of 20m between the Superficial and Leederville aquifers and an assumed vertical hydraulic conductivity for the confining layer of $1x10^{-5}$ m/day (Davidson 1995).

This method of estimation indicates a net vertical leakage of 2,003 ML/yr from the Superficial Aquifer.

Horizontal groundwater flow

To develop an estimate of the lateral superficial groundwater flow into and out of the study area, a flow net analysis has been undertaken. A series of flow lines were drawn over the average annual minimum groundwater level contours map. Transmissivity was calculated as 400m^2/day based on the typical saturated thickness of the superficial aquifer (20m) and the typical horizontal hydraulic conductivity of Bassendean sand (15m/day) and the dimensions of flow cells were measured directly using GIS.

Flow net calculations are provided in Table 17 and Table 18 showing a net inflow of 646 ML/yr is estimated. The flow net is shown in Figure 21.

Table 17: Flow net calculations at inflow boundary

Flow net channel	Channel width (m)	Average length (m)	Upper level (m/AHD)	Lower level (m AHD)	Level change (m)	Hydraulic gradient	Transmissivity (m2/day)	Q (m3/day)
1	950	1,800	71	42	29	0.016	400	4,592
2	200	1,700	71	42	29	0.017	400	1,024
3	240	1,800	71	42	29	0.016	400	1,160
4	300	1,900	66	42	24	0.013	400	1,137
5	300	2,100	64	42	22	0.010	400	943
6	450	2,000	60	42	18	0.009	400	1,215
7	1,000	1,300	55	42	13	0.010	400	3,000
8	300	1,000	55	42	13	0.013	400	1,170
9	1,500	1,100	55	42	13	0.012	400	5,318
Total inflow (m3/year)								9,518

Table 18: Flow net calculations at outflow boundary

Flow net channel	Channel width (m)	Average length (m)	Upper level (m/AHD)	Lower level (m AHD)	Level change (m)	Hydraulic gradient	Transmissivity (m2/day)	Q (m3/day)
1	1200	1700	42	27	15	0.009	400	3,176
2	600	3800	42	16	26	0.007	400	1,232
3	600	3900	42	16	26	0.007	400	1,200
4	900	3700	42	16	26	0.007	400	1,897
5	1200	2200	42	24	18	0.008	400	2,945
6	1000	1500	42	29	13	0.009	400	2,600
7	250	1900	42	30	12	0.006	400	474
8	450	1200	42	33	9	0.008	400	1,013
9	1300	600	42	37	5	0.008	400	3,250
Total outflow (m3/year)								8,656

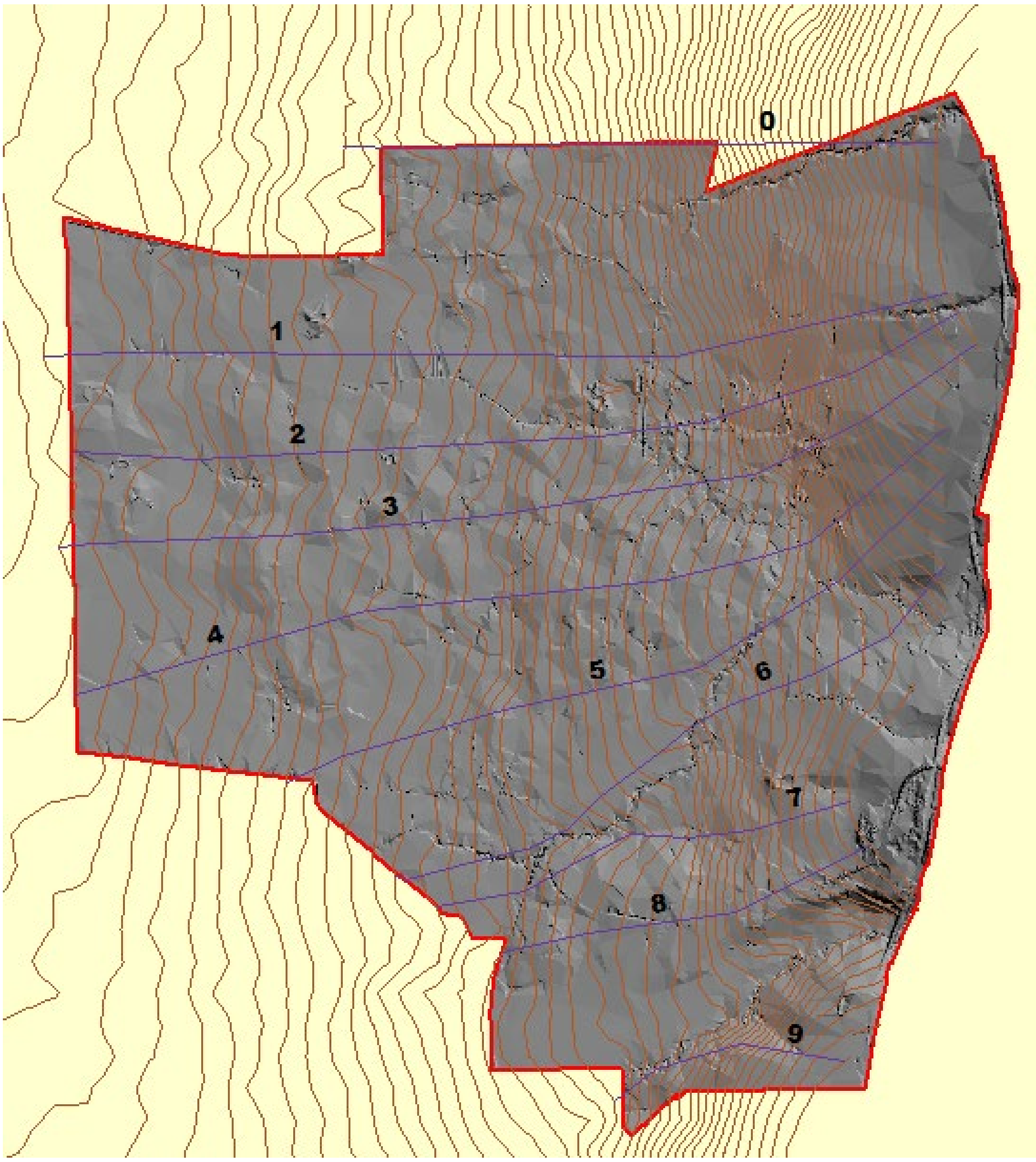


Figure 21: Flow net

Summary of the broadscale conceptual water balance

A boradscale predevelopment conceptual water balance for the Study Area is presented in Table 19, assuming a stable system with no storage decline.

Table 19: Broadscale conceptual water balance (Stable predevelopment system)

Superficial groundwater		
Inputs	***mm***	***ML***
Gross recharge from rainfall	345	9,474
Net drainage inflow	28	771
Recharge from irrigation returns	5	149
Net horizontal flow	24	646
	402	11,040
Outputs		
Evapotranspiration from groundwater	269	7,367
Abstraction from superficial groundwater	61	1,670
Vertical leakage	73	2,003
	402	11,040
Water balance (no storage change)	0	0

In future, recharge is expected to increase, while evapotranspiration is expected to decrease a little and small increases in groundwater abstraction are expected. These changes to the water balance indicate that groundwater levels could rise following development if no groundwater drainage systems are implemented as shown in Table 20.

Table 20: Broadscale conceptual water balance (Post-development no groundwater drainage)

Superficial groundwater		
Inputs	***mm***	***ML***
Gross recharge from rainfall	434	11,911
Net drainage inflow	28	771
Recharge from irrigation returns	11	296
Net horizontal flow	24	646
	497	13,625
Outputs		
Evapotranspiration from groundwater	246	6,745
Abstraction from superficial groundwater	45	1,234
Vertical leakage	73	2,003
	364	9,982
Water balance **surplus** (storage increase)	133	3,643

In reality, the most significant change likely within the study area is likely to be increased drainage as land is developed from low-lying, poorly drained pastures to urban land uses with constructed surface and groundwater drainage systems in place.

The use of fill and subsurface drainage systems to control groundwater levels for development is typically associated with a small rise in minimum groundwater levels as well as the expected reduction in maximum groundwater level. In part, this change, as shown in Figure 22, can be attributed to a shift in the extinction depth for evapotranspiration effects.

To maintain a stable groundwater system the installation of subsoil drainage would increase offsite discharges by approximately 3,643 ML/year resulting in a net drainage outflow of 2,872 ML/year.

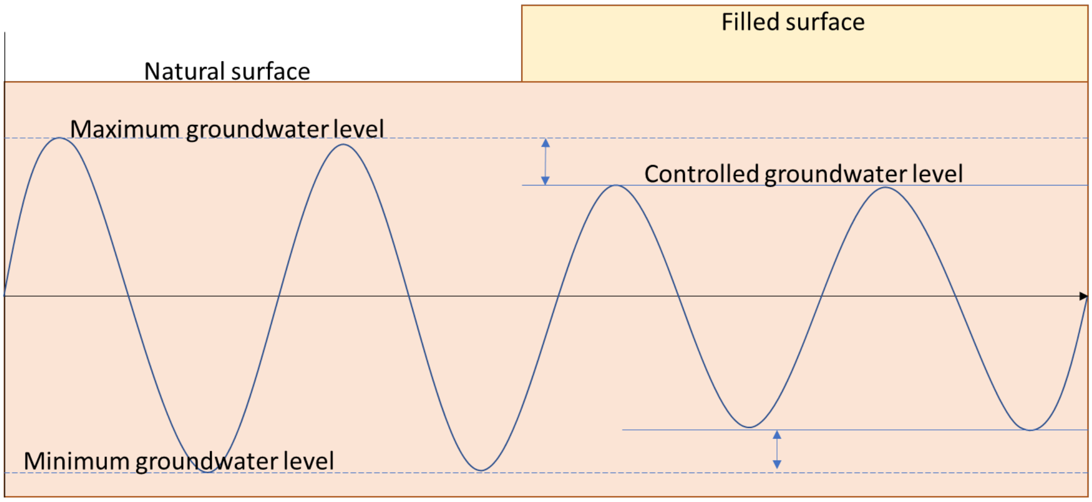


Figure 22: Visualisation of changing minimum and maximum groundwater levels following development

However, with declining rainfall leading to reduced runoff and recharge, and rising temperatures increasing evapotranspiration, declines in groundwater levels and streamflow into the Study Area are likely to be experienced.

