Government of **Western Australia**
Department of **Water**

Murray drainage and water management plan

Looking after all our water needs

Drainage and water management plan 4
June 2011

Department of Water

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CD

A CD containing this document and all attachments is available from the department.

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Murray River, looking towards South Yunderup

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Hydrological studies

Hall, J, Kretschmer, P, Quinton, B & Marillier, B 2010a, Murray hydrological studies: *Surface water, groundwater and environmental water – conceptual model report*, Water Science Technical Series, report no. 16, Department of Water, Western Australia.

Hall, J, Kretschmer, P, Quinton, B & Marillier, B 2010b, *Murray hydrological studies: Surface water, groundwater and environmental water – model construction and calibration report*, Water Science Technical Series, report no. 25, Department of Water, Western Australia.

Hall, J, Kretschmer, P, Quinton, B & Marillier, B 2010c, *Murray hydrological studies: Surface water, groundwater and environmental water – land development, drainage and climate change scenarios report*, Water Science Technical Series, report no. 26, Department of Water, Western Australia.

Kretschmer, P, Wallace-Bell, P & Hall, J 2011, *Murray hydrological studies: Surface water, groundwater and environmental water – acid sulfate soil risk assessment*, Water Science Technical Series, report no. 30, Department of Water, Western Australia.

Ecological water requirements to selected wetlands

GHD 2010b, *Ecological water requirements for selected wetlands in the Murray drainage and water management plan area*

GHD 2010c, *Wetland flora survey*

GHD 2010d, *Native fish and amphibian survey*

GHD 2010e, *Stygofauna baseline survey*

Nutrient studies

Kelsey, P, Hall, J, Kretschmer, P, Quinton, B & Shakya D 2011, *Hydrological and nutrient modelling of the Peel-Harvey catchment*, Water Science Technical Series, report no. 33, Department of Water, Western Australia.

Kelsey, P, King, L & Kitsios, A 2010, *Survey of urban nutrient inputs on the Swan Coastal Plain*, Department of Water, Western Australia.

Managed aquifer recharge

Kretschmer, P, Christie, E, Fisher, S, Marillier, B & Reitsema, T 2011, Feasibility of managed aquifer recharge using drainage water – draft, Water Science Technical Series, report no. 38, Department of Water, Perth.

Acknowledgement of Noongar country and people

Peel Inlet & Point Birch looking West towards Dawsville Cut

Noongar people have lived in south-western Australia for tens of thousands of years. The Perth-Peel region is within Noongar country and Noongar people continue to be its custodians. The Department of Water welcomes and respects the involvement of the Noongar community in the region's water planning and management. The South West Aboriginal Land and Sea Council and the department organised workshops with local Noongar Elders to capture their views on water planning and management in the Perth-Peel region. A statement that arose out of these workshops provides insight into the Noongar people's unique connection and perspective on the region's water resources. Following are some excerpts from the statement:

"We are part of Australian culture and have been for time immortal in the Perth-Peel region. Noongar people of the south-west of Western Australia know how our Dreaming explained the creation of the environment and the relationships between its parts. The Dreaming describes our philosophy of life. We live by this and take our responsibility in our environment seriously. Sun, water, humans, other animals, plants, rain, water and wind are inextricably associated in maintaining balance in ecosystems. Binjareb, Wadjuk and Yued people from various Boodjar (country) in the Perth-Peel region link into a wider community of Noongar peoples and further to other connected Aboriginal groups.

Noongar knowledge is owned by a collective and has developed over many generations. We as a collective of custodians wish to share our knowledge to manage water resources into the region's future. In the Perth-Peel region, geographical features and places with energy mark lived experiences of our ancestral spirits' journeys throughout Noongar country. These sites are the foundations of our culture and as custodians we have most important knowledge of sites and the associated activities. They are fundamental to the sense of self. Our ancestral spirits followed pathways to sites, along waterways, forming a strong connection with the land and water. Sacred sites and sites of significance are an integral part of Noongar culture. They are places that bear the marks of Noongar creative spirits, who continue to have a presence in land formations and water.

Life in our rivers needs space in order to flow freely and flourish. In Noongar ways of caring for Boodjar, to destroy or damage a site is a distressing and dangerous act, which threatens not only living and unborn generations, but also the spiritual forces and order of the world. Our intent as Noongar people is to protect and maintain our living cultural heritage by addressing the impacts of misuse of the Perth-Peel region water systems."

Summary

Serpentine River and Lake Amarillo

The challenges

Urban development in the *Murray drainage and water management plan* area will face many challenges. The area comprises a series of inter-connected wetlands, lakes, rivers and groundwater aquifers that contribute to the highly complex and internationally important hydrology and ecology of the Peel-Harvey estuary catchment.

The area's natural complexities (and the resulting challenges surrounding any development proposals) are compounded by the legacy of agricultural land uses that were once widespread. To facilitate these land uses, drainage systems designed to lower groundwater and drain wetlands and seasonally inundated areas were introduced. In addition, decades of fertiliser application has resulted in high levels of nutrients within the soils and shallow groundwater.

The Environmental Protection Authority recognised the impact of nutrients on the Peel-Harvey system in its *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008). This report quantified the required improvements and outlined expectations for all government and private activities in the catchment to positively contribute to achieving them.

The plan area's prevailing environmental condition, particularly during winter, consists of excess water coupled with limited availability of allocated water resources that are traditionally considered 'useable'.

Both the limited water availability and the seasonally wet landscape that supports critically important ecological systems present enormous challenges from an urban development perspective.

Inappropriate development of this land could result in residential areas prone to seasonal inundation by shallow groundwater, significant flooding during major storm events or extreme tidal conditions and storm surges – all of which would represent a substantial risk to human life and property.

Historically such areas were bypassed for urban development in favour of higher, drier and easier prospects.

Past attempts to modify the wetter, low-lying areas – including deep drainage, river training and filling wetlands to rapidly and permanently dispose of shallow groundwater – have resulted in a poor environmental and economic legacy.

It is the responsibility of all proponents of development to respond to the expectations of the *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008), ensuring that nutrient rich shallow groundwater is not drained to the downstream environment without suitable treatment and that a positive contribution is made to achieving the required nutrient load reductions to the Peel-Harvey system.

A new policy position

Rather than suggest the associated challenges make sections of the plan area unsuitable for urban development, the Department of Water considers that with sufficient initiative, effort and investment, they may be possible to overcome. Thus the landscape would become more suitable for urban development from a water management perspective – provided that the principles and strategies in this document are adhered to.

Water sensitive urban design as a response to total water-cycle management has been a development requirement for some time; however, any proposals in this plan area would have to consider more carefully how water in the landscape is managed and a new benchmark would have to be established.

Similarly, the use of groundwater as a fit-for-purpose water source is commonplace in Western Australia, but in this plan area new challenges need be to overcome. These relate to making use of shallow groundwater reserves that have not normally been considered a useable resource in the past. One potential solution the Department of Water is committed to investigating is managed aquifer recharge. This will allow water that was previously thought to be unusable, to be stored for later redistribution using a fit-for-purpose principle.

The department wants to encourage innovative solutions to these problems by facilitating policy change where necessary and contributing to investigations.

This *Murray drainage and water management plan* differs from earlier drainage and water management plans in both structure and content. Even though several of the plan's supporting technical studies have provided development and climate change scenarios to inform new management strategies and design criteria, no post-development infrastructure has been sized or otherwise designed for the following two reasons:

- at this stage in the development process there are few definite proposals or designs on which to base post-development infrastructure
- the Department of Water wishes to encourage innovation in design and allow proponents to take individual development approaches.

Document layout

Section 1, the Introduction, provides the scope and intent of the document.

Section 2, the Environmental Context, establishes the status of the existing environment and discusses the outcomes of technical studies undertaken in support of this plan.

Section 3, Principles and Strategies, defines the plan's three key principles; then outlines the strategies to deliver each of the principles in the context of existing environmental conditions:

Key Principle 1: Manage catchments to maintain or improve water resources

Strategy 1.1	Minimise changes to hydrology
Strategy 1.2	Maintain or improve water quality
Strategy 1.3	Manage and restore waterways and wetlands
Strategy 1.4	Safeguard the quality and availability of water resources for the future

Key Principle 2: Manage flooding and inundation risks to human life and property

Strategy 2.1	Provide adequate clearance from 1-in-100 annual exceedance probability flooding and surface or groundwater inundation
Strategy 2.2	Do not cause flooding or inundation of upstream or adjacent developed areas
Strategy 2.3	Manage surface water flows to prevent damage to downstream infrastructure and assets

Key Principle 3: Ensure the efficient use and re-use of water resources

Strategy 3.1	Minimise water use within developments
Strategy 3.2	Achieve highest-value use of fit-for-purpose water, considering all available forms of water for their potential as a resource
Section 4	(the Toolbox) provides advice, additional guidance and in some cases design criteria that link to the principles and strategies – helping development proponents deliver beneficial water resource outcomes.

T.1 Stormwater best practice

T.2 Monitoring best practice

T.3 Groundwater best practice

T.4 Wetland and waterway management best practice

T.5 Water re-use and efficiency best practice

Chapter One

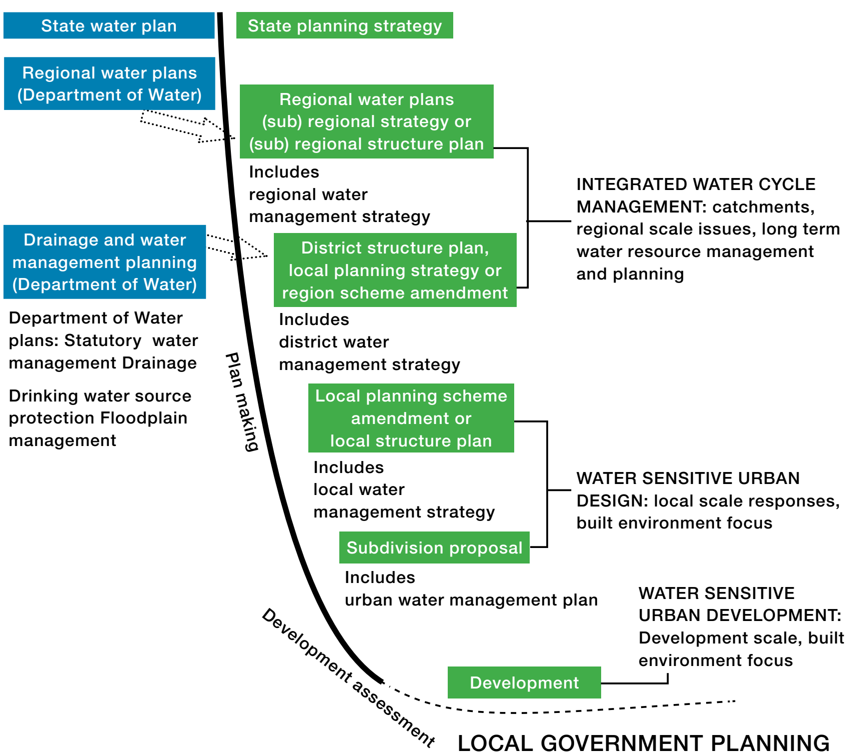
Introduction

Murray River and Serpentine River, looking east from Peel Inlet

This *Murray drainage and water management plan* fits within the water planning framework of the Department of Water. Under this framework, state and regional water plans set the strategic context and more detailed water management plans (such as allocation plans, water source protection plans and drainage and water management plans) provide more specific direction.

This plan outlines the department's direction on how water in the plan area should be managed, in response to the development proposed in the *South metropolitan-Peel structure plan* (WAPC in preparation).

The position of this plan within the state government planning framework is defined in Better urban water management (WAPC 2008a) and Planning bulletin no. *92, urban water management* (WAPC 2008c) and is outlined in Chart 1.



Note: The above diagram depicts the optimal process. In situations where there is existing zoning and a lack of guiding information, a flexible approach to implementation may be required. This is at the discretion of the Western Australian Planning Commission on advice of the Department of Water

Chart 1: Planning framework, integrating drainage planning with the land planning process (WAPC 2008)

Several supporting technical documents inform this plan's strategies and management principles, including:

- *Murray floodplain development strategy* (GHD 2010a)
- *Ecological water requirements for selected wetlands in the Murray drainage and water management plan area* (GHD 2010b)
- *Murray hydrological studies: Surface water, groundwater and environmental water* – suite of reports (Hall et al. 2010a–c)
- *Hydrological and nutrient modelling of the Peel-Harvey catchment* (Kelsey et al. 2010).

The plan has also been informed by the following report, which reviews the plan area's environmental characteristics in detail:

- *State of play, Peel-Harvey eastern estuary catchment environmental assessment discussion paper* (URS 2008).

1.1 Purpose of the plan

This plan aims to facilitate developments that embrace total water-cycle management principles and water sensitive urban design (WSUD) best-management practices. It provides a framework for future planning and development proposals and their associated (subsequent) site-specific water management strategies and plans. The plan has been undertaken at a subregional scale and does not absolve development proponents from undertaking detailed design studies and meeting all other statutory requirements, and investigating and incorporating relevant policies, by-laws and guidelines.

1.2 Scope of the plan

Total water-cycle management, also referred to as integrated water-cycle management, 'recognises that water supply, stormwater and sewage services are interrelated components of catchment systems, and therefore will need to be dealt with using a holistic water management approach that reflects the principles of ecological sustainability' (DoE 2004, Ch. 2, p. 14).

The scope of this plan is to provide direction on key aspects of total water-cycle management, including:

- protection of environmental assets and water resources, including meeting their water requirements and managing potential impacts from development
- consideration of the potential impacts of climate change
- water supply and demand management including options for efficiency, re-use, stormwater harvesting, aquifer recharge and the potential to use groundwater as a resource
- aspects of wastewater management surrounding the potential water quality impacts of septic tanks and options for re-use

- surface water, including flood management and the application of WSUD principles
- groundwater, including the impact of urbanisation, and options to manage groundwater levels
- water quality management, which includes acid sulfate soil management and control of catchment inputs from diffuse and point sources.

1.3 How to use the plan

This plan differs from earlier drainage and water management plans in both structure and content. Even though several of the plan's supporting technical studies have provided development and climate change scenarios to inform new management strategies and design criteria, no post-development infrastructure has been sized or otherwise designed for the following two reasons:

- at this stage in the development process there are few definite proposals or designs on which to base post-development infrastructure
- the Department of Water wishes to encourage innovation in design and allow proponents to take individual development approaches.

To avoid repetition, the plan's principles and strategies are discussed separately to its context. This structure may not always result in a perfect alignment of themes; thus the document is colour-coded to help readers navigate from the context to the principles and strategies, and to the Toolbox.

Section 2 discusses the environmental context of the plan area (Figure 1, Appendix A), including the key findings of recent technical studies. These are the environmental constraints that need to be overcome for development to proceed.

Section 3 establishes the principles central to the plan's development. These principles are linked to the objectives of the draft Perth-Peel regional water plan 2010–2030: responding to our drying climate (Department of Water 2009). This chapter also outlines the water management strategies for adhering to these principles. The Department of Water requires all development proponents to demonstrate compliance with these strategies when preparing subsequent water management strategies and plans.

Finally, Section 4 contains a Toolbox with further advice, guidance, and links to other material in support of the strategies presented in Section 3.

1.4 Implementation of this plan

The principles and strategies contained within this plan should be implemented as part of land use planning and development and are consistent with the framework and requirements in *Better urban water management* (WAPC 2008). This plan provides subregional pre-development water information and post-development objectives that should be addressed by proponents during the subsequent stages of the planning process. The planning process becomes more detailed as it progresses through regional, district and local planning to subdivision stage. This process, as well as details of the documentation required to address water management issues at each planning and development stage, is presented in *Better urban water management* (WAPC 2008) and the following publications, available from the department's website <www.water.wa.gov.au>:

- *Interim: Developing a local water management strategy (Department of Water 2008)*
- *Urban water management plan: Guidelines for preparing plans and complying with subdivision conditions (Department of Water 2008)*.

Each stage of the planning and development process will require consultation with the Department of Water and the relevant local government authority. We recommend this occurs at an early stage in the development of each water management document, to ensure accurate interpretation of the requirements and support for the proposed strategies and outcomes. Consultation may also be required with other drainage, water and wastewater service providers.

Discussions with development proponents and other agencies will lead to further clarification of the implementation requirements needed to safely and sustainably develop this difficult area.

Table 1 summarises the roles and responsibilities relating to implementation of this plan:

Table 1 Implementation roles and responsibilities

Implementation action	Responsible agency	Timeframe
Management of planning process including development of South Metropolitan-Peel structure plan consistent with this drainage and water management plan	Western Australian Planning Commission	2011–12
Assessment of water management strategies and plans	Shire of Murray with support from Department of Water	Ongoing
Arterial drainage planning for: • Winter Brook • Buchanans Drain	Department of Water/ Department of Planning/Shire of Murray	2011
Management of future revisions to arterial drainage plans	Shire of Murray with support from Department of Water	Ongoing

Management of future revisions to flood modelling	Department of Water	Ongoing
Investigations into suitability of managed aquifer recharge in the Murray DWMP area	Department of Water	2011–12
Guidelines for preparation of district water management strategies	Department of Water	2011

District water management strategies

A district water management strategy (DWMS) – for demonstrating to WAPC's satisfaction that the development area is capable of supporting the proposed change in land use and identifying land areas for water management – will need to be prepared by the proponent to support any district structure plan, local planning strategy or amendment to the Peel region scheme.

The Department of Water acknowledges that *Better urban water management* (WAPC 2008) contains broad guidance on the content for a DWMS. However, we are developing more detailed guidelines to support DWMS preparation (scheduled for release by the end of 2011).

Until these guidelines are released, and in response to the particular challenges of development in the plan area an outline of what proponents should include in a DWMS is given below. In it they should:

- demonstrate how this plan's key principles and strategies have been addressed with a particular focus on:
  - whole-of-catchment water management issues
  - links to adjacent structure planning activity
  - shared infrastructure and staging
  - total water-cycle planning
- demonstrate an understanding of the site's pre-development conditions and its water resource management characteristics, including presentation of a suitable annual water balance model that addresses the following items:
  - water supply and demand, recycling and efficiency
  - maintenance of recharge to groundwater aquifers
  - maintenance of ecological water requirements
  - seasonal and interannual drainage and inundation volume management
- present guiding principles and strategies for post-development management of the water resources
- incorporate requirements and commitments for future actions and investigations to be met at subsequent stages of planning.

Arterial drainage planning

Proponents should undertake catchment-scale arterial drainage planning as part of the district structure plan stage, and as part of a DWMS, to the satisfaction of the Department of Water, Shire of Murray and other relevant organisations. If district structure planning proceeds without consideration and preliminary design of any shared drainage infrastructure requirements, potentially a development may constrain other developments within the catchment.

In general, proponents will be responsible for undertaking catchment-scale arterial drainage planning within a DWMS in line with *Better urban water management* (WAPC 2008). However, where significant complexity exists and/or a particular catchment has a large number of individual proponents, the Department of Water - with support from the Department of Planning and Shire of Murray – will undertake catchment-scale arterial drainage planning. Criteria used for the selection of catchments (Figure 2, Appendix A) where Department of Water will undertake such planning are:

- Catchments larger than 10km2 where both of the following circumstances arise:
  - multiple tributaries pose a significant flood risk at or downstream of their confluence due to coinciding flood peaks
  - the peak flow in the downstream receiving watercourse is less than ten times the catchment peak flow
- Catchments containing Water Corporation rural drainage assets
- Catchments where extensive development is planned within an existing floodplain and may affect its flood detention capacity

Staging of arterial drainage planning activity is under consideration and will be guided by the *Outer metropolitan Perth and Peel sub-regional strategy* (WAPC 2010c) and the *South metropolitan Peel structure plan* (WAPC in preparation).

DWMS boundaries

The DWMS (including the need for arterial drainage) is likely to be a key driver of urban form. The boundary of a DWMS should therefore be at a district level and extend beyond planning and cadastral boundaries to be based on catchment hydrology (refer to Figure 2, Appendix A, for catchment boundaries). To achieve the required scale, we recommend a coordinated approach to the DWMS that incorporates multiple landowners. This approach will allow the gap between the subregional scale of this plan and the smaller-scale local water management strategy to be bridged and allow for appropriate water management information and outcomes at each level of the planning process.

DWMS modelling

Refinement of the Department of Water’s surface and groundwater interaction modelling will not normally be required at DWMS stage. However, in locations where substantial hydrologic complexities exist, the department may request refinement of modelling at this stage. Similarly, proponents may choose to undertake further modelling at this stage where local information suggests the regional-scale model is not accurately representing the site’s conditions.

Local water management strategies

The next stage of the planning process is a local planning scheme amendment, local structure plan or equivalent outline development plan.

In accordance with *Better urban water management* (WAPC 2008) this stage is to be supported by a local water management strategy (LWMS) prepared in accordance with the department's *Interim: Developing a local water management strategy* (2008). The LWMS should demonstrate to the satisfaction of the WAPC in accordance with this plan and any approved DWMS:

- how the key principles and strategies of this plan have been addressed
- how the urban structure will address water use and management
- existing and required water management infrastructure
- detailed land requirements for water management.

In accordance with *Better urban water management* (WAPC 2008) there are circumstances that may arise which make the preparation of a combined district and local water management strategy preferable. For instance; where a local planning scheme is amended to make it consistent with the relevant region planning scheme or where a local planning scheme amendment is progressed in tandem with a region planning scheme amendment. Where this occurs, the resulting document will need to contain both district level information and local level detail so that it can concurrently support both stages of the planning process.

Subdivision

This stage should be supported by an urban water management plan (UWMP) prepared in accordance with the department's *Urban water management plan: Guidelines for preparing plans and complying with subdivision conditions* (Department of Water 2008). The UWMP should demonstrate in accordance with this plan and any approved DWMS and/or LWMS:

- how the key principles and strategies of this plan have been addressed
- how the final urban form will use and manage water.

It should present finalised urban water management designs and commit to a final engineering design for drainage infrastructure.

Future technical studies

Modelling undertaken in support of this plan used the Mike21 (DHI) two-dimensional modelling system and the MikeSHE (DHI) surface and groundwater integrated modelling system. The models, including all input and output data, are available on request from the Department of Water. More detailed modelling should use software with the same or similar capabilities to model overland flow paths and complex surface and groundwater interactions.

Detailed district- and local-scale modelling should be validated against the Department of Water's subregional-scale modelling to ensure consistency. Any substantial discrepancies will need to be investigated and discussed with the department so that the necessary revisions to either scale or modelling can be put in place.

1.5 The plan area

The *Murray drainage and water management plan* area is shown in Figure 1 of Appendix A. It is approximately 375 km^2 and extends from the Nambeelup Brook catchment in the north; lower Serpentine River and Peel-Harvey estuary in the west; Fauntleroy Drain catchment in the south; and the Darling Range foothills in the east.

The plan area is traversed by the lower reaches of the Serpentine and Murray rivers and bounded to the west by the Peel-Harvey estuary. It is characterised by relatively flat terrain, high groundwater tables, surface inundation in winter, and wetlands of significance. Riverine flooding occurs periodically.

The plan area includes the localities of Keysbrook, North Dandalup, Nambeelup, Stake Hill, Barragup, Furnissdale, North Yunderup, Ravenswood, Fairbridge, Pinjarra, Meelon, Blythewood, West Pinjarra, Nirimba, South Yunderup and Dudley Park. Most of these localities are within the Shire of Murray; less than 10% of the study area is within the Shire of Serpentine-Jarrahdale.

1.6 Land and water planning and policy background

In addition to Better urban water management (WAPC 2008a) and Planning bulletin no. 92, urban water management (WAPC 2008c), the following documents were considered in defining this plan's key principles and objectives:

- *Environmental protection (Peel Inlet-Harvey Estuary) policy 1992* (EPA 1992a)
- *Environmental protection (Swan coastal plain lakes) policy 1992* (EPA 1992b)
- *Statement of planning policy 2.1: Peel-Harvey coastal plain catchment* (WAPC 2003a)
- *Statement of planning policy 2.6: Coastal planning policy* (WAPC 2003b)
- *Statement of planning policy 2.9: Water resources* (WAPC 2004)
- *Statement of planning policy 3.4: Natural hazards and disasters* (WAPC 2006)
- *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008)
- *Liveable neighbourhoods edition 4* (WAPC 2008b)
- *Statement of planning policy 4.2: Activity centres for Perth and Peel* (WAPC 2010a)
- *Directions 2031and beyond –spatial framework for Perth and Peel* (WAPC 2010b)
- *Perth-Peel regional water plan 2010–2030: responding to our drying climate*, draft for public comment (Department of Water 2009)
- *Murray groundwater allocation plan* (Department of Water 2010a).

The draft *Perth-Peel regional water plan 2010–2030: responding to our drying climate* (Department of Water 2009), *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008) and the *Murray groundwater allocation plan* (Department of Water 2010a) are particularly relevant to this plan, given they contain recent site-specific information and guidance.

Perth-Peel regional water plan

The Department of Water is preparing regional water plans for all areas of Western Australia. The plans outline strategic directions for the sustainable management of regional water resources. Each plan has a number of objectives for water management. The draft 2009 Perth-Peel regional water plan outlines six objectives:

1. Take the drying climate into account in all aspects of water resource management
2. Reduce water demand by using water more efficiently and effectively
3. Provide water security for public and private water supply consumers
4. Facilitate the use of alternative sources of water supply
5. Restore and protect waterway and wetland health
6. Create water sensitive cities and towns

Water quality improvement plan

The EPA's 2008 Peel-Harvey water quality improvement plan 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.

Murray groundwater allocation plan

The Murray groundwater area is proclaimed under the *Rights in Water and Irrigation Act 1914* (WA). Under Section 5C a licence is required for the taking of groundwater resources. The Department of Water's 2010 *Murray groundwater allocation plan* provides information and direction on managing groundwater allocation through licensing.

A number of environmental constraints will need to be considered as part of any proposed land use change in the plan area. These constraints, including extensive seasonal inundation by surface water and shallow groundwater, are discussed in detail in this section of the plan. Table 2 summarises the constraints for each 'development area' under consideration.

