Department of Water

North East Corridor Urban Water Management Strategy

February 2007

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Executive Summary

This Urban Drainage and Water Management Strategy has been developed to support the North East Corridor Structure Plan. As a Regional Drainage and Water Management Strategy it should be used as the foundation for developing more detailed District and Local Drainage and Water Management Plans that will support District and Local Structure Plans.

This strategy has been based on a review of the previous 1995 Drainage Management Strategy for the North East Corridor (Water Authority, 1995). Although endorsing the Water Sensitive Urban Design principles adopted by the 1995 strategy, it recommends alternative approaches to the relatively costly Water Pollution Control Ponds previously proposed.

This document proposes strategies for managing the quantity and quality of surface run-off, for managing groundwater levels and quality, for protecting wetlands and waterways and for managing the potential risks from Acid Sulphate Soils. It has been completed at a time when State Government agencies are proposing a more integrated approach to urban water management and land use planning. Subsequent and more detailed District and Local Drainage and Water Management Plans should include an assessment of some of the broader aspects of urban water management not addressed in this strategy, including potential water sources for potable and non-potable use, water conservation and re-use.

Water quantity management

To maintain the ecological water requirements of the receiving environment, the drainage system shall:

Seek to maintain the pre-development hydrology by retaining or detaining on site (or as close to source as practical), runoff resulting from rainfall events up to and including the 1 year ARI event

To protect infrastructure and assets from flooding, the drainage system drainage shall:

» Be designed for the safe conveyance of excessive runoff from extreme events, specifically the 100 year ARI event;

» Ensure that the flood channel capacity of the receiving waterway is not exceeded, by retaining or detaining the runoff from storm events in landscaped areas in public open space or linear multiple use corridors.

Water quality management

To protect water quality in the Swan River and other receiving wetlands and waterways, District Water Management Strategies should include specific water quality design targets for each sub-catchment. In all cases the water quality design targets must be consistent with the long-term Swan River targets.

Run-off from roads and other impervious areas must be diverted through a treatment system before infiltration or discharge for all flows up to the 1-year ARI event. Water Pollution Control Ponds at the outlet from sub-catchment are no longer recommended in this area as the primary treatment measure for managing water quality and have been deleted from this updated strategy.

Structural and non-structural measures, to improve water quality in the North East Corridor, and relevant to the local hydrology and proposed Structure Plans must be developed and implemented through District and/or Local Drainage and Water Management Plans.

Groundwater management

To protect buildings and other infrastructure, adequate separation from maximum groundwater levels must be provided. In some areas it may be possible to reduce the need for imported fill by the use of subsoil drainage where it can be demonstrated that:

» Nutrient export from the site will not be increased;

» Subsoil drainage is laid at or above the Controlled Groundwater Level (CGL) set at a level to protect groundwater dependent ecosystems; and

» The subsoil pipe system is designed to minimise and localise the discharge of sub-surface water to only that needed to manage the winter maximum groundwater level in the affected development area. Nutrient export from the site will not be increased.

Although District Drainage and Water Management Plans should provide guidance for CGLs, these should be reviewed at local structure plan scale to protect specific environmental values and after the results of more detailed groundwater monitoring information is available.

Wetland and waterways management

To protect significant wetlands in the North East Corridor, the following principles should be adopted:

» Existing drains located within conservation and resource enhancement wetlands should be retained to maintain the existing hydrological regime.

» No new drainage infrastructure shall be located in Conservation category wetlands or their buffers.

» Where overland flow paths discharge to Conservation category wetlands, peak flows should not be increased by development.

» Subsoil drainage will only be permitted where wetland and groundwater levels will not be adversely affected.

To protect watercourses of high conservation value and environmental significance, land and water planning must include for the restoration, revegetation and reservation of appropriate riparian buffers.

Acid sulphate soils

In areas where there is a risk of Acid Sulphate Soils (ASS) or Potential Acid Sulphate Soils (PASS), an initial site investigation shall be undertaken to assess soil conditions. An Acid Sulphate Soil Management Plan may be needed for any excavations or dewatering activities, prepared in accordance with guidelines published by the Department of Water.

District Drainage and Water Management Plans

In accordance with the approach adopted for the Southern River area (Southern River MOU Steering Committee, 2006), it is recommended that as District or Local Structure Plans are prepared for the North East Corridor, they are supported by Drainage and Water Management Plans (DWMP).

It is recognised that in some areas Local Structure Plans are prepared without the completion of a District Structure Plan. For this reason it is recommended that the Department of Water, in consultation with the Department for Planning and Infrastructure and the City of Swan, prepare a DWMP for areas where development is anticipated without a District Structure Plan. The highest priority is the Henley Brook-West Swan-Caversham DWMP, including those catchments south of Gnangara Road.

Should Local Structure Planning proceed before the completion of the necessary DWMP, the proponent should be required to prepare a Local Water Management Plan that addresses the issues that would otherwise have been included in the DWMP.

1. Introduction

1.1 Background

Urbanisation of the North East Corridor has been anticipated for some years, notably in the 1987 Department of Planning and Urban Development (DPUD) report “Planning for the Future of the Perth Metropolitan Region”, which introduced ideas for urban expansion in the North East Corridor. Prior to 1987, the area had been regarded as a near city rural zone supporting viticulture, horticulture, agistment, grazing and other rural pursuits. METROPLAN (DPUD 1990) and the 1990 Urban Expansion Policy Statement (DPUD 1990) further endorsed proposed urbanisation in the Corridor.

Associated with the land use changes that occur with urbanisation are the implicit changes that occur to the hydrologic regime in the altered landscape. The North East Corridor Drainage Strategy 1992 (Water Authority of Western Australia, 1992) and the updated Drainage Management Strategy for the North East Corridor (Water Authority of Western Australia, 1995) were developed to provide guidance to the agencies, corporations and individuals responsible for the development of land and the protection of water resources and dependent ecosystems within the North East Corridor.

Since the 1995 Drainage Management Strategy was developed, significant further urban development has taken place within the corridor. At the Ellenbrook Development in the Henley Brook Catchment and at the Vines Development area further north, pine forest or bushland has been replaced with urbanisation. At the southern end of the corridor, urban residential development alongside Bennett Brook has replaced pasture.

The Ellenbrook and Vines developments continue to proceed in accordance with the drainage management plans prepared for those developments. A major element of the earlier Strategy for Ellenbrook was construction of the Henley Brook Water Pollution Control Pond (WPCP). Monitoring to date has been unable to determine the overall effectiveness of the WPCP. Surface water entering the WPCP is already below catchment targets and monitoring shows that the WPCP reduces total phosphorus (TP) in the surface water passing through the pond. However, groundwater is intercepted by the pond and the expected relative improvements in discharged water quality have not been achieved.

This review investigates alternative approaches to the relatively costly WPCPs proposed by previous Drainage Management Strategies.

1.2 Integrated land and water management

This Regional Drainage and Water Management Strategy has been developed to support the North East Corridor Structure Plan. It has been completed at a time when State Government agencies are proposing a more integrated approach to urban water management and land use planning. The proposed model builds on the existing hierarchical planning process, matching urban water planning and investigation at appropriate geographical scales and detail.

Under the proposed framework, a Regional Drainage and Water Management Strategy (RDWMS) should support Regional Structure Plans such as the North East Corridor Structure Plan. A RDWMS would be expected to include identification and mapping of surface water catchments, water dependent ecosystems, potential sources of contamination as well as evaluating the impacts of land use change on the quantity and quality of water. As the community expects a more integrated approach to water management, RDWMSs will include assessments of water sources for potable and non-potable use.

Under the proposed framework, the North East Corridor Urban Water Management Strategy should be considered a RDWMS, noting that it does not include an evaluation of potential water sources. It should be used as the foundation for developing more detailed District and Local Drainage and Water Management Plans that will support District and Local Structure Plans developed by Local Government. The more detailed District and Local Drainage and Water Management Plans should include an assessment of potential water sources for potable and non-potable use, not addressed in this strategy.

The North East Corridor Regional Drainage and Water Management Strategy is a non-statutory document intended to provide guidance on planning, land use and development matters associated with the North East Corridor.

It is proposed that the document be submitted to the WAPC for adoption as a supplementary document to the North East Structure Plan. Once adopted it will provide guidance throughout the planning process and decision makers will be required to have regard for its contents. The document will also be referred to the EPA for endorsement. Once endorsed, it will provide guidance on consideration of planning assessment referrals in the structure plan area. The Department of Water will implement its contents through recommendations as part of the planning referral process.

1.3 Vision, Principles and Objectives

The overall objective of the North East Corridor Regional Drainage and Water Management Strategy is to demonstrate how development of land in the North East Corridor can be undertaken whilst protecting significant wetlands, groundwater dependent ecosystems and the Swan-Canning System.

The specific objectives of this study are:

- To develop objectives and criteria for minimising hydrological changes and nutrient export associated with development.
- To develop a strategy for the management of land use and water to ensure the developed objectives and criteria can be met.
- To undertake analysis, modelling and investigations, which demonstrate that the strategy is likely to meet the objectives and criteria.

The Stormwater Management Manual for Western Australia (Department of Environment, 2004) presents a new approach to the management of stormwater,

based on the principle that stormwater is a resource with social, environmental and economic value. This strategy adopts the Western Australia Stormwater Management Principles presented in that manual:

» Incorporate water resource issues as early as possible in the land use planning process.

» Address water resource issues at the catchment and sub-catchment level.

» Ensure stormwater management is part of the total water cycle and natural resource management.

» Define stormwater quality management objectives in relation to the sustainability of the receiving environment.

» Determine stormwater management objectives through adequate and appropriate community consultation and involvement.

» Ensure stormwater management planning is precautionary, recognises inter-generational equity, conservation of biodiversity and ecological integrity.

» Recognise stormwater as a valuable resource and ensure its protection, conservation and reuse.

» Recognise the need for site-specific solutions and implement appropriate non-structural and structural solutions.

1.4 Scope of this study

» To prepare a management strategy for surface and groundwater, land use, nutrient management, wetlands and watercourse protection, including the identification of constraints and areas suitable and unsuitable for intensive development.

» To identify physical, water and land management constraints to development, including existing watercourses and wetlands and their foreshore and buffer zone requirements, groundwater protection areas, capture and release zones at wetlands, and known point sources of pollution.

» To identify overland flood paths to protect new and existing developments.

» To establish criteria and targets for flood management and demonstrate that the targets can be achieved through the identified drainage management measures.

» To identify opportunities to manage and potentially reduce nutrient export rates from land developed in the North East Corridor, to receiving bodies such as Ellen Brook and significant wetlands and develop an approach for determining attainable water quality targets and criteria for both surface and groundwater systems which reflect the sensitivity of the receiving environment.

» To define a range of appropriate Best Management Practices (BMP's) for each of the major land management and catchment types, including opportunities for promoting source control, water use/reuse, detention and other treatment practices.

» To develop a framework for the implementation, monitoring and performance assessment of the Strategy, including consideration of ongoing maintenance responsibilities, optimising community involvement and estimated costs.

2. Review of Current North East Corridor Drainage Management Strategy

2.1 Description of the previous strategies

The 1992 North East Corridor Drainage Strategy (Water Authority, 1992) was developed as a planning supplement to the North East Corridor Structure Plan. The Strategy outlined in broad terms the drainage management standards that should be adopted for urban development in the North East Corridor. The Strategy discussed a range of management issues with respect to arterial drainage, groundwater, water quality, water conservation, pollution control and wetlands, without attempting to provide detailed guidance at a catchment scale.

Building on the 1992 Strategy document, G B Hill and Partners undertook surface water and groundwater modelling to ascertain areas of conflict between proposed development areas and the resources of groundwater, surface water and the environment. A focus of the study was the management of water tables across the western sub-catchments to protect groundwater dependent wetlands.

The revised 1995 Drainage Management Strategy North East Corridor provided a general discussion of management techniques. It concluded that Water Sensitive Urban Design (WSUD) principles should be adopted for managing drainage. Detention and infiltration of stormwater runoff from development areas was promoted to supplement and in some cases to replace the conveyance methods of traditional drainage practice.

The 1995 strategy document was not prescriptive, other than in establishing targets for managing groundwater (to Average Annual Maximum Groundwater Level, AAMGL), setting fill levels and defining subsoil drainage requirements. The study defined basic (default) requirements for stormwater infiltration basins, for Water Pollution Control Ponds (WPCP's), or detention basins to manage peak flows to pre-development levels.

In summary, the information and guidance notes prepared in the 1992 and 1995 documents presented the following:

1. A general discussion of water management standards that could be achieved without setting criteria or targets.
2. Identification of water management catchments.
3. Conceptual definition of arterial drainage routes and the siting of flood attenuation structures.
4. Estimates of 2-year and 10-year Average Recurrence Interval (ARI) peak flows for the catchments in their pre-development (pre-urbanised) state.
5. Sizing of flood detention and attenuation structures at a sub-catchment level.
6. Identification of WSUD as the preferred drainage management approach and a general discussion of Best Management Practices (BMP's) that might be applied.