Table 21 presents a post development scenario including 30% decline in annual rainfall and 10% increase in potential evapotranspiration, both of which have been identified as within plausible ranges by 2085 in the *Southern and South-Western Flatlands — National Hydrological Projections Assessment report* (Commonwealth of Australia, 2022).

Table 21: Broadscale conceptual water balance (Post-development with climate change)

Superficial groundwater		
Inputs	***mm***	***ML***
Gross recharge from rainfall	304	8,338
Net drainage inflow	11	308
Recharge from irrigation returns	11	296
Net horizontal flow	24	646
	350	9,589
Outputs		
Evapotranspiration from groundwater	271	7,420
Abstraction from superficial groundwater	45	1,234
Vertical leakage	73	2,003
	388	10,656
Water balance **deficit** (storage decrease)	-39	-1,068

In this scenario, there is a water balance deficit of 1,068 ML/year, indicating declining groundwater levels in future.

Chart 7 presents a breakdown of the water balance scenarios so that differences between the water balance components can be observed, including the impact of subsoil drainage combined with climate change although it is likely that declining groundwater levels due to climate change would reduce and possibly prevent discharges from any installed subsoil drainage systems.

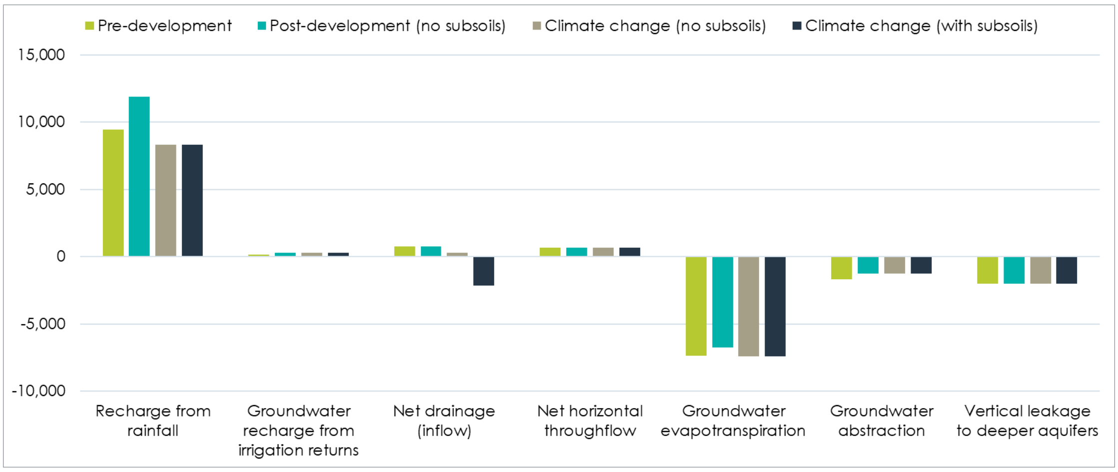


Chart 7: Broadscale conceptual water balance summary

The groundwater balance in all scenarios is dominated by recharge and evapotranspiration with net drainage and groundwater abstraction providing the next most significant areas of potential change.

Summary of water balance risks

The pre- and post-development water balance presented above indicates that the following key water balance risks associated with land use change in Mundijong will need to be considered during planning and development:

- Clearing and development increasing recharge and decreasing evapotranspiration potentially leading to groundwater level rise.
- Filling and draining of the land potentially changing the hydrology of wetlands and waterways.
- Installation of new drainage systems potentially mobilising legacy contamination.

Appendix C Hydrological modelling

Modelling presented in this district water management strategy is from a combined 1/2-dimensional hydrological and hydraulic model constructed using the InfoWorks Integrated Catchment Model (ICM), applying ensemble design rainfall analysis consistent with the procedures recommended by Australian Rainfall and Runoff (ARR2019) and with consideration of the following relevant previous modelling studies:

- East of Kwinana flood modelling and drainage study (DWER, 2021)
- Birrega and Oaklands flood modelling and drainage study (Hall, J., 2015)

Model conceptualisation

The Mundijong DWMS study area is mainly characterised by flat terrain traversed by a few natural waterways and shallow rural drains mainly flowing in a westerly direction. The most significant of these waterways are fed at the eastern boundary of the site by five catchments extending from the South Western Highway up into the steeper foothills of the Darling Scarp.

The upper catchment inflows to the study area can be suitably represented by 1-dimensional catchments to generate hydrographs at culverts and bridges beneath the South Western Highway.

Within the existing townsite and developing areas, it is necessary for the model to be capable of representing local drainage systems including constructed storage areas to provide design guidance for future development. Therefore, each precinct within the study area is represented by a series of 1-dimensional subcatchments together with 1-dimensional nodes and links to represent the constructed local drainage system.

To accurately represent the shallow, poorly defined drainage and extent of surface inundation present in the study area outside of developed areas it is necessary to provide a 2-dimensional model domain that can allow flooding to extend out of the waterways and across the flat terrain. Therefore, the 1-dimensional model is also overlain with a 2-dimensional digital terrain model.

The use of rain-on-grid was considered but discounted for this study because of the need to transition areas of the model from rural to urban as development occurs. The use of subcatchments instead allows design guidance such as storage requirements and peak discharge criteria to be provided more effectively at a precinct scale.

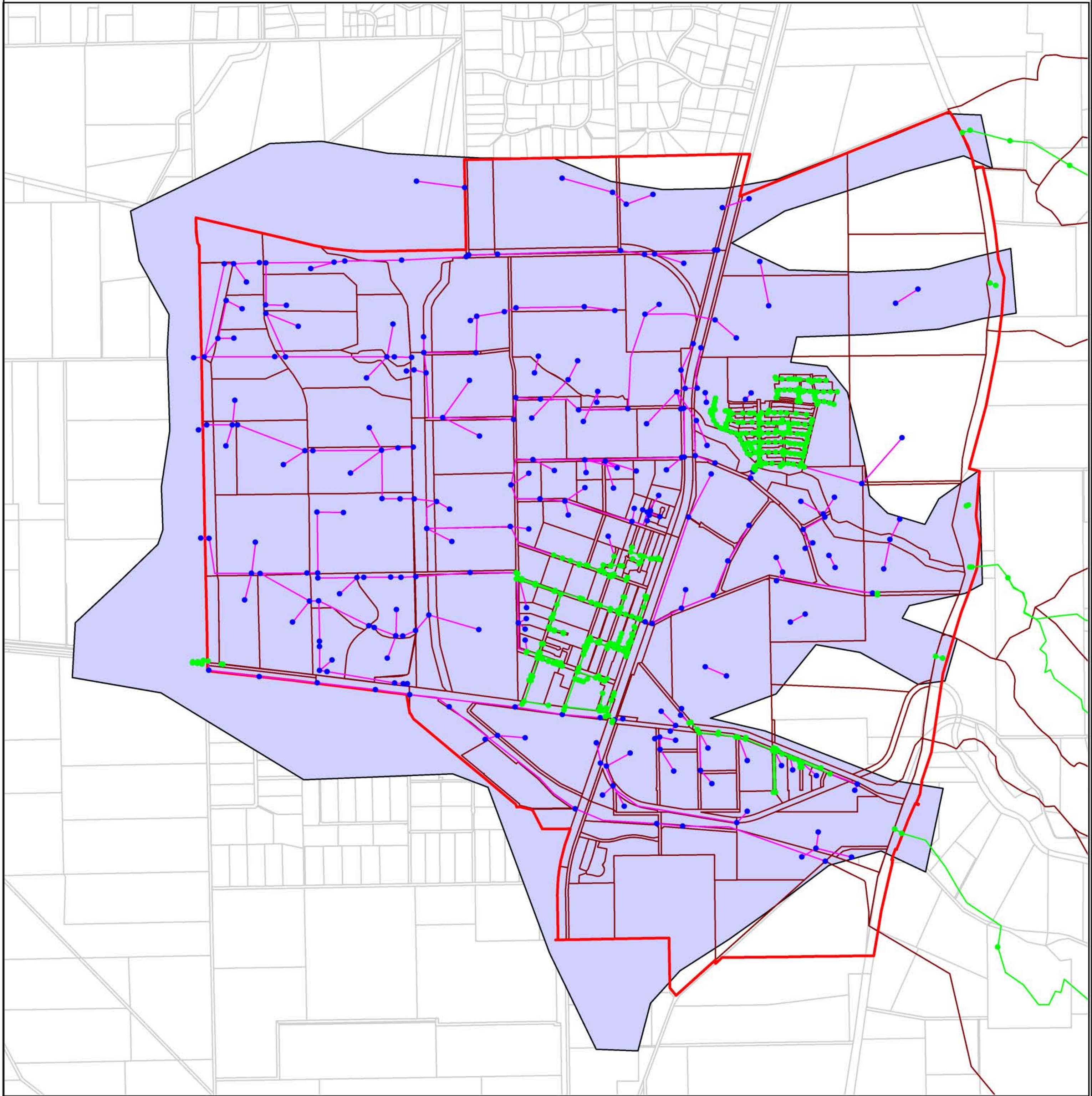
Figure 23 presents an overview of the model layout and construction which is described in the next section.

Model construction and calibration

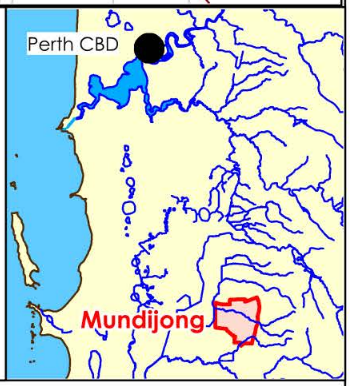
The model construction is discussed below in three components:

- Upstream rural catchment inflows (1D)
- Study area subcatchments and local drainage (1D)
- Study area digital terrain model domain (2D)

Shire of Serpentine-Jarrahdale - Mundijong District Water Management Strategy
Figure 23 - Model layout



LEGEND:
- Study area boundary
- Cadastre
- 1D model subcatchment
- 2D model domain
- Predevelopment model node
- Predevelopment model conduit
- Post-development model node
- Post-development model conduit



Data source: Landgate, Created by: HB Projection: MGA: zone 50.

0 800
metres
Scale 1:40,000 @ A4

urbaqua
land and water solutions

Hydrology of upstream rural catchments

Upstream catchment inflows are represented by individual 1-dimensional catchments terminating at culverts and bridges beneath the South Western Highway which forms the eastern boundary of the study area.

Catchment delineation

Upstream rural catchments have been delineated based on DWER hydrological catchments, local topography, and culvert and bridge locations from Main Roads WA.