Chapter Two

Context

Readhead Rd

Notes to Table 2:

- Seasonally inundated areas and those where the maximum groundwater level is within 2 m of the surface are derived from modelling undertaken for the *Murray hydrological studies: Surface water, groundwater and environmental water* – suite of reports (Hall et al. 2010a–c) and relates to the existing climate scenario.
- Natural surface levels are from the Department of Water's LiDAR (light detection and ranging) aerial survey of the Swan Coastal Plain (which included the entire Murray study area).
- Development cannot occur in floodways, therefore all 'development area' calculations exclude floodways.
  - Floodways are those areas of the floodplain where significant discharge or storage of water occurs during major flooding. They are often aligned with naturally defined channels and include areas that, if filled or even partially blocked, would cause a significant flood hazard by redistributing flood flow, and/or by detrimentally increasing flood levels in the general area.
  - The flood fringe is the area of the floodplain, outside of the floodway, which is affected by flooding but where development could be considered (provided appropriate measures are taken).
- The indicated area of storm surge risk is all areas below 2.1 mAHD (from the *Murray floodplain development strategy* (GHD 2010a)).
- Acid sulfate soil risk areas are from Planning bulletin no. 64 (WAPC 2009), which is based on a review of existing geomorphologic, geological and hydrological information, and uses standard Department of Environment and Conservation (DEC) risk categories.
- Allocations are correct at July 2010 but will vary and up-to-date information should be sought from the Department of Water.
- Water quality information is based only on available data from Department of Water bores and is indicative only. 'Yes' indicates total dissolved solids > 1000 mg/L; total nitrogen > 3.0 mg/L; total phosphorus > 0.25 mg/L; NA indicates that no Department of Water bore data currently exists in the area.

Table 2 Summary of environmental constraints

Development area name (refer Figure 1)	Area (km²)	% area seasonally inundated by maximum groundwater level	% area maximum groundwater level <2 m below ground level	Range of natural surface level (mAHD)	% area flood fringe (floodways are excluded from development areas)	% area floodplain	% area below 2.1 mAHD (storm surge risk zone)	% area high-risk acid sulfate soils	% area medium-risk acid sulfate soils	% groundwater allocated (Leederville Aquifer)	% groundwater allocated (Superficial/Rockingham Aquifer)	Contains potentially high-value wetlands	Superficial groundwater quality: total dissolved salts > 1000 mg/l	Indicative superficial groundwater quality: total nitrogen > 3.0 mg/l / total phosphorus > 0.25 mg/l
Austin	4.9	62%	100%	-0.1 to 8.9	71%	0%	51%	25%	75%	30-70	<30	Yes	Yes	Yes/No
Barragup	4.8	7%	99%	-0.3 to 6.2	29%	0%	38%	99%	1%	~100	<30	Yes	No	No/No
Buchanans	17.8	39%	99%	0.3 to 15.2	10%	7%	3%	3%	97%	30-70	<30	Yes	No	No/No
Carcoola	2.8	15%	80%	2.1 to 16.8	12%	2%	0%	0%	100%	~100	<30	No	No	NA
Nambeelup	21.4	29%	82%	0.6 to 26.4	3%	6%	1%	4%	96%	~100	<30	Yes	No	Yes/No
Nerrima	8.7	51%	100%	0.3 to 5.6	0%	30%	26%	0%	100%	30-70	<30	Yes	Yes	Yes/No
North Dandalup	2.1	28%	91%	29.7 to 54.4	0%	2%	0%	0%	22%	~100	<30	Yes	No	No/No
Pinjarra	1.5	1%	21%	0.7 to 12.1	20%	0%	0%	2%	98%	30-70	<30	Yes	No	Yes/No
Ravenswood	16.6	31%	93%	0.4 to 14.3	1%	18%	0%	1%	99%	~100	<30	Yes	No	Yes/Yes
South Murray	2.3	4%	82%	3 to 10.7	7%	0%	0%	3%	97%	30-70	<30	Yes	No	Yes/No
South Yunderup	1.2	25%	97%	-0.5 to 4.6	86%	0%	77%	100%	0%	30-70	<30	Yes	No	NA
Total	84.1	33%	91%											

2.1 Climate

The plan area has a Mediterranean climate typical of south-west Western Australia, with hot dry summers and cool wet winters.

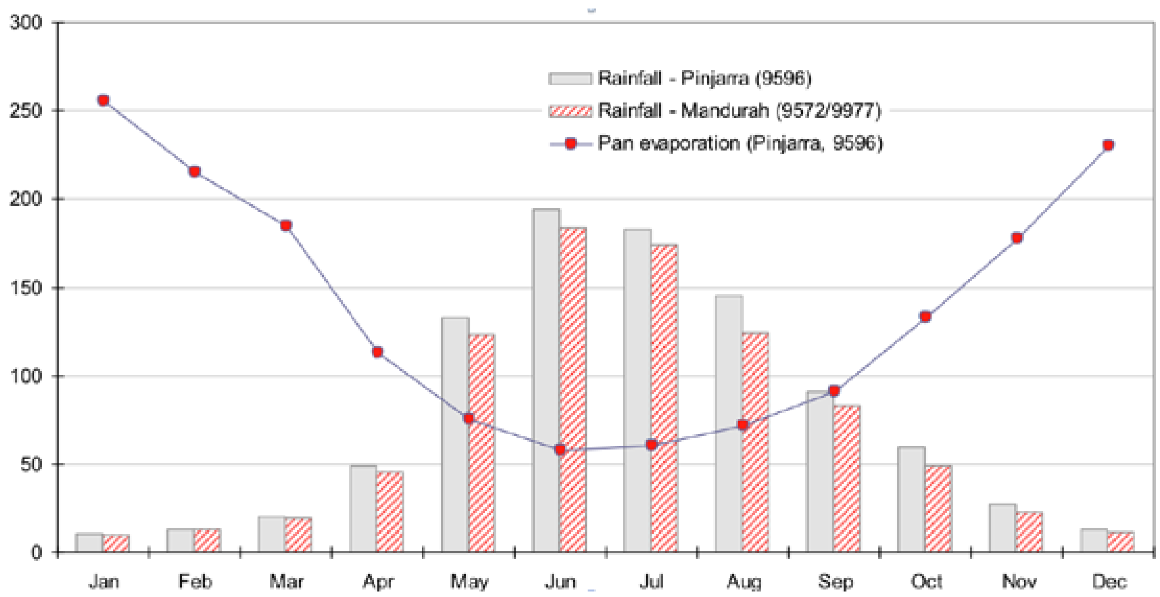


Chart 2 Monthly average rainfall and pan evaporation data for Pinjarra and Mandurah (Hall et al. 2010a

The average annual rainfall for Pinjarra for the period 1877–2008 is 939 mm, with a maximum rainfall of 1493 mm recorded in 1955; and a minimum rainfall of 531 mm recorded in 1941. An average of 86% of the rain falls within the May to October period.

Climatic conditions have little spatial variability within the plan area. Annual rainfalls range from 900 to 1000 mm.

Climate change

The average annual rainfall from 1877–1975 was 970 mm, which was 14% greater than the average rainfall between 1975 and 2008, indicating that the commonly known 'step-down' in rainfall over the past 30 years is present in the plan area. There has also been a second but less pronounced 'step-down' in rainfall since 1997, with the average rainfall since that year being a further 5% lower than the 1877–1975 average.

The mechanism for the 'step-down' in rainfall is generally due to the winter weather systems staying further south than previously. In the plan area, during the winter months, rainfall results from sub-polar, low-pressure cells that drive the cold fronts that cross the region. These weather conditions are usually accompanied by strong winds, cloudy skies and rainfall. Since 1968, the high-pressure anticyclone belt in the plan area has moved southward, deflecting the cold fronts further south, resulting in a drier climate for south-west Western Australia.

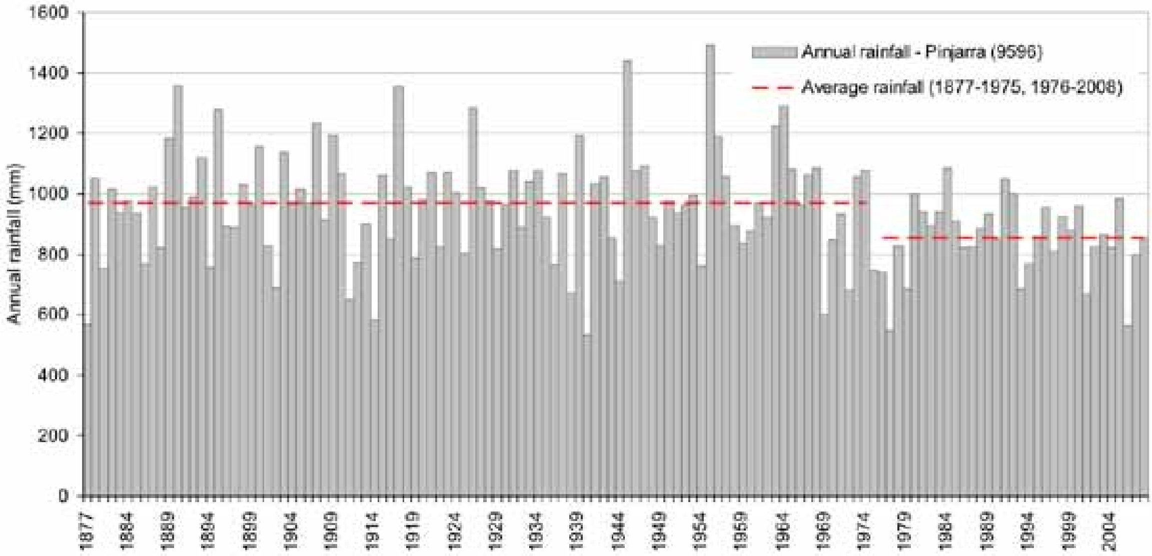


Chart 3 Annual rainfall in Pinjarra showing the 'step-down' in average rainfall post 1975 (Hall et al. 2010a)

International research reviewed by the Intergovernmental Panel on Climate Change (IPCC) (2007) indicates a warming world is leading to significant changes in regional climates. Evidence for global climate change includes:

- 11 of the last 12 years rank among the 12 warmest years in the post-1850 instrumental record of global surface temperature
- a linear global warming trend over the past 50 years of about 0.13°C per decade, increasing to 0.18°C per decade since the mid-1970s
- widespread warming of the atmosphere and ocean, and ice mass loss.

The IPCC concludes that most of the observed increase in global average temperature since the mid-20th century is very likely attributable to the observed increase in anthropogenic greenhouse gas concentrations.

Future climate scenarios for the technical studies undertaken in support of this plan used daily rainfall and evapotranspiration data developed for the South-west Western Australia sustainable yields project (CSIRO 2010) from 45 global climate model scenarios. The wet, medium and dry climate scenarios used in the technical studies represent the 10th, 50th and 90th percentile of the change in average annual rainfall for all 45 global climate model scenarios.

2.2 Aboriginal heritage

Strategy 1.3

The *Aboriginal Heritage Act 1972* (WA) protects Aboriginal heritage in Western Australia. The Act recognises the strong relationships Aboriginal people have with the land, which may go back many thousands of years. The Act provides automatic protection for all places and objects in the state that are important to Aboriginal people because of connections with their culture. These places and objects are referred to as Aboriginal sites, and are frequently associated with wetlands and waterways. As such, these environmental assets will continue to be particularly important to Aboriginal people.

The Department of Indigenous Affairs (DIA) maintains a register of known Aboriginal sites, which records the places and objects of significance that the Act applies to. The presence of an Aboriginal site places restrictions on what can be done to the land. Anyone who wants to use land for research, development or any other cause, should investigate whether an Aboriginal site is present.

The Minister for Indigenous Affairs is responsible for administration of the Act. Under the Act it is an offence for anyone to excavate, damage, destroy, conceal or in any way alter an Aboriginal site without the Minister's permission. DIA helps the Minister administer the Act.

DIA has previously identified several sites of Indigenous significance in the plan area. Many of these sites relate to the plan area's rivers and waterbodies.

These sites are shown in Figure 3 of Appendix A.

2.3 Post European settlement heritage

The Heritage Council of Western Australia maintains the State register of heritage places under the *Heritage of Western Australia Act 1990* (WA) to protect and recognise places of cultural heritage significance within the state. The register includes buildings, structures, gardens, cemeteries, landscapes and archaeological sites.

Under the Act, if a place is listed on the State register of heritage places, any changes or works that may affect its significance must be referred to the Heritage Council of Western Australia for advice. Several places within the plan area are listed on the register. These sites are shown in Figure 3 of Appendix 1.

2.4 Topography and surface geology

The plan area is within the Swan Coastal Plain geomorphic region. Elevation in most of the plan area shows little variation, although it does increase sharply toward the Darling Scarp in the east. Some localised elevated areas occur throughout (see Figure 4, Appendix A).

The plan area's surface geological characteristics are summarised in Table 3 below.

The plan area takes in four primary soil landscape zones, each with a number of component soil-landscape systems (progressing from west to east): Perth Coastal, Bassendean, Pinjarra and Darling Scarp. Much of the plan area is classified as Bassendean or Pinjarra zone, with small areas of lower Darling Scarp to the east and Perth Coastal zone to the west (see Figure 5, Appendix A).

Table 3 Landscape zone characteristics of the plan area

Landscape zone	Description	*Typical potential permeability (m/day)	*Typical phosphorus retention index
Perth Coastal	Consists of beach ridges and parabolic dunes of calcareous deep sands nearest the coast, and areas of low dunes with yellow deep sands overlying Tamala Limestone, inland to the east. The component soil-landscape systems are the Quindalup and Spearwood dunes and the Vasse estuarine deposits. Both the Quindalup and Spearwood dunes are underlain by limestone. The Quindalup dunes are composed of unconsolidated sand (quartz grains) and shell fragments. They have a high leaching ability.	10+	2–10
Bassendean	Consists of fixed dunes located inland from the coastal zone. It is a complex of low dunes, sand plains and swampy flats with pale deep sands and semi-wet and wet soils. Within the subregional structure plan area, the Bassendean zone comprises only one soil-landscape system of the same name. The soils are highly leached, infertile and acidic, and the low-lying areas are subject to inundation during winter. Under such conditions there is a high risk of nutrient export, an issue that has dominated environmental concerns for the coastal plain portion of the catchment for some time.	5–15	<5

Landscape zone	Description	*Typical potential permeability (m/day)	*Typical phosphorus retention index
Pinjarra	Covers the inland portion of the Swan Coastal Plain. The component soil-landscape systems include Pinjarra Plain and Forrestfield (the Ridge Hill Shelf). Much of the Pinjarra Plain has formed on the Guildford geological formation. It is a flat and generally poorly drained alluvial plain. Soils are a mix of grey, deep, sandy duplex soils; grey shallow sandy duplex soils; brown, shallow, loamy duplex soils; and wet soils. The low permeability in some areas can lead to salt accumulation.	1–10	0–10+
Darling Scarp	The oldest exposed geological unit is the Yoganup Formation, followed in order of age by the Guildford Formation, Bassendean Sand, Tamala Limestone, Tamala Sand and Safety Bay Sand. Concentrations of heavy mineral sands occur within the Yoganup Formation. The Guildford Formation consists of alluvial sands and clay.	1–2	10+

**Source: various, based on literature search for values reported in the South Metropolitan and Peel region*

Acid sulfate soils

Strategy 1.2

Planning bulletin no. 64 (WAPC 2009), which is based on a review of existing geomorphologic, geological and hydrological information, discusses the risks associated with potential acid sulfate soils (PASS) within the plan area. Although large areas are categorised at moderate to low risk of PASS occurring within 3 m of the natural soil surface, significant regions exist where there is a high risk of these soils occurring within 3 m of the natural soil surface (see Figure 6, Appendix A). These high-risk regions generally correspond with existing drainage routes and wetlands, representing significant potential threats to downstream water quality. This will require careful management so that development does not cause adverse downstream water quality impacts.

The Kwinana Freeway/Forrest Highway alignment transects the plan area. PASS were identified along the highway's northern section and around the Serpentine River, Nambeelup Brook and Murray River. Along the boundaries of the Harvey Estuary and Peel Inlet, the thickness of the deposits may be 3 to 5 m for swamp and lagoonal deposits, and 10 to 15 m for estuarine and alluvium deposits and reworked Bassendean sands.

Recent technical studies

Modelling and PASS data collected for this plan's supporting technical studies, combined with several third-party studies, has enabled a risk assessment for the likelihood of PASS being converted to actual acid sulfate soils (AASS) under different drainage, groundwater abstraction and climate scenarios. The results of this risk assessment are reported in *Murray hydrological studies: Surface water, groundwater and environmental water – acid sulfate soil risk* assessment (Kretschmer et al. 2011).

Overall, the report found only small increases or even decreases in the risk of PASS exposure due to shallow drainage and development alone – mainly because of increased recharge rates in urban areas and the effect of fill on vegetation root depth. However, the modelling found an increasing risk of PASS exposure when drying climate scenarios were considered and combined with the extensive use of garden bores. The historical wet climate meant little change in the PASS oxidation risk from 1950–1975 to 1978–2007. These results indicate the seasonally full aquifer has buffered the PASS oxidation risk in the past. However, if certain areas are left unmanaged, the combined effects of a drying climate and shallow bore abstraction may exhaust this buffer, leading to soil acidification and its associated impacts.

In general, the Department of Water considers it is appropriate to promote shallow, low-yield garden bores where a low or medium risk of PASS exists. However, higher-yield community-type bores may not be appropriate where there is a medium risk of PASS. This is because the resulting localised drawdown of the watertable may cause acidity issues.

2.5 Surface water

As shown in Figure 7 of Appendix A, the plan area is traversed by the lower reaches of the Murray River and bounded to the west by the Serpentine River and Peel-Harvey estuary. The Murray River and its major tributaries (the Hotham and Williams rivers) make up the largest of the catchments draining to the Peel-Harvey estuary. The flow is perennial, though generally winter-based, and saline all-year-round in the study area. The Murray River has a substantial floodplain, extending from south of Pinjarra to the Peel Inlet.

Flows in the Serpentine River are smaller than the Murray, due to its smaller catchment and considerable storage in the forested hills, and are also perennial. Flows are fresh upstream of estuarine influences. The river discharges to the Peel Inlet adjacent to the Murray River's mouth and the two rivers form a broad delta.

In the plan area, the Serpentine River's floodplain is close to the river itself and encompasses nearby low-lying lakes, including Goegrup and Black lakes.

A number of other smaller rivers and streams flow into or through the plan area, including Nambeelup Brook; the Dandalup River system, incorporating the North and South Dandalup rivers and Conjurunup Creek; Oakley and Marrinup brooks; and a number of small streams that enter the plan area from the east and drain into the Murray River. Most of these tributaries are fresh.

Three Water Corporation drainage systems – Buchanans, Greenlands and Fauntleroy – drain the plan area to the south-west of Pinjarra. Buchanans Main Drain discharges to the Murray River's lower reaches, while Greenlands Main Drain and Fauntleroy Drain both discharge to the Peel Inlet. The lower reaches of all three drains are tidally influenced.

There are many small drains on farmland within the plan area, particularly in and south of the Nambeelup Brook catchment. These were constructed to drain wetlands and seasonally inundated areas and to facilitate agriculture, mostly cattle for beef production.

The Water Corporation operates three major water supply dams on the Serpentine, North Dandalup and South Dandalup rivers. It also operates small pipehead dams on the Serpentine River and Conjurunup Creek. Alcoa's refinery, located just east of Pinjarra, operates a tailings storage facility, with some storage capacity for direct rainfall, and has water supply reservoirs on Barrett and Oakley brooks.

Human activities such as artificial drainage, clearing of riparian vegetation, and de-snagging, training and building of levee embankments primarily to fulfil drainage conveyance and flood protection functions, have substantially altered the plan area's rivers. These activities have occurred at the expense of the waterways' natural nutrient assimilation, erosion protection and ecological functions.

Previous floodplain development strategies and policy

Floodplain development strategies are in place for the Murray and Serpentine rivers (PWD 1984 and WAWA 1990 respectively). These strategies form the basis of the Peel region scheme floodplain management policy (WAPC 2002). The policy guides appropriate land use and development within floodplains to minimise damage during major floods and to help maintain the floodplains' natural flood-carrying capacity. The policy applies to all natural, modified and constructed watercourses within the scheme area and around the Peel Inlet and Harvey Estuary.

Discussions between the Department of Water and the broader community after the development of previous floodplain development strategies resulted in a series of flood management issues being identified. These have been included in Section 7.4 of the *Murray floodplain development strategy* (GHD 2010).

Recent technical studies

The *Murray floodplain development strategy* (GHD 2010) was prepared to address the issues identified above and to inform this plan.

A flood-frequency analysis was performed on gauging-station data for the Murray River. This determined flow estimates for a range of event probabilities. The net result was that the 1-in-100 annual exceedance probability peak discharge was approximately 15% lower than the 1984 flood study.

Runoff routing models were developed for the Murray River and a number of the hills catchments. Parameters in the Murray model were derived from calibration against data from observed events and predicted events verified against the flood-frequency data. Parameters for the RORB (a runoff routing model) models of the hills catchments were derived using a regional method and verified using available streamflow data.

For inclusion in the strategy, hydrographs from the Serpentine River were taken from the previous *Serpentine River floodplain management study* (SKM 2010).

Runoff generation within the flood study area was simulated within a hydraulic model: the parameters were derived using a regional method and verified against streamflow data.

The hydrodynamic model of the Peel-Harvey estuary was set up and verified using bathymetry data (both with and without the Dawesville Channel) and observed tide and wind information. The model was used to simulate tide and storm surge levels in the estuary near the Murray River mouth for a number of scenarios and these formed a boundary condition for the terrestrial model.

Guiding principles for floodplain development

Strategy 2.1
Strategy 2.2
Strategy 2.3

The following general principles were used to develop the *Murray floodplain development strategy* (GHD 2010):

- the proposed development needs an adequate level of flood protection
- the proposed development should not detrimentally impact on the existing flooding regime of the general area
- the public should have adequate protection from flood hazard (e.g. flow depth and velocity, frequency and duration of overtopping of road crossings)
- environmental impacts resulting from flood mitigation works are to be managed
- proposed flood mitigation measures – both structural and non-structural – need to be economically acceptable (e.g. the benefit of flood management works should be weighed against the cost of implementing or not implementing the works)
- social equity (i.e. who pays for works and who benefits) needs to be acceptable.

Revised floodway and flood-fringe mapping is shown in Figure 8 of Appendix A. The 1-in-100 annual exceedance probability flood extent is also delineated. This is mapped as areas greater than 10 ha flooded to greater than 0.05 m deep. Storm surge level at the estuary is set at 2.1 mAHD. Areas of surface and groundwater inundation in a wet winter are also included.

See the attached *Murray floodplain development strategy* (GHD 2010) for longitudinal sections of flows and water levels in the Murray River and the larger tributaries within the plan area. Peak flow rates and top water levels within the plan area's main waterways are also presented in the strategy.

Water quality

Most of the plan area's surface water is fresh (with the exception of the saline Murray River which originates in the Wheatbelt).

The plan area is low-lying throughout, is naturally poorly drained and has sandy soils with low nutrient-retention capability. The inherent difficulties have been exacerbated by historical development that relied on extensive and high nutrient use for agricultural and more recently urban developments, and artificial drainage networks.

The predominant soils in the plan area have a low (< 5) phosphorus retention index (PRI), with a tendency to leach phosphorus by movement with water through and across the soil.

Decades of declining water quality have led to severe algal blooms in the Peel Inlet and Harvey Estuary. In response to this, *a Peel Inlet and Harvey Estuary management strategy* (Peel-Harvey Study Group 1985) was developed. This resulted in construction of the Dawesville Channel; catchment management measures being put in place (including a catchment management plan); continued nuisance macroalgae harvesting; and monitoring being set up to measure the strategy's success.

Environmental protection policy targets

The Environmental protection (Peel Inlet-Harvey Estuary) policy 1992 (Government of Western Australia 1992) set out environmental quality objectives for the protection of the Peel-Harvey estuary. These are stated in part 2, clause 7 of the planning policy as:

'The environmental quality objectives to be achieved and maintained in respect of the estuary are a median annual load (mass) of phosphorous flowing into the estuary of less than 75 tonnes with –

(a) the median annual load of total phosphorus flowing into the estuary from the Serpentine River being less than 21 tonnes

(b) the median annual load of total phosphorus flowing into the estuary from the Murray River being less than 16 tonnes

(c) the median annual load of total phosphorus flowing into the estuary from the Harvey River being less than 38 tonnes'

The boundaries of each river catchment are presented in Figure 9, Appendix A.

The planning policy also stated in clause 8(2):

'The environmental quality objectives are to be achieved and maintained through –

(a) implementation of the planning policy by local authorities through their relevant town planning schemes, and by the state planning commission through the metropolitan region scheme

(b) appropriate land management by landholders and management authorities in the policy area

(c) government extension services including the provision of advice to land holders in the policy area

(d) local authorities and the State ensuring that decisions and actions are compatible with the achievement and maintenance of the environmental quality objectives'

That is, all government and private activities in the policy area must contribute to reaching these targets.

A report by the Environmental Protection Authority (EPA 2007) on the strategy's compliance with environmental conditions found the Dawesville Channel (opened in 1994) had improved water quality in the main body of the Peel Inlet and Harvey Estuary. However, water quality and environmental problems remained in the rivers, and areas such as the Serpentine Lakes. The strategy's second part, which explicitly addressed phosphorus inputs to the catchment's waterways, found that significant action was required.

In response, a series of projects co-funded by the Government of Western Australia and the Australian Government through the Coastal Catchments Initiative began. This included production of the *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008).

Water quality improvement plan

The *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008) was developed to address catchment management measures and control actions relating only to phosphorus loads to the waterways. The EPA recognises that other problems are occurring within the Peel-Harvey system. These include nitrogen concentrations in riverine and estuarine waters; estuarine and riverine habitat loss; acid soil drainage; and bacteria concentrations associated with animal and human effluent.

This report quantified the required improvements and outlined expectations for all government and private activities in the catchment to positively contribute to achieving them. It is the responsibility of all development proponents to respond to these expectations by preventing nutrient-rich shallow groundwater draining to the downstream environment without suitable treatment and making a positive contribution to achieving the required nutrient load reductions to the Peel-Harvey system.