7. Determinations of fill and subsoil drain requirements at a sub-catchment level.

Of the mapping produced, the following are of relevance to the current strategy:

» Proposed Land Use Boundaries

» Wetland management categories

» Basic Soil Types

» Arterial Drainage Plan

» Average Annual Maximum Groundwater Levels

» Minimum Fill & Drainage Criteria For Developments in Shallow Groundwater Areas

» Suitability for Development

2.2 Omissions from the previous strategies

Omissions were identified in the previous strategies that require attention. This strategy review is intended to redress some of these omissions, which include:

1. Water Quality Management - The anticipated impacts of urbanisation have been considered only briefly in the previous strategies. These propose managing stormwater runoff in constructed WPCP's. This management practice is no longer favoured as a primary method of water quality management. Greater recognition is needed of the treatment processes involved and the management practices available to improve water quality. The earlier strategies focussed on defining the Water Authority's main drainage assets in relation to water management. Improvements in source control and adoption of a treatment train approach within the catchment were covered only by reference.
2. The previous strategies adopted benchmarking performance against pre-development conditions. However reliably determining pre-development regimes in relation to water table levels, nutrient export and drainage flows is not always possible due to a lack of long-term monitored data sets. Since that time there has been some improvement in the catchment data now available. However performance data from local treatment train elements remains scarce or unavailable.
3. Conclusions about the water quality performance of the drainage schemes that are in place have been difficult to determine from the limited and incomplete monitoring data that has been collected. An alternative approach may be to directly establish relative (if not absolute) design targets for water quality parameters.
4. A comprehensive constraints map for drainage systems and dependent resources such as wetland ecosystems and groundwater resources is not currently available. A spatial information resource is required as a tool, for 'at a glance' assessment of development constraints across the North East Corridor project area. Information layers that are available to build a spatial constraints tool include the following:

» Ground surface contours

- Wetland mapping (wetland locations, types and management categories, wetlands protected by the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992*.
- Vegetation mapping (broad scale, Bush Forever sites, rare and priority flora, threatened and priority fauna, threatened ecological communities, designated environmentally sensitive areas under the *Environmental Protection (Clearing of Native Vegetation) Regulations 2004*).
- Peak groundwater contours (sandy areas only)
- Primary soil types
- Floodways
- Constructed trunk drains
- Cadastral boundaries
- MRS land uses
- Public Water Supply Areas
- Heritage Sites
- Railways, highways and roads
- Existing watercourses
- Groundwater bore sites.

Many of these datasets are presented at a regional or sub-regional scale. While considered adequate for broad-scale strategy planning, spatially some are not precise enough for local scale planning purposes. More detailed data will need to be obtained to facilitate precinct scale drainage planning.

2.3 Other current stormwater management policies and principles

Stormwater and drainage management in Western Australia is more generally addressed by the following documents:

- Stormwater Manual for Western Australia (Department of Environment, 2004)
- State Water Strategy (Government of Western Australia, 2003)
- State Water Quality Management Strategy (Government of Western Australia, 2001)
- Urban Main Drainage Manual (Water Corporation, 1998)
- Guidelines for Urban Stormwater Management, 2000 (ANZECC, 2000a)

3. Water Management Objectives

3.1 Western Australian Stormwater Management Objectives

The Stormwater Management Manual for Western Australia (Department of Environment, 2004) presents a new approach to the management of stormwater, based on the principle that stormwater is a resource with social, environmental and economic value. The manual reflects the Western Australian State Water Strategy (Government of Western Australia, 2003) and includes the following objectives:

- Water Quality: to maintain or improve the surface and groundwater quality within the development areas relative to pre-development conditions.
- Water Quantity: to maintain the total water cycle balance within the development areas relative to the pre-development conditions.
- Water Conservation: to maximise the reuse of stormwater.
- Ecosystem Health: to retain natural drainage systems and protect ecosystem health.
- Economic Viability: to implement stormwater management systems that are economically viable in the long term.
- Public Health: to minimise the public risk, including risk from injury or loss of life, to the community.
- Protection of Property: to protect the built environment from flooding and waterlogging.
- Social Values: to ensure that social, aesthetic and cultural values are recognised and maintained when managing stormwater.
- Development: to ensure the delivery of best practice stormwater management through planning and development of high quality developed areas in accordance with sustainability and precautionary principles.

These general objectives have been further developed into more specific stormwater management objectives for the North East Corridor.

3.2 Water quantity management

The management of water quantity in the North East Corridor has the twin objectives of:

- Maintaining the pre-development hydrologic regime and meet the ecological water requirements of the receiving environment; and
- The protection of property and infrastructure by the safe conveyance of excessive runoff from extreme events. This includes the protection of property and infrastructure within the North East Corridor Area as well as downstream and so needs to consider the impact of peak discharge from the study area.

3.3 Water quality management

Waterway water quality targets are intended to protect and enhance environmental values in the receiving water bodies into which the urban run-off will discharge. In the case of the North East Corridor, the receiving waterways are initially Ellen Brook and smaller waterways such as Henley Brook and Saint Leonards Creek and ultimately the Swan River and the Swan-Canning Estuary. These are important ecosystems as well as valuable recreational waterways and are subject to the *Environmental Protection (Swan and Canning Rivers) Policy 1988*.

The Swan-Canning Cleanup Program (SCCP) is a key instrument for the implementation of the *Environmental Protection (Swan and Canning Rivers) Policy 1988* and has developed specific water quality targets for the Swan-Canning system. These include short- and long-term targets for nutrient concentrations in tributaries of the Swan-Canning river system, including Ellen Brook, presented in Table 1.

In some parts of the North East Corridor surface water runoff will discharge directly and indirectly to wetlands, including Conservation and Resource Enhancement category wetlands, which may need separate water quality targets.

Table 1 Receiving waterway water quality targets

Guideline	Total nitrogen (mg/L)	Total phosphorus (mg/L)
Swan-Canning Cleanup Program targets		
Tributaries (Ellen Brook):		
Short-term	2.0	0.2
Long-term	1.0	0.1
Estuary target (Upper Swan)	1.0	0.1

3.4 Protection of wetlands and waterways

Wetlands

Wetlands on the Swan Coastal Plain have been evaluated and assigned to one of three management categories based on an assessment of their significance. The management categories of wetlands are displayed in the *Geomorphic Wetlands Swan Coastal Plain* dataset (Department of Environment and Conservation). The Environmental Protection Authority (2005) has defined the management categories and their management objectives as:

» Conservation category: Wetlands that support a high level of attributes and functions. Objective: Highest priority wetlands. Support a high level of attributes and functions. Objective is to preserve and enhance the existing conservation values of the wetlands through various mechanisms including:

  – Reservation in national parks, crown reserves and State owned land,

- Protection under Environmental Protection Policies, and
- Wetland covenanting by landowners.

  No development or clearing is considered appropriate. These are the most valuable wetlands and any activity that may lead to further loss or degradation is inappropriate.

» Resource Enhancement category: Wetlands which may have been partially modified but still support substantial attributes and functions. Objective: Priority wetlands. Ultimate objective is to manage, restore and protect towards improving their conservation and aesthetic values. These wetlands have the potential to be restored to Conservation category. This can be achieved by restoring wetland structure, function and biodiversity. Protection is recommended through a number of mechanisms.

» Multiple Use category: Use, development and management should be considered in the context of ecologically sustainable development and best management practice catchment planning.

In accordance with the EPA's recommendations (EPA 2000), further evaluation of wetlands in the North East Corridor is required as part of regional investigations ahead of land use changes in the area, to ensure that significant wetlands and their buffers are protected from impacts. Accordingly, the wetlands and buffers to be protected and can then be displayed in District and Local scale planning documents.

As part of regional investigations, ecological water requirements also need to be determined for wetlands to be protected. Drainage and Water Management Plans should demonstrate how the ecological water requirements will be maintained.

Waterways

The North East Corridor includes several watercourses of high conservation value and environmental significance, including Ellen Brook and the Avon River. There is a need to protect these waterways and to include in land and water planning the requirements for the restoration, revegetation and reservation of appropriate riparian buffers.

3.5 Management of groundwater levels

To protect buildings and other infrastructure, adequate separation from maximum groundwater levels must be provided. This is usually achieved by providing imported fill to increase local ground levels. It may be possible to reduce the need for imported fill by the use of subsoil drainage in some areas where it can be demonstrated that:

» nutrient export from the site will not be increased,

» Subsoil drainage is laid at or above the Controlled Groundwater Level (CGL) set at a level to protect groundwater dependent ecosystems

» The subsoil pipe system is designed to minimise and localise the discharge of sub-surface water to only that needed to manage the winter maximum groundwater level in the affected development area.

In most cases this is achieved by ensuring that subsoil drainage is laid at or above the calculated Controlled Groundwater Level (CGL).

3.6 Groundwater quality

Previous groundwater quality management has been focused on protecting public drinking water resources, including the adjacent Gnangara Mound. However, in parts of the North East Corridor shallow groundwater is intercepted by open drains and expressed in wetlands and waterways and is an important flux path for nutrients. Groundwater quality targets should be developed, consistent with the water quality targets for the receiving wetlands and waterways.

3.7 Water use

The State Water Strategy (Government of Western Australia, 2003) includes key objectives and targets for water conservation and reuse, specifically to:

» Increase reuse of treated wastewater, and

» Achieve a consumption level of 155 kL/person/year by 2012.

Where appropriate, urban development in the North East Corridor should seek to achieve these targets.

4. Constraints and Opportunities

4.1 Land use and planning

The current land use within the study area is predominantly rural in nature. The western boundary of the study area encompasses state forest and regional open space with pockets around Ellenbrook, Henley Brook and West Swan being earmarked for residential purposes. The Swan Valley takes up a large portion of land in the south-eastern corner of the study area. This area comprises viticulture, agriculture, and tourism land uses and has designated cells for urban village development. Poultry farms and industrial uses also exist throughout the study area.

The existing land use within the study area is consistent with zonings under the Metropolitan Region Scheme, the North East Corridor Structure Plan and the City of Swan Town Planning Scheme No. 9, shown in Figure 1. Presently, there are some Metropolitan Region Scheme Amendments being considered that propose additional urban pockets adjacent to Ellenbrook and lifting of the Urban Deferred Zone to Urban within the West Swan locality.

4.1.1 North East Corridor Structure Plan (NECSP)

The North East Corridor Structure Plan (DPUD 1994) provides the broad framework for the future development of a new urban corridor in the North East part of the Perth metropolitan region. The Metropolitan Region Scheme now reflects the findings and recommendations outlined within the North East Corridor Structure Plan. The majority of the area remains in the Rural Zone. Ellenbrook, and Henley Brook are zoned Urban and West Swan is zoned Urban Deferred.

The Structure Plan Report contains data and technical analysis including drainage and groundwater. It's objectives and principles are to ensure future urban drainage systems do not have an adverse impact on the water quality of the Swan River and its tributaries and to ensure important wetlands are protected. The North East Corridor Drainage Strategy is proposed as a supplement document to the North East Corridor Structure Plan.

4.1.2 City of Swan Town Planning Scheme No. 9

The City of Swan Town Planning Scheme No. 9 controls and guides land use and development within the Swan municipality. The Scheme's general objectives are to zone the District for the purposes described in the Scheme so as to strategically promote the orderly and proper development of land by making suitable provisions for the use of land within the District. The Scheme provides a list of appropriate uses within each of the zones in the municipality.

4.1.3 Identified Development Zones

The City of Swan has advised that there is ongoing pressure from landowners to develop the Upper Swan area that is located between the Great Northern Highway and the Midland to Gingin Railway line.