Modelled subcatchments are presented in Figure 23 and Table 22 provides a summary of catchment characteristics applied in modelling.

RAFTS runoff routing has been applied to upstream rural catchments.

Table 22: Summary of upstream rural catchment characteristics

Catchment ID	Total area (hectares)	Impervious area (hectares)	Cleared area (hectares)	Slope (m/m)	Degree urbanisation
Norman Rd Creek	316	0.00	154.71	0.1368	0.000
Cemetery Creek	113	0.00	100.59	0.1338	0.000
Manjedal Brook	1,822	9.51	475.34	0.0957	0.012
Pruden Creek	93	0.70	80.33	0.129	0.017
Mardella Brook	1,317	1.93	628.33	0.1202	0.003

Regional runoff parameterisation

ARR2019 provides spatially distributed recommendations for initial and continuing loss rates for application in pervious areas of rural catchments. For this site, the recommended rates are:

- Initial loss – 25 mm
- Continuing loss – 5.9 mm/hr

Impervious areas of rural catchments are modelled with 2mm initial loss and zero continuing loss.

Continuing losses from cleared pasture areas of upstream catchments were modified to 2.1mm/hr during calibration.

Calibration of upstream rural catchments

- East of Kwinana flood modelling and drainage study (DWER, 2021)
- Birrega and Oaklands flood modelling and drainage study (Hall, J., 2015)

Upstream catchment inflows have been calibrated to peak flows provided in the *Birrega and Oaklands flood modelling and drainage study* (Hall, J., 2015).

For calibration purposes, rainfall events were developed using *Australian Rainfall and Runoff* (ARR1987) procedures and aligned to those used in the *Birrega and Oaklands flood modelling and drainage study* (Hall, J., 2015).

During calibration, the RAFTS calibration adjustment parameter was modified to improve representation of upstream storage delays to achieve a good alignment of the timing and shape of hydrographs. Subsequently, the continuing loss rate applied to cleared rural land was adjusted to improve representation of peak flows.

Table 23 provides a summary of modelled peak flows achieved in calibration.

Table 23: Summary of rural catchment calibration

Catchment ID	Modelled peak flows at SW Highway			Peak flows from Birrega and Oaklands flood modelling and drainage study (Hall, J., 2015)		
	5-year	10-year	100-year	5-year	10-year	100-year
Norman Rd Creek	2.0	3.1	6.9	3.9	5.3	10.1
Cemetery Creek	1.1	1.8	3.9	1.1	1.5	2.9
Manjedal Brook	5.1	7.9	18.1	5.5	7.3	17.5
Pruden Creek	1.0	1.5	3.2	1.2	1.6	3.1
Mardella Brook	6.7	9.7	21.8	-		

Chart 8 presents 24 hour duration rainfall event hydrographs with varying ARI at Manjedal Brook from the calibrated model compared with those from the *Birrega and Oaklands flood modelling and drainage study* (Hall, J., 2015).

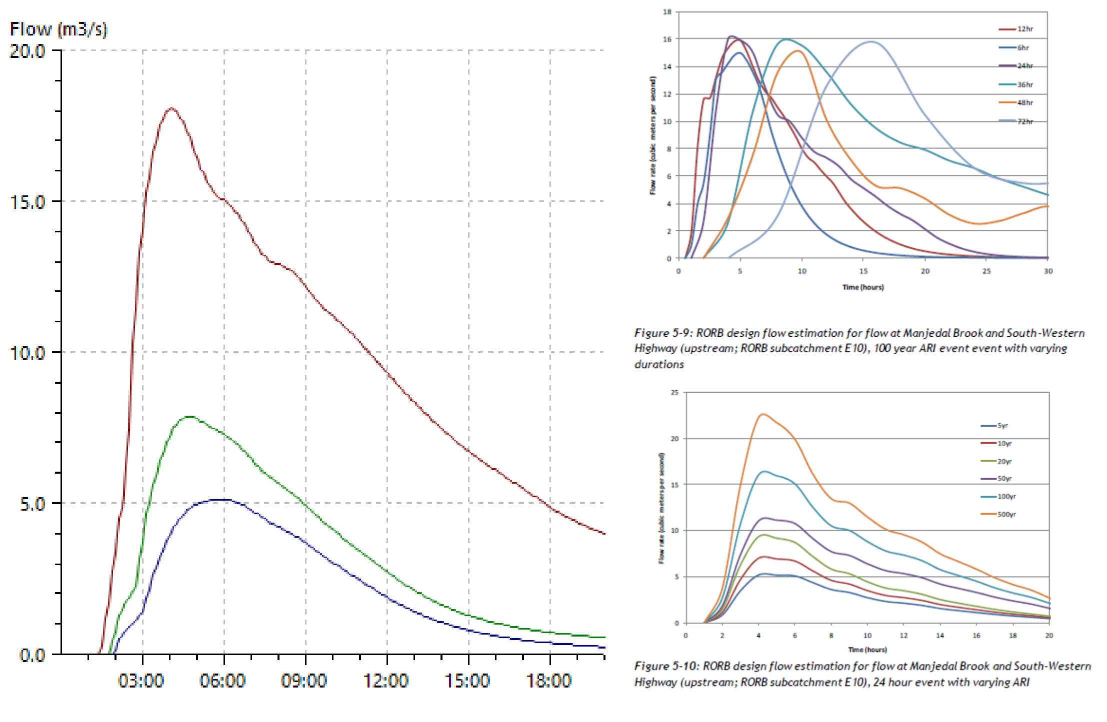


Chart 8: 24 hour duration calibration events at Manjedal Brook (Birrega-Oaklands study hydrographs shown on right hand side)

Study area subcatchments and local drainage

Following calibration of the upstream inflows, the model was developed further to include local drainage systems and subcatchments within the study area as described below.

Catchment delineation

Subcatchments within the study area have been delineated based on DWER hydrological catchments, local topography, precinct and lot boundaries, and drainage system information provided by the Shire of Serpentine Jarrahdale.

Modelled subcatchments are presented in Figure 23 and Table 24 provides a summary of catchment characteristics applied in modelling.

RAFTS runoff routing has been applied to subcatchments.