Recent technical studies

Recent water quality modelling of the Peel Harvey catchment by the Department of Water, using the Streamflow Quality Affecting Rivers and Estuaries (SQUARE) model, has identified applied and discharged loads of total nitrogen and phosphorus.

Table 4 presents average annual (1997–2007) loads of total nitrogen and total phosphorus discharged from each of the major waterways into the Peel-Harvey estuary, as well as the contributions from the Upper Murray catchment. Table 6 groups these into the Serpentine, Murray and Harvey river catchments, and also shows the median loads used for comparison with the phosphorus load targets given in the EPA (2008) water quality improvement plan.

Table 4 Total nitrogen and total phosphorus loads discharged into the Peel-Harvey estuary system (Kelsey et al. 2010)

Reporting catchments	Area (km2)	Total nitrogen (tonnes/year)	Total phosphorus (tonnes/year)
Peel Main Drain	120	25.8	4.5
Upper Serpentine	502	106	21.3
Dirk Brook	115	36.9	3.8
Punrack Drain	19	14.1	1.8
Nambeelup	143	43.8	10.5
Mandurah	24	7.9	1.3
Lower Serpentine	94	9.7	2.9
Upper Murray	6750	204	4.9
Lower Murray, Mid Murray and Dandalup	638	198	4.9
Coolup (Peel)	151	41.6	15.0
Coolup (Harvey)	113	26.3	14.4
Mayfield Drain	119	32.7	7.1
Harvey	710	259	39.0
Meredith Drain	56	16.1	8.3
Total*	**2805**	**818**	**135**

* Note: total does not include contribution from the upper Murray catchment.

Phosphorous targets

Phosphorous load targets for the coastal catchments of the Peel-Harvey estuary were deduced by considering the total allowable annual load for each of the river basins (21 tonnes from the Serpentine, 11 tonnes from the Murray and 38 tonnes from the Harvey) and the areas of the catchment that could contribute to this load. Note that the 16 tonne load for the entire Murray catchment has been reduced by 5 tonnes, which is the contribution from the upper Murray.

The areas that could contribute nutrient to the estuary are those already cleared and developed for agricultural and urban uses and those with the potential to be developed.

'Conservation' areas were defined from DEC mapping of 'managed lands and waters' and 'environmentally sensitive areas' which include:

- state forest
- nature reserves
- national parks
- conservation category wetlands
- Bush Forever sites

- environmental protection policy areas
- other environmentally sensitive areas with clearing constraints.

The remainder of the catchment was designated as 'developed' areas.

The Serpentine and Murray catchments have allowable phosphorous export loads per unit developed area of 0.3 kg/ha/year (Kelsey et al. 2010).

Nitrogen targets

The ANZECC guideline value for total nitrogen concentration in lowland rivers of south-western Australia for slightly disturbed ecosystems (1.2 mg/L) was used to deduce a nitrogen export target, because *the Environmental protection (Peel Inlet-Harvey Estuary) policy 1992* (Government of Western Australia 1992) did not focus on nitrogen delivery into the estuary. This is a default target, which may be used if appropriate local targets have not been set.

Using this concentration target, the Serpentine and Murray catchments have allowable nitrogen loads per unit developed area of 2.4 kg/ha/year (Kelsey et al. 2010).

See the Toolbox (T1.4) and Section 4 of the *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008) for advice on how to achieve these targets.

2.6 Groundwater

Underlying the plan area are three distinct aquifers, each assigned the name of its major contributing geological unit (Figure 10, Appendix A). These are the:

- Superficial/Rockingham Aquifer (unconfined with semi-confined areas)
- Leederville Aquifer (unconfined to confined depending on location depth and lithology with two distinct members present – Wanneroo (upper) and Mariginiup (lower))
- Yarragadee Aquifer (confined with two distinct members present – Cattamarra Coal Measures and Gage Sandstone).

Superficial Aquifer recharge is mostly by direct rainfall on the Swan Coastal Plain, particularly in areas with a sandy profile. Recharge to the Rockingham Aquifer is from the Superficial and Leederville aquifers. Recharge to the Leederville is mostly by downward vertical leakage from the Superficial Aquifer along its eastern margin.

Groundwater flow in all aquifers is driven by gravity from east to west across the plan area, although the rivers dissecting the plain cause a deviation of flow in some areas of the Superficial Aquifer.

Groundwater discharge from the Superficial Aquifer occurs by several mechanisms: surface drains, rivers, downward leakage, evapotranspiration, wetland-related pond evaporation, abstraction, and marine discharge. Downward leakage will only occur where a negative (downward) head gradient exists and no confining layer is present. Marine discharge for most of the Superficial Aquifer is likely to be through the Rockingham Aquifer, as a downward gradient and hydraulic connection exists between these aquifers. Discharge from the Rockingham Aquifer can only occur across the salt-water wedge or by abstraction. Where the Rockingham Aquifer is not present, flows from the Leederville and Superficial aquifers discharge offshore via a saltwater interface. Some throughflow in the Leederville Aquifer may discharge vertically to the Superficial Aquifer where upward vertical gradients are present; however, the latter are constrained by the Rockingham Aquifer and estuarine clays around the Peel Inlet.

Many ecosystems and wetlands on the coastal plain are groundwater-dependent and a number of rivers and creeks are also hydrologically linked to groundwater systems.

Murray groundwater allocation plan

The *Murray groundwater allocation plan* (Department of Water 2010a) supports the key principles of the *Murray drainage and water management plan* through the objectives set out in Section 2 of the allocation plan. In addition, the objectives and allocation limit decisions (see *Murray groundwater allocation plan: allocation limit decisions*) were informed by the same internal, state planning and policy documents considered in developing the *Murray drainage and water management plan* as set out in Section 1.5 above.

The *Murray groundwater allocation plan* has been developed to guide and balance the allocation of groundwater between users and the environment, while at the same time promoting efficient water use to optimise regional growth. The department has actively managed groundwater abstraction in the Murray groundwater area through licensing since 1998.

The allocation plan provides:

- revised allocation limits – the main tool used to manage abstraction
- information on how the department licenses and allocates groundwater resources in the plan area
- guidance to ensure that planning for drainage, land use and water allocation is done in a consistent way
- the department's approach to managing the impacts of abstraction on groundwater quality and groundwater-dependent ecosystems.

An allocation limit is the total volume of water the department sets aside to be abstracted annually from a resource, based on its sustainable use. The department divides the allocation limit into components. There are licensable components (including general licensing, public water supply) and unlicensable components (including water for exempt unlicensed use and future public water supply reserves). The water set aside for general licensing is the allocation limit minus the water set aside for unlicensed use.

The department uses the licensing process to share the available water, up to the allocation limit. The allocation limit, its components, and the status of water availability for licensing for each resource in the Murray groundwater area are set out in the *Murray groundwater allocation plan*.

The allocation limits in the Murray groundwater area will be reviewed in 2012. This will ensure the allocation limits and approach to licensing groundwater are aligned with the department's management of drainage and floodplain issues in the same area. The allocation limit review will consider new information gained from groundwater investigations completed to inform this drainage and water management plan.

The department applies the 'first-in first-served' approach to assessing applications for a water licence. Where water use in a resource approaches the allocation limit, the department may consider alternative mechanisms.

The department's regional office in Mandurah manages licensing in the Murray groundwater area. Any queries on groundwater licensing or licences should be directed to this office on 08 9550 4222. General licensing information and licence application forms are available on our website: <www.water.wa.gov.au> Doing business with us > Water licensing>.

Recent technical studies

The plan area exhibits a high degree of surface water/groundwater interaction. Due to the level of interaction, and because ecological water requirements (EWRs) for the wetlands were needed, both the surface water and groundwater aspects of the Murray region's hydrological regime required further investigation. This was the impetus for the Department of Water's *Murray hydrological studies* (Hall et al. 2010a–c), the first two reports of which discuss the conceptualisation and modelling of surface water and groundwater interactions in the plan area.

The resulting model, known as the Murray regional model, is an integrated surface water/groundwater model, and reflects the nature of the local environment with its wetlands of significant size and value.

The hydrological studies included the modelling of various climate scenarios, pre- and post-development scenarios, and WSUD construction philosophies to determine:

- maximum, minimum, average annual maximum and average annual minimum groundwater levels
- water balance modelling including changes in groundwater discharges, interaction with surface water and environmental water
- likely impacts of acid sulfate soils
- re-use opportunities such as community bores and surface detention
- likely areas of waterlogging
- flows in drains and tributaries
- flood, drought, wet, dry and average year impacts
- impacts on water-dependent ecosystems (wetlands) and ecology
- guidance for drainage design (surface water and groundwater infrastructure).

The third report of the *Murray hydrological studies* (Hall et al. 2010c) uses the Murray regional model to develop a suite of predictive simulations and determine changes to water budgets and groundwater levels under various climate and land use scenarios for the plan area. The report includes regional model scenarios and finer-scaled wetland model scenarios. The wetland model scenarios were used to help develop the wetland EWRs (GHD 2010b).

Scenarios for the Murray regional model included:

Climate change scenarios based on the IPCC (2000) predictions and predictive changes in rainfall, evapotranspiration and sea-level rise. The following climate change scenarios were chosen:

- historical wet climate (1945–1974): 14.3% increase in mean annual rainfall compared with the period 1975–2007
- wet extreme future climate: 1.43% decrease in mean annual rainfall compared with 1975–2007
- medium future climate: 8.70% decrease in mean annual rainfall compared with 1975–2007
- dry future climate: 16.18% decrease in mean annual rainfall compared with 1975–2007.

In addition, the wet extreme future climate scenario was run with 1917 annual rainfall at the end of the time-series. This scenario simulates the effect of a single extreme year of rainfall, or short-term return to a wetter climate

Development scenarios based on mapping from the South metropolitan-Peel structure plan (WAPC in preparation). Development scenarios included current development, areas zoned for immediate detailed investigation, and areas zoned for further investigation.

Groundwater drainage scenarios including depths of groundwater drainage systems at ground level with 1 m clean-fill, drainage at 1 m BGL with no extra clean-fill and drainage at average annual maximum groundwater level.

Areas of surface and groundwater inundation for a wet winter are shown in Figure 11 of Appendix A and are also included on Figure 8 of Appendix A.

It is important to note that the predicted maximum groundwater level for the wet extreme future climate scenario – when run in conjunction with 1917 annual rainfall – is in some locations higher than the 1-in-100 annual exceedance probability flood level. The risk of a short-term return to a wetter climate or single extreme year will need to be considered in planning for future development. This has potential implications for the capacity of groundwater drainage systems which are typically designed without reference to extreme events.

Groundwater management strategies

Strategy 1.1
Strategy 1.3
Strategy 1.4
Strategy 2.1
Strategy 2.3
Strategy 3.2

Surface water and groundwater management within the plan area cannot be considered in isolation of each other because of how much they interact. Similarly, because the plan area's prevailing environmental condition (particularly in winter) is one of excess water coupled with limited availability of allocated water resources that are traditionally considered 'useable', water use and efficiency will also need to be considered alongside surface water and groundwater management. When the Department of Water considers the water management strategies and plans prepared in support of development proposals, it will seek to ensure that groundwater levels are managed responsibly.

Development in areas with shallow groundwater has traditionally involved construction of drainage systems to lower groundwater and drain wetlands and seasonally inundated areas. Technical investigations undertaken in support of this plan demonstrate this approach has the potential to mobilise substantial volumes of nutrient-rich water. It is therefore considered unacceptable to dispose of this water without addressing the following criteria:

- ensure that EWRs are satisfied
- investigate all potential uses of these water sources
- ensure that downstream water quality is maintained or improved.

Table 5 shows volumes of water mobilised in a selection of the modelled drainage scenarios. Because this data is extracted from a subregional-scale model, the volumes presented are not exact. The intention is to highlight how much groundwater is mobilised under different climate and drainage scenarios.

Table 5 Comparison of water discharged from drainage infrastructure in a selection of modelled scenarios (Hall et al. 2010c)

			Change in discharged volume (ML/ha/yr)			
Development area name (refer Figure 1)	Area (km2)	Base case – current climate, current drains only (ML/ha/yr)	Medium future climate, no additional drains	Medium future climate, new drains at ground level	Medium future climate, new drains at mod-elled average annual maxi-mum ground-water level	Medium future climate, new drains at ground level, garden bores
Austin	4.9	24	-18	147	164	34
Barragup	4.8	4	-4	4	57	-1
Buchanans	17.8	70	-37	133	156	52
Carcoola	2.8	102	-26	31	62	29
Nambeelup	21.4	47	-27	91	115	8
Nerrima	8.7	38	-27	171	191	40
North Dandalup	2.1	167	-60	103	110	101
Pinjarra	1.5	257	-36	11	34	6
Ravenswood	16.6	26	-14	130	162	-13
South Murray	2.3	13	-3	6	69	-3
South Yunderup	1.2	10	-4	5	52	0
Average (ML/ha/year):	69	-23	76	107	23	

These results, based on the medium climate change scenario, show that while climate change might reduce the volumes of water discharged from the proposed development areas should their drainage remain unchanged, the installation of new drainage would potentially result in mobilisation of 11 GL/yr of additional water across the entire area being considered for development. Should drainage inverts be limited to the existing ground level, the volume of additional water mobilised varies from 4 to 171 ML/ha/yr; as drainage inverts are lowered, these volumes increase. The introduction of widespread shallow bore use (30% of developed lots assumed to be using bores for irrigation purposes) has the potential to lessen this impact, but may still result in additional mobilisation of up to 101 ML/ha/yr of potentially useable water.

Groundwater quality

Strategy 1.2

The area's natural complexities (and the resulting challenges surrounding any development proposals) are compounded by the legacy of agricultural land uses that were once widespread. To facilitate these land uses, drainage systems designed to lower groundwater and drain wetlands and seasonally inundated areas were introduced. In addition, decades of fertiliser application has resulted in high levels of nutrients within the soils and shallow groundwater.

The EPA recognised the impact of nutrients on the Peel-Harvey system in its 2008 water quality improvement plan (discussed in Section 2.5). This report quantified the required improvements and outlined expectations for all government and private activities in the catchment to positively contribute to reaching them.

The Department of Water does not recommend the drinking of bore water from the Superficial Aquifer in the Murray groundwater area. (If groundwater is used for private drinking-water supplies, it is advisable to filter, treat and test the water according to advice from the Department of Health.) However, the department considers this water to be a useable water resource. Modelling suggests that bores could be promoted as a fit-for-purpose water source option in areas categorised at low or medium risk of PASS occurring within 3 m of the natural soil surface. This is provided they are of limited depth and yield so the likelihood of PASS being converted to AASS is not significantly increased.

The Superficial Aquifer in the Murray groundwater area has patches of poor water quality. Groundwater in the aquifer is rich in nutrients, with increasing drainage and use of the water for irrigation leading to heightened mobilisation of nutrients into surface water systems. Salinity generally ranges from fresh to brackish, with saline groundwater occurring near the Peel-Harvey estuary. Groundwater within 5 m of the surface is generally fresh.

The groundwater salinity of the upper and lower Leederville Aquifer ranges from fresh to brackish. Salinity may be higher beneath and immediately adjacent to the Peel-Harvey estuary due to leakage of saline water from the overlying Superficial Aquifer.

Groundwater salinity in the Yarragadee Aquifer is generally fresh (< 500 mg/L) near the Darling Scarp, becoming brackish to saline towards the coast. Salinity is believed to increase with depth.

Groundwater in the Gage Sandstone Aquifer is generally brackish (~2000 mg/L).

Public drinking water source areas

No gazetted public drinking water source areas (PDWSAs) exist within the plan area. The Ravenswood water reserve draws groundwater from the confined lower Leederville Aquifer using three production bores. Water is supplied to Perth's Integrated Water Supply Scheme (IWSS) when storage levels in the hills dams are low. Because the aquifer is confined in this area, no associated PDWSA is required.

The Murray River does not support any public water supply dams, although it was once identified as a possible future water resource and its catchment designated as a surface water reserve.

2.7 Wetlands

Strategy 1.1
Strategy 1.2
Strategy 1.3

The Perth region's wetlands have been defined as 'areas of seasonally, intermittently or permanently waterlogged soils or inundated land, whether natural or otherwise, fresh or saline; for example, waterlogged soils, ponds, billabongs, lakes, swamps, tidal flats, estuaries, rivers and their tributaries' (Tiner 1999).

Hundreds of wetlands of regional, national and international significance are found within the plan area. Approximately 80% of the plan area has been identified as supporting some form of wetland. As indicative samples, the EWRs of some key wetlands have been defined by assessing the water regime required to maintain their ecological values. For details of the assessments, see the attached *Ecological water requirements of selected wetlands in the Murray drainage and water management plan area* (GHD 2010b).

Ramsar wetlands – international significance

Australia's internationally significant wetlands are listed under the Ramsar Convention on Wetlands (1971). The convention encourages the listing of wetland sites containing representative, rare or unique wetland types, or that are important for conserving biological diversity. The Peel Yalgorup system is the largest registered Ramsar site in the state's south-west, and has many interconnected wetlands, lakes, rivers, drainage features and groundwater aquifers that contribute to the area's complex hydrology. These systems are highly vulnerable to nutrient discharges from surrounding urban and rural land uses.

The Peel Yalgorup system is listed as internationally significant for the following reasons:

- it includes the largest and most diverse estuarine complex in south-western Australia and has particularly good examples of coastal saline lakes and freshwater marshes
- the site is one of only two locations in south-western Australia and one of very few in the world where living thrombolites occur in hypersaline water (these thrombolites are listed as a critically threatened ecological community).
- the site comprises the most important area for waterbirds in south-western Australia, supporting more than 20 000 waterbirds annually, with greater than 150 000 individuals recorded at one time
- the site regularly supports 1% of the population of at least six shorebirds: red-necked avocet, red-necked stint, red-capped plover, banded stilt, Caspian tern and fairy tern.

Wetlands of national and regional significance

Nationally important wetlands within the plan area that are in the *Directory of important wetlands in Australia* include the following:

- The state recreation reserve located at Barragup Swamp is a major breeding area for the largest-known breeding colony of yellow-billed spoonbill in Western Australia.
- The Peel-Harvey estuary is the principal migration stop-over and drought refuge area for waterbirds in south-western Australia. It is one of only two breeding areas for the Australian pelican in the south-west, has major waterbird roost sites, and supports moulting of ducks. It is a significant nursery area for fish and crustaceans including commercial species.

The EPA's *Environmental protection (Swan coastal plain lakes) policy 1992* identifies certain lakes on the coastal plain and provides them with statutory protection from disturbance. The policy applies specifically to lakes and not to other types of wetlands. It prohibits the filling, mining, pollution or changing of drainage into or out of those lakes without assessment and approval by the EPA. The protected lakes within the plan area are shown in Figure 7 of Appendix A.

DEC has evaluated and classified most of the coastal plain wetlands of the Perth-Bunbury region. The classification's purpose was to ensure an integrated approach to the management of catchments, and to manage water quantity and quality where these had the potential to affect environmental, cultural and other wetland values. Management objectives were assigned to the following wetland categories:

- conservation: to maintain and enhance natural wetland attributes and functions
- resource enhancement: to maintain and enhance existing ecological functions
- multiple-use: to consider wetlands in the context of catchment and land use planning, in terms of current values and potential value if rehabilitated.

The DEC geomorphic wetland mapping including conservation, resource enhancement, and multiple-use wetlands is shown in Figure 12 of Appendix A.

Recent technical studies

Within the plan area, seven wetlands were selected as representative samples to have their EWRs defined. This involved a detailed assessment of the water regime required to maintain the ecological values of the wetlands, based primarily on the wetland vegetation's water requirements. To assess the EWR component, a detailed hydrological assessment of the wetlands was undertaken, including conceptual representation of the wetlands (surface and subsurface), calibrated water level and flow modelling (surface water and groundwater), and expected change in water level under various climate and land use scenarios.

The process to select the wetlands for the EWR analysis involved staff from the Department of Water's Drainage and Waterways, Water Science and Allocation branches and DEC's Wetlands Section, specialist vegetation scientists from GHD, local landowners and local environmental consultants.

The following criteria were satisfied by each of the seven selected wetlands:

- all stakeholders agreed that the wetland was of high ecological value, appropriate for the EWR study
- wetlands were accessible by drill rig
- land access and drilling permissions could be obtained
- all wetlands were within the plan area.

Wetland monitoring

Several groundwater monitoring bores were drilled adjacent to the selected wetlands as part of developing the EWRs. Water-level data for all bores has been collected monthly since July 2009.

Gauge boards were installed in the deepest part of each wetland, and water levels have been monitored monthly since August 2009.

Detailed water chemistry data was collected during 2009 for all wetland monitoring bores and waterbodies. The suite of chemicals collected included major anions and cations, nutrient species, and heavy metals in some locations. In addition, pH, dissolved oxygen, and salinity were measured in-situ, and for wetlands only, this occurred on a monthly basis.

Site-specific ecological surveys were also conducted during 2009 for the wetland sites. These included surveys of:

- vegetation and flora
- native fish and amphibians
- the stygofauna baseline.

Wetland scenario modelling

Five separate integrated surface water/groundwater wetland models with grids ranging between 30 and 50 m were used to model the seven key wetlands. Scott Road wetland (UFI 5033) and Benden Road wetland (UFI 5724) were included in the same model, as were Lakes Road wetland (UFI 5033), Greyhound Road wetland (UFI 5032) and Airfield wetland (UFI 4835).

Model scenarios for the wetland models were selected primarily to establish the hydrologic regimes to help develop the EWRs. Additional scenarios were used to consider the potential impacts of climate change and imported fill on surface water and groundwater drainage systems, and removal of dunal landscapes.

Other model scenarios use the concept of a hydrologic zone to consider the effect of groundwater drainage systems on the seven selected high-value wetlands in the plan area. These scenarios are outlined in *Murray hydrological studies: Surface water, groundwater and environmental water – land development, drainage and climate change scenarios report (Hall et al. 2010c)*.

A hydrologic zone is defined as the area surrounding a wetland where the installation of infrastructure (including groundwater drainage systems or bores) may have an undesirable hydrological influence on the wetland without being a development exclusion zone.

Hydrologic zones were found to vary with the depth of drainage infrastructure, topography, geology, and hydrogeology. These scenarios should work as a guide to proponents when designing strategies and infrastructure to manage water resources. Proponents should undertake appropriate investigations to ensure development infrastructure does not detrimentally affect the water balance and hydrology of surrounding waterbodies and environmental assets. Table 6 summarises the key results of this analysis.

Table 6 Wetland scenario modelling summary (Hall et al. 2010c)

Wetland ID	Hydrologic zone (groundwater controlled to modelled AAMaxGL, 1978–2008)	Change in modelled average minimum depth (1978–2008) due to modelled climate change	Change in modelled average minimum and maximum depth (1978–2008) due to sea-level rise	Change in modelled average minimum depth due to dune removal (1978–2008)
Wetland UFI 3945 (Barragup Swamp)	200 m	-0.24 m (126%)	Min +0.26 m (137%) Max +0.21 m (16%)	n/a
Wetland UFI 5724 (Benden Road wetland)	50 m	-0.60 m (127%)	n/a	-0.06 m (13.1%)
Wetland UFI 5180 (Scott Road wetland)	50 m	-0.34 m (30%)	n/a	-0.03 m (2.7%)
Wetland UFI 4835 (Airfield wetland north)	100 m	-0.28 m (52%)	n/a	-0.16 m (29.9%)
Wetland UFI 4835 (Airfield wetland south)	300 m	-0.23 m (33%)	n/a	-0.03 m (4.9%)
Wetland UFI 5032 (Greyhound Road wetland)	50 m	-0.13 m (11%)	n/a	-0.04 m (3.5%)
Wetland UFI 5056 (Phillips Road wetland)	200 m	-0.15 m (12%)	n/a	n/a

Wetland ID	Hydrologic zone (groundwater controlled to modelled AAMaxGL, 1978–2008)	Change in modelled average minimum depth (1978–2008) due to modelled climate change	Change in modelled average minimum and maximum depth (1978–2008) due to sea-level rise	Change in modelled average minimum depth due to dune removal (1978–2008)
Wetland UFI 5033 (Lakes Road Wetland)	300 m	-0.10 m (7%)	n/a	n/a
Wetland UFI 7046 and UFI 7029 (Elliot Road wetland)	200 m	-0.17 m (10%)	n/a	n/a

* Note: all % changes refer to the % change in maximum distance of the watertable below the ground level.

Ecological water requirements (EWRs)

EWRs are defined as the water regime needed to maintain the ecological values of water-dependent ecosystems at a low level of risk (ARMCANZ & ANZECC 1996). A water regime is a prevailing pattern of water behaviour over a given time, components of which include depth, rate of rise and duration (Froend et al. 2004).

The EWRs for the plan area's wetlands were derived using the methodology outlined in the draft *Guidelines for ecological water requirements for urban water management* (Department of Water in prep.(a)).

For details of the EWRs for each of the selected wetlands, see the attached *Ecological water requirements of selected wetlands in the Murray drainage and water management plan area* (GHD 2010b).

To protect flora and fauna in wetlands within the plan area, a limit of acceptable change to water levels in wetlands of 10% was adopted as an EWR for wetlands in the supporting technical studies (*WST26 Murray hydrological studies, land development, drainage and climate scenario report* (August 2010)). Further work has since been presented in *Guideline for assessing potential impacts on groundwater dependent ecosystems when applying for a groundwater licence* (Department of Water in prep.(b)). It is recommended that these guidelines be used as the guiding principles for determining EWRs for wetlands including the design of groundwater drainage systems.

2.8 Bush Forever sites

The far northern portion of the plan area is subject to the Bush Forever policy, which identifies areas of regionally significant bush along with Threatened Ecological Communities (TECs) and Declared Rare and Priority flora for protection.

Bush Forever aims to protect at least 10% of the 26 original vegetation complexes within the Swan Coastal Plain section of metropolitan Perth, and to conserve TECs. The Bush Forever sites within the plan area are shown in Figure 13 of Appendix A and listed below:

- site 77: Yangedi Swamp, Keysbrook, within the Shire of Serpentine-Jarrahdale
- site 78: Page Street, Keysbrook, within the Shire of Serpentine-Jarrahdale
- site 426: Myara Brook, Keysbrook, within the Shire of Serpentine-Jarrahdale.