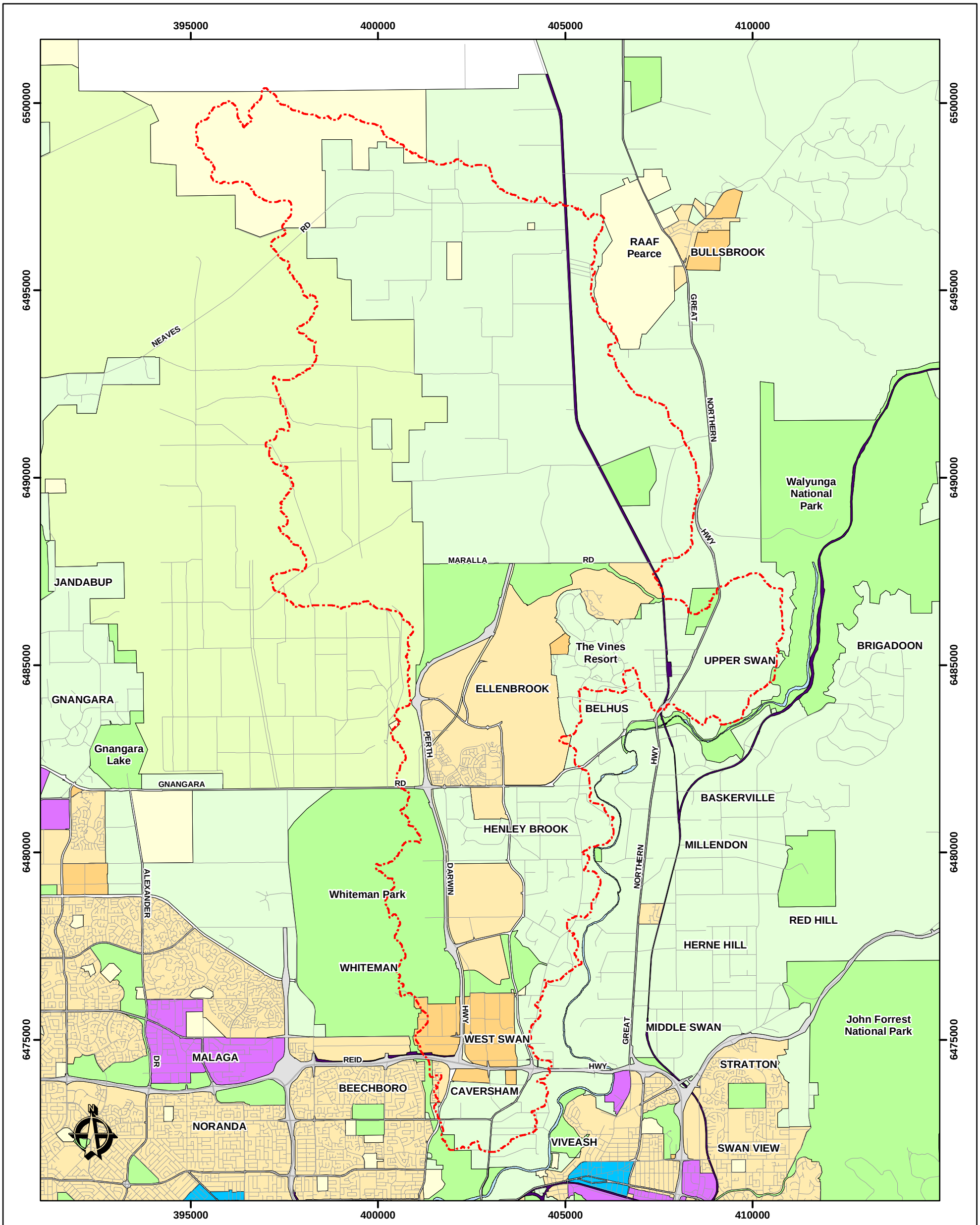
This was addressed in a further study titled the North East Corridor Expansion Strategy that covers the area to the north of this Structure Plan and identifies the opportunity for further urban and industrial development within the Corridor. This Strategy recommends three options, the preferred being Option B that earmarks urban development within the Upper Swan area and industrial development southwest of the Pearce Air Force Base. This report is yet to be finalised and the final recommendations will require an MRS Amendment to reflect proposed changes. For the purposes of this drainage study we will assume development in accordance with Option B.

The North East Corridor includes parts of the Swan Valley. The Swan Valley Planning Act constrains development in the area to protect the rural character, comprising those elements of viticulture, agriculture and tourism, from encroaching urban sprawl. The Swan Valley boundary is depicted within the North East Corridor Structure Plan (Figure 1). The Act divides the Swan Valley into 4 areas including Areas A, B, C and D. The following depicts these four areas (Figure 2).

The general planning objectives for the Swan Valley are:

- Encouragement of the traditional agricultural and other productive uses of the area;
- Protection of the environment and the character of the area;
- Reduction of nutrient levels in the Swan River; and
- Promotion of tourism.

In terms of development, the objective for Area A is that subdivision is consistent with the prevailing lot sizes in the area. The Act encourages lots greater than 4ha in Areas B and C. Area D is earmarked for villages in a rural setting with a range in residential lot sizes of 2000m^2 to 4000m^2.



LEGEND

- Study Area
- Roads

Metropolitan Regional Scheme (2001)

- Central City Area
- Industrial
- Other Regional Roads
- Parks & Recreation
- Primary Regional Roads
- Public Purposes
- Railways
- Rural
- State Forests
- Urban
- Urban Deferred
- Waterways

NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP

PERTH - NORTH METRO

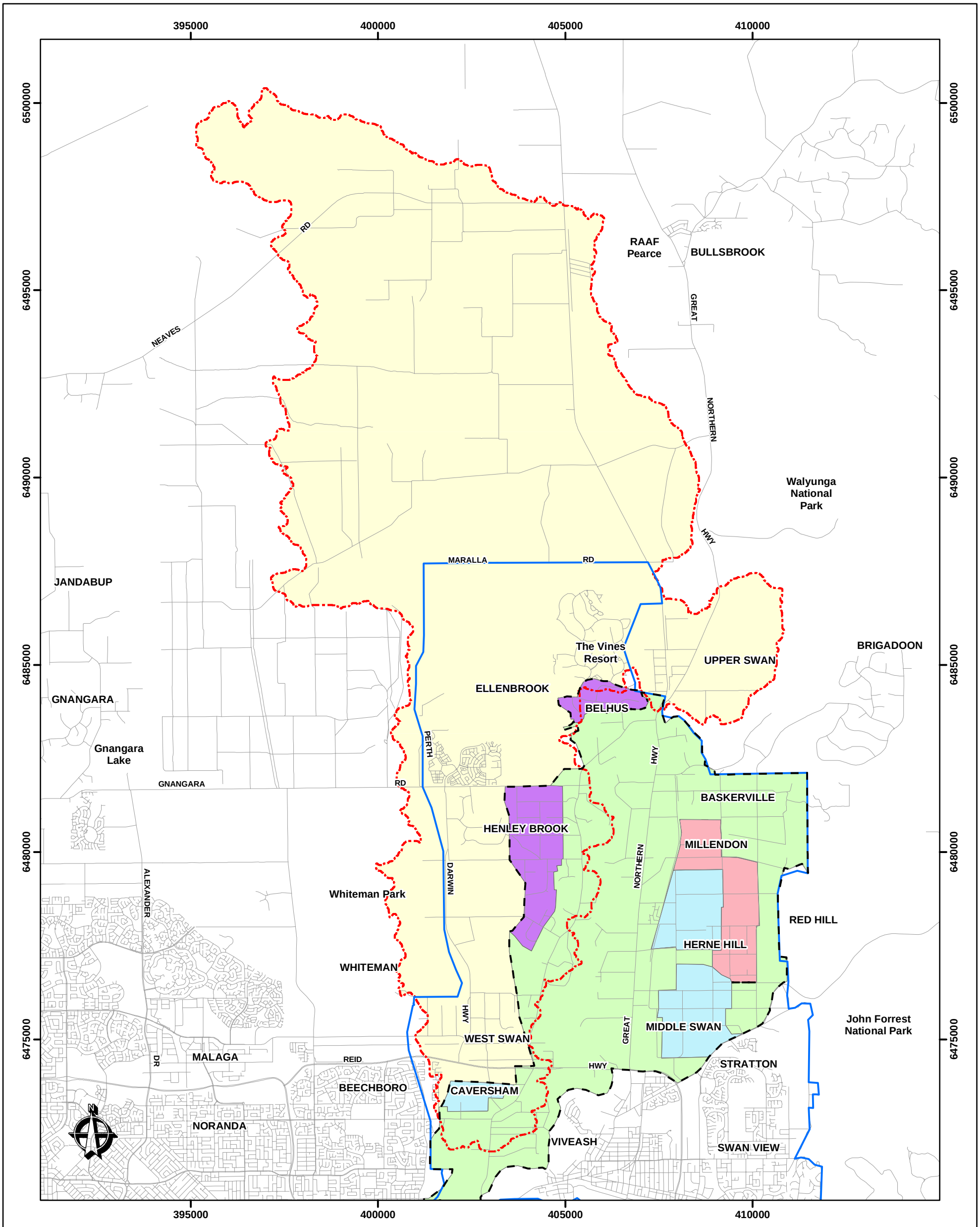
CREATED BY	CHECKED	APPROVED
MD	MO	

HORIZONTAL DATUM: GDA 94 **PROJECTION:** MGA ZONE 50
HEIGHT DATUM: NA **METADATA RECORDED:** 100%

DATE	FILE LOCATION
11.09.2006	N:\61\1182905\GIS\MXDS\611182905-G1_Rev1.MXD
REVISION	**DRAWING NO**
1	611182905-G1

DEPARTMENT OF WATER
REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY

Figure 1
Land Use and Planning



LEGEND

- Study Area
- North East Corridor Structure Plan Area
- Swan Valley Planning Area Boundary
- Roads
- AREA A
- AREA B
- AREA C
- AREA D

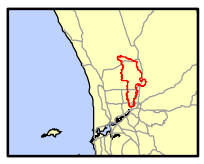
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP



PERTH - NORTH METRO

CREATED BY	CHECKED	APPROVED
MO	MO	

HORIZONTAL DATUM: GDA 94 **PROJECTION:** MGA ZONE 50
HEIGHT DATUM: NA **METADATA RECORDED:** 100%

DATE	FILE LOCATION
11.09.2006	N:\61\1182905\GIS\MXDS\611182905-G9.MXD
REVISION	**DRAWING NO**
0	611182905-G9

DEPARTMENT OF WATER
REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY
Figure 2
Swan Valley Planning Areas and North East Corridor Structure Plan Boundary

4.1.4 Land Use Constraints

Aboriginal Sites

The area comprises various sites of aboriginal significance. In relation to development of the site this requires confirmation from the Aboriginal Affairs department on the level of protection and the process required for Section 18 clearance for certain uses.

European Heritage Sites

The Class identifies the type of environment as Aboriginal, Historic or Natural. Aboriginal refers to all indigenous places, Historic refers to the post-European settlement environment including building, ruins, city parks, arboretum, botanic gardens, and trees of social significance and Natural refers to wilderness, remnant forest, geological areas and endangered species. The status of the sites is conducive to the level of protection.

Perth-Darwin Highway

The Perth-Darwin Highway alignment south of Maralla Road has been finalised by Main Roads Western Australia (MRWA). The northern section to Brand Highway is still to be determined.

Geraldton-Perth Railway

The Geraldton-Perth Railway Freight Line is an existing line that currently runs to Geraldton. As part of the North East Corridor Planning Study, it was proposed to connect the line through Ellenbrook. A public purpose site has been delineated under the Metropolitan Region Scheme. This line currently terminates at Maralla Road. It appears that this railway line will link up to the Perth-Geraldton railway line.

ANEF Contours

The Defence Department produced an Australian Noise Exposure Forecast (ANEF) plan for Pearce Air Base that indicates the areas affected by the different projected aircraft noise levels. Land within the 20 ANEF contour is considered to be inappropriate for new urban areas.

Aircraft Noise Projections for the Perth Domestic and International Airport have been prepared. Noise levels are delineated by Australian Noise Exposure Capacity (ANEC) contours. It is recommended that no residential zoning take place inside the 25 ANEC noise contour.

Poultry Farms and Industrial Uses

There are a number of poultry farms scattered within the study area. These sites still contain poultry sheds. Until such time as these sheds are removed from the site, a 500m buffer area applies which precludes residential development from occurring.

There are a number of industrial areas within the study area resulting in a constraint for urban development. Brickworks are located in Viveash and West Swan and a Tile factory in Caversham, which require a 500m buffer from urban development.

4.2 Landform and soil types

The strategy area lies west of the Darling Scarp and contains the generally north-south valleys of the Swan River and Ellen Brook. Outwash slopes of gravels, silts and clay extend from the Darling Scarp on the east side of the rivers. The main rivers are incised into the riverine deposits of the valleys.

To the west of the rivers, seasonally waterlogged flats (palusplains) of the Pinjarra Plain rise gently to meet sand dunes of the Bassendean Dune System. Ephemeral watercourses that have either formed naturally, or have been constructed for land drainage purposes intersect the palusplains.

At the eastern margin of the Bassendean Dune System, relatively thin layers of sand are interspersed with silts and clays of riverine origin. In this complex zone, the low permeability of the clays has caused perched aquifers to form in the sandy layers. In places the less permeable layers have forced groundwater to the surface, resulting in ephemeral creeks forming near the margins with the Bassendean Dune System. Within the Corridor, these creeks flow in an easterly to south-easterly direction to meet Ellen Brook and the Swan River.

Further west, undulating dunes have formed over the deeper sands that contain the Gnangara Groundwater Mound. Surface presentations of the water table within the interdunal swales have formed a myriad of wetlands in this western portion of the study area. The wetland types present are predominantly sumplands (seasonally inundated basins) and damplands (seasonally waterlogged basins).