Table 24: Summary of study area catchment characteristics

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
Pruden	93.187	0.8%	0.8%
Cemetery	113.182	0.0%	0.0%
A6L5	0.364	0.0%	9.9%
A6L7	0.366	0.0%	10.1%
A6L9	0.453	0.0%	9.9%
A6L11	0.434	0.0%	9.9%
A6L13	0.486	0.0%	10.1%
A6L15	0.453	0.0%	9.9%
A6L17	0.358	0.0%	10.1%
R6	19.714	0.0%	0.0%
J2	24.988	0.0%	5.3%
G13	34.607	0.0%	8.9%
KR9	0.764	0.0%	n/a
A8	32.089	0.0%	11.6%
A3	93.333	0.0%	12.6%
G1R14	0.436	0.0%	10.1%
M11	55.505	0.0%	11.1%
X1R9	4.367	0.9%	69.7%
E2R3	5.251	0.0%	10.2%
X1R1	1.147	0.0%	69.0%
A6L2	0.272	0.0%	9.9%
S7	2.262	12.7%	28.7%
X1R2	3.27	1.1%	7.9%
HR1	2.357	0.0%	n/a
BR20	0.725	25.7%	33.4%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
BR1	0.744	24.3%	32.3%
F7R7	0.262	28.6%	33.2%
DR6	0.654	28.9%	35.3%
CR1	0.336	0.0%	0.0%
BR2	1.786	23.6%	69.5%
F11	2.943	0.3%	0.0%
G3R2	0.371	0.0%	36.7%
F3R3	1.317	30.1%	37.4%
F3R1	0.715	29.7%	36.8%
M1R9	0.773	0.0%	10.0%
A10	1.673	0.0%	0.0%
G11	6.957	4.0%	0.0%
DR16	1.921	18.6%	17.6%
HR2	0.435	0.0%	n/a
H3	40.535	0.0%	n/a
I	113.012	0.0%	4.8%
CR5	0.418	0.0%	10.0%
BR4	0.342	17.0%	25.7%
F62	2.023	0.0%	10.0%
DR11	0.571	29.9%	37.0%
F66	1.819	0.0%	10.0%
F61	1.619	0.0%	10.0%
G1R3	1.77	15.1%	74.7%
G2R5	0.733	30.2%	70.0%
E3R2	17.316	5.4%	57.2%
X1R3	1.234	29.2%	69.9%
G2R1	0.713	0.0%	27.1%
F1R3	0.388	25.8%	32.0%
LR1	3.012	0.0%	73.4%
BR5	1.145	24.8%	16.1%
F1R6	0.408	29.7%	31.4%
DR2	0.422	29.9%	31.3%
A6L21	0.213	0.0%	9.9%
A6L24	0.396	0.0%	10.1%
A6L28	0.364	0.0%	9.9%
A6L31	0.319	0.0%	10.0%
A6L35	0.319	0.0%	10.0%
A6L38	0.324	6.2%	9.9%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
A6L39	0.439	0.0%	10.0%
A6L40	0.476	0.0%	10.1%
A6L43	0.516	3.5%	10.1%
A6L44	0.496	0.0%	10.1%
A6L46	0.323	0.0%	9.9%
E13	19.156	0.0%	9.7%
E11	23.974	0.0%	11.4%
F51	4.048	0.0%	10.0%
F53	4.687	0.0%	10.0%
F47	0.806	0.0%	10.0%
F23	4.239	0.0%	5.2%
F27	2.048	0.0%	9.0%
F140	0.852	0.0%	10.0%
L4	3.834	0.0%	n/a
DR3	0.541	0.0%	33.6%
A5	83.82	0.0%	13.0%
A7	11.584	0.1%	7.2%
HR3	6.473	0.0%	n/a
A1	72.642	0.0%	0.0%
X1R4	3.868	0.0%	70.1%
F63	1.797	0.0%	10.0%
F64	1.488	0.0%	10.0%
A6R28	0.24	40.4%	10.0%
D12	2.776	0.0%	10.0%
H7	13.488	0.0%	3.8%
DR4	1.072	30.0%	36.8%
M1R2	1.425	30.0%	67.9%
E12	23.888	0.0%	9.0%
F81	1.294	0.0%	10.0%
G1R4	2.43	29.8%	70.0%
F129	1.418	0.0%	10.0%
A6L16	0.514	0.0%	9.9%
A6L19	0.262	0.0%	9.9%
A6L22	0.265	0.0%	10.2%
A6L25	0.429	0.0%	10.0%
A6L29	0.303	0.0%	9.9%
A6L30	0.493	0.2%	3.7%
G3R1	1.077	0.0%	26.9%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
F2R2	1.15	29.9%	37.7%
B1	5.129	0.0%	0.2%
BR7	0.767	28.2%	35.1%
J1	29.424	0.0%	n/a
D11	1.794	0.0%	18.8%
HR4	4.67	0.0%	67.3%
F21	2.626	0.0%	10.0%
A6L32	0.265	0.0%	10.2%
BR8	0.325	29.5%	70.2%
F4R4	0.817	29.7%	36.1%
F1R7	0.958	30.0%	36.8%
A6L36	0.293	0.0%	9.9%
A6L41	0.525	3.6%	10.1%
X1	49.36	1.8%	8.7%
A6L45	0.422	4.3%	10.0%
A6R10	0.297	31.6%	10.1%
A6R25	0.248	38.3%	10.1%
C1	62.882	0.0%	0.0%
DR5	0.235	28.9%	32.3%
BR9	0.63	30.2%	21.6%
A6L6	0.389	0.0%	10.0%
A6L8	0.506	0.0%	10.1%
A6L10	0.532	0.0%	10.0%
A6L12	0.446	0.0%	10.1%
A6L14	0.481	0.0%	10.0%
F7R4	0.203	41.9%	46.3%
BR10	0.721	24.8%	32.5%
R2	14.207	0.0%	0.0%
DR7	1.146	26.5%	36.6%
HR5	14.731	0.0%	59.7%
BR11	0.298	25.2%	30.2%
AR1	0.502	59.4%	42.4%
G2R3	0.799	0.0%	41.7%
E2R1	1.518	0.0%	31.8%
G1R6	0.887	34.8%	70.1%
LR2	0.441	0.0%	n/a
G12	31.352	0.0%	12.3%
H4	40.608	0.0%	3.1%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
F52	4.047	0.0%	10.0%
F42	5.603	0.0%	10.0%
F33	4.855	0.0%	10.0%
F211	0.645	0.0%	10.1%
F135	0.92	0.0%	10.0%
F141	0.897	0.0%	10.0%
L5	14.163	0.0%	n/a
HR6	0.717	29.8%	n/a
HR7	0.391	0.0%	n/a
G1R7	0.849	0.0%	10.2%
IR2	2.011	0.0%	n/a
E1R1	1.324	0.0%	30.0%
KR4	1.305	0.0%	n/a
F4R1	0.432	33.6%	39.4%
G31	2.629	0.0%	13.0%
A6L20	0.201	0.5%	10.0%
A6L23	0.254	0.0%	9.8%
A6L26	0.248	0.0%	10.1%
A6L33	0.293	0.0%	9.9%
A4	61.5	0.0%	14.3%
M1R3	1.011	0.0%	13.6%
C4	8.235	0.0%	0.0%
JR3	1.633	30.6%	69.3%
R1	13.767	0.0%	0.1%
F65	2.023	0.0%	10.0%
A6L37	0.286	0.0%	10.1%
A6L42	0.453	0.0%	9.9%
A6L47	0.535	3.4%	10.1%
M12	61.312	0.0%	9.5%
G1R8	2.473	0.0%	10.0%
BR12	0.397	31.0%	28.5%
BR13	0.78	22.9%	32.9%
CR10	2.452	0.1%	14.9%
F3R2	0.767	29.7%	34.3%
F5R3	0.448	29.5%	38.2%
A9	12.98	0.0%	19.3%
A9R	0.51	0.0%	10.0%
E2R2	10.656	0.0%	70.6%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
HR8	8.218	0.0%	n/a
A6L18	0.586	0.0%	10.1%
JR1	1.621	0.0%	n/a
IR3	0.399	0.0%	n/a
B6	19.099	0.0%	10.0%
D3	3.102	0.0%	10.0%
G21	11.88	0.0%	10.0%
F43	8.084	0.0%	10.0%
F34	7.331	0.0%	8.4%
F24	3.704	0.0%	10.0%
F29	0.981	0.0%	10.0%
X3	15.506	0.0%	0.0%
S1	5.872	0.0%	0.0%
KR6	0.339	0.0%	n/a
HR9	1.012	0.0%	n/a
HR10	0.952	0.0%	n/a
D4	8.752	0.0%	10.0%
D2	4.021	0.0%	8.3%
M21	3.972	0.0%	10.1%
M1R4	3.684	0.0%	10.9%
H1	8.007	0.0%	n/a
F54	2.019	0.0%	10.0%
F44	8.326	0.0%	10.0%
R3	56.679	0.0%	0.0%
F6R3	0.956	30.5%	38.1%
S5	2.702	0.0%	0.0%
H6	32.804	0.0%	n/a
G16	28.056	0.0%	7.6%
CR11	3.802	0.0%	0.0%
A6	36.236	0.0%	6.9%
D5	7.122	0.0%	8.3%
BR16	0.629	0.0%	10.0%
AR3	0.779	0.0%	10.0%
LR4	1.788	23.8%	n/a
F36	2.67	0.0%	0.1%
F25	2.91	0.0%	9.0%
F134	0.863	0.0%	10.0%
F6R1	1.084	2.0%	70.1%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
E1R3	2.321	30.5%	70.0%
G22	19.511	0.0%	5.2%
B12	22.616	0.0%	10.1%
F83	3.066	0.0%	22.3%
F124	1.419	0.0%	10.0%
F125	1.419	0.0%	10.0%
F130	1.419	0.0%	10.0%
A2	63.487	0.0%	7.7%
DR10	1.164	15.4%	23.4%
A6L48	0.496	0.0%	10.1%
A6R4	0.317	42.6%	10.1%
D10	11.855	0.0%	10.0%
D9	7.206	0.0%	6.3%
C2	28.66	0.0%	14.7%
X1R5	4.541	0.0%	69.8%
F117	6.041	1.2%	0.0%
A6R11	0.296	52.0%	35.1%
A8R	1.715	0.0%	15.3%
A6L27	0.246	0.0%	10.2%
A6L34	0.245	0.0%	10.2%
M1R6	1.482	30.2%	70.0%
G1R11	1.462	31.5%	70.1%
A6R18	0.316	50.3%	40.2%
HR11	3.246	30.0%	n/a
B8	6.362	0.0%	10.0%
B9	4.947	0.0%	10.0%
G15	60.803	0.0%	9.9%
F5R1	1.261	30.6%	70.1%
S4	7.567	0.0%	0.0%
K	61.564	0.0%	n/a
H5	25.652	0.0%	n/a
E2	51.367	0.0%	9.1%
F82	4.731	0.0%	10.0%
F72	1.138	0.0%	10.0%
F45	4.038	0.0%	10.0%
F132	0.711	0.0%	10.5%
F35	3.872	0.0%	3.4%
F136	0.894	0.0%	12.3%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
F139	0.482	0.0%	10.0%
M13	12.816	0.0%	0.0%
C6	50.039	0.0%	0.0%
D6	3.992	0.0%	10.0%
L6	12.019	0.0%	n/a
L3	2.186	0.0%	n/a
A6R24	0.663	30.6%	10.0%
A6R9	0.303	52.8%	37.0%
AR7	2.477	0.0%	12.2%
G1R12	2.821	30.1%	70.0%
X1R6	2.127	30.4%	63.4%
A6R21	0.247	39.3%	10.1%
F1R20	0.558	31.0%	37.1%
F4R2	1.487	30.7%	36.9%
JR2	3.252	0.1%	10.2%
F1R21	0.54	31.9%	38.3%
F4R3	1.054	30.6%	37.1%
A6R34	0.385	40.8%	10.1%
B7	15.423	0.0%	15.8%
H2	21.806	0.0%	n/a
G33	16.406	0.0%	10.0%
B10	21.779	0.0%	10.0%
F73	1.414	0.0%	10.0%
F75	5.458	0.0%	10.0%
R5	17.765	0.0%	10.7%
L2	8.402	0.0%	n/a
C5	12.227	0.0%	10.0%
A6R30	0.21	40.5%	10.0%
X1R7	3.236	0.0%	3.8%
F128	1.416	0.0%	10.0%
G14	36.236	0.0%	10.6%
F26	5.193	0.0%	10.0%
B11	25.751	0.0%	10.0%
F126	1.419	0.0%	10.0%
F131	0.994	0.0%	10.4%
M2R6	1.248	20.0%	69.6%
DR13	2.484	30.8%	70.0%
F28	0.787	0.0%	8.0%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
F137	0.895	0.0%	10.1%
L1	12.053	0.0%	n/a
F123	1.417	0.0%	10.0%
F138	0.493	0.0%	9.1%
D8	5.172	0.0%	10.0%
F133	1.278	0.0%	8.7%
S6	1.478	0.0%	0.0%
F71	0.853	0.0%	10.0%
D1	1.182	0.0%	10.0%
E3	33.896	0.0%	10.8%
X1R8	1.329	0.0%	47.1%
DR14	1.864	19.5%	70.1%
M22	29.736	0.0%	14.2%
F210	0.942	0.0%	10.0%
E3R1	2.255	0.0%	10.1%
F74	3.84	0.0%	10.0%
F120	1.518	0.0%	10.0%
M23	8.208	0.0%	12.6%
D7	17.844	0.0%	10.2%
F119	2.77	0.0%	0.0%
G1R13	7.31	0.0%	20.2%
G2R4	2.178	0.0%	16.0%
F2R7	3.632	1.0%	16.1%
M1R8	4.425	0.8%	20.5%
F2R8	1.734	21.9%	70.0%
F1R27	5.035	25.1%	70.0%
C3	70.794	0.0%	11.4%
F212	0.362	0.0%	9.9%
F121	1.479	0.0%	10.0%
F127	1.419	0.0%	10.0%
F122	1.464	0.0%	10.0%
DR15	4.148	0.0%	10.0%
DR9	4.96	0.1%	10.3%
B3	4.27	0.0%	0.0%
B2	3.244	0.0%	11.5%
B5	5.553	0.0%	0.0%
B4	2.691	0.0%	0.0%
CR4	2.103	8.2%	16.5%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
F1R8	0.244	31.1%	28.7%
F1R2	0.368	28.3%	34.5%
F48	2.803	0.0%	8.8%
CR2	7.792	0.0%	0.2%
R4	11.684	0.0%	1.7%
KR3	11.238	0.0%	69.0%
E1R4	4.81	0.0%	11.8%
E1R2	1.929	0.0%	10.4%
G1R2	2.805	0.0%	10.9%
G1R1	4.269	0.0%	10.8%
A6R7	0.526	47.5%	10.1%
A6R16	0.235	38.7%	10.2%
A6R17	0.206	36.9%	10.2%
A6R13	0.338	47.3%	10.1%
A6L1	0.496	33.7%	10.1%
A6R3	0.312	38.8%	9.9%
A6R22	0.298	39.3%	10.1%
A6R29	0.314	40.8%	9.9%
A6R6	0.319	41.4%	11.9%
M2R7	0.993	25.2%	29.8%
LR3	4.685	9.9%	40.0%
F8R2	2.069	23.8%	33.6%
F7R2	0.377	0.0%	10.1%
F1R1	1.532	20.8%	29.4%
F1R13	1.498	22.6%	31.2%
F1R4	1.163	28.1%	52.0%
F2R9	0.732	28.6%	34.0%
BR18	2.973	0.4%	11.4%
CR6	1.279	29.5%	37.4%
M1R1	1.424	0.0%	10.0%
DR8	3.758	1.0%	15.0%
F1R22	4.107	0.0%	17.4%
F1R24	4.385	0.1%	n/a
BR3	1.739	24.6%	64.1%
BR6	1.577	23.7%	65.0%
A6R2	0.563	41.0%	9.9%
A6R19	0.691	36.0%	10.0%
X4	14.599	4.5%	11.2%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
G32	9.186	0.0%	10.0%
X5	4.066	0.0%	0.0%
A6R12	0.239	42.3%	33.5%
A6R14	0.347	52.2%	37.8%
A6R1	0.261	39.1%	10.0%
A6R5	0.407	40.0%	10.1%
A6R8	0.33	40.3%	10.0%
A6R15	0.225	46.7%	10.2%
A6R20	0.306	34.3%	10.1%
A6R26	0.241	48.5%	10.0%
A6R27	0.222	47.7%	9.9%
A6R23	0.103	49.5%	9.7%
A6L3	0.94	0.0%	10.0%
A6L50	0.875	0.0%	9.9%
A6L51	0.825	0.0%	10.1%
A6L52	0.813	0.0%	10.0%
A6L53	0.501	0.0%	10.0%
A6L54	1.033	0.0%	10.0%
A6L55	0.328	0.0%	10.1%
A6L56	0.364	0.0%	9.9%
A6L57	0.307	0.0%	10.1%
Manjedal Brook 2	332.121	0.0%	0.0%
Manjedal Brook 4	400.31	0.2%	0.2%
Manjedal Brook 6	222.585	0.2%	0.2%
Manjedal Brook 1	316.157	0.0%	0.0%
Manjedal Brook 3	334.644	0.0%	0.0%
Manjedal Brook 5	216.283	0.0%	0.0%
Mardella Brook 2	353.781	1.2%	1.2%
Mardella Brook 1	392.596	0.4%	0.4%
Mardella Brook 3	321.076	0.9%	0.9%
Mardella Brook 4	250.445	0.3%	0.3%
Norman 2	97.526	0.0%	0.0%
Norman 3	136.319	0.0%	0.0%
Norman 1	82.354	0.0%	0.0%
WMI_C8b	29.113	n/a	2.5%
WMI_C11	16.968	n/a	0.2%
WMI_C9b	26.637	n/a	5.8%
WMI_C8t	22.022	n/a	0.2%