Throughout the plan area, other regionally significant bush, TECs, Declared Rare and Priority flora, and scattered remnant vegetation is protected by other mechanisms.

2.9 Biodiversity hotspots

Biodiversity hotspots are areas that support natural ecosystems that are largely intact and where native species and communities associated with these ecosystems are well represented. They are also areas with a high diversity of locally endemic species; that is, species not found or rarely found outside the hotspot.

The Australian Government's Threatened Species Scientific Committee identified 15 national biodiversity hotspots in October 2003. The Peel-Harvey catchment forms part of two national biodiversity hotspots: Busselton-Augusta and Central-Eastern Avon Wheatbelt respectively.

Conservation International, a non-profit environmental organisation based in the United States, has identified 31 biodiversity hotspots around the world, including the 'Southwest Australia biodiversity hotspot' which encompasses the plan area.

2.10 Flora and fauna

By 1997 about 85% of the plan area's native vegetation had been cleared for agriculture and settlement, mostly on the Bassendean dunes, Pinjarra Plain and along the river systems. In the past decade it has been cleared further, especially for residential areas. The plan area has 10 natural landform and vegetation subdivisions. The Pinjarra Plain makes up just over half the plan area: it is almost completely cleared due to its relatively fertile soils and has been extensively drained for agriculture.

The State of play – Peel-Harvey eastern estuary catchment environmental assessment discussion paper (URS 2008) presents a detailed account of the plan area's flora and fauna. The paper found that beyond the areas of strong saline influence, the vegetation of the Serpentine, Murray and Harvey rivers is also predominantly cleared. Relatively intact areas are uncommon and provide reference sites for rehabilitation activities. The vegetated areas in the lower reaches of the Serpentine River are of particular significance because they are not typical of similar communities found elsewhere on the Swan Coastal Plain – due to the presence of salt-tolerant vegetation, unusual combinations of species and areas of ironstone.

The vegetation of the Pinjarra Plain is the most diverse and has the greatest number of significant flora. A total of 887 species has been recorded in the plan area, 112 of which are considered significant flora. Of these, 11 are listed as Declared Rare flora and 33 are listed as Priority flora (Figure 13, Appendix A): these are considered significant for reasons such as being 'disjunct occurrences' or 'ends of geographic ranges'. Several species are presumed extinct in the plan area, including *Grevillea obtusifolia and Dioscorea hastifolia* (the native yam) (URS 2008).

The populations of all types of native fauna in the plan area have declined or are presumed to have declined since European settlement, principally due to loss of habitat. Recent sightings and observations show the presence of only six out of the plan area's original 22 mammal species. Records indicate the likely presence of another four species of bat, while recent sightings on the Swan Coastal Plain (adjacent to the plan area) indicate the western false pipistrelle may be present. Unfortunately the current small- to medium-sized ground mammal fauna is now dominated by the introduced cat, house mouse, black rat and fox. At least four species – the western long-billed corella, barking owl, western whipbird and crested shrike-tit – are now extinct in the plan area (URS 2008).

Some species may be surviving in recently isolated remnants but will not persist in the long-term unless strategic regional ecological linkages are established and rehabilitation work is carried out (URS 2008).

When investigating the seven selected wetlands described in *Ecological water requirements for selected wetlands in the Murray drainage and water management plan area* (GHD 2010b), detailed flora and selected fauna were studied and are presented in *Report for Murray wetland study – wetland flora study* (GHD 2010c), *Report for Murray wetland study – native fish and amphibian survey* (GHD 2010d), *Report for Murray wetland study – Stygofauna baseline study* (GHD 2010e).

Invasive species

Invasive diseases, fungi and parasites can affect the health of native species, reducing their ability to reproduce or survive. Within the plan area, chytrid amphibian fungus and phytophthora dieback are of particular concern because of their impact on native species. The high watertable in the Lake McLarty area increases the risk of phytophthora dieback transmission (URS 2008).

Many plants introduced into Australia since European settlement are now environmental weeds. More than 160 weeds are known to occur in the plan area, threatening the survival of many plants and animals as they compete with native plants for space, nutrients and sunlight (URS 2008).

Feral animals of concern in the plan area are the European wild rabbit, European red fox, feral cat and feral pig. These animals typically have few natural predators or fatal diseases and some have high reproductive rates (URS 2008).

Mosquito control

The mosquitoes inhabiting vegetation around the salt marshes fringing the Peel-Harvey estuary are a nuisance to nearby residential areas and pose a health risk. Increased nutrient flow into the estuary and acid sulfate soils have the potential to exacerbate the mosquito problem, because mosquitoes actively seek out acid drainage for breeding. Future climate change also has the potential to exacerbate the mosquito problem (URS 2008).

2.11 Swan Bioplan

Proponents of development in the Murray DWMP area are advised that the Office of the *Environmental Protection Authority (OEPA) has recently published Environmental protection bulletin no.12: Swan bioplan – Peel regionally significant natural areas* (December 2010), which provides information to guide strategic land use and conservation planning. This work has identified regionally significant natural areas that should be considered during strategic planning.

The information provides guidance on firstly avoiding, then minimising, the impacts of development proposals and planning schemes on natural areas. Development proposals and planning scheme amendments that impact on the Peel Regionally Significant Natural Areas (PRSNAs) will require detailed investigations of their natural values consistent with EPA guidance statements 10, 51 and 56. As some PRSNAs may also provide important flood attenuation and ecological functions, a holistic approach to their management consistent with the strategies and principles outlined in the Murray DWMP is recommended.

2.12 Land use

Since extensive land clearing began in the early 1800s, agriculture has been the primary land use in the plan area. Cattle grazing for beef is the main land use (68% of the plan area), with sheep grazing, dairy farming, horses, lifestyle blocks and existing urban uses comprising significant areas of the catchment.

Recent years have seen new urban developments and intensification of rural land uses close to waterways and wetlands – in response to peri-urban land pressures and in advance of new rail and highway infrastructure.

Figure 14 of Appendix A shows that urban and urban-deferred areas are found mainly around the townsites of Furnissdale, Yunderup, Ravenswood, Pinjarra and North Dandalup. Regional open space areas exist in scattered locations along the Peel-Harvey estuary and Murray and Serpentine rivers. Industrial areas exist near Pinjarra and in Nambeelup.

The Peel-Harvey estuary is used extensively for public recreation, particularly fishing. Its eastern shores are currently zoned for nature conservation, recreation and urban land uses.

The plan area is rich in basic raw materials and, according to the Department of Mines and Petroleum, has areas that may be set aside for future mining.

Infrastructure

Two major highways cross the plan area: Pinjarra Road and the South-West Highway. The Kwinana Freeway/Forrest Highway has recently been extended and dissects the plan area. The south-western railway line also cuts across the area.

Scheme water from the Water Corporation's IWSS and its reticulated sewerage services are generally confined to the plan area's southern portion, and large areas rely on private bores and rainwater tanks for supply and septic tanks for disposal (Figure 15, Appendix A).

Extensive development within the plan area may require expansion of the Water Corporation's IWSS and its reticulated sewerage services. Advice about the planning or provision of existing or future scheme water or reticulated sewerage services should be sought from the Water Corporation or alternative service provider, where applicable.

The Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management (EPA 2008) cites both animal and human effluent as one of the causes of poor water quality in the Peel-Harvey estuary and concludes that where connection to reticulated sewerage is not possible, aerobic treatment units (ATUs) should be used in preference to traditional septic tanks.

Proposed development

The plan area is experiencing significant urban growth pressure. Understanding how this will affect the region's hydrology is a key consideration of this plan.

The South metropolitan-Peel structure plan (WAPC in preparation) (Figure 16, Appendix A) will guide the planning and growth management of urban and rural land and infrastructure in the southern metropolitan and Peel regions.

The structure plan is a strategic document (non-statutory) to guide the planning and management of urban growth and development in these regions until 2031, through a broad set of policy principles and responsibilities. The plan informs and guides the following:

- the preparation of strategic and statutory plans and policies: by landowners, land and infrastructure developers, and by certain state government agencies
- the 'consideration for approval process' of district and local structure plans by the state government agencies, local governments and the WAPC.

The structure plan is the culmination of three years' work including a land capability and suitability assessment, traffic and transport modelling, and stakeholder consultation. Associated with this process was preparation of a policy statement that identified specific land areas (designated as 'urban growth management policy areas'), where land and infrastructure development was either encouraged or discouraged. The plan identifies three distinct areas:

- areas under immediate detailed investigation for development and/or protection
- areas under further investigation
- areas not under consideration for urban development.

The areas under 'immediate detailed investigation' and those under 'further investigation' determined the development areas considered in this plan. These areas were used in some of the subregional-scale investigations of the technical studies supporting this plan. The combined development areas cover 84.1 km^2, with 38 km^2 identified for 'immediate detailed investigation'.

Chapter Three

Principles and strategies

Serpentine River looking east

The Department of Water has developed the following strategies with the aim to facilitate developments that embrace total water-cycle management principles and WSUD best-management practices. They do not absolve development proponents from meeting all other statutory requirements, and investigating and incorporating relevant policies, by-laws and guidelines.

Key Principle 1: Manage catchments to maintain or improve water resources

The principle of managing catchments to maintain or improve water resources has three components related to the objectives of the *Perth-Peel regional water plan 2011–2031: responding to our drying climate* and brings together aspects of resource and asset management, as well as recognition of the social value of water resources.

Provide water security for public and private water supply consumers

Water resources within the plan area are currently used for a variety of purposes including public, private, agricultural and industrial self-supply. The maintenance and improvement of the existing quality and quantity of water resources is essential not only for maintaining existing supplies but also to ensure that additional supplies are available for future needs.

Restore and protect waterway and wetland health

The plan area has a large number of interconnected wetlands, lakes, rivers, drainage features and groundwater aquifers that contribute to the area's complex hydrology. Development within the plan area has the potential to result in unsustainable changes to the hydrology of receiving environments through increased inundation or discharge due to changed land use or redirection of floodwaters, or drying out due to over-abstraction of water resources or lowering of groundwater levels.

These environments support numerous Declared Rare and Priority flora and fauna species and play a critical role in supporting migratory bird populations. To ensure protection of water-dependent ecosystems, the ecological, hydrological and hydrogeological regimes of these ecosystems will need to be maintained by the development of and subsequent compliance with site-specific EWRs.

The plan area's water quality is a significant issue, which was recognised in the *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008). This report quantified the required improvements and outlined expectations for all government and private activities in the catchment to positively contribute to achieving them.

The presence of acid sulfate soils is a particular concern in the catchment and it is critical that the risks are appropriately managed. Traditional construction methods with associated dewatering, stripping of in-situ organic material, excavation and deep drainage, and unmanaged abstraction of groundwater, can significantly increase acid sulfate soil risk including transport of acid waters and should be avoided wherever possible.

Create water sensitive cities and towns

An essential step in creating water sensitive cities and towns is to facilitate development that embraces the social, economic and environmental values of water resources and their linkages to one another.

A strong relationship with water is an integral part of the Western Australian lifestyle and as a consequence, development often occurs preferentially in areas surrounding naturally-occurring surface water features or seeks to construct them as an aesthetic feature. The expectations of current and future communities for access to wetlands and waterways are not always compatible with the needs of the ecologies that they sustain, but it is important to recognise that the desirability of wetlands and waterways is directly related to their ecological health.

Water and waterways (including rivers, pools, wells, soaks and estuaries) hold an important place in the spiritual and mythological realm for Aboriginal people. Water is also significant to Aboriginal people as a crucial survival factor for people living traditional lifestyles. Proponents should ideally consider opportunities to address and include heritage management principles in their proposals that go beyond the scope of the *Aboriginal Heritage Act 1972*.

Related information from the supporting technical studies

Derived EWRs for seven selected high-value wetlands including associated risk-of-impact mapping and hydrologic zones are given in the attached report, *Ecological water requirements of selected wetlands in the Murray drainage and water management plan area* (GHD 2010).

Hydrographs at key locations along the Murray and Serpentine rivers are provided in the attached report, *Murray floodplain development strategy* (GHD 2010).

Longitudinal sections of flows and water levels in the Murray River and the larger tributaries within the plan1.2 area are given in the attached report, *Murray floodplain development strategy* (GHD 2010).

Surface and groundwater inundation mapping is shown in Figure 11 of Appendix A

Strategy 1.1 Minimise changes to hydrology

Proponents of development will need to:

- maintain and/or restore desirable environmental flows and hydrological cycles of high-value water resources — *Toolbox T1.1*
- investigate opportunities to mitigate for the potential impacts of climate change — *Toolbox T1.2*

- maintain or replace the surface water and/or groundwater detention capacity of seasonally inundated land

Toolbox T1.4

- preserve topographic features including dunal landscapes that have a hydrological recharge function linked to high-value water resources
- prepare and implement a monitoring plan that will provide information about changes to hydrology as a result of development including:

Toolbox T.2

  – flows entering the development from the upstream catchment
  – flows leaving the development

Toolbox T.3

  – groundwater levels within the development area
  – surface water and groundwater levels within wetlands
- locate surface water and groundwater drainage inverts such that any lowering of groundwater levels does not detrimentally affect aquifers or waterbodies and makes best use of all fit-for-purpose water

Toolbox T.3

- refer any development proposals likely to have a significant impact on a matter of national environmental significance (including but not limited to hydrological impacts on downstream Ramsar sites) to the Australian Government's Minister for Sustainability, Environment, Water, Population and Communities in accordance with the *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
- demonstrate to the satisfaction of the Department of Water and the Department of Environment and Conservation (DEC) that any infrastructure that controls, manages or alters groundwater levels does not cause minimum groundwater levels to be lowered
- demonstrate to the satisfaction of the Department of Water and DEC that any infrastructure that controls, manages or alters groundwater levels does not detrimentally impact the hydrological regime and ecological values of aquifers and waterbodies.

Toolbox T.3

Strategy 1.2 Maintain or improve water quality

Proponents of development will need to:

Toolbox T.6

- ensure that all residential developments are provided with connections to reticulated sewer where available, or appropriate ATU
- ensure that nutrient loads to downstream waterways and wetlands (including from groundwater drainage systems) do not exceed:

Toolbox T1.5

  – 0.3 kg/ha/year phosphorus
  – 2.4 kg/ha/year nitrogen
- incorporate WSUD strategies to mitigate the impacts of urbanisation on downstream water quality:

Toolbox T1.5

  – implement controls at or near the source to prevent pollutants entering the system

– install in-transit measures to remove pollutants that have entered the conveyance system

– implement end-of-pipe controls to address remaining pollutants before discharge to receiving environments

- prepare and implement a detailed monitoring plan with information about water quality both on-site and within downstream waterways including: Toolbox T2

  – surface water and groundwater quality entering the development from the upstream catchment

  – surface water and groundwater quality within the development area

  – surface water and groundwater quality leaving the development into downstream waterways

  – surface water and groundwater quality for wetlands

- identify and manage the risk of contamination of surface water and groundwater by disturbance of acid sulfate soils during dewatering for construction and, in accordance with *Treatment and management of soils and water in acid sulfate soil landscapes* (DEC 2009), prepare an acid sulfate soils management plan
- identify and manage the risk of contamination of surface water and groundwater by disturbance of acid sulfate soils due to proposed groundwater abstraction bores
- identify and manage the risk of contamination of surface water and groundwater by disturbance of acid sulfate soils due to proposed drainage levels
- report known or suspected contaminated sites and manage contaminated sites in accordance with the *Contaminated Sites Act 2003* (WA)

Strategy 1.3 Manage and restore waterways and wetlands

Proponents of development will need to:

- maintain and restore floodplain areas of watercourses and wetlands Toolbox T4.1
- improve and restore degraded areas of wetlands and waterways – this may include revegetation with local native species, erosion and weed management, fencing, improvements to crossings and maintaining fish passage, where required Toolbox T4.1 Toolbox T4.2
- determine foreshore areas using biophysical and other criteria to the satisfaction of the Western Australian Planning Commission (WAPC) in consultation with the Department of Water
- determine and maintain the social and environmental values of watercourses and wetlands Toolbox T1.1
- maintain connectivity between environmental assets and make use of watercourses as natural biodiversity corridors Toolbox T1.1

- minimise potential mosquito breeding sites and take steps to ensure that future residents are informed about mosquito breeding prevention Toolbox T1.7
- obtain a permit to modify bed and banks of a waterway from the Department of Water in areas covered by the *Rights in Water and Irrigation Act 1914* Toolbox T4.1
- avoid carrying out unnecessary modifications to existing, healthy, functioning watercourses and wetlands Toolbox T4.1
- ensure new stormwater infrastructure is not constructed within conservation category wetlands, high-value wetlands and their ecological buffers Toolbox T1.3
- ensure that new stormwater infrastructure constructed within resource enhancement wetlands and their ecological buffers is authorised by DEC or the Environmental Protection Authority (EPA) Toolbox T1.3
- ensure that a hydrologic zone is determined for all high-value wetlands and used to ensure that development infrastructure does not detrimentally affect their water balance and hydrology Toolbox T1.3
- ensure new stormwater infrastructure is not constructed within a waterway foreshore area, unless authorised by the WAPC in consultation with the Department of Water Toolbox T4.2
- ensure development does not occur within a waterway foreshore area unless it is demonstrated, to the satisfaction of the WAPC in consultation with the Department of Water, that no adverse impacts on the waterway will be the result (if requested, a foreshore management plan will need to be developed and approved by the department) Toolbox T4.2
- ensure compliance with the *Waterways Conservation Act 1976* (WA), particularly in regard to obtaining licences to dredge or dispose of wastewaters within the gazetted Peel Inlet management area.

Aboriginal consultation

- Any government agency, organisation or individual who is the proponent for strategic or statutory planning documents, construction of individual developments or engaged in any ground-disturbing activities should seek advice from the Department of Indigenous Affairs (DIA) on their requirements and obligations under the *Aboriginal Heritage Act 1972*, and any other investigations that may be required. This may include but not be limited to:
  - consultation with relevant Aboriginal people about the proposal in general, or areas that may be subject to physical alteration
  - undertaking an Aboriginal heritage survey or investigation, or predictive modelling for any specific location to identify unregistered sites
  - development of a full inventory of heritage values.

Strategy 1.4 Safeguard the quality and availability of water resources for the future

The Department of Water in conjunction with others will:

- protect groundwater resources through implementation and review of the *Murray groundwater allocation plan* (Department of Water 2010a)
- develop regulation and market mechanisms including financial incentives and/or assistance to facilitate change
- develop strategies for water management that will lead to the development of water-sensitive cities *Toolbox T5.4*
- encourage the development of fit-for-purpose sources to meet potable and non-potable water demands

Key Principle 2: Manage flooding and inundation risks to human life and property

The principle of managing flooding and inundation risks to human life and property is about establishing appropriate levels of service for drainage infrastructure, providing management strategies for major storm-event management and dealing with inundation threats to building integrity without compromising the environmental and social function of water resources. This principle has four parts and relates to the objectives of the draft *Perth-Peel regional water plan 2010–2030: responding to our drying climate*.

Building integrity and construction methods

The plan area is characterised by shallow groundwater and large areas of seasonally inundated or waterlogged land. Development proponents will need to take these characteristics into consideration when identifying appropriate construction methods. This will ensure the structural integrity of buildings is not compromised by repeated inundation and provide suitable living conditions for residents and their property.

Traditional development uses a combination of groundwater drainage and imported fill to provide dry, stable foundations for buildings. However, alternative construction methods (such as stronger foundations, raised sand pads, stilts or damp-proofing) can reduce and even eradicate the need for substantial areas of groundwater drainage and imported fill. Locations that may require an alternative approach include those where the permanent lowering of the seasonal groundwater table may have unacceptable impacts on water-dependent ecosystems or available water resources. The increasing cost of sourcing and transporting fill also needs to be considered.

The Department of Water is not the relevant approval agency for determining adequate separation from maximum groundwater levels for new buildings.

Major storm-event management and emergency planning for the plan area

Substantial parts of the proposed development areas are close to existing constructed drains or waterways with large upstream catchments – in particular the Murray River. These waterways are prone to flooding during major storm events, which may represent a substantial risk to human life and property. In addition, parts of the proposed development areas may be at risk of flooding from extreme tidal conditions and storm surges. Appropriate clearances and setbacks from predicted flood levels and areas will need to be maintained to minimise those risks. Where an identified risk of flooding exists, it is also necessary to ensure provision of appropriate entry and egress for emergency services as well as safe evacuation points.

Opportunities for stormwater management in the plan area may be limited by shallow groundwater and seasonal inundation, which may result in a need for greater than 10% of the development to be set aside as public open space.

Levels of service, governance and institutional arrangements

Existing drainage infrastructure in the plan area largely consists of small rural drains and natural or modified creeks or brooks. In the early part of the last century the government constructed drains designed to drain wetlands and seasonally inundated areas and move water downstream. Other minor drains were later constructed by landholders. In the second half of the last century the Public Works Department developed a 'serviceability objective' for maintenance of their drainage assets, such that land adjacent to their assets would flood for short periods (less than 72 hours) during more significant events.

The transition of an area from rural to semi-urban or urban requires improvements to the level of service and may trigger the need for changes to the drains' governance and institutional arrangements. However, development does not occur in a uniform manner and modifying a site's drainage may affect up or downstream areas. It is essential that up and downstream impacts of development are also considered when drainage designs are prepared.

Sea-level rise

As a result of possible future sea-level rise, parts of the proposed development areas may be at an increased risk of flooding (Figure 8, Appendix A). Appropriate clearances and setbacks from predicted flood levels and areas will need to be maintained to minimise those risks.

Revised floodway and flood-fringe mapping delineating the 1-in-100-year annual exceedance probability flood extent is shown in Figure 8 of Appendix A. The mapping shows the areas greater than 10 ha predicted to be inundated to a depth of at least 0.05 m during the 1-in-100-year annual exceedance probability event. Storm surge level at the estuary is set at 2.1 mAHD.

Related information from the supporting technical studies

Hydrographs at key locations along the Murray and Serpentine rivers are provided in the attached report, *Murray floodplain development strategy (GHD 2010)*.

Longitudinal sections of flows and water levels in the Murray River and the larger tributaries within the plan area are given in the attached report, *Murray floodplain development strategy* (GHD 2010).

Surface and groundwater inundation mapping is shown in Figure 11 of Appendix A

Strategy 2.1 Provide adequate clearance from 1-in-100 year annual exceedance probability flooding and surface water or groundwater inundation

Proponents of development will need to:

- demonstrate detailed understanding of pre- and post-development groundwater levels (including presentation of maximum groundwater levels) to support the identification of appropriate earthworks and building methodologies *Toolbox T.3*
- provide adequate separation for new buildings from maximum groundwater levels as specified by other relevant authorities
- adhere to the development recommendations within the *Murray Floodplain development strategy (GHD 2010a)* (Section 7.5.2 Building and development controls) *Toolbox T1.4*
- design developments outside defined floodplains to ensure:
  - the 1-in-100-year annual exceedance probability flood is contained below kerb height (assuming pipes and pits blocked)

    and
  - the habitable floor level of residential dwellings have a minimum of 300 mm clearance above the kerb height
- design developments such that residential streets are trafficable at the 1-in-5-year annual exceedance probability flood level, incorporating sea-level rise
- design developments such that commercial and industrial streets are trafficable in the 1-in-10-year annual exceedance probability flood event, incorporating sea-level rise.

It is the proponent's responsibility to undertake the necessary reviews, assessments and modelling to demonstrate, to the satisfaction of the Department of Water, that the proposed development is consistent with these floodplain management principles.

It is recommended that local government authorities:

- define emergency evacuation assembly points and safe zones with 2 m clearance above the 1-in-100-year annual exceedance probability flood level, incorporating sea-level rise, in conjunction with state emergency services
- ensure that major arterial roads (as defined by the local government authority) remain trafficable in the 1-in-100-year annual exceedance probability flood event, incorporating sea-level rise
- consider and manage the risk of surface and groundwater inundation for a short-term return to a wetter climate or a single extreme rainfall year.

Strategy 2.2 Do not cause flooding or inundation of upstream or adjacent developed areas

Proponents of development will need to:

- demonstrate that sufficient capacity exists to contain the 1-in-100-year annual exceedance probability event within watercourses and their floodplains without causing increased flooding upstream or in adjacent developed areas.

Strategy 2.3 Manage surface water flows to prevent damage to downstream infrastructure and assets

Proponents of development will need to:

- demonstrate in areas of residential development, that downstream peak-flow rates and levels for the critical 1-in-5-year and 1-in-100-year annual exceedance probability events are not increased, except where additional downstream capacity exists and the downstream asset owner/manager has given approval
- demonstrate in areas of commercial and industrial development, that downstream peak-flow rates and levels for the critical 1-in-10-year and 1-in-100-year annual exceedance probability events are not increased, except where additional downstream capacity exists and the downstream asset owner/manager has given approval
- demonstrate that additional downstream capacity exists and obtain approval from the downstream asset owner/manager if proposing that a controlled release to the environment will increase volumes of surface and groundwater (including through the use of groundwater drainage systems or flood detention)
- maintain the hydraulic capacity of existing waterways and drainage systems.

Toolbox T.3

Key Principle 3: Ensure the efficient use and re-use of water resources

The principle to ensure the efficient use and re-use of water resources is concerned with appropriately and adaptively managing water resources at all stages of the water cycle. This principle has three parts relating to the objectives of the *Perth-Peel regional water plan 2011–2031: responding to our drying climate*.

A drying climate

It is widely known that the climate of south-west Western Australia has been generally drying during the past 35 years and has become substantially drier within the past 10 years. This has led to reduced availability of supply from existing surface water and groundwater sources, as well as activity to identify and plan for the future development of alternative sources. Alternative sources have been identified but water availability remains limited. Continued climate change is expected in the future and its impacts are likely to include further reductions in availability of water from both existing and planned sources.

Reducing demand through innovation in design

Development within the plan area will lead to an increased population and more industrial operations, leading to an increased demand for water. Pressure on existing and planned water sources will be minimised by development that embraces innovative water efficiency methods and explores opportunities to reduce demands.

Using alternative sources

Previous sections have discussed the naturally-occurring shallow groundwater and large areas of seasonally inundated or waterlogged land that are prevalent in the plan area. This water should not be dismissed as water to be drained away or discarded. Instead, it should be viewed as a resource and incorporated accordingly into the urban water cycle. Similarly, stormwater or wastewater generated by existing and new developments should be investigated as a fit-for-purpose resource.