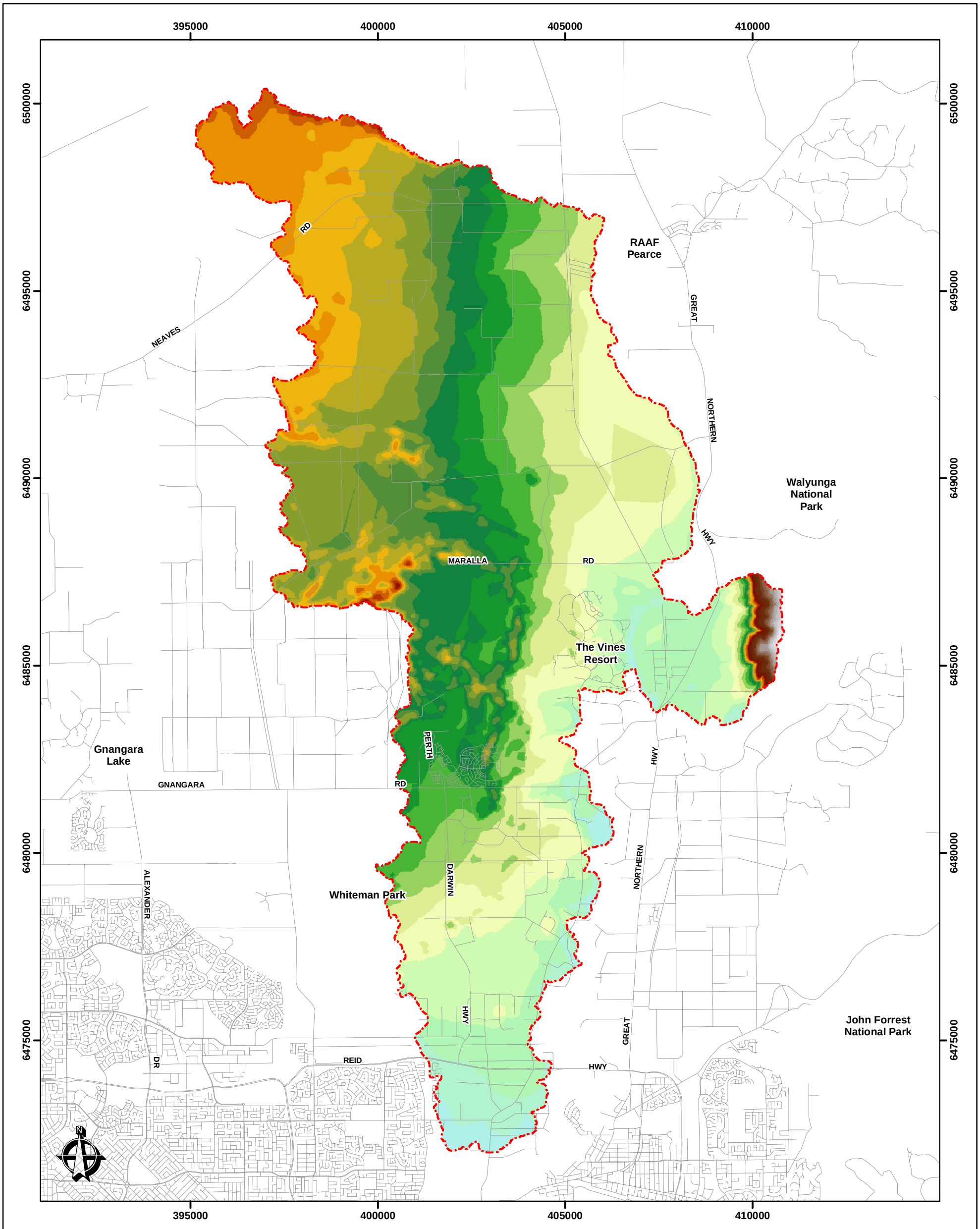
The main geological units that dominate the North East Corridor strategy area are the Guildford Formation comprising alluvium and the Bassendean Sand comprising aeolian sand (Figure 4). The soil types of the study area vary considerably but may be classified into three fundamental zones:

» Eastern Zone: To the east of the rivers, outwash slopes and palusplains derived from Guildford Formation silts and clays;

» Central Zone: Immediately to the west of the rivers, palusplains derived from Guildford Formation merge into a zone of perched water tables and groundwater seepage in complex soils derived from interspersed layers of Bassendean Sand and Guildford formation silts and clays; and

» Western Zone: Along the western side of the study area, deeper sands derived from the Bassendean Sand unit.

Urbanisation on the Eastern and Central Zone soils present challenges to provision of drainage. The Bassendean Sand of the western zone is generally well drained, but potentially high mobility of pollutants carried in the groundwater.



LEGEND

Study Area

Roads

Topography m AHD (based on 5 m contours)

5 - 10	55 - 60	110 - 120
10 - 15	60 - 65	120 - 130
15 - 20	65 - 70	130 - 140
20 - 25	70 - 75	140 - 150
25 - 30	75 - 80	150 - 160
30 - 35	80 - 85	160 - 170
35 - 40	85 - 90	170 - 180
40 - 45	90 - 95	180 - 190
45 - 50	95 - 100	190 - 200
50 - 55	100 - 110	200 - 210
		210 - 220

NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP

PERTH - NORTH METRO

CREATED BY	CHECKED	APPROVED
MO	MO	

HORIZONTAL DATUM: GDA 94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: AHD **METADATA RECORDED:** 100%

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11.09.2006	N:\61\1182905\GIS\MXDS\611182905-G7.MXD
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0	611182905-G7

DEPARTMENT OF WATER
REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY

Figure 3
Topography

395000 400000 405000 410000

6500000 6495000 6490000 6485000 6480000 6475000

RAAF Pearce

Walyunga National Park

The Vines Resort

Gnangara Lake

Whiteman Park

John Forrest National Park

NEAVES RD

GREAT NORTHERN HWY

MARALLA RD

PERTH RD

GNANGARA RD

ALEXANDER DR

DARWIN HWY

REID HWY

N

LEGEND

Study Area

Roads

Environmental Geology

- Cps : PEATY CLAY, Swamp Deposits
- M1: SILT, Swamp Deposits
- Mc1: CLAYEY SILT, Aluvium
- Msg: SAND SILT Colluvium
- LS5: LIMESTONE, Tamala Limestone
- S8: SAND, Bassendean Sand
- S10: SAND, Thin Bassendean Sand over Guildford Formation
- G1: GRAVEL
- S11: SAND, Guildford Formation
- S12: SAND, Yoganup Formation
- Mgs1: PEBBLEY SILT, Guildford Formation
- GR: GRAVEL

NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP

PERTH - NORTH METRO

CREATED BY	CHECKED	APPROVED
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HORIZONTAL DATUM: GDA 94 **PROJECTION:** MGA ZONE 50

HEIGHT DATUM: NA **METADATA RECORDED:** 100%

DATE	FILE LOCATION
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REVISION	DRAWING NO
1	611182905-G3

DEPARTMENT OF WATER REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY

Figure 4
Environmental Geology

4.3 EPP wetlands and waterways

4.3.1 EPP wetlands

The North East Corridor area contains numerous wetlands of conservation significance, including Conservation and Resource Enhancement management category wetlands (Figure 5). Wetland mapping for this area is displayed in the *Geomorphic Wetlands Swan Coastal Plain* dataset (Department of Environment and Conservation). A number are also identified under the *Environmental Protection (Swan Coastal Plain Lakes) Policy 1992*. Significant wetlands are located in State reservations (Parks and Recreation and State Forest reserves) at Whiteman Park, Melaleuca Park, Ellenbrook Reserve and Twin Swamps Reserve.

In the deep Bassendean Sands to the west, interdunal swales reflect the near surface groundwater of the Gnangara Mound. In the central zone, the sandy dunes overlie less permeable Guildford Clays and produce seepage zones along the interface of these major soil types. The streams and creeks that form at this interface flow east and southwards across the flat clay-soil plains towards Ellen Brook and the Swan River. To the east of the Swan River, the silt and clay outwash slopes of the Darling Scarp concentrate groundwater seepage and surface runoff flows to depression wetlands and out flowing creeks that are also tributaries of the Swan River.

The majority of the interdunal wetland systems on the Swan Coastal Plain operate as 'through flow' lakes. Under this regime the wetlands act as conduits, with shallow groundwater from up-gradient of the wetland rising within the aquifer to pass through the water body, before being recharged to the groundwater system on the down-gradient side of the lake. In many respects these interdunal lakes can be considered as 'windows' to the wider superficial groundwater system. The primary implication in managing these systems is then to recognise the linkage between the wetlands and groundwater systems that feed them. The significance of the capture and recharge zones in managing these shallow wetlands must be recognised.

Land uses that generate groundwater pollutants within the capture zones of wetlands have the potential to result in direct contamination of these water bodies. Proposed development within these zones therefore needs to be considered with caution.

Wetlands used as treatment and disposal sites for trunk drainage can act as potential point sources for contamination of the wider superficial aquifer. The hydrological regime of a wetland is significantly altered when relatively large volumes of urban stormwater are discharged to the wetland. This process can result in localised mounding of the water table, particularly over the winter months.

Groundwater abstraction from within the capture and release zones of wetlands can directly impact wetland hydrology by altering the local watertable. This process may be important in affecting change in wetland vegetation.

The shallow groundwater chemistry will be distinct between the wetland's capture and release zones. Down gradient of wetlands, higher salinities tend to be encountered resulting from evapo-concentration effects within the wetland. In sites with acid

sulphate soils, the recharge zone might display acidic profiles potentially with elevated levels of arsenic and other metal contaminants that may pose a health risk to bore water users.

4.3.2 Waterways and drainage paths

Arterial drainage for the Corridor is focussed around the main rivers and streams. Ellen Brook, Jane Brook, Susannah Brook and the Swan River are the main watercourses that collect runoff from the Corridor. They are fed by a number of smaller ephemeral creeks and streams that include Bennett Brook, Henley Brook, St Leonard's Creek, Wandoo Creek, and Saw Pit Gully.

Declared main drainage catchments extend off Bennett Brook and Henley Brook that serve recent residential developments at Caversham, Lockridge, Beechboro, Henley Brook and Ellenbrook.

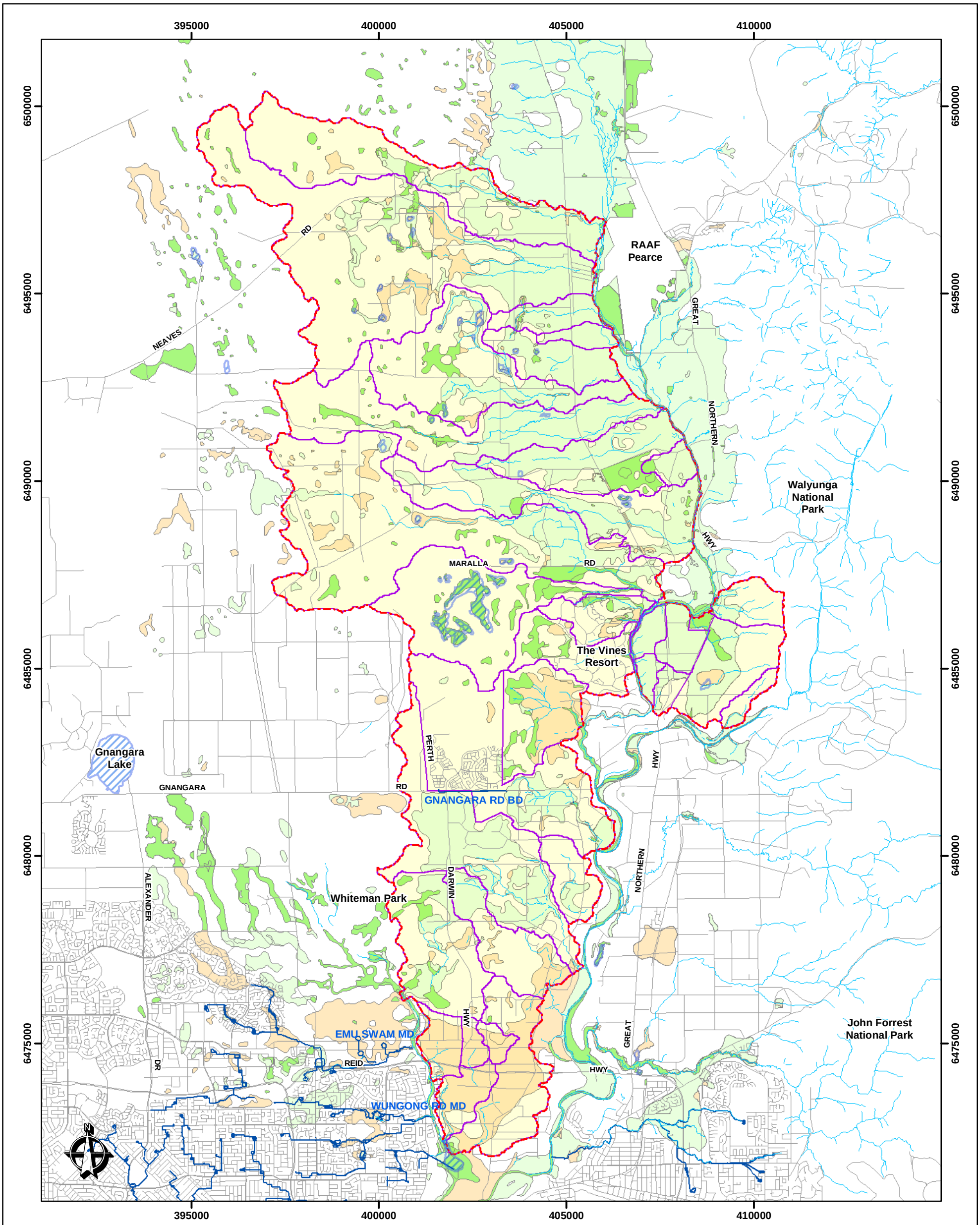
Constructed rural drains comprising open earth channels and culverts traverse much of the palusplain of the Corridor. Some of these follow the natural drainage paths: constructed to "enhance" the natural flow capacity to drain rural land. Others have been constructed as collector drains to reduce waterlogging or to provide a surface outflow route from shallow depression basins. Some of these existing rural drains and watercourses may form the basis of an arterial drain system to service future urbanisation.

4.4 Groundwater

General hydrogeology of the western parts of the North East Corridor is described in the Perth Groundwater Atlas (Water and Rivers Commission, 1997) and is shown on Figure 6. Groundwater flows in the area is dominated by the Gnangara Mound to the north west of the study area, which is a major recharge zone, and the major north-south drainage lines.