Catchment ID	Total area (hectares)	Impervious area (hectares)	
		Predevelopment	Post-development
WMI_C9t	32.569	n/a	8.0%
WMI_C5t	41.486	n/a	3.1%
WMI_C5b	28.263	n/a	2.2%
WMI_C4b	13.553	n/a	7.2%
WMI_C2b	16.417	n/a	14.2%
WMI_C12	18.015	n/a	13.3%
WMI_C12b	19.139	n/a	2.8%
WMI_C11b	7.959	n/a	0.3%
WMI_C14b	18.67	n/a	2.7%
WMI_C14	21.666	n/a	18.3%
WMI_C10	9.124	n/a	2.6%
WMI_C10t	21.04	n/a	4.8%
WMI_C13	19.209	n/a	0.1%
WMI_C6	46.017	n/a	8.3%
WMI_C1	19.929	n/a	2.0%
WMI_C4	13.786	n/a	6.4%
WMI_C2	15.445	n/a	7.7%

Runoff parameterisation

Consistent with the recommendations of ARR2019, modelling of the study area includes three different surface types:

Effective Impervious Areas (EIA): These are Impervious areas that are directly connected to a modelled part of the drainage system, eg areas draining into drains or storages.

Road surfaces within the study area are modelled as effective impervious areas with 2mm initial loss and zero continuing loss.

Indirectly Connected Areas (ICA): This includes a mix of pervious and impervious areas that are not directly connected to the drainage system – eg: residential lots with soakwells or footpaths in road reserves that drain to adjacent pervious areas.

Existing rural and large peri-urban residential lots and road verges are modelled as indirectly connected areas with an initial loss of 15mm, assuming no direct drainage connection has been provided, and continuing loss of 2.1mm/hr consistent with cleared but otherwise unimproved rural land.

More recently developed urban residential and industrial lots and road verges are modelled as indirectly connected areas with an initial loss of 15mm, assuming on-site management of small rainfall events, and continuing loss of 4mm/hour, assuming the use of clean imported fill.

Pervious areas: Because urban pervious areas are considered as part of the ICA, this surface type is reserved for undeveloped rural pervious areas.

Modified regional initial and continuing loss rates determined during calibration have been applied to undeveloped rural land within the study area:

- Initial loss – 25 mm
- Continuing loss (Vegetated areas) – 5.9 mm/hr
- Continuing loss (Cleared pasture areas) – 2.1 mm/hr

A summary of model hydrological parameters used in the study is provided in Table 25.

Table 25: Summary of model hydrological parameters

Parameter	Unit	
Catchment roughness (Manning's N)		
Rural pervious areas (vegetated)	-	0.130
Rural pervious areas (cleared)	-	0.040
Indirectly connected areas (ICA)	-	0.035
Effective impervious areas (EIA)	-	0.025
Hydraulic roughness (Manning's N)		
Natural waterways	-	0.050
Vegetated open swales/drains	-	0.040
Culverts and piped drainage	-	0.015
Initial Loss		
Rural pervious areas	mm	25
Indirectly connected areas (ICA)	mm	15
Effective impervious areas (EIA)	mm	2
Continuing loss		
Rural pervious areas (vegetated)	mm/hr	5.9
Rural pervious areas (cleared)	mm/hr	2.1
Indirectly connected areas (ICA) – rural	mm/hr	2.1
Indirectly connected areas (ICA) – urban	mm/hr	4
Effective impervious areas (EIA)	mm/hr	0
Infiltration rate		
Existing storage basins	m/day	1

Local Drainage System

The model domain is traversed by a network of local urban and agricultural drains that feed into Oaklands Main Drain which is a more significant rural drain that flows westwards alongside Mundijong Road and discharges into the Birrega Main Drain which ultimately joins the Serpentine River.

Culverts on waterways and local agricultural drains, together with open swales and piped drains in urban areas have been built into the model as a 1D network. The dimensions and invert levels for local drains have been obtained, where possible, from the Shire of Serpentine-Jarrahdale's drainage asset database. Where data was found to be missing or unreliable, invert levels and dimensions were inferred based on upstream and downstream available data supported by a review of LiDAR information.

The 1D model network is presented in Figure 23.

Study area 2-dimensional model domain (predevelopment)

The study area 2-dimensional model domain has a total area of over 2,800 hectares and extends sufficiently to allow representation of flooding of roads and rural land from of the local drainage system and defined waterways and minimise the risk of edge effects at boundaries.

Model topography

Model topography was developed based on the Swan Coastal Plain 1m LiDAR digital terrain model (DTM). The modelled DTM is presented in Figure 24.

The DTM was used within the model to directly generate the variable mesh elements based on local slope. Heights at the vertices of the generated mesh elements were calculated by interpolation from the DTM.

The model domain is constructed as a Shewchuk Triangle variable mesh with maximum and minimum triangle areas of 5m and 100m respectively. The mesh varies according to the local terrain, resulting in a smaller mesh in steeper parts of the domain. Figure 23 presents the model domain and basic structure. A global eddy viscosity of 1.33 m2/s was applied throughout the model domain.

Infiltration and inundation

Infiltration was varied across the model domain based on soil type from Department of Primary Industries and Regional Development (DPIRD) drainage potential mapping and groundwater inundation based on the average annual maximum groundwater level (Scenario S0) from Lower Serpentine groundwater modelling (Hall et al, 2010).

These datasets are presented in Figure 25. Four infiltration rates were applied within the model, these were:

- Inundated areas and roads – zero infiltration
- Urban lots – 2mm/hour (assumes implementation of WSUD for onsite infiltration)
- Poorly draining soils – 0.2 mm/hour
- Well-draining soils (rural lots and reserves) – 2.1mm/hour

Surface Roughness

After losses due to infiltration have been accounted for and depression storage has been used up, the flow of runoff across the model domain is controlled by slope and surface roughness. Roughness values were applied to the model domain based on an assessment of land use and vegetation cover shown in Figure 26. Five different roughness rates (applied as Manning's N) have been modelled, which are:

- Roads – 0.025
- Urban lots – 0.060
- Pasture/rural lots – 0.040

- Vegetation – 0.130
- Drainage channels – 0.050

Outflow Boundary Conditions

Model outflow boundaries are set to 'normal' flow conditions, meaning that it is assumed that slope balances friction forces (normal flow). Depth and velocity are kept constant when water reaches the boundary, so water can flow out of the domain without losses.

Design simulations

Rainfall

Rainfall for design events were developed using *Australian Rainfall and Runoff* (ARR2019) and BoM (2016) IFD ensemble methodology resulting in an ensemble of 10 rainfall simulation events for each design storm. Ensembles were generated for 1EY, 20%, 10%, and 1% AEP events of 30min, 1hr, 3hr, 6hr, 12hr, and 24hr durations.

Critical duration events were selected based on a review of the ensemble mean peak discharges from upstream catchment inflows to reduce the number of simulations required to be run with the full 2-dimensional domain in place and these events have been used in subsequent model simulations.

Pre-development model performance

Downstream discharge hydrographs for the critical 6-hour duration 1% AEP event, are shown in Chart 9.