The Department of Water has undertaken preliminary investigations into the potential for managed aquifer recharge or aquifer storage and recovery in the plan area. The outcomes of this work are presented in this plan's Toolbox section (T5.4–T5.5). Full details of the study may be found in *Feasibility of managed aquifer recharge using drainage water* – draft (Kretschmer et al. 2011).

Surface water and groundwater inundation mapping is shown in Figure 11 of Appendix A.

Strategy 3.1 Minimise water use within developments

Proponents of development will need to:

- develop a site-specific water balance that demonstrates compliance with the following targets:
  - total water use within the development of less than 100 kL/person/yr
  - re-use of not less than 30% of the total water demand for the development as fit-for-purpose sources to satisfy non-potable demands
- follow waterwise design practices including the use of waterwise gardens and irrigation systems — Toolbox T5.1
- minimise irrigation of areas of public open space; that is, include hydrozoned and/or ecozoned areas within public open spaces — Toolbox T5.1, Toolbox T5.3
- ensure that waterwise designs for public open space areas incorporate planning for successful ongoing management and maintenance. — Toolbox T5.1

Strategy 3.2 Achieve highest-value use of fit-for-purpose water, considering all available forms of water for their potential as a resource

Proponents of development will need to:

- investigate and make recommendations on the suitability of garden bores as a source option for watering domestic gardens, considering the risk of contamination of surface water and groundwater by acid sulfate soils and other contaminants, as well as the benefits/impacts of garden bores on any non-drinking water scheme — Toolbox T5.2, Toolbox T1.6
- maximise opportunities for stormwater harvesting and re use — Toolbox T5.4
- investigate opportunities for groundwater use and re-use schemes including aquifer storage and recovery and managed aquifer recharge — Toolbox T.3, Toolbox T5.4
- investigate opportunities for wastewater re-use — Toolbox T6
- prioritise all available on-site water resources for use and/or re-use without discounting them on a water quality or seasonal availability basis, but rather identifying fit-for-purpose options and developing strategies for water quality improvement
- raise community awareness of water management issues to ensure recognition of the true value of water
- abide by the *Rights in Water and Irrigation Act 1914* and take water (when available) within the legislative requirements of the Act

- investigate the beneficial use of all water resources before considering draining surface and/or groundwater

Toolbox T5.4

- avoid the use of imported scheme water for irrigation of public open space or domestic gardens
- investigate all potential fit-for-purpose sources before proposing the use of imported scheme water for in-house non-potable purposes
- demonstrate that all preferred uses of stormwater and shallow groundwater reserves have been fully investigated and found to be unsuitable or unfeasible before proposing controlled downstream release of increased volumes of surface water or groundwater (including through the use of groundwater drainage systems).

Chapter Four

Toolbox

Fauntleroys Drain outlet

The following Toolbox items contain advice and suggested design criteria, where relevant, for satisfying the strategies outlined in this plan. Alternative design criteria to achieve the aims of the strategies may, in some cases, be proposed by development proponents in subsequent water management strategies and plans – subject to the approval of the Department of Water.

T.1 Stormwater best practice

Acceptable design criteria to achieve the strategies specified in KP1 are:

T1.1 Desirable environmental flows and hydrological cycles of high-value water resources

Strategy 1.1

Strategy 1.3

Water resources that may be considered high value in the plan area include wetlands, waterways and groundwater aquifers. Determination of the relative value of a water resource should not be confined to consideration of current statutory classifications.

Guidance on the determination of specific water resource values should be sought from the Department of Water and DEC.

EWRs have been derived for seven selected high-value wetlands in the plan area. These are outlined in the attached report, *Ecological water requirements of selected wetlands in the Murray drainage and water management plan area* (GHD 2010b).

These wetlands were selected as indicative samples to guide the development of EWRs for other high-value wetlands, which should be determined in accordance with the *Guidelines for ecological water requirements for urban water management* (Department of Water in prep.(a)). Wetlands without a 'conservation category' designation may still be high value.

T1.2 Climate change

Strategy 1.1

Development could help to mitigate the potential impacts of climate change by careful design of drainage infrastructure.

For example, discharge of drainage flows from surrounding developed areas into treatment areas or naturalised constructed wetlands (not constructed lakes) could provide valuable recharge to groundwater stores surrounding the wetland. Additionally, when combined with overland flow paths, this arrangement may help to maintain periodic inundation cycles and even allow for future redirection of additional flow into the wetland should the need arise.

Climate change scenarios are based on the IPCC (2000) predictions, and include predictive changes in rainfall, evapotranspiration and sea-level rise. For future technical studies, all of the following scenarios will need to be considered for their impact on proposed infrastructure designs, waterway and wetland health, and water supply schemes:

- medium future climate: 8.70% decrease in mean annual rainfall compared with 1975–2007, as the most likely future climate scenario
- current climate: with rainfall from the period 1978–2009, as a feasible long-term wet scenario
- dry future climate: 16.18% decrease in mean annual rainfall compared with 1975–2007, as a potential dry scenario.

In addition, the effect of the wet future climate scenario in conjunction with a single extreme rainfall year (1917 annual rainfall) should be considered. This scenario simulates the effect of a single extreme year, or short-term return to a wetter climate, and is an important consideration for development design.

T1.3 Hydrologic zones and ecological buffers

Strategy 1.1

Strategy 1.2

A hydrologic zone differs from an ecological buffer and is defined as the area surrounding a wetland where the installation of infrastructure (including groundwater drainage systems or bores) may have an undesirable hydrological influence on the wetland without being a development exclusion zone.

The hydrologic zones presented in *Murray hydrological studies: Surface water, groundwater and environmental water – land development, drainage and climate change scenarios* (Hall et al. 2010c) were found to vary with the depth of drainage infrastructure, topography, geology and hydrogeology.

Proponents should undertake appropriate investigations to ensure that hydrologic zones are determined and used to prevent development infrastructure from detrimentally affecting the water balance and hydrology of surrounding waterbodies and environmental assets.

The Department of Water does not normally play a role in determining appropriate ecological buffers and thus advice should be sought from DEC on this matter. Infrastructure, including drainage, may not normally be constructed within the ecological buffer of wetlands and surface water flows to wetlands may only be via overland flow paths. An ecological buffer is the only area where development and infrastructure is always excluded.

Proponents should undertake appropriate investigations to ensure development infrastructure outside the ecological buffer does not detrimentally affect the water balance and hydrology of surrounding waterbodies and environmental assets.

T1.4 Flood and inundation management

Strategy 1.1

Strategy 1.2

Land may be inundated by a number of different mechanisms including:

- flooding, when the capacity of an adjacent watercourse or waterbody is exceeded
- direct rainfall where no runoff route is available because the land is flat or is a low-point
- surface expression of rising groundwater levels.

The *Murray floodplain development strategy* (GHD 2010a) makes development recommendations to manage inundation by flooding for areas within or adjacent to defined floodways, flood fringes and floodplains (Section 7.5.2 Building and development controls).

Inundation by direct rainfall or rising groundwater levels play an important role in significant volumes of water and nutrient loads being retained within the Murray catchment. Deterioration in the water quality of the downstream Peel-Harvey estuary system and flooding where the capacity of the receiving watercourse or waterbody is exceeded are both potential impacts of draining these areas for development and are considered unacceptable.

It may be acceptable to drain and develop areas of land inundated by direct rainfall or rising groundwater provided the land is not a defined wetland or waterbody and has little or no ecological value. Proponents of development in these areas must demonstrate, through the use of a suitable water balance model, that equivalent detention capacity can be provided and that the potential for use of this water as a fit-for-purpose source has been maximised. Where discharge to a downstream watercourse or waterbody is proposed, proponents will be required to demonstrate that water quality targets can be achieved, that hydraulic capacity exists and that the downstream asset owner/manager has given their consent.

T1.5 Stormwater quality management

Strategy 1.1

Strategy 1.2

As part of water sensitive urban design (WSUD), structural and non-structural strategies should be combined to achieve the desired stormwater treatment outcomes.

The Department of Water is developing a ‘water quality decision tool’ to help with the selection of appropriate WSUD strategies to achieve the required reductions in nutrient loads to downstream waterways and wetlands. Until such time, the following stormwater quality management strategies are deemed to achieve no net increase from pre-development nutrient loads to downstream waterways and wetlands:

- retain the volume of the one-hour-duration 1-in-1 year annual exceedance probability event from constructed impervious areas at source
- maintain the pre-development critical 1-in-1 year annual exceedance probability event peak flow rates and volumes for the subcatchment

- biofiltration systems to be sized at a minimum of 2% of the connected impervious area they receive runoff from
- soil amendment to include a 300-mm-deep layer of material that will reduce nutrient export (with a PRI greater than 10) and should be undertaken across a minimum of 10% of the site including, but not limited to, all landscaped public open space and landscaped drainage features
- swales and bioretention or infiltration systems to be designed with sufficient clearance from groundwater levels to ensure they do not remain permanently wet.

The Department of Water does not generally support direct connection of lots to the drainage network. If hydraulic design considerations and comprehensive geotechnical information concludes that infiltration of the one-hour-duration 1-in-1-year annual exceedance probability event is not possible at source, then an overflow connection from detention capacity provided within rainwater tanks or soakwells may be acceptable.

Current best-practice stormwater management measures at the different scales include:

Residential lot scale:

- on-site detention and/or retention
- waterwise and nutrient-wise landscaping
- maximise permeable surfaces
- porous pavements
- amended topsoils
- rainwater tanks
- raingardens
- vegetated soakwells.

Commercial lot scale:

as for residential and in addition:

- landscaped infiltration structures
- hydrocarbon management and sediment traps.

Street scale:

as for residential lots and in addition:

- landscaped infiltration structures
- hydrocarbon management and sediment traps
- conveyance biofilter systems.

Estate scale:

As for street scale and in addition:

- end-of-catchment treatment structures
- maintain or improve ecology and channel morphology of existing waterways
- soil amendment within bed and banks of existing waterways
- non-structural strategies such as interpretive signage and community engagement.

Area scale:

- non-structural strategies such as public education campaigns and materials.

The above practices may be limited by several factors, such as local soil and hydrological conditions, the depth and type of fill imported, public safety and public health standards, design life/reliability requirements, maintenance/management costs, legal authority and streetscape aesthetics.

If water quality modelling is to be undertaken to refine or minimise use of the above strategies, then the method used will need to demonstrate (to the satisfaction of the Department of Water) that post-development nutrient load targets to downstream waterways and wetlands are achieved as defined in Strategy 2.1. In addition it should be noted that:

- soil amendment using material that will reduce nutrient export (with a PRI greater than 10) will also need to satisfy soil permeability and compaction criteria specified by the local government authority.

T1.6 Acid sulfate soils

Strategy 1.2

Strategy 3.2

The following is considered to be best practice for managing the downstream risks of potential acid sulfate soils on the quality of receiving waterbodies:

- undertake construction activities in accordance with *Treatment and management of soils and water in acid sulfate soil landscapes* (DEC 2009), minimising the use of dewatering wherever possible
- retain existing vegetation wherever possible, with imported clean fill preferably being applied without first disturbing the in-situ soils or vegetation so that the existing buffering capacity of the organic material is retained
- locate surface water and groundwater drainage inverts such that minimum groundwater levels are not lowered
- establish appropriate maximum depth and pumping rates for all proposed groundwater abstraction bores, including unlicensed garden bores, to ensure that individual drawdown cones do not result in localised lowering of the average annual minimum groundwater level.

T1.7 Mosquito control

Strategy 1.3

Mosquito breeding sites can occur where there is standing water.
Mosquito breeding can be controlled by ensuring:

- areas of standing water drain within three days of filling
- areas of standing water are free from depressions, potholes and related irregularities
- areas of standing water do not seep to other low-lying areas
- stream water depths are adequate to support natural predators (e.g. fish) to consume larvae
- bank gradients are steep enough not to trap pockets of stagnant water
- weeds are controlled in streams and areas of standing water
- stream water quality is adequate to support natural predators (e.g. fish) to consume larvae
- future residents are informed about mosquito breeding and are advised to:
  - dispose of all containers which hold water
  - keep ornamental ponds stocked with mosquito-eating fish
  - empty plant pot drip trays once a week or fill with sand
  - empty and clean animal and pet drinking water once a week
  - keep swimming pools well chlorinated and filtered and free of dead leaves
  - fill or drain depressions in the ground that hold water
  - prevent leaking taps which can maintain semi-permanent pools
  - avoid over-watering lawns
  - fit mosquito-proof cowls to vent pipes on septic tank systems
  - screen rainwater tanks and/or add paraffin oil to cover the surface
  - ensure roof guttering does not hold water
  - empty leaf axils of plants that hold water (especially bromeliads) once a week

Chemical larviciding and adulticiding may be used if preventative measures are ineffective.
In addition, mosquito monitoring traps may be set up to assess the numbers of mosquitoes in an area, for targeted control.

T.2 Monitoring best practice

Strategy 1.1
Strategy 1.2

Better urban water management (WAPC 2008a) requires monitoring to be undertaken to establish the pre-development condition of surface water and groundwater and the impact of development.

The Department of Water, in conjunction with partner organisations, is investigating creation of a coordinated urban water monitoring program to allow development proponents to satisfy their post-development monitoring obligations via a financial contribution scheme. The department will report on the outcomes of this project on its completion.

Proponents will need to determine the appropriate level of pre-development monitoring before development may proceed. It is essential they discuss this with the Department of Water as early in the process as possible.

The following questions may be useful as a guide to the likely requirements:

Is the land to be developed close to, or does it contain any of the following sensitive water resource areas?

- public drinking water source area or underground water pollution control area
- environmental protection policy or any other natural or artificial lake or surface waterbody
- 'conservation category', 'resource enhancement' or any other natural or artificial wetland
- coastal water, estuary, river, creek, drain or any other waterway.

Yes: *The proximity and direction of surface water and groundwater flow will need to be considered by experienced hydrologists and/or hydrogeologists to determine appropriate monitoring where any of the above exists near the development.*

No: *Monitoring of pre-development surface water is unlikely to be required, however pre-development groundwater level and quality monitoring will still be required as indicated by the following questions.*

Does good quality groundwater information exist either on or within reasonable proximity to the site?

Yes: The amount and duration of monitoring required will vary according to the groundwater levels indicated by the existing information. The following two questions will help to determine the likely requirements.

No: 12 to 18 months of monthly groundwater-level monitoring, including a minimum of two winters, may be required to establish with some accuracy the seasonal groundwater trends on the site.

Does existing information indicate that groundwater is within 5 m of the ground surface?

Yes: 12 to 18 months of monthly groundwater-level monitoring, including a minimum of two winters, will be required to establish with some accuracy the seasonal groundwater trends on the site.

No: A limited number of bores may be required on-site to confirm seasonal groundwater trends, but a short period of record is often satisfactory when combined with longer records from other bores within reasonable proximity to the site.

Does existing information indicate that groundwater is within 10 m of the ground surface?

Yes: A limited number of bores may be required on-site to confirm seasonal groundwater trends, but a short period of record is often satisfactory when combined with longer records from other bores within reasonable proximity to the site.

No: Test pitting or bores to a minimum depth of 5 m will be required on the site to demonstrate that no groundwater is intercepted.

Monitoring of sites that require groundwater quality monitoring because of the presence of sensitive water resource areas, but where the groundwater is shown to be deep (> 5 m from the surface), may be discontinued if it is demonstrated that:

- there is no ecological impact on sensitive water resource areas
- the local soil is capable of retaining and/or removing nutrients and other pollutants.

Post-development monitoring is always required and the extent and duration of this requirement will be established during the preparation of water management strategies or plans. Post-development monitoring will usually continue for a minimum of three years from practical completion of the development's final stage and following review, may extend for a further two years in some circumstances.

The Department of Water is preparing guidelines for the monitoring programs. The guidelines are expected to be completed in late 2010.

T.3 Groundwater management best practice

The Department of Water is preparing a document aimed at guiding the management of shallow groundwater levels. It sets out three principles to support a groundwater management strategy. These principles are:

Strategy 1.1

Strategy 1.2

- Protect water quality and quantity of significant environmental assets and receiving environments

Strategy 3.2

- Protect urban amenity and infrastructure integrity for public health and safety
- Fit for purpose use of all water resources

The Department of Water requires any proposal to manage or control groundwater levels to consider and satisfy these principles so that positive water management outcomes are achieved.

Any proposal to manage shallow groundwater will need to be supported by appropriate information and investigations to show the how proposed land use change will affect the pre-development water balance, as well as how post-development changes in any of the water balance components will affect water volumes, rates and levels in aquifers and waterbodies.

The potential for groundwater management systems to impact on waterbodies needs to be carefully considered as a part of the water requirements of the area. Drained groundwater is a potentially important fit-for-purpose water source and its beneficial use will need to be investigated. In addition, if the water is proposed to be discharged, its potential impact on downstream water quality will also need to be addressed.

Identifying an appropriate level for groundwater drainage systems is complex and will need to be supported by local monitoring and/or modelling with a level of detail appropriate to the proposed level of control. For example, a proposal to install a groundwater drainage system at or above the long-term pre-development maximum groundwater level may require substantially less supporting information than a proposal to control groundwater to any lower level. Similarly, a proposal to control groundwater in an area remote from any high-value water resources may require substantially less supporting information than a proposal adjacent to a high-value wetland.

Even though proposing to install a groundwater drainage system at or near the long-term pre-development maximum groundwater level may require less supporting information, it may not be the level that provides the most beneficial water resource management outcomes; hence careful consideration by proponents will still be needed.

T.4 Wetland and waterway management best practice

T4.1 Management and restoration of waterways

Strategy 1.3

Modification to the bed and banks of a waterway within the Serpentine, Murray and Dandalup surface water management areas proclaimed under the *Rights in Water and Irrigation Act 1914* will require a permit from the Department of Water. Permits, if granted, may contain conditions such as revegetation and bank stabilisation.

Refer to the following literature for policy on river restoration and practical advice on how to manage and restore degraded waterways:

- *River restoration manual, a guide to the nature, protection, rehabilitation and long-term management of waterways in Western Australia* (WRC/DoE 1999–2003).

Refer to the following literature for policy on wetland conservation and practical advice on how to manage and restore degraded wetlands:

- *Wetlands conservation policy for Western Australia* (Government of Western Australia 1997)
- *Environmental protection of wetlands position statement no. 4* (EPA 2004)
- *Position statement: wetlands* (WRC 2001a) and relevant environmental protection policies
- *A guide to managing and restoring wetlands in Western Australia* (DEC in prep.)
- *Environmental guidance for planning and development – guidance statement no. 33* (EPA 2008).

T4.2 Foreshore areas and reserves

Strategy 1.3

Refer to the following literature for policy on foreshore areas and reserves and practical advice on how to determine foreshore areas and reserves:

- *Foreshore policy 1 – identifying the foreshore area* (WRC 2002) under revision
- *Environmental guidance for planning and development – guidance statement no. 33* (EPA 2008)
- *Environmental protection (Peel Inlet–Harvey Estuary) policy* (EPA 1992)
- *River restoration report 16: determining foreshore reserves* (WRC 2001b)
- *Water note 23: determining foreshore reserves* (WRC 2001c).

T4.3 Design of new wetlands and waterways

The design of new surface drainage infrastructure should, wherever possible, result in wetlands and waterways that are functionally similar to naturally occurring local wetlands and waterways.

Refer to the following literature for practical advice on designing naturally functioning wetlands and waterways:

- *Stormwater management manual for Western Australia* (Department of Water 2004-07)
- *River restoration manual* (DEC 2004)
- *Interim position statement: constructed lakes* (Department of Water 2007)
- *River Science issue 26: Constructed ephemeral wetlands on the Swan Coastal Plain – the design process* (Swan River Trust 2007)

T5 Water re-use and efficiency best practice

Strategy 3.1

T5.1 Water efficiency guidance and tools

The Water Agencies (Water Use) By-laws 2010 outline the level of water restrictions applicable to scheme water and domestic bore users. Currently, the stage of restrictions that applies to the use of scheme water and domestic bore water in the plan area is Stage 6, from 1 June to 31 August; commonly known as a 'winter sprinkler ban' where lawns or gardens must not be watered except by hose or watering can.

Throughout the year Stage 3 restrictions apply, which means there is a daytime (9am-6pm) sprinkler ban for watering of domestic lawns and gardens.

Also throughout the year, a three-day-per-week roster applies to garden bore users and a two-day-per-week water roster applies to all scheme water users. For details, see the Department of Water website: <www.water.wa.gov.au>.

Licensed groundwater users (e.g. local governments, private and public golf courses, educational institutions, state government agencies and race complexes) in the state's south-west have had their licenses amended to include a condition prohibiting the use of sprinklers during the winter months and in the daytime during any other time of the year.

An online tool kit – which aims to promote water conservation and non-drinking water supply options to local government, developers and householders – is available on the department's website: <www.water.wa.gov.au>.

T5.2 Unlicensed residential bore use guidance

Strategy 1.1

Strategy 1.2

Strategy 3.1

Strategy 3.2

Private domestic water supply from the watertable aquifer is managed through the Rights in Water and Irrigation Act Exemption and Repeal (Section 26C) Order 2010. The taking of groundwater in the study area is not licensed where it is used for fire fighting, watering of stock other than those raised under intensive conditions, watering of an area of lawn or garden that does not exceed 0.2 ha, and other ordinary domestic uses.

The Department of Water considers that in general, the promotion of shallow, low-yield garden bores where there is a low or medium risk of acid sulfate soils is appropriate within the plan area. Higher-yield community-type bores, however, may not be appropriate where a medium risk of acid sulfate soils exists – because the resulting localised lowering of the groundwater table may cause acidity issues.

It is expected that development proponents will undertake the necessary site investigations to confirm the viability of unlicensed bore use and provide this information to the ultimate landowners (to satisfy their obligation to investigate all potential fit-for-purpose water supply options).

T5.3 Licensed bore use guidance

Strategy 1.2

The *Murray groundwater area allocation plan* (Department of Water 2010a) has information about the licensing of groundwater abstraction within the plan area.

The department's *Water recycling and efficiency note: community bores* (Department of Water 2010c) provides information on using community bores to irrigate public open space and domestic gardens, particularly in new residential areas in the greater Perth metropolitan region.

T5.4 Hierarchies for optimising use of drainage water through the *Murray drainage and water management plan*

Strategy 1.1
Strategy 1.2
Strategy 1.4
Strategy 3.1

In determining the potential quantities of water that may be available as a fit-for-purpose source, a presumption is made that the EWRs of existing downstream receiving environments will be maintained. This means that water currently discharged from a site into wetlands and watercourses should continue to do so in similar quantities, at similar rates and with similar seasonal, annual and interannual variation.

Strategy 3.2

Development also has the potential to help mitigate the impacts of climate change on wetlands and watercourses, by redirecting additional flow into the wetland or watercourse (should the need arise and in consultation with the Department of Water and DEC). To maximise opportunities for this potential mitigation of future climate change, it will be essential to carefully consider the location and design of drainage and stormwater harvesting infrastructure.

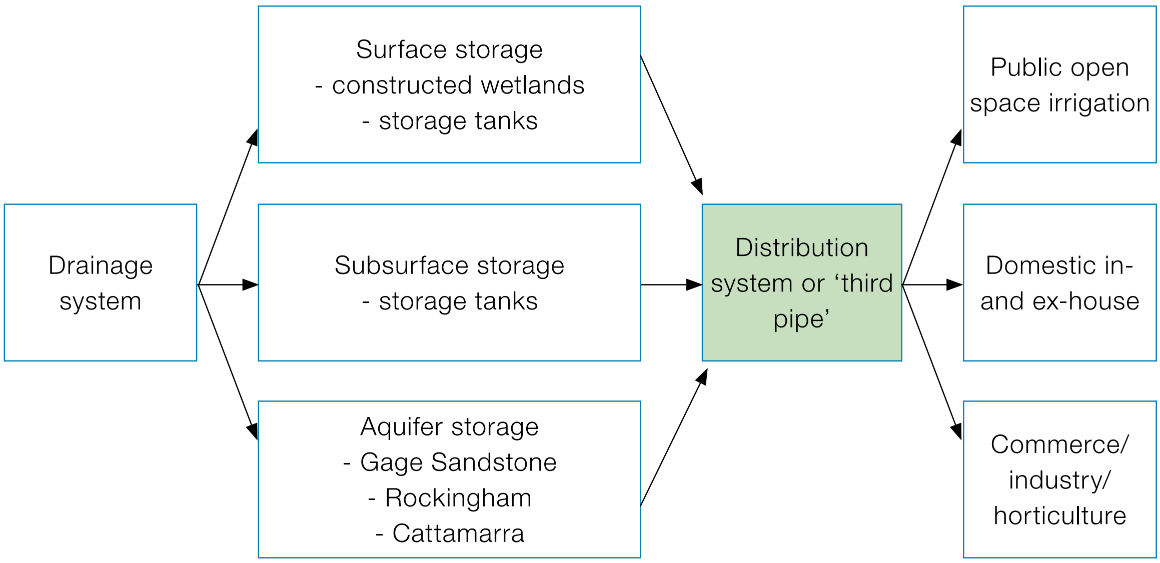
The Department of Water has a hierarchy of preferred uses for stormwater and shallow groundwater reserves for development areas in the plan area. These are:

- use on-site (lot-street scale)
  - stormwater is harvested at the lot scale within rainwater tanks before entering the shallow groundwater for lot-scale in- and ex-house fit-for purpose supply
  - shallow groundwater is left in-situ and accessed by shallow low-yield (garden) bores, and where appropriate (refer T5.2) used for lot-scale and local public open space irrigation.

It is expected that the opportunities for these uses will be maximised within all developments to satisfy the requirement that 30% of total water use be from fit-for-purpose sources (refer Strategy 3.2) and that the following will be used in combination, as required and appropriate to the prevailing site-specific circumstances:

- use on-site (street-district scale)
  - stormwater and shallow groundwater is harvested from surface water and groundwater drainage systems, treated and stored for fit-for-purpose use
- use off-site
  - stormwater and shallow groundwater is harvested from surface water and groundwater drainage systems, treated, stored and transferred for off-site fit-for-purpose commercial industrial/horticultural use.