Groundwater flow in the area west of Ellen Brook and the Swan River is generally from the west to the east, towards those rivers. Bennett Brook also influences groundwater flows at the southern end of the study area.

East of Ellen Brook and the Swan River, groundwater flows are less pronounced and are generally from east to west. There is anecdotal evidence of some shallow artesian aquifers in this zone that are supplied from recharge areas near the Darling Scarp to the east.



LEGEND

- Study Area
- Roads
- Watercourses
- Drains
- EPP Lakes (1992)
- Surface Water Catchments

DoE Geomorphic Wetlands

- Conservation
- Multiple Use
- Resource Enhancement

NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP

PERTH - NORTH METRO

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HORIZONTAL DATUM: GDA 94 **PROJECTION:** MGA ZONE 50
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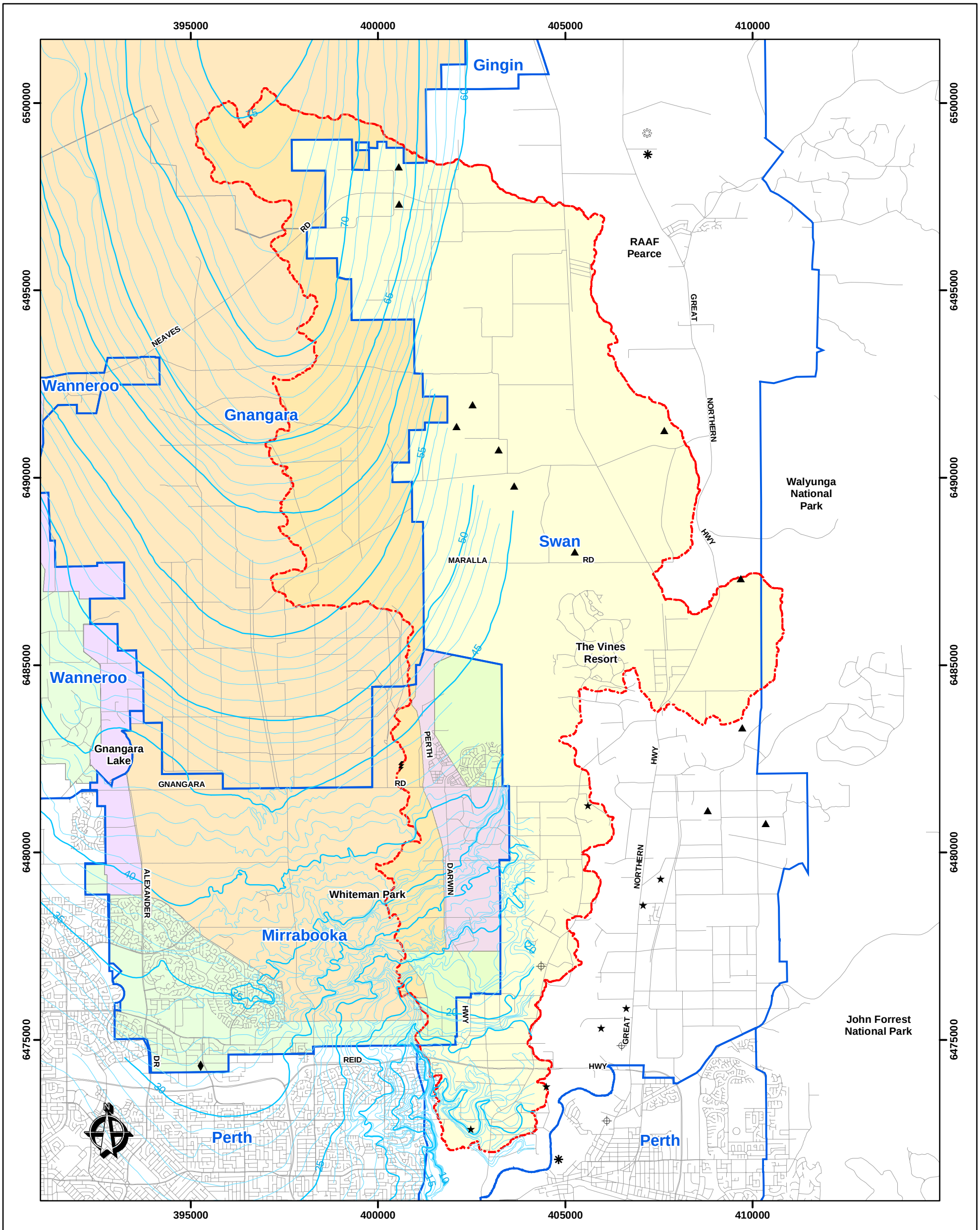
REVISION	**DRAWING NO**
2	611182905-G2

DEPARTMENT OF WATER
REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY
Figure 5
EPP Lakes, Geomorphic Wetlands and Drainage



LEGEND

- Study Area
- Roads
- Perth Atlas Maximum Groundwater Contours
- Groundwater Areas

Underground Water Pollution Control Areas (UWPCA's) Priorities

- P1
- P2
- P3

DoE Identified Potential Contaminated Sites (January 2006)

Note: Please refer to DEC, Contaminated Sites Register.

- ▲ Animal-based wastes
- ○ Cemetery and animal disposal
- ♦ Commerical and general industry
- ★ Food industry waste
- ✱ Landfill sites
- ❁ Remediated Landfill sites
- ϟ Liquid waste disposal and sewerage treatment sites
- ⌖ Residential activities

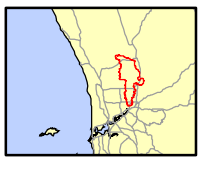
NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP



PERTH - NORTH METRO

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HORIZONTAL DATUM: GDA 94	**PROJECTION:** MGA ZONE 50
HEIGHT DATUM: AHD	**METADATA RECORDED:** 100%
DATE 11.09.2006	**FILE LOCATION** N:\61\1182905\GIS\MXDS\611182905-G4_Rev1.MXD
REVISION 1	**DRAWING NO** 611182905-G4

DEPARTMENT OF WATER
REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY
Figure 6
Groundwater and Potential Contaminated Sites Location

GHD

Waterlogging and flooding are common in lower-lying areas, especially in the vicinity of existing natural drainage lines and wetlands. Winter waterlogging of palusplains is prevalent due to the clay soils and low surface gradients. Several historical rural drains were constructed in these areas to control the accumulation of surface water and prevent flooding. This has contributed to the extensive degradation of large areas of palusplain in the area.

The deeper existing drains and watercourses, such as Bennett Brook and the Horse Swamp Drain near Lord Street, have a significant local impact on groundwater levels. Drainage effects extend over several hundred metres in areas of sandy alluvium and Bassendean sands. In areas of Guildford Formation silts and clays, drains are less effective, typically affecting groundwater levels for less than 150 m.

4.4.1 Public Water Supply Areas – Groundwater

The western margins of the study area fall in or adjacent to proclaimed Underground Water Pollution Control Areas (UWPCA's) and Public Water Supply Areas (PWSA's) from which groundwater is abstracted (Figure 6). Some areas proposed for development under the Structure Plan fall within UPWCA Priority 2 and Priority 3 protection zones.

4.4.2 Identified Groundwater Pollution Sources

The inventory work compiled by Hirschberg (1988) was reviewed to identify known sites within the Corridor with the potential to cause pollution. A total of 28 sites were identified within the study boundaries and are shown on Figure 6. All but two are situated east of the proclaimed PWSA. These sites have been summarised in Table 2. Half of the sites collect animal wastes. Hirschberg (1988) remains the most up to date inventory on pollutant sites publicly available (pers. comm. Sharon Clark, DEP). The current operating status of the listed sites is not known.

Table 2 Groundwater Contamination Sites in the North East Corridor Study Area (compiled from Hirschberg, 1988)

Landfill Sites	2
Liquid Disposal Sites	5
Animal Based Waste	14
Industrial Waste	1
Chemicals, Fertilisers	0
Food Industry Waste	5
Cemeteries, Animal Disposal	1
Total	**28**

4.4.3 Areas with shallow depth to groundwater

Figure 7 shows areas that may experience seasonal inundation and waterlogging. The likelihood of inundation is based on an analysis of regional groundwater levels, soil type, basin wetlands and topographic. The map is indicative only and the risk of waterlogging at any specific site should be confirmed by more detailed hydrogeological assessment of the site.

Areas with a high risk of seasonal inundation and water logging are not recommended for development without more detailed investigation.

- If the area is a wetland of significance, development should not occur (see 3.4);
- If the subject land is not assessed or its assessment is doubtful or challenged, then the proponent must carry out site-specific investigations to better determine vulnerability to the satisfaction of the approval authorities;
- If the subject land is assessed as being “High Risk” then the proponent must make specific allowance for managing development of a site with shallow water table and potential for waterlogging and flooding and must carry out site-specific investigations either to quantify the degree of protection required or to satisfy the approval authorities that the land should be in a lower risk category;
- If the subject land is assessed as being “Moderate Risk” then the proponent must make specific allowance for managing development of a site with shallow water table and potential for waterlogging and flooding or must carry out site-specific investigations to satisfy the approval authorities that the land should be in a lower risk category;
- If the subject land is assessed as being “Low Risk” then the proponent must carry out site-specific investigations to confirm to the approval authorities that the land is at low risk from waterlogging and flooding.

4.5 Acid Sulphate Soils

The North East Corridor area includes significant areas with moderate to high risk of Acid Sulphate Soils less than 3 m from natural surface in the high risk areas and more than 3m below surface soil in the medium to low risk areas.

Acid Sulphate Soil (ASS) is the common name for soils containing iron sulphides or their oxidation products. In Australia the acid sulphate soils of most concern occur in estuarine areas and coastal lowlands including the Swan Coastal Plain. These iron sulphide rich soils were created during periods of rapid sedimentation since the last major sea level rise 10,000 years ago. Bacteria in these waterlogged, high organic content sediments converted sulphate from coastal waters and iron contained in the sediments to iron disulphide (pyrite).

When exposed to air these iron sulphides oxidise and produce sulphuric acid. Layers of waterlogged sulphide rich sediments are referred to as Potential Acid Sulphate Soils (PASS). When these materials are exposed to air and oxidise producing sulphuric acid they are known as Actual Acid Sulphate Soil. This evolved sulphuric acid causes the environmental impacts associated with Acid Sulphate Soils.

395000 400000 405000 410000

6500000 6495000 6490000 6485000 6480000 6475000

RAAF Pearce

Walyunga National Park

The Vines Resort

Gnangara Lake

Whiteman Park

John Forrest National Park

NEAVES RD

GREAT NORTHERN HWY

MARALLA RD

PERTH GNANGARA RD

DARWIN ALEXANDER DR

REID HWY

LEGEND

- Study Area
- Roads
- Watercourses

Seasonal Waterlogging Vulnerability

- Very High Risk
- High Risk
- Moderate Risk

NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP

PERTH - NORTH METRO

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MO		

HORIZONTAL DATUM: GDA 94 **PROJECTION:** MGA ZONE 50
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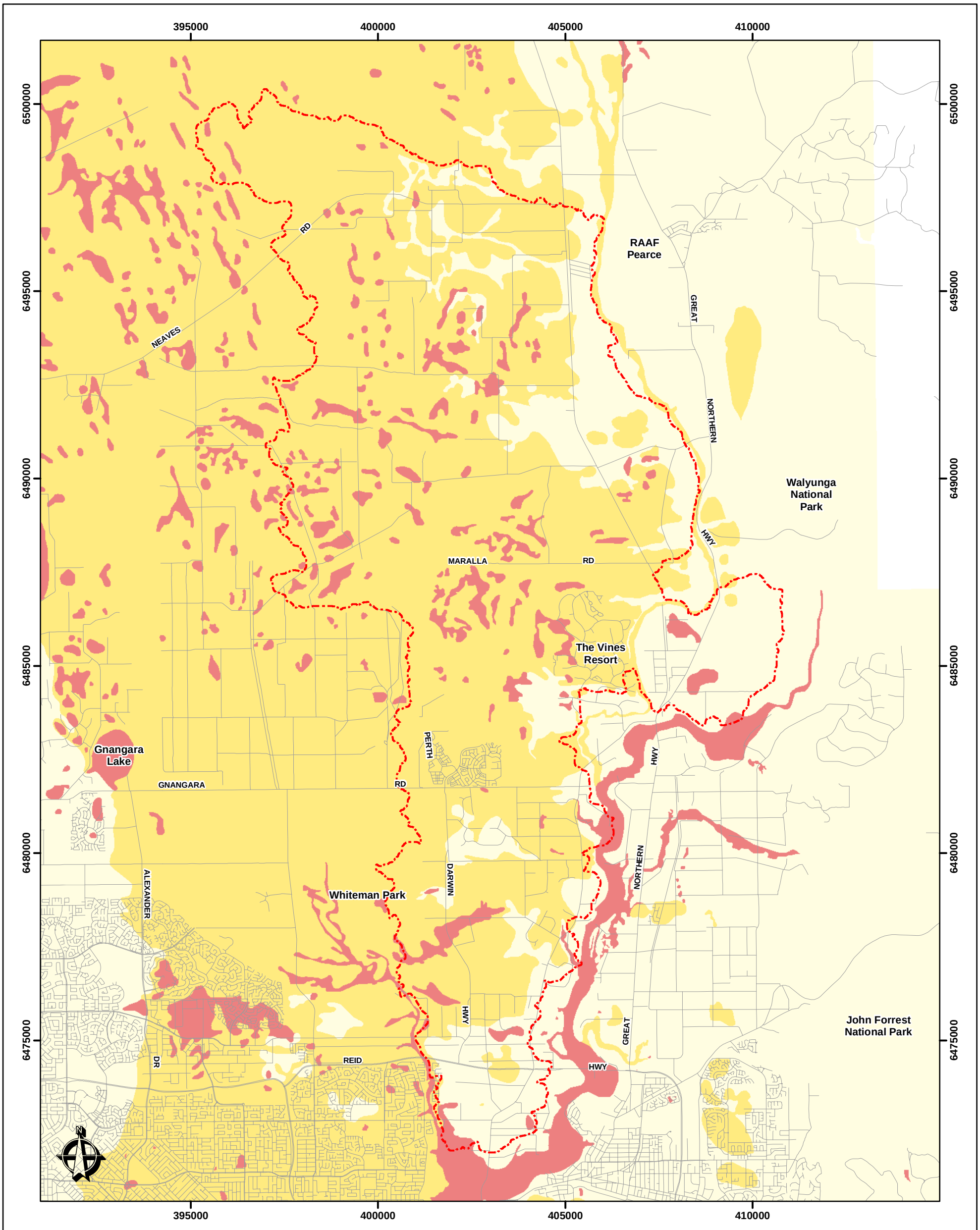
REVISION	**DRAWING NO**
1	611182905-G5