Figure 27 presents the maximum extent and depth of inundation within the 2-Dimensional model domain for the critical 6-hour duration 1% AEP event.

Post-development modelling

A post-development model scenario, incorporating modified land uses consistent with the district structure plan and approved local structure plans.

A post-development digital terrain model, shown in Figure 28, was also developed based on the following assumptions applied to development precincts:

- New urban roads and selected proposed POS areas elevated as required to achieve 0.6m vertical separation from the average annual maximum groundwater level (Scenario S0) from Lower Serpentine groundwater modelling (Marilllier et al, 2012).
- New urban residential and industrial lots and schools elevated as required to achieve 1.2m vertical separation from the average annual maximum groundwater level (Scenario S0) from Lower Serpentine groundwater modelling (Marillier et al, 2012).

Downstream discharge hydrographs for the critical 6-hour duration 1% AEP event, are shown in Chart 10.

Figure 29 presents the maximum extent and depth of inundation within the 2-Dimensional model domain for the post-development critical 6-hour duration 1% AEP event.

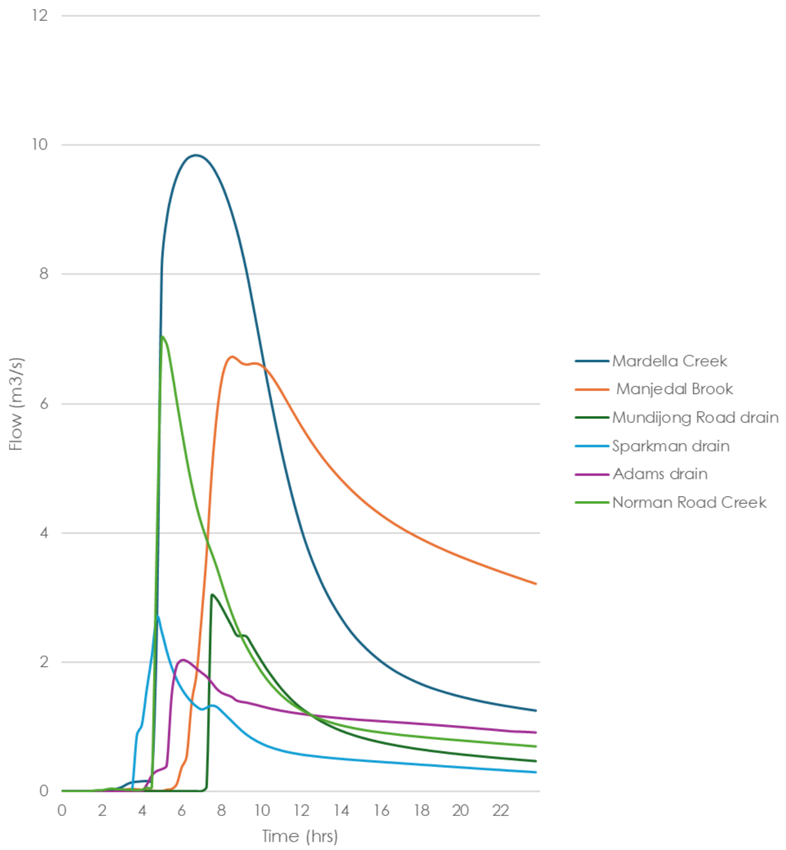


Chart 9: Predevelopment discharge hydrographs

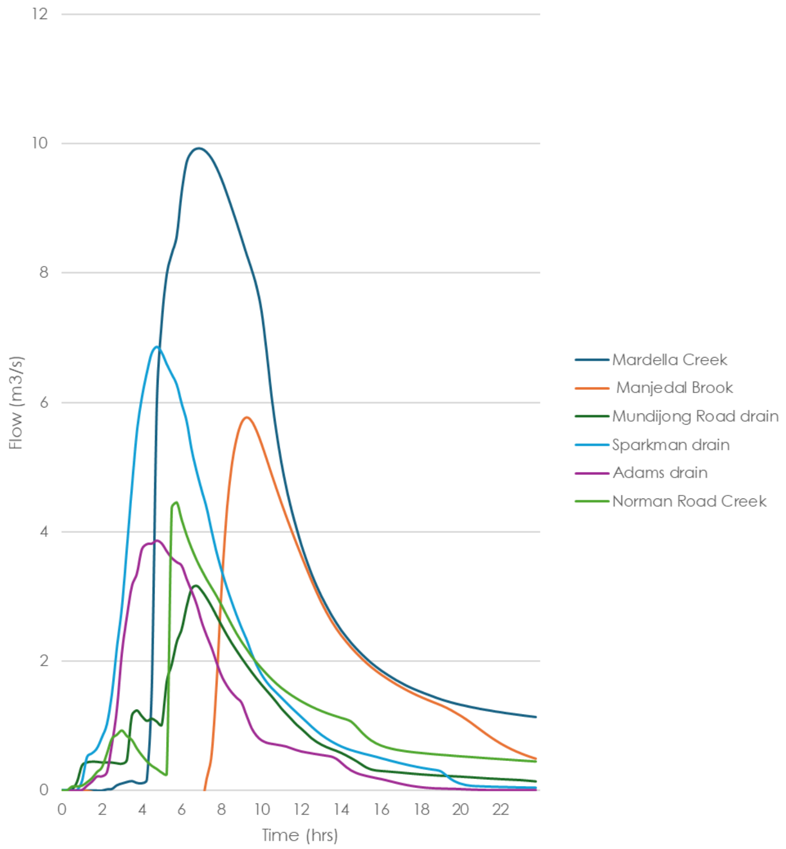


Chart 10: Post-development discharge hydrographs

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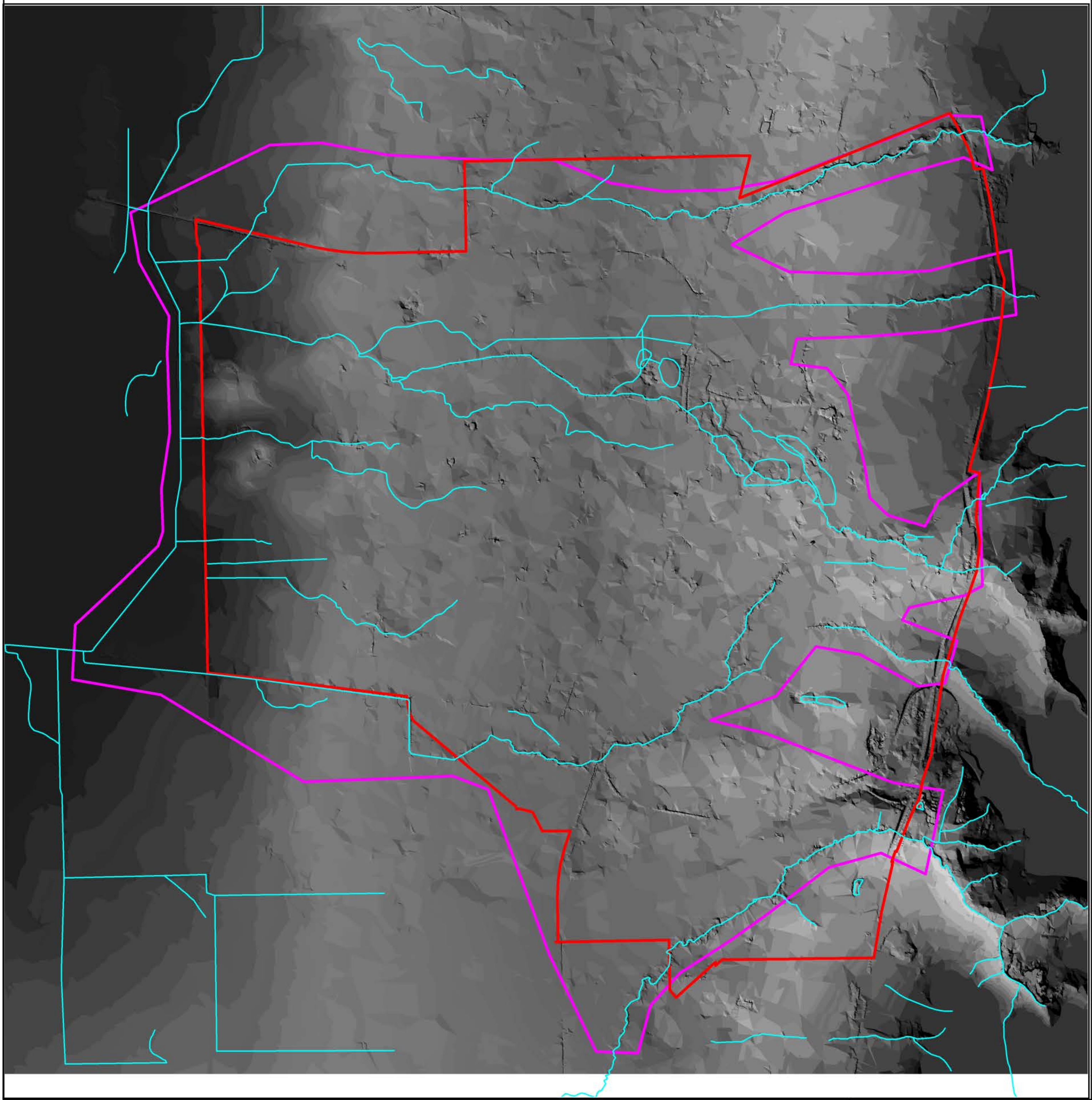
Figure 24 - Digital terrain model



LEGEND:
Study area boundary
Cadastre
2D model domain
Drainage
Predevelopment model node
Predevelopment model conduit

Data source: Landgate, Created by: HB Projection: MGA: zone 50.