Potential methodologies for use on- or off-site are summarised in the following diagram, in each case the distribution system is critical to the scheme's success and will need to be designed at the earliest stage of development:



The determination of an appropriate use for stormwater and shallow groundwater reserves will take into consideration:

- on-site and off-site demands
- the availability and potential yield of stormwater and shallow groundwater
- the suitability of site conditions and availability of land for surface and/or subsurface storage
- the suitability of aquifers for storage
- infrastructure cost (including replacement)
- management and maintenance cost
- service provision cost
- land cost and relative footprints of options.

Where the preferred uses for stormwater and shallow groundwater reserves have been fully investigated and found to be unsuitable or unfeasible, or where there is a remaining surplus, it may be appropriate to consider the following:

- controlled release to the environment.

Stormwater and shallow groundwater is treated for release to downstream waterways and wetlands where EWRs are satisfied, additional downstream capacity exists and the downstream asset owner/manager has given approval.

Table 7 provides a checkbox summary of each use option's suitability for each of the development areas.

Table 7 Checkbox summary of stormwater and shallow groundwater use option suitability by development area

	Rainwater tanks	Shallow/low-yield (garden) bores	Surface/subsurface storage	Gage Sandstone					Distance to commercial /Industrial/ horticultural users
				Mariginiup	Cattamarra Coal Measures	Rockingham	Wanneroo	Gage Sandstone	
Austin	ˇ	ˇ	ˇ	ˇ			ˇ	ˇ	> 10 km
Barragup	ˇ	ASS	ˇ	ˇ		ˇ	ˇ	ˇ	> 10 km
Buchanans	ˇ	ˇ	ˇ	ˇ			ˇ	ˇ	On-site
Carcoola	ˇ	Clay	ˇ	ˇ					< 10 km
Nambeelup	ˇ	ˇ	ˇ	ˇ		ˇ	ˇ	ˇ	On-site
Ravenswood	ˇ	ˇ	ˇ	ˇ		ˇ	ˇ	ˇ	< 10 km
Nerrima	ˇ	ˇ	ˇ	ˇ			ˇ	ˇ	> 10 km
North Dandalup	ˇ	Clay	ˇ	ˇ	ˇ				< 10 km
Pinjarra	ˇ	Clay	ˇ	ˇ			ˇ	ˇ	> 10 km
South Murray	ˇ	ˇ	ˇ	ˇ			ˇ	ˇ	> 10 km
South Yunderup	ˇ	ASS	ˇ	ˇ		ˇ	ˇ	ˇ	> 10 km

T5.5 Managed aquifer recharge

Strategy 1.4

Strategy 3.2

The Department of Water is undertaking a study to consider in more detail the potential for managed aquifer recharge or aquifer storage and recovery for the plan area's various aquifers.

The Department of Water's preliminary investigations indicate that potentially five stratigraphic units are present within three aquifers, in parts of the plan area, which may be wholly or partially suitable for managed aquifer recharge or aquifer storage and recovery. These aquifers are:

Rockingham – there is potential for storage within the saltwater interface of this partially-confined shallow stratigraphic unit, which is part of the Superficial Aquifer. This methodology is commonly used in California. Treatment to Class A may be required.

Wanneroo – this is a member of the upper Leederville Aquifer and there is some potential for storage, although the presence of Water Corporation public drinking water supply bores means Class A treatment will be needed before injection.

Mariginiup – this is a member of the lower Leederville Aquifer and has multiple users, including the Water Corporation for public drinking water supply. Soils are predominantly clay, making injection very difficult. Because of how it is used, injected water will require Class A treatment.

Gage Sandstone – this is a member of the Yarragadee Aquifer and is not generally considered a useable water resource as a result of high salinity (>2000 mg/L). There is good potential for storage within this deep (~300 m) confined aquifer using the 'saltwater displacement' methodology commonly used in South Australia, where water is pumped into the saline aquifer, forming a freshwater bubble that can later be withdrawn for use. It is possible that treatment would only be required to remove suspended solids for infrastructure protection.

Cattamarra Coal Measures – this is a member of the Yarragadee Aquifer and is fully allocated (not public drinking water). The largest single user is Alcoa and a 20 m decline in head has been associated with this abstraction. The aquifer generally is thought to increase in salinity with depth. This aquifer is structurally suitable for managed aquifer recharge but only on the eastern margin, and thus would only be relevant to the North Dandalup development area.

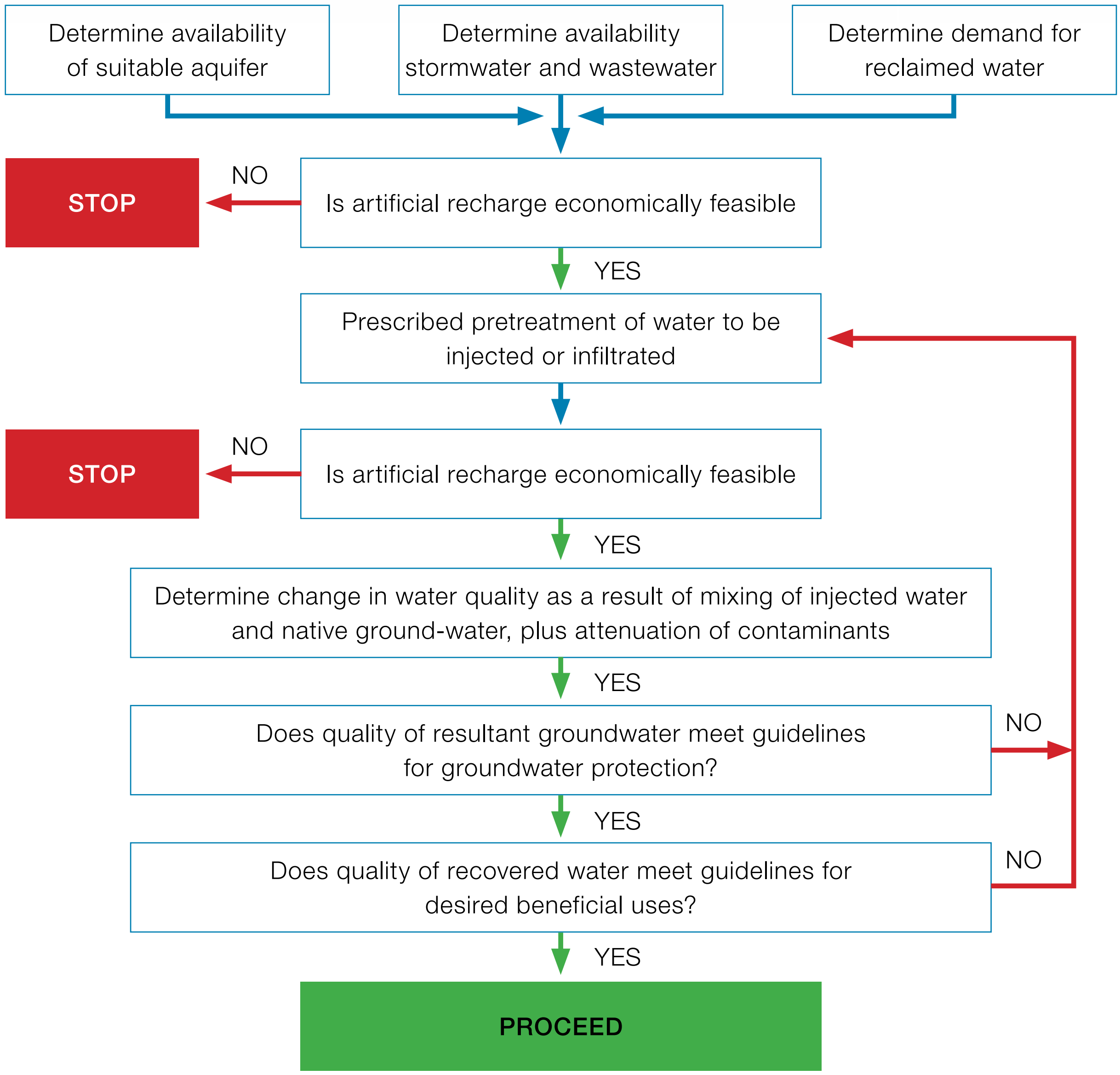


Chart 4 Flow chart outlining the process that needs to be undertaken to establish the feasibility of managed aquifer recharge (example only, to be refined)

T6 Wastewater management

Extensive development within the plan area may require expansion of the Water Corporation's IWSS or its reticulated sewerage services. Advice about the planning or provision of existing or future scheme water or reticulated sewerage services should be sought from the Water Corporation or alternative service provider where applicable.

The *Water quality improvement plan for the rivers and estuary of the Peel-Harvey system – phosphorus management* (EPA 2008) cites both animal and human effluent as one of the causes of poor water quality in the Peel-Harvey estuary and concludes that where connection to reticulated sewerage is not possible, aerobic treatment units (ATUs) should be used in preference to traditional septic tanks.

ATUs are a more advanced multi-stage alternative to conventional septic tanks and provide an improved quality of effluent treatment. Those proposed for use within the plan area should be approved as 'phosphate removing'.

The installation of an ATU must be approved by the Department of Health or delegated local authority. Detailed advice on the application process as well as technical information about the installation and operation of ATUs may be found on the Department of Health website <*www.public.health.wa.gov.au*> Water > Wastewater management.

The Department of Water considers that wastewater generated by existing and new developments should be viewed as a resource and incorporated accordingly into the urban water cycle for investigation as a fit-for-purpose resource.

Appendices

Appendix A — Figures

Upper Nambeelup Brook downstream of Wescott Road

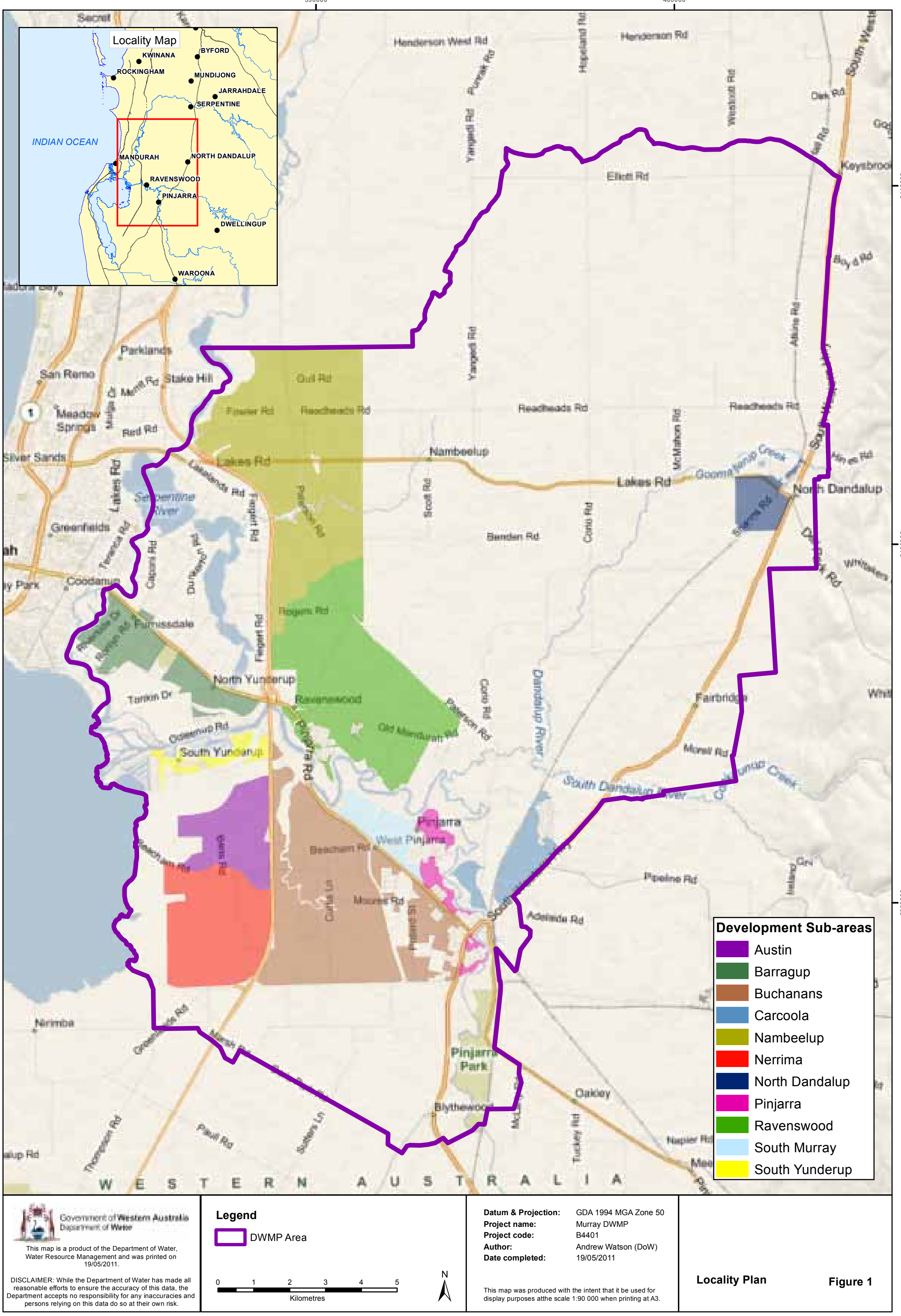


Figure 1

Locality plan

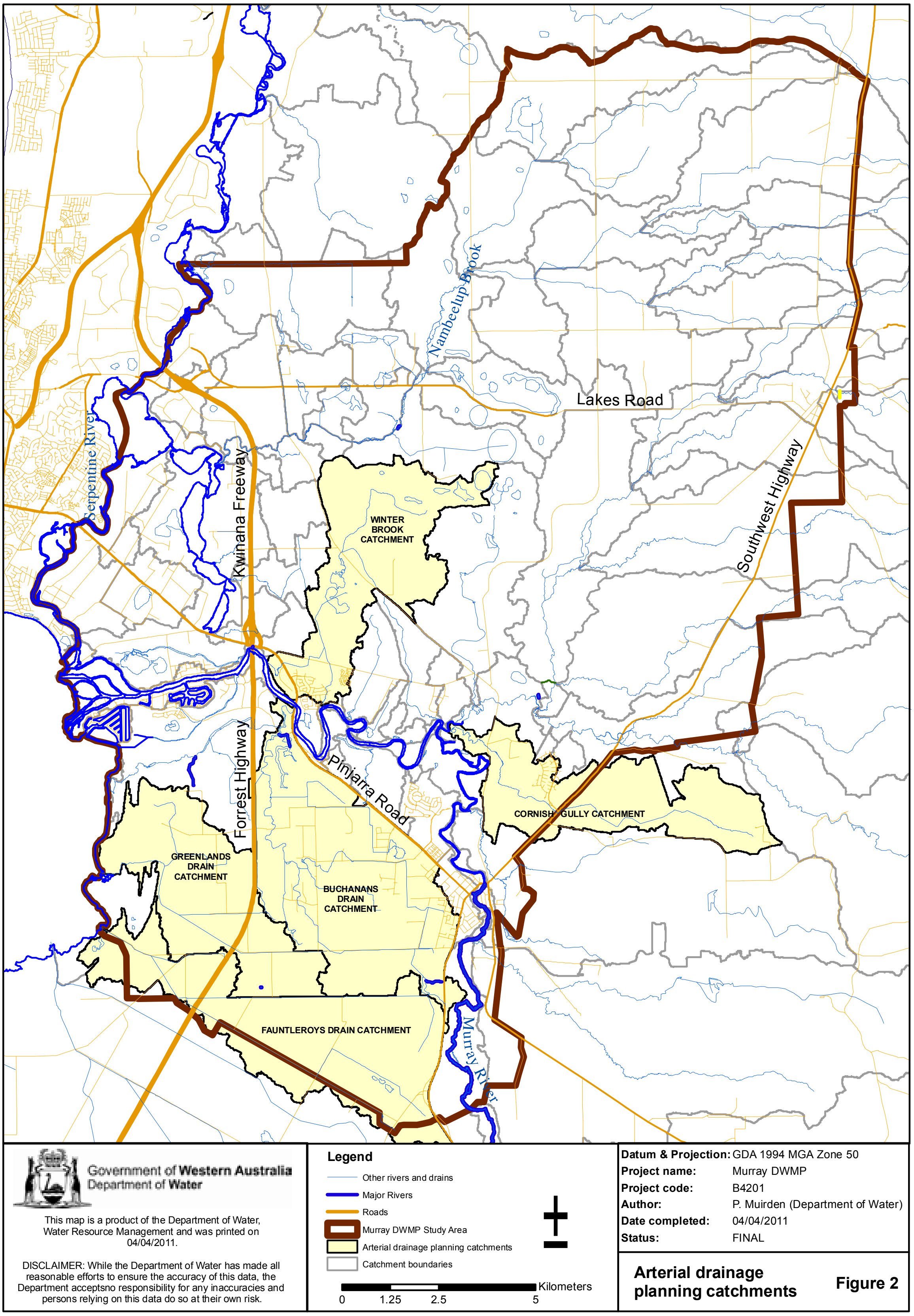
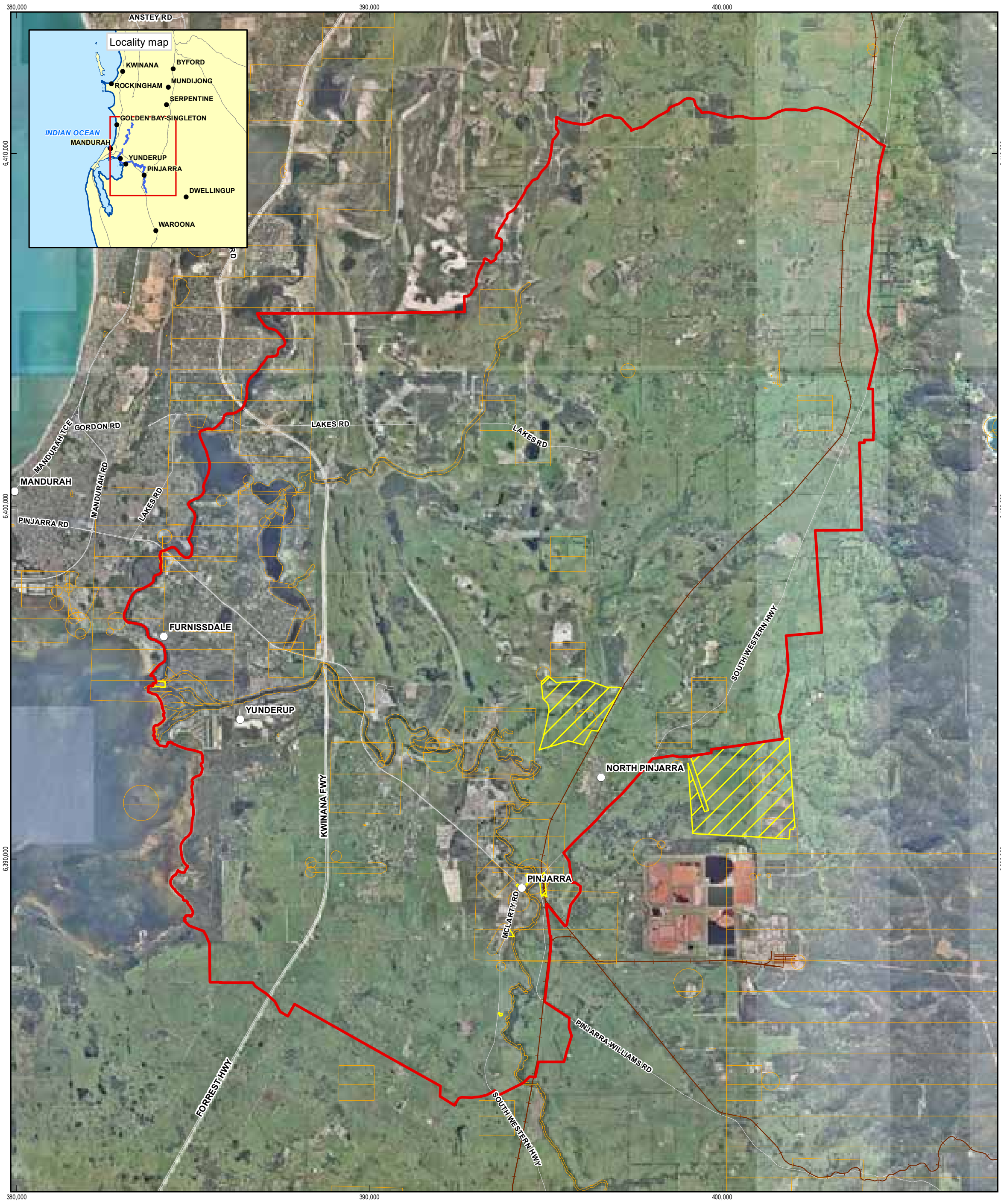


Figure 2

Arterial drainage planning catchments



LEGEND

Locality	Heritage council sites
Road	Aboriginal heritage sites
Railways	Study area

1:100,000 (at A3)

0 0.5 1 2 3 4 5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

N

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Department of Water
Murray drainage and water management plan

Job Number 61-2393706
Revision 0
Date 15 Apr 2011

Heritage sites

Figure 3

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GHD House, 239 Adelaide Terrace Perth WA 6004 T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data Source: DOW: Study Area - 20081202; GA: Locality - 2006; DPI: Heritage Council Sites - 200812; DIA: Aboriginal Heritage Sites - 20090424; Landgate: Railway - 200905, Roads - 200905, Fremantle, Jarrahdale, Pinjarra and Dwellingup 2008 Mosaics - 200908. Created by: xntan, KDIralu, KDIRALU, jhchen, cagilbert

Figure 3
Heritage sites

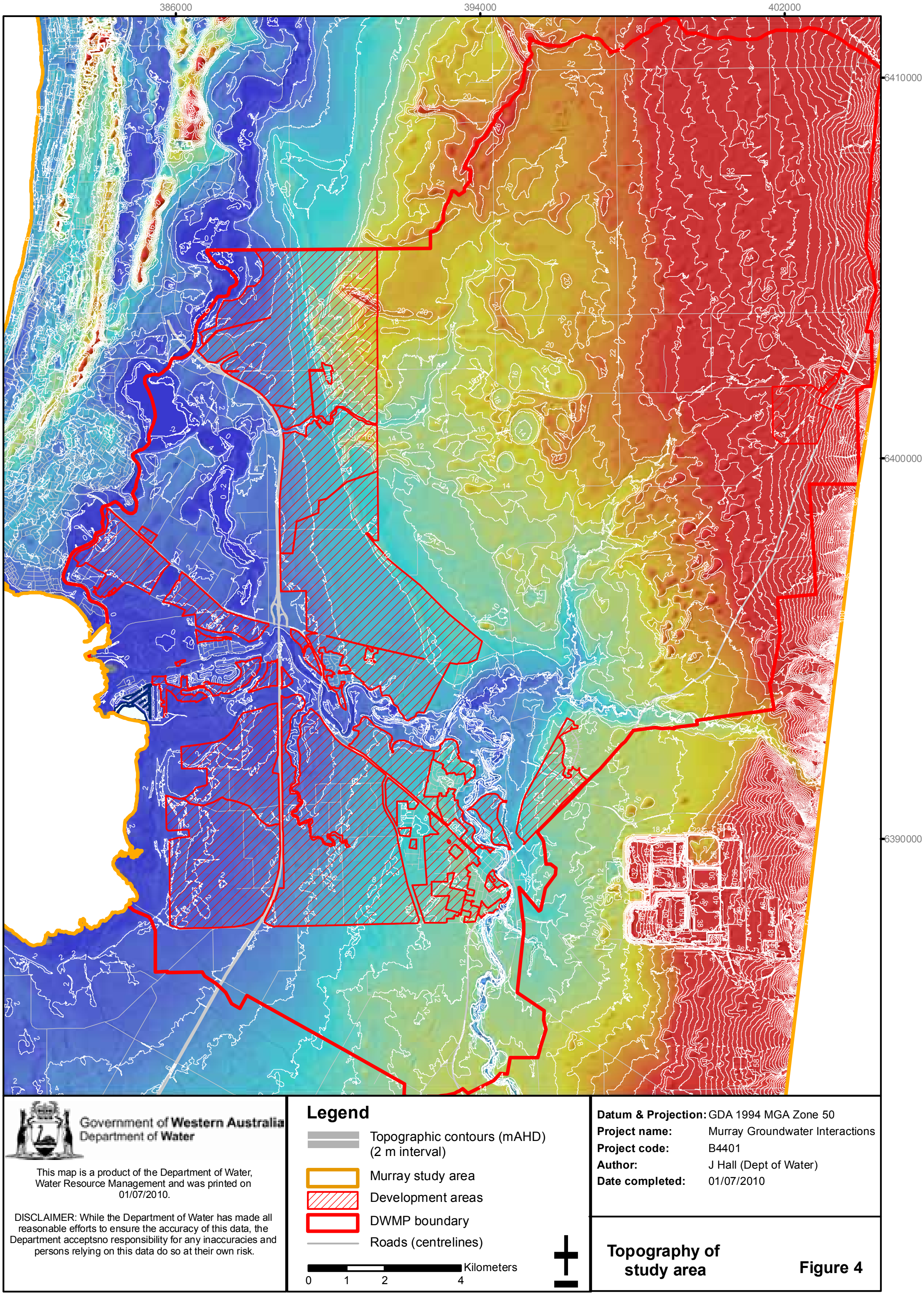
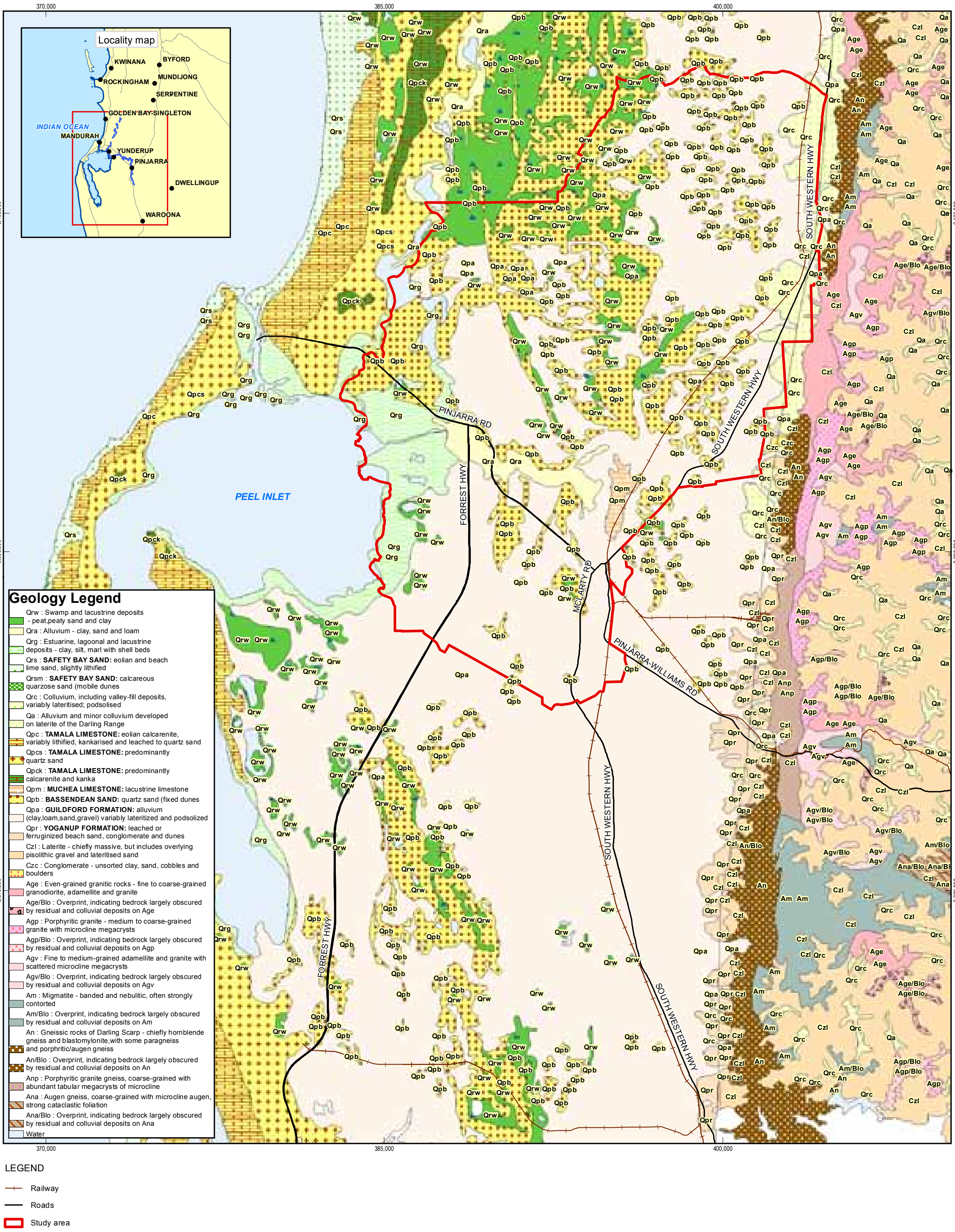