DEPARTMENT OF WATER REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY

Figure 7
Areas of Shallow Groundwater



LEGEND

Study Area

Roads

Acid Sulphate Soils Risk (ASS), Department of Water Mapping

Class 1 - Moderate to high risk of ASS <3 m from soil surface

Class 2 - Moderate to high risk of ASS or PASS occurring >3 m from soil surface; no risk of occurrence <3m from soil surface

Class 3 - Low to nil risk of ASS occurring >3 m from soil surface; no risk of occurrence <3m from soil surface.

NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP

PERTH - NORTH METRO

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HORIZONTAL DATUM: GDA 94 **PROJECTION:** MGA ZONE 50

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0	611182905-G8

DEPARTMENT OF WATER REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY

Figure 8
Acid Sulphate Soils Risk Mapping

4.5.1 Acid Sulphate Soil Impacts

Acid Sulphate Soil Impacts can include:

- Adverse changes to the water quality of soil water, groundwater, wetlands, watercourses and estuarine environments;
- Deterioration of ecosystems and ecosystem services;
- Local and regional loss of biodiversity;
- Loss of quality of ground or surface water sources used for irrigation or other purposes;
- Human health concerns, metal contamination;
- Acid sulfate soils used as landfill can affect plant growth, future landscaping and create erosion problems;
- Corrosion of concrete, iron, steel and aluminium structures;
- Loss of visual amenity from staining, scum, slime;
- Costs associated with minimizing impacts and repairing disturbed areas.

4.6 Environmental and heritage issues

4.6.1 Remnant Vegetation

The North East Corridor area contains a number of remnant vegetation communities, including areas listed as Bush Forever (Figure 9). Although some areas of remnant vegetation are within the area proposed for urbanisation under the North East Corridor Structure Plan, areas listed as Bush Forever are mostly within existing reserves. Bush Forever Sites are located along Bennett Brook, the Swan River, Ellen Brook and the lower reaches of Jane and Susannah Brooks, with significant sites at Whiteman Park, Melaleuca Park, Maralla Road Bushland (at the Lexia Wetlands complex), Ellenbrook Reserve, Twin Swamps Reserve, Caversham Airstrip (Albion) and Pearce Airbase.

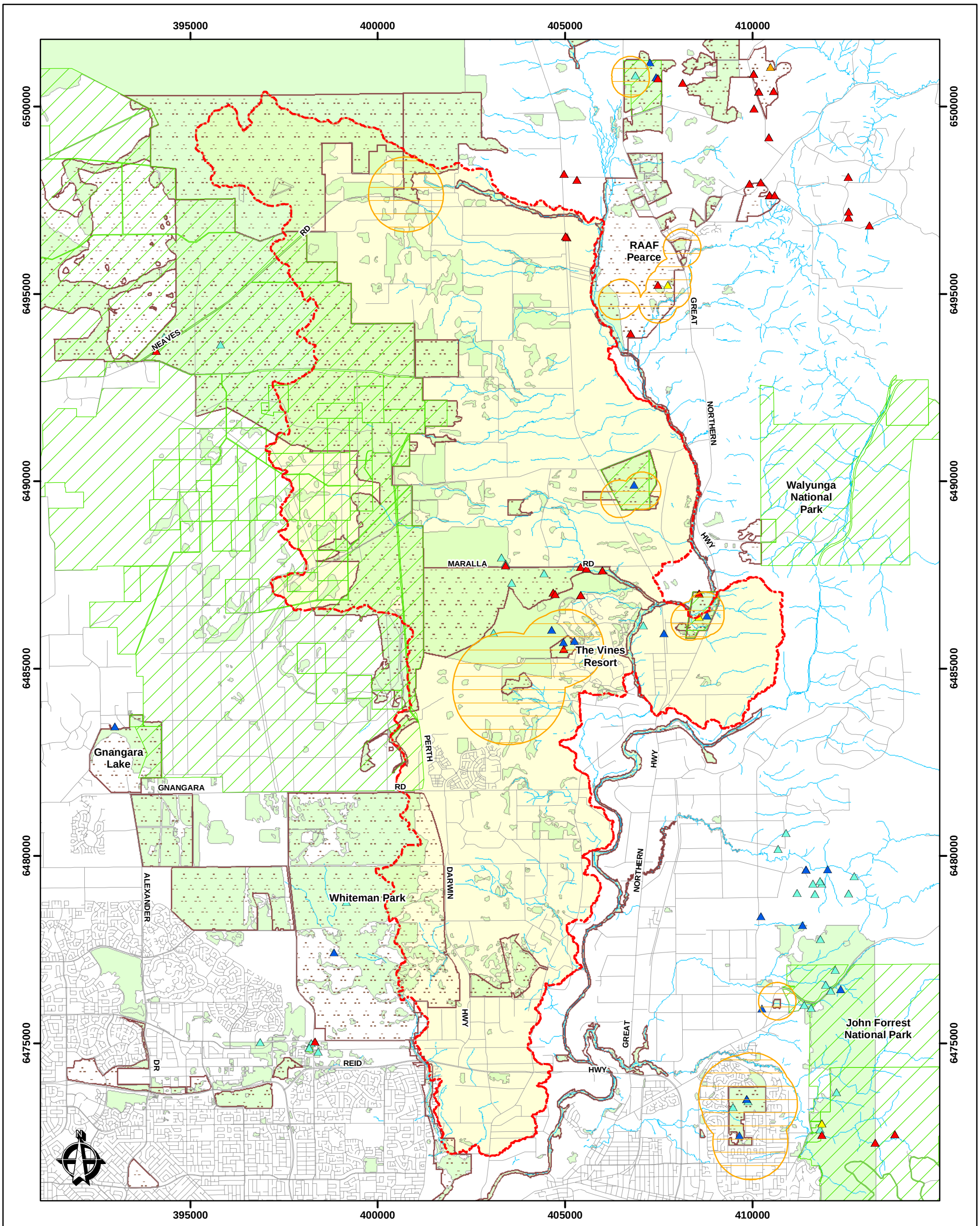
An Environmental Protection Policy (EPP) has been prepared by the Environmental Protection Authority (EPA) that addresses protection of the critically endangered Western Swamp Tortoise habitat at Twin Swamps Nature Reserve (Bullsbrook) and Ellenbrook Reserve (Upper Swan) The Western Swamp Tortoise is the most endangered tortoise or turtle species in the world. The *Environmental Protection (Western Swamp Tortoise Habitat) Policy Approval Order 2002* (EPA 2002) defines a policy area boundary to protect the beneficial uses of Twin Swamps and Ellenbrook Reserves from the adverse impacts of land use change. The policy area follows cadastral boundaries to encompass the immediate surface water and groundwater catchments of the two Nature Reserves.

Bordering the western edge of the Corridor there are further areas of remnant vegetation at Whiteman Park, at the Lexia wetlands complex and at Melaleuca Park. Generally, these areas fall outside the proposed development zones, or are secured within conservation reserves.

Identified Threatened Ecological Communities and Declared Rare Flora are shown on Figure 9 together with the broader areas of remnant vegetation. While most of the threatened communities are secured within reserves, some, at The Vines and at Egerton, are on land that is currently zoned Urban or Urban Deferred. Another site just north of Neaves Road is on uncleared land zoned rural.

4.6.2 Aboriginal Heritage

Several aboriginal heritage sites have been identified within the study area. These sites of cultural significance varying from individual locations to extensive sites such as Ellen Brook itself. Specific sites exist within (or very close to) land zoned for urbanisation at Egerton, Upper Swan, Caversham and Jane Brook.



LEGEND

- Cadastral Boundaries
- Watercourses
- CALM Reserves
- Bushforever (2000)
- Remnant Vegetation
- Threatened Ecological Community Buffers

Declared Rare Flora

- (R) Declared Rare Flora - Extant Taxa
- Priority 1 - Poorly Known Taxa
- Priority 2 - Poorly Known Taxa
- Priority 3 - Poorly Known Taxa
- Priority 4 - Rare Taxa

NOTE THAT POSITIONAL ERRORS CAN BE > 5M IN SOME AREAS

SCALE

0 0.5 1 2 3 4 Kilometres

1:100,000 at A3

LOCALITY MAP

PERTH - NORTH METRO

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1	611182905-G6

DEPARTMENT OF WATER
REVIEW OF NE CORRIDOR DRAINAGE MANAGEMENT STRATEGY

Figure 9
Environmental Constraints

5. Water Quantity management

5.1 For ecological protection

In managing drainage flows for ecological protection, development should seek to maintain the pre-development hydrology.

Water management within the North East Corridor must meet the ecological water requirements of the receiving environment. Where practical, runoff from the 1 year ARI rainfall event should not exceed the predevelopment flow, unless otherwise established through determination of ecological water requirements. In most cases this will be achieved by retaining or detaining on site (or as close to source as practical), the runoff from constructed impervious surfaces, resulting from rainfall events up to the 1-year ARI event.

5.2 For flood protection

Peak flows from urban run-off must be managed to protect property and infrastructure. Specifically, flood management in developed areas shall provide protection from the 100 year ARI event.

The design peak discharge from any catchment should ensure that the flood channel capacity of the receiving waterway is not exceeded. In most cases, this will be achieved by retaining or detaining the runoff from storm events in landscaped areas in public open space or linear multiple use corridors. Where practical, any discharge to wetlands or waterways should be by overland flow paths across vegetated surfaces.

Flood paths and flood levels for the 100-year ARI event should be clearly identified in District and Local Drainage and Water Management Strategies.

5.3 Flood storage and detention areas

Where peak discharge from any catchment exceeds the hydraulic capacity of the receiving waterway resulting in a risk of downstream flooding or environmental harm, the peak discharge shall be compensated by providing additional flood storage within the catchment.

In developing District and Local Drainage and Water Management Strategies, existing waterways should be reviewed to assess their capacity to convey the increased run-off from major events. This may require streamflow monitoring or modelling. This stream capacity should form the basis for determining the necessary flood storage within the District Structure Plan Area.

Flood storage should be provided in areas of Public Open Space and Multiple Use Corridors in the form of dry detention basins. Since these flood storage areas are only infrequently inundated, they can be landscaped or used for other purposes compatible with their primary purpose of flood storage and conveyance.

6. Groundwater Management

To protect buildings and other infrastructure, adequate separation from maximum groundwater levels must be provided. In some areas it may be possible to reduce the need for imported fill by the use of subsoil drainage where it can be demonstrated that:

- Nutrient export from the site will not be increased, and
- Subsoil drainage is laid at or above the Controlled Groundwater Level (CGL) set at a level to protect groundwater dependent ecosystems
- The subsoil pipe system is designed to minimise and localise the discharge of sub-surface water to only that needed to manage the winter maximum groundwater level in the affected development area.

Although District Drainage and Water Management Strategies should provide guidance for CGLs, these should be reviewed in Local Drainage and Water Management Strategies at local structure plan scale to protect specific environmental values and after the results of more detailed groundwater monitoring information is available.

Areas with a high risk of seasonal inundation and water logging are identified on

Figure 7 and are not recommended for development.

District Drainage and Water Management Strategies should include groundwater monitoring and modelling at a scale more appropriate for groundwater management. The Department of Water is responsible for regional groundwater monitoring.

In areas with shallow depth to groundwater, the District Drainage and Water Management Strategy will require groundwater modelling to investigate the effect of land use change on groundwater levels, to determine need for imported fill and subsoil drainage, to examine the potential use of shallow groundwater as a resource and to assess any potential impacts on wetlands and groundwater dependent ecosystems.

In areas where there is a risk of Actual Acid Sulphate Soils (AASS) or Potential Acid Sulphate Soils (PASS), groundwater levels should not be lowered to expose iron sulphide minerals below the water table.