N

0 800
metres
Scale 1:40,000 @ A4

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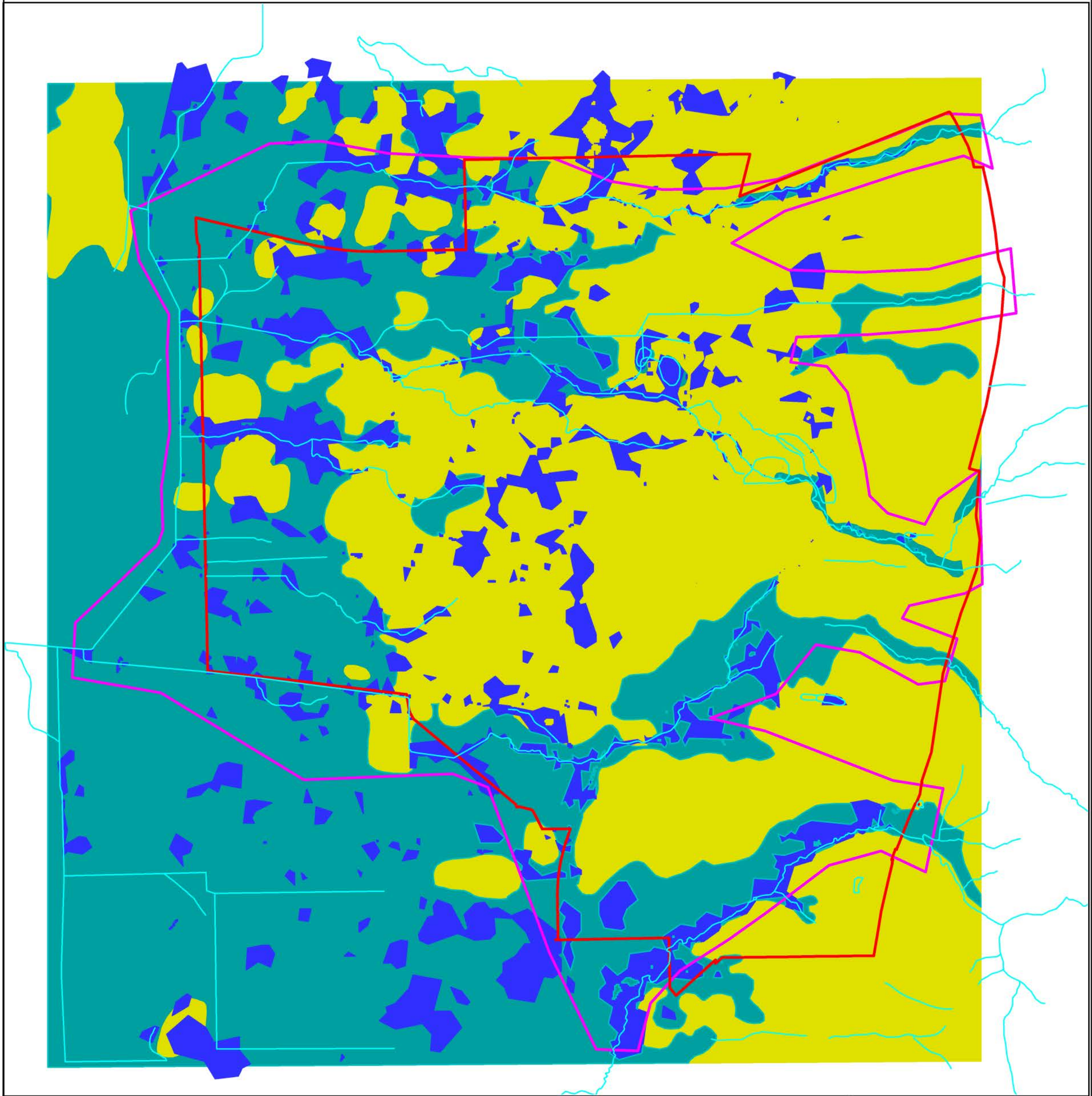
Figure 25 - Infiltration zones



LEGEND:

- Study area boundary
- Cadastre
- 2D model domain
- Drainage
- Predevelopment model node
- Predevelopment model conduit

Infiltration zones

- Inundated
- Well draining
- Poorly draining

Data source: Landgate, Created by: HB Projection: MGA: zone 50.

N

0 800
metres
Scale 1:40,000 @ A4

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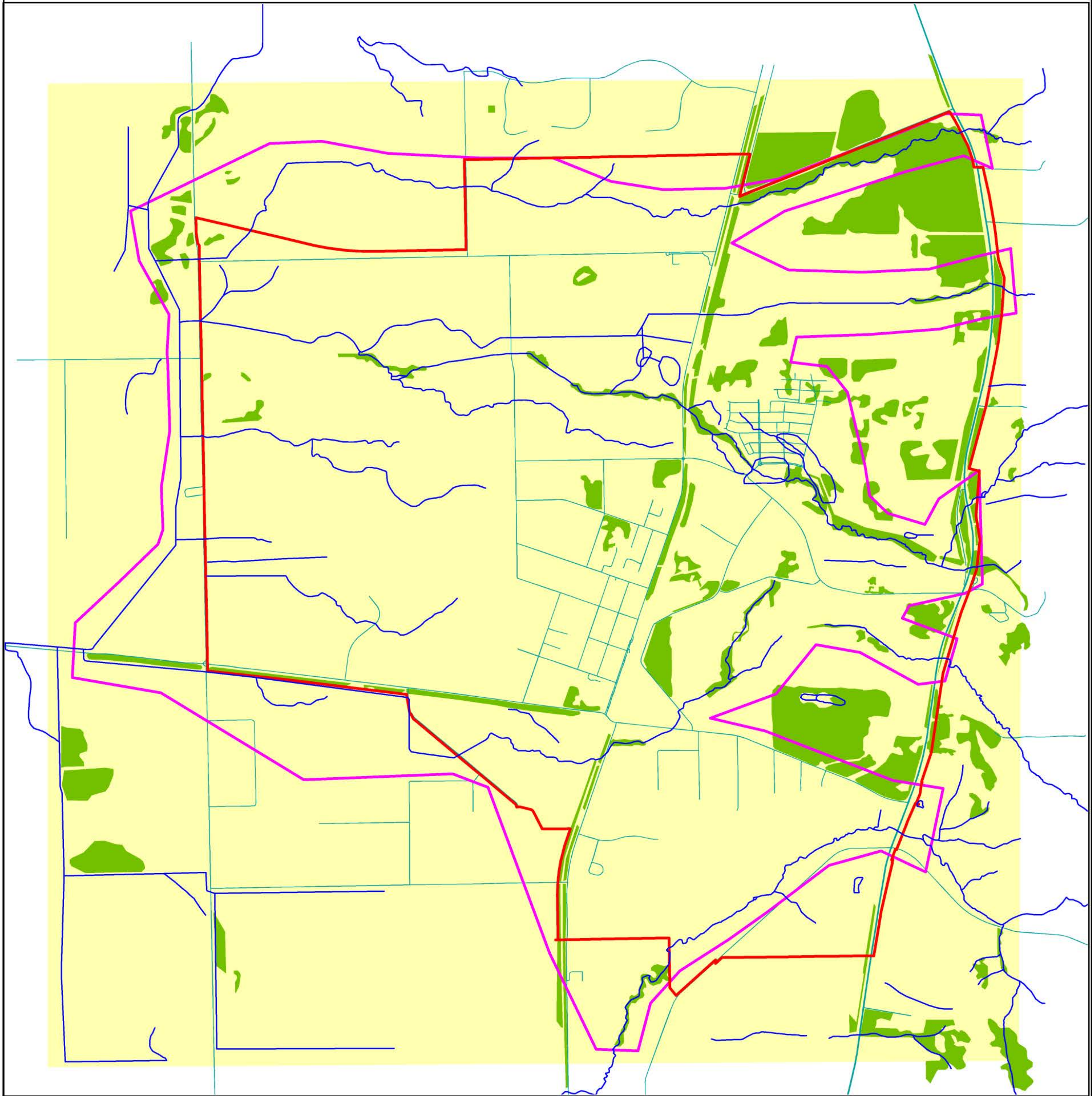
Figure 26 - Roughness zones

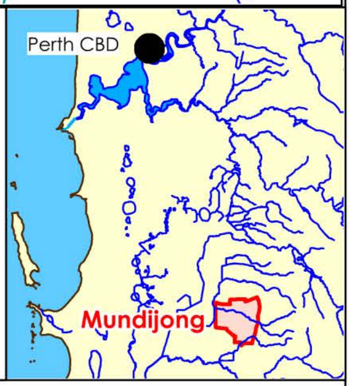


LEGEND:

- Study area boundary
- Cadastre
- 2D model domain
- Predevelopment model node
- Predevelopment model conduit

Roughness zones

- Pasture
- Vegetation
- Drainage
- Road



Data source: Landgate, Created by: HB Projection: MGA: zone 50.

N

0 800
metres

Scale 1:40,000 @ A4

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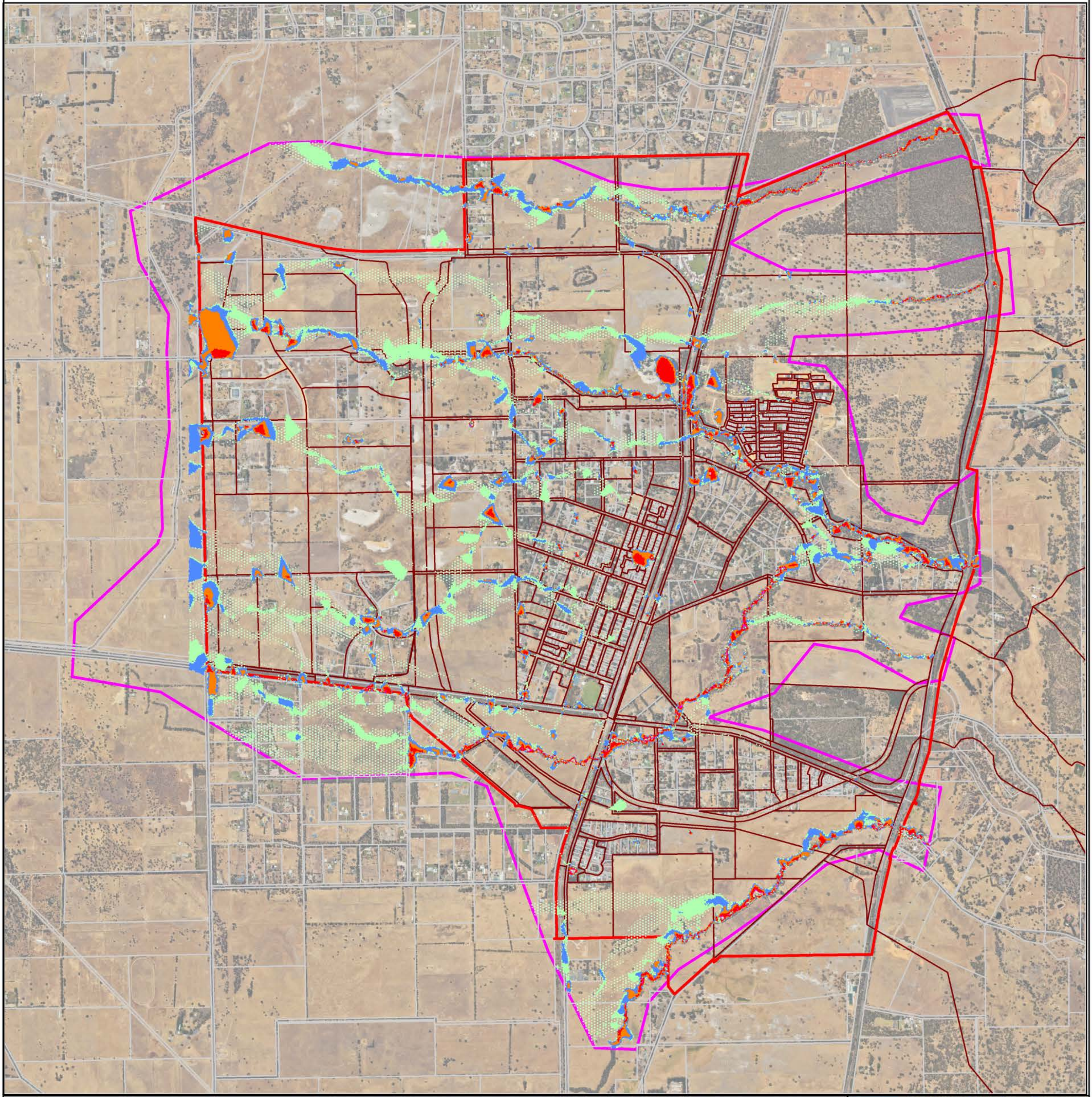
Figure 27 - Predevelopment extent and maximum depth of inundation