Figure 4

Topography of the study area



1:150,000 (at A3)

0 0.75 1.5 3 4.5 6 7.5

Kilometers

Map Projection: Transverse Mercator
Horizontal Datum: Geocentric Datum of Australia (GDA)
Grid: Map Grid of Australia 1994, Zone 50

N

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Department of Water
Murray drainage and water management plan

Job Number 61-2393706
Revision 0
Date 15 Apr 2011

Geology

Figure 5

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GHD House, 239 Adelaide Terrace Perth WA 6004 **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

Data Source: DOW: Study Area - 20081202; Landgate: Railway - 200905, Roads - 20090501; DMP: 250K Geology - 20001114. Created by: xntan, mdalton2, KDIRALU, abarrett-lennard, jhchen, cagilbert

Figure 5

Geology

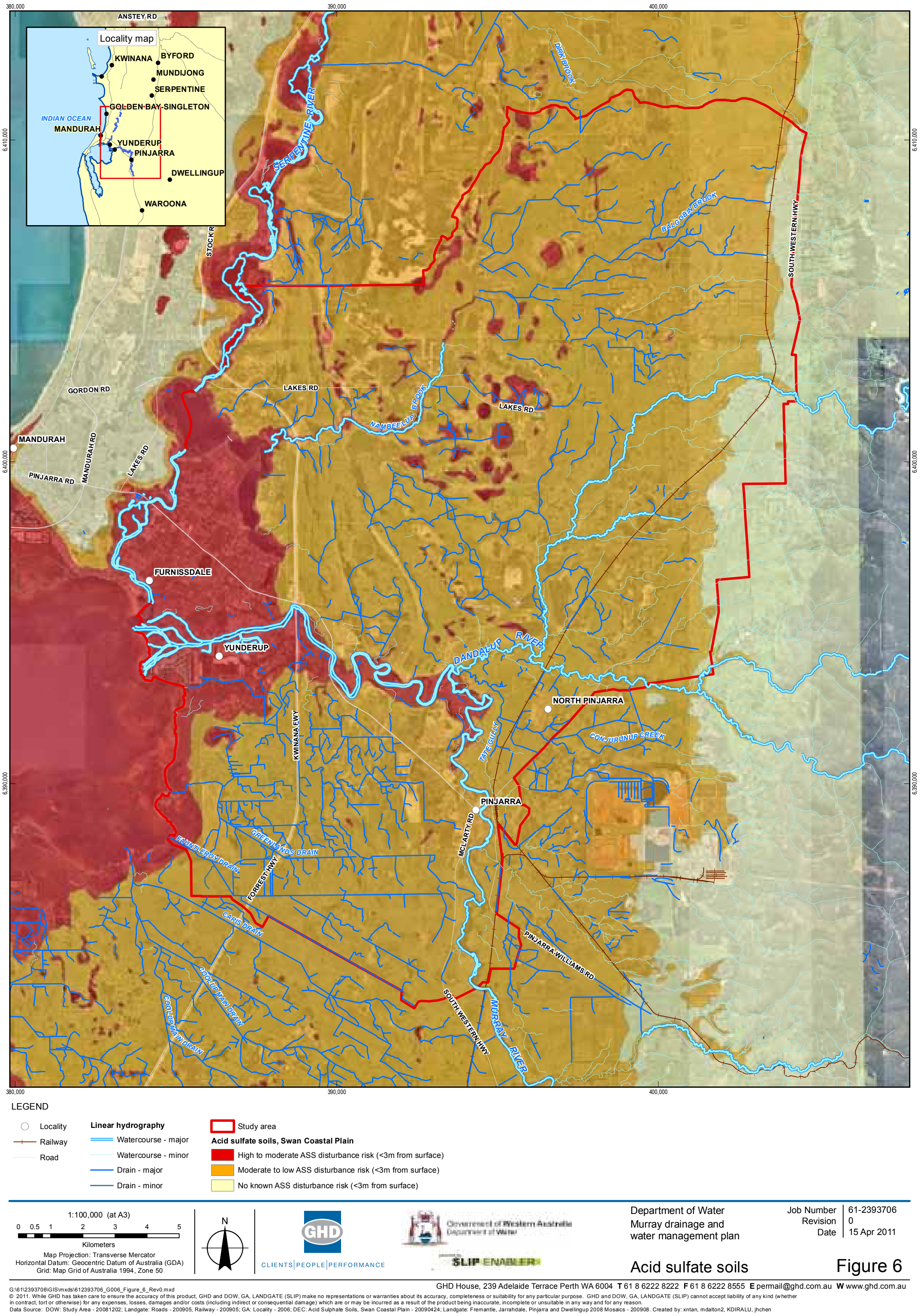

Figure 6

Acid sulfate soils

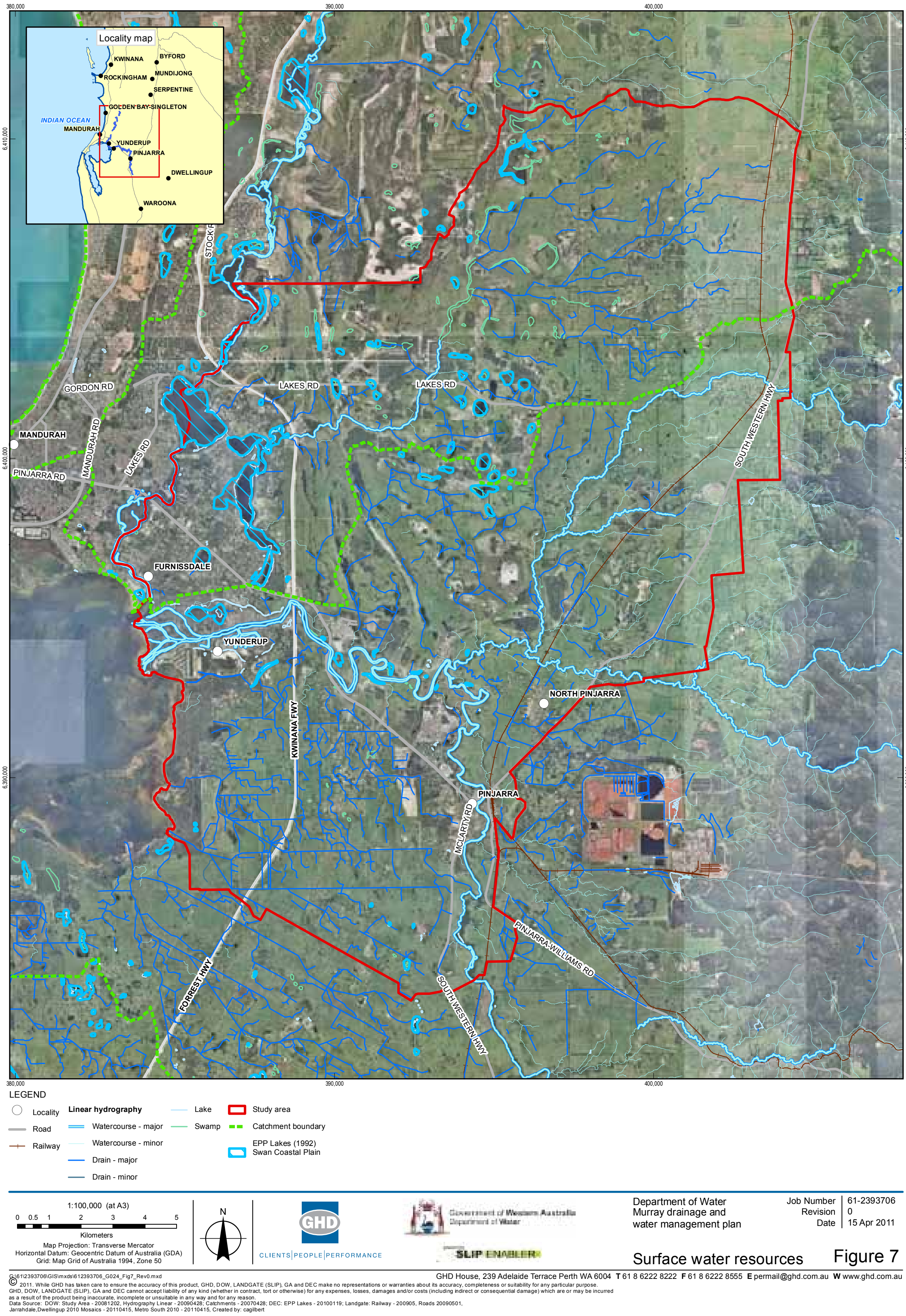

Figure 7

Surface water resources

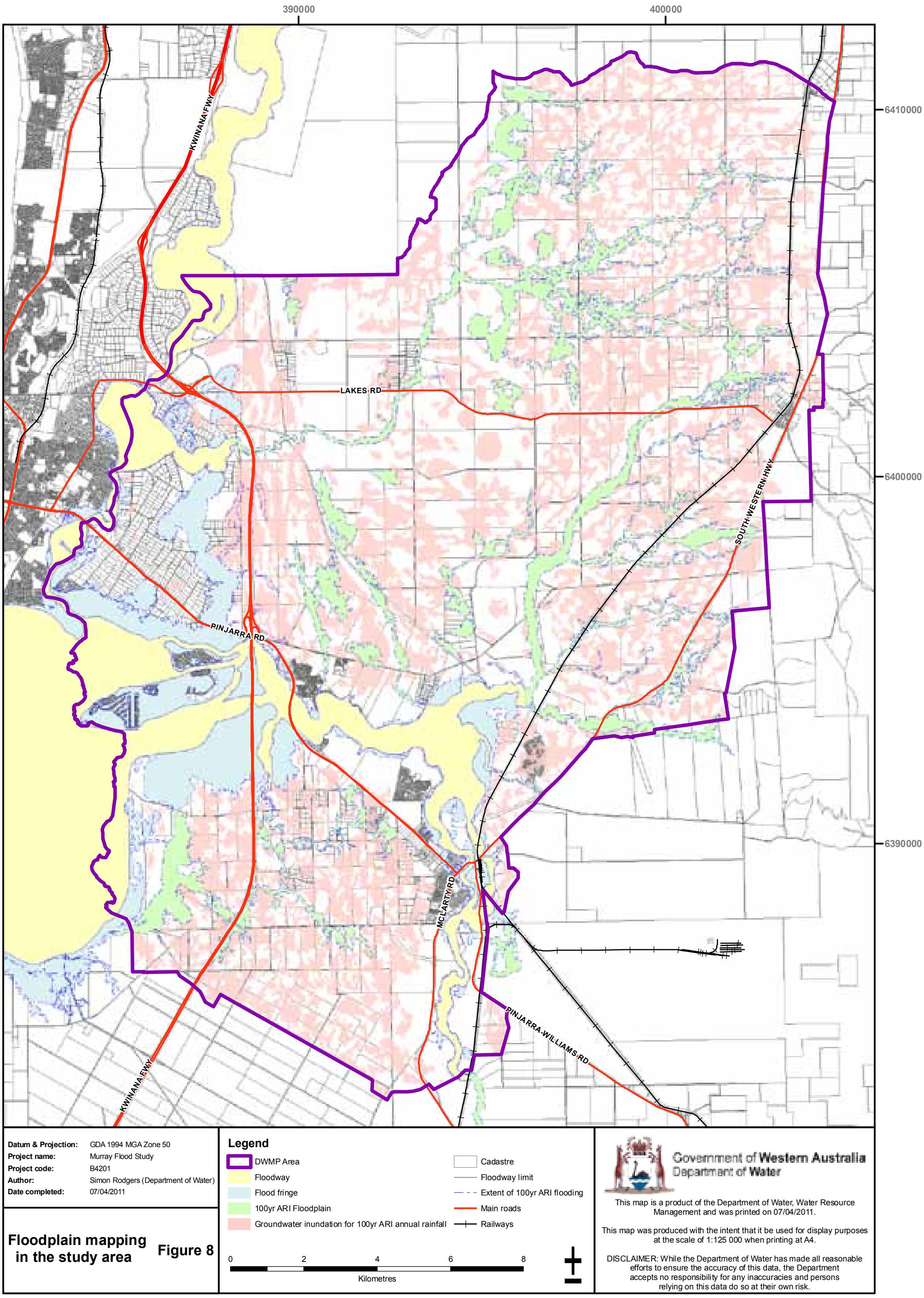

Figure 8

Floodplain and inundation mapping in the study area

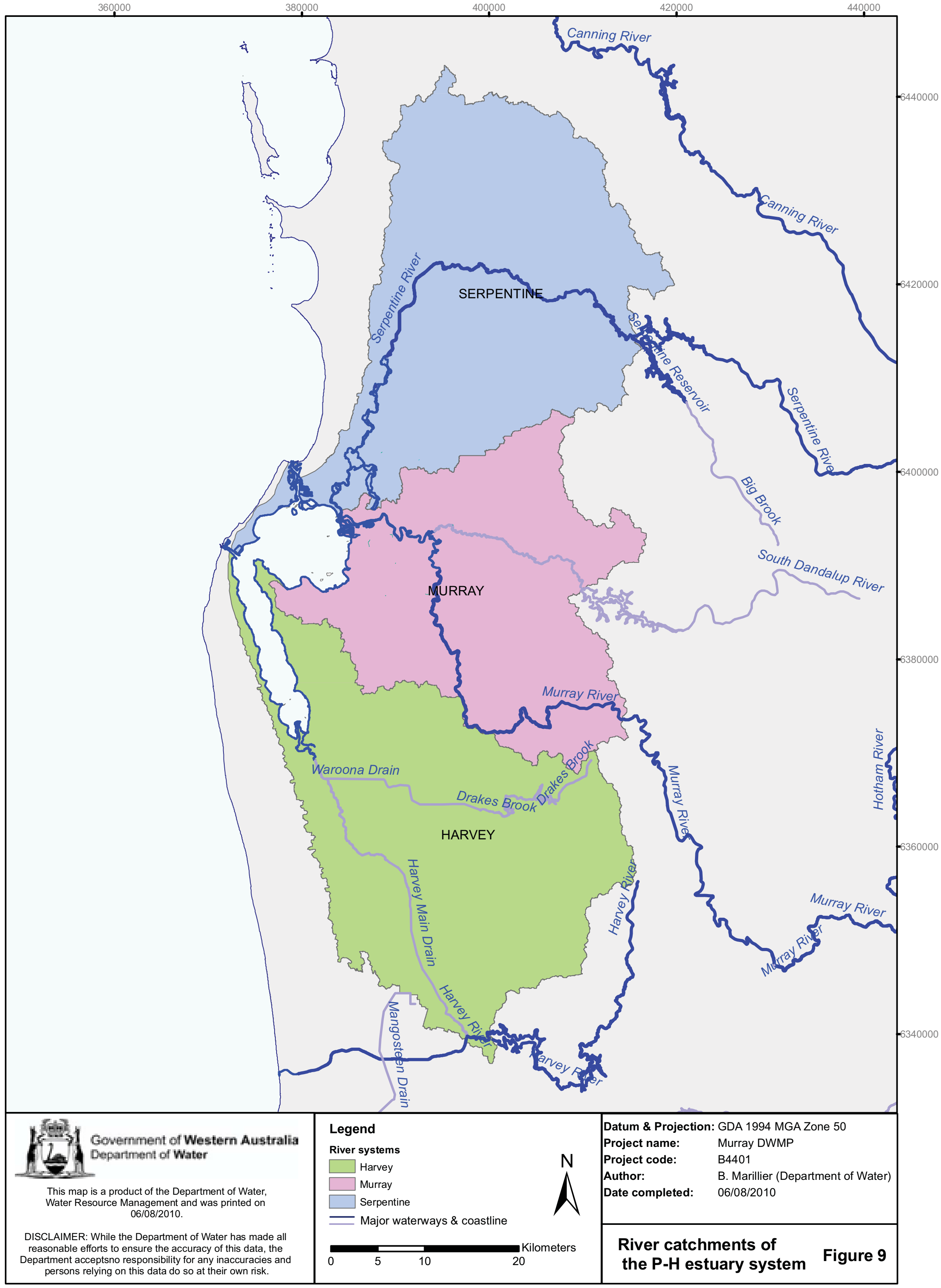

Figure 9

River catchments of the Peel-Harvey estuary system area

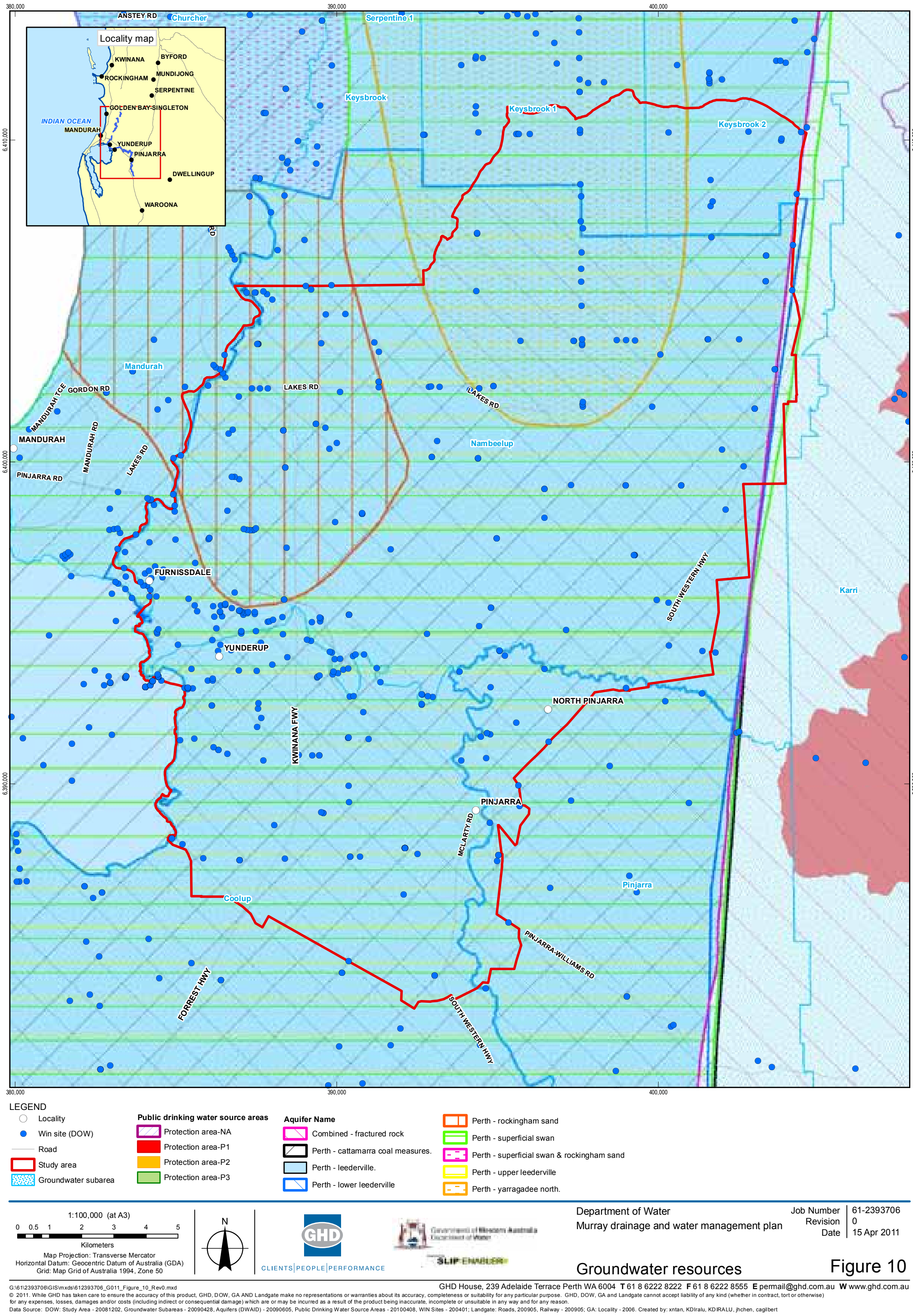

Figure 10

Groundwater resources

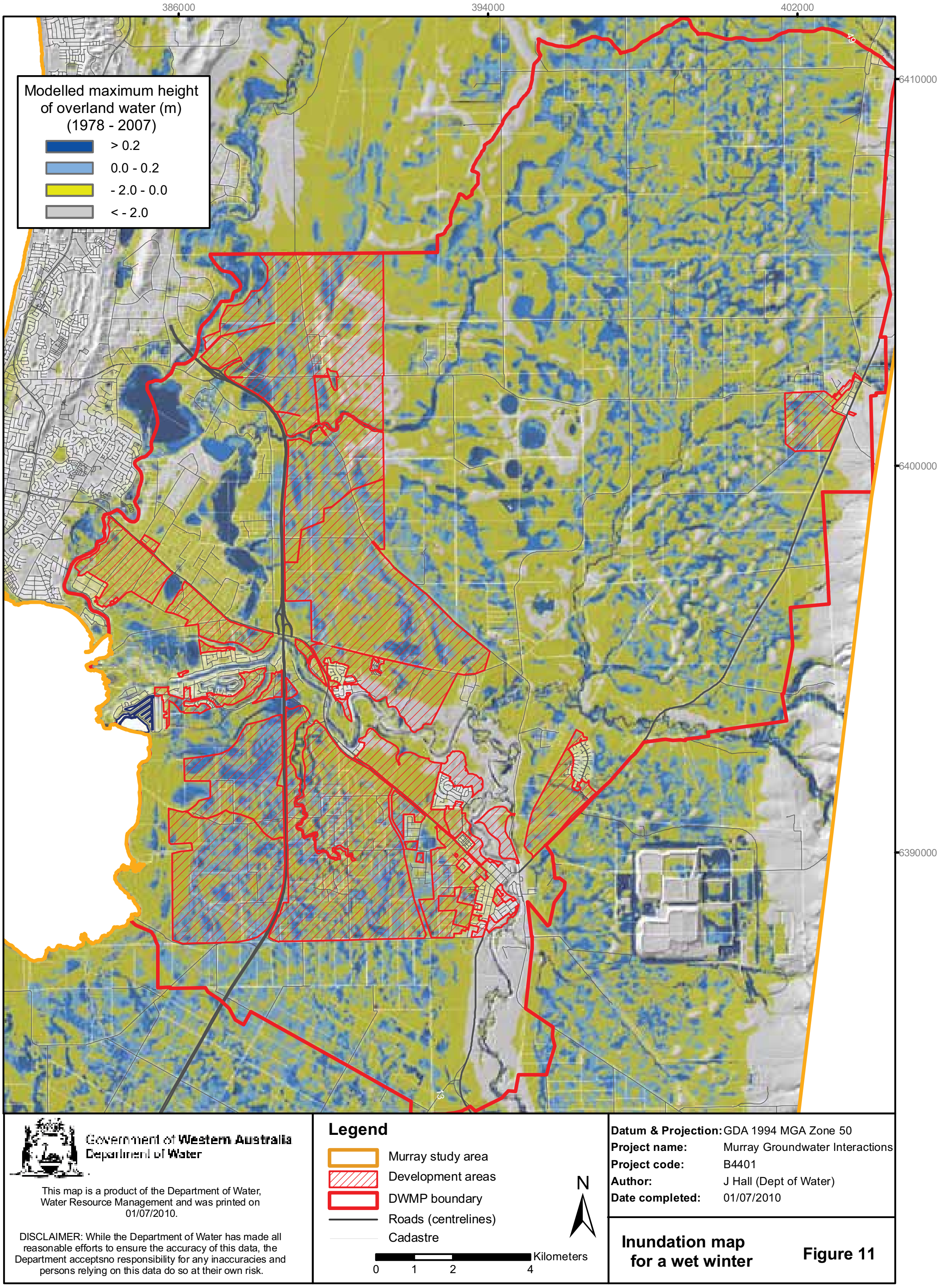

Figure 11

Inundation map for a wet winter

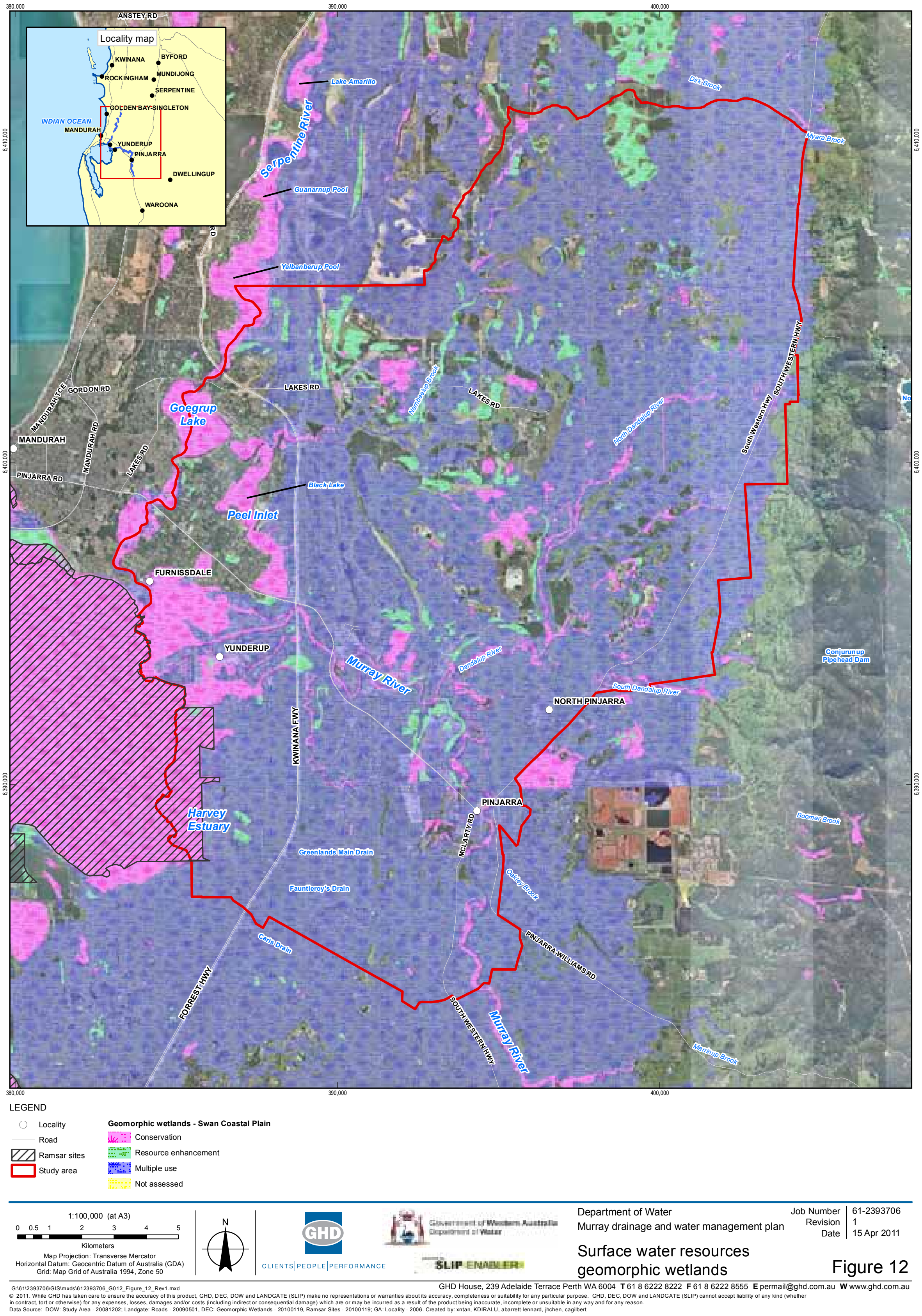

Figure 12

Wetlands

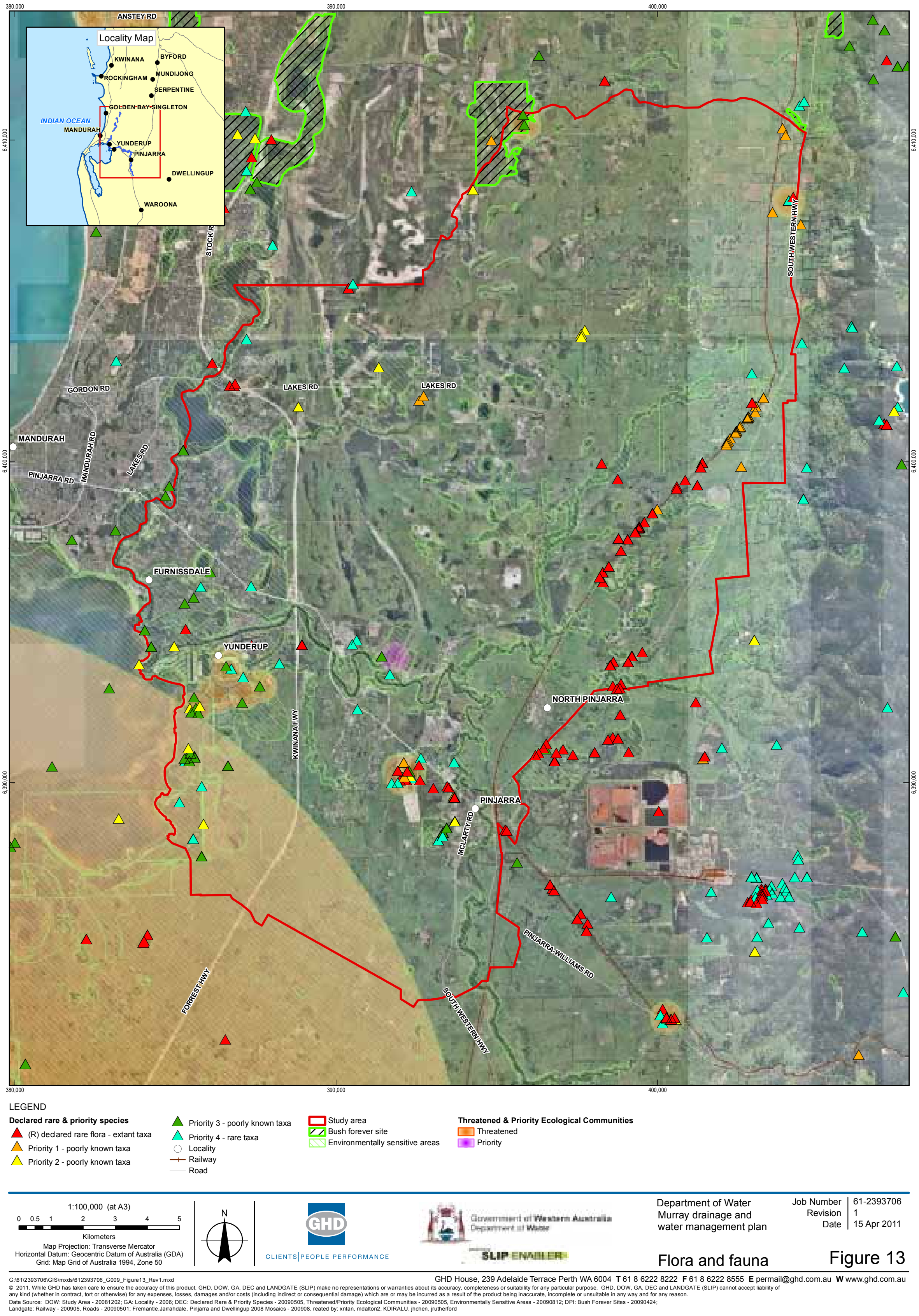

Figure 13

Flora and fauna

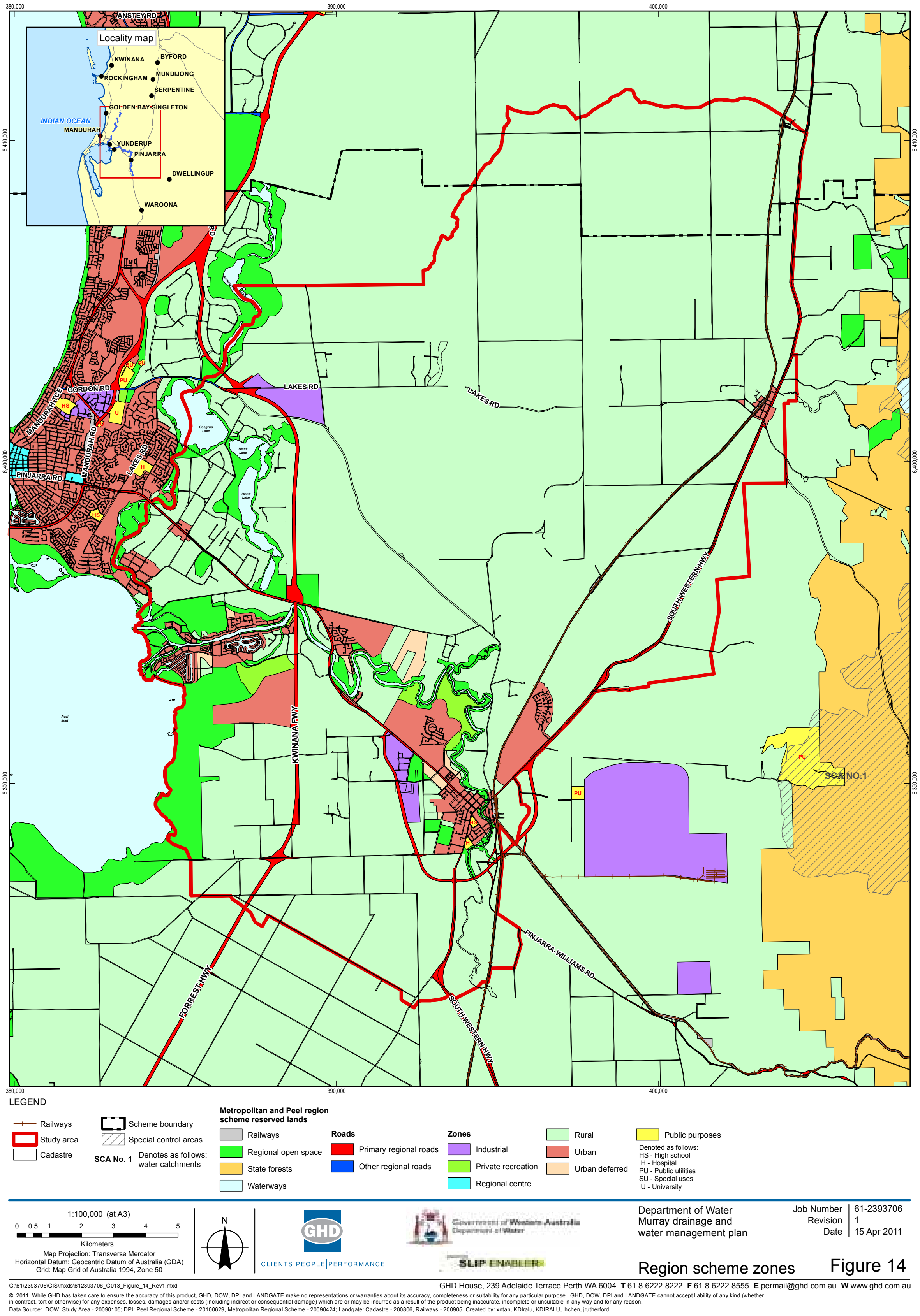

Figure 14

Existing regional scheme zonings

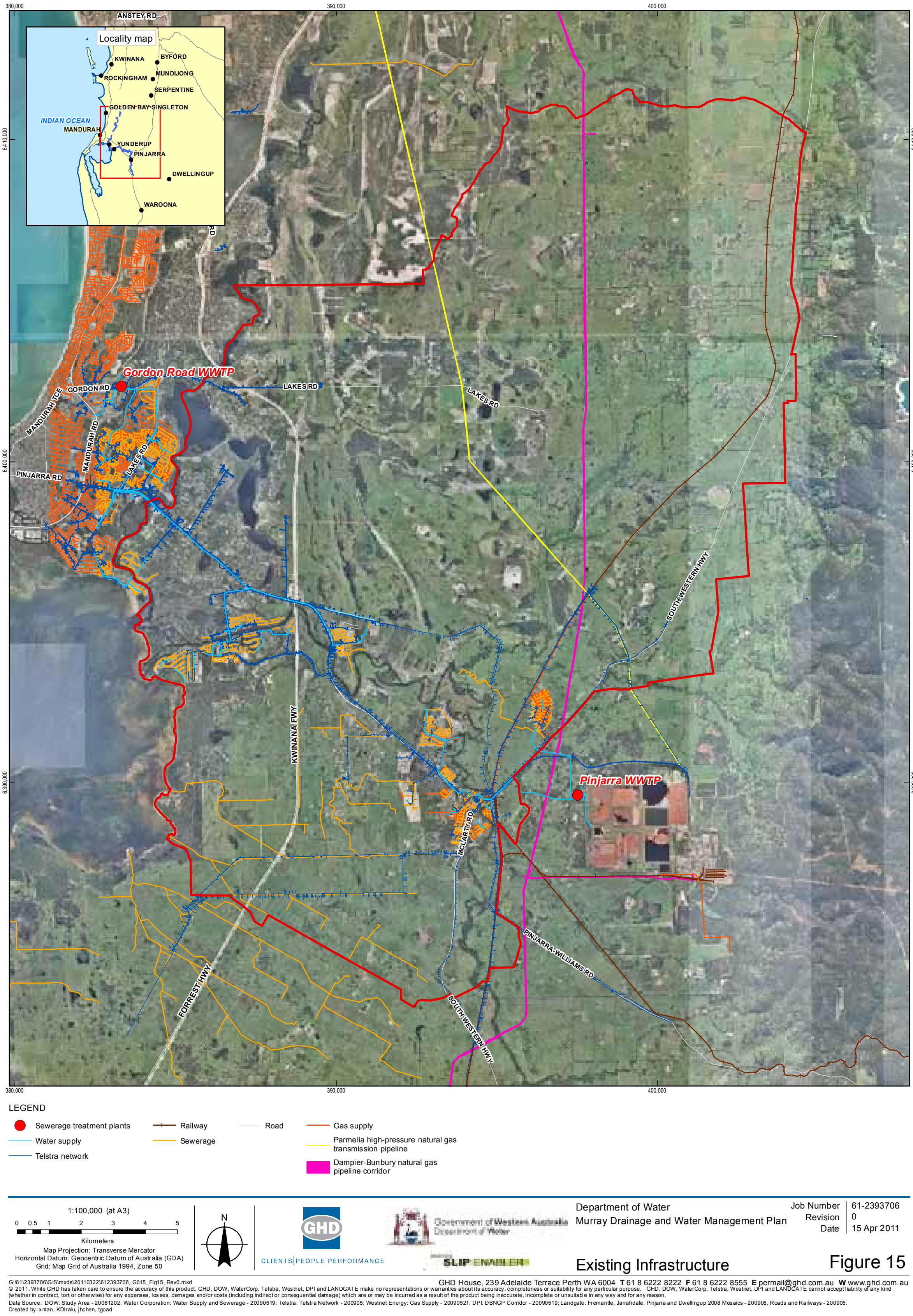

Figure 15
Existing infrastructure

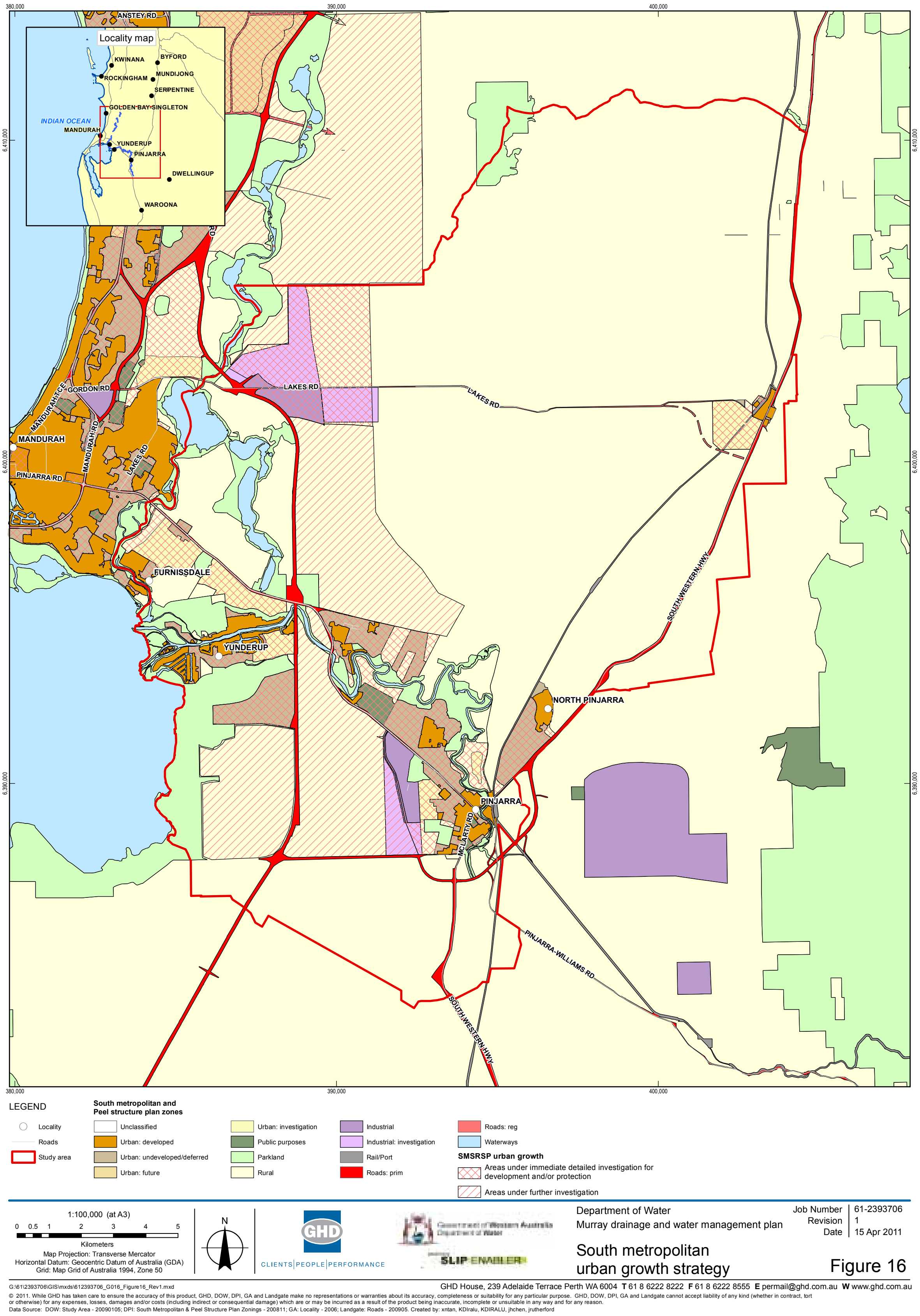

Figure 16

Proposed urban growth strategy

Coolup Main Drain outlet

Glossary

Average annual maximum groundwater level	The average of annual peak groundwater levels over the period 1978–2008. In areas of seasonal inundation, it may also be the level of standing water above ground surface.
Annual exceedance probability (AEP)	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. The use of the term average recurrence interval can lead to confusion. It is preferable, therefore, to express the rarity of a rainfall event in terms of annual exceedance probability.
Aquifer	Aquifer A water-bearing layer of soil, sand, gravel, or rock. Confined: An aquifer that is bounded above and below by formations of distinctly lower permeability than that of the aquifer itself. *Unconfined*: An aquifer in which water is not contained by an impermeable layer of rock or soil.
Aquifer storage and recovery	Water is stored by targeted infiltration or direct injection within an aquifer for later use.
Average recurrence interval (ARI)	The average, or expected, value of the periods between exceedances of a given rainfall total accumulated over a given duration. The average recurrence interval of a flood event gives no indication of when a flood of that size will occur again. A flood having an average recurrence interval of 100 years has a 1% chance of occurring in any one year. A flood having an average recurrence interval of 5 years has an 18% chance of occurring in any one year. A flood having an average recurrence interval of 1 year has a 63% chance of occurring in any one year.
Acid sulfate soils (ASS)	Acid sulfate soil (ASS) is the common name given to soils and sediments containing iron sulfides, the most common being pyrite. When exposed to air due to drainage or disturbance, these soils produce sulfuric acid, often releasing toxic quantities of iron, aluminium and heavy metals.
Aerobic treatment unit (ATU)	Aerobic treatment units (ATUs) are a more advanced multi-stage alternative to conventional septic tanks and provide an improved quality of effluent treatment.

Glossary

Ecological buffer	An area of vegetation which usually begins from the boundary of wetland-dependent vegetation and extends outward, ending at the interface with another landuse. The buffer will vary in size and nature depending upon the specific purpose for which it was created.
Catchment	An area of land with a single outflow point.
Climate	Climate The average weather conditions at a particular place over a long period of time.
Climate change	Changes in climate (such as temperature, precipitation, wind) that differ significantly from previous average conditions and are seen to endure, bringing about corresponding changes in ecosystems and socioeconomic activity.
Constructed wetland	A constructed wetland is not a constructed lake. Generically, wetlands have water levels that are below the surface in summer.
Development Area	An area proposed to be developed over the next 20 years as defined in *South metropolitan-Peel structure plan* (WAPC in preparation)
Design rainfall event	A synthetic rainfall profile used for design or analysis of a hydraulic structure or system.
Ecological water requirements (EWRs)	The water regime needed to maintain ecological values of water dependent ecosystems at a low level of risk. A water regime is a prevailing pattern of water behaviour over a given time – the components of which include depth, rate of rise and duration