An assessment of shallow groundwater quality is required to determine the status of groundwater contamination and its vulnerability to acidification. This will then determine the level of management required to prevent groundwater degradation particularly in areas where soil-buffering capacity is low or negligible.

7. Water Quality Management

7.1 Potential contaminants

A wide range of pollutants are potentially leached into the groundwater or transported in stormwater runoff to receiving water bodies. Urbanisation introduces four main types of pollutants requiring management. These are defined in Table 3 along with their common sources. Structural controls for removal of these pollutants from drainage waters are assessed in Section 7.4.

Table 3 Potential contaminants and their sources

Pollutant Type	Source
Nutrients	**Urban / Commercial:** Fertiliser application to gardens & POS, septic tanks, pet waste detergents and car washing, draining nutrient enriched groundwater **Rural:** Intensive animal rearing, viticulture, horticulture / orchards, fertilising pastures, draining nutrient enriched groundwater **Industrial:** Nightsoil, landfills
Sediment Load	**Urban / Commercial / Industrial:** Erosion of water courses, wash-off from roads, poor water management controls during construction **Rural:** Erosion of watercourses, sheet erosion.
Gross Pollutants	**Urban / Commercial / Industrial:** General litter, organic matter, illegal dumping **Rural:** General litter, organic matter, illegal dumping
Oils and Hydrocarbons	**Urban / Commercial:** Garages, service stations and wash-off from roads **Rural:** Service stations **Industrial:** Garages, service stations, transfer stations, wash-off from roads and areas of hard-standing, general workshops.

7.2 Existing Condition (Ellen Brook)

Although it is not entirely representative of the North East Corridor, the Ellen Brook catchment has been the focus of a number of investigations and is perhaps better understood than other catchments in the area. The following discussion is presented as useful background information for the management of water quality in the area.

The Ellen Brook catchment is recognised as being one of the highest contributors of nutrients to the Swan-Canning Estuary. Very high levels of phosphorus and moderate levels of nitrogen are consistently recorded in Ellen Brook. Of the gauged catchments to the Swan-Canning Estuary, in an average year Ellen Brook contributes 36% of the total phosphorus load in only 6% of the total flow, the highest of any gauged site (Shams and Smith 2000, 2002). Very low nitrogen to phosphorus ratios of 4:1 in the tributary creeks and Ellen Brook identifies these waters as being highly susceptible to the growth of nitrogen fixing blue-green algae.

Nutrient Pathways

Surface water runoff is generated by both direct runoff and through the generation of overland flows resulting from seasonal waterlogging of Guildford Formation type soils. The combined impact of both overland flow and direct runoff is particularly significant as published data suggests these pathways introduce the bulk of nutrients to Ellen Brook.

Subsurface flows are recognised as occurring in the duplex soils of the eastern catchments and in the transition zone between the Guildford and Bassendean formations where clay lenses are inter-bedded with sandy profiles. Shallow subsurface flows of summer are likely to become overland flows during the winter as the watertable rises and the subsurface flow pathways intersect ground level. Water movement in this part of the soil profile, typically within 2 m below ground level, has the potential to mobilise a significant fraction of the nutrients applied to pasture and from other agricultural activities. No direct measurements of sub-surface nutrient concentrations within the Ellen Brook Catchment are available in the published literature.

Groundwater flows discharging into Ellen Brook from deeper in the soil profile (up to 16 m below ground level) have been monitored and reported as having lower nutrient contents. Table 4 summarises published median figures for nitrogen and phosphorus concentrations monitored in Ellen Brook, in selected tributaries and at groundwater sites along the Ellen Brook channel for years 1987-2000.

It is evident from Table 4 that the concentrations of nutrients in the creeks and Ellen Brook are comparable, but that the concentrations in the monitored groundwater bores are much lower than the surface water concentrations. This suggests that the nutrient enrichment of surface water discharging to Ellen Brook is greater than that of the deeper groundwater component.

Table 4 Nutrient Concentrations in the Ellen Brook Catchment (reproduced from Shams 2000, P50)

Nutrients	Median Concentration (mg/L)		
	Groundwater	Creeks	Ellen Brook
Total Nitrogen	0.48	2.7	2
Total Phosphorus	0.135	0.72	0.47

This result is of significance when considering the relative yields of surface water and groundwater discharging to Ellen Brook. Over a monitored 3.6 km reach of Ellen Brook the median water yield and nutrient loadings for both surface water and groundwater were calculated by the WRC for the year 1999. From the estimates presented in Table 5, the surface water input is 2 to 3 times greater than the groundwater input and generates the bulk of the total nutrient load entering this section of Ellen Brook. Managing surface water therefore needs to be recognised as a priority in addressing water quality.

Table 5 Estimates of relative loadings of nitrogen and phosphorus over a 3.6 km long reach of Ellen Brook (reproduced from Shams 2000, P53)

Pathway	Discharge ML/yr	TN Load T/yr	TP Load T/yr
Groundwater	2,505	0.9	0.4
Seasonal Creeks	6,703	18.1	4.8

Nutrient Forms and Sources

Monitored nutrient concentrations in Ellen Brook between 1987 and 2000 show that 88% of nitrogen is in the form of organic-N, while 69% of phosphorus is Dissolved Inorganic Phosphorus (DIP) (Jackowyna 2002, P43). The high proportion of phosphorus in a soluble reactive form suggests that little phosphorus is associated with sediment particles (Deeley 1993). This contrasts distinctly with reported phosphorus fractions in urban stormwater from urban catchments elsewhere in Australia with clay soils where the fractions of inorganic and organic are in the order of 4% soluble and 96% particulate (Ball et al. 2000). Elevated organic-N concentrations are likely to be attributed to peaty soils, wetlands, or even sewerage/organic water leachate (Jackowyna 2002, P434).

Both TN and DIP showed a mid-winter peak in concentrations, with a trough late in the year (December). Neither TN nor DIP showed a strong positive response to storm induced flows suggesting that the transport mechanism is gradual, with groundwater induced sub-surface and overland flows identified as the likely pathways.

The nutrient load in the Ellen Brook catchment is mainly from diffuse sources associated with current and previous rural land use (Jackowyna, 2002).

7.3 Potential improvement from change in land use

Urban run-off from existing urban areas in Perth show typically lower nutrient concentrations than reported for Ellen Brook (Tan, 1991). It is possible that the change in land use, from active rural to urban, may lead to an improvement in water quality of surface run-off that flows to waterways in the North East Corridor. However, legacy nutrients are expected to remain in the groundwater under the some areas for many years, slowly migrating towards waterways and represent a continuing source of nutrients. Strategies for managing water quality must consider future nutrient loads from both groundwater and surface water, which are expected to be site specific.

In the absence of high quality data for existing water quality and nutrient export loads and concentrations, it is difficult to determine whether the receiving waterway water quality targets will be met by a proposed drainage strategy. It is therefore not always practical to use waterway water quality targets to assess and approve drainage designs.

An alternative approach is to develop design objectives that do not specify absolute water quality targets but rather:

- require quantitative outcomes that support the waterway water quality targets;
- can be predicted using established design methods and tools;
- can be used during design stage to assess the potential impact of alternative design approaches; and
- are achievable using best practice.

For the purposes of assessing alternative stormwater management approaches and treatment measures, these objectives can be expressed as the required quantitative improvement over the export loads and concentrations that would be achieved using traditional piped drainage systems.

District Drainage and Water Management Plans should include specific water quality design targets for each sub-catchment, noting the variability in hydrogeological and environmental conditions and the receiving waterway. In all cases the water quality design targets must be consistent with the long-term Swan River targets (Table 1).

To protect receiving wetlands and waterways, development should minimize the discharge of nutrients to the shallow groundwater. Adopting the approach endorsed in the Southern River area, it is proposed that District Drainage and Water Management Strategies also include water quality design targets for drainage discharges to the groundwater in the North East Corridor.

Where waterways and wetlands intercept the shallow groundwater, development should minimize the discharge of nutrients to those waterways and wetlands, including open drains and subsoil drains.

The shallow groundwater under some areas of the North East Corridor is expected to have elevated nutrient concentrations due to previous land uses. A number of procedural, technical and governance issues regarding legacy groundwater nutrient contamination on the Swan Coastal Plain remain unresolved to date. The management

of legacy nutrients in groundwater needs to be resolved prior to development so that all involved parties are clearly aware of the relevant roles and responsibilities for managing legacy nutrients.

7.4 Structural measures for managing stormwater quality

All stormwater must be managed to improve water quality before discharge to the environment. Run-off from roads and other paved areas must be diverted through a treatment system for all flows up to the 1-year ARI event.

A major element of the previous Drainage Management Strategy was the use of large Water Pollution Control Ponds (WPCPs) at the outlet from each urban catchment to manage stormwater quality. However, monitoring to date has been unable to determine the overall effectiveness of the WPCP constructed at Henley Brook in accordance with the previous strategy. Surface water entering the WPCP is already below catchment targets and monitoring shows that the WPCP reduces total phosphorus (TP) in the surface water passing through the pond. However, groundwater is intercepted by the pond and the expected relative improvements in discharged water quality have not been achieved. It is recommended that WPCPs no longer be adopted as the primary structural control for managing stormwater quality.

Chapter 9 of the Stormwater Management Manual for Western Australia (Department of Environment, 2004) provides more detailed guidelines for the selection and specification of structural controls and should be referred to in the development of District and Local Water Management Strategies for the North East Corridor.

Since site constraints may make some structural controls unsuitable in some areas (for example due to soil type, groundwater or land use), it is important that suitable structural controls are selected for each precinct.

The efficacy of some structural controls for the management of stormwater, urban waterways and shallow groundwater has yet to be demonstrated under Western Australian conditions. Many of the measures currently being proposed and implemented in Perth have been developed in other parts of Australia for different climatic and hydrogeological conditions.

Although some trials have been established, there has not been a program to systematically evaluate the performance of the various structural controls being proposed over a range of conditions (eg soil types, depth to groundwater, land use). It is recommended that the performance of structural controls be monitored, not for compliance purposes, but to establish performance characteristics of these measures in the North East Corridor.

7.5 Non-structural measures for managing stormwater quality

In addition to structural BMPs, non-structural measures must be adopted to improve water quality in the North East Corridor. Non-structural source controls can include:

» Actions that aim to change behaviour such as public awareness campaigns and community education;

- Local government operations and maintenance activities such as street sweeping and waste management; and
- Land use and management measures, such as sediment and erosion control during construction and porous pavements.

Non-structural measures have been shown to be cost-effective long-term methods of improving stormwater quality and reducing contamination. These include nutrient control and landscaping, sediment and litter control and construction management, street sweeping and community awareness and education programs.

Nutrient control and landscaping

- Develop landscaping guidelines that recommend the use of appropriate native species in landscaping and provide advice on the responsible use of fertilisers and herbicides.

Sediment and litter control and construction management

- Provide an effective waste management plan for the area to ensure that litter and other waste does not collect in the compensating basins and drainage system.
- Require all development construction projects, including road and infrastructure construction, to implement sediment and erosion control measures.
- Provide suitable protection during precinct construction to bio-retention systems and other stormwater BMPs.

Community awareness and education

- Provide residents, commercial tenants and visitors with information on the Swan River and other significant wetlands and waterways, identifying environmental values that are being protected and linking catchment management practices to the health of these ecosystems.
- Actively seek out opportunities to directly engage the community in catchment management through signage and other information in Public Open Space areas, particularly at multiple use corridors, wetlands and waterways.

Chapter 7 of the Stormwater Management Manual for Western Australia (Department of Environment, 2004) provides more detailed guidelines for non-structural controls and should be referred to in the development of District and Local Water Management Strategies for the North East Corridor.

7.6 Water quality monitoring

Subsequent District Water Management Strategies must identify the potential for short-term and long-term mobilisation of nutrients and contaminants in the groundwater. This will require more detailed water quality monitoring of surface and groundwater by the relevant planning authority.

Although this strategy has proposed interim water quality design objectives, further monitoring is required to confirm that stormwater discharged from development areas does not adversely affect the receiving environment and that these interim water

quality targets remain appropriate. It is recommended that the Department of Water monitor water quality in the receiving waterways discharging to the Swan River.

It is recommended that water quality and flows pre- and post-development be monitored within individual developments by developers for a period of 3 years pre- and post-development, and after that time by the relevant Local Government Authority.

It is recommended that all water quality data collected be provided to the Department of Water for collation and analysis and to establish baseline water quality data throughout the North East Corridor area.

7.7 Wetlands and watercourses

The North East Corridor includes several watercourses of high conservation value and environmental significance, including Ellen Brook and the Avon River. There is a need to protect these waterways and to include in land and water planning the requirements for the restoration, revegetation and reservation of appropriate riparian buffers.

The EPA has recommended (EPA, 2000) the following minimum buffer width guidelines for watercourses:

- Watercourses – permanent water 50 m
- Watercourses – seasonally flowing 30 m
- Watercourses – flow in response to rainfall events 10 m

These waterways should be considered as multiple use corridors and identified at the local structure planning stage.

7.8 Acid sulphate soils

The North East Corridor includes areas with a moderate to high risk of Acid Sulphate Soils (ASS) within the upper 3 m of the soil profile. These areas are shown on Figure 8 and are generally associated with low-lying areas including wetlands and waterways. However ASS occurrence is also found in the medium to low risk areas at depths greater than 3m from surface soil.