LEGEND:

- Study area boundary
- Cadastre
- 1D model subcatchment
- 2D model domain
- Predevelopment model node
- Predevelopment model conduit

Depth of inundation

- >1m
- 0.5 to 1
- 0.3 to 0.5
- 0.1 to 0.3
- 0.05 to 0.1
- <0.05m

Data source: Landgate, Created by: HB Projection: MGA: zone 50.

N

0 800
metres
Scale 1:40,000 @ A4

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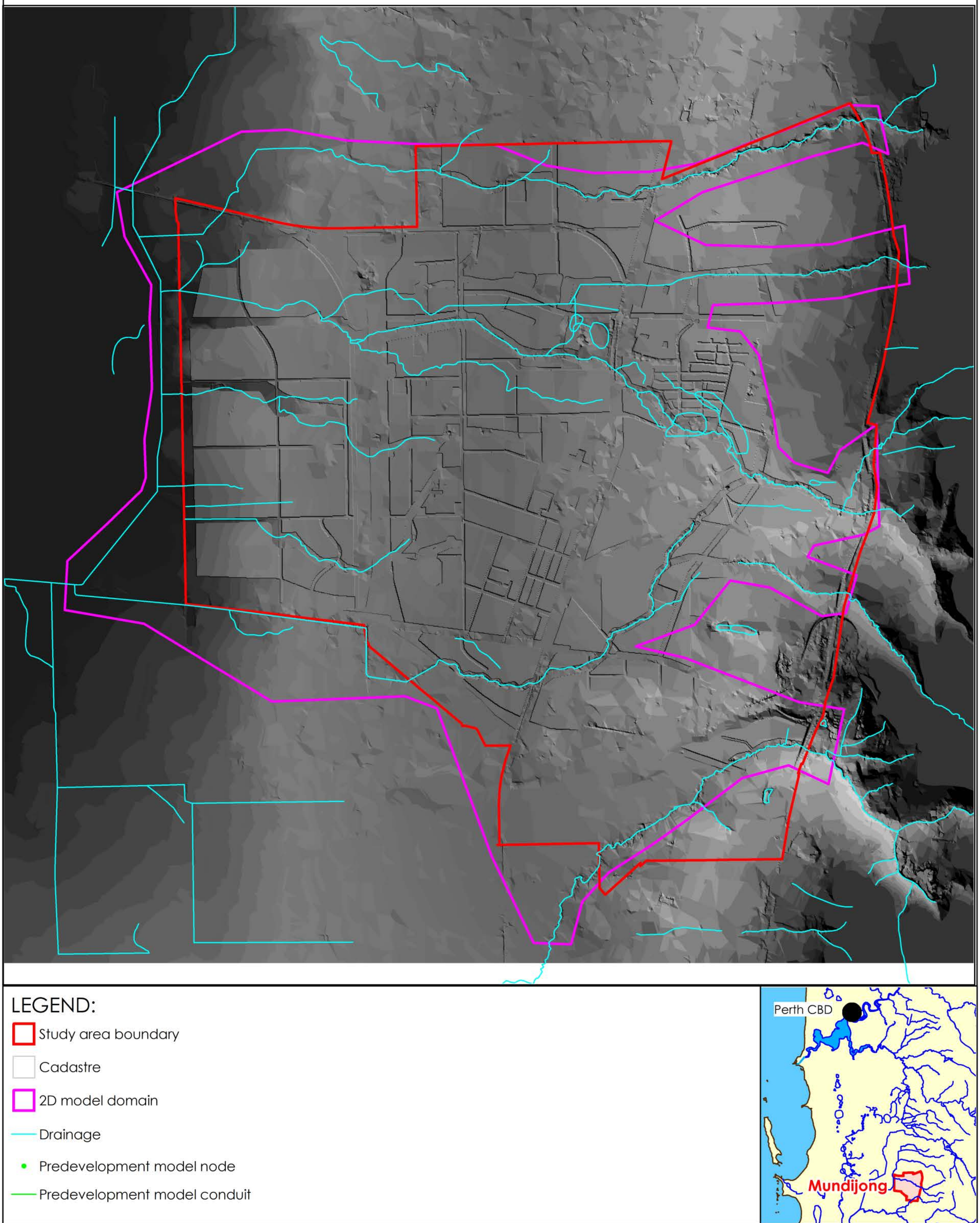
Figure 28 - Post-development digital terrain model



Data source: Landgate, Created by: HB Projection: MGA: zone 50.

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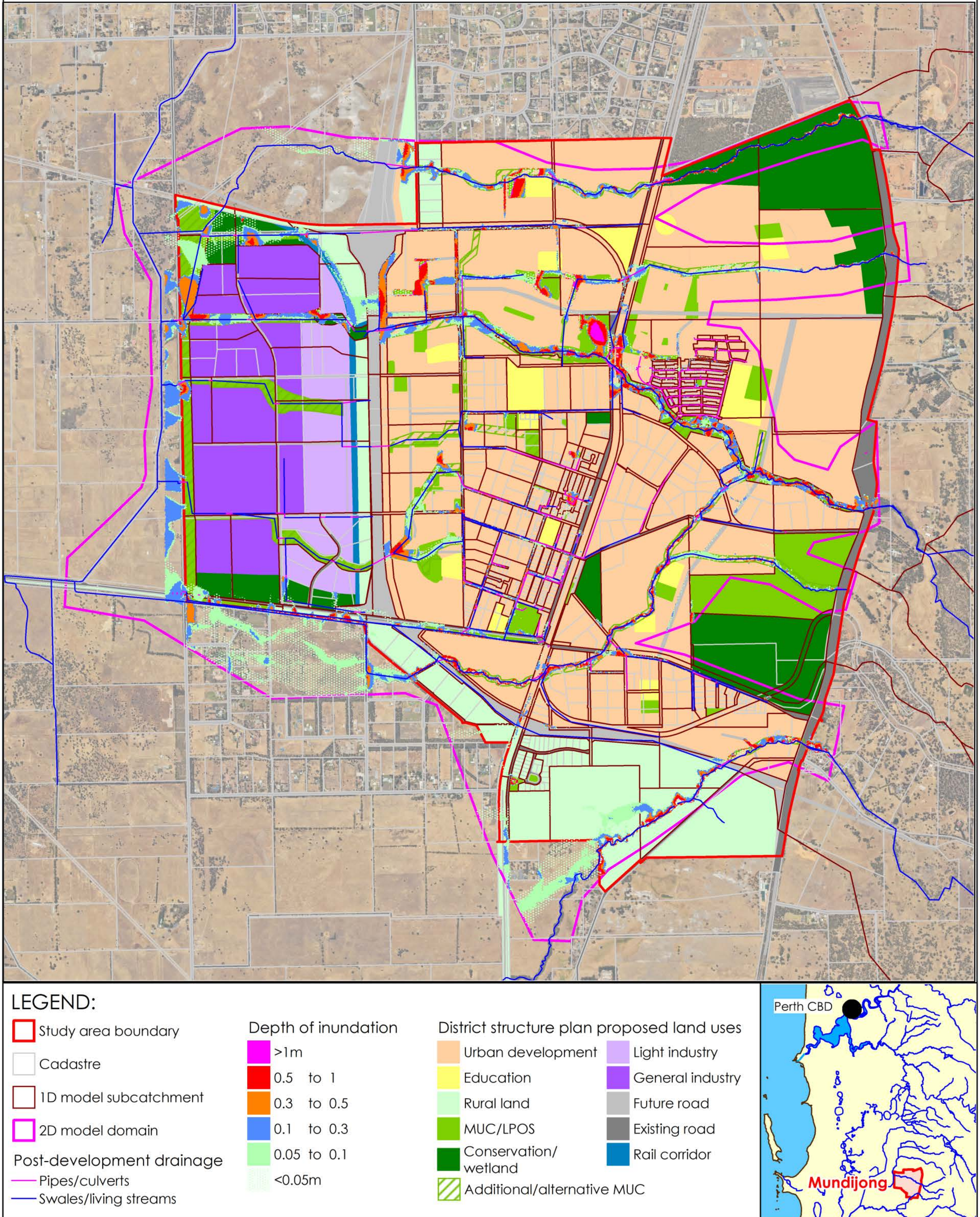
Figure 29 - Post-development extent and maximum depth of inundation



Data source: Landgate, Created by: HB Projection: MGA: zone 50.

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Client: Shire of Serpentine-Jarrahdale

Report	Version	Prepared by	Reviewed by	Submitted to Client	
				Copies	Date
Preliminary draft	V1	HB		Electronic	November 2024
Final draft	V2	HB	SSh	Electronic	November 2024
Revised final draft	V3	HB	SSh	Electronic	December 2024
Final report	V4	HB	SSh	Electronic	January 2025

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