Ecozone	Areas within public open space used for passive or active recreation with alternative ground cover treatments, waterwise planting or local native bushland planting are used in place of turf
Evaporation	The transformation of water liquid to water gas (or vapour) by energy from heat or air movements.
Evapo-transpiration	The sum of evaporation and plant transpiration from the Earth's land surface to atmosphere.
Fit-for-purpose water	Water that is of a quality that is appropriate to its purpose. A purpose may be proposed for a particular water source that suits its current quality without a requirement for additional treatment. Treatment may be provided to a particular water source for it to achieve the required quality or standard for a specified use
Flood	When the water level within a watercourse or waterbody becomes high enough to inundate surrounding land.

Floodway	Areas of the floodplain where significant discharge or storage of water occurs during major flooding. They are often aligned with naturally defined channels and include areas which, if filled or even partially blocked, would cause a significant flood hazard by redistributing of flood flow, and/or by detrimentally increasing flood levels in the general area.
Flood fringe	The area of the floodplain, outside of the floodway, which is affected by flooding but where development could be considered, provided appropriate measures are taken.
Flood plain	The area of land that includes the floodway and the flood fringe that may be inundated during a flood.
Garden bore	Garden bore Bore that is used to reticulate one or more properties for the purpose of maintaining domestic gardens only.
Groundwater	Water that is below the ground.
High value	The value of water resources are defined by cultural, social, environmental and/or economic criteria.
Hydrograph	Graph of water level, flow or volume over time
Hydrology	The study of how water behaves on land, including both surface and groundwater.
Hydrologic zone	The area around a waterbody or watercourse where the installation of groundwater drainage systems may have an undesirable hydrological influence on the wetland. Hydrologic zones vary with topography, geology, hydrogeology and the presence of drainage infrastructure. It is acceptable to develop within a hydrologic zone provided that the impact of any infrastructure on the wetland is minimal (i.e. change in maximum and minimum water levels and hydroperiod are less than 10%. The use of hydrologic zones for water quality treatment areas or constructed wetlands is encouraged.
Hydroperiod	The period of time during which a wetland is covered by water
Hydrozones	Areas of public open space where different water application rates that are specific to the planting and function of the zone are used.
Lake	Waterbody that is permanently inundated (it may dry out in extremely dry years).
Load	Mass of a water quality parameter being transferred by a water flow.
Linear wetland	Linear area of land that is seasonally or permanently inundated with water, usually associated with an ephemeral or semi-permanent watercourse.
Managed aquifer recharge	Method of increasing or targeting recharge of water into an aquifer. May be by targeted infiltration or direct injection.
Mean	Same as average = sum of values / number of values.

Median	The middle value in a ranked series of values. It is often a better indicator of 'normal' flow or concentration than the mean in highly variable series.
Maximum groundwater level	Absolute maximum groundwater level over the period 1978–2008. May also be level of standing water above ground surface.
Model	Simplification of a complex process used to understand behaviour of the process
Peak	Maximum level, flow rate, concentration or load during an event.
Runoff	The portion of rainfall which leaves a catchment. May be expressed as a depth per catchment area or as a percent of the total rainfall
Salinity	The concentration of salt within water, usually expressed as total dissolved salts in mg/L.
Sediment	Anything other than water, carried by the stream. Includes dissolved solids, suspended solids and bed load.
Surface water	Water in waterbodies and watercourses that are above the ground surface.
Waterbody	A waterbody is any area that in a normal year has water flowing or standing above ground to the extent that evidence of an ordinary high water mark is established. Wetlands contiguous to the waterbody are considered part of the waterbody.
Watercourse	A channel, having defined bed and banks, down which surface water flows on a permanent or semi-permanent basis or at least, under natural conditions, for a substantial time after periods of heavy rainfall within its catchment.
Water quality	The parameters that are contained within water, which may be physical, chemical or biological. May be used as a value, concentration or load.
Water resources	Water in all states within the hydrologic cycle that has economic, environmental, social or cultural significance.
Wetland	Area of land that is seasonally or permanently inundated with water.

References

Robert Bay Wetland

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