In areas where there is a risk of Actual Acid Sulphate Soils (AASS) or Potential Acid Sulphate Soils (PASS), the development of a Local Structure Plan must include an Acid Sulphate Soil investigation to determine the extent and severity of ASS occurrence and an Acid Sulphate Soil Management Plan should be submitted and approved by the Department of Environment and Conservation (DEC)

In areas where there is a risk of AASS or PASS occurrence, the oxidation of acid sulphate soils, that can affect land productivity and water resource, should not be caused by the lowering of the groundwater table by dewatering and/or drainage infrastructure.

Acid Sulphate Soil Management

Disturbance of Acid Sulphate Soils should be avoided wherever possible by restricting development. Where development is unavoidable, an Acid Sulphate Soil Management Plan is required for any excavations or dewatering activities. Preparation and implementation of an Acid Sulphate Soil Management Plan shall be in accordance with guidelines published by the Department of Environment and Conservation and should include a commitment to implement Best Management Practises.

The management of acid sulphate soils will generally involve containment, neutralization and/or removal for subsequent treatment or disposal off-site to an approved facility. The methods to be adopted are likely to be site specific. If acid sulphate soils are identified within an area planned for development, then appropriate environmental and geotechnical investigations will be required to determine the extent and the severity of the affected land and to identify best management practices to be implemented to achieve a sound environmental outcome.

Containment may involve preserving the surface soil structure and hydrologic regime, thus denying or significantly compromising urban development of the land. Other options include:

- Strategic reburial – remove and rebury PASS below water level to avoid oxidation;
- Stable containment – remove and bury in a stable containment cell (such as limestone cell) where leachate is contained or can be neutralised; (Generally the DEC do not support burial of ASS materials without treatment as they represent a continual risk if unmanaged. If ASS is sufficiently treated they can be used for soil blending, landfill cover materials or reuse onsite.)
- Direct neutralisation – mix a neutralising component such as Aglime or limestone of equivalent effective neutralising value, in situ, or remove, mix and replace.

8. Implementation Framework

8.1 District Drainage and Water Management Plans

This North East Corridor Drainage and Water Management Strategy Review is a regional strategy and sets a framework for future drainage and water management planning and identifies significant issues that should be addressed as development proceeds. In accordance with the approach adopted for the Southern River area (Southern River MOU Steering Committee, 2006), it is recommended that as District Structure Plans are prepared for the North East Corridor they are supported by District Drainage and Water Management Plans (DWMP), prepared by the Department of Water in conjunction with the Department for Planning and Infrastructure.

It is recognised that in some areas Local Structure Plans are prepared without the completion of a District Structure Plan. For this reason it is recommended that the Department of Water, in consultation with the Department for Planning and Infrastructure and the City of Swan, prepare a DWMP for areas where development is anticipated without a District Structure Plan. The highest priority is the Henley Brook-West Swan-Caversham DWMS, including those catchments south of Gnangara Road.

Each DWMP should be guided by this North East Corridor Regional Drainage and Water Management Strategy and should address the following issues for the District Structure Plan (DSP) area:

- Recognition of the principles, objectives and requirements of total water cycle management as outlined in the *Statement of Planning Policy No 2.9: Water Resources Policy* (WAPC, 2006), *Liveable Neighbourhoods Edition 3* (WAPC, 2004) and the *Stormwater Management Manual for WA* (Department of Water, 2004);
- Review the water management objectives and develop appropriate water quality design objectives for the DSP area;
- More detailed desktop risk assessment of contaminated sites, potential groundwater contamination, acid sulphate soils and other water management constraints;
- Discussion of potential water sources, particularly for non-drinking water, having consideration of the impacts on the district water balance and infrastructure needs and identifying preferred options;
- Results of more detailed water quality investigations, including monitoring and modelling studies, focussing on potential risk areas;
- Conceptual stormwater management plan, identifying arterial drainage elements and flood paths, to be developed in consultation with the Department of Water, the Water Corporation and the relevant Local Government, and based on surface water modelling where necessary;
- Recommendations for strategies and responsibilities for local pre- and post-development groundwater and surface water monitoring;

» Identification of specific issues likely to requires specialised investigation and management at later stages of planning; and

» Recommended implementation framework identifying funding and roles and responsibilities for ongoing operation and maintenance.

The level of detail included in the DWMP should be sufficient to manage the risks to land planning posed by the issues addressed, noting that further investigations will be undertaken during subsequent more detailed planning. These more detailed investigations include Local Water Management Plans prepared to support Local Structure Plans and Town Planning Scheme amendments and Urban Water Management Plans prepared to support Subdivision Applications. Should Local Structure Planning proceed before the completion of the necessary DWMP, the proponent should be required to prepare a Local Water Management Strategy that addresses the issues that would otherwise have been included in the DWMP, including the necessary groundwater and surface water monitoring.

8.2 Further investigations and monitoring

The following regional investigations are required to support the development of District Water Management Plans in the North East Corridor.

» **Digital Elevation Model:** Accurate topographic information over the North East Corridor is required for both surface and groundwater modelling, for the development of surface and groundwater management plans and the estimation of fill levels.

» **Groundwater monitoring:** Further monitoring is required to assess groundwater levels and quality at a spatial scale more appropriate for DSP. The Department of Water is responsible for regional monitoring, but this should be supported by more detailed monitoring within each DSP area by the City of Swan. Typically this monitoring should be carried out for at least three years.

» **Groundwater modelling:** Regional groundwater modelling may be required to investigate the effect of land use change on groundwater levels, to determine need for imported fill and subsoil drainage, to examine the potential use of shallow groundwater as a resource and to assess any potential impacts on wetlands and groundwater dependent ecosystems.

» **Surface water modelling:** Hydrologic and hydraulic modelling is expected to be required to identify pre-development and post-development run-off, to determine flood channel capacities of receiving waterways and to develop an arterial drainage strategy that identifies flood paths and land requirements to manage minor and major events.

» **Wetland assessment:** In accordance with the EPA's recommendations (EPA 2000), further assessment of wetlands in the North East Corridor is required as part of more detailed planning required ahead of land use changes in the area, to ensure that significant wetlands and their buffers are protected from impacts. Determination of ecological water requirements for significant wetlands is also required.

- **Watercourse and riparian buffers:** Significant watercourses and their buffers should be identified for consideration at district structure planning stage.
- **Streamflow monitoring:** It may be necessary to monitor flows in existing waterways to establish the ecological flow requirements and set drainage objectives.

8.3 Action Plan

Table 6 identifies State Government agencies responsible for undertaking regional scale investigations necessary to support the subsequent development of District Drainage and Water Management Plans in the North East Corridor. The table also lists the minimum time needed to undertake each of the investigations and recommends a completion date in order to allow the earliest development.

Table 6 Action Plan

Task	Responsible	Expected duration	Required start	Required completion
Surface Water Modelling, with development of a Digital Elevation Model (DEM), if required.	Department of Water	6 months	April 2007	September 2007
Stream flow monitoring	Department of Water	3 winters	April 2007	September 2009
Regional groundwater monitoring	Department of Water	3 winters	April 2007	September 2009
Regional groundwater modelling	Department of Water	6 months		
Initial review			March 2007	June 2007
Detailed Model			July 2007	December 2007
Wetland assessment and determination of Ecological Water Requirements	Department of Water	7 months	August 2007	February 2008
Henley Brook-West Swan-Caversham DWMS	Department of Water	6 months	September 2007	April 2008

The proposed timeframe assumes that:

- Regional groundwater modelling can be commenced using the existing PRAMS model data and the results of additional groundwater monitoring from winter 2007 can be input to a more detailed Regional Model to be developed in the second half of 2007,
- Wetland assessment and identification of significant watercourses and riparian buffers is completed in spring 2007,
- Surface water modelling is undertaken as part of the Henley Brook-West Swan-Caversham DWMS, and
- Surface water modelling is either uncalibrated/unvalidated, or based on limited streamflow monitoring undertaken in the winter 2007.

9. References

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2000a). Australian Guidelines for Urban Stormwater Management, National Water Quality Management Strategy.

Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand (2000b). Australian and New Zealand Guidelines for Fresh and Marine Water Quality, National Water Quality Management Strategy.

Department of Environment (2004). *Stormwater Management Manual for Western Australia*, Department of Environment, Perth.

Department of Planning and Urban Development (1987). Planning for the Future of the Perth Metropolitan Region. SPC, Perth.

Department of Planning and Urban Development (1990). Metroplan: A Planning Strategy for the Perth Metropolitan Region. SPC, Perth.

Department of Planning and Urban Development (1990). Urban Expansion Policy Statement. SPC, Perth.

Department of Planning and Urban Development (1994). North East Corridor Structure Plan. SPC, Perth.

Environmental Protection Authority (1994). Metropolitan Region Scheme Amendment 950/33 and North East Corridor Structure Plan - Bulletin 754.

Environmental Protection Authority (2000). North East Corridor Extension Strategy, A submission by the EPA under Section 16(j) of the Environmental Protection Act, Bulletin 1001.

Environmental Protection (Western Swamp Tortoise Habitat) Policy Approval Order 2002

Environmental Protection Authority (2005) Environmental Guidance for Planning and Development, Draft Guidance Statement No. 33, Environmental Protection Authority, Perth.

Government of Western Australia (2000). *State Water Quality Management Strategy Objectives , Principles, Strategies and Implementation Framework*.

Government of Western Australia (2001). *State Water Quality Management Strategy – No 1 Framework for Implementation*, May 2001.

Government of Western Australia (2000). *Securing Our Water Future – A State Water Strategy for Western Australia*, February 2003.

Hill A L, Semeniuk C A , Semeniuk V, Del Marco A (1996). Wetlands of the Swan Coastal Plain, Volume 2A: Wetland Mapping, Classification and Evaluation, Water & Rivers Commission and Department of Environmental Protection.

Hirschberg K-J (1988). Inventory of Proven and Inferred Groundwater Contamination Sites to accompany Perth North and Perth South 1:100,000 Map Sheets. Record 1988/4, Geological Survey of Western Australia.

Institution of Engineers Australia (2003). *Australian Runoff Quality (Draft)*, Australian Runoff Quality Symposium, June 2003.

Jakowyna B, Donohue R (2002). Swan-Canning cleanup program: trends in total phosphorus and total nitrogen concentrations of tributaries to the Swan-Canning estuary (Western Australia) 1987 to 1998, Swan River Trust Report No. 6, p. 43

Lloyd, S.D., Fletcher, T.D., Wong, T.H.F. and Wootton, R.M. (2001), Assessment of Pollutant Removal in a Newly Constructed Bioretention System, proceedings of the 2nd South Pacific Stormwater Conference, Auckland, New Zealand, 27 – 29 June 2001, pp.20-30.

Shams R, Smith R (2002). Hydrogeological Information for Management planning in the Ellenbrook Catchment, Salinity and Land Use Impacts Series – SLUI 11 Perth, WA: WRC [not yet published].

Shams, R, and Smith R (2000). Understanding nutrient movement into Ellenbrook, WRC Salinity and Land Use Impacts Series - SLUI 6. Perth, WA: WRC [not yet published]

Shire of Swan (1985). Town Planning Scheme No. 9 (as amended), Perth.

Tan, H.T.H. (1991). Nutrients in Perth Urban Surface Drainage Catchments Characterised by Applicable Attributes, Water Authority of Western Australia Report No WS 85, September 1991.

Southern River Steering Committee (2006). Interim Approach for Integrating Urban Water Management with Land Use Planning within the Southern River Area – Guidance for developers, prepared by Essential Environmental Services.

The Institution of Engineers Australia (2002). Australian Rainfall & Runoff. A Guide to Flood Estimation. Volume 1.

Water Corporation (1998). Urban Main Drainage Manual – Design & Construction Requirements for Urban Main Drains

Water & Rivers Commission (1996). Water Resource Protection map, WRC Policy and Planning Division.

Water & Rivers Commission (1997). Perth Groundwater Atlas. Government of Western Australia.

Water & Rivers Commission (1998). A Manual for Managing Urban Stormwater Quality in Western Australia. Prepared by Evangelisti & Associates, Assoc. Prof. Tony Wong and Alan Tingay & Associates for Water & Rivers Commission.

Water & Rivers Commission (2001). Southern River/Forrestdale/Brookdale/Wungong Structure Plan: Urban Water Management Strategy (Volume 1). Prepared by JDA Consultant Hydrologists for Water & Rivers Commission.

Water & Rivers Commission (2001). Water and Rivers Commission Position Statement: Wetlands. Water and Rivers Commission, East Perth.

Water & Rivers Commission (2002). Acid Sulphate Soils Guideline Series: Preparation of Acid Sulphate Soil Management Plans (Draft). Circulated by the Department of Environment, Water and Catchment Protection.

Water & Rivers Commission (2002). Draft DEWCP and EPA guidance on managing acid sulphate soils. Circulated by the Department of Environment, Water and Catchment Protection.

Water Authority of Western Australia (1995). Drainage Management Strategy for the North East Corridor. Prepared by G B Hill & Partners Pty Ltd.

Water Authority of Western Australia (1992). North East Corridor Drainage Management Strategy.

Western Australian Government (1985). Swan Valley Planning Act 1995.

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